

Selecting Protective Devices

BUSSMANN
SERIES

SPD

Electrical protection handbook

Based on the 2017 NEC®



Powering Business Worldwide

Introduction

Welcome to Eaton's Bussmann series Selecting Protective Devices (SPD) handbook. This reference document is based on the 2017 National Electrical Code (NEC®) and is a comprehensive guide to electrical overcurrent protection and electrical design considerations. The information within this resource is presented on numerous applications as well as code and standard requirements for a variety of electrical equipment and distribution systems.

For this edition, considerable change was made to the overall structure and organization to improve readability, and to organize the discussions around the important topics of safety and protection.

This edition is comprised of major sections containing content that can be easily located by three methods.

- Table of contents with new or expanded content highlighted in red.
- Index arranged alphabetically by topic with corresponding page numbers
- NEC index to located information associated with specific code references.

For more technical resources and general product information, visit Eaton.com/bussmannseries.



About the front cover

Electricians installing a Bussmann series Quik-Spec™ Coordination Panelboard (QSCP) which uses the Compact Circuit Protector and UL® Class CF CUBEFuse™. The QSCP makes it easy to achieve selective coordination by using published upstream fuse and circuit breaker tables. Available in flush- or surface-mount NEMA 1 enclosures or a NEMA 3R enclosure, the QSCP increases worker electrical safety by featuring dead front protection and finger-safe fuses.

George Ockuly

This 2018 Edition of the Bussmann series Selecting Protective Devices (SPD) handbook is dedicated to George Ockuly for his service to the electrical industry.

Ockuly joined Bussmann in 1972, where he held various positions of increasing importance, including district sales engineer, regional sales manager, director of North American sales, and finally vice-president of sales. His responsibilities included worldwide codes and standards activities, technical literature development, application engineering, product certification and testing, training, and product safety. Mr. Ockuly retired after 28 years of service.

Outside of Bussmann, Ockuly held positions on NEMA's Standards Policy Committee, the International and Regional Standards Committee, the fuse section, and served as vice chairman of the Codes and Standards Committee.



He was a member of the NFPA Board of Directors, a member of the National Electrical Code Panels 10 and 11, and was a principal on NFPA 70B Recommended Practices for Electrical Equipment Maintenance. He served as vice-president of the U.S. National Committee of the International Electrotechnical Commission (USNC/IEC), and technical advisor for UNSC, IEC C32B Low Voltage Fuses. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Electronic Industries Alliance, and an associate member of the International Association of Electrical Inspectors (IAEI). He is a recipient of the NEMA Kite and Key award which recognizes individuals who have advanced the interests of the electrical industry through active and sustained involvement in the affairs of the association.

This handbook is intended to clearly present product data and technical information that will help the end user with design applications. Eaton reserves the right, without notice, to change design or construction of any products and to discontinue or limit their distribution. Eaton also reserves the right to change or update, without notice, any technical information contained in this handbook. Once a product has been selected, it should be tested by the user in all possible applications. Further, Eaton takes no responsibility for errors or omissions contained in this handbook, or for misapplication of any Bussmann series product. Extensive product and application information is available online at: Eaton.com/bussmannseries

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Benefits of the modern current-limiting fuse

Provides a flexible and worry-free solution

- With interrupting ratings up to 300 kA, fuses can be installed in almost any system without fear of misapplication
- With straight voltage ratings, fuses can be installed in any system independent of its grounding as opposed to slash voltage rated devices that can only be installed on a solidly grounded Wye system
- The fuse's interrupting rating is typically at least equal to, or in many cases greater than, the available fault current at the line terminals
- The fuse's high interrupting rating provides flexibility should system changes, such as utility transformers or equipment relocation, increase fault current levels

Increases electrical safety

- Finger-safe protection is provided in the latest fuse technology for fuse holders and blocks, switches, and power distribution fuse blocks, including the patented Bussmann™ series Low-Peak™ CUBEFuse™ and revolutionary Compact Circuit Protector (CCP) disconnect switch
- With interrupting ratings up to 300 kA, available fault currents exceeding these high values due to system changes is virtually eliminated
- UL Class branch circuit fuses have physical rejection features that help ensure the same voltage and equal to or greater interrupting ratings are retained throughout the system's life
- Arc flash hazards can be greatly reduced when fuses operate in their current-limiting range

Reduces risk and improved reliability

- Fuse rejection features reduce the potential to install an overcurrent protective device (OCPD) with different performance characteristics and lower interrupting ratings that can compromise the protection level
- Fuses do not vent during a fault, safely containing and extinguishing the arcing inside the fuse body. On some OCPDs venting is inherent, possibly causing damage to other system components
- Factory-calibrated replacement fuses ensure the same protection level throughout the system's life and eliminate the possible need to test and recalibrate an OCPD after a fault
- The fuse's enclosed, sand-filled design operates on proven thermal principles that eliminate the risk something may not be properly adjusted or operate correctly under short-circuit conditions as is the case with some mechanical OCPDs
- The enclosed, fixed design eliminates the need to adjust and change device settings in the field, thus reducing confusion and risk of misapplication

Saves time and money

- Fuses eliminate the need for expensive, time-consuming fault current studies when using 300 kA interrupting rated Low-Peak fuses
- Current-limiting fuses make achieving selective coordination easy and simple by maintaining a minimum amp ratio between upstream and downstream fuses. Using published ratio tables eliminates the need for selective coordination studies and ensures the affected circuits are isolated and prevents unnecessary power loss to upstream portions of the electrical system.
- Because fuses are an enclosed, non-venting design, they eliminate the need for additional system guards or barriers to protect from venting
- Fuses reduce the need for OCPD maintenance as they require no additional maintenance or servicing beyond periodically checking conductors and terminations

Helps achieve high equipment short-circuit current ratings (SCCR)

- Fuses have high interrupting ratings (up to 300 kA) and will not be the limiting factor in a panel SCCR
- Current limitation drastically reduces the peak let-through current to protect downstream components and help raise branch SCCRs

Reduces downtime and improved protection

- Specifying Type 2 "No Damage" (versus Type 1) protection with properly sized current-limiting fuses helps eliminate the need to replace components after a fault
- Current limitation helps reduce the extreme, destructive thermal and mechanical forces associated with short-circuit events

Facilitates code compliance

- Compliance with NEC 110.9 is easily achieved with high interrupting ratings up to 300 kA
- Compliance with NEC 110.10 for protecting equipment and components from extensive damage from short-circuits is easy with current-limiting fuses
- Compliance with OSHA 1910.334(b)2 is met by eliminating the invitation for an operator to reset the OCPD after a fault without first determining its cause. Resetting circuit breakers or replacing fuses without investigating and fixing the cause is prohibited by federal law.

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2 Electrical safety

The safety implications for electrical system design, installation, inspection, testing, maintenance, trouble-shooting and repair are significant.

In most cases, applicable enforceable codes and standards provide requirements that are the minimum for safety. In order to provide electrical systems and equipment well suited for the owner's environment and needs, designers and installers must go beyond these minimum requirements to provide systems and equipment that are efficient and adequate for the present and to easily accommodate future changes. There may also be additional safety features that can be incorporated beyond the minimum required by Codes and standards.

In some cases, this publication on Selecting Protective Devices (SPD) for overcurrent protection applications presents solutions that merely meet the minimum Code requirements. For other cases, there are recommended solutions that provide superior safety, reliability and practicality.

Safety in regards to electrical equipment and systems has evolved to mean more than just protecting people and property against shock and fire hazards due to equipment failures. It includes considerations for electrical systems that deliver electrical power to loads vital for life safety and public safety, such as emergency systems and critical power operations systems. In these cases, the code and standard requirements focus on electrical system reliability and power continuity to the loads which are vital for life and public safety.

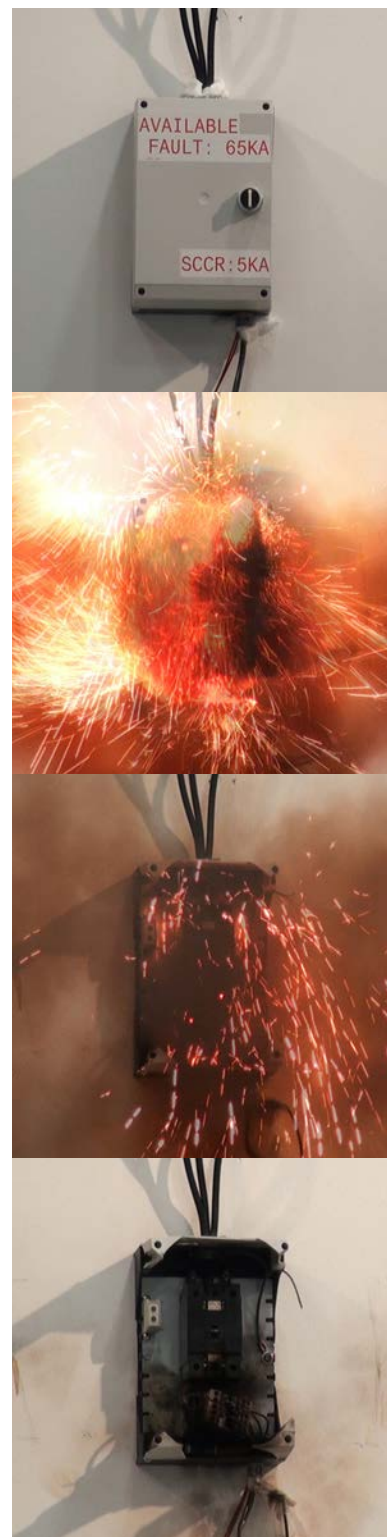
Another safety perspective is electrical safety related work practices. Federal regulations mandated by OSHA require owners to provide a safe workplace. This includes workers who must work on or near electrical equipment and systems. The hazards of electrical shock, arc flash and arc blast can be eliminated or mitigated by good design practices, proper installation and maintenance procedures.

Selecting and using overcurrent protective devices (OCPDs) can have a profound impact on the level of safety an electrical system provides. To that end, this handbook covers many subjects associated with selecting overcurrent protective devices:

- Fuseology and breaker basics cover how overcurrent devices work, their varieties, ratings and operating characteristics that make them suitable for various applications.
- Power system analysis, covered in Section 4 examines fault currents, selective coordination and arc flash that directly related to electrical system safety and reliability. Specifically covered in this section are the National Electrical Code (NEC®) requirements related to these subjects.
- The impact maintenance, or the lack there of, has on ensuring overcurrent protective device operation and performance over time is covered in Section 5.
- Electrical safe work practices focuses on NFPA 70E and OSHA requirements, and how to ensure worker safety.
- Equipment application and protection deals with applying OCPDs for various applications, and why some are better suited for use with regards to operation, reliability, electrical safety and reducing or eliminating equipment damage.

Our section on special applications focuses on those considerations unique to protecting data centers, HVAC and photovoltaic systems, and fuses used in hazardous locations.

All the sections described above can stand on their own, but they also interrelate. Taken all together, they will provide a comprehensive understanding about selecting protective devices for reliability, code, standards and regulatory compliance, and, most importantly, safety for people, plant and equipment.



Fault currents release tremendous amounts of destructive energy and magnetic force. Selecting the correct overcurrent protective device can help ensure they do not result in a short-circuit event like the one shown above.

The power of space



The revolutionary **Bussmann™ series Low-Peak™ CUBEFuse™** delivers the smallest footprint compared to any Class J or RK fuse solution — requiring up to 70% less space when combined with its unique fuse holder or UL® 98 Listed Compact Circuit Protector.

Freeing up space is powerful. And the CUBEFuse does just that, while packing up to a 300 kA interrupting rating and enabling higher panel SCCR. Plus, it features plug-in capability for easier installation.

What will you do with all that space?

CUBEFuse.com

The evolution continues. 2018.

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3 Fuseology and breaker basics

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3.1 Fuseology

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Sidebars

Sidebars in this handbook contain additional information or present related subject material

Look for these in the yellow boxes

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3



First published in the 1920s, the Bussmann Fuseology handbook on fuses has promoted electrical safety by advancing the understanding of overcurrent protection.

3.1.1 Overcurrent protective device basics

Fuseology is the study of the fuse’s fundamental operating principles. These include the ratings and operating characteristics that make the fuse an efficient overcurrent protective device (OCPD) as well as its construction that creates its unique leadership role in circuit protection.

In the simplest terms, a fuse is an overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

A fuse is comprised of all the parts that form a unit that can perform these functions. It may or may not be the complete device necessary to connect it into an electrical circuit.

Electrical distribution systems can be simple or complicated. Regardless, they cannot be absolutely fail-safe and are subject to destructive overcurrent events such as overloads, ground faults or short-circuits. Harsh environments, general deterioration, damage (whether accidental or from natural causes), excessive electrical system expansion or overloading are common factors leading to overcurrent events. Reliable OCPDs like the fuse shown in Figure 3.1.1.a prevent or minimize costly damage to transformers, conductors, motors and many other components and loads that make up a complete power distribution system. Reliable circuit protection is also essential to electrical safety for personnel as well as avoiding severe monetary losses from power blackouts or prolonged facility downtime.



Figure 3.1.1.a A regular and x-ray view of the Bussmann™ series Low-Peak™ LPN-RK dual-element fuse showing the overload and short-circuit links.

The fuse is a reliable and simple OCPD made in a variety of configurations that are fundamentally comprised of a “fusible” link or links encapsulated in a tube or housing that are connected to terminals. The link’s electrical resistance is so low that it acts as a conductor until it encounters current levels above its amp rating. Then it melts and opens the circuit to protect conductors, components and loads.

Fuses for electrical distribution systems typically have three unique performance characteristics that address Friemel’s Laws of Overcurrent Protection (see sidebar “Friemel’s Laws of Overcurrent Protection” for details):

- High interrupting rating to safely open very high fault currents without rupturing.
- Current limitation to “limit” fault currents to low values for optimum component and equipment protection, and help equipment achieve high short-circuit current ratings (SCCRs).
- Electrical system selective coordination for the full range of overcurrent events to help prevent needless “blackouts” caused by upstream OCPDs cascading open when applied with the correct amp rating ratios.

3.1.1.2 Friemel’s Laws of Overcurrent Protection and the NEC

Law 1 — Interrupting rating

- OCPDs shall be applied with an interrupting rating equal to or greater than the maximum available fault current
- Code compliance: 110.9

Law 2 — Component protection

- OCPDs shall be selected and installed to clear a fault without extensive damage to electrical equipment and components
- Code compliance: 110.10

Law 3 — Selective coordination

- A properly engineered and installed electrical system will restrict outages to ONLY the nearest upstream OCPD for the full range of overcurrents and associated opening times, leaving the remainder of the system undisturbed and preserving service continuity
- Code compliance: 620.62, 645.27, 695.3(C)(3), 700.32, 701.27, 708.54

Friemel’s Law	Code section	How it’s achieved
1. Interrupting rating	110.9	Current limiting fuses, especially Low-Peak
2. Component protection	110.10 and numerous sections involving SCCR	Current limiting fuses, especially Low-Peak and high SCCR control panel products (CCP, PDFB, etc.)
3. Selective Coordination	620.62, 645.27, 695.3, 700.32, 701.27, 708.54	Current limiting fuses, especially Low-Peak, QSCP, Power Module, CCPLP and engineering services

Figure 3.1.1.2.a Friemel’s Laws of Overcurrent Protection in table form.



3.1.2 How fuses work

As an overcurrent protective device, the fuse acts as “electricity’s safety valve” by providing a weak link in the circuit path that, when properly applied, will melt and open the circuit to minimize or eliminate any damage that can be caused by an excessive flow of current. There are many fuse varieties and constructions, each developed to address an application’s need for a particular kind of overcurrent protection.

3.1.2.1 Overcurrent protection

An overcurrent is either an **overload** or a **fault/short-circuit**. The overload current is an excessive current flow relative to normal operating current, but still confined to the normal circuit paths provided by the conductors, components and loads. A fault (often referred to as a short-circuit) flows outside the normal circuit paths.

Overloads

Overloads are most often up to 6 times the normal current level. They are usually caused by harmless, temporary in-rush currents that occur when motors start up or transformers are energized. Such overloads, or transients, are normal occurrences, and their brief duration is not harmful to circuit components as the associated temperature rise is minimal with no harmful affect. It’s important that OCPDs are properly sized and have the appropriate operating characteristics so they do not react to these temporary overloads or cause “nuisance openings.”

Persistent, non-temporary overloads can result from defective motors (worn bearings) or when too many loads are on a single circuit and must not be permitted to last long enough to damage electrical system components such as conductors. This damage may eventually lead to severe fault events if the overload is not interrupted.

Due to the overload’s inherent low magnitude nature, removing them within seconds or even minutes will generally prevent thermal damage.

Faults

Faults, also referred to as short-circuits, differ from overloads as they can be hundreds to thousands of times greater than the normal operating current. A high level short-circuit may be up to 30 kA or 200 kA, and must be interrupted as quickly as possible to minimize the damage that can include:

- High magnetic forces that warp and distort busbars and associated bracing beyond repair
- Severe insulation damage
- Melting or vaporizing conductors
- Vaporizing metal, including buswork in electrical equipment
- Ionized gases
- Arcing fires
- Explosions

Note: “fault current” is a general term that’s used in this publication and includes ground fault, arcing fault and short-circuit currents.

Friemel’s Laws of Overcurrent Protection

Paul Friemel was known in the electrical industry as the Professor of Overcurrent Protection from the mid-1960s until his passing in 2015. As a licensed professional engineer, he presented seminars on electrical overcurrent protection for more than 40 years.

Among his many accolades, he was awarded the Outstanding Educator Award by the IEEE as a Life Senior Member in 2004 and recognized as an Outstanding Professional Engineer by the St. Louis Society of Professional Engineers in 2010. He served on the St. Louis Electrical Code Review Committee for St. Louis County for over two decades, actively participated in the International Association of Electrical Inspectors, and was a guest lecturer at Washington University and the University of Missouri. He was a long standing member of the Electrical Board of Missouri and Illinois where he served several terms on the board of directors. Friemel taught the three **C**’s of overcurrent protection which are now known as Friemel’s Laws of Overcurrent Protection:

1. Interrupting rating (**C**apacity)
2. **C**omponent Protection
3. Selective **C**oordination

An understanding of these three key electrical overcurrent protection principles will lead to a safe, reliable and code compliant electrical system.



3.1.3 Construction

The fuse is a highly efficient OCPD with a simple design based upon basic principles of physics to interrupt and limit overcurrent events. Insight into their construction helps in understanding their application.

As shown in Figure 3.1.3.a, fuses have four parts common to most designs: case/housings (tube or cartridge), terminals (end blades or ferrules), fuse link (element), and arc-quenching filler. There are different fuse types that provide the operating characteristics required to address differing circuit protection needs.

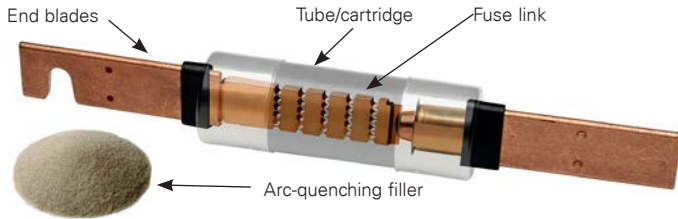


Figure 3.1.3.a A dual-element, time-delay Low-Peak LPS-RK fuse showing the four common construction characteristics.

A fuse's construction typically offers these benefits:

Physical rejection — Fuses have rejection features based on physical size or by a construction characteristic. Generally, a fuse of one class and case size cannot be installed in another fuse class and case size mounting. This ensures that the replacement fuse being installed will have the same voltage and interrupting ratings. A mild exception is that Class R fuses can be installed in Class H(K) fuse mountings for a protection upgrade, but, lower performing Class H(K) fuses cannot be installed in Class R fuse holders or blocks.

The Class J fuse is another example. Its size rejection prevents installing any other fuse type and virtually eliminates installing the wrong fuse type having different, potentially lower performance characteristics. Unless a user replaces the holder, block or switch, it's very difficult to install the wrong replacement fuse.

Enclosed, non-venting design — Fuses do not vent when they interrupt fault currents. All arcing is contained and extinguished inside the fuse body. This reduces the risk of metal vapors causing unnecessary damage to other components inside an enclosure. As part of their design, some mechanical OCPDs will vent when they interrupt fault currents. In addition, using fuses reduces cost by eliminating the need for guards or barriers to protect from the venting.

Enclosed, fixed, thermal design — Modern current-limiting fuses are constructed with an enclosed case, tube or body and have no moving parts when they open from an overcurrent. By operating on thermal energy principles of physics, the fuse improves electrical system reliability by not relying on springs, levers or latches that require periodic maintenance to ensure continued proper operation.

Factory calibrated replacements

There is no worry that a fuse may seize or not operate as intended as it's factory calibrated with no need for field adjustment. This minimizes possible misapplication by eliminating the need to adjust or change device settings in the field. Engineers and specifiers can be certain the required overcurrent protection level is met and retained.

When fuses are replaced, system integrity is maintained by ensuring the same protection for many years to come.

Using thermal or electronic OCPDs in electrical systems to protect against overloads, such as motor starters, is beneficial as they can easily be reset by an operator or user (after the overload cause has been corrected) so that production can quickly resume. On the other hand, if a fault occurs, a qualified electrician must investigate and remedy the cause prior to resetting the device or replacing the fuse. If an unqualified person is allowed to simply reset a device, a safety hazard could occur if the fault is still on the line.

Fuses help in complying with federal law and other safety standards by eliminating the invitation for an operator to "reset" a device after a fault without investigating or remedying the cause. OSHA 1910.334(b)2 does not allow this practice and similar requirements are found in NFPA 70E Section 130. Fuses help prevent this from happening as a qualified person is much more likely to be involved in replacing the fuse. In addition, many maintenance personnel in industrial facilities prefer fuses for the simple reason that the troubleshooter is more likely to investigate the cause for the fuse opening rather than simply replacing the fuse.



3.1.3.1 Non-time-delay fuse

Depending upon the fuse's amp rating, the "single-element" non-time delay fuse (often called a fast-acting fuse) may have one or more links. They are electrically connected to the terminals (end blades or ferrules) (see Figure 3.1.3.1.a) and enclosed in a case/housing (tube or cartridge) that contains an arc-quenching filler material that surrounds the link. Many Bussmann series Limitron™ fuses are "single-element" fuses.

Under normal operation, when the fuse is applied at or near its amp rating, it simply functions as a conductor. If an overload occurs and persists for more than a short time interval, as illustrated in Figure 3.1.3.1.b, the link's temperature eventually reaches a level that causes a restricted link segment (neck) to melt. As a result, a gap is formed and an electric arc established. As the arc causes the link to "burn back," the gap becomes progressively larger. The electric arc's resistance eventually reaches such a high level that it cannot be sustained and is extinguished with the help of the filler material's arc-quenching properties (see Figure 3.1.3.1.c). The fuse will have then completely cut off all current flow in the circuit.

Present day single-element fuse designs respond very quickly to overcurrents with excellent fault current component protection. However, temporary, harmless overloads (in-rush currents associated with inductive loads such as motors, transformers and solenoids) may cause nuisance openings unless these fuses are oversized. Therefore, they are best used in circuits not subject to heavy inrush currents.

Whereas overload normally falls between 1.35 and 6 times normal current, fault currents are quite high and the fuse may be subjected to fault currents of 30 kA or higher. The fuse's current-limiting response to such high currents is extremely fast as its restricted link sections will simultaneously melt within a matter of two or three-thousandths of a second.

The multiple arcs' high total resistance, together with the arc-quenching filler material, results in rapid arc suppression and clearing the fault (see Figures 3.1.3.1.d and Figure 3.1.3.1.e). Fault current is cut off in less than a quarter-cycle, long before it can reach its full value (fuse operating in its current-limiting range).

Bussmann series UL Listed branch circuit fuses play a major role in industrial or commercial facilities by providing reliable, maximum protection to power systems. Their physical size or rejection features prevent replacing a fuse with one from another fuse class. This helps ensure the correct replacement fuse is always installed and the voltage and interrupting ratings remain the same. Shown are the case sizes for each fuse class relative to the size of a US quarter (left edge of image).



Figure 3.1.3.1.a Cutaway view of typical single-element fuse.



Figure 3.1.3.1.b Under sustained overload, a section of the link melts and an arc is established.



Figure 3.1.3.1.c The "open" single-element fuse after opening a circuit overload.



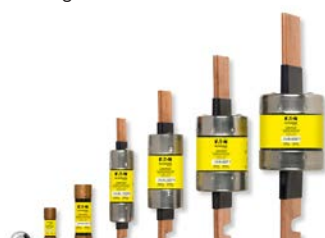
Figure 3.1.3.1.d When subjected to a fault current, several sections of the fuse link melt almost instantly.



Figure 3.1.3.1.e The "open" single-element fuse after opening a shorted circuit.



FRN-R — Class RK5, 250 V, 200 kA IR up to 600 A



LPN-RK — Class RK1, 250 V, 300 kA IR up to 600 A



LPJ — Class J, 600 V, 300 kA IR up to 600 A



LP-CC, FRQ-R, KTK-R — Class CC, 600 V, 200 kA IR up to 30 A



FRS-R — Class RK5, 600 V, 200 kA IR up to 600 A



LPS-RK — Class RK1, 600 V, 300 kA IR up to 600 A



JJN — Class T, 300 V, 200 kA IR up to 1200 A



JJS — Class T, 600 V, 200 kA IR up to 800 A

3.1.3.2 Dual-element, time-delay fuse

There are many advantages to using “dual-element,” time-delay fuses that feature an overload link and a short-circuit element connected in series — hence, the “dual-element” designation. Unlike single-element fuses, Bussmann series dual-element, time-delay fuses can be sized closer to the load to provide high performance for both short-circuit and overload protection.

The overload element provides the intentional “time-delay” that permits temporary overloads to harmlessly pass. This is the reason these fuses can be sized much closer to the load than non-time delay fuses that must be oversized to pass inrush currents and not produce nuisance openings.

The short-circuit element is there to handle fault currents, and when the fuse is operating in its current-limiting range, it's not possible for the full available fault current to flow through the fuse — it's a matter of physics. The small restricted link sections in the short-circuit element quickly vaporize with the filler material assisting in forcing the current to zero; and so it's able to “limit” the fault current.

Anatomy of a dual-element, time-delay fuse



Figure 3.1.3.2.a Typical Class R Low-Peak fuse.

The Low-Peak LPS-RK-100SP, 100 A, 600 V, Class RK1, dual-element fuse has excellent time-delay to withstand high inrush currents along with excellent current limitation and a 300 kA interrupting rating. Figure 3.1.3.2.a shows the fuse's internal construction. The real fuse has a non-transparent tube and arc-quenching material that completely surrounds the element and fills the tube's internal space.

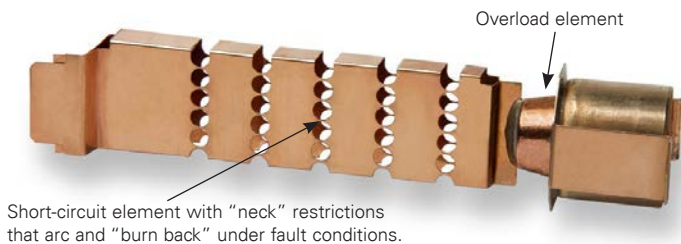
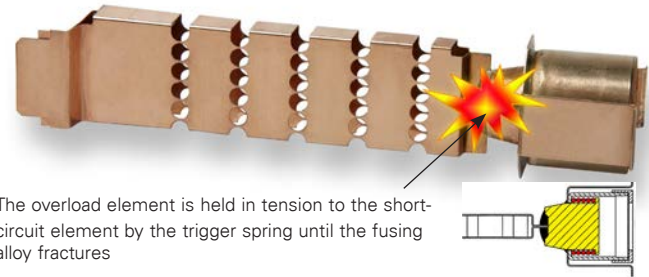
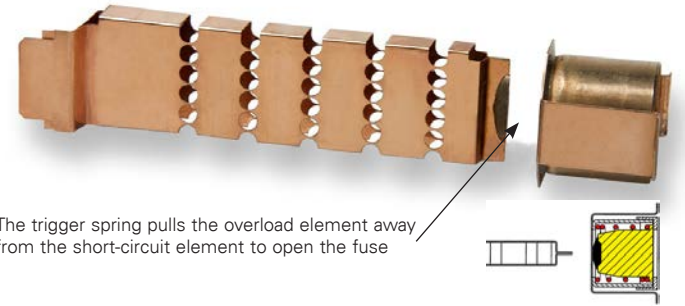


Figure 3.1.3.2.b “Dual-element” construction.

The true dual-element fuse has separate and distinct overload and short-circuit elements connected in series as shown in Figure 3.1.3.2.b.



The overload element is held in tension to the short-circuit element by the trigger spring until the fusing alloy fractures



The trigger spring pulls the overload element away from the short-circuit element to open the fuse

Figure 3.1.3.2.c Overload element operation.

Operation under persistent overload conditions as shown in Figure 3.1.3.2.c causes the trigger spring to fracture the calibrated fusing alloy and releases the “connector.” The insets show the overload element before and after it opens. The coiled spring pushes the connector from the short-circuit element and the circuit is interrupted.

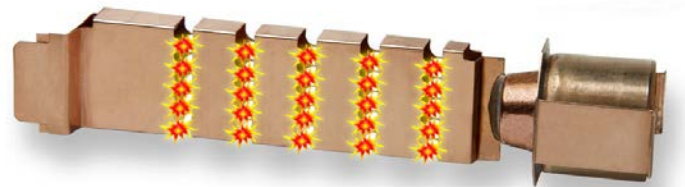


Figure 3.1.3.2.d Short-circuit element operation under fault conditions.

For operation under fault conditions, the short-circuit element is designed with minimum metal in the restricted portions to greatly enhance the fuse's current limitation and minimize the short-circuit current let-through. Fault current causes the short-circuit element's restricted portions to quickly vaporize and commence arcing as shown in Figure 3.1.3.2.d. The arcs burn back the element, resulting in longer arcs that reduce the current with the arc-quenching filler helping to extinguish the arcs and force the current to zero.



Figure 3.1.3.2.e Arc-quenching filler material helps suppress the arcing by melting and forming folgurite.

As a result of short-circuit operation, the special small granular, arc-quenching material plays an important part in the interruption process as it assists in quenching the arcs by absorbing their thermal energy and melting to form an insulating barrier material called folgurite as shown in Figure 3.1.3.2.e.

Advantages of dual-element over single element fuses

Bussmann series dual-element, time-delay fuses have six distinct advantages over single-element, non-time delay fuses:

1. Motor overload and short-circuit protection

When Bussmann series dual-element, time-delay fuses protect circuits with high inrush currents, such as motors, transformers and other inductive components, the Bussmann series Low-Peak and Fusetron™ dual-element, time-delay fuses can be sized close to full-load amps to maximize overcurrent protection. Sized properly, they will hold until normal, temporary overloads subside. For example, a 200 volt three-phase 10 Hp motor with a 1.15 service factor has a 32.2 A full-load current rating (see Figure 3.1.3.2.f).

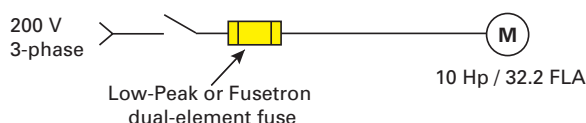


Figure 3.1.3.2.f Motor circuit with a dual-element, time-delay fuse.

A 40 A, dual-element, time-delay fuse will protect the 32.2 A motor, compared to a much larger, 100 A, non-time delay, single-element fuse that would be necessary to withstand the temporary inrush current. If a harmful, sustained 200% overload occurred in the motor circuit, the 100 A, non-time delay, single-element fuse would never open and the motor would be damaged because it only provides ground fault and short-circuit protection. Additionally, the non-time delay fused circuit would require separate motor overload protection per the NEC. In contrast, the 40 A time-delay dual-element fuse provides the same ground fault and short-circuit protection, plus overload protection (eliminating the code requirement for separate motor overload protection) (see Figure 3.1.3.2.g).

Fuse and switch sizing for 10 Hp motor (200 V, 3 Ø, 32.2 FLA)

Fuse type	Max fuse (A)	Required switch (A)
Dual-element, time-delay Fusetron FRS-R or FRN-R	40*	60
Single element non-time delay Limitron	100†	100

* Per NEC 430.32

† Per NEC 430.52

In normal installations, Bussmann series dual-element fuses sized for motor-running, overload protection, provide better fault protection plus a high degree of back up protection against motor burnout from overload or single-phasing should other overload protective devices fail (see sidebar “Single-phasing...are fuses an issue?” on page 3-8). If thermal overloads, relays or contacts should fail to operate, the properly sized dual-element fuse will act independently to provide “back-up” protection for the motor.

When secondary single-phasing occurs, current in the remaining phases increases from 173% to 200% of the motor’s rated full-load current. When primary single-phasing occurs, unbalanced voltages occurring in the motor circuit also cause excessive current. Dual-element fuses sized for motor overload protection can help protect against overload damage caused by single-phasing.

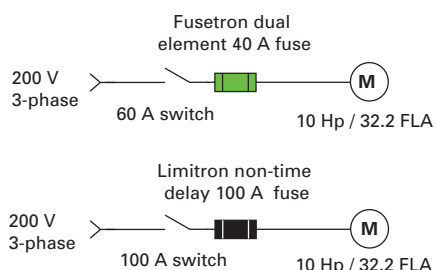


Figure 3.1.3.2.g Closer fuse sizing to load can result in using smaller, less costly switches.

2. Permit using smaller and less costly switches

Bussmann series dual-element, time-delay fuses permit using smaller, space saving and less costly switches because a properly sized higher amp rated single-element fuse would make it necessary to use larger switches as the switch rating must be equal to or larger than the fuse’s amp rating. As a result, a larger switch may cost two or three times more than necessary rather than using a dual-element Bussmann series Low-Peak or Fusetron fuse. (Note: should a larger switch already be installed for single-element fuses, smaller, properly sized dual-element fuses can also be installed for motor overload or back-up protection using fuse reducers. These permit installing a smaller case size fuse into a larger case size mounting.)

3. Better short-circuit component protection (current limitation)

Bussmann series dual-element, time-delay fuses provide better component protection than non-time delay, fast-acting fuses that must be oversized for circuits with in-rush or temporary overloads. Oversized non-time delay fuses respond slower to faults than smaller, time-delay fuses because the current will build up to a higher level before the fuse opens, thus the oversized fuse’s current limitation is less than a fuse with an amp rating that’s closer to the circuit’s normal full-load current.

4. Simplify/improve selective coordination for blackout prevention

The larger an upstream fuse is relative to a downstream fuse (feeder to branch), the less likely an overcurrent in the downstream circuit to cause both fuses to open (lack of selective coordination). To be selectively coordinated, Bussmann series Low-Peak fuses require only a 2:1 amp rating ratio. Contrast this to a fast-acting, non-time delay fuse that would require at least a 3:1 amp rating ratio between a large upstream, lineside Low-Peak time-delay fuse and the downstream, loadside Bussmann series Limitron fuse.

As shown in Figure 3.1.3.2.h, closely sized Bussmann series Low-Peak dual-element fuses in the branch circuit for motor overload protection provides a large difference in the amp ratings (3.75:1 ratio) between the feeder and branch fuses, compared to the single-element, non-time delay Limitron fuse (1.67:1 ratio) with the 90 A Limitron fuse not conforming to the 3:1 published ratio needed for selective coordination.

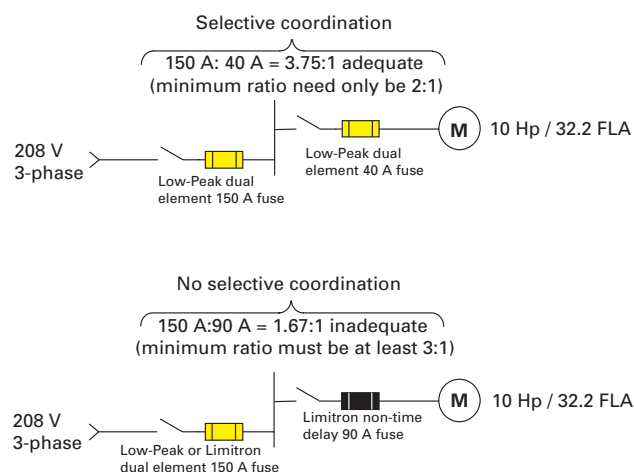


Figure 3.1.3.2.h Using Low-Peak fuses permits closer fuse sizing to load for better protection and using smaller, less costly switches while retaining selective coordination to help prevent blackouts.

Single-phasing...are fuses an issue?

Single-phasing conditions on three-phase motor circuits can create unbalanced voltage and/or overcurrent conditions that, if allowed to persist, will damage motors. In modern motor circuits, properly applied fuses and overload protective devices provide a high degree of single-phasing protection. Major considerations of single-phasing include the following.

- Single-phasing cannot be eliminated, there are numerous causes including:
 - The utility loses one phase
 - Overheated conductor termination
 - Disconnect does not “make” one pole
 - Controller contact burns open
- Prior to 1971, single-phasing plagued three-phase motors installed per the NEC because overload protection was only required on two phases. The 1971 NEC remedied this problem by adding the requirement for three-phase-motor circuits to have motor overload protection on all three phases. This provided protection for the worst condition seen when a utility loses a phase on the transformer primary.
- Three properly sized (to the actual motor running current) motor overload protective devices, now required in NEC 430.37, provide sufficient protection
- Most electronic overloads, soft-start controllers, and drives have options to sense voltage imbalance to provide single-phasing protection
- Although circuit breakers do not cause single-phasing, unless one pole's contact does not “make,” they do not provide single-phasing protection
- Fuses provide excellent short-circuit, current limitation to protect motor circuit starters and conductors, including Type 2 “No-Damage” protection when properly sized
- Fusible motor control centers benefit from the fast clearing time of a current-limiting fuse that also helps to reduce incident energy levels, mitigate arc flash hazards and protect workers

5. Better motor protection in elevated ambient temperatures

Before selecting a fuse or any OCPD, the application's ambient temperature should be known so the proper amp rating can be determined through what's called “derating.” Like all fuses, the dual-element fuse should be derated based on increased ambient temperatures. The fuse derating curves closely parallel motor derating curves in elevated ambient temperatures. Figure 3.1.3.2.i illustrates the affect ambient temperature has on Bussmann series Fusetron and Low-Peak dual-element fuse operating characteristics. This unique feature allows for optimum motor protection, even in high temperatures. For derating affects of single-element or non-time delay fuses, see Figure 3.1.3.2.j.

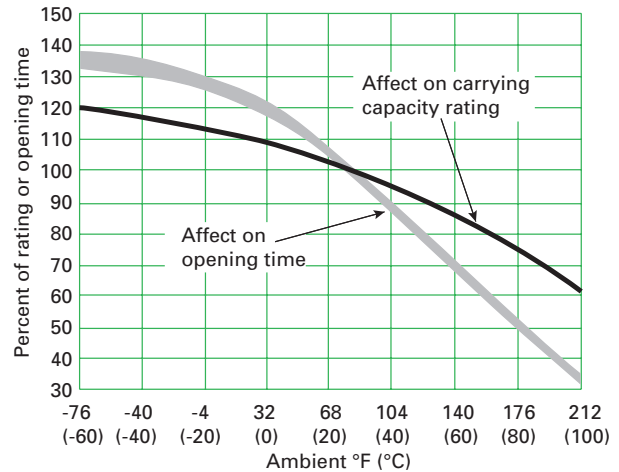


Figure 3.1.3.2.i Ambient temperature dual-element fuse derating curve.

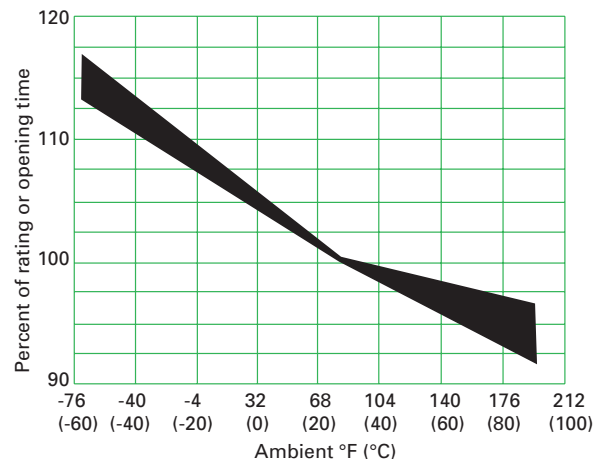
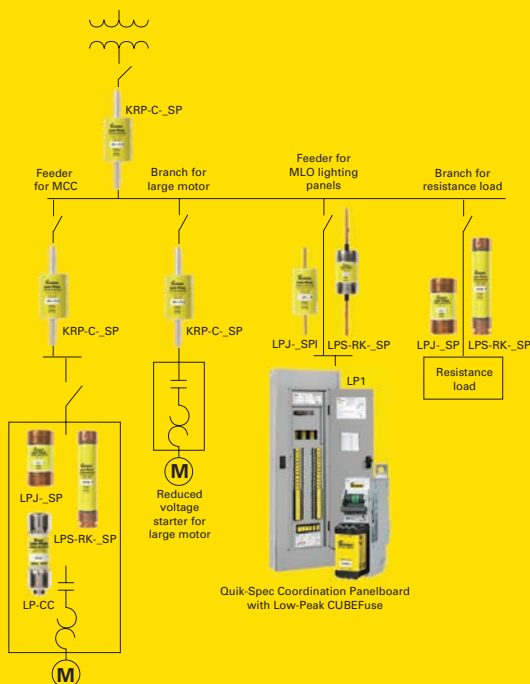


Figure 3.1.3.2.j Ambient temperature single-element derating curve.

6. Provide Type 2 “No Damage” motor starter protection when properly sized

Fuses help reduce downtime when Type 2 “No Damage” (versus Type 1) protection is specified with properly sized fuses. Type 2 protection ensures that no damage, within specified limits, occurs to the contactor or overload relay. With Type 2 protection, light contact welding is allowed, but must be easily separable allowing equipment to be placed back into service without having to replace or re-calibrate any components. A current-limiting device is necessary to achieve Type 2, often requiring Class CC, CF, J, or RK1 fuses. In this scenario, when the branch-circuit fuse protects the motor circuit, the starter does not need replacing and downtime is reduced or eliminated.

The Bussmann series Low-Peak fuse system



Specifying the Low-Peak fuse family throughout a building results in:

- Built-in fuse size and class rejection for greater safety
- Selective coordination with a minimum 2:1 amp ratio
- Maximum current-limiting protection for distribution equipment
- Type 2 “No Damage” motor starter protection when properly sized
- Reduced inventory
- Up to 300 kA interrupting ratings
- Arc flash hazard mitigation

3.1.4 Ratings

All fuses have three basic ratings:

- Voltage (AC, DC or both)
- Amp
- Interrupting

Understanding these three ratings, their significance and how they apply to circuit protection is crucial to specifying the correct, and in many cases, optimal circuit protection.

3.1.4.1 Voltage rating

One aspect of proper OCPD application requires the OCPD’s voltage rating be equal to or greater than the system voltage. When an OCPD is applied beyond its voltage rating, there may not be any initial indications that anything is wrong, but when it attempts to interrupt an overcurrent, adverse consequences can result and it may self-destruct in an unsafe manner. There are two OCPD voltage rating types: straight voltage rated and slash voltage rated.

Straight rated devices

A straight voltage rated OCPD can be installed in any electrical system regardless of the grounding system.

All fuses are straight voltage rated and their proper application is straightforward (i.e., 600 V, 480 V, 240 V). These OCPDs have been evaluated for proper performance with full phase-to-phase voltage used during testing, listing and marking.

The fuse’s voltage rating is its ability to open under an overcurrent condition while suppressing the internal arcing that occurs after the link melts and an arc is produced. If a fuse is applied with a voltage rating lower than the circuit voltage, arc suppression will be impaired, and, under some conditions, it may not safely clear the overcurrent.

The fuse’s voltage rating must be at least equal to or greater than the circuit voltage. For example, a 600 V rated fuse can be used in a 208 V circuit, but a 250 V rated fuse cannot be used in a 480 V circuit.

Most low voltage power distribution fuses have 250 V or 600 V ratings (other ratings include 125 V, 300 V, and 480 V). Bussmann series Low-Peak LPJ (Class J) fuses are rated at 600 V and can be used on any 600 V or less system, whether it’s solidly grounded, ungrounded, impedance grounded or corner grounded Delta.

A straight rated OCPD (whether a fuse or circuit breaker) that protects a single pole can be used to protect single-phase, line-to-neutral loads when supplied from a three-phase, solidly grounded circuit. For example, a 300 V rated fuse can be used to protect single-phase, line-to-neutral loads when supplied from a three-phase, solidly grounded, 480/277 V circuit, where the single-phase, line-to-neutral voltage is 277 V. This is allowed in this application because a 300 V fuse will not have to interrupt a voltage greater than its 300 V rating.

Slash rated devices

Slash voltage rated OCPDs have limitations imposed upon them that straight rated voltage OCPDs do not. Multiple-pole, mechanical OCPDs with a slash voltage rating, such as circuit breakers, self-protected starters and manual motor controllers, are limited in their application and require extra evaluation for use.

The slash rating can be broken down into its higher and lower numbers and are understood as follows:

- The lower rating number pertains to overcurrents at **line-to-ground** voltages, intended to be cleared by one pole of the device.
- The higher rating number pertains to overcurrents at **line-to-line** voltages, intended to be cleared by two or three poles of the device.



The proper slash rated circuit breaker application is such that:

- The **line-to-ground** voltage does not exceed the device's lower voltage rating
- The **line-to-line** voltage (between any two conductors) does not exceed the device's higher voltage rating. (Reference NEC Section 240.85.)

Understanding the higher and lower ratings is important as slash rated device misapplication can result in it being applied outside its voltage rating with dire consequences should the device be called upon to interrupt overcurrents.

Slash voltage rated circuit breakers are not intended to open line-to-line (phase-to-phase) voltages across only one pole. Where it is possible for line-to-line voltage to appear across only one pole, a straight rated OCPD must be used. For example, a 480 V circuit breaker may have to open an overcurrent at 480 V with only one pole, such as might occur when Phase A goes to ground on a 480 V, B-phase, corner grounded Delta system.

Slash voltage rated circuit breakers can only be used on solidly grounded power distribution systems. The proper application of molded case circuit breakers on three-phase systems, other than solidly grounded Wye, particularly on corner grounded Delta systems, must consider the circuit breakers' individual pole-interrupting capability. (Ref. NEC Section 240.85).

Slash rated devices cannot be used on the following systems (Ref. NEC Section 430.83(E)):

- Impedance-grounded
- Ungrounded Wye systems
- Ungrounded Delta systems
- Corner-grounded Delta systems

Other slash rated devices have these same limitations. They include, but are not limited to:

- Manual motor controllers — UL 508
- Self-protected Type E combination starters — UL 508
- Supplementary protectors — UL 1077. These look like small circuit breakers and are sometimes referred to as a mini-breaker. However, these devices are not rated for branch circuit protection and cannot be used where branch circuit protection is required.

Product standards require slash voltage rated devices to be marked with their rating such as 480Y/277 V. If a machine or equipment panel utilizes a slash voltage rated device, it's recommended that the equipment nameplate or label designate the slash voltage rating as the equipment voltage rating. UL 508A industrial control panels require the electrical panel voltage marking to be slash-rated if one or more devices in the panel are slash voltage rated.



3.1.4.2 Amp rating

In general, the OCPD amp rating indicates the amount of current that can flow through the device without causing it to open. Standard amp ratings for fuses and inverse time circuit breakers are shown in the Figure 3.1.4.2.a below (Reference NEC Section 240.6).

Understanding this NEC table is important. NEC Section 240.6 is referenced whenever the requirements specify "... the next standard overcurrent device size shall be used..." The next standard OCPD size is not based on a manufacturer's literature, but always obtained from NEC 240.6.

Fuse only ratings

1	3	6	10	601

Fuse and circuit breaker ratings

15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

Figure 3.1.4.2.a NEC Table 240.6, standard amp ratings. Also see sidebar on The NEC and "Fuses only ratings."

In selecting the fuse's amp rating, consideration must be given to the load type and code requirements. The fuse amp rating normally should not exceed the circuit's conductor current carrying capacity that's determined by ampacity adjustment factors covering how and where it's routed or other NEC related adjustment areas. For the most part, if a conductor's current carrying capacity is 20 A, a 20 A fuse is the largest that should be used to protect it.

There are specific circumstances in which the OCPD amp rating is permitted to be greater than the circuit's current carrying capacity, with motor circuits a common exception. Dual element time-delay fuses are generally permitted to be sized up to 175% and non-time delay fuses up to 300% of the motor's full-load amps. As a rule, the fuse amp rating and switch combination should be selected at 125% of the continuous motor load current (this usually corresponds to the circuit capacity, which is also selected at 125% of the load current). There are exceptions, such as when the fuse-switch combination is approved for continuous operation at 100% of its rating.



Figure 3.1.4.2.b Fires can result if the correct OCPD amp rating is not applied.

The photograph in Figure 3.1.4.2.b vividly illustrates the impact overcurrents have on electrical components when the OCPD's amp rating is not sized to the component's rating.

The NEC and “Fuse only ratings”

As part of the 1978 NEC, the “fuse only ratings” shown in Table 3.1.4.3.b were added because public inputs focused on protecting motors and the desire to provide the smallest fuse amp rating possible for effective short-circuit protection. There were two inputs accepted.

One public input addressed fuses rated less than 15 amps with the submitter noting in the substantiation that these fuses are often required on motor branch circuits to provide short-circuit and ground-fault protection. The substantiation for these fuse ratings came from test results showing fuses rated 1, 3, 6 and 10 amps provided the intended protection in motor branch circuits for motors with full load currents less than 3.75 amps ($3.75 \times 400\% = 15$). These ratings are also commonly shown on control manufacturers’ overload relay tables. Overload relay elements for very small motors, with small full load motor currents, have such a high resistance that a bolted fault at the controller load terminals produces a less than 15 amp fault current, regardless of the available current at the line terminals. An overcurrent protective device rated or set for 15 amps is unable to provide the short-circuit or ground fault protection required by Section 110.10 in such circuits.

The other public input added the 601 A Class L fuse for motor protection as the 601 A fuse size was not listed in this table, and the next standard size up that would be permitted would be a 700 A fuse. When the NEC called for the next standard OCPD size to be permitted, and when the calculated amp rating is greater than 500 A, only a 700 A Class L fuse would have been permitted for the installation.

Before the 1978 NEC, the 1975 NEC cycle placed the 601 A fuse as an exception to Section 430-52 (the requirements for rating or setting for individual motor circuits). This exception is still a part of the NEC as Exception “d” to this requirement and states, “The rating of a fuse of 601—6000 ampere classification shall be permitted to be increased but shall in no case exceed 300 percent of the full-load current.”

The public input pointed out in the substantiation that “since the intent of Table 430-52 and Section 430-52 is to encourage closer short-circuit protection, it seems prudent to encourage availability and use of 601 amp fuses in combination with motor controllers that can accept a Class L fuse.

The submitter recognized that inverse time circuit breakers are not subjected to the same limitation that fuses are when related to the fuse mounting means. For this reason, a distinction between 600 and 601 amps in circuit breakers has no purpose, and thus simply adding 601 A to the list for all OCPDs was not supported by the code panel.

3.1.4.3 Interrupting rating

An OCPD must be able to safely interrupt destructive fault current energy. If a fault current exceeds a level beyond the OCPD’s capability, it may rupture, causing damage and posing a safety hazard. The rating that defines OCPD’s capacity to maintain its integrity when reacting to fault currents is its interrupting rating. It’s important when applying a fuse or circuit breaker, to use one that can safely interrupt the largest potential fault currents. Most modern, current-limiting fuses have a 200 kA or 300 kA interrupting rating and can be used in just about any system without fear of misapplication. NEC 110.9 requires equipment intended to break current at fault levels to have an interrupting rating sufficient for the available fault current at point of application.

The fuse interrupting rating is not dependent on a particular voltage when applied within its rating. For example, a 600 Vac rated LPJ fuse has a UL Listed 300 kA interrupting rating for any voltage up to 600 Vac. Whether for the initial installation or system updates, a fusible system can maintain a sufficient interrupting rating throughout its life. There is little need for additional fault current calculation or worry that a fuse will be misapplied due to an improper interrupting rating. Nor is a short-circuit study needed when applying Bussmann series Low-Peak fuses for selective coordination, so meeting NEC 110.9 requirements is easy. Additionally, high interrupting ratings help equipment achieve a high short-circuit current rating that may be limited by the installed OCPD’s low interrupting rating. Finally, fuses provide peace of mind as the interrupting rating is always at least equal to or, in many cases, greater than the available fault current at the line terminals.

When applying a fuse or circuit breaker, as shown in Figure 3.1.4.3.a, the chosen OCPD must be able to safely interrupt the largest available fault currents at its line terminals (Ref. NEC Section 110.9).

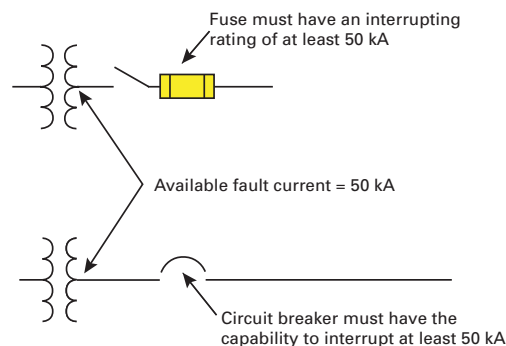


Figure 3.1.4.3.a The interrupting rating of the fuse or circuit breaker must be greater than the calculated maximum available fault current at its line terminals.

As with other ratings, applying an OCPD in an AC or DC system matters because interrupting ratings for alternating current (AC) will generally be different from direct current (DC), with AC interrupting ratings being higher in general. The primary difference between AC and DC interrupting ratings is alternating current has a zero voltage potential that happens 60 times a second (60 Hz) when its sine wave passes through zero. It’s when the voltage potential is at zero that arc suppression is easiest to achieve. On the other hand, there aren’t any “zero voltages” in DC, so the arc that’s generated never experiences “zero volts” and, as such, is more difficult to suppress.

Products must be rated for the application within which they are placed. The fuse’s simplicity limits areas of misapplication with this regard, as most modern current-limiting fuses have an AC interrupting rating of 200 kA or 300 kA. For example, Bussmann series Low-Peak* fuses are UL Listed at 300 kA IR at 600 Vac, allowing them to be safely applied on any 600 V or less system and still provide a 300 kA interrupting rating.

* Does not include LP-CC Class CC fuses which are 200 kA.

Table 3.1.4.3.b on the following page illustrates the highest AC and DC interrupting ratings available for Bussmann series low voltage branch circuit fuses by fuse class.

Bussmann series fuse voltage and interrupting ratings

Bussmann series product	UL Class	Catalog symbol	Amps	Vac	IR AC (kA)	Vdc	IR DC (kA)
Low-Peak	CC	LP-CC	Up to 30	600	200	300 (1/2 to 2-1/2 and 20-30 150 (2-8/10 to 15 A))	20
	CF*	TCF	Up to 100	600	300	300	100
	J	LPJ	Up to 600	600	300	300	100
	L	KRP-C	601 to 6000	600	300	300 (601-200, 300 A)	100
	RK1	LPN-RK	Up to 600	250	300	125 (up to 60 A) 250 (70-600 A)	100
		LPS-RK	Up to 600	600	300	300	100
Fast-acting CUBEFuse	CF*	FCF	Up to 100	600	300	600	50
Fusetron	RK5	FRN-R	Up to 600	250	200	125 (1/10 — 60, 110-200 A) 250 (225-600 A)	20
		FRS-R	Up to 600	600	200	300 (1/10 — 30, 65-600 A) 250 (35-60 A)	20
		CC	FNQ-R	Up to 30	600	200	300 (15-20 A)
Limitron		KTK-R	Up to 30	600	200	—	—
	J	JKS	Up to 600	600	200	—	—
	L	KLU	601 to 4000	600	200	—	—
		KTU	601 to 6000	600	200	—	—
	RK1	KTN-R	Up to 600	250	200	250 (70-350 A)	100
		KTS-R	Up to 600	600	200	—	—
	T	JJN	Up to 1200	300	200	160 (15-600 A) 170 (601-1200 A)	20 100
		JJS	Up to 800	600	200	—	—
	General purpose	G	SC	Up to 60	600 (1/2-20 A)	100	170 (1/2-20 A)
480 (25-60 A)					170 (1/2 — 20 A) 300 (25-60 A)		
H(K)		NON	250	Up to 600	50 (up to 60 A) 10 (65-600 A)	125 (up to 100 A)	50
		NOS	600	Up to 600	50 (up to 60 A) 10 (70-600 A)	—	—

* UL Class CF fuses have UL Class J electrical performance.

Table 3.1.4.3.b Interrupting ratings of Bussmann series UL branch circuit fuses.

Interrupting rating examples

Figure 3.1.4.3.c shows four different scenarios involving an OCPD with an interrupting rating of 10 kA and varying levels of fault currents that they will be called upon to interrupt. This illustrates the importance of knowing the available fault current and the advantage of applying a fuse with 100 kA, 200 kA or higher interrupting rating.

In the first three scenarios, the circuit current conditions are within the OCPD's safe operating capabilities. However, the fourth instance involves an OCPD misapplication. A fault on the device's loadside resulted in a 50 kA fault current that's well above the OCPD's interrupting rating. This resulted in a violent rupture and possible damage to equipment or injury to personnel. Using high interrupting rated fuses (typically rated at 200 kA or 300 kA) would prevent this potentially dangerous situation.

The examples on the next page are from fault current tests. They demonstrate the destructive power associated with fault currents.

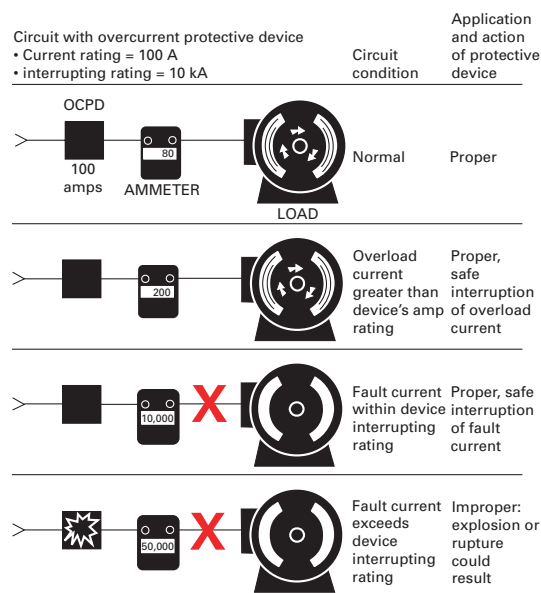


Figure 3.1.4.3.c Interrupting ratings are important for protecting against short-circuits.

Misapplied circuit breaker

Figure 3.1.4.3.d is a series of images depicting a test conducted on a 480 V circuit breaker with a 14 kA interrupting rating and a test circuit capable of delivering fault current of 50 kA at 480 V. The dramatic results are shown below. This video is available through the QR code below.

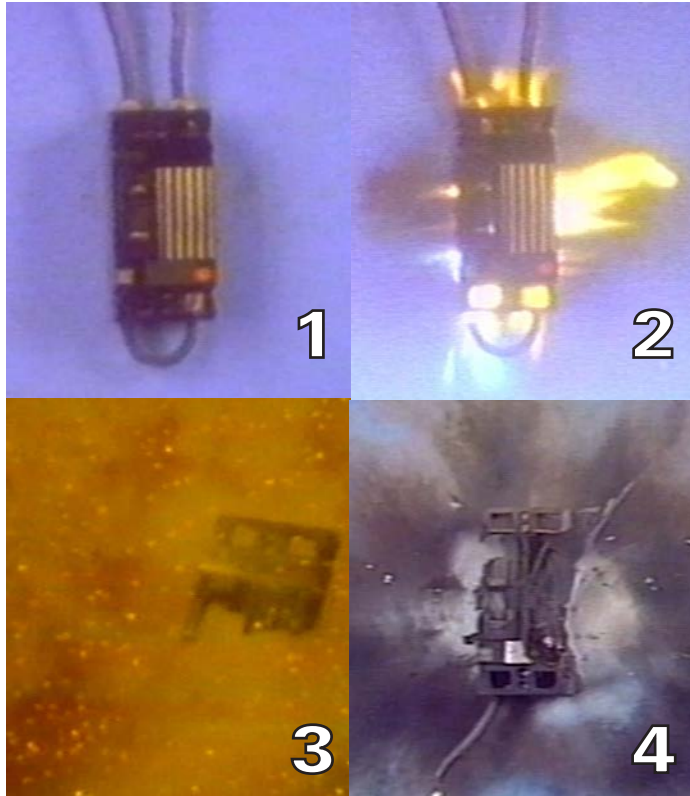


Figure 3.1.4.3.d A circuit breaker severely misapplied beyond its interrupting rating.



Misapplied general purpose fuses

Figure 3.1.4.3.e is a series of images depicting the same test circuit as the previous test with a pair of 600 V, general purpose fuses having a 10 kA interrupting rating. Notice in this test (as well as the circuit breaker test), the large destructive force that was released. Misapplying OCPDs in this manner is a serious safety hazard as shrapnel and molten metal could strike electricians or maintenance personnel, or anyone who happens to be nearby. This video is available through the QR code below.

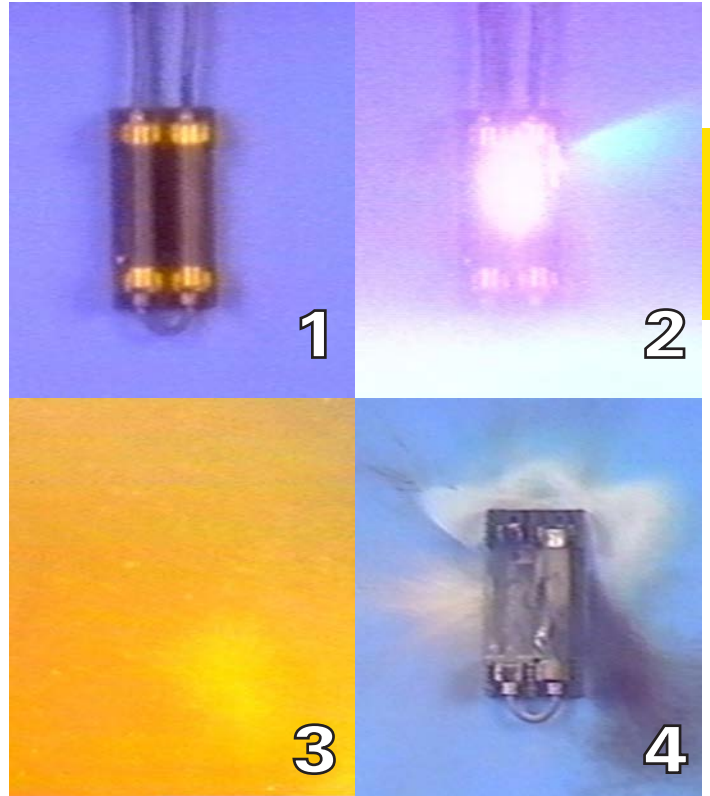


Figure 3.1.4.3.e A fuse severely misapplied beyond its interrupting rating.



Properly applied Low-Peak fuses

Figure 3.1.4.3.f is a series of images depicting the same test circuit as the previous two tests (50 kA available at 480 V) only this time the test was performed with modern, Bussmann series Low-Peak current-limiting fuses with a 300 kA interrupting rating. Notice that the fault was contained and cleared without violence. This video is available through the QR code below.

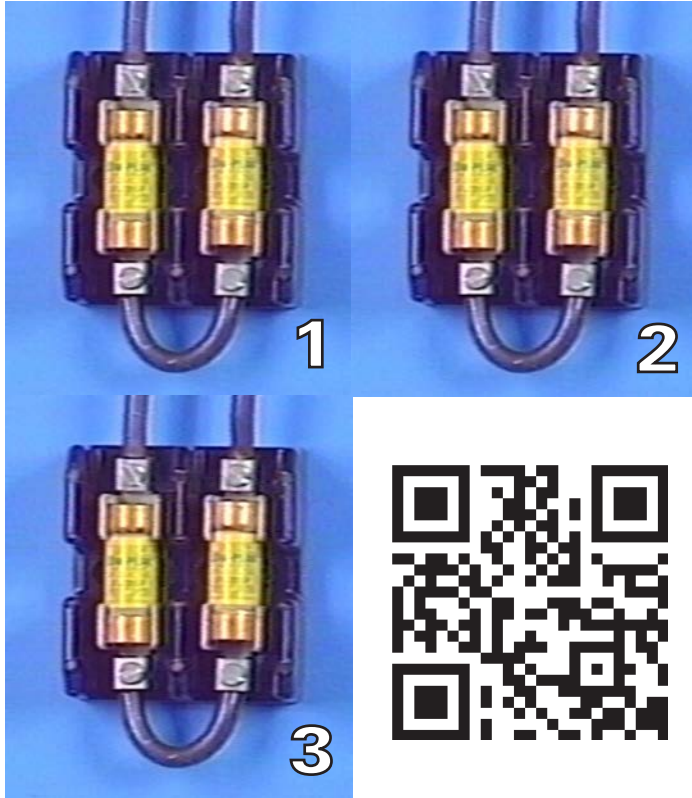


Figure 3.1.4.3.f A fuse applied within its interrupting rating.

As depicted in Figure 3.1.4.3.g, it becomes necessary to determine the available fault currents at each OCPD location. The fault currents in an electrical system can be easily calculated if sufficient information is known. The advantage of high 200 kA or 300 kA fuse interrupting ratings are that they can be used to eliminate the need for fault current calculations — 200 kA and 300 kA will exceed available fault currents for virtually all power distribution system.



Test conditions for a 300 kA interrupting rated fuse

The NEC defines interrupting rating as the highest current at rated voltage that an overcurrent protective device can safely interrupt under standard test conditions. The phrase “under standard test conditions” considers the importance of understanding how the overcurrent protective device is tested in order to ensure it is properly applied.

The UL 248 Standard defines the branch circuit fuse test configuration to establish the necessary performance requirements for interrupting ratings. The process to achieve a UL Listed 300 kA interrupting rating is:

- To confirm that the interrupting capacity is not less than the interrupting rating, the test circuit is established without any additional conductor lengths in the test circuit configuration. The fuse is efficient at interrupting very high fault currents and does not require any help from additional impedances in the configuration.
- The test circuit is calibrated to have at least 300 kA fault current at the rated fuse voltage. During the test circuit calibration, a busbar is used in place of the fuse to verify the 300 kA fault current level.
- The busbar is then replaced with a fuse and the test conducted. If the fuse passes the test, the fuse can be marked with a 300 kA interrupting rating.

This test procedure ensures the fuse has an interrupting rating equal to or greater than the fault current available at its line terminals for both three-phase bolted faults and for one or more phase-to-ground faults. Per UL/CSA/ANCE 248 Fuse Standards, fuses are tested and evaluated as single-pole devices. Although most electrical systems are designed with OCPDs having adequate three-phase interrupting ratings, the single/individual pole interrupting capabilities are easily overlooked. Because the fuse interrupting rating is all encompassing, there is no need for concern about single-pole interrupting capabilities.

300 kA Low-Peak fuses

Bussmann series Low-Peak fuses (excluding Class CC) are the only fuses tested and Listed by UL to 300 kA IR. This high interrupting rating is capable of safely interrupting virtually any available fault current level to be encountered in a 600 V or less system. The 300 kA IR provides assurance that when a properly sized Low-Peak fuse is installed, the system is covered for any worst case overcurrent event.

Electrical system short-circuit current levels and appropriate protection

Knowing the available fault current levels throughout an electrical system helps determine the necessary OCPD interrupting ratings. Figure 3.1.4.3.g is a one-line diagram showing available fault current levels at different points in an electrical system.

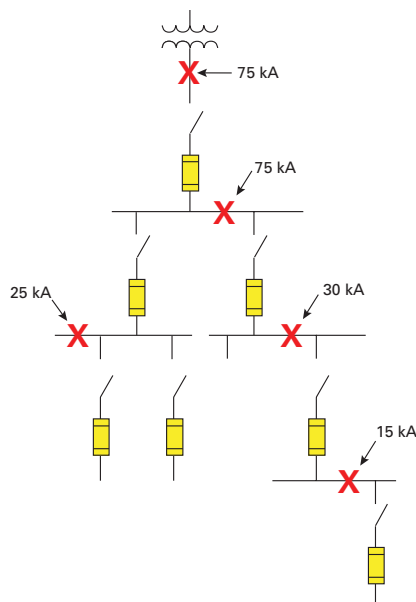


Figure 3.1.4.3.g Determining the fault current at each OCPD is necessary to ensure proper device application.

Fuses can be applied on single-phase or three-phase circuits without any concern for single-pole interrupting capabilities. There is no need to perform special calculations due to the grounding system utilized. All Bussmann series Low-Peak LPJ, KRP-C, LPS-RK and LPN-RK fuses have UL Listed 300 kA single-pole interrupting ratings.

This is a simple solution to ensure adequate interrupting ratings for present and future systems regardless of the grounding scheme.

Figure 3.1.4.3.h illustrates the fusible, high impedance grounded system allowing the fuse performance during fault conditions to be reviewed.

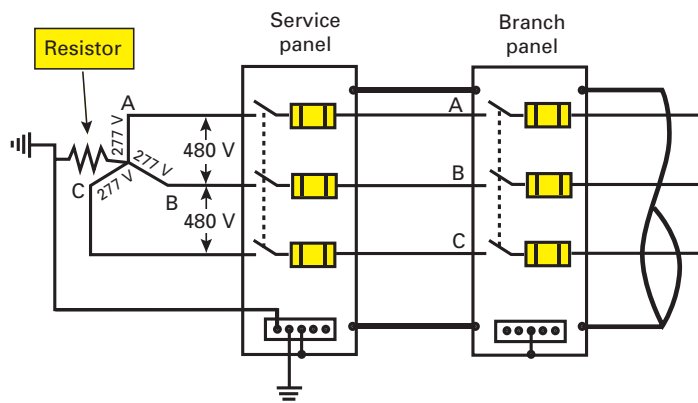


Figure 3.1.4.3.h Fusible high impedance grounded system.

Figure 3.1.4.3.i illustrates what occurs during the first system fault which is limited by the grounding resistor's impedance that keeps the ground fault current in the low range of 5 amps. Here the fuse does not open as expected and designed.

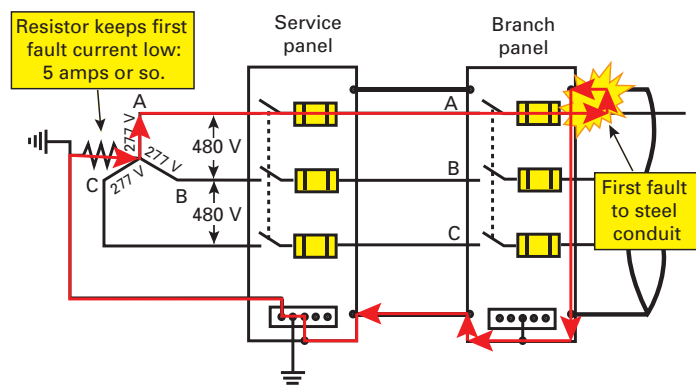


Figure 3.1.4.3.i The grounding resistor's impedance keeps the ground fault current low.

Figure 3.1.4.3.j illustrates the system should a second fault occur before the first fault can be addressed. The fault is essentially line-to-line with the conductors and ground path impedance, and the fuse must interrupt this second fault. Since a fuse's interrupting rating is the same as its single-pole interrupting capacity, fuses with 200 kA or 300 kA interrupting rating can be applied without further analysis for single-pole interrupting capabilities.

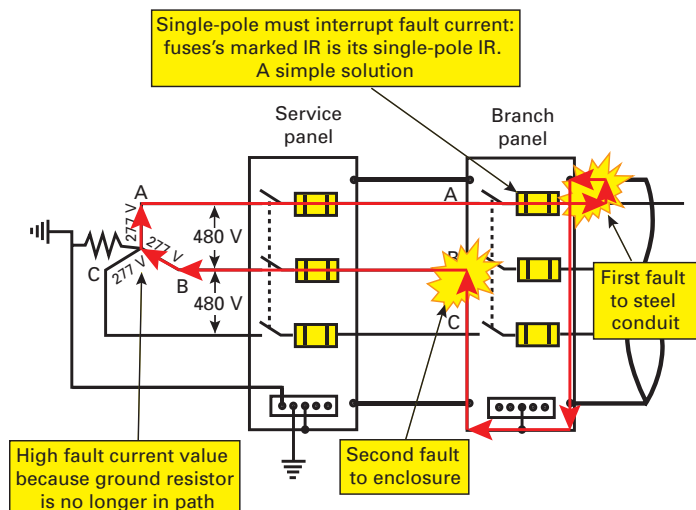


Figure 3.1.4.3.j The fault is essentially line-to-line with the conductors and ground path impedance.

As fault current levels increase with the continued growth in electrical power generation, so too has the need for OCPDs with higher interrupting ratings.

Utilities desire to obtain greater efficiencies, lower energy costs and improved voltage regulation by installing lower impedance transformers with larger kVA ratings that produce higher available fault currents. To meet this challenge, OCPDs that only interrupt moderate fault current levels are being replaced with fuses able to interrupt fault currents up to 300 kA.



Utilities are increasing available fault current through installing lower impedance and larger kVA transformers.

3.1.5 Performance characteristics

3.1.5.1 Current limitation

Current limitation is a function of how quickly the fuse can react to a fault and clear it before the fault current can build up to destructive magnitudes.

NEC 240.2 defines a current-limiting device as:

“Current-Limiting Overcurrent Protective Device: A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.”

Fuses that limit the let-through current to downstream components provide protection from thermal and magnetic forces while providing numerous benefits.

- Current-limiting fuses enhance workplace safety by reducing the incident energy personnel are exposed to under fault conditions. Arc flash hazards may be greatly reduced when compared to using a non-current limiting OCPD, especially at 600 amps and below.
- Fuses can protect components and equipment from extreme thermal and magnetic forces by clearing the fault current within the first half or quarter cycle. Conductors, busway, motor starters, switches and other devices can be well protected with current-limiting fuses. In addition, fuses, when properly sized, help comply with NEC 110.10 by protecting equipment and components from extensive damage.
- Fuse current limitation helps equipment achieve a high SCCR. Branch circuit components inside industrial control panels and machines, HVAC control panels, and other UL 508A Listed equipment can be protected by current-limiting fuses in the feeder circuit. The low peak let-through current can help raise the overall equipment short-circuit current rating — even with lower rated devices in the branch circuit — so long as the peak let-through current is less than the branch components’ SCCR and the branch circuit overcurrent protective device’s interrupting rating is sufficient.
- Current limitation is a key part of selective coordination and current-limiting fuses save the engineer or designer time and money by reducing the need for a selective coordination study. As long as a minimum amp ratio is maintained between upstream and downstream fuses (2:1 for Bussmann series Low-Peak fuses), selective coordination is achieved and unnecessary power loss to upstream circuits is prevented for any fault current up to the interrupting rating of the fuse. See “Bussmann series fuse selectivity ratios” (Table 3.1.5.5.b on page 3-30).

Figure 3.1.5.1.a shows the minimum Low-Peak fuse amp rating ratios required for “selective coordination” (discrimination) between upstream and downstream fuses.

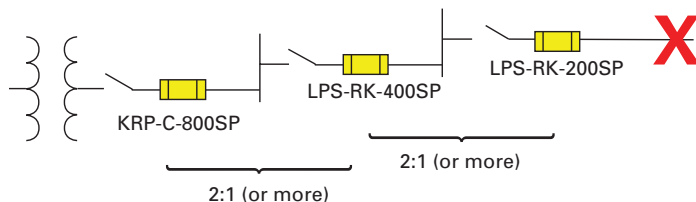


Figure 3.1.5.1.a Low-Peak fuses only need a 2:1 amp ratio for selective coordination.

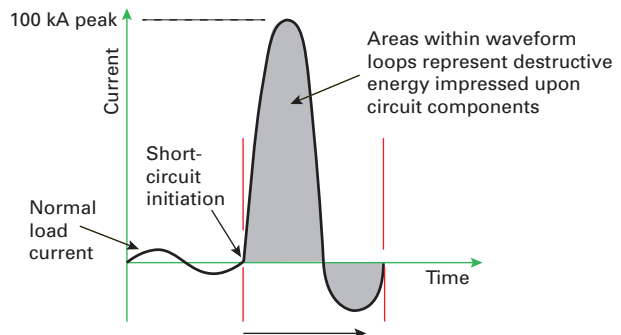
It’s a simple matter to selectively coordinate modern design fuses. By maintaining a minimum fuse amp rating ratio between an upstream and downstream fuse, selective coordination is achieved. Minimum selectivity ratios for Bussmann series fuses can be found on page 3-30.

Most electrical distribution systems today can deliver very high fault currents, some in excess of 200 kA. Many circuit components have relatively low (a few thousand amps) short-circuit current withstand capabilities.

If the components can’t withstand these high fault currents, they can be easily damaged or destroyed. The fuse’s current-limiting ability allows components with low SCCR to be specified despite high available fault currents.

Protecting electrical system components from fault currents is critical when selecting OCPDs. The engineer or specifier should consider the electrical circuit components’ SCCR, such as wire, bus or motor starters, and whether proper circuit protection will improve reliability and reduce the possibility of injury. Electrical systems can be destroyed if OCPDs do not limit the fault current to within the system’s component SCCRs. Merely matching the component amp rating with the protective device amp rating does not ensure component protection under fault conditions.

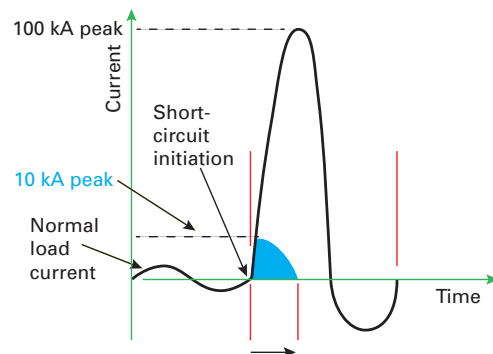
Current limitation is illustrated in Figures 3.1.5.1.b and 3.1.5.1.c. When not protected by a current-limiting OCPD, the prospective available short-circuit current is shown in Figure 3.1.5.1.b. A non-current-limiting OCPD permits fault current to build up to its full value and lets through an immense amount of destructive current, heat and magnetic energy before opening. Some OCPDs will permit short-circuit currents to flow for more than 1 cycle.



Non-current limiting OCPD opens short-circuit in about 1 cycle

Figure 3.1.5.1.b Fault current can become great in the first full cycle.

The waveform in Figure 3.1.5.1.c demonstrates this same short-circuit when the fuse operates within its current-limiting range. A current-limiting fuse has such a fast response speed that it cuts off the current long before it can build up to its full peak value.



Current limiting fuse opens and clears short-circuit in less than 1/2 cycle

Figure 3.1.5.1.c Cutting off the fault current in the first 1/4 cycle greatly reduces its magnitude.

The shaded area under the curve represents energy being dissipated in the circuit with both magnetic forces and thermal energy being directly proportional to the square of the current, making it important to limit the short-circuit current to as small a value as possible. The maximum magnetic forces vary as the square of the “peak” current and thermal energy varies as the square of the “RMS” current.

In the first major fault current cycle loop depicted by the waveform in Figure 3.1.5.1.b, a non-current limiting OCPD would let through approximately 100 times as much destructive energy as the current-limiting fuse would — $(100 \text{ kA} \div 10 \text{ kA})^2 = 100$.

The current-limiting fuse in Figure 3.1.5.1.c opens and clears the fault within the first 1/2 cycle and limits the let-through energy to a fraction of the system's available short-circuit current.

This performance is an important consideration when selecting OCPDs. Most fuses are current-limiting and greatly reduce a fault current's destructive peak and duration to protect downstream equipment, and can reduce the bracing needs for bus structures and minimize the need for components to have high SCCRs (withstand ratings).

Current-limiting fuses reduce the magnetic forces on downstream equipment during fault events that, if not limited, can reach levels of 30 kA or higher (even above 200 kA) in the first half cycle (0.008 seconds, at 60 Hz). The immense heat that can be produced in circuit components can cause conductor insulation damage or violent component explosions. At the same time, huge magnetic forces developed between conductors can crack insulators and distort or destroy bracing structures with the maximum mechanical force exerted being proportional to the square of the instantaneous peak current (I_p^2). Thus, it is important that an OCPD limit fault currents before they reach their full potential.

Cable whip test

The "cable whip test" is a current limitation demonstration that visually illustrates the difference between current-limiting and non-current limiting OCPDs. The following tests (A and B) were conducted with the same parameters/configuration:

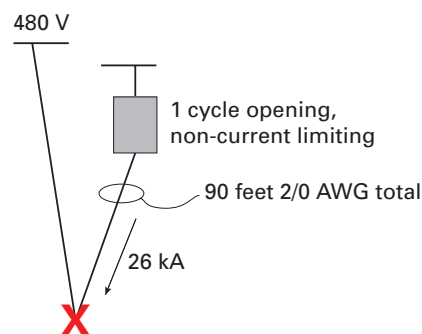
- Test voltage: 480 volts
- Conductor: 90 ft. of 2/0 AWG cable placed on the test lab floor
- The short-circuit current during a calibration test: asymmetrical with an approximately 26 kA RMS Sym. component

Test A was conducted without current limitation and Test B utilized a 200 A current-limiting fuse.

Tests videos are available through the QR codes. Figure 3.1.5.1.d is a photograph of the test configuration that was performed without an upstream current-limiting OCPD. Figure 3.1.5.1.e illustrates how Test A was conducted with the resulting peak current that flowed in one cycle.



Figure 3.1.5.1.d Test A: One cycle interrupting time — non-current limiting OCPD.

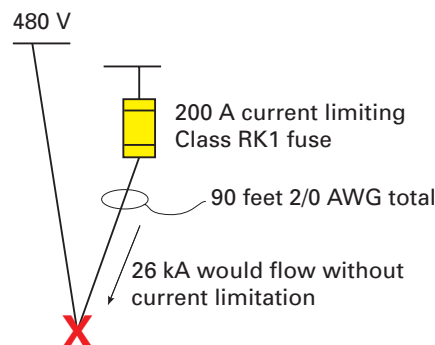


Test results:

- I_p let-through = 48,100 A
- Clearing time = 0.0167 sec.

Figure 3.1.5.1.e Test A with a non-current limiting OCPD.

Test B results and video are available in Figure 3.1.5.1.f. This test was conducted with an upstream current-limiting device with dramatically different results from Test A.



Test results:

- I_p let-through = 10,200 A
- Clearing time = 0.004 sec.

Figure 3.1.5.1.f Test B with a 200 A current-limiting OCPD.

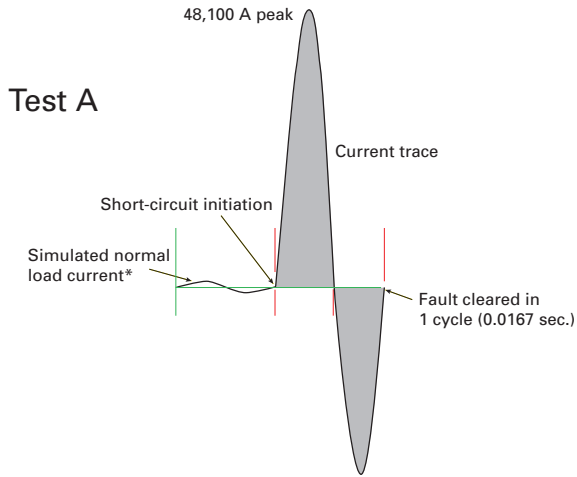
Reviewing the Test A and Test B cable whip results demonstrate a significant reduction in let-through current by the 200 A current-limiting fuse versus the one-cycle non-current limiting OCPD. Since the mechanical forces exerted on electrical equipment is directly proportional to the instantaneous peak current squared (I_p^2) let-through, the current-limiting fuse reduced the maximum mechanical force let-through by over 95% as shown in this equation:

$$(10,200 \div 48,100)^2 \approx 1/22$$



Test A and B short-circuit current waveforms

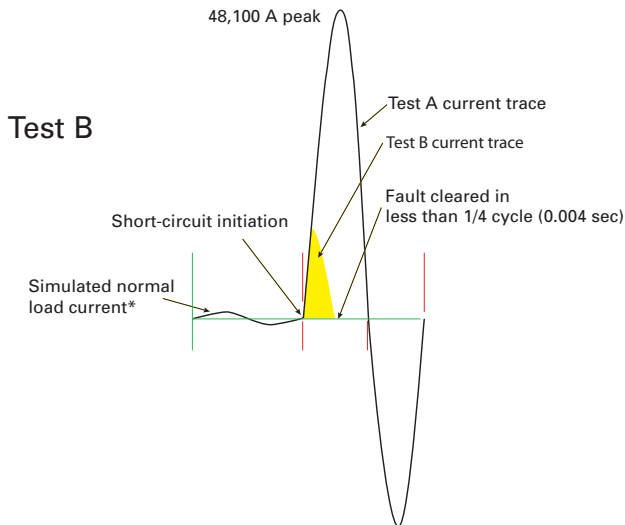
The equivalent Test A and Test B waveforms are illustrated in Figure 3.1.5.1.g and Figure 3.1.5.1.h.



* Normal load current did not flow prior to short-circuit initiation.

Figure 3.1.5.1.g Test A fault current waveform.

Figure 3.1.5.1.g illustrates the current trace of Test A depicting normal current flow until the fault occurs, and then the fault current that flows for one cycle, achieving a peak let-through of 48,100 A.



* Normal load current did not flow prior to short-circuit initiation.

Figure 3.1.5.1.h Test B fault current waveform.

Figure 3.1.5.1.h illustrates the current trace of Test B showing normal current until the fault occurs, and then the short-circuit current being cleared in less than 1/4 cycle by the Bussmann series current-limiting Low-Peak LPS-RK-200SP fuse that limited the instantaneous peak current to only 10.2 kA.

For simplicity, this section does not provide the measurement parameter to assess the thermal energy let-through for these tests. However, the recording instrumentation documented that Test B let-through current was 1/123 the thermal energy compared to Test A.

How to use current limitation charts

Analysis of current-limiting fuse let-through graphs

The degree of current limitation of a given size and type of fuse depends, in general, upon the available fault current that can be delivered by the electrical system. Current-limitation of fuses is best described in the form of a let-through curve (see Figure 3.1.5.1.i) that, when applied from a practical point of view, is useful to determine the let-through currents when a fuse opens.

Fuse let-through curves are plotted from actual test data. The test circuit that establishes line A—B corresponds to a short circuit power factor of 15% that is associated with an X/R ratio of 6.6. The fuse curves represent the cutoff value of the prospective available fault current under the given circuit conditions. Each type or class of fuse has its own family of let-through curves.

The let-through data has been generated by actual short-circuit tests of current-limiting fuses. It is important to understand how the curves are generated, and what circuit parameters affect the let-through curve data. Typically, there are three circuit parameters that can affect fuse let-through performance for a given available fault current. These are:

1. Short-circuit power factor
2. Short-circuit closing angle
3. Applied voltage

Current-limiting fuse let-through curves are generated under worst case conditions, based on these three variable parameters. The benefit to the user is a conservative resultant let-through current (both I_p and I_{RMS}). Under actual field conditions, changing any one or a combination of these will result in lower let-through currents. This provides for an additional degree of reliability when applying fuses for equipment protection.



Current-limiting fuse analysis

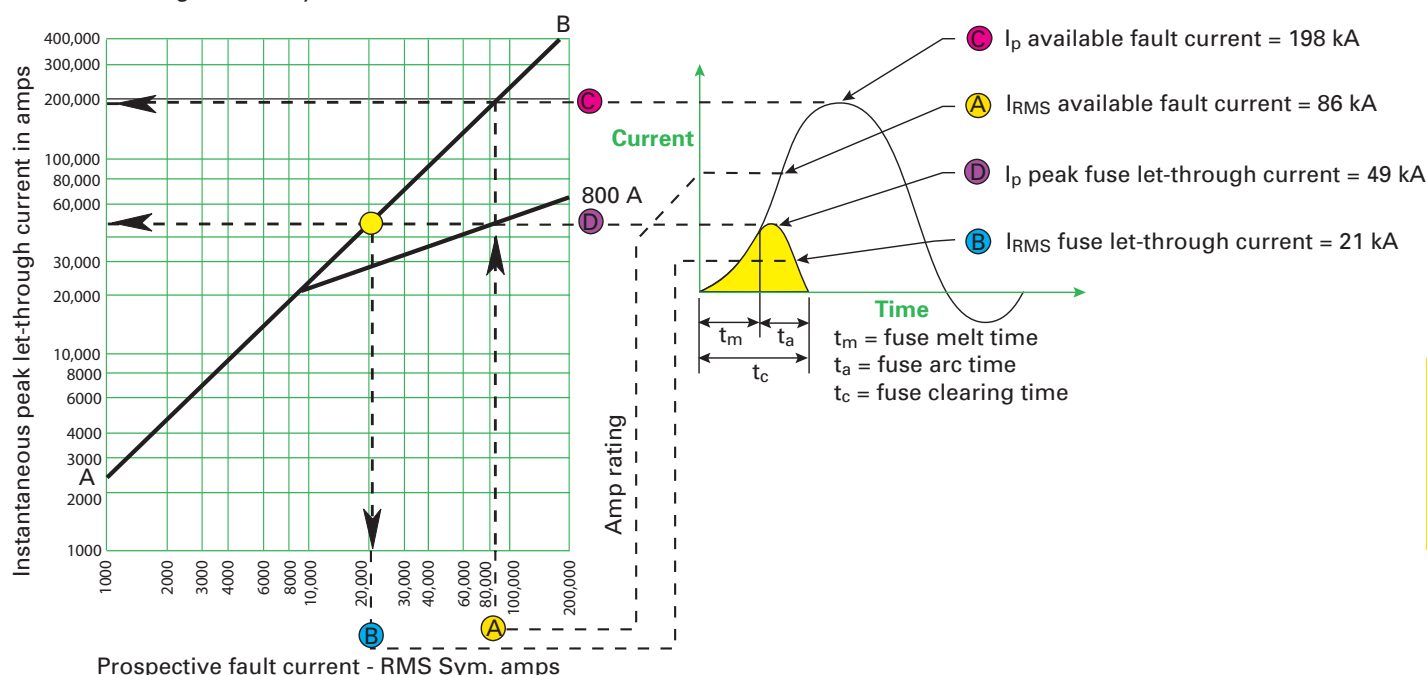


Figure 3.1.5.1.i Current-limiting fuse let-through curve for a Bussmann series 800 A KRP-C-800SP Class L Low-Peak, time-delay fuse.

Prior to using the fuse let-through curves, it must be determined what let-through data is pertinent to equipment SCCRs (withstand ratings).

Equipment SCCR can be described as how much fault current the equipment can handle, and for how long. Based on standards presently available, the most important data that can be obtained from the fuse let-through curves and their physical effects are:

- Peak let-through current (mechanical forces)
- Apparent prospective RMS symmetrical let-through current (heating effect)
- Clearing time: less than 1/2 cycle when fuse is in its current-limiting range (beyond where fuse curve intersects A—B line).

This typical example in Figure 3.1.5.1j shows the available fault current in an 800 A circuit and an 800 A Low-Peak current-limiting time-delay fuse.

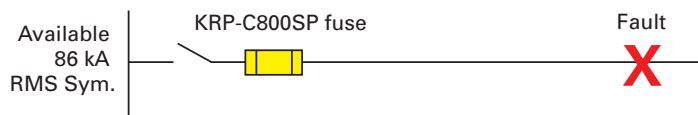


Figure 3.1.5.1j 800 A Low-Peak current-limiting time-delay fuse and associated let-through data

Fuse current limitation let-through curves

Using the example given, one can determine the pertinent let-through data for the KRP-C-800SP amp Low-Peak fuse. The let-through curve pertaining to the 800 A Low-Peak fuse is illustrated in Figure 3.1.5.1.i.

A. Determine the peak let-through current.

- Step 1. Enter the chart on the prospective short-circuit current scale at 86 kA and proceed vertically until the 800 A fuse curve is intersected.
- Step 2. Follow horizontally until the Instantaneous peak let-through current scale is intersected.
- Step 3. Read the peak let-through current as 49 kA (if a fuse had not been used, the peak current would have been 198 kA).

B. Determine the apparent prospective RMS Sym. let-through current.

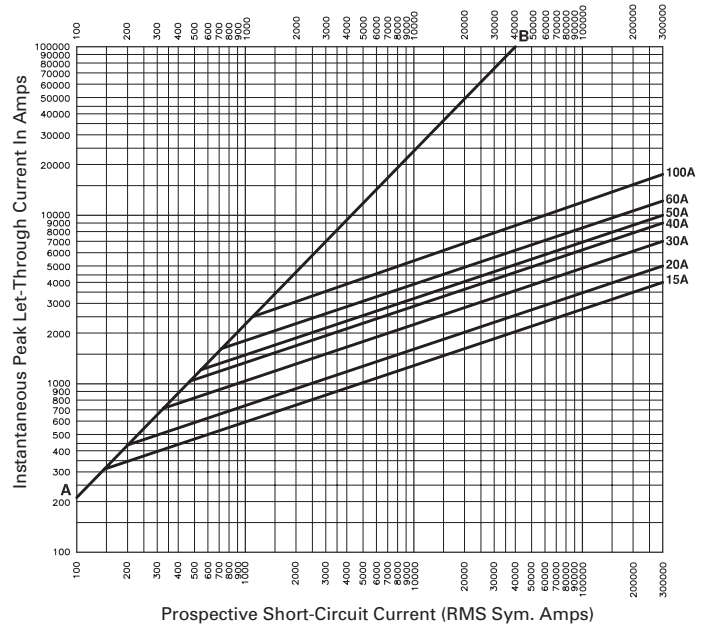
- Step 1. Enter the curve on the prospective short-circuit current scale at 86 kA and proceed vertically until the 800 A fuse curve is intersected.
- Step 2. Follow horizontally until line A—B is intersected.
- Step 3. Proceed down to the prospective short-circuit current.
- Step 4. Read the prospective fault current — RMS Sym. amps as 21 kA. (The RMS Sym. let-through current would be 86 kA if there were no fuse in the circuit.)

3.1.5.2 Current let-through curves

Class CF fuses

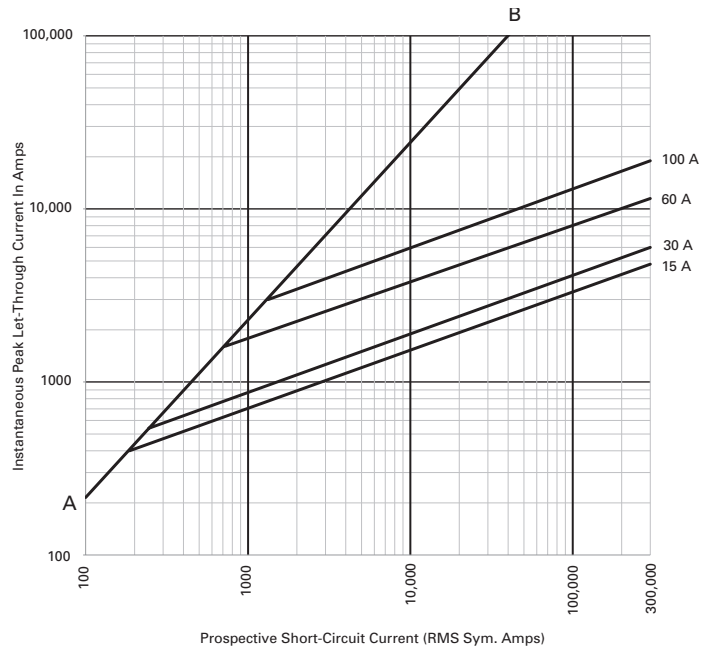
TCF_ and TCF_RN current-limiting, dual-element, time-delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)			
	15	30	60	100
	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1000	1	1	1	1
3000	1	1	2	2
5000	1	1	2	2
10,000	1	1	2	3
15,000	1	2	2	3
20,000	1	2	3	3
25,000	1	2	3	4
30,000	1	2	3	4
35,000	1	2	3	4
40,000	1	2	3	4
50,000	1	2	3	5
60,000	1	2	4	5
80,000	2	2	4	5
100,000	2	3	4	5
150,000	2	3	5	6
200,000	2	3	5	7
250,000	2	3	5	7
300,000	2	3	5	8



FCF_RN current-limiting, non-time delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)			
	15	30	60	100
	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1000	1	1	1	1
3000	1	1	1	2
5000	1	1	2	2
10,000	1	1	2	3
15,000	1	1	2	3
20,000	1	1	3	4
25,000	1	2	3	4
30,000	1	2	3	4
35,000	1	2	3	4
40,000	1	2	3	4
50,000	1	2	3	4
60,000	2	2	3	5
80,000	2	2	4	5
100,000	2	2	4	6
150,000	2	3	4	6
200,000	2	3	5	7
250,000	2	3	5	8
300,000	2	3	5	8



TCF CUBEFuse



FCF CUBEFuse

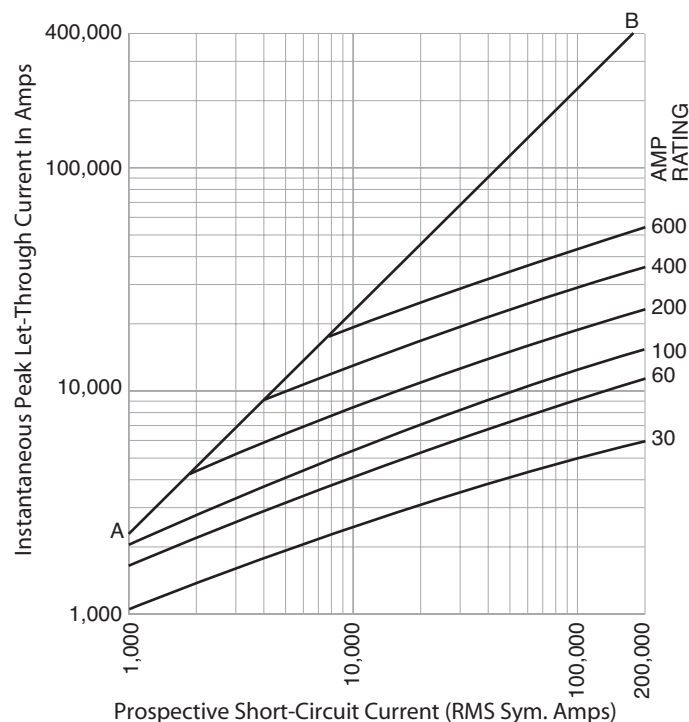
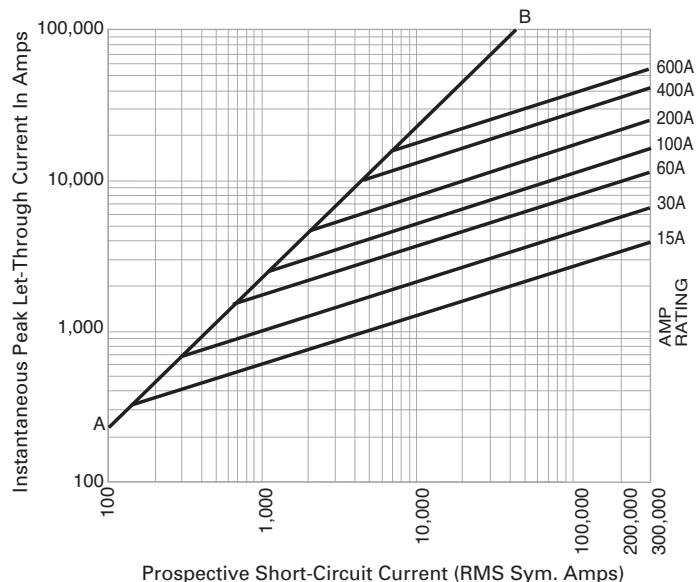
Class J fuses

LPJ-SP current-limiting, dual-element, time-delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)						
	15	30	60	100	200	400	600
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
1000	1	1	1	1	1	1	1
3000	1	1	1	2	2	3	3
5000	1	1	1	2	3	5	5
10,000	1	1	2	2	4	6	8
15,000	1	1	2	3	4	7	9
20,000	1	1	2	3	4	7	10
25,000	1	1	2	3	5	8	10
30,000	1	1	2	3	5	8	11
35,000	1	1	2	4	5	9	12
40,000	1	2	3	4	6	9	12
50,000	1	2	3	4	6	10	13
60,000	1	2	3	4	6	11	14
80,000	1	2	3	5	7	12	15
100,000	1	2	4	5	8	12	17
150,000	1	2	4	6	9	14	19
200,000	2	3	4	6	9	16	21
250,000	2	3	5	7	10	17	23
300,000	2	3	5	7	11	18	24

JKS current-limiting, non-time delay fuse RMS let-through currents (kA)

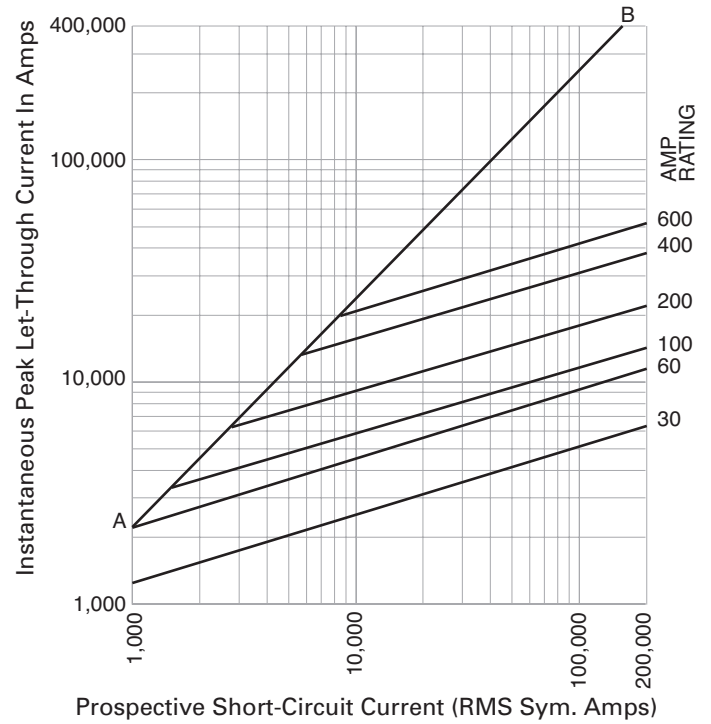
Prosp. short C.C.	Fuse size (amps)					
	30	60	100	200	400	600
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
5000	1	1	2	3	4	5
10,000	1	2	3	4	6	9
15,000	1	2	3	4	7	10
20,000	1	2	3	5	8	11
25,000	2	3	3	6	9	12
30,000	2	3	3	6	9	13
35,000	2	3	4	6	9	13
40,000	2	3	4	7	10	14
50,000	2	3	4	7	10	15
60,000	2	3	5	7	11	16
70,000	2	3	5	8	11	17
80,000	2	3	5	8	12	17
90,000	2	4	6	9	13	18
100,000	2	4	6	9	13	18
150,000	2	5	6	9	14	22
200,000	3	5	7	10	16	24



Class RK1 fuses — 250 V and 600 V

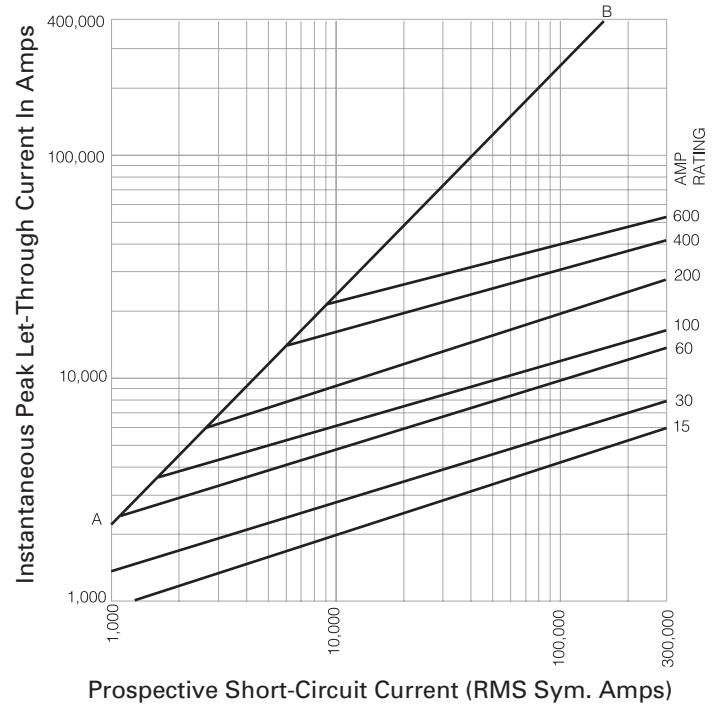
250 V LPN-RK-SP current-limiting, dual-element, time-delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)					
	30	60	100	200	400	600
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
1000	1	1	1	1	1	1
2000	1	1	2	2	2	2
3000	1	1	2	3	3	3
5000	1	2	2	3	5	5
10,000	1	2	3	4	7	9
15,000	1	2	3	5	8	11
20,000	1	3	3	5	8	11
25,000	1	3	3	5	9	12
30,000	2	3	4	6	9	12
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	13
50,000	2	3	4	7	11	14
60,000	2	3	4	7	11	16
70,000	2	3	4	7	12	16
80,000	2	4	5	8	12	16
90,000	2	4	5	7	13	17
100,000	2	4	5	8	13	17
150,000	2	4	6	9	15	19
200,000	3	5	6	11	16	20
250,000	3	5	7	11	17	21
300,000	3	6	7	12	18	22



600 V LPS-RK-SP current-limiting, dual-element, time-delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)					
	30	60	100	200	400	600
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
1000	1	1	1	1	1	1
2000	1	1	2	2	2	2
3000	1	1	2	3	3	3
5000	1	2	2	3	5	5
10,000	1	2	3	4	7	10
15,000	1	2	3	5	8	11
20,000	2	3	3	5	9	12
25,000	2	3	4	6	9	12
30,000	2	3	4	6	10	13
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	14
50,000	2	3	5	7	11	15
60,000	2	4	5	7	12	15
70,000	2	4	5	8	13	16
80,000	2	4	5	8	13	16
90,000	2	4	5	8	13	17
100,000	2	4	6	9	14	17
150,000	3	5	6	10	15	19
200,000	3	5	7	11	16	21
250,000	3	6	7	12	17	22
300,000	3	6	7	12	18	23



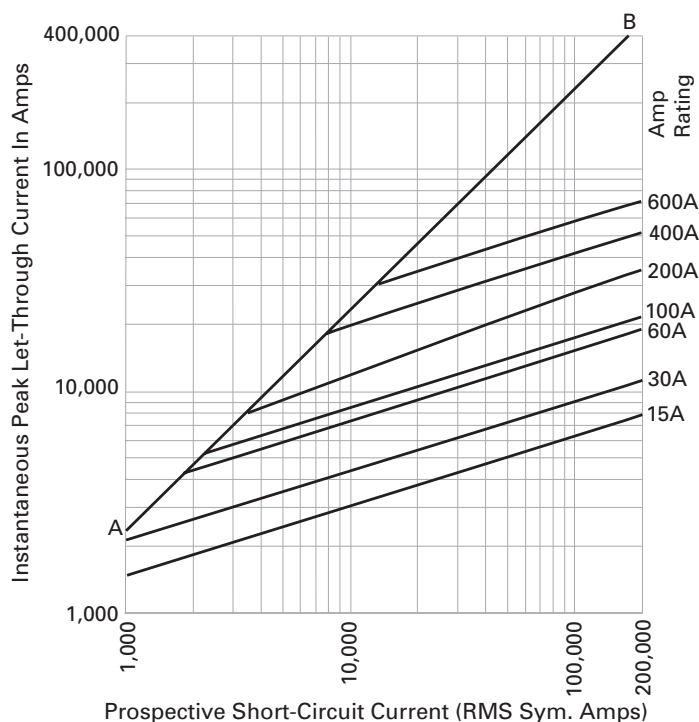
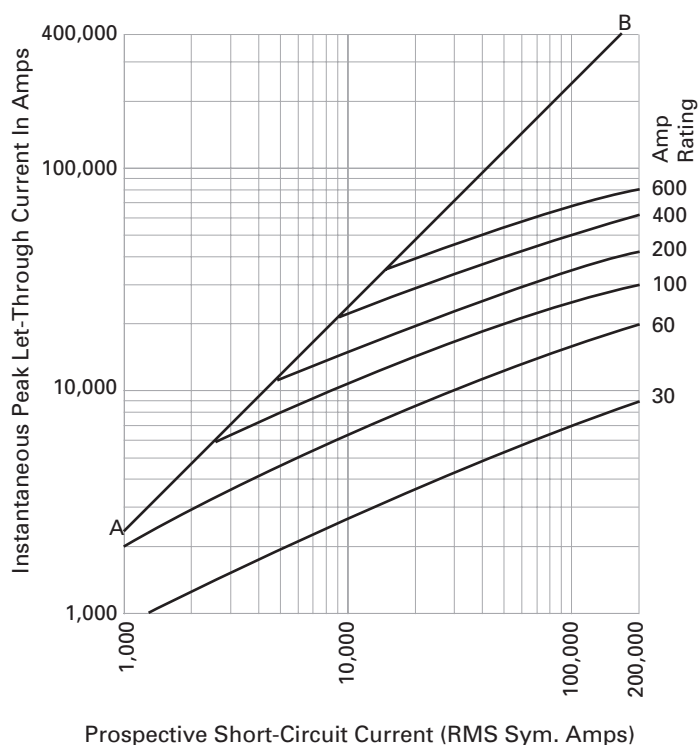
Class RK5 fuses — 250 V and 600 V

250 V FRN-R current-limiting, dual-element, time-delay fuse
RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)					
	30	60	100	200	400	600
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
5000	1	2	3	5	5	5
10,000	2	3	4	7	10	10
15,000	2	3	5	8	11	15
20,000	2	4	5	8	12	16
25,000	2	4	6	9	13	17
30,000	2	4	6	10	14	18
35,000	2	4	6	10	15	19
40,000	2	5	7	11	15	20
50,000	3	5	7	11	17	21
60,000	3	5	8	12	18	22
70,000	3	6	8	13	19	23
80,000	3	6	8	13	19	24
90,000	3	6	9	14	20	25
100,000	3	6	9	14	21	26
150,000	4	7	10	16	24	29
200,000	4	8	11	18	26	32

600 V FRS-R current-limiting, dual-element, time-delay fuse
RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)					
	30	60	100	200	400	600
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
5000	1	1	3	4	5	5
10,000	1	2	4	5	9	10
15,000	1	2	4	6	10	14
20,000	2	2	5	7	11	15
25,000	2	2	5	7	12	17
30,000	2	3	5	8	13	18
35,000	2	3	5	8	13	18
40,000	2	3	6	9	14	19
50,000	2	3	6	9	14	20
60,000	2	3	6	10	15	22
70,000	3	4	7	11	17	23
80,000	3	4	7	12	17	23
90,000	3	4	7	12	17	24
100,000	3	4	8	13	18	25
150,000	3	5	9	14	21	27
200,000	4	6	9	16	23	32



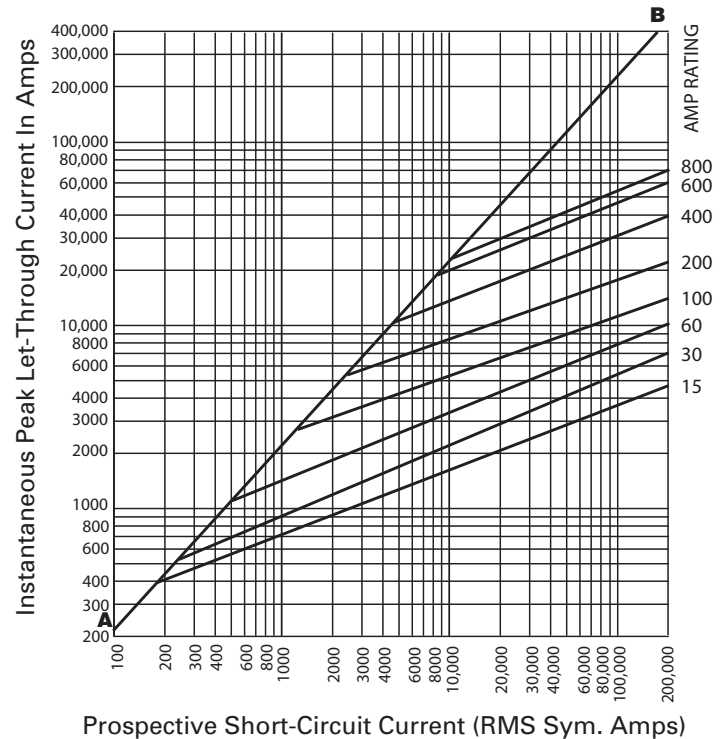
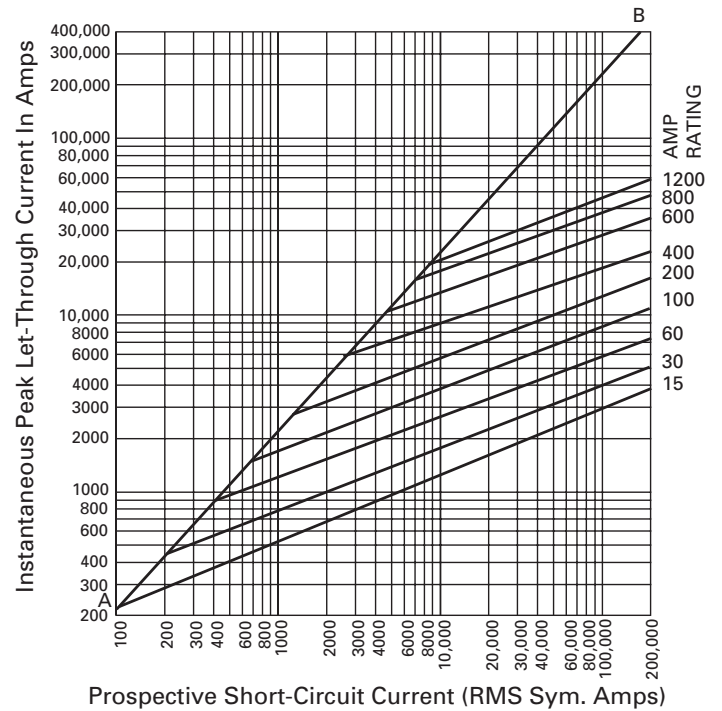
Class T fuses — 300 V and 600 V

300 V JJN current-limiting, non-time delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)								
	15	30	60	100	200	400	600	800	1200
500	1	1	1	1	1	1	1	1	1
1000	1	1	1	1	1	1	1	1	1
5000	1	1	1	1	2	3	5	5	5
10,000	1	1	1	2	2	4	6	7	9
15,000	1	1	1	2	3	4	6	9	10
20,000	1	1	1	2	3	5	7	10	11
25,000	1	1	2	2	3	5	7	10	12
30,000	1	1	2	2	3	5	8	11	13
35,000	1	1	2	3	4	6	8	11	13
40,000	1	1	2	3	4	6	9	11	13
50,000	1	1	2	3	4	7	9	12	15
60,000	1	1	2	3	4	7	10	13	16
70,000	1	1	2	3	5	7	10	14	17
80,000	1	2	2	3	5	8	11	15	17
90,000	1	2	2	3	6	8	11	15	18
100,000	1	2	2	4	6	8	12	16	19
150,000	1	2	3	4	6	9	13	17	22
200,000	2	2	3	4	7	9	15	19	23

600 V JJS current-limiting, non-time delay fuse RMS let-through currents (kA)

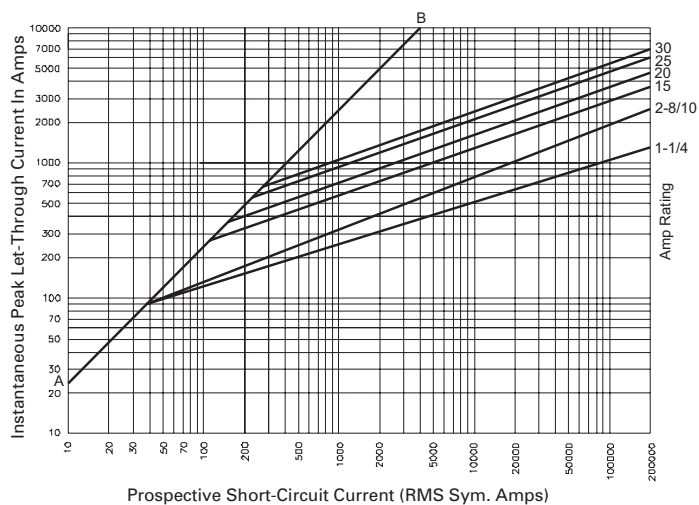
Prosp. short C.C.	Fuse size (amps)							
	15	30	60	100	200	400	600	800
500	1	1	1	1	1	1	1	1
1000	1	1	1	1	1	1	1	1
5000	1	1	1	2	3	4	5	5
10,000	1	1	1	2	3	6	8	9
15,000	1	1	2	3	4	7	10	11
20,000	1	1	2	3	4	7	10	12
25,000	1	1	2	3	5	7	11	13
30,000	1	1	2	3	5	8	12	14
35,000	1	1	2	3	5	9	13	15
40,000	1	2	2	4	5	9	13	15
50,000	1	2	2	4	6	10	14	17
60,000	1	2	3	4	6	10	16	18
70,000	1	2	3	4	7	11	17	19
80,000	1	2	3	4	7	11	17	20
90,000	1	2	3	4	7	12	18	21
100,000	2	2	3	5	7	12	19	22
150,000	2	3	4	6	8	14	22	25
200,000	2	3	4	6	9	16	24	28



Class CC fuse

LP-CC current-limiting, time-delay fuse RMS let-through currents (kA)

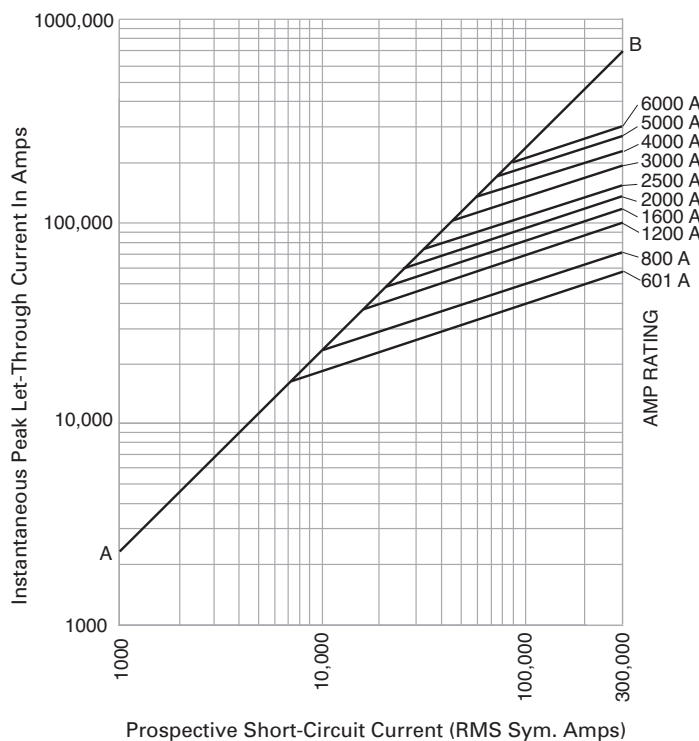
Prosp. short C.C.	Fuse size (amps)					
	1-1/4	2-8/10	15	20	25	30
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
1000	100	135	240	305	380	435
3000	140	210	350	440	575	580
5000	165	255	420	570	690	710
10,000	210	340	540	700	870	1000
20,000	260	435	680	870	1090	1305
30,000	290	525	800	1030	1300	1520
40,000	315	610	870	1150	1390	1700
50,000	340	650	915	1215	1520	1820
60,000	350	735	1050	1300	1650	1980
80,000	390	785	1130	1500	1780	2180
100,000	420	830	1210	1600	2000	2400
200,000	525	1100	1600	2000	2520	3050



Class L fuses

KRP-C-SP current-limiting, time-delay fuse RMS let-through currents (kA)

Prosp. short C.C.	Fuse size (amps)									
	601	800	1200	1600	2000	2500	3000	4000	5000	6000
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
5000	5	5	5	5	5	5	5	5	5	5
10,000	8	10	10	10	10	10	10	10	10	10
15,000	9	12	15	15	15	15	15	15	15	15
20,000	10	13	17	20	20	20	20	20	20	20
25,000	11	14	19	22	25	25	25	25	25	25
30,000	11	14	20	24	27	30	30	30	30	30
35,000	12	15	21	25	29	35	35	35	35	35
40,000	13	16	22	26	30	35	40	40	40	40
50,000	14	17	23	28	32	37	50	50	50	50
60,000	15	18	25	30	34	40	49	60	60	60
70,000	15	19	26	32	36	42	52	62	70	70
80,000	16	20	27	33	38	44	54	65	76	80
90,000	17	21	29	34	39	45	56	67	79	90
100,000	17	22	30	36	41	47	58	70	81	100
150,000	20	25	34	41	47	54	67	80	93	104
200,000	22	27	37	45	51	59	73	87	102	114
250,000	24	29	40	49	55	64	79	94	110	123
300,000	25	31	43	52	59	68	84	100	117	140



3.1.5.3 The OCPD's role in electrical safety

OCPD selection and performance play a significant role in electrical safety. Extensive tests and analysis by industry have shown that the energy released during an arcing fault is related to two OCPD characteristics:

1. The time it takes the OCPD to open
2. The amount of fault current the OCPD lets through

For instance, the faster OCPD clears the fault, the lower the energy released. If the OCPD can also limit the current, thereby reducing the actual fault current magnitude that flows through the arc, the lower the energy released. The lower the energy released, the better for both worker safety and equipment protection.

Simple method for arc flash hazard analysis per 2018 NFPA 70E

The following is an example of identifying the arc flash hazard per 130.5(E) for the arc flash boundary (AFB) and 130.5(G) using the incident energy analysis method.

Various information about the system may be needed to complete this analysis, but two values are absolutely necessary:

1. The available 3 Ø bolted fault current
2. The fuse type/amp rating

Consider the one-line diagram in Figure 3.1.5.3.a and then follow the examples that take the steps needed to conduct an arc flash hazard analysis.

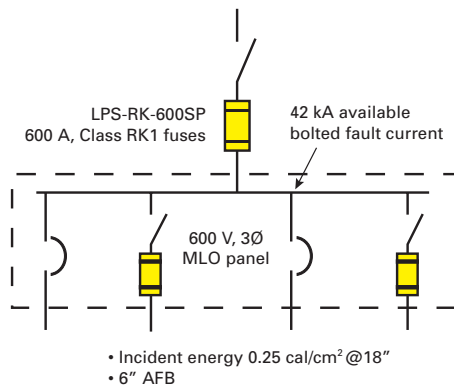


Figure 3.1.5.3.a: One-line diagram used in arc flash hazard analysis.

The following information utilizes the simplified fuse formulas based upon IEEE 1584-2002 Guide for Arc Flash Hazard Analysis and shown in 2018 NFPA 70E Annex D.4.6 and shows the steps necessary to conduct an arc flash hazard analysis when using Low-Peak fuses and Table 3.1.5.3.b: arc flash incident energy.

1. Determine the available bolted fault current on the lineside terminals of the equipment that will be worked on.
2. Identify the amp rating of the upstream Low-Peak fuse that's protecting the panel where work is to be performed.
3. Consult Table 3.1.5.3.b to determine the Incident Energy Exposure (I.E.) level.
4. Determine the AFB that will require personal protective equipment (PPE) based upon the incident energy. This is simplified by using the column for AFB in Table 3.1.5.3.b.
5. Identify the minimum requirements for PPE when work is to be performed inside of the AFB by consulting the requirements found in NFPA 70E Table 130.5(G).

Example 1: Arc flash hazard analysis using Bussmann series current-limiting fuses (notes referenced appear on page 3-28)

The following is a simple method when using certain Bussmann series fuses; this method is based on actual data from arcing fault tests (and resulting simplified formulas shown in NFPA 70E Annex D.4.6 and 2002 IEEE 1584) with Bussmann series current-limiting fuses. Using this simple method, the first thing that must be done is to determine the incident energy exposure level. We have simplified this process when using LPS-RK, LPJ, TCF, LP-CC or KRP-C Low-Peak fuses, or JJN or JJS Limitron fuses and FCF fuses. In some cases the results are conservative; see Note 6.

In this example, the lineside OCPD in Figure 3.1.5.2.a is an LPS-RK-600SP, Low-Peak current-limiting fuse. Simply take the available 3 Ø bolted fault current at the panel — in this case 42 kA — and locate it on the vertical column in Table 4. Then proceed directly to the right to the 401-600 A fuse column and identify the I.E. (incident energy) and AFB.

With 42 kA of 3 Ø bolted available fault current, the table shows that when relying on the LPS-RK-600SP Low-Peak fuse to interrupt an arcing fault, the incident energy is 0.25 cal/cm². Notice the variables required are the available 3 Ø bolted fault current and the Low-Peak current-limiting fuse amp rating. See Notes 7 and 8.

The next step in this simplified arc flash hazard analysis is to determine the AFB. With an incident energy of 0.25 cal/cm² and using the same table, the AFB is approximately 6 inches, which is found next to the incident energy value previously located. See Note 6. This AFB distance means that anytime work is to be performed inside of this distance, including voltage testing to verify that the panel is de-energized, the worker must be equipped with the appropriate PPE.

The last step in the arc flash hazard analysis is to determine the appropriate PPE for the task. To select the proper PPE, utilize the incident energy exposure values and the requirements from NFPA 70E. NFPA 70E Table 130.5(G) has requirements for the PPE based upon the incident energy exposure level. NFPA 70E Annex H is a resource for guidance in selecting PPE; specifically Tables H.2 and H.3.

When selecting PPE for a given application or task, keep in mind that these requirements from NFPA 70E are minimum requirements. Having additional PPE, above what is required, can further assist in minimizing the effects of an arc flash incident. Another thing to keep in mind is that PPE available on the market today does not protect a person from the pressures, shrapnel and toxic gases that can result from an arc-blast, which are referred to as "physical trauma" in NFPA 70E. Existing PPE is only tested to minimize the potential for burns from the arc flash. See Notes 1 and 2.



Arc flash incident energy levels based upon 1-600 A Low-Peak LPS-RK and 601-2000 A Low-Peak KRP-C fuses

Incident Energy (I.E.) values expressed in cal/cm², Arc Flash Boundary (AFB) expressed in inches.

Bolted fault current (kA)	1-100 A		101-200 A		201-400 A		401-600 A		601-800 A		801-1200 A		1201-1600 A		1601-2000 A	
	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB
1	2.39	29	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
2	0.25	6	5.20	49	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
3	0.25	6	0.93	15	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
4	0.25	6	0.25	6	20.60	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
5	0.25	6	0.25	6	1.54	21	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
6	0.25	6	0.25	6	0.75	13	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
8	0.25	6	0.25	6	0.69	12	36.85	>120	>100	>120	>100	>120	>100	>120	>100	>120
10	0.25	6	0.25	6	0.63	12	12.82	90	75.44	>120	>100	>120	>100	>120	>100	>120
12	0.25	6	0.25	6	0.57	11	6.71	58	49.66	>120	73.59	>120	>100	>120	>100	>120
14	0.25	6	0.25	6	0.51	10	0.60	11	23.87	>120	39.87	>120	>100	>120	>100	>120
16	0.25	6	0.25	6	0.45	9	0.59	11	1.94	25	11.14	82	24.95	>120	>100	>120
18	0.25	6	0.25	6	0.39	8	0.48	10	1.82	24	10.76	80	24.57	>120	>100	>120
20	0.25	6	0.25	6	0.33	7	0.38	8	1.70	23	10.37	78	24.20	>120	>100	>120
22	0.25	6	0.25	6	0.27	7	0.28	7	1.58	22	9.98	76	23.83	>120	>100	>120
24	0.25	6	0.25	6	0.25	6	0.25	6	1.46	21	8.88	70	23.45	>120	29.18	>120
26	0.25	6	0.25	6	0.25	6	0.25	6	1.34	19	7.52	63	23.08	>120	28.92	>120
28	0.25	6	0.25	6	0.25	6	0.25	6	1.22	18	6.28	55	22.71	>120	28.67	>120
30	0.25	6	0.25	6	0.25	6	0.25	6	1.10	17	5.16	48	22.34	>120	28.41	>120
32	0.25	6	0.25	6	0.25	6	0.25	6	0.98	16	4.15	42	21.69	>120	28.15	>120
34	0.25	6	0.25	6	0.25	6	0.25	6	0.86	14	3.25	35	18.58	116	27.90	>120
36	0.25	6	0.25	6	0.25	6	0.25	6	0.74	13	2.47	29	15.49	102	27.64	>120
38	0.25	6	0.25	6	0.25	6	0.25	6	0.62	11	1.80	24	12.39	88	27.38	>120
40	0.25	6	0.25	6	0.25	6	0.25	6	0.50	10	1.25	18	9.29	72	27.13	>120
42	0.25	6	0.25	6	0.25	6	0.25	6	0.38	8	0.81	14	6.19	55	26.87	>120
44	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.49	10	3.09	34	26.61	>120
46	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.36	>120
48	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.10	>120
50	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.84	>120
52	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.59	>120
54	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.33	>120
56	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.07	>120
58	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.81	>120
60	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.56	>120
62	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.30	>120
64	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.04	>120
66	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.92	33	23.75	>120
68	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.80	32	22.71	>120
70	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.67	31	21.68	>120
72	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.54	30	20.64	>120
74	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.42	29	19.61	120
76	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.29	28	18.57	116
78	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.17	27	17.54	111
80	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.04	26	16.50	107
82	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.91	25	15.47	102
84	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.79	24	14.43	97
86	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.66	22	13.39	93
88	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.54	21	12.36	88
90	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.41	20	11.32	83
92	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.28	19	10.29	77
94	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.16	18	9.25	72
96	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.03	16	8.22	66
98	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.90	15	7.18	61
100	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.78	13	6.15	55
102	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.65	12	5.11	48
104	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.53	10	4.08	41
106	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.40	9	3.04	34

Table 3.1.5.3.b Arc flash incident energy levels. See next page for applicable notes.

Table notes for arc flash hazard analysis in Table 3.1.5.3.b

1. This information is not to be used as a recommendation to work on energized equipment. This information is to help assist in determining the PPE to help safeguard a worker from the burns that can be sustained from an arc flash incident. This information does not take into account the effects of pressure, shrapnel, molten metal spray or the toxic vapor resulting from an arc-fault. This information does not address the maintenance conditions of the overcurrent protective device.
2. This data is based upon the simplified fuse formulas in NFPA 70E Annex D.4.6 and 2002 IEEE 1584 guide for arc flash hazard analysis.
3. PPE must be utilized any time work is to be performed on equipment that is not placed in an electrically safe work condition. Voltage testing, while completing the lockout/tagout procedure (putting the equipment in an electrically safe work condition), is considered as working on energized parts per OSHA 1910.333(b).
4. The data is based on 32 mm (1-1/4") electrode spacing, 600 V 3 Ø ungrounded system, and 20" x 20" x 20" box. The incident energy is based on a working distance of 18 inches, and the AFB is based on 1.2 cal/cm² (threshold for a second-degree "just curable" burn).
5. The data is based upon tests that were conducted at various fault currents for each Bussmann series Low-Peak KRP-C and LPS-RK fuse indicated in the charts. These tests were used to develop the formulas as shown in NFPA 70E Annex D.4.6 and 2002 IEEE 1584. Actual results from incidents could be different for a number of reasons, including:
 - System voltage
 - Short-circuit power factor
 - Distance from the arc
 - Arc gap
 - Enclosure size
 - Fuse manufacturer
 - Fuse class
 - Orientation of the worker
 - Grounding scheme
 - Electrode orientation

100 A LPS-RK fuses were the smallest fuses tested. Data for the fuses smaller than that is based upon the 100 A data. Arc flash values for actual 30 and 60 A fuses would be considerably less than 100 A fuses. However, it does not matter since the values for the 100 A fuses are already so low.

6. The fuse incident energy values were chosen not to go below 0.25 cal/cm² even though many actual values were below 0.25 cal/cm². This was chosen to keep from encouraging work on energized equipment without PPE because of a low AFB.
7. Table 3.1.5.3.b can also be used for LPJ, TCF, FCF, JJS and LP-CC fuses to determine the incident energy available and AFB.
8. These values from fuse tests take into account the translation from available three-phase bolted fault current to the arcing fault current.
9. To determine the AFB and incident energy for applications with other fuses, use the basic equations in 2002 IEEE 1584 or NFPA 70E Annex D.4.
10. Where the arcing current is less than the current-limiting range of the fuse when calculated per NFPA 70E Annex D.4.6 and 2002 IEEE 1584, the value for incident energy is given as >100 cal/cm². For the incident energy and arc flash boundary in these cases, use 2002 IEEE 1584 basic equation methods with the fuse time-current curve.



3.1.5.4 Time-current characteristic curve (TCC)

Time-current characteristic curves (TCC) are graphical representations of the OCPD's operation under different overcurrent conditions as plotted by amps and time (see Figure 3.1.5.4.a). TCCs also provide a visual means for comparing OCPD operation and whether they will selectively coordinate, or not (see Selective coordination on page 3-30).

Figure 3.1.5.4.a illustrates the TCCs for 400 A and 100 A dual-element, time-delay fuses in series as depicted in the one-line diagram. The graph's horizontal axis represents the RMS symmetrical current in amps. The vertical axis represents the time in seconds. Each fuse is represented by a band comprised of the minimum melt characteristic (solid blue line showing the lower operating characteristics) and the total clear characteristics (hash red line showing the higher operating characteristics). The area between these two lines represents the fuse's tolerance band under specific test conditions that, for a given overcurrent, a specific fuse, under the same circumstances, will open at a time within the its time-current tolerance band.

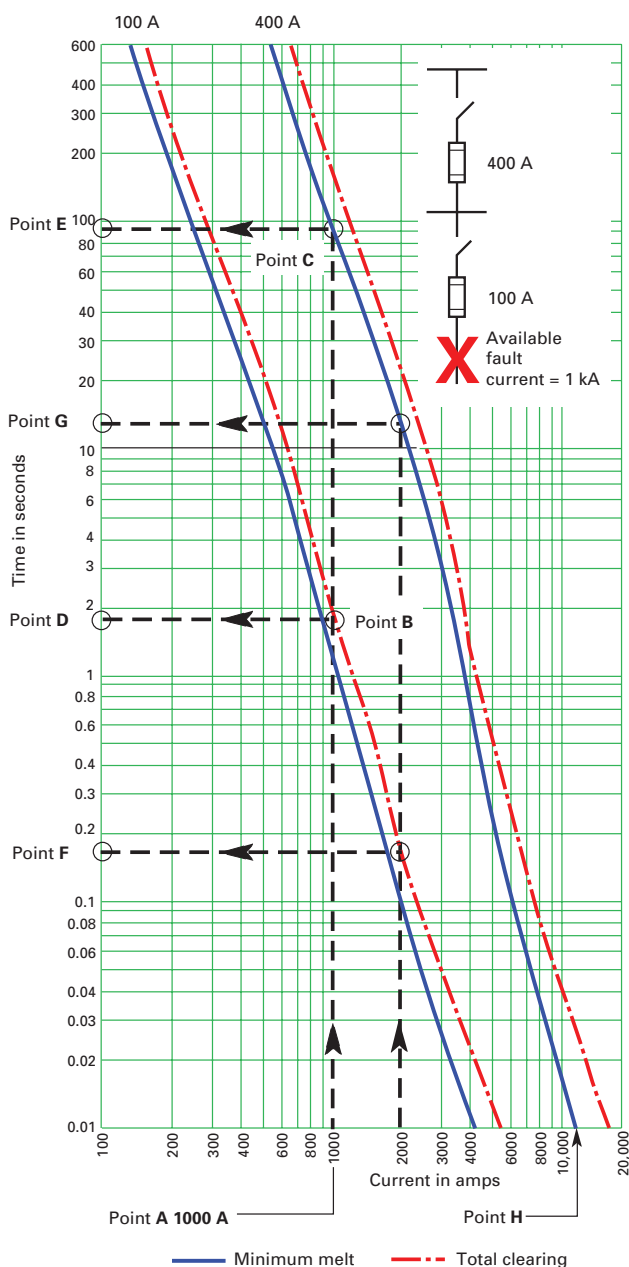


Figure 3.1.5.4.a Minimum melt and total clearing curves for 100 A and 400 A dual-element, time-delay fuses.

Fuses have an inverse time-current characteristic meaning the greater the overcurrent, the faster they open and interrupt. For example, the 100 A fuse in Figure 3.1.5.4.a subjected to a 200 A overcurrent shows by its TCC that it will open and clear in approximately 200 seconds, and for a 2000 A overcurrent, its TCC shows it will open and clear in approximately 0.15 second.

In some cases, assessing coordination between two or more fuses is possible by comparing their TCCs. This method is limited to only the overcurrent range up to the point at which the upstream fuse crosses 0.01 second. For example: assume there is a 1 kA RMS symmetrical overcurrent on the 100 A fuse's loadside. To determine the time it would take this overcurrent to open both the 100 A and 400 A fuses:

- Find 1 kA on the horizontal axis (Point A)
- Follow the dotted line vertically to the intersection of the 100 A fuse's total clear curve (red line at Point B) and the 400 A fuse's minimum melt curve (blue line at Point C).
- Then, horizontally from both intersection points, follow the dotted lines to Points D and E.

At 1.75 seconds, Point D represents the maximum time the 100 A fuse will take to open the 1 kA overcurrent. At 90 seconds, Point E represents the minimum time at which the 400 A fuse could open this overcurrent. These two fuses are coordinated for a 1 kA overcurrent.

For overcurrents up to approximately 11 kA (Point H), it can be determined that these two fuses selectively coordinate as there isn't any curve overlap and the current is less than where the 400 A upstream fuse crosses 0.01 second. When overcurrents exceed 11 kA, selective coordination cannot be determined by using TCCs and fuse selectivity ratio tables must be used. Using the Bussmann series fuse selectivity ratio table makes it simple to determine whether fuses selectively coordinate or not and eliminates the need for plotting and comparing fuse TCCs (see the Bussmann series fuse selectivity ratios Table 3.1.5.5.b on page 3-30).



Technical assistance is available to all customers. Application support is available Monday-Friday, 7:00 a.m. - 5:00 p.m. Central Time. Toll-free phone: 855-287-7626 (855-BUSSMANN), email: FuseTech@Eaton.com.

3.1.5.5 Selective coordination

While important, selecting OCPDs based solely on their ability to carry system load current and interrupting the maximum fault current at their respective application points is not enough. As the demand for power system reliability increases, the OCPD's performance in the system becomes more and more critical as its function should, ideally, limit a power system outage to only that portion of the circuit which is faulted. The selected OCPD types and ratings (or settings) determine whether they are selectively coordinated upstream and downstream in a system so that only the nearest upstream OCPD will open for the full range of overcurrents and opening times, and leave the remainder of the system undisturbed to preserve service continuity.

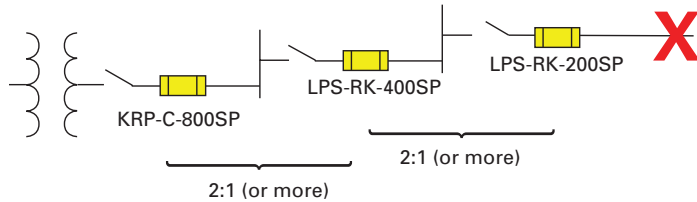


Figure 3.1.5.5.a Low-Peak fuses applied with a simple 2:1 amp rating ratio achieves selective coordination.

Figure 3.1.5.5.b shows the minimum amp rating ratios for Bussmann series Low-Peak fuses required to provide “selective coordination” (discrimination) between upstream and downstream fuses.

It's a simple matter to selectively coordinate a system using published fuse amp rating ratio tables and maintaining the minimum ratios between an upstream and downstream fuse. This will ensure selective coordination is achieved for all fault currents up to the fuse's interrupting rating. These selectivity ratios are for all overcurrent levels up to the fuse interrupting or 200 kA, whichever is lower.

For an in-depth examination of this subject, see selective coordination in Section 4.

Coordination, Selective (selective coordination)

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the selection and installation of overcurrent protective devices and their ratings or settings for the full range of available overcurrents, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents.

Selective coordination is mandatory per the NEC for the circuit paths of some vital loads on specific systems including:

- Elevator circuits — 620.62
- Critical operations data systems — 645.27
- Campus style fire pumps — 695.3
- Emergency systems — 700.32
- Legally required standby systems — 701.27
- Critical operations power systems — 708.54

Bussmann series fuse selectivity ratios

Circuit				Downstream / loadside fuse											
Amp rating range	Fuse type	Trade name (fuse class)	Bussmann fuse symbol	601-6000 A	601-4000 A	1-100 A	0-600 A			601-6000 A	0-600 A	0-1200 A	0-600 A	0-60 A	0-30 A
				Time-delay	Time-delay	Time-delay	Dual-element, time-delay			Fast-acting	Fast-acting	Fast-acting	Fast-acting	Time-delay	
				Low-Peak (L)	Limitron (L)	CUBEFuse (CF ²)	Low-Peak (J)	Low-Peak (RK1)	Fusetron (RK5)	Limitron (L)	Limitron (RK1)	Limitron (T)	Limitron (J)	SC (G)	(CC)
				KRP-C-SP	KLU	TCF	LPJ-SP	LPN-RK-SP LPS-RK-SP	FRN-R FRS-R	KTU	KTN-R KTS-R	JJN JJS	JKS	SC	LP-CC FNQ-R KTK-R
601 to 6000 A	Time-delay	Low-Peak (L)	KRP-C-SP	2:1	2.5:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	2:1	2:1
601 to 4000 A	Time-delay	Limitron (L)	KLU	2:1	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	2:1	2:1
0 to 600 A	Dual-element	Low-Peak (RK1)	LPN-RK-SP LPS-RK-SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
0 to 600 A	Dual-element	Low-Peak (J)	LPJ-SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
0 to 100 A	Dual-element	CUBEFuse (CF ²)	TCF	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
0 to 600 A	Dual-element	Fusetron (RK5)	FRN-R FRS-R	—	—	1.5:1	1.5:1	1.5:1	2:1	—	1.5:1	1.5:1	1.5:1	1.5:1	2:1
601 to 6000 A	Fast-acting	Limitron (L)	KTU	2:1	2.5:1	3:1	3:1	3:1	6:1	2:1	2:1	2:1	2:1	2:1	2:1
0 to 600 A	Fast-acting	Limitron (RK1)	KTN-R KTS-R	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
0 to 1200 A	Fast-acting	Limitron (T)	JJN JJS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
0 to 600 A	Fast-acting	Limitron (J)	JKS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
0 to 60 A	Time-delay	SC (G)	SC	—	—	3:1	3:1	3:1	4:1	—	2:1	2:1	2:1	2:1	—

General notes: Ratios given in this table apply to only Bussmann fuses. When fuses are within the same case size, consult Bussmann.

1. Where applicable, ratios are valid for indicating and non-indicating versions of the same fuse. At some values of fault current, specified ratios may be lowered to permit closer fuse sizing. Consult Bussmann.
2. Time-delay Class CF TCF CUBEFuse OCPDs are 1 to 100 A Class J performance; dimensions and construction are a unique, finger-safe design.

Table 3.1.5.5.b This selectivity ratio table identifies the fuse amp rating ratios that ensure selective coordination.

3.1.6 Fuse types and classes

3.1.6.1 Low voltage, branch circuit fuses

The NEC defines the branch circuit OCPD as capable of providing protection for service, feeder and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating. They're also the only OCPDs the NEC permits to be installed in a building's electrical system. The definition found in Article 100 is as follows:

"Overcurrent Protective Device, Branch Circuit. A device capable of providing protection for service, feeder, and branch-circuits and equipment over the full-range of overcurrents between its rated current and its interrupting rating. Such devices are provided with interrupting ratings appropriate for the intended use but no less than 5,000 amperes."

Per this definition, branch circuit OCPDs are suitable to protect branch and feeder circuits and service conductors at any point in the electrical system, and must be capable of protecting against the full range of overcurrents, including overloads and faults. In addition, the OCPD must have an interrupting rating sufficient for the application per NEC 110.9. Branch circuit OCPDs meet common, minimum standard requirements for spacing and operating time-current characteristics defined by UL.

Figure 3.1.6.1.a illustrates acceptable OCPDs that can be used for branch circuit protection.

Device type	Acceptable devices	Bussmann series fuses
UL 248 branch circuit fuses	Class CC	LP-CC, FNQ-R, KTK-R
	Class CF	TCF, FCF
	Class G	SC
	Class H(K)	NON, NOS
	Class J	LPJ-, JKS, DFJ
	Class L	KRP-C, KLU, KTU
	Class RK1	LPN-RK, LPS-RK, KTN-R, KTS-R
	Class RK5	FRN-R, FRS-R
UL 489 circuit breakers	Molded case CBs	—
	Insulated case CBs	
UL 1066 circuit breakers	Low voltage power CBs	

Figure 3.1.6.1.a Acceptable OCPDs for branch circuit protection.

The UL 248 fuse standards cover distinct low-voltage (600 volts or less) fuse classes. Of these, modern current-limiting fuse Classes CC, CF, G, J, L, R and T are the most important. The branch circuit current-limiting fuses' rejection feature helps ensure electrical system safety over its life because it prevents installing other fuse types or larger case sizes. Thus, fuses that cannot provide a comparable minimum protection level for critical ratings and performance cannot be inadvertently installed.

This is inherent in all current-limiting fuse classes. Each fuse class must meet:

- Maximum let-through limits (I_p and I^2t) during fault conditions
- Minimum voltage ratings
- Minimum 200 kA interrupting ratings for Class CC, CF, J, L, R and T
- Physical rejection of
 - Different fuse classes and case sizes*
 - Non current-limiting fuses (see Figures 3.1.6.1.b and 3.1.6.1.c)

* Branch circuit fuse blocks and holders are made to hold a fuse class case size that corresponds to a particular amp range. This prevents fuses from the same class with a larger case size from being installed and helps prevent overfusing. There are instances where it is desirable to install a class fuse with a smaller case size than the block or holder. For these situations, it is permitted to use fuse reducers.

These product standards ensure branch circuit fuses provide specific, minimum circuit protection when current-limiting fuses and equipment are used. A given fuse class will ensure the voltage and interrupting rating, and degree of current limitation for the electrical system's life.

For example, by using Class J fuses and equipment, only Class J fuses can be installed. This ensures the voltage rating is always 600 V (whether the system is 120, 208, 480, or 575 V), the interrupting rating is at least 200 kA, and the fault current protection provided by its current-limiting, let-through characteristics. If the fuse needs replacing, only a Class J fuse can be installed.



Figure 3.1.6.1.b Low-Peak Class J fuses achieve rejection by their unique physical size that is unlike other UL class fuses.

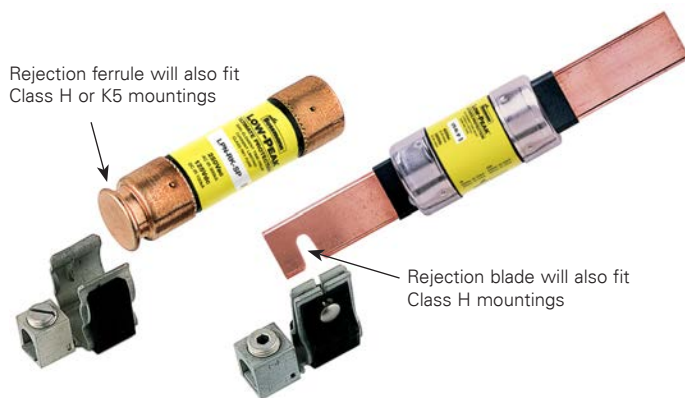


Figure 3.1.6.1.c Class R fuse rejection clips (restriction on the ferrule or notch on the blade) that will only accept Class R fuses.

Bussmann series branch circuit power distribution fuses

Class CC

Time-delay, Low-Peak LP-CC

- 600 Vac, 1/2 to 30 A current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, File E4273, 1/2-2.8 A (300 Vdc 20 kA IR), 3-15 A (150 Vdc 20 kA IR), 20-30 A (300 Vdc 20 kA IR), CSA Class 1422-02, CSA File #53787

The Bussmann series Low-Peak LP-CC was developed specifically for a growing need in the industry to have a compact, space saving branch circuit fuse for motor circuits (see data sheet no. 1023).

Time-delay, Limitron FNQ-R

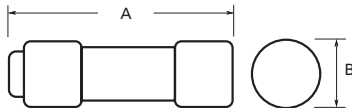
- 600 Vac, 1/4 to 30 A, current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, UL File E4273, CSA Class 1422-01, CSA File 53787

Ideal for control transformer protection, the FNQ-R can be sized to meet requirements of NEC 430.72 and UL 508. Its small size and branch circuit rating allow it to be used for motor branch circuit and short-circuit protection required by NEC 430.52 (see data sheet no. 1014)

Non-time delay (fast-acting), Limitron KTK-R

- 600 Vac, 1/10 to 30 A, current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, UL File E4273, CSA Class 1422-02 CSA File 53787

KTK-R fuses are small, high performance, fast-acting, single-element fuses for protecting branch circuits, motor control circuits, lighting ballasts and street lighting fixtures (see data sheet no. 1015).



Dimensions — in (mm)

Amp range	A	B
Up to 30	1.5 (38)	0.41 (10)



Class CF

The UL Class CF CUBEFuse provides the same electrical performance as UL Class J fuses. Available in time-delay or fast-acting versions, the CUBEFuse is the world's first finger-safe fuse with the smallest installed footprint of any power class fuse and meets IEC 60529 requirements for IP20 finger-safe protection.



The CUBEFuse mounts in 35 mm DIN-Rail and panel mountable amp rating rejecting holders (30, 60 and 100 A) that will not accept a fuse rating greater than the holder's. Additionally, the CUBEFuse can be mounted in the UL 98 Compact Circuit Protector available in 1-, 2- and 3-pole factory configured units in the same 30, 60 and 100 amp rating rejection increments.

Time-delay, Low-Peak CUBEFuse TCF

- 600 Vac, 1 to 100 A, dual-element, current-limiting 300 kA IR AC
- UL Listed Class CF, Std. 248-8 Class J performance, Guide JDDZ, File E4273, 300 kA IR AC, (300 Vdc – 100, kA IR), CSA Class 1422-02, CSA File 53787, 200 kA IR AC, (300 Vdc, 100 kA IR)

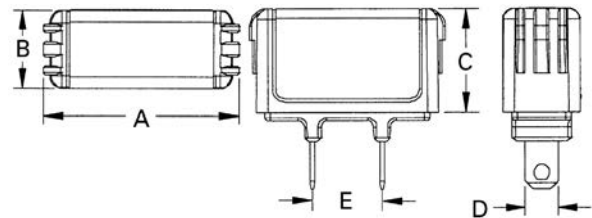
The Low-Peak TCF CUBEFuse provides Type 2 "No Damage" motor starter protection when sized properly. Available with optional open fuse indication (6 to 100 A) (see data sheet no. 9000).



Non-time delay (fast-acting), CUBEFuse FCF

- 600 Vac/dc, 1 to 100 A, current-limiting 300 kA (up to 60 A) 200 kA (70 to 100 A) IR, 50 kA IR DC
- UL Listed Class CF, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787, 200 kA IR AC

The fast-acting FCF CUBEFuse is a non-indicating fuse specifically designed to meet the needs of UPS and critical power applications (see data sheet no. 2147)



Dimensions — in (mm)

Amp range	A	B	C	D	E
1-15				0.23 (6)	
17-1/2	1.88 (48)	0.75 (19)	1.0 (25)	0.27 (7)	
20				0.31 (8)	0.63 (16)
25-30				0.36 (9)	
35-40				0.44 (11)	
45-50	2.13 (54)		1.13 (29)		
60		1.0 (25)			
70				0.49 (12)	0.58 (15)
80-90	3.01 (76)		1.26 (32)		
100				0.57 (14)	



Quik-Spec Coordination Panelboard (QSCP)

The Bussmann series Quik-Spec™ Coordination Panelboard uses the CUBEFuse for its branch circuit OCPD. The QSCP makes selective coordination easy in an all-fused system utilizing the fuse selectivity ratios table.

Features

- Addresses NEC selective coordination requirements
- Flexible configurations — up to 400 A, 600 Vac or less
- Same size footprint as traditional circuit breaker panelboards
- Finger-safe construction for greater safety
- Saves time
- Easy-to-spec
- Amp rating rejection branch switches help prevent overfusing
- Built-in spare fuse storage



(See data sheet no. 1160 and application note no. 3148.)

Class G

Non-time delay/fast-acting (up to 6 A) and time-delay (7 to 60 A) general purpose SC

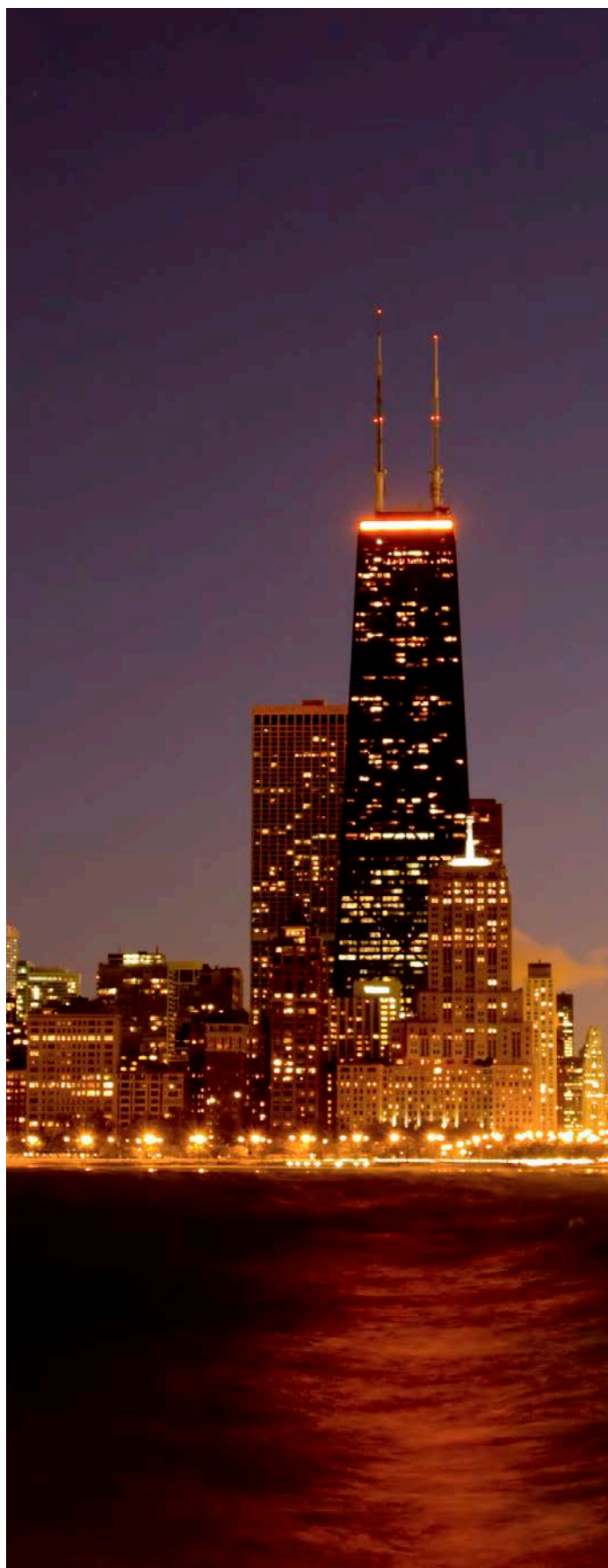
- 600 Vac (1/2 to 20 A), 480 Vac (25 to 60 A), 170 Vdc (1/2 to 20 A), 300 Vdc (25-60 A), current-limiting 100 kA IR AC, 10 kA IR DC
- UL Std. 248-5 Class G, Guide JDDZ, File E4273 0-20 A (170 Vdc 10 kA IR), 25-30 A (300 Vdc 10 kA IR), 35-60 A (300 Vdc 10 kA IR), CSA Class 1422-01, CSA File 53787

A high performance general-purpose branch circuit fuse for lighting, appliance and motor branch circuits. SC fuse lengths vary with amp rating from 1-5/16 to 2-1/4 inches to serve as a rejection feature and help prevent oversizing (see data sheet no. 1024).



Dimensions — in (mm)

Fuse amp rating	A
1/2 to 15	1-5/16 (33)
20	1-13/32 (36)
25-30	1-5/8 (41)
35-60	2-1/4 (57)



Class J

Time-delay Low-Peak LPJ-SP

- 600 Vac, 1 to 600 A, dual-element, current-limiting, 300 kA IR AC
- UL Std. 248-8 Class J, Guide JDDZ, File E4273, 300 kA IR AC, 1 to 600 A (300 Vdc, 100 kA IR), CSA Class 1422-02, CSA File 53787

Space saving LPJ fuses have the time-delay “advantage” that permits them to pass temporary, harmless overloads while offering back-up overload, and short-circuit protection. Ideal for IEC starters, they provide Type 2 “No Damage” protection when properly sized (see data sheet no. 1006, up to 60 A, and no. 1007, 70 to 600 A).

Non-time delay (fast-acting) Limitron JKS

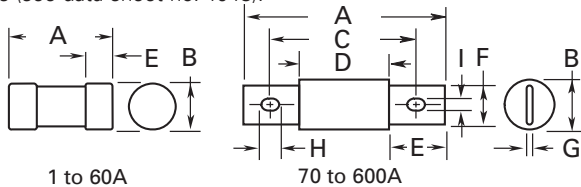
- 600 Vac, 1 to 600 A, current-limiting, 200 kA IR AC
- UL Std. 248-8 Class J, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

JKS Limitron fuses are essentially the same as RK1 Limitron fuses, but smaller in physical size. JKS fuses are single-element units with no intentional time-delay and are thus best applied in circuits free of the temporary overloads from motors and transformers. The smaller dimensions of Class J fuses prevent their replacement with conventional fuses (see data sheet no. 1026, up to 60 A, and no. 1027, 70 to 600 A).

High speed drive fuse DFJ

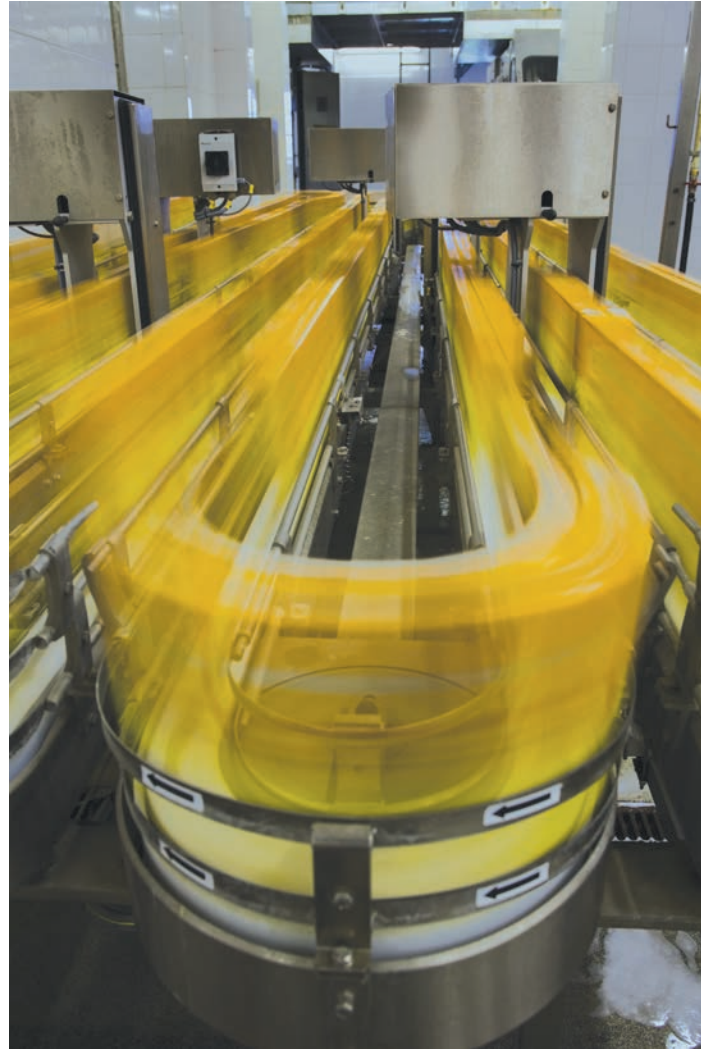
- 600 Vac, 450 Vdc (15 to 600 A), 1 to 600 A, current-limiting 200 kA IR AC, 100 kA DC
- UL Std. 248-8 Class J, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The DFJ high speed fuse offers the advantage of meeting NEC and UL branch circuit protection requirements. Designed specifically for protecting drives, soft starters, solid state relays and other power electronics, the DFJ is capable of limiting fault currents like a semiconductor fuse. The DFJ fits into all standard Class J fuse holders and blocks (see data sheet no. 1048).



Dimensions — in (mm)

Amp range	A	B	C	D	E	F	G	H	I
1-30	2.25 (57)	0.81 (21)	—	—	0.5 (13)	—	—	—	—
35-60	2.38 (60)	1.06 (27)	—	—	0.63 (16)	—	—	—	—
70-100	4.63 (118)	1.13 (29)	3.63 (92)	2.63 (67)	1.0 (25)	0.75 (19)	0.13 (3)	0.41 (10)	0.28 (7)
110-200	5.75 (146)	1.63 (41)	4.38 (111)	3.0 (76)	1.38 (35)	1.13 (29)	0.19 (5)	0.38 (10)	0.28 (7)
225-400	7.12 (181)	2.11 (54)	5.25 (133)	3.26 (83)	1.87 (48)	1.62 (41)	0.25 (6)	0.56 (14)	0.4 (10)
450-600	8.0 (203)	2.6 (66)	6.0 (152)	3.31 (84)	2.12 (54)	2.0 (51)	0.53 (14)	0.72 (18)	0.53 (14)



Innovative Bussmann series products, like the patented Class J power distribution fuse block above, combine fuse block and power distribution block into one assembly to reduce component count and speed equipment assembly.

Class L

Time-delay, Low-Peak KRP-C

- 600 Vac, 601 to 6000 A, current-limiting, 300 kA IR AC
- UL Std. 248-10 Class L, Guide JFHR, File E56412, 300 kA IR AC, 601-2000 and 3000 A (300 Vdc 100 kA IR), CSA Class 1422-02, CSA File 53787

The KRP-C is an all purpose fuse for both overload and short-circuit protection of high capacity systems. Its minimum time-delay of four seconds at five times amp rating permits sizing closer to loads. The use of downstream 1/10 to 600 A Low-Peak dual-element time-delay fuses and upstream 601 to 6000 A KRP-C Low-Peak fuses is recommended for easy selective coordination and blackout protection with a simple 2:1 amp rating ratio. Low-Peak fuses can also reduce bus bracing and provide excellent overall protection of circuits and loads (see data sheet no. 1008, 601 to 2000 A, and no. 1008, 2001 to 6000 A).



Non-time delay (fast-acting), Limitron KTU

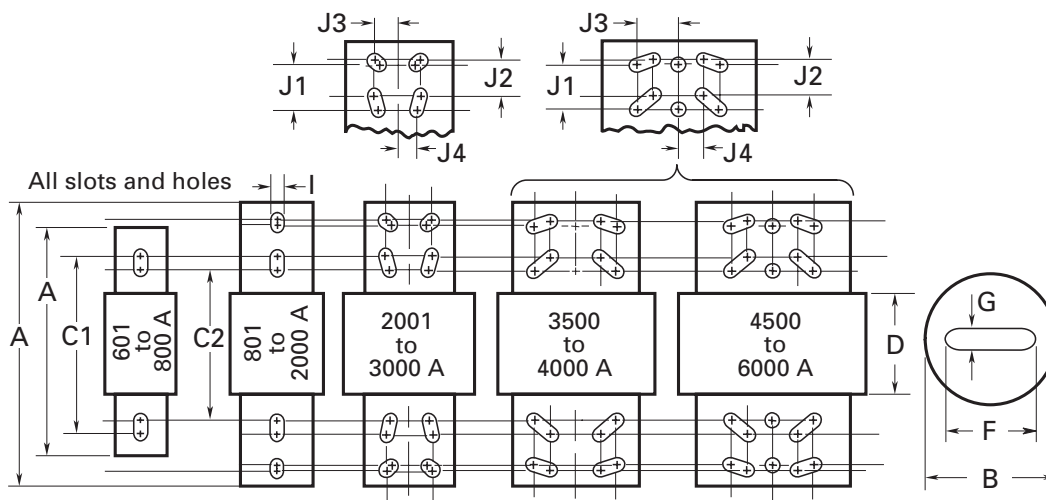
- 600 Vac, 601 to 6000 A current-limiting, 200 kA IR AC
- UL Std. 248-10 Class L, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The KTU is a single-element non-time delay fuse that's very fast-acting with a high degree of current limitation to provide excellent component protection. In motor circuits, the KTU is sized at approximately 300% of motor full-load amps (see data sheet no. 1010).

Time-delay, Limitron KLU

- 600 Vac, 601 to 4000 A, current-limiting, 200 kA IR AC
- UL Std. 248-10 Class L, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The KTU has a minimum five second delay at 500% of rated current. The KTU is not as current-limiting as KRP-C or KTU fuses (see data sheet no. 1013).



Dimensions — in (mm)

Amp range	A	B	C1	C2	D	F	G	I	J1	J2	J3	J4
601-800	8.63 (219)	2.4 (61)				2.00 (51)	0.38 (10)		—	—	—	—
801-1200									—	—	—	—
1350-1600		3.0 (76)				2.38 (60)	0.44 (11)		—	—	—	—
1800-2000		3.5 (89)				2.75 (70)	0.5 (13)		—	—	—	—
2001-2500	10.75 (273)	4.8 (122)	6.75 (172)	5.75 (146)	3.75 (95)	3.50 (89)		0.63 (16)			0.88 (22)	0.81 (21)
3000		5.0 (127)				4.00 (102)	0.75 (19)					
3500-4000		5.75 (146)				4.75 (121)			1.75 (45)	1.38 (35)		
4500-5000		6.25 (159)				5.25 (133)					1.63 (41)	0.88 (22)
6000		7.13 (181)				5.75 (146)	1.0 (25)					

Class RK1

Time-delay, Low-Peak LPN-RK and LPS-RK

- LPN-RK (250 Vac) and LPS-RK (600 Vac), up to 600 A, current-limiting, dual-element, 300 kA IR AC, 100 kA IR DC
- UL Std. 248-12 Class RK1, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787 — LPN-RK 0-60 A (125 Vdc, 50 kA IR), 70-600 A (250 Vdc, 50 kA IR), LPS-RK 0-600 A (300 Vdc, 50 kA IR)

Low-Peak RK1 fuses provide a very high degree of fault current limitation of Limitron fuse plus the overload protection of the Fusetron fuse in all types of circuits and loads.

They can be closely sized to motor full load amps for reliable backup protection. Close sizing to loads permits using smaller and more economical switches (and fuses), better selective coordination, and a greater degree of current limitation for component protection. RK1 Low-Peak fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see LPN-RK data sheet no. 1001, up to 60 A, and no. 1002, 70 to 600 A, and LPS-RK data sheet no. 1003, up to 60 A, and no. 1004, 70 to 600 A).

Non-time delay (fast-acting), Limitron KTN-R and KTS-R

- KTN-R (250 Vac) and KTS-R (600 Vac), up to 600 A, current-limiting, 200 kA IR AC
- UL Std. 248-12 Class RK1, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

KTN-R and KTS-R single-element, fast-acting fuses have no intentional time-delay and provide a high degree of fault current limitation (component protection). They are well suited for circuits and loads without the in-rush currents. RK1 Limitron fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see KTN-R data sheet no. 1043, and KTS-R data sheet no. 1044).

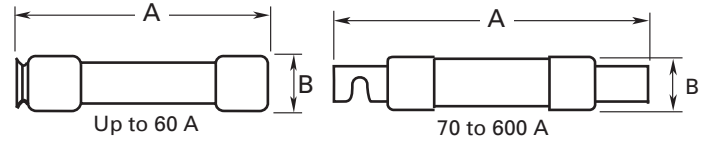
Class RK5 — Time-delay, Fusetron FRN-R and FRS-R

- FRN-R (250 Vac) and FRS-R (600 Vac), up to 600 A, current-limiting, dual-element, 200 kA IR AC, 20 kA IR DC
- UL Std. 248-12 Class RK5, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787 — FRN-R and FRS-R, up to 600 A, 200 kA IR AC, FRN-R 125 Vdc, 20 kA IR DC (up to 60 A and 110 to 200 A), 250 Vdc, 20 kA IR DC (225 to 600 A), FRS-R 300 Vdc, 20 kA IR DC (up to 30 A and 65 to 600 A), 250 Vdc, 20 kA IR DC (35 to 60 A)

FRN-R and FRS-R RK5 time-delay fuses provide excellent overload protection for loads with inrush current like motors, transformers and solenoids. Fusetron fuses are not as fast-acting on short-circuits as Low-Peak fuses, and do not give as high a degree of component short-circuit protection.

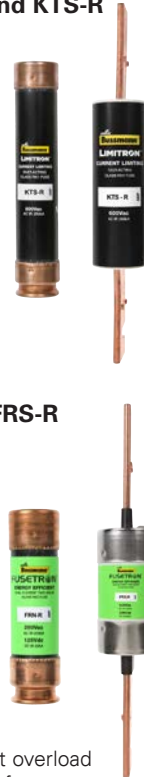
Like the Low-Peak fuse, Fusetron fuses can be sized closer to loads to permit using smaller size and less costly switches. RK5 Fusetron fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see FRN-R data sheet no. 1017, up to 60 A, and no. 1018, 70 to 600 A, and FRS-R data sheet no. 1019, up to 60 A, and no. 1020, 70 to 600 A).

Basic dimensions are same as Class H(K), general purpose (NON and NOS) fuses. **Note:** relating to dimensional compatibility these fuses can replace existing Class H, RK1 and RK5 fuses.



Dimensions — in (mm)

Amp range	250 V fuses		600 V fuses	
	A	B	A	B
Up to 30	2 (51)	0.56 (14)	5.0 (127)	0.81 (21)
35-60	3 (76)	0.81 (21)	5.5 (140)	1.06 (27)
RK5 FRN-R, FRS-R, — RK1 KTN-R, KTS-R				
70-100	5.88 (149)	1.06 (27)	7.88 (200)	1.34 (34)
110-200	7.13 (181)	1.56 (40)	9.63 (245)	1.84 (47)
225-400	8.63 (219)	2.38 (61)	11.63 (295)	2.59 (66)
450-600	10.38 (264)	2.88 (73)	13.38 (340)	3.13 (80)
RK1 LPN-RK, LPS-RK				
70-100	5.88 (149)	1.16 (30)	7.88 (200)	1.16 (30)
110-200	7.13 (181)	1.66 (42)	9.63 (245)	1.66 (42)
225-400	8.63 (219)	2.38 (61)	11.63 (295)	2.38 (61)
450-600	10.38 (264)	2.88 (73)	13.38 (340)	2.88 (73)



Busmann series modular Class R fuse blocks feature a snap-together construction to create the required number of poles. Either DIN-Rail or panel mount, these blocks are available with optional covers that provide a lockout/tagout provision for enhanced electrical safety. Also available in power distribution fuse block versions.

Class H(K)

General purpose, NON and NOS

- NON (250 Vac) and NOS (600 Vac) up to 600 A, non-current-limiting, 50 kA IR AC up to 60 A) and 10 kA (65 to 600 A)
- UL Std. 248-9 Class K5, Std. 248-9, UL Std. 248-6 Class H, Guide JDDZ, File E4273, CSA Class 1421-01, CSA File 53787 (NON 65-600 A) 10 kA IR AC, (NOS 70-600 A) 10 kA IR AC.

NON and NOS Class H(K) general purpose fuses are not considered current-limiting fuses, do not incorporate intentional time-delay and are used in circuits with low available fault currents. We recommend upgrading to Class R fuses that can be installed without the need to change fuse blocks or holders (see NON/NOS data sheet no. 1030).

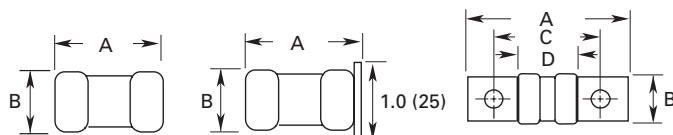


Class T

Non-time delay/fast-acting, Limitron JJN and JJS

- JJN (300 Vac up to 1200 A) and JJS (600 Vac up to 800 A), current-limiting, 200 kA IR AC
- UL Std. 248-15 Class T, Guide JDDZ, File E4273, JJN 15-600 A (160 Vdc, 20 kA IR), JJN 601-1200 A (170 Vdc 100 kA IR), CSA Class 1422-02, CSA File 53787

JJN and JJS fuses are the space-saving counterparts to KTN-R/KTS-R Limitron fuses. At one-third the size, they are well suited for applications where space is very restricted. These single-element fuses are extremely fast-acting and provide a high degree of current limitation on short-circuits for excellent component protection. These fuses will give only short-circuit protection and must be oversized for circuits with inrush currents common to motors, transformers and other inductive components (see JJN data sheet no. 1025, and JJS data sheet no. 1029).



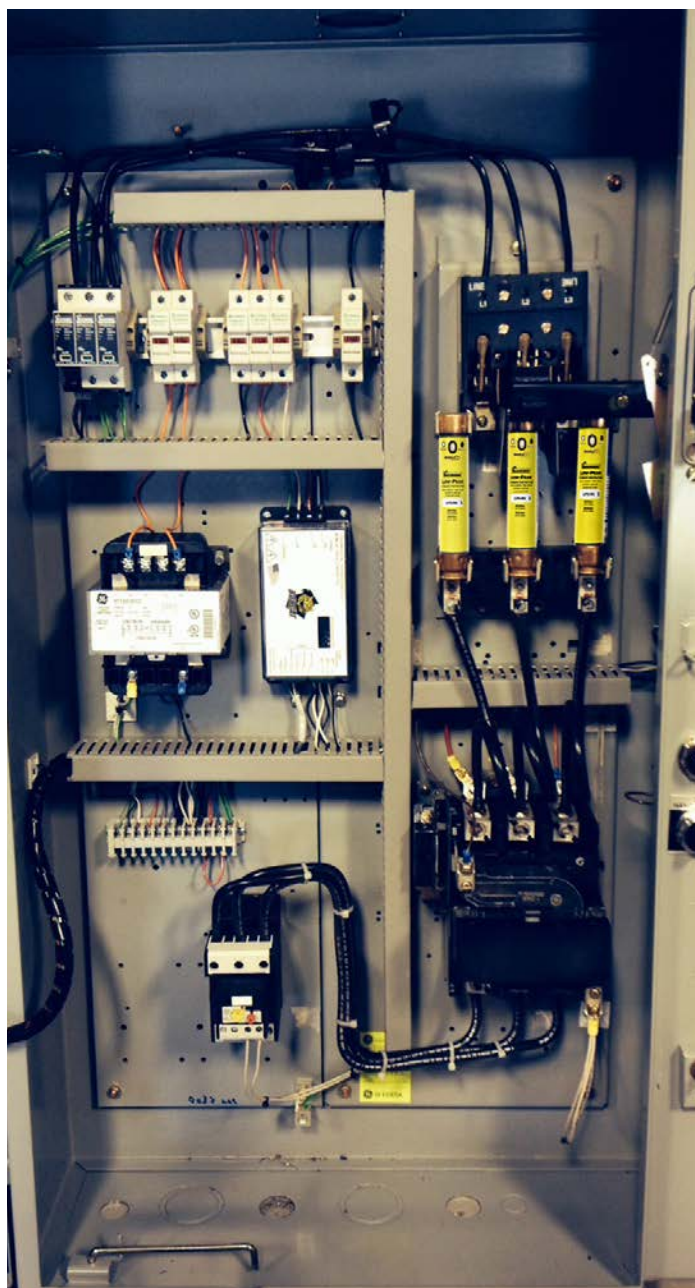
JJN up to 60 A
JJS up to 30 A

JJS 35 to 60 A

JJN 70 to 1200 A
JJS 70 to 800 A

Dimensions — in (mm)

Amp range	A	B	C	D
300 V JJN				
Up to 30	0.88 (22)	0.41 (10)	—	—
35-60	0.88 (22)	0.56 (14)	—	—
70-100	2.16 (55)	0.75 (19)	1.56 (40)	0.84 (21)
110-200	2.44 (62)	0.88 (22)	1.69 (43)	0.84 (21)
225-400	2.75 (70)	1.00 (25)	1.84 (47)	0.86 (22)
450-600	3.06 (78)	1.25 (32)	2.03 (52)	0.88 (22)
601-800	3.38 (86)	1.75 (45)	2.22 (56)	0.89 (23)
801-1200	4.00 (102)	2.00 (51)	2.53 (64)	1.08 (27)
600 V JJS				
Up to 30	1.50 (38)	0.56 (14)	—	—
35-60	1.56 (40)	0.81 (21)	—	—
70-100	2.95 (75)	0.75 (19)	2.36 (60)	1.64 (42)
110-200	3.25 (83)	0.88 (22)	2.50 (64)	1.66 (42)
225-400	3.63 (92)	1.00 (25)	2.72 (69)	1.73 (44)
450-600	3.98 (101)	1.25 (32)	2.96 (75)	1.78 (45)
601-800	4.33 (110)	1.75 (45)	3.17 (81)	1.88 (48)



Bussmann series branch circuit fuse selection chart (600 V or Less)

Circuit	Load	Amp rating (A)	Fuse type	Catalog symbol	Voltage rating (AC)	Fuse class	Interrupting rating (kA)	Remarks
100 kA IR (RMS Sym.) or greater, current-limiting	Conventional dimensions—Class RK1, RK5 (0-600 A), L (601-6000 A)							
	All type loads (optimum overcurrent protection)	Up to 600	Low-Peak (dual-element, time-delay)	LPN-RK-SP	250 V	RK1††	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection.
		601 to 6000	Low-Peak (time-delay)	LPS-RK-SP	600 V		300	
	Motors, welder, transformers, capacitor banks (circuits with heavy inrush currents)	Up to 600	Fusetron (dual-element, time-delay)	FRN-R	250 V	RK5††	200	Moderate degree of current limitation. Time-delay passes in-rush currents.
		601 to 4000	Limitron (fast-acting)	FRS-R	600 V		200	
	Non-motor loads (circuits with no heavy inrush currents). Limitron fuses particularly suited for circuit breaker protection. Up to 600 A	Up to 600	Limitron (fast-acting)	KLU	600 V	L	200	All-purpose fuse. Time-delay passes in-rush currents.
				KTN-R	250 V	RK1††	200	Same short-circuit protection as Low-Peak fuses but must be sized larger for circuits with inrush currents; i.e., up to 300%.
				KTS-R	600 V		200	
		601 to 6000		KTU	600 V	L	200	A fast-acting, high performance fuse.
	Reduced dimensions for installation in restricted space—CUBEFuse Class CF (0-100 A), Class J (0-600 A), T (0-1200 A), CC (0-30 A), G (0-60 A)							
	All type loads (optimum overcurrent protection)	Up to 100	CUBEFuse (finger-safe, dual-element, time-delay)	TCF	600 V	(CF) J***	300	Finger-safe, all-purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
	All type loads (optimum overcurrent protection)	Up to 600	Low-Peak (dual-element, time-delay)	LPJ	600 V	J	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
	Power electronic applications such as drives and SSRs	Up to 600	Drive fuse (high speed Class J)	DFJ	600 V	J	200	Where branch circuit protection is needed with high speed fuse characteristics.
	Non-motor loads (circuits with no heavy inrush currents)	Up to 600	Limitron (fast-acting)	JKS	600 V	J	200	Very similar to KTS-R Limitron, but smaller.
		Up to 1200	Limitron fast-acting	JJN	300 V	T	200	The space saver (1/3 the size of KTN-R).
		Up to 800	Limitron fast-acting	JJS	600 V	T	200	The space saver (1/3 the size of KTS-R).
	Motor loads (circuits with heavy inrush currents)		Low-Peak (time-delay)	LP-CC	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for motor circuit protection.
	Non-motor loads (circuits with no heavy inrush currents)	Up to 30	Limitron (fast-acting)	KTK-R	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for outdoor highway lighting.
	Control transformer circuits and lighting ballasts; etc		Limitron (time-delay)	FNQ-R	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for control transformer protection.
	General purpose; i.e., lighting panelboards	Up to 60	General purpose (1/2-6 A fast-acting, 7-60 A time-delay)	SC	600 (0-20 A) 480 V (25-60 A)	G	100	Current limiting; 13/32" dia. x varying lengths per amp rating.
10-50 kA IR	Miscellaneous	Up to 600	General purpose	NON NOS	250 V 600 V	H or K5†	10	Forerunners of the modern cartridge fuse.
	Plug fuses can be used for branch circuits and small component protection.	Up to 30	Type S (dual-element, time-delay)	S	125 V	S	10	Base threads of Type S differ with amp ratings (size rejecting). T and W are Edison base. T and S Type fuses recommended for motor circuits. W not recommended for circuits with motor loads.
			Type T (dual-element, time-delay)	T	125 V	**	10	
		Up to 12	Type W (fast-acting)	W	125 V	**	10	

** UL Listed as Edison base plug fuse.

† Some amp ratings are available as UL Class K5 with a 50 kA interrupting rating.

†† RK1 and RK5 fuses fit standard switches, equipped for non-rejection fuses (K1, K5 and H) fuse blocks and holders; however, the rejection feature of Class R switches and fuse blocks designed specifically for rejection type fuses (RK1 and RK5) prevents the insertion of the non-rejection fuses (K1, K5, and H).

*** Class J performance, special finger-safe dimensions.

**** For many of these fuse types, there are indicating and non-indicating versions, each with different catalog numbers.

Table 3.1.6.1.d Branch circuit fuse selection chart.

3.1.6.2 Supplemental/application limited OCPDs

The supplemental or application limited OCPDs in Figure 3.1.6.2.a are not branch circuit rated (cannot be installed in a building's electrical system) and serve specific functions within a circuit. Two application limited OCPD examples include motor circuit protectors and supplemental protective devices.

Application limited OCPDs cannot be used in place of branch circuit OCPDs, however a branch circuit rated OCPD can be used in lieu of an application limited OCPD.

Understanding the differences between these devices is important to ensure their proper application. Not using a branch circuit OCPD where required could result in potentially serious electrical safety hazards to people or damage to property. In addition, NEC violations could be tagged by the authority having jurisdiction (AHJ), resulting in project delays and unplanned delays and costs.



Figure 3.1.6.2.a Supplemental OCPDs cannot be used for branch circuit protection.

Supplemental OCPDs are not general use devices and must be evaluated for appropriate application in every instance where they are used. Supplemental OCPDs are extremely application oriented, and prior to application, the differences and limitations of these devices must be investigated and found acceptable.

Bussmann series supplemental fuses

The following pages contain examples of non-time delay/fast-acting and time-delay fuses with their specifications that must be considered before a correct selection can be determined for a particular application. Of particular note with these fuses are the following:

- Agency information is not applicable to all ratings
- Specific fuse amp ratings may have different voltage ratings and corresponding interrupting ratings
- Construction may vary, depending on amp rating, and impact the available mounting means (see FNA, page 3-43)
- Some are pin-indicating to provide a visual notification means or activating a microswitch for remote monitoring systems
- Their labels are color coded to indicate maximum voltage rating that can coincide within an amp range inside a fuse family

All these factors must be reviewed to be sure the appropriate supplemental fuse is specified and meets the application's requirements for:

- Operation (time-delay or non-time delay/fast-acting)
- Voltage rating (by fuse amp rating)
- Amp rating
- Interrupting rating at applied amp rating and system voltage
- Special needs (pin-indication)

Exceptions in the Code for applying supplemental OCPDs

There are exceptions that do allow using a supplemental, application specific OCPD in a branch circuit, but defined NEC conditions must be met.

(1) Permitted for specific branch circuit applications under limited conditions per the specific reference in the NEC: These OCPDs have some limitation(s) and are not true branch circuit devices, but may be permitted if qualified for the use in question. Examples include:

- High speed fuses that are not branch circuit OCPDs, but can be used for fault current protection on motor circuits utilizing power electronic devices by 430.52(C)(5).
- Motor Circuit Protectors (MCPs) are recognized devices (not listed) and can be used for fault current protection of motor branch circuits, if applied in combination with a listed combination starter for which the MCP has been tested and found acceptable [per 430.52(C)(3)].
- Self-protected starters listed only for motor branch circuit protection; they cannot be used on other branch circuit types or for main or feeder protection.
- When considering supplemental, application specific OCPDs, special attention must be paid to the circuit type, NEC requirements and the device's product listing or recognition.

(2) Supplemental overcurrent protective devices: These devices have limited applications and must always be in compliance with 240.10.

240.10 Supplementary Overcurrent Protection. Where supplementary overcurrent protection is used for luminaires, appliances, and other equipment...it shall not be used as a substitute for required branch-circuit overcurrent devices or in place of the required branch-circuit protection.



Applying supplemental OCPDs in branch circuits

The NEC defines a supplemental OCPD as “A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires (lighting fixtures) and appliances. This limited protection is in addition to the protection provided in the branch circuit by the required branch-circuit overcurrent protective device.”

Supplemental OCPDs can:

- Only be used for additional protection when installed on the branch circuit overcurrent device’s loadside
- Not be applied where branch circuit OCPDs are required
- Be properly used in appliance applications and for additional (supplemental) protection where branch circuit overcurrent protection is already provided. In appliance applications, the supplemental device inside the appliance provides protection for internal circuits and supplements the branch circuit OCPD’s protection.

Using supplemental OCPDs is permitted by 240.10 for lighting and appliances shown in Figure 3.1.6.2.b. The supplemental protection is in addition to that provided by the branch circuit OCPD protecting the branch circuit located in the lighting panel in Figure 3.1.6.2.b.

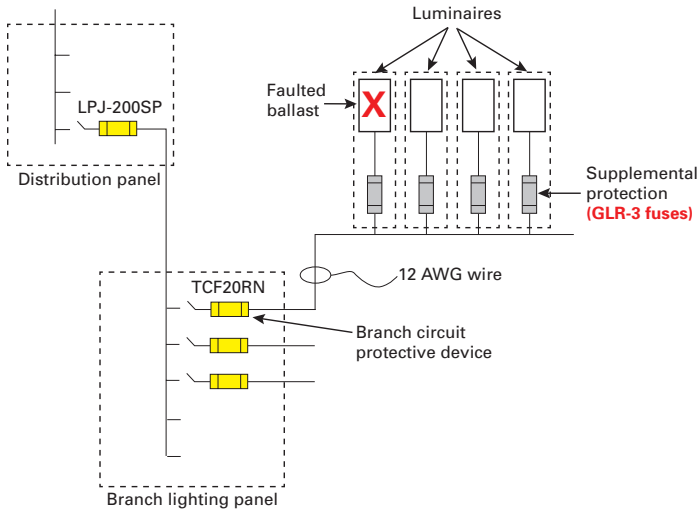


Figure 3.1.6.2.b Supplemental OCPDs may be used per 240.10, but will not be considered as protecting a branch circuit.

Branch circuit OCPDs are permitted for supplemental protection and can replace a supplemental OCPD (see Figure 3.1.6.2.c). Rather than using a supplemental OCPD for supplemental luminaire protection, a branch circuit OCPD (a KTK-R-3 fuse) is used where a supplemental device is permitted does not turn the circuit between the lighting panel and the fixture from a branch circuit into a feeder circuit. In the case of Figure 3.1.6.2.c, the branch circuit starts on the 20 A fuse’s loadside in the lighting panel.

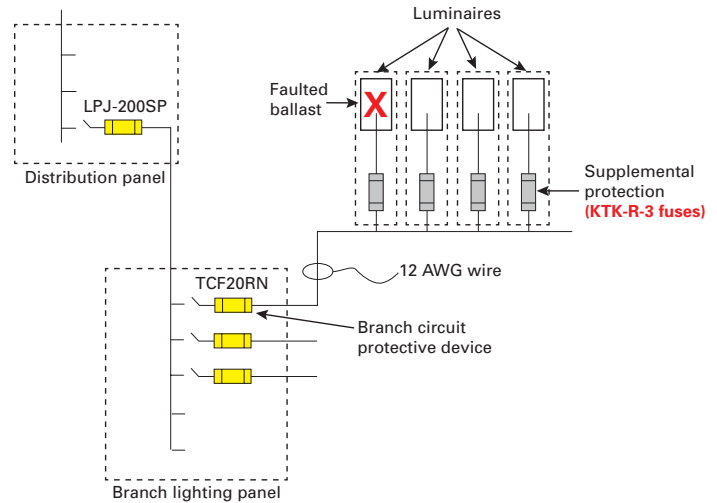


Figure 3.1.6.2.c Branch circuit OCPDs can be used for supplemental protection.

Another difference and limitation is that supplemental OCPDs may have creepage and clearance spacing that are considerably less than a branch circuit OCPD. Two such creepage and clearance spacing differences include:

- A supplemental protector, recognized to UL 1077, has 3/8 inch through air spacing requirements between terminals and 1/2 inch over surface at 480 V.
- A branch circuit rated UL 489 molded case circuit breaker with 1 inch through air and 2 inches over surface has spacing requirements between terminals at 480 V.

Further, branch circuit OCPDs have standard overload characteristics to protect branch and feeder circuits, and service entrance conductors. Supplemental OCPDs do not have standard overload (time-current) characteristics and may differ considerably from standard branch circuit overload characteristics. Also, supplemental OCPDs have interrupting ratings that range from 32 A to 100 kA. When supplemental OCPDs are considered for proper use, it’s important to be sure the interrupting rating equals or exceeds the available fault current, and that the device has the proper voltage rating for the installation (including compliance with slash voltage rating requirements, if applicable).



10 Reasons why supplemental protectors are not allowed to protect branch circuits

1. Supplemental protectors are not intended to be used, nor are they evaluated for branch circuit protection in UL 1077.
2. Compared to branch circuit OCPDs, supplemental protectors have drastically reduced spacings, and often depend upon a separate, upstream branch circuit OCPD.
3. Supplemental protectors do not have standard calibration limits or overload characteristic performance levels, and cannot ensure proper protection for branch circuits.
4. Multi-pole supplemental protectors used in three-phase systems are not evaluated for protection against all overcurrent types nor tested to protect circuits from all fault types (e.g., line-to-ground faults on B-phase grounded systems).
5. Most supplemental protectors are fault current tested with an upstream branch circuit OCPD and rely upon this device for proper performance.
6. Supplemental protectors do not require testing for closing into a fault.
7. Supplemental protector re-calibration (for supplemental protection by circuit breakers) is not required and depends upon the manufacturer's preference. There is no performance assurance following a fault or resetting the device. The product standard does not require supplemental devices to be re-calibrated and operational after interrupting a fault.
8. Considerable damage to a supplemental OCPDs is allowed following short-circuit testing.
9. Supplemental protectors are not intended for use as a disconnecting means.
10. Supplemental protectors are not evaluated for fault current performance such as energy let-through limits or protecting test circuit conductors.



3



BAF non-time delay (fast-acting) 13/32" x 1-1/2"

Fast-acting, supplemental fuse. Green color code (250 Vac max) (see data sheet no. 2011).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at system voltage		Agency information	
	250 Vac	125 Vac	UL	CSA
1/4 to 1	35 A	10 kA	—	X
1-1/2 to 2-1/2	100 A	10 kA	—	X
3	100 A	10 kA	X	X
4 to 10	200 A	10 kA	X	X
12 to 15	750 A	10 kA	X	X
20 to 30	200 A	10 kA	—	—

Agency information

- UL Listed, Std. 248-14, 250 Vac (3 to 15 A) Guide JDYX, File E19180, CSA Certified, 250 Vac (1/4 to 15 A) Class 1422-01, File 53787

BBS non-time delay (fast-acting) 13/32" x 1-3/8"

Fast-acting supplemental fuse. Color codes black (600 Vac max 1/10 to 6 A), green (250 Vac max 7 to 10 A), and purple (48 Vac max 12 to 30 A) (see data sheet no. 2010).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at system voltage			Agency information	
	600 Vac	250 Vac	48 Vac	UL	CSA
1/10 to 6	10 kA	—	—	X	X
7 to 10	—	10 kA	—	X	X
12 to 30*	—	—	—	—	—

* For interrupting rating, contact factory.

Agency information

- UL Listed, Std. 248-14 (1/10-6 A@600 Vac, 7-10 A@250 Vac), Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14 (1/10-6 A @ 600 Vac, 7-10 A @ 250 Vac), Class 1422-01, File 53787, CE

KLM non-time delay (fast-acting) 13/32" x 1-1/2"

Fast-acting supplemental fuse. Color code black (600 Vac/dc max) (see data sheet no. 2020).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

For protecting PV systems, use PVM 10x38mm PV fuses (see data sheet no. 10121).

Ratings

Fuse amp range	IR at rated voltage		Agency information	
	600 Vac	600 Vdc	UL	CSA
1/10 to 30	100 kA	50 kA	X	X

Electrical characteristics

% of amp rating	Opening time
110%	4 hours minimum
135%	AC opens within 1 hour

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, RoHS compliant, CE

KTK non-time delay (fast-acting) 13/32" x 1-1/2"

Fast-acting supplemental fuse. Black color code (600 Vac max) (see data sheet no. 1011).

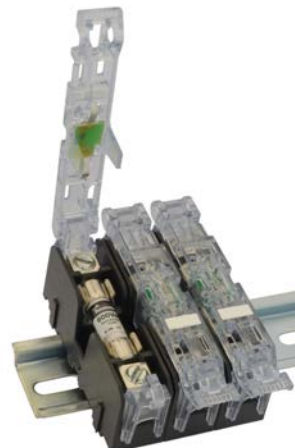
For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at rated voltage	Agency information	
	600 Vac	UL	CSA
1/10 to 30	100 kA	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, HRC-MISC, RoHS compliant, CE



Bussmann series modular fuse blocks easily dovetail together to create the desired number of poles. Installation flexibility is provided with either DIN-Rail or panel mounting. They are available with optional covers to provide IP20 finger-safe protection and feature a built-in lockout/tagout provision for added electrical safety.

MIC non-time delay (fast-acting) 13/32" x 1-1/2" pin-indicating

Fast-acting, pin-indicating supplemental fuse. Green color code (250 Vac max 1 to 15 A), grey (32 Vac max 20 to 30 A) (see data sheet no. 10246).



Ratings

Fuse amp range	IR at voltage rating		Agency information	
	250 Vac	32 Vac	UL	CSA
1	35 A	—	X	—
2 to 3	100 A	—	X	—
5 to 10	200 A	—	X	—
15	750 A	—	X	—
20 to 30	—	10 kA	—	—

Electrical characteristics

% of fuse rating	Opening time
110%	Indefinitely
135%	1 hour max

Agency information

- UL Listed, Std. 248-14, 1-15 A, Guide JDYX, File E19180, CE

FNA time-delay 13/32" x 1-1/2" pin-indicating

Pin-indicating time-delay supplemental fuse. Color coded green (250 Vac max 1/10 to 6 A), blue (125 Vac max 6-1/4 to 15 A) and grey (32 Vac max 20 to 30 A) (see data sheet no. 2029).



Dual-tube construction 12 A and up

Ratings

Fuse amp range	IR at system voltage			Agency information	
	250 Vac	125 Vac	32 Vac	UL	CSA
1/10 to 8/10	35 A	10 kA	—	X	X
1 to 6	200 A	10 kA	—	X	X
6-1/4 to 15	—	10 kA	—	X	X
20 to 30	—	—	1 kA	—	—

Agency information

- UL Listed, 1/10 to 8/10 A @ 125/250 Vac, 1-15 A @ 125 Vac, Guide JDYX, File E19180, CSA Certified, 1/10 to 10 A @ 125 Vac, Class 1422-01, File 53787, CE

FNM time-delay 13/32" x 1-1/2"

Time-delay supplemental fuse. Color code green (250 Vac max) (see data sheet no. 2028).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).



Ratings

Fuse amp range	IR at system voltage		Agency information	
	250 Vac	125 Vac	UL	CSA
1/10 to 1	35 A	10 kA	X	X
1-1/8 to 3-1/2	100 A	10 kA	X	X
4 to 10	200 A	10 kA	X	X
12 to 30	10 kA	—	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX; File E19180, CSA Certified, Class 1422-01, File 53787, RoHS compliant, CE

FNQ time-delay 13/32" x 1-1/2"

Time-delay supplemental fuse. Color code orange (500 Vac max) (see data sheet no. 1012).

For superior protection, Eaton recommends upgrading to Bussmann series Limitron FNQ-R Class CC fuses (see data sheet no. 1014).



Ratings

Fuse amp range	IR at rated voltage	Agency information	
	500 Vac	UL	CSA
1/10 to 30	10 kA	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, HRC-MISC, RoHS compliant, CE



Bussmann series finger-safe CH modular fuse holders for supplemental, PV and Class CC fuses feature a snap-together construction to create the required number of poles. These DIN-Rail mount holders are available with optional open fuse indication and PLC remote fuse monitoring for faster troubleshooting, and accessories like comb busbars for easy ganging.

3.1.6.3 Medium voltage fuses

Medium voltage fuses generally have ratings that range from 2.5 kV to 38 kV and are designated under one of three ANSI/IEEE C37.40 defined classifications:

- **General Purpose Current-Limiting:** A fuse capable of interrupting all currents from the rated interrupting current down to the current that causes the fusible element to melt in one hour
- **Back-up Current-Limiting:** A fuse capable of interrupting all currents from the maximum rated interrupting current down to the rated minimum interrupting current
- **Expulsion:** A vented fuse in which the expulsion effect of gasses (produced by the arc and housing, either alone or aided by a spring) extinguish the arc

The general purpose and back-up current-limiting fuses are constructed in a sealed, non-venting design that, when the element melts from a current within the fuse's interrupting rating, produces arc voltages exceeding the system voltage which, in turn, forces the current to zero. The arc voltages are produced by a series of high resistance arcs within the fuse's element to create a fuse that typically interrupts high fault currents within the first 1/2 cycle.

The expulsion fuse, in contrast, depends on the interruption process being initiated by a single arc that acts as a catalyst to create and cause a de-ionizing gas to escape from its housing.

The arc is then elongated, either by the gases' force or a spring so that, at some point, the arc elongates sufficiently enough to prevent a restrike after the AC current cycle passes through zero volts and may take many cycles to clear.

Application

Many rules for applying expulsion and current-limiting fuses are the same, with some additional rules applied to current-limiting fuses because they operate much faster on high fault currents. The three basic factors to consider when applying any medium voltage fuse are:

- Voltage rating
- Continuous current carrying capacity
- Interrupting rating

Voltage rating

As a rule, medium voltage fuses should be applied on systems as close to their voltage rating as possible (unlike low voltage fuses that can be applied on a system at or below their rating). This is particularly important with current-limiting fuses that function by creating multiple high resistance arcs that will drive up the fuse's peak arcing voltage. The arcing voltage should never exceed the system basic insulation level (BIL) and create a safety hazard.

Continuous current carrying capacity

Continuous current values shown on the fuse label represent the continuous current the fuse can carry without exceeding the temperature rise specified in ANSI C37.46. An application that exposes the fuse to a current slightly above its continuous rating, but below its minimum interrupting rating, may cause damage to the fuse from excessive heat. This is the main reason motor circuit protection uses overload relays in series with back-up current-limiting fuses.

Interrupting rating

As with all fuses, medium voltage fuses need to have an interrupting rating equal to or greater than the available fault current.

Rules for medium voltage current-limiting fuses

To ensure proper current-limiting fuse application, it's important to apply the following:

- As stated earlier, current-limiting fuses produce arc voltages that exceed the system voltage. Care must be taken to ensure the peak voltages do not exceed the system's basic insulation level (BIL). If the fuse voltage rating is not permitted to exceed system voltage by 140%, there should not be a problem. This does not mean that a higher rated fuse cannot be used, but points out that one must ensure the system's BIL will handle the peak arc voltage produced.
- As with the expulsion fuse, current-limiting fuses must be properly coordinated with other system OCPDs. For this to happen, the rules for applying an expulsion fuse must be used at all currents that cause the fuse to interrupt in 0.01 second or greater.

When other current-limiting OCPDs are on the system, it becomes necessary to use I^2t (the thermal energy required to melt a specific fuse element at rated current under test condition, expressed "current squared times seconds" or as A^2s "amps squared times seconds" values for coordination at currents causing the fuse to interrupt in less than 0.01 second. These may be supplied as minimum and maximum values, or minimum melting and total clearing I^2t curves. In either case, apply the following:

- The fuse's minimum melting I^2t should be greater than the downstream current-limiting device's total clearing I^2t .
- The fuse's total clearing I^2t should be less than the upstream current-limiting device's minimum melting I^2t .

Applying R-Rated fuses

The current-limiting fuse should be selected so that the overload relay's curve crosses the fuse's minimum melting curve at a current greater than 110% of the motor's locked rotor current.

A preliminary choice is obtained through the following formula:

$$6.6 \times \text{Full Load Current} \div 100 = \text{R rating of fuse}$$

This value is rounded up to the next R-Rated fuse size.

Example:

A 2300 V motor has a 100 amp full load current rating and 600 amps locked rotor current. The preliminary choice is:

$$6.6 \times 100 \div 100 = 6.6$$

When rounded up to the next standard R-Rated size, it becomes a 9R fuse, but this must be checked against the appropriate time-current characteristics curves, shown in Figure 3.1.6.3.a.

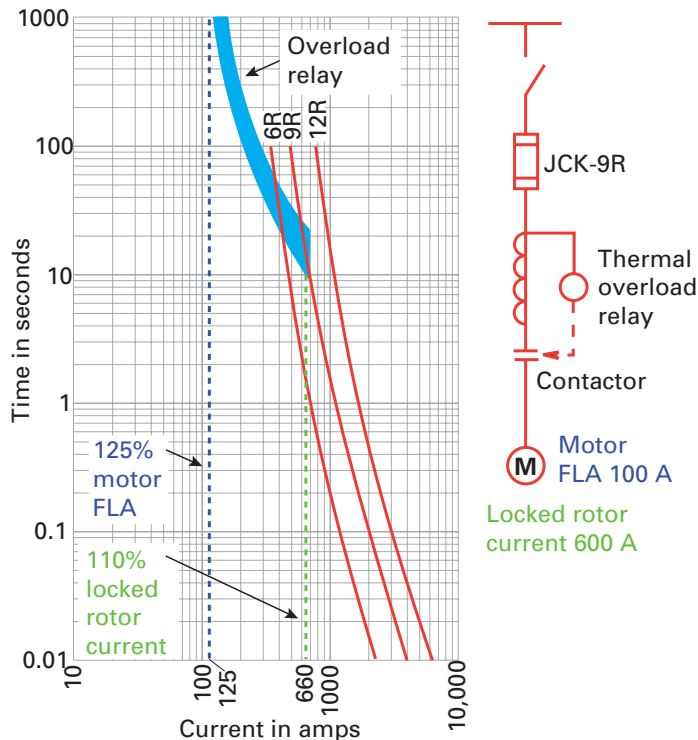


Figure 3.1.6.3.a Special care must be taken to ensure the fuse amp rating is compatible with the motor's overload relay.

The overload relay in this example has the time-current characteristic shown in Figure 3.1.6.3.a. To ensure the proper fuse is selected, one must plot 110% of the locked rotor current and the range (6R, 9R, 12R) of R-Rated fuses on the same graph as the overload relay.

The selected fuse should be the smallest whose minimum melting characteristic crosses the overload relay at a current greater than 110% of the motor's locked rotor current. In this example, it would be a 2400 V 9R fuse determined in the given formula. This agrees with the quick selection choice. Depending on the type of installation and starter being used, a JCK-9R, JCK-A-9R, or 2BCLS-9R would be the correct choice.

Additional rules

When choosing an expulsion fuse, it's important that it be properly coordinated with other upstream and downstream OCPDs. To accomplish this, one must consider the devices' melting and clearing characteristics. Two curves, the minimum melting and the total clearing curve, provide this information. To ensure proper coordination, the following should apply:

- The total clearing curve for any downstream protective device must be below a curve representing 75% of the applied fuse's minimum melting curve
- The total clearing curve for the applied fuse must lie below a curve representing 75% of the minimum melting curve for any upstream protective device

R-Rated medium voltage fuses and motor circuits

R-Rated medium voltage fuses are back-up current-limiting fuses used in conjunction with medium voltage motors and controllers. These fuses are only for short-circuit protection and do not protect themselves or other components during extended overloads. They offer a high level of fault current interruption in a self-contained, non-venting package that can be mounted indoors or in an enclosure. All Bussmann series R-Rated fuses come with open fuse indication, with some available with a Hookeye option for use with a hookstick for non-loadbreak isolation.

R-Rated fuses do not have "amp ratings," but rather an R-rating when they meet the following requirements:

- The fuse will safely interrupt any current between its minimum and maximum interrupting rating
- The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the "R" number (ANSI C37.46).

Application

Medium voltage motors are efficiently protected by overload relays applied in conjunction with back-up current-limiting fuses that open the circuit under high fault conditions. The overload relay is chosen to interrupt currents below the fuse's minimum interrupting rating. Since multiple devices are used to provide motor protection, it is very important that they be properly coordinated. The motor starter manufacturer typically designates the proper fuse R-rating, overload relay and contactor.



The Eaton Bussmann Division's Paul P. Gubany Center for High Power Technology is the electrical industry's most comprehensive facility for testing and certifying device and equipment SCCRs. Capable of performing electrical tests up to 600 V three-phase, 300 kA fault current for meeting ANCE, ANSI, CE, CSA, ETL, IEC and UL testing requirements.

R-Rated for motor circuits

- 2.4 kV: 2CLS, 2ACL, JCK, JCK-A, 2HCLS, 2BCLS — 25 to 450 A
- 4.8 kV: 5CLS, JCL, 5LCLS, JCL-A, 5ACLS, 5HCLS, 5BCLS, 5MCLS — 30 to 800 A
- 7.2 kV: 8CLS, 7CLS, 8ACLS, 7ACLS, 7BCLS — 70 to 800 A
- 50 kA IR Sym.
- 80 kA IR Asym.



R-Rated medium voltage fuses are back-up current-limiting fuses used in conjunction with medium voltage motors and motor controllers to provide short-circuit protection.

Current-limiting fuses may be designated as R-Rated if they meet the following requirements:

- The fuse will safely interrupt all currents between its minimum and maximum interrupting ratings.
- The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the “R” number (ANSI C37.46).

Bussmann series R-Rated fuses offer a high level of fault current interruption in a self-contained, non-venting package that can be mounted indoors or in an enclosure.

Available styles include standard, AMPGARD™ Hookeye, hermetically sealed and bolt-on with open fuse indication standard on all fuses (see data sheet no. 6001).

E-Rated for transformer and feeder protection

- 2.75 kV: 2CLE, JCX — 1 to 450 A (see data sheet no. 10350)
- 5.5 kV: AHLE, BHLE, HCL, 5CLE, 5HLE, JCY, MV055F — 1 to 1350 A (see data sheet no. 10351)
- 8.3 kV: 8CLE, 8HLE, 8AHLE, 8BHLE, 8HCL — 10 to 350 A (see data sheet no. 10352)
- 15.5 kV: 15CLE, 15HLE, 15LHLE, MV155F, 15BHLE, 15HCL — 10 to 300 A (see data sheet no. 10353)
- 5.5 to 38 kV (DIN dimensioned for switchgear): 55GDMSJ, 55GFMSJ, 155GQJSJ, 175GDMSJ, 175GFMSJ, 175GXMSJ, 175GXQJSJ, 258GDQJSJ, 258GXQJSJ, 258GXZSJ, 38GFZSJ — 10 to 450 A (see data sheet no. 10638)
- 25 to 65 kA IR catalog number dependent



E-Rated medium voltage fuses are general purpose current-limiting fuses. The E-rating defines the fuse's melting time-current characteristic and the ratings are used to allow electrical interchangeability among different manufacturers. A general purpose E-Rated fuse must meet these requirements:

- The current responsive element shall melt in 300 seconds at an RMS current within the range of 200% to 240% of the fuse's continuous current rating (ANSI C37.46).
- The current responsive element above 100 amps shall melt in 600 seconds at an RMS current within the range of 220% to 264% of the fuse's continuous current rating (ANSI C37.46).

Bussmann series E-Rated fuses provide primary protection for transformers, feeders and branch circuits. They are non-venting fuses which must be mounted indoors or in an enclosure. Their current-limiting ability reduces the fault current (I^2t) that the system components must withstand.



E-Rated for potential and small transformers

- 2.475 kV: 2NCLPT —
0.25 to 5 A
- 3.6 kV: 3.6ABCNA,
3.6ABWNA, 3.6CAV —
2 to 10 A
- 5.5 kV: JCW, 5CLPT, 5NCLPT,
5.5ABWNA, 5.5AMWNA,
5.5CAV, 5.5CAVH —
0.5 to 15 A
- 7.2 kV: 7.2ABWNA, 7.2ABCNA,
7.2AMWNA, 7.2CAV —
0.5 to 10 A
- 8.3 kV: 8CLPT, CLPT, 8NCLPT —
0.5 to 10 A
- 12 kV: 12ABCNA, 12CAV —
2 to 3.15 A
- 15.5 kV: 15CLPT, 15NCLPT, 15.5CAV, 15.5CAVH —
0.5 to 10 A
- 17.5 kV: 17.5ABGNA, 17.5CAV —
2 to 10 A
- 24 kV: 24ABGNA, 24CAV —
2 to 4 A
- 25.5 kV: 25CLPT —
0.5 to 1 A
- 36 kV: 36ABGNA, 36CAV —
2 to 4 A
- 38 kV: 38CAV, 38CAVH, 38CLPT —
0.5 to 4 A
- 25 to 80 kA IR Sym., catalog number dependent.

Low amp, E-Rated medium voltage fuses are general purpose current-limiting fuses defined by their melting time-current characteristic that permits their electrical interchangeability with fuses having the same E-rating. To be E-Rated, the fuse responsive element shall melt in 300 seconds at a RMS current within the range of 200% to 240% of the fuse's continuous current rating. (For fuses rated 100E or less)(ANSI C37.46).

Bussmann series low amp, E-Rated fuses provide primary protection for potential, small service and control transformers. These fuses offer a high level of fault current interruption in a self-contained, non-venting package that can be mounted indoors or in an enclosure (see data sheet no. 6002).



3.1.6.4 High speed fuses

High speed fuses are often called “semiconductor fuses” and sometimes feature a diode symbol on their label. This does not mean there’s a diode in the fuse’s construction. The symbol is there to indicate the fuse is primarily used to protect solid state devices.

In general terms, high speed fuses are not full range fuses. They are applied for short-circuit protection that requires a very “high speed” response to faults. As such, their proper specification and selection requires greater attention to application details and correction factors too numerous to cover in this section. More information on this subject is available in the Bussmann series high speed fuse application guide, publication no. 10507.

Protecting solid-state power equipment often differs significantly from electrical equipment and requires the unique operating characteristics only offered by high speed fuses. Because power diodes and silicon controlled rectifiers (SCRs) cannot withstand heavy fault current, they require ultra-fast current-limiting fuses. The circuits in which these fuses are applied have certain requirements that are generally more stringent than those for typical 60 cycle AC power distribution systems.

The diodes or SCRs in solid-state power equipment have relatively low fault current withstand capabilities. Their thin silicon material has a very low transient thermal capacity that makes them highly susceptible to damage from the heat produced by low, moderate and high faults that can occur in a very short time. Thus, it’s essential to restrict fault energy with a high speed fuse.

NEC 430.52(C)(5) recognizes using high speed fuses for motor protection

There are several criteria used to judge high speed fuse performance. Among these are the current-limiting/short-circuit capability and the ability to quickly interrupt DC currents found in rectifiers and drives. From a design standpoint, I^2t is most often used to evaluate the current-limiting/short-circuit performance. I^2t (RMS amps-squared seconds) indicates the heating affect associated with a current pulse. A semiconductor’s data sheet often specifies its maximum I^2t withstand capability. If the selected fuse has an I^2t let-through less than the semiconductor’s I^2t withstand rating, it is protected.

High speed fuses are often applied where DC interrupting capabilities are essential, with some high speed fuses specifically designed and rigorously tested to have excellent DC operating characteristics.

Specialized knowledge about circuit types is essential for proper application. Included in Figures 3.1.6.4.a through 3.1.6.4.h are common circuits protected by high speed fuses.

Typical circuits

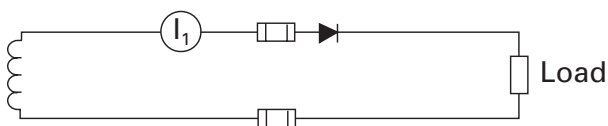


Figure 3.1.6.4.a Single-phase, half-wave.

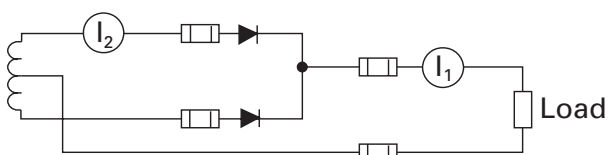


Figure 3.1.6.4.b Single-phase, full-wave, center-tap.

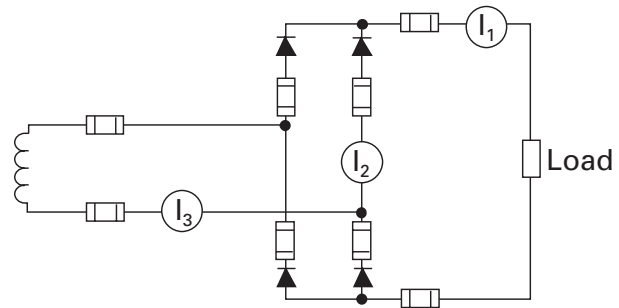


Figure 3.1.6.4.c Single-phase, full-wave, bridge.

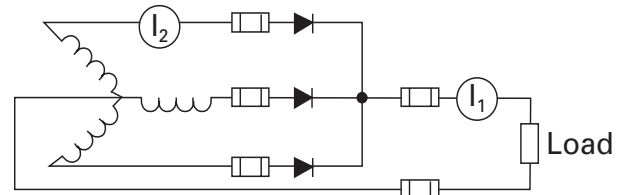


Figure 3.1.6.4.d Three-phase, half-wave.

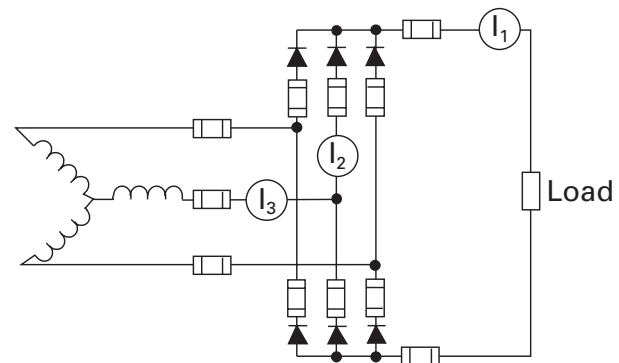


Figure 3.1.6.4.e Three-phase, full-wave.

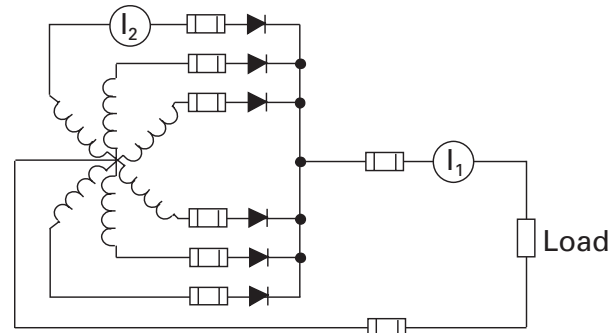


Figure 3.1.6.4.f Six-phase, single wave.

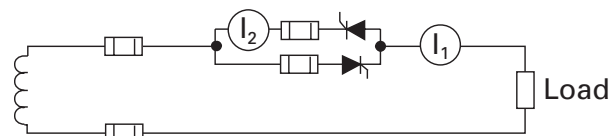


Figure 3.1.6.4.g Single-phase, anti-parallel, AC control.

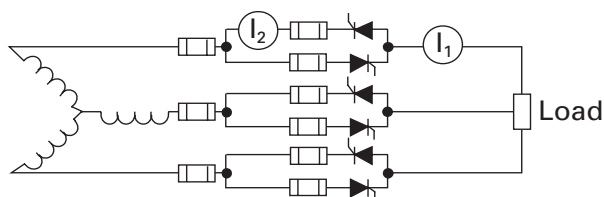
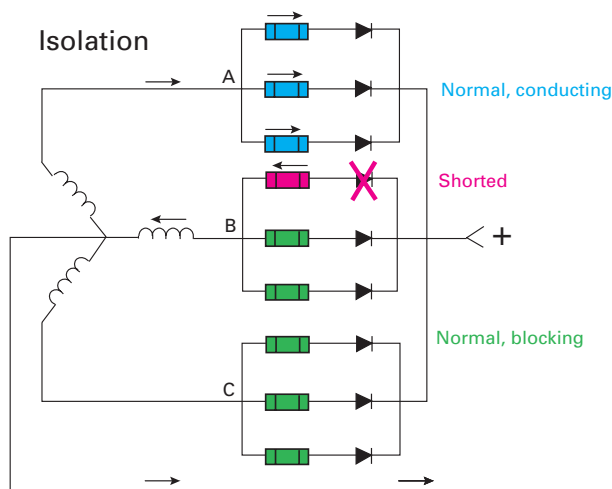


Figure 3.1.6.4.h Three-phase, anti-parallel, AC control.

Not all systems with diodes or SCRs have the fuse provide full protection and they are applied to achieve varying design objectives:

1. Prevent device rupture — The fuse merely needs to interrupt current before the diode or SCR ruptures.
2. Isolate failed device — Used typically where only three or more diodes or SCRs are used per conduction path. An individual fuse is not intended to protect an individual device, but rather its purpose is to isolate the diode or SCR after it shorts out and permit the overall circuit to continue operating. At this level, the fuse must be able to protect the diodes or SCRs that are splitting the fault current in another leg, as illustrated in Figure 3.1.6.4.i.



Fuse on shorted diode in leg B should be able to open and clear before any damage is done to the diodes in leg A

Figure 3.1.6.4.i High speed fuses can be applied to simply isolate faulted circuit paths and allow the remainder of the device to operate.

3. Protect the device (faults) — In this case, the fuse is applied to protect the diode or SCR against faults external to the SCR or diode. Typically, the fuse is selected to give a much lower let-through current than that required for design objectives 1 and 2 shown above.

CHSF — UL compact high speed fuse

- 50 to 400 A
- 500 Vac/dc
- 200 kA IR
- Operating class aR, UL Recognized, Guide JFHR2, File E56412, CSA Component Acceptance, Class 1422-30, File 53787, IEC aR (self certified), RoHS compliant, CE

Bussmann series compact high speed fuses feature space-saving case sizes for protecting semiconductor devices while providing superior current cycling performance to help withstand demanding applications.

The CHSF fuse requires up to 48% less enclosure space to help reduce the overall assembly size. Its innovative design allows for a significantly smaller package without compromising heat rise performance, preventing extensive equipment redesign.

With a bolt-on design the CHSF provides design flexibility for installation in fuse blocks or direct mounting on busbars and meets JASO D622 spec for thermal shock, humidity, and vibration (see data sheet no. 10414).



DFJ — UL Class J full range high speed fuse

- 1 to 600 A
- 600 Vac/450 Vdc
- IR
 - 200 kA RMS Sym.
 - 100 kA DC
- Operating class aR, UL Listed, Std 248-8, Class J, Guide JDDZ, File E4273, CSA Certified, C22-2 No 248.8, Class 1422-02, File 53787

UL Class J high speed, full range current-limiting fuses provide maximum protection for AC and DC drives and controllers.

The UL Class J DFJ fuse has the lowest I^2t of any branch circuit fuse to protect power semiconductor devices that utilize diodes, GTOs, SCRs and SSRs.

The DFJ fuse combines the performance of high speed fuses in a full range Class J branch circuit package, allowing the use of readily available Class J fuse blocks, holders and switches. The DFJ uses standard Class J holders and blocks (see data sheet no. 1048).



British style (BS88)

CT, ET, EET, FE, FEE, FM, FMM, LCT, LET, LMT, LMMT, MT, MMT

- 6 to 900 A
- 240 to 690 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to BS88: Part 4 and IEC 60269: Part 4



A wide range of British style semiconductor fuses that use innovative arc-quenching techniques and high grade materials to provide:

- Minimal energy let-through (I^2t)
- Excellent DC performance
- Good in-rush withstand profile

Found in equipment manufactured in the United Kingdom or British Commonwealth countries. North American manufacturers have begun to specify BS88 fuses — particularly in UPS applications at 240 volts or less — to take advantage of their size, performance and cost benefits.

See Bussmann series full line product catalog 1007 for complete product offering.

Ferrule

FWA, FWX, FWH, FWC, FWP, FWK, FWJ, FWL, FWS

- 1 to 100 A
- 150 to 2000 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to IEC 60269:Part 4



Bussmann series full line of ferrule style (cylindrical and clip-mounted) high-speed fuses are designed and tested to meet standards and requirements in various locations around the world. Their unique design and construction provide:

- Superior cycling
- Low energy let-through (I^2t)

Ferrule high-speed fuses provide an excellent solution for small UPS, small AC drives and other low power applications where space is at a premium.

See Bussmann series full line product catalog 1007 for complete product offering.



Square body

170M

- 10 to 7500 A
- 690 to 1300 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to IEC 60269: Part 4

Complete range of square body high-speed fuses and accessories suited for high power applications requiring a compact design with superior performance. End fitting options include:

- DIN 43 653
- DIN 43 620
- Flush end (Metric/US)
- French style
- US style

See Bussmann series full line product catalog 1007 for complete product offering.

North American

FWA, FWH, FWJ, FWP, FWX, KAC, KBC

- 1 to 4000 A
- 130 to 1000 V
- 200 kA IR AC
- UL Recognized

North American The Bussmann series high speed fuses have a complete range of blade and flush-end styles, and accessories designed to provide:

- Low energy let-through (I^2t)
- Low watts loss
- Superior cycling capability
- Low arc voltage
- Excellent DC performance

While there are currently no published standards for these fuses in medium power applications, the industry has standardized on mounting centers that accept Bussmann series fuses.

See Bussmann series full line product catalog 1007 for complete product offering.



3.1.6.5 Photovoltaic (PV) fuses

Unlike a grid connected AC system, the available fault current within a PV system is limited, requiring the OCPD to operate effectively on higher DC voltage and low fault current. For this reason, PV-specific fuses were developed.

The International Electrotechnical Commissions and Underwriters Laboratories recognize that PV system protection is different and is reflected in IEC 60269-6 (gPV) and UL 248-19 with PV OCPDs for protecting strings and arrays specifically designed to meet these standards:

- Fully tested to the requirements of IEC 60269-6 and exceeding the requirements of operating at $1.45 \times I_n$ (1.45 times the nominal current).
- Meet the requirements of UL 248-19 that are very similar to the IEC standards, except they operate at $1.35 \times I_n$ (1.35 times the nominal current).

These IEC and UL ratings do not reflect a continuous service rating. The assigned service rating should be reduced as ambient temperatures increase. To ensure PV fuse longevity, they should not be subjected to a continuous current of more than 80% of the assigned IEC and UL ratings.

Photovoltaic system trends

As with any electrical system, primary goals in a photovoltaic system are efficiency and economies. To do this requires:

- Using smaller, less costly conductors and system components
- Simplifying system design (e.g., in-line holders that combine fuse and holder in one assembly)
- Operating at higher system voltages

Additionally, circuit protection comes into play on the balance of system components from the DC (direct current) side (arrays, combiner boxes, recombiner boxes and inverters - where high speed fuses are needed) to the AC (alternating current) side and, ultimately, connecting to a building's electrical system or the grid.

For more information on selecting and sizing PV fuses, see the solar circuit protection application guide, publication no. 10191.

PVM 600 Vdc 13/32" x 1-1/2" midget

A range of UL 248-19 fast-acting 600 Vdc 13/32" x 1-1/2" (10x38mm) midget fuses specifically designed to protect solar power systems in extreme ambient temperature, high cycling and low level fault current conditions (reverse current, multi-array fault) (see data sheet no. 2153).



Ratings

- Volts 600 Vdc
- Amps 4-30 A
- IR 50 kA DC (4-30 A)

Agency information

- UL Listed 248-19, Guide JFGA, File E335324, CSA Component Certified C22.2, RoHS compliant

PVS-R 600 Vac/dc Class RK5

A range of UL 248-19 fast-acting 600 Vdc Class RK5 fuses specifically designed to protect photovoltaic power systems in extreme ambient temperature, high cycling and low level fault current conditions (reverse current, multi-array fault) (see data sheet no. 4203)

Ratings

- Volts
 - 600 Vac to UL 248-12 and 600 Vdc to UL 248-19
- Amps 20-400 A
- IR
 - 200 kA RMS Sym. AC
 - 20 kA DC (20-60 A)
 - 10 kA DC (70-400 A)

Agency information

- UL Listed, Std. 248-12, Class RK5, Guide JFGA, File E335324. Photovoltaic to UL 248-19, CSA Component Certified C22.2



PV 1000 Vdc 10x38mm PV fuses

A range 10x38mm, 1000 Vdc PV fuses for the protection and isolation of photovoltaic strings that are specifically designed for use in PV systems with extreme ambient temperature, high cycling and low fault current conditions (reverse current, multi-array fault) string arrays. For application flexibility, the PV 10x38mm fuse is available as a cylindrical fuse as well as bolt-on, single and dual PCB tab and in-line crimp terminal versions (see data sheet no. 10121).

Ratings

- Volts 1000 Vdc
- Amps 1-20 A
- IR 50 kA

Terminals and conductors

- Crimp connection for single, 75°C/90°C Cu Stranded 12-8 AWG PV wire

Agency information

- UL Listed to 248-19†, Guide JFGA, File E335324, IEC 60269-6 (gPV), CSA File 53787, Class 1422-30 (1-15 A), 20 A Pending, CCC (1-20 A), RoHS Compliant

† Except crimp terminal version that is UL Recognized to UL 248-19, Guide JFGA2, File E335324.



HPV 1000 Vdc in-line PV fuse assembly

A single-pole, non-serviceable photovoltaic in-line fuse holder and fuse assembly in an IP67 dust tight, submersible insulating boot for use in photovoltaic wire harnesses (see data sheet no. 2157).

Ratings

- Volts 1000 Vdc
- Amps 1-20 A
- IR 33 kA

Agency information

- UL Listed to 4248-1 and 4248-19, File E 348242, CSA Component Acceptance, Class 6225 30, File # 47235, IP67 submersible, RoHS compliant, CE



PV 1000/1100 Vdc 14x51mm

A range of 14x51mm PV fuses specifically designed for protecting and isolating photovoltaic strings. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault) (see data sheet no. 720132).

Ratings

- Volts
 - 1000 Vdc (25 and 32 A)
 - 1100 Vdc (15 and 20 A)
- Amps 15-32 A
- IR 10 kA

Agency information

- UL Listed, Guide JFGA, File E335324, Photovoltaic to, UL 248-19, IEC 60269-6 gPV, CSA Pending, CCC Pending, RoHS compliant



NH 1000 Vdc blade and bolt-on

A range of 1000 Vdc NH size PV fuses specifically designed for protecting and isolating array combiners/re-combiners, disconnects and inverters (see data sheet no. 720133).

Ratings

- Volts 1000 Vdc
- Amps 32-400 A
- IR 50 kA

Agency information

- UL Listed, Guide JFGA, File E335324, Photovoltaic to UL 248-19, IEC 60269-6 gPV, CSA Class 1422-30, File 53787 (32-160 A), UL Listed, IEC gPV, CSA, CCC Pending, RoHS compliant



PV 1500 Vdc 10x85mm

A range of 10x85mm PV fuses specifically designed for protecting and isolating photovoltaic strings. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault). Also available with crimp terminals (see data sheet no. 10658).

Ratings

- Volts 1500 Vdc
- Amps 2.25-30 A
- IR 30 kA, 1 ms

Agency information

- UL 248-19, IEC 60269, RoHS compliant



PV15M-4A-CT 1500 Vdc in-line crimp terminal fuse

Bussmann series PV15M-4A-CT is a 1500 Vdc in-line photovoltaic fuse with crimp terminals for use in wire harnesses and other applications where an in-line PV fuse is desirable. This in-line fuse can be electrically insulated with customer-supplied overmolding or approved heat-shrink (see data sheet no. 10639).

Ratings

- Volts 1500 Vdc
- Amps 4 A
- IR 15 kA DC
- Time constant 1~3 ms

Agency information

- UL Recognized, 248-19, File E484317 Vol. 1 Sec. 1, CSA pending, RoHS compliant



PV XL 1000 Vdc and 1500 Vdc

A range of XL size PV fuses specifically designed for protecting and isolating photovoltaic array combiners and disconnects. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault). Optional microswitches available for use in monitoring systems (see data sheet no. 10201).

Ratings

- Volts
 - 1000 Vdc (60-630 A)
 - 1500 Vdc (50-400 A)
- Amps
 - 63-630 A (1000 Vdc)
 - 50-400 A (1500 Vdc)
- IR
 - 50 kA (1000 Vdc 63-160 A 01XL and 350-630 A 3L)
 - 30 kA (1000 Vdc 200 A 1XL, 160-355 A 2XL)
 - 30 kA (1500 Vdc 50-160 A 01XL, 100-200 A 1XL, 125-250 A 2XL, 250-400 A 3L)

Agency information

- UL 248-19, Guide JFGA, File E335324, IEC 60269-6 gPV, CSA Class 1422-30, File 53787, RoHS compliant



3.1.7 Fuseology summary — the power of the modern, current-limiting fuse

Current limitation

- Enhances workplace safety by reducing the incident energy and arc flash hazards personnel may be exposed to under fault conditions
- Protects components and equipment from extreme thermal and mechanical forces associated with a fault event
- Helps compliance with NEC 110.10 by protecting equipment and components from extensive fault current damage when properly sized
- Helps achieve high equipment short-circuit current ratings by drastically reducing peak let-through current
- Type 2 “No Damage” (versus Type 1) protection with properly sized fuses reduces downtime and improves system protection

Highest interrupting ratings up to 300 kA

- Provides flexibility for use in any system with available fault currents up to 300 kA without fear of misapplication
- Provides a no-worry solution in the case system changes (utility transformer or equipment relocation) result in higher available fault current
- Saves time by eliminating the need for fault current studies when using 300 kA IR Low-Peak fuses
- Improves compliance with NEC 110.9 and removes the fear of misapplication
- Helps achieve high equipment short-circuit current ratings as the fuse will not be the limiting factor
- Peace of mind as a fuse’s interrupting rating is always at least equal to or, in many cases, greater than the available fault current at the line terminals

Straight voltage rating

- Straight voltage rated fuses provide flexibility in any system regardless of its grounding (a slash voltage rated OCPD is limited to installation in ONLY a solidly grounded Wye system)

Physical rejection

- Provides a safe and reliable system by ensuring the same class fuse with the same voltage and interrupting rating is installed
- Reduces the risk that the wrong fuse type with a higher short-circuit energy let-through and lower interrupting ratings can be installed and compromise the protection level

Factory calibrated replacements

- Improved system reliability throughout the system’s life by ensuring the same protection level is installed after a fault
- Maintained system integrity as replacement fuses utilize the latest design and performance improvements
- Helps comply with OSHA 1910.334(b)2 by eliminating the invitation for an operator to reset a device after a fault occurs without first determining its cause (resetting circuit breakers or replacing fuses in a circuit without investigating and fixing the cause is prohibited by federal law)

Enclosed non-venting design

- Fuses do not vent, so they eliminate the venting that’s inherent on some mechanical OCPDs that could cause unnecessary damage to other system components
- Reduces cost by eliminating the need for additional system guards or barriers to protect from venting

Enclosed, fixed, thermal design

- Improved fault protection integrity by not relying on springs, levers and latches to open the circuit
- Reduced operating costs by eliminating the need for device maintenance or calibration
- Minimizes possible misapplication and confusion by eliminating the need to adjust and change device settings in the field

Finger-safe designs

- Increase system and personnel safety by utilizing the latest in finger-safe fuse technology covering blocks, holders, disconnect switches and power distribution fuse blocks
- Of special note is the finger-safe Bussmann series CUBEFuse that’s used with the patented UL 98 Listed Bussmann series Compact Circuit Protector (CCP) switch — together they provide a finger-safe fused switch that’s horsepower rated and can be used on branch circuits



3.2 Breaker basics

Contents

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3.2.1 Introduction

The NEC defines a circuit breaker as “A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.” There are two basic circuit breaker classifications and three types used for low voltage circuit protection. The two basic classes are:

1. Low Voltage Power Circuit Breaker (LVPCB) which comply with these standards:
 - ANSI Std. C37.6 — Preferred Ratings
 - ANSI Std. C37.17 — Trip Devices for LVPCB
 - ANSI Std. C37.50 — Test Procedures
 - IEEE Std. C37.13 — LVPCB used in Enclosures
 - UL 1066 - LVPCB
2. Molded Case Circuit Breakers (MCCBs) that comply with these standards:
 - UL 489 — MCCB
 - UL 489 — Molded Case Switches (MCS)

The classifications themselves lend their names to the first two of the three circuit breakers types. The third circuit breaker type is derived from the molded case class and known as an insulated case circuit breaker.

The three circuit breaker types are:

1. Low Voltage Power Circuit Breakers (LVPCBs)
2. Molded Case Circuit Breakers (MCCBs)
3. Insulated Case Circuit Breakers (ICCBs)

Molded case circuit breaker current carrying parts, mechanisms and trip devices are completely contained within a molded case of insulating material. MCCBs are available in small and medium frame sizes with various interrupting ratings for each frame size. Some larger MCCBs are available in drawout design and used primarily in panelboards and switchboards where they are mostly fixed mounted.

Low voltage power circuit breakers are used primarily in drawout switchgear. LVPCBs have replaceable contacts and are designed to be field maintainable. The term power circuit breaker also applies to medium voltage (1 - 72.5 kV) or high voltage (over 72.5 kV) breakers.

Preferred low voltage power circuit breaker ratings are as indicated in ANSI IEEE C37.16. Standards for low voltage AC power circuit breakers used in enclosures are as indicated in ANSI/IEEE C37.13. Test procedures for low voltage power circuit breakers used in enclosures are as indicated in ANSI/IEEE C37.50-1973. Application recommendations are discussed in ANSI/IEEE C37.16-1980 and application factors in ANSI/IEEE C37.20. LVPCBs are generally UL Listed and can be UL labeled.

ICCBs are rated and tested according to the UL 489 Standard. However, they utilize design characteristics from both LVPCB and MCCB breaker classes. They are of large frame size with short time capabilities and

utilize stored energy operating mechanisms. ICCBs are designed and tested to the UL 489 Standard, and used primarily in fixed mounted switchboards, but are also available in drawout configurations. They are generally considered not field maintainable, but they do have several maintenance operations that can be field performed.

3.2.2 Ratings

3.2.2.1 Voltage ratings

Voltage is an extremely important rating for overcurrent protective devices (OCPDs). The proper OCPD application according to its voltage rating requires that the device voltage rating be equal to or greater than the system's voltage. For example, a 600 V rated circuit breaker can be used in a 208 V circuit, but a 250 V rated circuit breaker cannot be used in a 480 V circuit. When a circuit breaker is applied beyond its voltage rating, there may not be any initial indicators anything is wrong. Adverse consequences typically result when it is applied outside of its voltage rating and it attempts to interrupt an overcurrent, at which point it may self-destruct in an unsafe manner.

There are two circuit breaker voltage rating types:

- Straight voltage
- Slash voltage

Straight voltage rated breakers

Proper straight rated circuit breaker application is relatively straightforward. These devices are marked with a straight voltage rating (e.g., 240 V, 480 V, 600 V) and are evaluated for proper operation with full phase-to-phase voltage used for testing, listing and marking.

Slash voltage rated breakers

Some circuit breakers have a slash voltage rating. The slash rating can be broken down into the higher and lower of two numbers included in its rating. They are understood as:

- The lower rating pertains to overcurrent protection at line-to-ground voltages, intended to be cleared by one pole of the device
- The higher rating pertains to overcurrent protection at line-to-line voltages, intended to be cleared by two or three poles of the device

The proper slash-rated circuit breaker application is such that the line-to-ground voltage cannot exceed the device's lower voltage rating, and the voltage between any two conductors (line-to-line) cannot exceed the device's higher voltage rating. (Reference NEC Section 240.85) Slash voltage rated circuit breakers are not intended to open phase-to-phase voltages across only one pole. Where it's possible for phase-to-phase voltage to appear across only one pole, a straight rated breaker must be used. For example, a 480 V circuit breaker may have to open an overcurrent at 480 V with only one pole, such as might occur when Phase A goes to ground on a 480 V, B-phase, corner grounded delta system.

The slash rated breaker misapplication can cause it to be applied outside its voltage rating with dire ramifications should the device be called upon to interrupt fault currents.

Slash voltage rated circuit breakers can only be utilized on solidly grounded Wye systems.

Slash voltage rated circuit breakers cannot be used on the following systems (use only straight voltage rated devices on these systems):

- Impedance-grounded
- Ungrounded Wye
- Ungrounded Delta
- Corner-grounded Delta

Similarly, slash rated equipment also have limitations. For example, a slash voltage rated motor controller is restricted to only solidly grounded systems and not appropriate for corner grounded delta, impedance grounded or ungrounded systems. (NEC Section 430.83(E))



Devices that may be slash-rated include, but are not limited to:

- Molded case circuit breakers — UL 489
- Manual motor controllers — UL 508
- Self-protected Type E combination starters — UL 508
- Supplemental protectors — UL 1077 (these look like and are sometimes referred to as mini-breakers, but they are not circuit breakers; they are not rated for branch circuit protection and can't be a substitute where branch circuit protection is required.)

If devices have a slash voltage rating limitation, product standards require them to be marked with the rating such as 480Y/277 V. If a machine or equipment electrical panel utilizes a slash voltage rated device, it's recommended that the equipment nameplate (or label) designate this slash voltage rating as the voltage rating. UL 508A industrial control panels requires the electrical panel voltage marking to be slash rated if one or more devices in the panel are slash voltage rated.

A straight rated fuse or circuit breaker protecting a single pole can be used to protect single-phase line-to-neutral loads when supplied from a three-phase, solidly grounded circuit. For example, a 300 V rated fuse can protect single-phase line-to-neutral loads when supplied from three-phase, solidly grounded, 480/277 V circuits, where the single-phase line-to-neutral voltage is 277 V. This is permitted because in this application, a 300 V fuse will not have to interrupt a voltage greater than its 300 V rating.

3.2.2.2 Amp ratings

Every circuit breaker has a specific amp rating. Standard amp ratings for inverse time circuit breakers are shown in the table below (NEC Section 240.6).

Circuit breaker ratings (amps)				
15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

Understanding and using this NEC table is important. NEC Section 240.6 is leveraged whenever requirements specify "...the next standard overcurrent device size shall be used..." The next standard overcurrent device size is not based on manufacturers' literature; it is always obtained from NEC 240.6.

In selecting a circuit breaker amp rating, consideration must be given to the load type and code requirements. The circuit breaker amp rating normally should not exceed the circuit's current carrying capacity. The conductor current carrying capacity is that current rating arrived upon after ampacity adjustment factors are applied to a given conductor, based on how and where it's routed or other NEC related ampacity adjustment factors. For example, if a conductor's current carrying capacity is 20 A, a 20 A circuit breaker is the largest that should be used to protect this conductor.

3.2.2.3 Interrupting ratings

A circuit breaker interrupting rating establishes the maximum fault current value at specified voltage which the device has been evaluated to safely interrupt under standard test conditions. Circuit breaker interrupting ratings vary based upon applied voltage. Interrupting ratings, if other than 5 kA, are required to be marked on circuit breakers (240.83(C)).

3.2.3 Circuit breakers types and classifications

Description	LVPCB (Type Magnum DS® and Series NRX®)	ICCB (Type Magnum SB and Series NRX)	MCCB (QUICKLAG®/Series C®/Series G®)
Select trip short-time rating	Selective trip over full range of fault currents up to interrupting rating (high short-time ratings)	Selective trip over partial range of fault currents within the interrupting rating (medium short-time ratings). Typically up to 35 kA	Selective trip over a smaller range of fault currents within the interrupting rating (low short-time ratings). Typically 10-13 times the frame size
Operator type	Types of operators: mechanically operated and electrically operated two-step stored energy	Types of operators: mechanically operated and electrically operated two-step stored energy	Types of operators: mechanically operated over-center toggle or motor operator
Closing speed	5-cycle closing for electrically operated devices	5-cycle closing for electrically operated devices	Greater than 5-cycle closing for electrically operated devices
Mounting	Available in drawout construction permitting racking to a distinct "test position" and removal for maintenance	Available in drawout construction permitting racking to a distinct "test position" and removal for maintenance	Typically fixed-mounted but large frame sizes may be available in drawout construction
Interrupting rating	Interrupting duty at 635 Vac: 42-130 kA and current limiting with or without fuses up to 200 kA	Interrupting duty at 508 Vac: 42-130 kA	Interrupting duty at 480 Vac: 22-100 kA without fuses and up to 200 kA with integral fuses or for current-limiting type
Current limiting	Special current limiting types available with or without fuses up to 200 kA	Special current limiting types available without fuses up to 150 kA	Current limiting available with and without fuses up to 200 kA
Relative cost	Higher	Medium	Low
Available frame sizes	Small number of frame sizes available. Typical 800-6000 A	Small number of frame sizes available. Typical 800-6000 A	Large number of frame sizes available. Typical 100-2500 A
Maintenance	Extensive maintenance possible on all frame sizes	Limited maintenance possible on larger frame sizes	Very limited maintenance possible on larger frame sizes
Enclosure types	Used in enclosures, MCCs, switchboards and switchgear	Used in enclosures, MCCs and switchboards	Used in enclosures, panelboards, switchboards, MCCs and control panels
Series ratings	Not available in series ratings	Not available in series ratings	Available in series ratings
Enclosed rating	100% continuous current rated in its enclosure	80% continuous-current rated, unless specifically stated to be rated 100% in an enclosure	80% continuous-current rated, unless specifically stated to be rated 100% in an enclosure
Standards	ANSI/IEEE C37 UL 1066	NEMA AB1/AB3 UL 489 or UL 1066	NEMA AB1/AB3 UL 489

3.2.3.1 Molded case circuit breakers (MCCB)

As a class, molded case circuit breakers are tested and rated according to UL 489. Their current carrying parts, mechanisms, and trip devices are completely contained within a molded case of insulating material. MCCBs are available in small and medium frame sizes with various interrupting ratings for each frame size.

Current-limiting molded case circuit breakers are also available. They are characterized by fast interruption short-circuit trip elements.

Molded case circuit breakers are designed and tested to the UL 489 Standard. Some of the larger molded case circuit breakers are available in drawout design. They are used primarily in panelboards and switchboards where they are mostly fixed mounted.

3.2.3.2 Insulated case circuit breaker (ICCB)

Insulated case circuit breakers are also rated and tested according to the UL 489 Standard. However they utilize characteristics of design from both classes. They are of large frame size, have short time capabilities and utilize stored energy operating mechanisms.

Insulated case power circuit breakers, designed and tested to the UL 489 Standard, are used primarily in fixed mounted switchboards but are also available in drawout configuration. They are generally considered not field maintainable but there are several maintenance operations that can be performed in the field.

3.2.3.3 Power circuit breaker (PCB)

Low voltage power circuit breakers are used primarily in draw-out switchgear; they have replaceable contacts, and are designed to be maintained in the field.

The term power circuit breaker also applies to medium voltage (1 kV to 72.5 kV) or high voltage (over 72.5 kV) breakers.

3.2.4 How circuit breakers work

All circuit breakers are mechanical OCPDs that share three operating functions:

1. Thermal, magnetic or electronic current sensing
2. Mechanical unlatching (opening) mechanism
3. Current/voltage interruption means, whether mechanical contact parting, arc chute or both

The circuit breaker's operating physics are significantly different than a fuse's. First, the circuit breaker senses the overcurrent. If the overcurrent persists for too long, the sensing means causes or signals the contact mechanism to unlatch. The unlatching function causes the contacts to start parting. As the contacts start to part, the current is "stretched" through the air causing arcing between the contacts to commence. The further the contacts separate, the longer the arc becomes, which aids in interrupting the overcurrent. However, in most cases, especially for fault current, the contacts alone are not sufficient to interrupt. The arcing is "thrown" to the arc chute which further stretches and cools the arc so that interruption can be made. Figure 3.2.4.a shows a simplified model with the three operating components (1, bimetal and magnetic elements, 2, latch and 3, spring-loaded contacts and arc chutes) for a thermal magnetic circuit breaker, which is the most commonly used circuit breaker. It should also be noted that there are various contact mechanism designs that can significantly affect the interruption process.

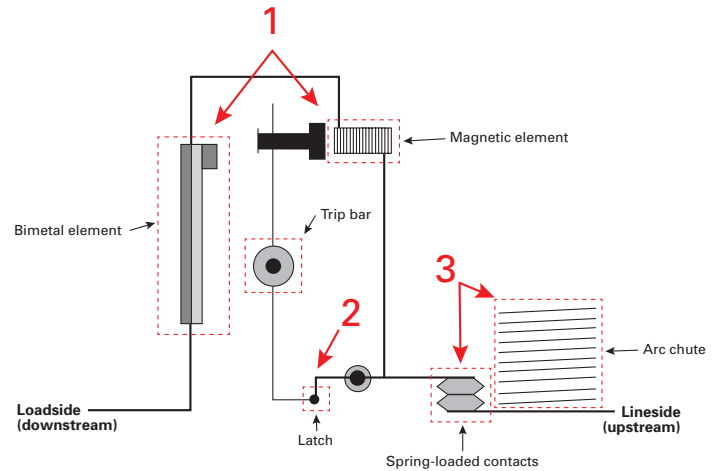


Figure 3.2.4.a

Circuit breaker overload operation

Figures 3.2.4.b and 3.2.4.c illustrate thermal circuit breaker operation by a bimetal element sensing a persistent overload. The bimetal element senses an overload condition by the unequal expansion rates of its material. In some circuit breakers, the overload sensing function is performed by electronic means. Regardless, the unlatching and interruption process is the same. Figure 3.2.4.b illustrates that as the overload persists, the bimetal sensing element bends. If the overload persists for too long, the force exerted by the bimetal sensor on the trip bar becomes sufficient to unlatch the circuit breaker. Figure 3.2.4.c shows that once a circuit breaker is unlatched, it's on its way to opening. The spring-loaded contacts separate and the overload is cleared. There can be some arcing as the contacts open, but the arcing is not as prominent as when interrupting fault current.

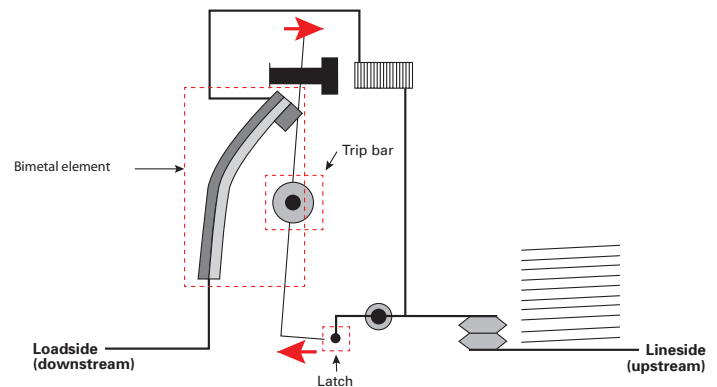


Figure 3.2.4.b

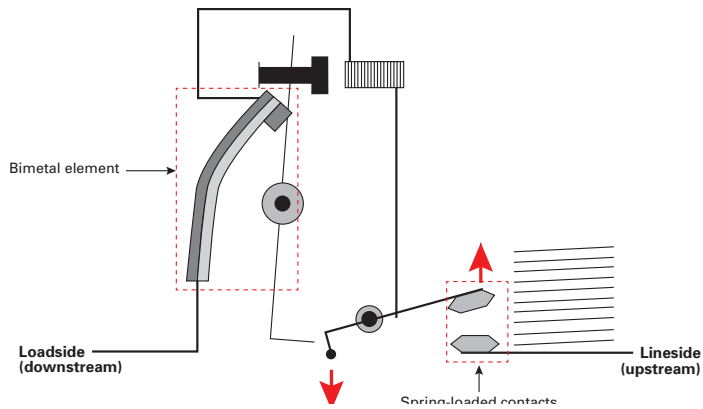


Figure 3.2.4.c

Circuit breaker fault (short-circuit) operation

Figures 3.2.4.d, 3.2.4.e and 3.2.4.f illustrate circuit breaker operation during a fault current. The magnetic element (often referred to as the instantaneous trip that operates without any intentional delay) senses the higher level overcurrent condition. In some circuit breakers, the “instantaneous trip” is performed by electronic means. In either case, the unlatching and interruption process is the same as illustrated in Figures 3.2.4.e and 3.2.4.f. Figure 3.2.4.d illustrates the high current due to a short-circuit causing the trip bar to be pulled toward the magnetic element. If the fault current is high enough, the resulting magnetic force causes the trip bar to exert enough force to unlatch the circuit breaker.

Figure 3.2.4.e shows that once unlatched, the contacts start to part. It is important to understand that once a circuit breaker unlatches it will open, but interrupting the current does not commence until the contacts start to part. As the contacts part, the current continues to flow through the air (arcing current) between the stationary and the movable contacts. At some point the arc is “thrown” to the arc chute that further “stretches” and cools the arc. The speed at which the contacts open depends on the circuit breaker design. The total current interruption time for circuit breaker “instantaneous tripping” depends on the specific design and condition of the breaker’s mechanisms. Smaller amp rated circuit breakers may open and clear in as little as 1/2 cycle or less. Larger amp rated circuit breakers may clear in a range typically between 1 to 3 cycles, depending on the design. Circuit breakers that are listed and marked as current-limiting can interrupt in 1/2 cycle or less when the fault current is in the circuit breaker’s current-limiting range. With the assistance from the arc chute, as well as the alternating current crossing zero voltage (60 or 50 times a second) and the contacts traveling a sufficient distance, the fault current is interrupted (see Figure 3.2.4.f). As energy is released in the contact interruption path and via the arc chutes during the current interruption process, circuit breakers are designed with specific interrupting ratings at specific voltage ratings. For instance, a circuit breaker may have a 14 kA IR at 480 Vac and 25 kA IR at 240 Vac.

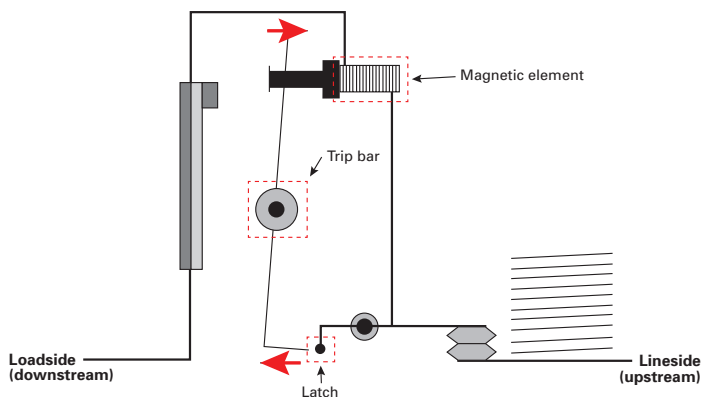


Figure 3.2.4.d

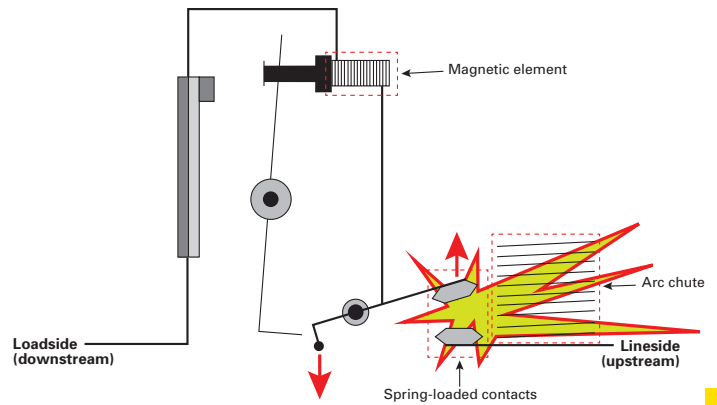


Figure 3.2.4.e

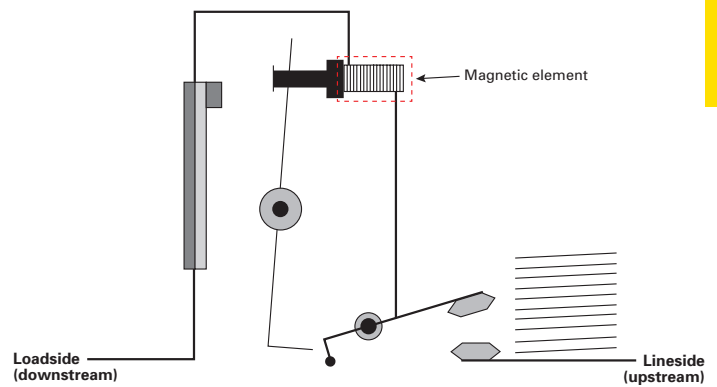


Figure 3.2.4f



3.2.5 Circuit breaker time-current characteristic curves

When using molded case circuit breakers, there are three basic curve considerations to understand:

1. Overload region
2. Instantaneous region with unlatching
3. Interrupting rating

Overload region - overloads can typically be tolerated by circuit components for relatively longer times than faults with OCPD opening times ranging from seconds to minutes. As can be seen in Figure 3.2.4.g, the overload region has a tolerance band (between minimum unlatching and maximum interrupting time), which means the breaker should open within that area for a particular overcurrent.

Instantaneous region — here the circuit breaker will open as quickly as possible. The instantaneous trip (IT) setting indicates the full load rating multiple at which the circuit breaker starts to operate in its instantaneous region. Circuit breakers with instantaneous trips have either (1) fixed settings or (2) adjustable settings. The instantaneous region in Figure 3.2.4.g, (and for this example), is shown to be adjustable from 5x to 10x the breaker amp rating. When the breaker senses an overcurrent in the instantaneous region, it unlatches the contacts and permits them to commence the parting process.

The unlatching time is represented by the curve labeled “average unlatching times for instantaneous tripping” (this is the instantaneous trip curve continuing below 0.01 second). This is important when evaluating lineside to loadside breaker coordination. The manufacturer of the circuit breaker depicted in Figure 3.2.4.g also published unlatching times for various currents (table in upper right). Unlatching starts the contacts parting and the overcurrent is not cleared until the breaker’s contacts are mechanically separated and the arc is extinguished (depicted in Figure 3.2.4.f as the maximum interrupting time).

Consequently, the time from unlatching to interruption, is indicated by the overload region between the minimum unlatching time and the maximum interrupting time curves. This time range affects the ability circuit breakers with instantaneous trips to selectively coordinate when the overcurrent magnitude is in the instantaneous trip range. Two instantaneous trip settings for a 400 A breaker are shown in Figure 3.2.4.g (solid blue and red dashed lines). The solid blue line instantaneous trip region represents an IT = 5x, or five times 400 A = 2000 A. At this setting, the circuit breaker will trip instantaneously on currents of approximately 2000 A or more. The $\pm 25\%$ band represents the area in which it’s uncertain whether the overload trip or the instantaneous trip will operate to clear the overcurrent. The dashed red line instantaneous trip region represents the same 400 A breaker with an IT = 10x, or 10 times 400 A = 4000 A. At this setting the overload trip will operate up to approximately 4000 A ($\pm 10\%$). Overcurrents greater than 4000 A ($\pm 10\%$) would be sensed by the instantaneous setting. The $\pm 25\%$ and $\pm 10\%$ band mentioned in this paragraph represents a tolerance that can vary by circuit breaker manufacturer and type.

Many lower amp rated circuit breakers (100 A and 150 A frame CBs) have non-adjustable or fixed instantaneous trip settings. For larger molded case, insulated case and power breakers the instantaneous trip setting can usually be adjusted by an external dial.

The circuit breaker’s IT is typically set at its lowest setting when shipped from the factory. Note that most published circuit breaker time-current curves show the vertical time axis from 0.01 second up to about 100 or 1000 seconds. The published curves do not normally provide the instantaneous unlatching characteristic. However, if a circuit breaker has an instantaneous trip, it has unlatching times usually less than 0.01 second.

Some circuit breakers have short time-delay trip settings (STD). The short time-delay trip option can be used in conjunction with (1) an instantaneous trip settings or (2) without instantaneous trip settings. Typically, MCCBs and ICCBs with short time-delay settings have an instantaneous trip override. This means at some fault current level, the instantaneous trip operates to protect the circuit breaker. LVPCBs can be specified with a short time-delay setting which does not inherently incorporate an instantaneous trip override.

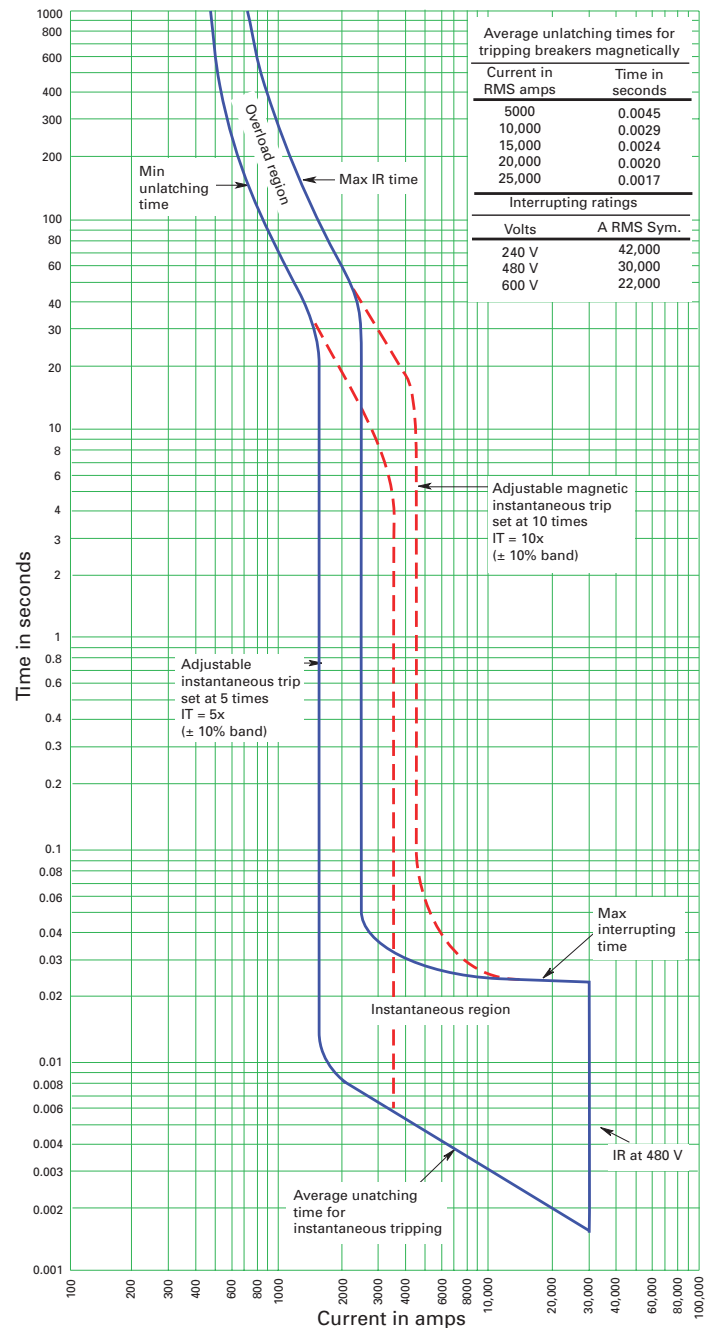


Figure 3.2.4.g: Typical circuit breaker time-current characteristic curve.

Interrupting rating - the interrupting rating is represented in Figure 3.2.4.g by a vertical line at the lower right end of the curve. The circuit breaker’s interrupting rating varies based on the voltage level (see the table in Figure 3.2.4.g that lists the interrupting ratings for this specific circuit breaker). For coordination purposes, the vertical line is often drawn at the fault current level in lieu of the interrupting rating (if the interrupting rating is greater than the available fault current). However, if the fault current is above the interrupting rating, a misapplication and NEC 110.9 violation is evident. In Figure 3.2.4.g, the circuit breaker interrupting rating at 480 V is 30,000 amps.

Two instantaneous trip circuit breakers

Figure 3.2.4.h illustrates a 90 A circuit breaker and an upstream 400 A circuit breaker having an instantaneous trip setting of 5x (5 times 400 A = 2000 A). The minimum instantaneous trip current for the 400 A circuit breaker could be as low as 2000 A times 0.75 = 1500 A ($\pm 25\%$ band). If a fault above 1500 A occurs on the 90 A breaker's loadside, both breakers could open. The 90 A breaker may unlatch before the 400 A breaker. However, before the 90 A breaker can part its contacts and clear the fault current, the 400 A breaker could have unlatched and started the irreversible contact parting process.

Assume a 4000 A fault exists on the 90 A circuit breaker's loadside, the sequence of events would be:

1. The 90 A breaker will unlatch (Point A) and free the breaker mechanism to start the contact parting process.
2. The 400 A breaker will unlatch (Point B) and it, too, would begin the contact parting process. Once a breaker unlatches, it will open. At the unlatching point, the process is irreversible.
3. At Point C, the 90 A breaker will have completely interrupted the fault current.
4. At Point D, the 400 A breaker will also have opened, which unnecessarily disrupts power to all other loads.

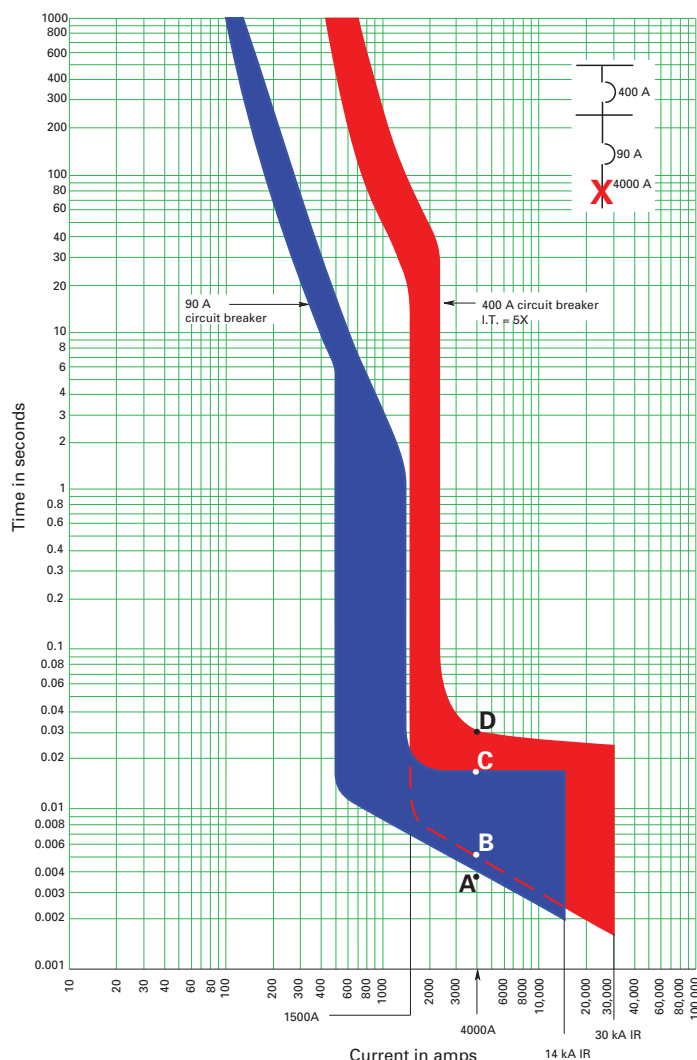
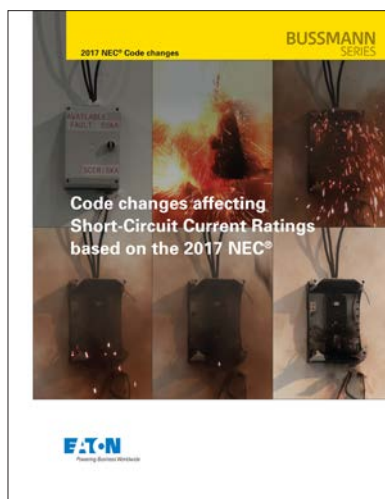


Figure 3.2.4.h These two specific circuit breakers with the settings as stated are coordinated for any overcurrent up to approximately 1500 A. However, this is a non-selective system where fault currents above 1500 A* cause a blackout to all the loads fed by the 400 A breaker. As mentioned previously, this is typical for molded case circuit breakers due to the instantaneous trip and band of operation on medium to high fault conditions. Additionally, this can affect other, larger upstream circuit breakers, depending upon the upstream circuit breaker's size and instantaneous setting, and the fault current magnitude.

* Circuit breaker manufacturers provide coordination tables that show specific circuit breakers types and amp ratings coordinating to fault values greater than the crossing point where two circuit breaker time-current characteristic curves intersect.

Do you know about the new 2017 NEC® SCCR requirements?



Finding out is easy. Eaton's handbook *Code changes affecting Short-Circuit Current Ratings based on the 2017 NEC* will help you:

Know why SCCR is important.

Understand hazards associated with insufficient SCCR.

Know what specific NEC chapters, articles, parts and sections are involved.

Comply with Code requirements for marking and documenting SCCR.

If you're designing, installing or inspecting equipment, download your copy at Eaton.com/nec2017sccr.

4 Power system analysis

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4.1 Fault current calculations

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4.1.1 Overview

The fault current calculation is the most basic calculation performed on a power distribution system and vital for the proper electrical equipment application. There are several NEC sections with requirements directly pertaining to the proper electrical product application and available fault current. Safe and reliable electrical equipment application, including OCPDs, relies on such power systems analysis study information obtained from fault current and selective coordination studies.

4.1.2 Code requirements

Knowing available fault current throughout the power distribution system is important for proper product application. The NEC recognizes the importance of fault currents in many areas within its requirements, including these important topics and sections:

Available fault current markings

- 110.24 — Service Entrance Equipment
- 409.22(B) — Industrial Control Panels
- 440.10(B) — Air Conditioning & Refrigeration Equipment
- 620.51(D)(2) — Elevator Control Panels
- 670.5(2) — Industrial Machinery

Applying solutions within their ratings

- 110.9 — Interrupting Rating
- 110.10 — Component Protection
- 110.24 — Available Fault Current
- 240.4 — Conductor Protection
- 250.122 — Equipment Grounding Conductor Protection
- 409.22(A) — Industrial Control Panels
- 440.10(A) — Air Conditioning & Refrigeration Equipment
- 620.16(B) — Elevator Control Panels
- 670.5(1) — Industrial Machinery

Marking Short-Circuit Current Ratings (SCCR)

- 230.82(3) — Meter Disconnect
- 409.110(4) — Industrial Control Panels
- 430.8 — Motor Controllers
- 430.98 — Motor Control Centers
- 440.4(B) — Air Conditioning & Refrigeration Equipment
- 620.16(A) — Elevator Control Panel
- 670.3(A)(4) — Industrial Machinery
- 700.5(E) — Transfer Equipment for Emergency Systems
- 701.5(D) — Transfer Equipment for Legally Required and Standby Systems
- 702.5 — Transfer Equipment for Optional Standby Systems
- 708.24(E) — Transfer Equipment for Critical Operations Power Systems

Selective coordination

- 620.62 — Selective Coordination for Elevator Circuits
- 645.27 — Critical Operations Data Systems
- 695.3(C) — Multi-building Campus-Style Complexes
- 700.32 — Emergency Systems
- 701.27 — Legally Required Standby Systems
- 708.54 — Critical Operations Power Systems

4.1.3 One-line diagram

The one-line diagram, often referred to as a single-line, plays an important role in many aspects of power distribution system design, maintenance and construction. A one-line diagram graphically represents the power distribution system. Developing this diagram is the first step in making fault current, selective coordination and incident energy studies. This diagram should show all fault current sources and significant circuit elements. Significant circuit element reactance and resistance values should be included in the diagram. The one-line diagram should be updated any time the power distribution system changes. Changes must be reviewed with attention paid to the impact upon the studies that are based on this diagram's contents.

4.1.3.1 Fault current contributors

Fault current sources in a power distribution system include:

Utility

Utilities provide power through a transformer or series of transformers depending upon where in the distribution system the facility obtains its power. Most rural locations have a transformer dedicated to a facility or multiple facilities. In some urban areas, for reliability sake, power is derived from utility secondary networks where utility transformers are operated in parallel. Available fault currents on these secondary network systems are very high, in a range greater than 100 kA and upwards of 200 kA.

The fault current that's typically provided from the utility is an infinite bus calculation based upon the supply transformer's kVA size and minimum impedance. For applications on a secondary network, consulting the utility is the only way to obtain the available fault current for any given installation.

Generators

On-site generation for backup power must be a consideration for the power distribution system equipment. In most cases, the local generation will not provide fault currents greater than what can be seen from a utility. When large systems have multiple generators installed in parallel, such as hospitals or other similar applications, it's conceivable that available fault currents are greater than that available from utility sources.

The available fault current will depend upon the kVA of the generator and sub-transient reactance. NEC Section 445.11 specifies the information to be included on the generator's nameplate consisting of:

- Sub-transient, transient, synchronous, and zero sequence reactances
- Power rating category
- Insulation system class
- Indication if the generator is protected against overload by inherent design, overcurrent protective relay, circuit breaker or fuse
- Maximum fault current for inverter-based generators, in lieu of the synchronous, sub-transient, and transient reactances

The sub-transient reactance is an impedance value used in determining generator fault contribution during the first cycle after a fault occurs. In approximately 0.1 second, the reactance increases to the transient reactance which is typically used to determine the fault current contribution after several cycles. In approximately 1/2 to 2 seconds, the generator's reactance increases to the synchronous reactance, which is the value that determines current flow after a steady-state condition is reached by the system, should fault currents be permitted to flow this long.

Motors

Voltages collapse during a fault, and when this happens to operating motors, their rotors will continue to turn and convert this rotating motion from a load to a fault current source. It's not practical to consider the contribution of each small motor in a system. IEEE rules of thumb deal with small motors by combining motors ≤ 50 Hp at each bus to which they are attached, and modeling them as one motor with an assumed sub-transient reactance, with 25% the typical assumed value.

The basic equation to determine motor contribution I_{sc} is:

$$I_{sc \text{ motor}} = (\text{Motor FLA} \times 100) \div \%X_d'$$

Motor sub-transient reactances range from 15% to 25%, with 25% being the more popular value used.

The motor's sub-transient reactance is an impedance value used to determine the motor's fault current contribution during the first cycle after a fault occurs. In approximately 0.1 second, the reactance increases to the transient reactance, which is typically used to determine the fault current contribution after several cycles. In approximately 1/2 to 2 seconds, the motor's reactance increases to the synchronous reactance, which is the value that determines current flow after a steady-state condition is reached by the system, should fault currents be permitted to flow this long.

Alternate power sources

Alternative energy sources are becoming more and more common in power distribution systems. In addition to an inverter that's collecting energy from solar or wind power, batteries are also fault current contributors and should be considered when appropriate.

4.1.3.2 Fault current reducers (impedances)

Impedance components considered in fault calculations, and shown on one-line diagrams, include:

Conductors

Unlike rotating machinery and transformers, conductors have a resistance and reactance mix to add to the power distribution system. Impedance values can be obtained from Table 9 of the NEC. As an example, a 500 kcmil copper conductor in a metallic raceway has impedance values as:

- Resistance = 0.029 ohms per 1000 ft.
- Reactance = 0.048 ohms per 1000 ft.

This is typically expressed in a rectangular format as:

$$Z_{\text{conductor}} = 0.029 + j0.048 \text{ ohms per 1000 ft.}^*$$

* "j" is a 90 degree operator signifying a vector at a 90 degree angle. Each impedance is comprised of real and reactive components. Real components are a magnitude at a 0 angle and inductive reactive components are a magnitude at a 90 degree angle.

This conductor's impedance is represented graphically in Figure 4.1.3.2.a.

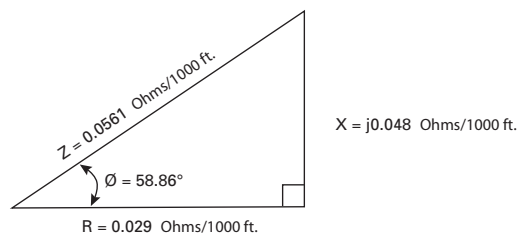


Figure 4.1.3.2.a

Conductor length is important when determining the impedance of any branch, feeder or service circuit. The impedance for 200 ft. of the 500 kcmil conductor referenced above is calculated as:

$$Z_{(200 \text{ ft.})} = 200 \text{ ft.} \times \frac{0.029 + j0.048 \text{ Ohms}}{1000 \text{ ft.}}$$

$$Z_{(200 \text{ ft.})} = 0.0006 + j0.0096 \text{ Ohms}$$

Impedance values will be different depending upon the conductor size and material (copper or aluminum) as well as what raceway in which it is installed and its length. One-line diagrams must have enough information to determine the correct conductor ampacity as well as determining the correct impedance for calculations.

Transformers

Transformers add considerable impedance to a power distribution system. The transformer nameplate will include its %Z value, which is based on the transformer's secondary.

When actual information is not available, the rule of thumb for typical transformer impedance ranges is shown in the following table.

kVA 3-phase	X/R	Range of %Z
112.5	3.0	1.6 — <u>2 Min</u> — 6.2
150	3.5	1.5 — <u>2 Min</u> — 6.4
225	4.0	2.0 — <u>2 Min</u> — 6.6
300	4.5	2.0 — <u>4.5 Min</u> — 6.0
500	5.0	2.1 — <u>4.5 Min</u> — 6.1
750	6.0	3.2 — <u>5.75</u> — <u>6.75</u> — 6.8
1000	7.0	3.2 — <u>5.75</u> — <u>6.75</u> — 8.0
1500	7.0	3.5 — <u>5.75</u> — <u>6.75</u> — 6.8
2000	8.0	3.5 — <u>5.75</u> — <u>6.75</u> — 6.8
2500	9.0	3.5 — <u>5.75</u> — <u>6.75</u> — 6.8

Table notes:

1. Underlined values are from ANSI C57.12.10-1977[1], ANSI C57.12.22-1980 [2] and NEMA 210-1976 [10].
2. Network transformers with three-position switches have 5.0%Z for 500-750 kVA. See ANSI C57.12-40-1982 [3].
3. Three-phase banks with three single-phase transformers may have values as low as 1.2%.

The infinite bus calculation for the maximum fault current that can be possibly seen on the transformer's secondary is calculated with the following equation:

$$I_{\text{infinite bus}} = \frac{\text{FLA} \times 100}{\% Z}$$

A transformer manufacturer determines impedance through what's called a short-circuit test conducted as follows:

- The transformer secondary is short-circuited
- Voltage on the primary is increased until full load current flows in the secondary
- The applied voltage divided by the rated primary voltage (times 100) is the transformer's impedance

Example: For a 480 volt rated primary, if 9.6 volts cause secondary full load current to flow through the shorted secondary, the transformer impedance is $9.6 \div 480 = 0.02 = 2\%Z$.

Busway

Busway presents a flexible method to distribute power in a facility. Busway originated in Detroit's automotive industry during late 1920's in a response to a need for overhead wiring systems that would simplify electric motor-driven machine connections and permit a convenient arrangement for these production line machines. Busway has grown in popularity for many applications beyond manufacturing.

Busway presents a very low impedance to the distribution system, making it a very efficient power distribution means with attractive low voltage drop qualities. Busway also presents a low impedance during fault events.

The following table presents typical busway impedance values for use in voltage drop and fault calculations.

Typical busway parameters, line-to-neutral, in mΩ/100 ft, 25°C				
Current rating (amps)	Aluminum		Copper	
	R	X	R	X
600	2.982	1.28	2.33	1.57
800	2.00	0.80	1.63	1.25
1000	1.60	0.64	1.27	0.92
1200	1.29	0.55	0.97	0.69
1350	1.03	0.44	0.86	0.63
1600	0.89	0.38	0.72	0.55
2000	0.70	0.32	0.58	0.46
2500	0.57	0.26	0.41	0.32
3000	0.46	0.21	0.37	0.29
4000	0.34	0.16	0.28	0.21
5000	—	—	0.20	0.16

Reactors

There are various reasons that reactors are used in a power distribution system. One reason is to limit fault current. Current-limiting reactors, connected in series, are primarily used to reduce fault currents and to match the impedance of parallel feeders. For example, to reduce the available fault and arcing current at the equipment, low voltage motor control centers can be supplied with three single-phase reactors that limit available fault current.

Reactors are also used in grounding neutrals of generators directly connected to the distribution system bus to limit the line-to-ground fault to somewhat less than the three-phase fault at the generator terminals. If the reactor is so sized, in all probability, the system will remain effectively grounded.

4.1.4 Procedures and methods

To determine the fault current at any point in the system, first secure an up to date one-line diagram. The one-line diagram must include all major fault current sources and impedances to fault currents. Next, an impedance diagram is created that includes all major power system components represented as impedances.

The impedance tables in Section 4.1.7 include three-phase and single-phase transformers, cables and busway. Use these tables if information from the manufacturer is not readily available.

Fault current calculations are performed without current-limiting devices in the system. To determine the maximum "available" fault current, calculations are made as though these devices are replaced with copper bars. This is necessary to project how the system and the current-limiting devices will perform.

Also, multiple current-limiting devices do not operate in series to "compound" a current-limiting effect. The downstream, loadside fuse will operate alone under a fault condition if properly coordinated.

The application of the point-to-point method permits determining available fault currents with a reasonable degree of accuracy at various points for either three-phase or single-phase electrical distribution systems. This method can assume unlimited primary fault current (infinite bus) or it can be used with limited available primary fault current.

4.1.4.1 Maximum and minimum fault currents

Fault current calculations should be performed at all critical points in the system including:

- Service entrance equipment
- Transfer switches
- Panelboards
- Load centers
- Motor control centers
- Disconnects
- Motor starters

Normally, fault studies involve calculating a bolted three-phase fault condition. This can be characterized as all three phases "bolted" together to create a zero impedance connection. This establishes a "worst case" (highest current) condition that results in maximum three-phase thermal and mechanical stress in the system.

From this calculation, other fault condition types can be approximated. This "worst case" condition should be used for interrupting rating, component protection, "Table" method for determining PPE per NFPA 70E and selective coordination.

Arc flash hazard analysis calculations should consider both maximum and minimum fault current calculations. Incident energy depends upon current and time. For lower arcing current values, clearing times could be longer than those for higher arcing current values, which could result in higher incident energy values. Therefore, an arc flash analysis must consider both spectrum of available fault current for calculating arcing currents, which are then compared with OCPD TCC curves to determine clearing times.

There are several variables in a distribution system affecting calculated bolted three-phase fault currents. Variable values applicable for the specific application analysis must be selected. The point-to-point method presented in this section includes several adjustment factors given in notes and footnotes that can be applied, and that will affect results. Some of the parameters that must be considered include utility source fault current, motor contribution, transformer percent impedance tolerance and voltage variance.

In most situations, the utility source(s) or on-site energy sources (such as generators) are the major fault current contributors. The point-to-point method includes steps and examples that assume an infinite available fault current from the utility source. Generally, this is a good assumption for highest, worst case conditions since the property owner has no control over the utility's system and future utility changes. In many cases, a large increase in the utility available fault current does not increase the building system's fault current a great deal on the secondary of the service transformer. However, there are cases where the actual utility medium voltage available fault current provides a more accurate fault current assessment (minimum bolted fault current conditions) that may be needed to assess arc flash hazards.

When motors are in the system, motor fault current contribution is also a very important factor to include in any fault current analysis. When a fault occurs, motor contribution adds to the fault current magnitude, with running motors contributing four to six times their normal full load current. Series rated combinations can't be used in specific situations due to motor fault current contributions (see the section on Series Ratings in this book).

For short time duration capacitor discharge currents, certain IEEE (Institute of Electrical and Electronic Engineers) publications detail how to calculate these currents if they are substantial.

4.1.5 Point-to-point calculation method

The application of the point-to-point method permits determining available fault currents with a reasonable degree of accuracy at various points for either 3 Ø or 1 Ø electrical distribution systems.

4.1.5.1 Basic point-to-point calculation

The following are the basic steps to employ in the point-to-point method of calculating fault current.

Step 1: Determine the transformer full load amps (FLA) from either the nameplate, the following formulas or Table 4.1.7.1.a:

$$3 \text{ } \varnothing \text{ Transformer } I_{FLA} = \frac{kVA \times 1000}{E_{L-L} \times \sqrt{3}}$$

$$1 \text{ } \varnothing \text{ Transformer } I_{FLA} = \frac{kVA \times 1000}{E_{L-L}}$$

Step 2: Find the transformer multiplier (see Notes 1 and 2).

$$\text{Multiplier} = \frac{100}{\%Z_{\text{transformer}}}$$

Note 1. Get %Z from nameplate or Table 4.1.7.1.a. Transformer impedance (Z) is used to determine what the fault current will be on the transformer secondary.

Note 2. 25 kVA and larger UL 1561 listed transformers have a $\pm 10\%$ impedance tolerance. Fault current levels can be affected by this tolerance. Therefore, for high end, worst case, multiply %Z by 0.9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a $\pm 7.5\%$ impedance tolerance (two-winding construction).

Step 3: Determine by formula or Table 4.1.7.1.a the transformer let-through fault current. See Notes 3 and 4.

$$I_{sc} = \text{Transformer FLA} \times \text{Multiplier}$$

Note 3. Utility voltages may vary $\pm 10\%$ for power and $\pm 5.8\%$ for 120 volt lighting services. Therefore, for highest fault current conditions, multiply values as calculated in Step 3 by 1.1 or 1.058 respectively. To find the lower end worst case, multiply results in Step 3 by 0.9 or 0.942 respectively.

Note 4. Motor fault current contribution, if significant, may be added at all fault locations throughout the system. A practical motor fault current contribution estimate is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Step 4: Calculate the “f” factor.

$$3 \text{ } \varnothing \text{ Faults } f = \frac{\sqrt{3} \times L \times I_{3\varnothing}}{C \times n \times E_{L-L}}$$

For the next two equations, see note 5

$$1 \text{ } \varnothing \text{ Line-line faults } f = \frac{2 \times L \times I_{L-L}}{C \times n \times E_{L-L}}$$

$$1 \text{ } \varnothing \text{ Line-neutral faults } f = \frac{2 \times L \times I_{L-N}}{C \times n \times E_{L-N}}$$

Where:

L = Conductor length to the fault in feet

C = Constant from Table 4.1.7.6.a of “C” values for conductors and Table 4.1.7.7.a of “C” values for busway

n = Number of conductors per phase (adjust C value for parallel runs)

I = Available fault current in amps at circuit’s beginning

E = Circuit voltage

Note 5. On a single-phase center-tapped transformer, the L-N fault current is higher than the L-L fault current at the secondary terminals. The fault current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L-N} = 1.5 \times I_{L-L}$ at transformer terminals.

Depending upon wire size, at some distance from the terminals, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on a change in turns ratio between primary and secondary, infinite source available, zero feet from transformer terminals and $1.2 \times \%X$ and $1.5 \times \%R$ for L-N versus L-L resistance and reactance values. Begin L-N calculations at the transformer’s secondary terminals, then proceed point-to-point.

Step 5: Calculate “M” (multiplier) or take from Table 4.1.7.2.

$$M = \frac{1}{1+f}$$

Step 6: Calculate the available short-circuit symmetrical RMS fault current at the point of fault. Add motor contribution, if applicable.

$$I_{SC \text{ RMS Sym.}} = I_{SC} \times M$$

Step 6A: Significant motor fault current contribution may be added at all fault locations throughout the system. A practical motor fault current contribution estimate is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

4.1.5.2 Point-to-point calculation when available primary fault current is known

The following procedure can be used to calculate the fault current level at a downstream transformer’s secondary in a system when the fault current level at the transformer primary is known.

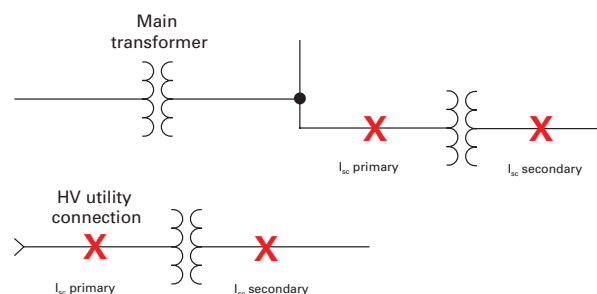


Figure 4.1.5.2.a

Step A: Calculate the “f” factor (I_{sc} primary known)

3 Ø Transformer (I_{sc} primary and I_{sc} secondary are 3 Ø fault values);

$$f = \frac{I_{sc \text{ primary}} \times V_{\text{primary}} \times \sqrt{3} \times \%Z}{100,000 \times kVA_{\text{transformer}}}$$

1 Ø Transformer (I_{sc} primary and I_{sc} secondary are 1 Ø fault values: I_{sc} secondary is L-L);

$$f = \frac{I_{sc \text{ primary}} \times V_{\text{primary}} \times \%Z}{100,000 \times kVA_{\text{transformer}}}$$

Step B: Calculate “M” (multiplier)

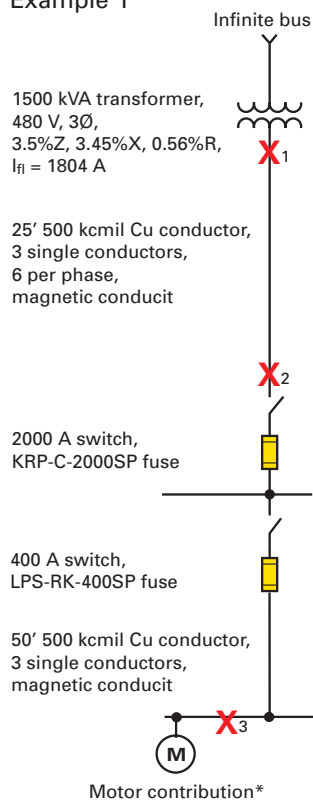
$$M = \frac{1}{1+f}$$

Step C: Calculate the fault current at the transformer secondary (see Note under Step 3 of “Basic point-to-point calculation procedure”)

$$I_{SC \text{ secondary}} = \frac{V_{\text{primary}}}{V_{\text{secondary}}} \times M \times I_{SC \text{ primary}}$$

4.1.5.3 Point-to-point calculation

Example 1



Note: The following “Step” numbers pertain to the steps described in “4.1.5.1. Point-to-point calculation basic.”

Fault X1

$$\text{Step 1: } I_{fL} = \frac{1500 \times 1000}{480 \times \sqrt{3}} = 1804 \text{ A}$$

$$\text{Step 2: Multiplier} = \frac{100}{3.5 \times 0.9^\dagger} = 31.746$$

$$\begin{aligned} \text{Step 3: } I_{sc} &= 1804 \text{ A} \times 31.746 = 57,279 \text{ A} \\ I_{sc} \text{ motor contribution}^* &= 4 \times 1804 \text{ A} = 7217 \text{ A} \\ I_{sc} \text{ total} &= 57,279 \text{ A} + 7217 \text{ A} = 64,496 \text{ A} \end{aligned}$$

Fault X2

$$\text{Step 4: } \frac{\sqrt{3} \times 25 \times 57,279}{22,185 \times 6 \times 480} = 0.0388$$

$$\text{Step 5: } M = \frac{1}{1 + 0.0388} = 0.9626$$

$$\begin{aligned} \text{Step 6: } I_{sc} &= 57,279 \text{ A} \times 0.9626 = 55,137 \text{ A} \\ I_{sc} \text{ motor contribution}^* &= 4 \times 1804 \text{ A} = 7217 \text{ A} \\ I_{sc} \text{ total} &= 55,137 \text{ A} + 7217 \text{ A} = 62,354 \text{ A} \end{aligned}$$

* See Note 4 on page 4-4. Assumes 100% motor load. If 50% of this load is from motors, $I_{sc} \text{ motor contribution} = 4 \times 1804 \text{ A} \times 0.5 = 3608 \text{ A}$.

† See Note 2 on page 4-4.

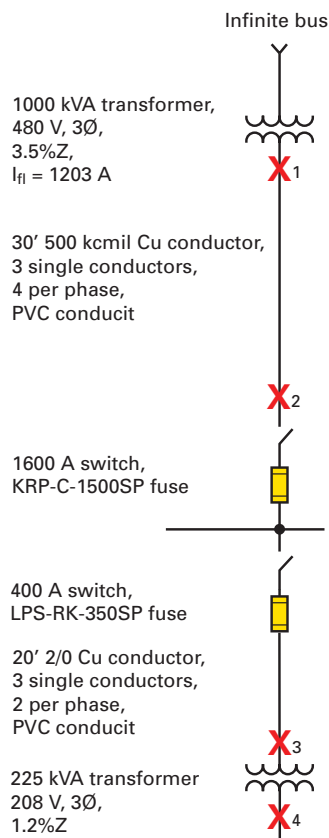
Fault X3

$$\text{Step 4: } \frac{\sqrt{3} \times 50 \times 55,137}{22,185 \times 1 \times 480} = 0.4484$$

$$\text{Step 5: } M = \frac{1}{1 + 0.4483} = 0.6904$$

$$\begin{aligned} \text{Step 6: } I_{sc} &= 55,137 \text{ A} \times 0.6904 = 38,067 \text{ A} \\ I_{sc} \text{ motor contribution} &= 4 \times 1804 \text{ A} = 7217 \text{ A} \\ I_{sc} \text{ total} &= 38,067 \text{ A} + 7217 \text{ A} = 45,284 \text{ A} \end{aligned}$$

Example 2



Note: The following Step numbers pertain to the steps described in “4.1.5.1 Point-to-point calculation basic.”

Fault X1

$$\text{Step 1: } \frac{1000 \times 1000}{480 \times \sqrt{3}} = 1202.8 \text{ A}$$

$$\text{Step 2: Multiplier} = \frac{100}{3.5 \times 0.9} = 31.746$$

$$\text{Step 3: } I_{sc} = 1202.8 \text{ A} \times 31.746 = 38,184 \text{ A}$$

Fault X2

$$\text{Step 4: } \frac{\sqrt{3} \times 30 \times 38,184}{26,706 \times 4 \times 480} = 0.0387$$

$$\text{Step 5: } M = \frac{1}{1 + 0.0387} = 0.9627$$

$$\text{Step 6: } I_{sc} = 38,184 \text{ A} \times 0.9627 = 36,761 \text{ A}$$

Fault X3

$$\text{Step 4: } \frac{\sqrt{3} \times 20 \times 36,761}{2 \times 11,424 \times 480} = 0.1161$$

$$\text{Step 5: } M = \frac{1}{1 + 0.1161} = 0.8960$$

$$\text{Step 6: } I_{sc} = 36,761 \text{ A} \times 0.8960 = 32,937 \text{ A}$$

Fault X4

$$\text{Step A: } \frac{32,937 \times 480 \times \sqrt{3} \times 1.2 \times 0.9}{100,000 \times 225} = 1.3144$$

$$\text{Step B: } M = \frac{1}{1 + 1.3144} = 0.4321$$

$$\text{Step C: } I_{sc} = \frac{480 \times 0.4321 \times 32,937 \text{ A}}{208} = 32,842 \text{ A}$$

4.1.5.4. Single-phase system fault currents

Fault current calculations on a single-phase center tapped transformer system require a slightly different procedure than 3 Ø faults on 3 Ø systems.

Primary available fault current

It is necessary that the proper impedance be used to represent the primary system. For 3 Ø fault calculations, a single primary conductor impedance is used from the source to the transformer connection. This is compensated for in the 3 Ø fault current formula by multiplying the single conductor or single-phase impedance by 1.73 ($\sqrt{3}$).

However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer, and back to the source. This is compensated for in the calculations by multiplying the 3 Ø primary source impedance by two.

Center-tapped transformer impedance

The center-tapped transformer impedance must be adjusted for the half-winding (generally line-to-neutral) fault condition.

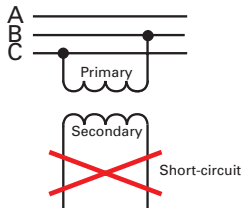


Figure 4.1.5.4.a

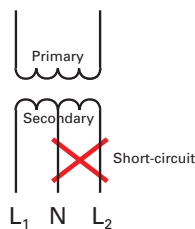


Figure 4.1.5.4.b

Figure 4.1.5.4.b illustrates that during line-to-neutral faults, the full primary winding is involved, but only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are:

- 1.5 times full winding %R on full winding basis
- 1.2 times full winding %X on full winding basis

Note: %R and %X multipliers given in “Impedance Data for Single-Phase Transformers” Table may be used. However, calculations must be adjusted to indicate transformer kVA ÷ 2.

Cable and two-pole switch impedances

The cable and two-pole switch impedance on the system must be considered “both-ways” since the current flows to the fault and then returns to the source. E.g., if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation. (Figure 4.1.5.5.c.)

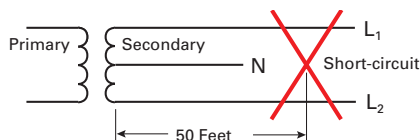
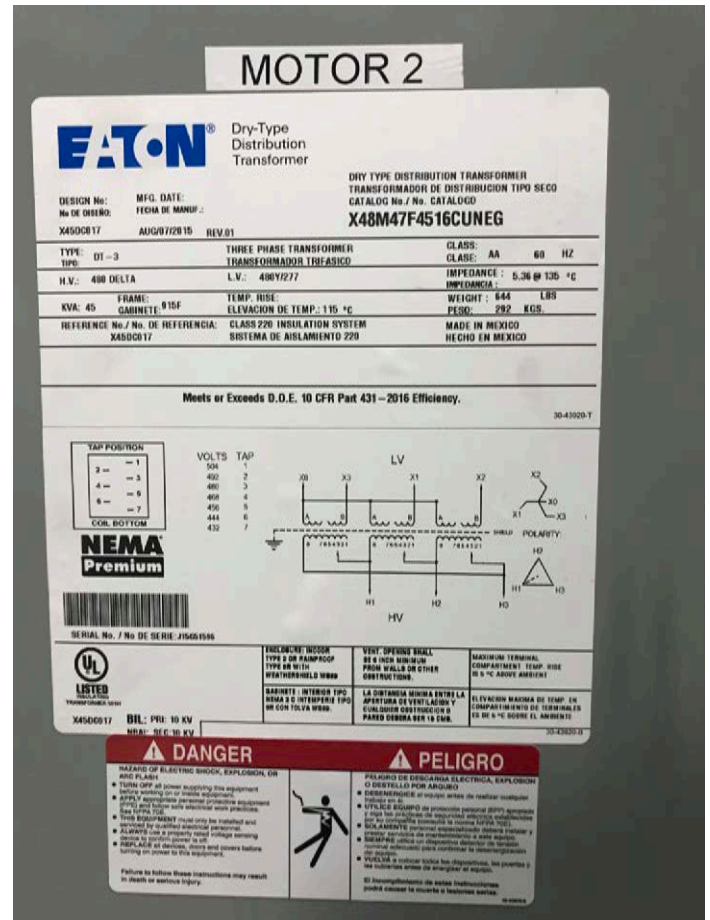


Figure 4.1.5.4.c

The following calculations illustrate 1 Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.

Note in these examples:

- The multiplier is 2 for some electrical components to account for the single-phase fault current flow
- The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation along with impedance and reactance data



Single-phase system fault current calculation

Example 1 — line-to-line

Note: The following Step numbers pertain to the steps described in “4.1.5.1. Point-to-point calculation basic.”

Fault X1

Step 1: $\frac{75 \times 1000}{240} = 312.5 \text{ A}$

Step 2: Multiplier = $\frac{100}{1.4 \times 0.9} = 79.37$

Step 3: $I_{sc} \text{ L-L} = 312.5 \text{ A} \times 79.37 = 24,802 \text{ A}$

Fault X2

Step 4: $\frac{2 \times 25 \times 24,802}{22,185 \times 1 \times 240} = 0.2329$

Step 5: $M = \frac{1}{1 + 0.2329} = 0.8111$

Step 6: $I_{sc} \text{ L-L} = 24,802 \text{ A} \times 0.8111 = 20,116 \text{ A}$

Fault X3

Step 4: $\frac{2 \times 50 \times 20,116}{4774 \times 1 \times 240} = 1.7557$

Step 5: $M = \frac{1}{1 + 1.7557} = 0.3629$

Step 6: $I_{sc} = 20,116 \text{ A} \times 0.3629 = 7300 \text{ A}$

* In addition, 25 kVA and larger UL 1561 listed transformers have a $\pm 10\%$ impedance tolerance that can affect fault current. Therefore, for high end worst case, multiply %Z by 0.9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a $\pm 7.5\%$ impedance tolerance (two-winding construction).

Example 2 — line-to-neutral

Note: The following Step numbers pertain to the steps described in “4.1.5.1. Point-to-point calculation basic.”

Fault X 1

Step 1: $\frac{75 \times 1000}{240} = 312.5 \text{ A}$

Step 2: Multiplier = $\frac{100}{1.4 \times 0.9} = 79.37$

Step 3*: $I_{sc} \text{ L-L} = 312.5 \text{ A} \times 79.37 = 24,802 \text{ A}$
 $I_{sc} \text{ L-N} = 24,802 \times 1.5 = 37,202 \text{ A}$

Fault X2

Step 4: $\frac{2 \times 25 \times 37,202}{22,185 \times 1 \times 120} = 0.6987$

Step 5: $M = \frac{1}{1 + 0.6987} = 0.5887$

Step 6*: $I_{sc} \text{ L-L} = 37,202 \text{ A} \times 0.5887 = 21,900 \text{ A}$

Fault X3

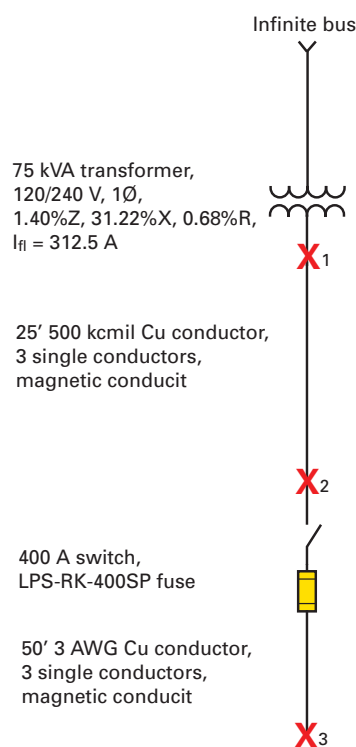
Step 4: $\frac{2 \times 50 \times 21,900^{**}}{4774 \times 1 \times 120} = 3.8323$

Step 5: $M = \frac{1}{1 + 3.8323} = 0.2073$

Step 6*: $I_{sc} = 21,900 \text{ A} \times 0.2073 = 4540 \text{ A}$

* The L-N fault current is higher than the L-L fault current at the single phase center-tapped transformer's secondary terminals. The available fault current (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center-tapped transformer terminals, $I_{L-N} = 1.5 \times I_{L-L}$ at transformer terminals.

** Assumes same size neutral and line conductors.



4.1.6 Equipment evaluations

The first step to properly applying electrical solutions, as well as complying with Code requirements, is the fault current study. Once the fault current levels are determined, equipment has to be evaluated for proper application including:

- OCPD interrupting ratings
- System selective coordination
- Component protection (SCCR)
- Incident energy analysis

See the various sections in this handbook for further information on these topics.

Low voltage fuses have their interrupting rating expressed as symmetrical component of fault current. They are given an RMS symmetrical interrupting rating at a specific power factor. This means that the fuse can also interrupt the asymmetrical current associated with this rating. Thus, only the symmetrical component of fault current need be considered to determine the necessary low voltage fuse interrupting rating.

The NEC includes requirements for marking and/or documenting, available fault current for various locations throughout the power distribution system. NEC 110.24 requires field marking service equipment (other than dwelling units and certain industrial facilities) with the maximum available fault current. Additionally, other requirements include either marking the available fault current on the equipment, or documenting the available fault current covering industrial control panels, HVAC equipment, elevator control panels and industrial machinery.

In addition to OCPD interrupting ratings and equipment SCCR ratings, the available fault current is used for other purposes, including determining selective coordination and arc flash boundary, along with the proper arc rated PPE per NFPA 70E. Whether determined by the incident energy method or arc flash PPE category method (70E 130.5), the available fault current is required.

Available Fault Current Calculator

FC² is an online or downloadable application (for both Apple and Android devices) that utilizes the point-to-point method for calculating and documenting available fault current levels in single- and three-phase systems.

It's capable of producing equipment labels in English, Spanish or French for local language needs. Scan the QR code or visit the Bussmann division website at Eaton.com/bussmannseries.



4.1.7 Tables

4.1.7.1 Fault currents available from transformers

Table 4.1.7.1 includes values based on actual field nameplate data or from utility transformer worst case impedance.

Voltage and phase	kVA	Full load amps	% impedance [†] (nameplate)	Fault current amps ^{††}
120/240 single-phase*	25	104	1.50	12,175
	37.5	156	1.50	18,018
	50	208	1.50	23,706
	75	313	1.50	34,639
	100	417	1.60	42,472
	167	696	1.60	66,644
120/208 three-phase**	45	125	1.00	13,879
	75	208	1.00	23,132
	112.5	312	1.11	31,259
	150	416	1.07	43,237
	225	625	1.12	61,960
	300	833	1.11	83,357
	500	1388	1.24	124,364
	750	2082	3.50	66,091
	1000	2776	3.50	88,121
	1500	4164	3.50	132,181
	2000	5552	4.00	154,211
	2500	6940	4.00	192,764
277/480 three-phase**	75	90	1.00	10,035
	112.5	135	1.00	15,053
	150	181	1.20	16,726
	225	271	1.20	25,088
	300	361	1.20	33,451
	500	602	1.30	51,463
	750	903	3.50	28,672
	1000	1204	3.50	38,230
	1500	1806	3.50	57,345
	2000	2408	4.00	66,902
	2500	3011	4.00	83,628

Table 4.1.7.1.a

* Single-phase values are L-N at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 kVA primary, zero feet from transformer terminals, 1.2 %X and 1.5 %R multipliers for L-N vs. L-L reactance and resistance values, and transformer X/R ratio = 3.

**Three-phase fault currents based on "infinite" primary.

† 25 kVA or greater UL Listed transformers have a ± 10% impedance tolerance. Fault current shown in Table 4.1.7.1.a reflect -10% condition. Transformers constructed to ANSI standards have a ± 7.5% impedance tolerance (two-winding construction)

††System voltage fluctuations will affect the available fault current. For example, a 10% increase in system voltage will result in a 10% greater available fault current than as shown in Table 4.1.7.1.a.

4.1.7.2 “M” multiplier

The “M” multiplier is used in the point-to-point calculations. The basic equation used to derive the values in this table is:

$$M = \frac{1}{1+f}$$

The “f” value is based upon a calculation as described in Step 4 of the point-to-point method for calculating fault currents.

f	M	f	M	f	M
0.01	0.99	0.50	0.67	7.00	0.13
0.02	0.98	0.60	0.63	8.00	0.11
0.03	0.97	0.70	0.59	9.00	0.10
0.04	0.96	0.80	0.55	10.00	0.09
0.05	0.95	0.90	0.53	15.00	0.06
0.06	0.94	1.00	0.50	20.00	0.05
0.07	0.93	1.20	0.45	30.00	0.03
0.08	0.93	1.50	0.40	40.00	0.02
0.09	0.92	1.75	0.36	50.00	0.02
0.10	0.91	2.00	0.33	60.00	0.02
0.15	0.87	2.50	0.29	70.00	0.01
0.20	0.83	3.00	0.25	80.00	0.01
0.25	0.80	3.50	0.22	90.00	0.01
0.30	0.77	4.00	0.20	100.00	0.01
0.35	0.74	5.00	0.17	—	—
0.40	0.71	6.00	0.14	—	—

Table 4.1.7.2 “M” multiplier

4.1.7.3 Transformer single-phase impedance data

Table 4.1.7.3 is reprinted from IEEE Std. 242-1986 (R1991), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Copyright 1986 by the Institute of Electrical and Electronics Engineers, Inc. with the permission of the IEEE Standards Department.

25 kVA and greater UL Listed transformers have a ± 10% tolerance on their impedance nameplate.

kVA 1 Ø	Suggested X/R ratio for calculation	Normal range of percent impedance*	Impedance multipliers — line-neutral faults**	
			for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

Table 4.1.7.3

* National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

**Based on winding rated current (one-half nameplate kVA divided by secondary line-to-line voltage).

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4.1.7.4. Impedance data for single-phase and three-phase transformers supplement

The data included in Table 4.1.7.4 provides actual transformer nameplate ratings taken from field installations. 25 kVA and greater UL Listed transformers have a ± 10% tolerance on their nameplate impedance.

kVA		%Z	Suggested X/R ratio for calculation
1 Ø	3 Ø		
10	—	1.2	1.1
15	—	1.3	1.1
—	75	1.11	1.5
—	150	1.07	1.5
—	225	1.12	1.5
—	300	1.11	1.5
333	—	1.9	4.7
—	500	1.24	1.5
500	—	2.1	5.5

Table 4.1.7.4

4.1.7.5 Various fault current types as a percent of three-phase bolted faults (typical)

This table provides some general information on various fault current types as a percentage of three-phase bolted fault currents. These are general rules of thumb that should not replace actual calculations that can be provided by software applications.

Fault type	Percentage
Three-phase bolted	100%
Line-to-line bolted	87%
Line-to-ground bolted	25-125%* (Use 100% near transformer, 50% otherwise)
Line-to-neutral bolted	25-125% (Use 100% near transformer, 50% otherwise)
Three-phase arcing	89% maximum
Line-to-line arcing	74% maximum
Line-to-ground arcing minimum	38% minimum

Table 4.1.7.5

* Typically much lower, but can actually exceed the three-phase bolted fault if it is near the transformer terminals. Will normally be between 25% to 125% of three phase bolted fault value.

4.1.7.6 “C” values for conductors

Table 4.1.7.6 data is used as part of the point-to-point fault current calculation when determining the “f” factor as part of Step 4.

AWG or kcmil	Three single conductors						Three-conductor cable					
	Steel conduit			Non-magnetic conduit			Steel conduit			Non-magnetic conduit		
	600 V	5 kV	15 kV	600 V	5 kV	15 kV	600 V	5 kV	15 kV	600 V	5 kV	15 kV
Copper												
14	389	—	—	389	—	—	389	—	—	389	—	—
12	617	—	—	617	—	—	617	—	—	617	—	—
10	981	—	—	982	—	—	982	—	—	982	—	—
8	1557	1551	—	1559	1555	—	1559	1557	—	1560	1558	—
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053
2/0	10,755	10,062	9390	11,424	10,878	10,319	11,245	11,045	10,500	11,703	11,529	11,053
3/0	12,844	11,804	11,022	13,923	13,048	12,360	13,656	13,333	12,613	14,410	14,119	13,462
4/0	15,082	13,606	12,543	16,673	15,351	14,347	16,392	15,890	14,813	17,483	17,020	16,013
250	16,483	14,925	13,644	18,594	17,121	15,866	18,311	17,851	16,466	19,779	19,352	18,001
300	18,177	16,293	14,769	20,868	18,975	17,409	20,617	20,052	18,319	22,525	21,938	20,163
350	19,704	17,385	15,678	22,737	20,526	18,672	22,646	21,914	19,821	24,904	24,126	21,982
400	20,566	18,235	16,366	24,297	21,786	19,731	24,253	23,372	21,042	26,916	26,044	23,518
500	22,185	19,172	17,492	26,706	23,277	21,330	26,980	25,449	23,126	30,096	28,712	25,916
600	22,965	20,567	17,962	28,033	25,204	22,097	28,752	27,975	24,897	32,154	31,258	27,766
750	24,137	21,387	18,889	29,735	26,453	23,408	31,051	30,024	26,933	34,605	33,315	29,735
1000	25,278	22,539	19,923	31,491	28,083	24,887	33,864	32,689	29,320	37,197	35,749	31,959
Aluminum												
14	237	—	—	237	—	—	237	—	—	237	—	—
12	376	—	—	376	—	—	376	—	—	376	—	—
10	599	—	—	599	—	—	599	—	—	599	—	—
8	951	950	—	952	951	—	952	951	—	952	952	—
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977
4/0	10,741	10,167	9700	11,174	10,749	10,387	11,185	11,022	10,642	11,409	11,277	10,969
250	12,122	11,460	10,849	12,862	12,343	11,847	12,797	12,636	12,115	13,236	13,106	12,661
300	13,910	13,009	12,193	14,923	14,183	13,492	14,917	14,698	13,973	15,495	15,300	14,659
350	15,484	14,280	13,288	16,813	15,858	14,955	16,795	16,490	15,541	17,635	17,352	16,501
400	16,671	15,355	14,188	18,506	17,321	16,234	18,462	18,064	16,921	19,588	19,244	18,154
500	18,756	16,828	15,657	21,391	19,503	18,315	21,395	20,607	19,314	23,018	22,381	20,978
600	20,093	18,428	16,484	23,451	21,718	19,635	23,633	23,196	21,349	25,708	25,244	23,295
750	21,766	19,685	17,686	25,976	23,702	21,437	26,432	25,790	23,750	29,036	28,262	25,976
1000	23,478	21,235	19,006	28,779	26,109	23,482	29,865	29,049	26,608	32,938	31,920	29,135

Table 4.1.7.6.a “C” values for conductors.

Note: These values are equal to one over the impedance per foot, and based upon resistance and reactance values found in IEEE Std. 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commercial Buildings & IEEE Std. 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 kV & 15 kV are from the Gray Book only (Values for 14-10 AWG at 5 kV and 14-8 AWG at 15 kV are not available and values for 3 AWG have been approximated).

4.1.7.7 “C” values for busway

Table 4.1.7.7 data is used as part of the point-to-point fault current calculation when determining the “f” factor as part of Step 4.

Ampacity	Busway				
	Plug-in	Feeder		High impedance	
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Table 4.1.7.7.a “C” values for busway.

Note: These values are based on a survey of industry and equal to one over the impedance per foot for busway impedance. Busway manufacture information should be consulted for specific applications.

4.2 Selective coordination

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4.2.1 Overview

Selective coordination is critical for electrical distribution system reliability. A reliable system is not only important for life safety, it's important from a business perspective as nothing will stop all activity, paralyze production, inconvenience and disconcert people more than a major power failure.

Selectively coordinated overcurrent protective devices address localizing faulted conditions on the power distribution system and is quite often a reliability design goal. In addition, the NEC mandates selectively coordinated OCPDs for circuits that supply power to vital loads in specific building system applications.

A properly engineered and installed system that's selectively coordinated will allow only the nearest upstream OCPD to open for the full range of overcurrents (both overloads and all fault types), leaving the remainder of the system undisturbed and preserving continuity of service. Figure 4.2.1.a illustrates the difference between a selectively coordinated system and one that is not. Isolating the circuit's faulted portion is important for overall system reliability.

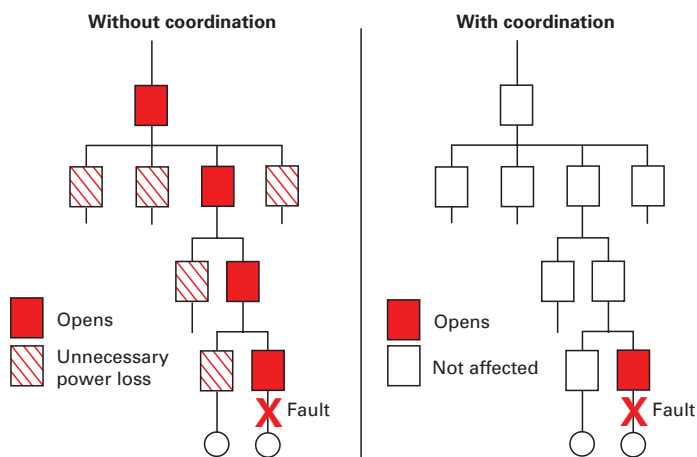


Figure 4.2.1.a

Selective coordination isolates the circuit's faulted portion and only the faulted portion. The OCPD closest to the fault is the only device to open to limit the impact on the balance of the system. To achieve selective coordination, the selection and installation of OCPDs and their ratings or settings are important. This must be addressed in any project's design phase. Once switchboards, distribution panels, motor control centers, lighting panelboards and OCPDs are selected and installed, retroactively “fixing” a system that does not selectively coordinated can be expensive.

The following sections explain how to evaluate whether OCPDs provide selective coordination for the full range of overcurrents.



4.2.2 Coordination analysis

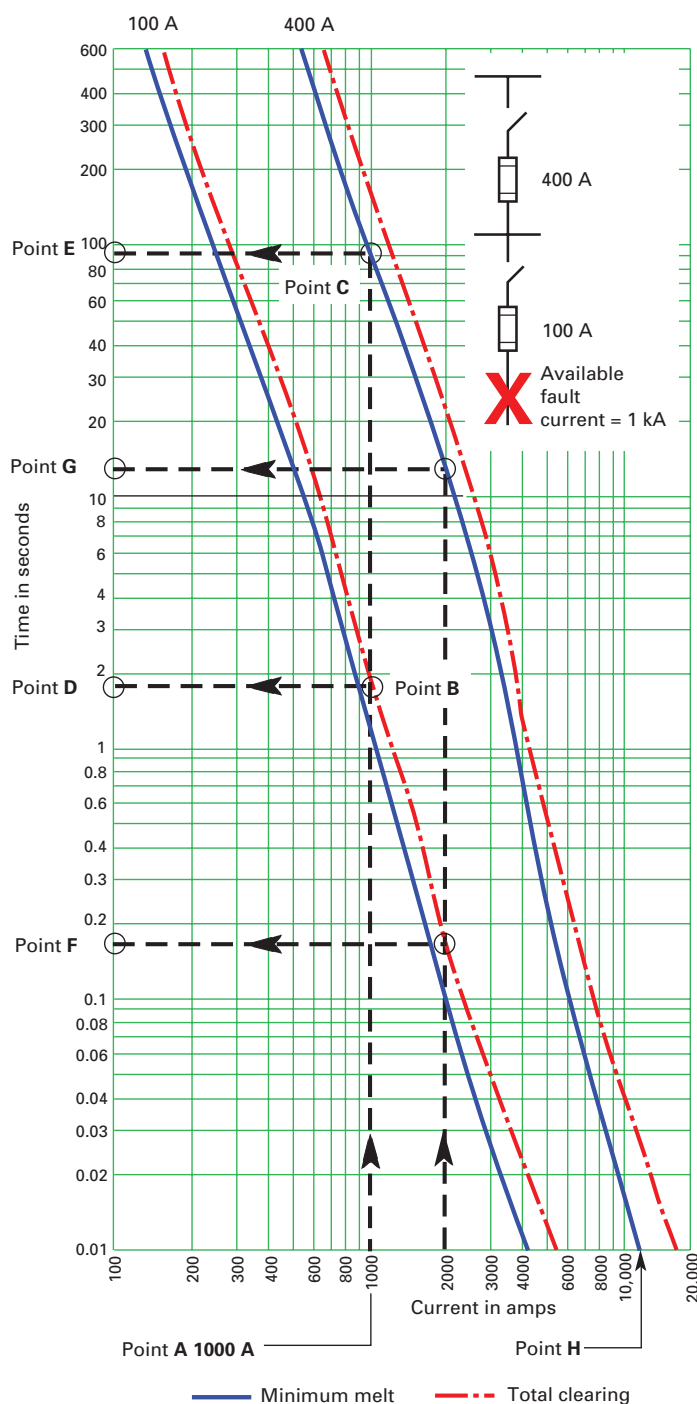


Figure 4.2.2.a

Figure 4.2.2.a illustrates the time-current characteristic curves for a 400 A and 100 A time-delay, dual-element fuses in series, as depicted in the one-line diagram. The graph's horizontal axis represents the RMS symmetrical current in amps. The vertical axis represents the time, in seconds. Each fuse is represented by a tolerance band which is the space between the minimum melt characteristic (solid line) and the total clear characteristics (hash line). This band represents the fuse's tolerance under specific test conditions. For a given overcurrent, a specific fuse, under the same circumstances, will open at a time within the fuse's time-current tolerance band.

Fuses have an inverse time-current characteristic. This means the greater the overcurrent, the faster they interrupt. Look at the 100 A fuse curve: for a 200 A overcurrent, the fuse will clear the overcurrent in approximately 200 seconds, and for an 2000 A overcurrent, the fuse will clear the overcurrent in approximately 0.15 second.

In some cases, it's possible to assess coordination between two or more fuses through comparing their time-current curves. This method is limited to only the overcurrent range up to the point at which the upstream fuse crosses 0.01 second. For example: assume an 1000 A RMS symmetrical overcurrent on the loadside of the 100 A fuse. To determine the time it would take this overcurrent to open the two fuses:

- Find 1000 A on the horizontal axis (Point A)
- Follow the dotted line vertically to the intersection of the 100 A fuse's total clear curve (Point B) and the 400 A fuse's minimum melt curve (Point C).
- Then, horizontally from both intersection points, follow the dotted lines to Points D and E.

At 1.75 seconds, Point D represents the maximum time the 100 A fuse will take to open the 1000 A overcurrent. At 90 seconds, Point E represents the minimum time at which the 400 A fuse would open this overcurrent. These two fuses are coordinated for the 1000 A overcurrent.

For overcurrents up to approximately 11,000 A (Point H), since no curve overlapping exist and the current is less than where the upstream fuse crosses 0.01 second, it can be determined that the two fuses are selectively coordinated. The 100 A fuse will open before the 400 A fuse can melt for all currents up to approximately 11,000 A. When currents exceed 11,000 A, selective coordination cannot be determined by the time-current curves. For currents in this curve region, the fuse selectivity ratio tables must be used. Eaton's Bussmann division publishes fuse selectivity ratios that make it simple to assess whether fuses selectively coordinate. Using the selectivity ratios makes plotting fuse TCC curves unnecessary.

4.2.3 Selective coordination tools

There are many resources available to the qualified person who must specify the correct OCPDs to achieve selective coordination. Systems that leverage the fuse, circuit breaker or both technologies can achieve selective coordination for the full range of overcurrents, but attention to proper procedures and resources is important.

The following tools are available to assist in determining selective coordination:

4.2.3.1 Systems analysis software applications

Computer programs allow the designer to select OCPD time-current curves published by manufacturers and overlay, on one graph, multiple curves of selected OCPDs in a particular circuit. These curves provide the relationship of devices and show how each will respond in relation to each other for any given current value. The qualified individual must review the plotted curves in relation to the available fault current to determine whether or not selective coordination is achieved.

4.2.3.2 Manually creating a TCC curve

When computer software programs are not available, it's possible for the qualified individual to manually create TCC curves and analyze one or more OCPDs in the system. Time-current curve overlays (from manufacturer published data) can be hand traced onto log-log paper. The qualified individual must review the plotted curves in relation to the available fault current to determine whether or not selective coordination is achieved.

4.2.4 Fuse selective coordination

Selective coordination for fused systems is simple when the fuses are specified per the selective coordination amp ratio tables. When selectively coordinating a fused system, the available fault current is only used to determine proper interrupting and short-circuit current ratings — as fuse tables only stipulate upstream/downstream amp ratios that apply equally to all available overcurrents. Because fuses have such a high interrupting capability, calculating available fault currents throughout the distribution system for selective coordination purposes is often not necessary. The fuse amp ratio table established and discussed in Section 4.2.5 is an important tool to understand before conducting a fused system selective coordination analysis.

4.2.4.1 Fuse example 1

The following fused system illustrates how simple it is to achieve selective coordination. Review the fused system one-line diagram in Figure 4.2.4.1.a. All fuses shown are Low-Peak fuses. The selectivity amp ratio table provides the minimum amp rating ratio that must exist between a lineside and loadside fuse in order to achieve selective coordination. If the entire electrical system maintains these minimum fuse amp rating ratios for each circuit path, the entire electrical system will be selectively coordinated for all overcurrents (note there is no need to plot time-current curves). It's important to understand that the fuse amp ratio tables apply only to that manufacturer's specific fuses.

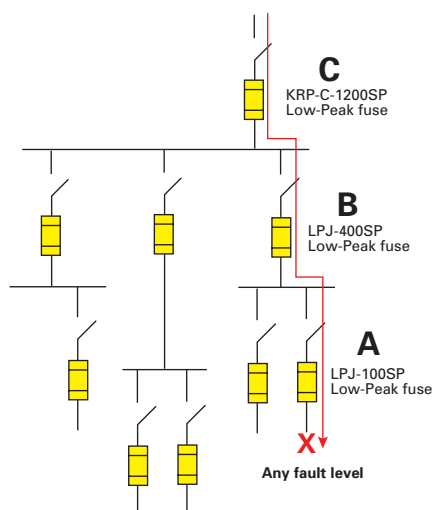


Figure 4.2.4.1.a

Always begin closest to the load and check device pairs for selectivity. A review of the system shown in Figure 4.2.4.1.a includes the following steps:

Point A: LPJ-100SP fuse downstream of LPJ-400SP fuse

In this circuit path, the amp rating ratio for these fuses is 400:100, or a 4:1 ratio. Checking the selectivity amp ratio table, the intersection of lineside LPJ (left column) to loadside LPJ (top row), yields a minimum 2:1 ratio. This indicates there is selective coordination for these two fuses for any overcurrent up to 200 kA. For any overcurrent on the LPJ-100SP fuse's loadside, only the LPJ-100SP fuse opens. The LPJ-400SP fuse remains in operation as well as all other fuses in the system.

Point B: LPJ-400SP fuse downstream of KRP-C-1200SP fuse

Use the same steps as in the previous paragraph. The amp rating ratio for the two fuses in this circuit path is 1200:400, or a 3:1 ratio. The selectivity amp ratio table shows that the amp ratio must be maintained at 2:1, or more, to achieve selective coordination for these specific fuses. Since these fuses have a 3:1 ratio, and a minimum 2:1 is all that's needed, these two fuses are selectively coordinated for any overcurrent up to 200 kA. The result is this entire circuit path is selectively coordinated for all overcurrents up to 200 kA as shown in Figure 4.2.4.1.b.

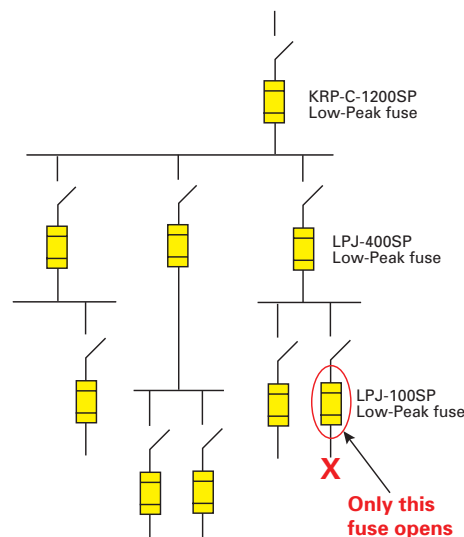
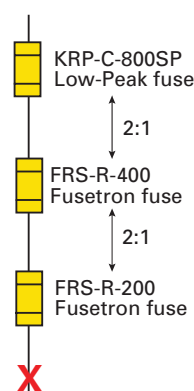


Figure 4.2.4.1.b

4.2.4.2 Fuse example 2

Figure 4.2.4.2.a is an example where the selected fuses do not initially meet the minimums in the selectivity amp ratio table. This system does not selectively coordinate. This example will work through resolving this situation without changing fuse sizes which would impact equipment and conductor sizes.



Overloads or faults of any level up to 200 kA

Selectivity amp ratios

Lineside fuses	Loadside fuses		
	KRP-C-SP	FRS-R	LPS-RK-SP
KRP-C-SP	2:1	4:1	2:1
FRS-R	—	2:1	1.5:1
LPS-RK-SP	—	8:1	2:1

Figure 4.2.4.2.a

To address the lack of selective coordination, each upstream/downstream fuse pair must be evaluated for using alternative fuses. Figure 4.2.4.2.b shows an analysis for obtaining selective coordination by specifying other fuse types while keeping each fuse's amp rating the same. The original non-selectively coordinated system is one-line diagram "A" in Figure 4.2.4.2.b.

The following steps are necessary to evaluate this system. Always start at the fuse furthest from the source and work back towards the source as follows:

FRS-R-200 fuse downstream of FRS-R-400 fuse

The FRS-R-200 fuse selectively coordinates with the FRS-R-400 fuse since they have a 2:1 amp ratio and the selectivity amp ratio table for FRS-R to FRS-R fuses is a 2:1 minimum.

FRS-R-400 fuse downstream of KRP-C-800SP fuse

As applied, these two fuses have a 2:1 amp rating ratio. The selectivity amp ratio table requires at least a 4:1 ratio for selectivity. To address this, the Bussmann series Fusetron FRS-R-400 fuse can be substituted with another that fits the same block and has similar, if not the same, overload characteristics. The LPS-RK-400SP fuses can be applied because they can be sized for loads in the same manner as the FRS-R-400 fuses, while offering better current-limiting performance for a better ratio with the upstream KRP-C-800SP fuse. This simple substitution ensures a minimum 2:1 ratio can be maintained for selective coordination. This is shown as “B” in Figure 4.2.4.2.b. Because the FRS-R-400 was substituted with a different fuse type that’s already been evaluated with the downstream FRS-R-200 fuse, it necessary to start the evaluation again from the most downstream point in the system to ensure selectivity with the downstream fuse was not lost.

FRS-R-200 fuse downstream of LPS-RK-400SP fuse

Because the FRS-R-400 fuse was changed to the LPS-RK-400SP fuse, evaluating the downstream FRS-R-200 fuse is necessary to ensure selectivity is maintained. Upon review, the FRS-R-200 and LPS-RK-400SP fuses do not meet the minimum selectivity 8:1 ratio for these fuses. The FRS-R-200 must be substituted to maintain the existing 2:1 amp rating ratio needed for selective coordination. The FRS-R-200 fuse is changed to an LPS-RK-200SP fuse to maintain the 2:1 ratio and achieve selective coordination (the minimum ratio is 2:1 for pairs of Low-Peak fuses). This is shown as “C” in Figure 4.2.4.2.b and the entire system is now selectively coordinated.

LPS-RK-400SP fuse downstream of KRP-C-800SP fuse

The LPS-RK-400SP fuse selectively coordinates with the KRP-C-800SP fuses since it has a 2:1 ratio and the selectivity amp ratio table minimum is 2:1 between LPS-RK-SP and KRP-C-SP fuses.

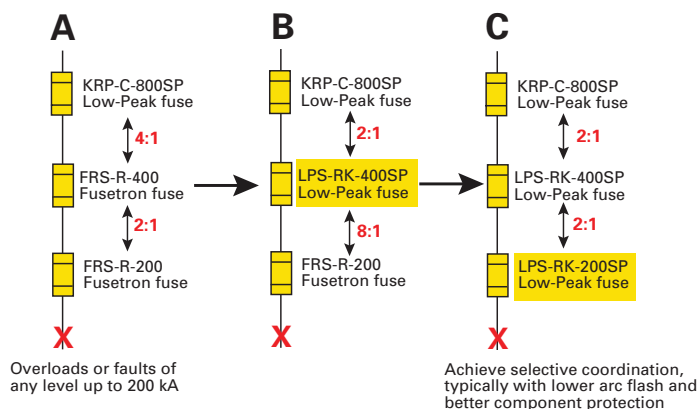


Figure 4.2.4.2.b

4.2.4.3. Fusible solutions

Performing a fused system selective coordination analysis is relatively simple. However, there are many fuse types with their associated ratios.

For 600 V or less electrical systems, the following Low-Peak fuses are recommended for applications from 1/10 to 6000 A, (note the LPN-RK-SP is rated 250 V or less, but all other Low-Peak fuses are rated 600 V or less and can be used on any system up to 600 V). All Low-Peak fuses have 2:1 selectivity amp ratio with any other Low-Peak fuse in the system.

Fusible panelboards

The Bussmann series Quik-Spec™ Coordination Panelboard (QSCP) provides a fusible branch panelboard solution, making it simple and cost effective to selectively coordinate lighting and other branch circuits with upstream Bussmann series fuses.

This QSCP is available in Main Lug Only (MLO), as well as fused or non-fused main disconnect configurations with a choice of 18, 30 and 42 branch positions in NEMA 1 or 3R enclosures to easily meet branch or service panel installation needs. This fused panelboard uses the Bussmann series finger-safe CUBEFuse (1 to 100 A, UL Listed, Class CF, current-limiting, time-delay or fast-acting versions) for the branch circuit OCPDs as an integral part of the innovative, UL 98, horsepower rated Compact Circuit Protector Base (CCPB) disconnect switch that’s available in 1-, 2- and 3-poles.



Figure 4.2.4.3.a

The fused main disconnect options are either 100 through 400 A Class J Bussmann series Low-Peak LPJ-SP fuses, or 30, 60 or 100 A CUBEFuse. The panel is rated 600 Vac/125 Vdc and provides high SCCRs up to 200 kA. The footprint is the same size as traditional circuit breaker panelboards: 20" W x 5-3/4" D x 33" to 69" H (height depends on configuration and number of branch circuit positions).



Figure 4.2.4.3.b

Two key features of this panelboard is the fuse/CCPB disconnect switch interlock that prevents fuse removal in the ON position along with an amp rating rejection feature that coincides with standard branch circuit amp ratings to help prevent overfusing.

The Low-Peak CUBEFuse and Low-Peak LPJ-SP fuses are easy to selectively coordinate with each other and any other Low-Peak fuses used in upstream power distribution panelboards and switchboards. Merely maintain at least a 2:1 fuse amp rating ratio between upstream and downstream Low-Peak fuses and selective coordination is ensured up to 200 kA.

For more information on the QSCP solution visit Eaton.com/bussmannseries for data sheet no. 1160, application notes and more.

4.2.4.4. Summary — fuse selective coordination

With modern current-limiting fuses, selective coordination can be achieved by adhering to published selectivity amp rating ratios. There is no need to plot time-current curves nor calculate the available fault currents (for systems up to 200 kA). Simply maintain the minimum amp rating ratios provided in the selectivity amp ratio table and the system will be selectively coordinated. Not only is this simple method quick and easy, but selectivity is retained regardless if the available fault current increases due to a transformer change or for any other reason. To maintain a selectively coordinated system throughout its life, an electrician should always replace an opened fuse with one from the same manufacturer matching the type and amp rating (i.e., same catalog number). The ratios shown in the selectivity amp ratio table are only valid for the Bussmann series fuses shown. Do not mix Bussmann series fuses with another manufacturer’s fuses.

If a design does not initially provide selective coordination, investigate other Bussmann series fuse types that may have different selectivity ratios. If another fuse type is evaluated, the application sizing guidelines for that fuse should also be reviewed. If selective coordination still cannot be achieved, then a design change may be necessary.

4.2.5 Fuse selectivity ratio tables

For 600 V or less systems that leverage the fuse for overcurrent protection, they can use published selectivity ratio tables. The published ratios apply for all overcurrent conditions (overloads and faults). Using the fuse selectivity ratio method is easy and quick. Knowledge of fault currents for fuse selective coordination applications (provided the fuse interrupting ratings are not exceeded) is not required to properly select and apply fuses when using these ratio tables.

These selectivity ratios in Figure 4.2.5.a are for all overcurrent levels up to the fuse interrupting rating, or 200 kA whichever is lower.

Maintaining the specified current rating ratio for each given fuse as per the table below ensures the downstream fuse will always open before the upstream fuse for all currents up to the fuse's interrupting rating. Nor is there a need to calculate the available fault current throughout the system, provided they are always less than the fuses' interrupting ratings, typically 200 kA.

Notice the Low-Peak fuses (highlighted in yellow — LPJ-SP, LPN-RK-SP, LPS-RK-SP, and KRP-C-SP) as well as the CUBEFuse (TCF) — only require a 2:1 amp rating ratio to achieve selective coordination and simplifies the design process.

Circuit					Downstream / loadside fuse												
Amp rating range					601-6000 A	601-4000 A	1-100 A	0-600 A			601-6000 A	0-600 A	0-1200 A	0-600 A	0-60 A	0-30 A	
	Fuse type				Time-delay	Time-delay	Time-delay	Dual-element, time-delay			Fast-acting	Fast-acting	Fast-acting	Fast-acting	Time-delay		
		Trade name (fuse class)				Low-Peak (L)	Limitron (L)	CUBEFuse (CF ²)	Low-Peak (J)	Low-Peak (RK1)	Fusetron (RK5)	Limitron (L)	Limitron (RK1)	Limitron (T)	Limitron (J)	SC (G)	(CC)
			Bussmann fuse symbol	KRP-C-SP	KLU	TCF	LPJ-SP	LPN-RK-SP LPS-RK-SP	FRN-R FRS-R	KTU	KTN-R KTS-R	JJN JJS	JKS	SC	SC	LP-CC FNQ-R KTK-R	
Upstream / lineside fuse	601 to 6000 A	Time-delay	Low-Peak (L)	KRP-C-SP	2:1	2.5:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	2:1	2:1	
	601 to 4000 A	Time-delay	Limitron (L)	KLU	2:1	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	2:1	2:1	
	0 to 600 A	Dual-element	Low-Peak (RK1)	LPN-RK-SP LPS-RK-SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1	
	0 to 600 A	Dual-element	Low-Peak (J)	LPJ-SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1	
	0 to 100 A	Dual-element	CUBEFuse (CF ²)	TCF	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1	
	0 to 600 A	Dual-element	Fusetron (RK5)	FRN-R FRS-R	—	—	1.5:1	1.5:1	1.5:1	2:1	—	1.5:1	1.5:1	1.5:1	1.5:1	2:1	
	601 to 6000 A	Fast-acting	Limitron (L)	KTU	2:1	2.5:1	3:1	3:1	3:1	6:1	2:1	2:1	2:1	2:1	2:1	2:1	
	0 to 600 A	Fast-acting	Limitron (RK1)	KTN-R KTS-R	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—	
	0 to 1200 A	Fast-acting	Limitron (T)	JJN JJS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—	
	0 to 600 A	Fast-acting	Limitron (J)	JKS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—	
	0 to 60 A	Time-delay	SC (G)	SC	—	—	3:1	3:1	3:1	4:1	—	2:1	2:1	2:1	2:1	—	

Figure 4.2.5.a This fuse selectivity ratio table identifies the fuse amp rating ratios that ensure selective coordination.

General notes: Ratios given in this table apply to only Bussmann series fuses. When fuses are within the same case size, consult factory.

- Where applicable, ratios are valid for indicating and non-indicating versions of the same fuse. At some values of fault current, specified ratios may be lowered to permit closer fuse sizing. Consult factory.
- Time-delay Class CF TCF or TCF_RN CUBEFuse are 1 to 100 A Class J performance; dimensions and construction are a unique, finger-safe design.

How fuse ratio tables are used

The fuse selective coordination ratio tables make life for the designer easy by taking the burden off of the shoulders of the qualified individual. To read the fuse selectivity table shown in this section, one must understand its content.

The top rows contain loadside fuse information and the left columns contain lineside fuse information. The intersection for any given row and column establishes that fuse pair's amp rating ratio. These selectivity ratios are for all overcurrents up to the fuse interrupting ratings or 200 kA, whichever is lower. Selective coordination is ensured for the fuse pairs selected per this table.

The design professional should specify fuses that adhere to the selectivity table shown. The design professional does not need to plot time-current curves or perform a fault current analysis — provided the available fault current is less than 200 kA or less than the interrupting rating of the fuses. All that's necessary is to make sure the fuse types and amp rating ratios for the mains, feeders and branch circuits meet or exceed the applicable selectivity amp ratios. If the ratios are not satisfied, then the designer should investigate another fuse type or design change.

The role of the installer is to install the proper fuse type and amp rating with a full understanding that the manufacture and model/catalog numbers are important to ensure selectivity is maintained. It is not possible to mix manufacturers as the tables are based on the specific manufacturer's product.

How fuse ratio tables are made

The fuse selectivity ratio tables result from testing fuse pairs whose performance is dictated by the basic physics of current limitation. The principle requirements for fuse selective coordination is that the total clearing energy of the loadside fuse is less than the melting energy of lineside fuse.

Figure 4.2.5.b demonstrates the basic fuse selective coordination principles when the available fault current is greater than the current value where the upstream fuse curve crosses 0.01 second.

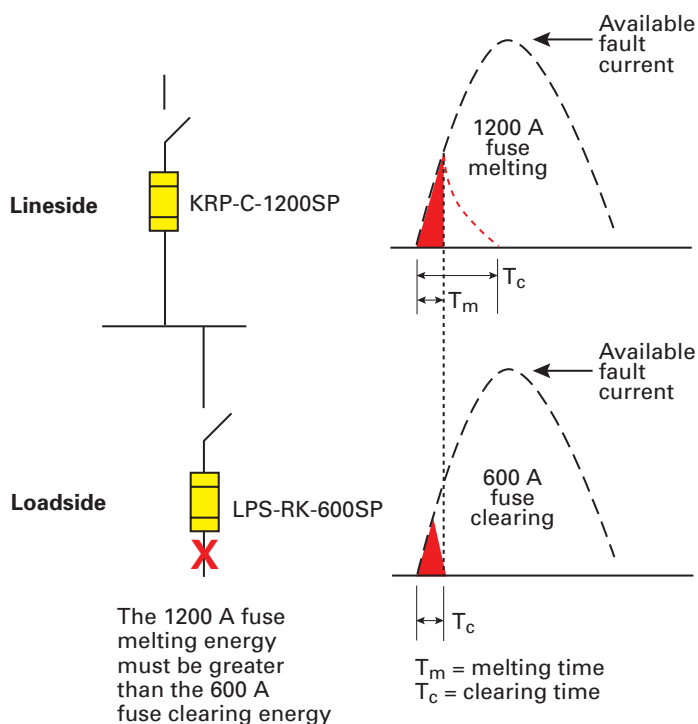


Figure 4.2.5.b

For the high fault current levels that both fuses see, the downstream fuse clearing time, as it relates to the upstream fuse, is critical in determining if the downstream fuse will open and the upstream fuse will not. Current limitation principles can help describe the physics behind the selective coordination ratio tables.

The available fault current that could flow is depicted by the dotted line of Figure 4.2.5.b. The current-limiting nature of the current-limiting fuse closest to the fault is such that it must clear the fault before the upstream fuse that sees the same current level does. Note that T_m in Figure 4.2.5.b is the fuse's melting time and T_c is the fuse's total clearing time. The area under the current curves over a time period indicates the energy let-through. The amount of thermal energy delivered is directly proportional to the square of the current multiplied by clearing time (I^2t). The amount of energy being released in the circuit while the fuse element is melting (or vaporizing) is called the melting energy, and energy released during the entire interrupting process (melting plus arcing) is called total clearing. To achieve a selectively coordinated system the downstream fuse's T_c and clearing I^2t must be less than the upstream fuse's T_m and melting I^2t .

The fuse selectivity ratio tables result from the physics just discussed and have been tested in a lab for the fuse pairs in the tables. Adhering to fuse selectivity ratios makes it easy to design and install fusible systems that are selectively coordinated.

4.2.6 Circuit breaker selective coordination

The first step in the circuit breaker selective coordination process is calculating available fault currents. The next step is plotting and overlaying the TCC curves for the circuit breaker pairs being evaluated. When it comes to selective coordination, circuit breaker performance depends upon the available fault current that passes through each device. Circuit breaker pairs must be analyzed to determine if the downstream device will open and the upstream device remain closed for all currents up to the fault current that both devices will see. Before attempting a selective coordination analysis for a circuit breaker system, it's important to review circuit breaker basics (as covered in breaker basics in Section 3.2), is another important section to review and understand as circuit breaker selective coordination principles are reinforced when one understands how circuit breakers work - especially in relation to how they respond to overcurrents.

The ability to achieve selective coordination with circuit breakers depends upon the amount of fault current and the selected circuit breaker types. The upstream circuit breaker's ability to hold its contacts closed long enough to let the downstream device clear the fault current is the basic premise. This performance depends upon the amount of current flowing through both circuit breakers, and the relationship of their trip curves at that fault current level.

Circuit breakers are not like fuses. Applying circuit breakers to achieve selective coordination is not, and cannot be, based upon an amp ratio of their handle ratings. These devices are current dependent and react to the fault current that passes through them. The flexibility that some circuit breakers provide through adjustable pickup values and delays requires that TCC curves be plotted to ensure selectivity in their overload regions.

4.2.6.1. Circuit breaker example 1

Figure 4.2.6.1.a shows three circuit breakers in series. This figure is a TCC curve plot of a 30 A BAB thermal magnetic molded case circuit breaker downstream from a thermal magnetic F Frame 150 A FD circuit breaker which, in turn, is downstream from an N Frame 800 A ND molded case circuit breaker with an electronic trip unit. Circuit breaker pairs are reviewed for selectivity beginning with the circuit breaker that's furthest downstream from the source.

BAB 30 A downstream from FD 150 A

Per the TCC curve in Figure 4.2.6.1.a, the BAB 30 downstream from the FD 200 selectively coordinates to 750 A, which is the leading edge of the FD 150 A circuit breaker's instantaneous pickup. Based on the TCC curves, the selectivity threshold is 750 A. Any current greater than 750 A passing through this circuit breaker pair will open both. Leveraging the circuit breaker-to-circuit breaker Table 4.2.6.5.a, this same circuit breaker pair will selectively coordinate up to 1500 A. Based on the tested pair information provided as part of the circuit breaker selective coordination tables, the selectivity threshold is 1500 A. When these two devices see currents greater than 1500 A, they will both open. These devices do not selectively coordinate when the available fault current exceeds 1500 A.

FD 150 A downstream from ND 800 A

Per the TCC curve in Figure 4.2.6.1.a, the FD 150 A downstream from the ND 800 A selectively coordinates up to 11,900 A, which is the leading edge of the ND 800 A circuit breaker's instantaneous pickup. Based on the TCC curves, any current greater than 11,900 A passing through this pair of circuit breakers will open both. Leveraging the circuit breaker-to-circuit breaker tables, this same circuit breaker pair will selectively coordinate up to 30 kA. This means that, based on the tested pair information provided as part of the circuit breaker selective coordination tables, the selectivity threshold is 30 kA. When these two devices see currents greater than 30 kA, they will both open. These devices do not selectively coordinate when the available fault current exceeds 30 kA.

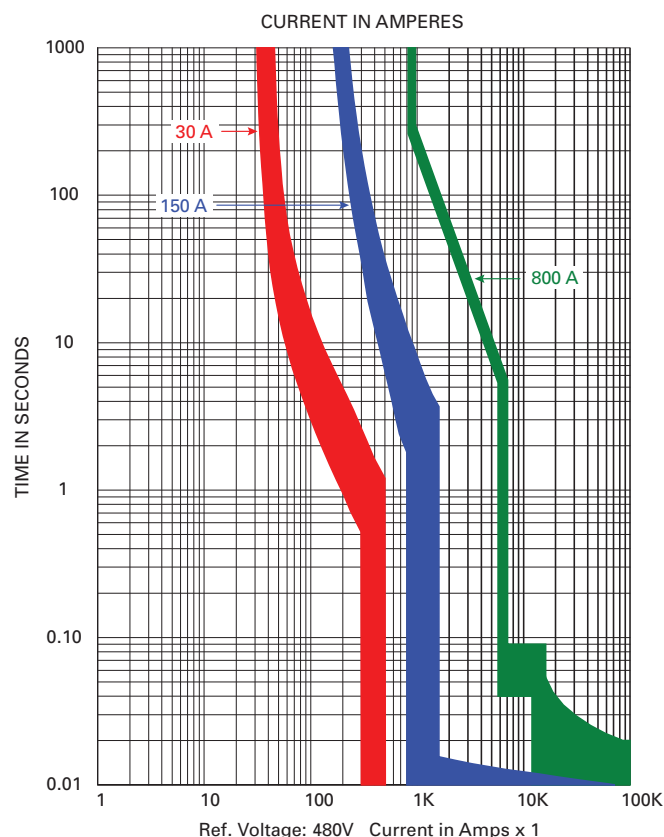


Figure 4.2.6.1.a Simply plotting time current characteristic curves in a circuit breaker system is not enough to ensure selective coordination. The fault current must be known and compared to the upstream circuit breaker's instantaneous pick-up. For values beyond this point, the circuit breaker-to-circuit breaker tables must be consulted. In the case of the 30 A and 150 A breakers, the level of selective coordination is increased from 750 A to 1500 A by using the tested values. Beyond this point, both devices will open; in which case the 150 A breaker rating would need to increase to accommodate higher fault currents.

4.2.6.2 Circuit breaker example 2

For the same three circuit breakers in series discussed in example 1, 4.2.6.1.a, an evaluation can be made when the available fault current that all three would see is 8500 A. In this case, the BAB 30 A must selectively coordinate with the FD 150 circuit breaker for all currents up to 8500 A. Based on the trip curves shown in Figure 4.2.6.1.a, 8500 A is greater than the instantaneous pickup of both the BAB 30 and the FD 150 circuit breakers, but less than the ND 800 A. Based on information provided by the TCC curves, it would appear both the BAB 30 A and FD 150 A circuit breakers would not selectively coordinate at this high fault current level. Leveraging the circuit breaker-to-circuit breaker curves, the BAB 30 A would definitely not selectively coordinate with the FD 150, as they will both open for all currents greater than 1500 A.

To fix this, the FD 150 A circuit breaker could be increased to an LD 300 A circuit breaker, but system changes would have to occur as an LD 300 A would not be able to provide the same conductor protection level as the FD 150 A. Conductors would have to increase in size to ensure NEC requirements for protection are still satisfied. Should the LD 300 A be chosen, the feeder circuit conductors would have to increase from what's adequate for 150 A to what's needed for 300 A.

To avoid system changes, the BAB 30 A can be replaced with a TCF 30 A CUBEFuse. Based on the circuit breaker-to-fuse selective coordination amp rating Table 4.2.7.c, selective coordination is achieved with the upstream FD 150 A circuit breaker for all currents up to 35 kA. No additional upstream changes are needed to the circuit breakers for selective coordination up to 8500 A.

4.2.6.3 Circuit breaker example 3

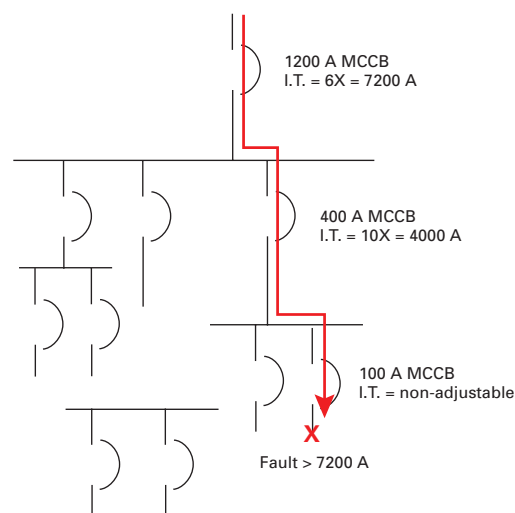


Figure 4.2.6.3.a shows a one-line diagram with three molded case circuit breakers in series: 1200 A main, 400 A feeder and 100 A branch circuit. The other circuit breakers on the one-line diagram supply other circuits and loads. The fault current path from the power source is depicted by the red arrow/line. For the coordination analysis, faults on both the branch and feeder circuit must be analyzed.



The following discussion will analyze the TCC curves shown in Figure 4.2.6.3.b.

TCC curve analysis for branch circuit fault

For a branch circuit fault current less than 3600 A on the 100 A circuit breaker's loadside, the 400 A and 1200 A circuit breakers will keep their contacts closed, as the instantaneous pickup values are greater than the 3600 A, providing the 100 A branch circuit breaker sufficient time to open and clear the fault without causing the upstream devices to open.

If the fault current flowing is greater than 3600 A but less than 6500 A, both the 100 A branch and the 400 A feeder circuit breakers may unnecessarily open, as the fault current exceeds the instantaneous trip pickup values for both. The upstream 1200 A feeder breaker would not open, as the fault current flowing is less than its instantaneous pickup value. The outage to the distribution system in this case would cause unnecessary power loss to loads.

If the branch circuit fault current is greater than 6500 A, it's possible that the 100 A, 400 A and then the 1200 A main circuit breakers could all unnecessarily open, causing an extensive outage to the facility.

TCC curve analysis for feeder circuit fault

For any feeder fault less than 6500 A on the 400 A circuit breaker's loadside, the 400 A and 1200 A circuit breakers will selectively coordinate, as the fault current is less than the 1200 A main circuit breaker's instantaneous pickup. For feeder faults greater than 6500 A, the 1200 A circuit breaker is not selectively coordinated with the 400 A feeder circuit breaker, and they may both open as the fault current exceeds their instantaneous pickup.

TCC curve analysis conclusions

When only TCC curves are used, the available fault current (as compared to the circuit breakers' TCC curves) must be compared to the instantaneous pickup values of each circuit breaker in series. The circuit breakers' performance depends upon how much current passes through them.

When the available fault current exceeds the instantaneous pickup values of two or more circuit breakers, circuit breaker selective coordination tables should be leveraged to determine selectivity.

4.2.6.4 Circuit breaker solutions

Circuit breaker selective coordination is dependent upon the upstream circuit breakers' ability to keep their contacts closed long enough for downstream circuit breakers to open, clear and isolate the system's faulted portion. Because of this fundamental principle, circuit breakers that have higher instantaneous pickup values and longer short-time delay values should be used closer to the utility source (see Section 3.2 for more information). Circuit breakers equipped with electronic trip units offer more flexibility when it comes to meeting selective coordination and protection needs. Microprocessor based trip units offer the ability to add intentional delays to provide downstream devices the necessary time to clear and isolate faulted portions of the circuit.

The following will review the various circuit breaker families and discuss their location in the circuit.

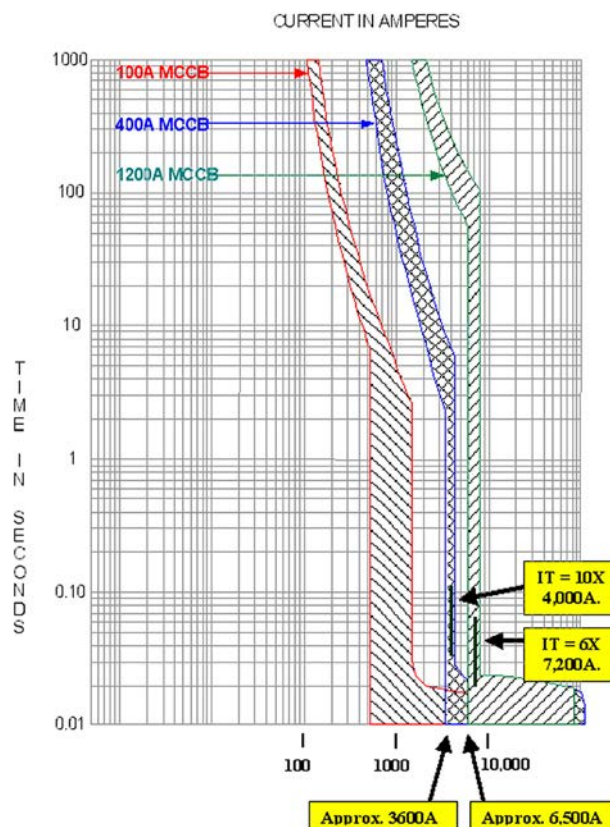


Figure 4.2.6.3.b



4.2.6.5 Circuit breaker selective coordination tables

600 V or less systems that leverage circuit breakers can also take advantage of published selective coordination tables. These tables include circuit breaker pairs that selectively coordinate up to the fault current values shown.

These circuit breakers will NOT selectively coordinate for fault current levels above these values.

These tables are leveraged when the maximum available fault current exceeds the instantaneous pickup of both circuit breakers being evaluated. The table below is for select Eaton circuit breakers from Eaton publication number IA01200002E.

Upstream breaker													
Breaker family	EG	F	F	F	F	F	F	J	J	J			
Type trip unit	T/M	T/M	T/M	T/M	ETU	ETU	ETU	T/M	T/M	T/M			
Digitrip RMS trip unit	—	—	—	—	310+	310+	310+	—	—	—			
OPTIM trip unit	—	—	—	—	—	—	—	—	—	—			
Minimum trip (plug/trip)	125 A	100 A	150 A	225 A	15 A	60 A	100 A	70 A	150 A	250 A			
Maximum trip (frame)	125 A	100 A	200 A	225 A	80 A	160 A	225 A	125 A	225 A	250 A			
Pow-R-Line: main	3E			1a, 2a, 3a, 3E					3a				
Pow-R-Line: branch	3E			3a, 4, Swbd					4, Swbd				
Pow-R-Line: sub-feed	—			1a, 2a, 3E					3a				
Downstream breaker													
Pow-R-Line panelboard/switchboard													
	Main	Branch	Sub-feed										
BR, BAB, HQP and QC (10 kA at 240 Vac) single-, two- and three-pole													
15	—	1a, 3a, 4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	4.0
20	—	1a, 3a, 4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	3.4
30	—	1a, 3a, 4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	0.7	2.1	3.4
40	—	1a, 3a, 4, Swbd	—	0.8	1.0	1.5	2.2	0.6	1.2	2.3	—	1.5	3.4
50	—	1a, 3a, 4, Swbd	—	0.8	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5
60	1a	1a, 3a, 4, Swbd	—	0.8	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5
70	1a	1a, 3a, 4, Swbd	—	—	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5
80	1a	1a, 3a, 4, Swbd	—	—	—	—	2.2	—	—	2.3	—	—	2.5
90	1a	1a, 3a, 4, Swbd	—	—	—	—	2.2	—	—	2.3	—	—	2.3
100	1a	1a, 3a, 4, Swbd	—	—	—	—	1.8	—	—	2.3	—	—	2.3

Table 4.2.6.5.a This table pertains only to circuit breakers manufactured by Eaton. Values in the shaded area are kA. E.g., 1.5 = 1500 amps.

How circuit breaker selective coordination tables are made

Circuit breaker manufacturers publish circuit breaker-to-circuit breaker coordination tables based on testing. In addition to these coordination tables, Eaton also publishes circuit breaker-to-fuse coordination tables to take advantage of the downstream current-limiting Bussmann series fuses.

The tables illustrate the performance of two circuit breakers in series and the maximum fault current values up to which the circuit breakers selectively coordinate. The tables assume all circuit breaker settings are on maximum. Using the tables does not preclude the plotting of circuit-breaker trip curves to ensure selective coordination in the overload and short-time regions.

The testing is typically conducted by using a test configuration as established in UL 489 for testing series rated pairs. The same conductor lengths are used in the test configuration as the fault current is increased through each circuit breaker pairs until both trip. That point at which both circuit breakers trip is the threshold current level, where selectivity is no longer achievable.

How circuit breaker selective coordination tables are used

To read the circuit breaker-to-circuit breaker selectivity table shown above, one must understand the content. The top rows show upstream (lineside) circuit breaker information and the left columns show the downstream (loadside) circuit breaker information. Their intersection within the table for any given row and column establishes current value beyond which both circuit breakers will open. The installer just needs to install the proper circuit breakers and, where applicable, program the proper settings. It's still necessary to plot time-current curves as the table only applies when the fault current is in both circuit breakers' instantaneous region. It's also necessary to perform a fault current study as the values within the table are the fault currents beyond which selective coordination is not achieved.

Selectively coordinating circuit breakers first requires calculating the maximum fault current. Next, the circuit breakers' TCC curves are plotted and evaluated with respect to the calculated fault current. When the fault current that both devices will see exceeds both circuit breakers' instantaneous pickup, the circuit breaker-to-circuit breaker selective coordination tables are used to determine if selectivity is achieved at the higher current level. If selective coordination is not achieved, the current level must be reduced or the upstream circuit breaker must be increased in size. A simple remedy to this situation is to replace the downstream circuit breaker with a current-limiting Bussmann series fuse, such as the TCF CUBEFuse in a Bussmann series Quick-Spec Coordination Panelboard (QSCP)(see section 4.2.4.3).

How circuit breaker-to-fuse selective coordination tables are made

The circuit breaker-to-fuse selective coordination tables are result from testing pairs upstream (lineside) circuit breakers and downstream (loadside) fuses, the performance of which is dictated by the current limiting fuses' basic physics. The basic principle leveraged for fuse to circuit breaker selectivity is similar to that discussed in 4.2.5 covering fuse selectivity ratio tables. The downstream (loadside) fuse's total clearing energy must be less than what is required to open the upstream (lineside) circuit breaker.

The downstream fuse's fast-acting nature is such that the fault current is removed so quickly that the upstream circuit breaker is not able to respond, thus keeping its contacts closed through much higher fault current levels than what's achievable for circuit breaker-to-circuit breaker pairs as discussed in Section 4.2.6.5. Those values presented within this circuit breaker-to-fuse table are often the upstream circuit breaker's interrupting ratings.

This circuit breaker-to-fuse selectivity table is the result of the physics and lab testing for the fuse and circuit breaker pairs shown. The test circuit configuration is the same circuit configuration used for the circuit breaker-to-circuit breaker tables discussed in 4.2.6.5. The testing is conducted such that the upstream circuit breaker settings, where applicable, were set at maximum.

How circuit breaker-to-fuse selective coordination tables are used

To read the circuit breaker-to-fuse selectivity table shown in Section 4.2.7.1, one must understand the content. The table illustrates that for each upstream (lineside) circuit breaker there are downstream (loadside) CUBEFuse amp ratings that selectively coordinate up to a maximum fault current, which happens to be the listed circuit breakers' interrupting ratings. As an example, an F Frame FD 150 A circuit breaker upstream of a 70 A or less CUBEFuse will selectively coordinate for all fault currents up to and including 65 kA. This assumes that the upstream circuit breaker settings, if applicable, are set to maximum.

Molded case circuit breakers (MCCB)

Molded case circuit breakers are offered in ratings from 15 A through 2500 A, in either a simple thermal magnetic construction or as microprocessor-driven electronic trip units. In this family, the thermal magnetic MCCB is the lowest cost solution.

All molded case circuit breakers have a built-in instantaneous override to protect it from high fault currents. One of the most difficult and stressful things for a circuit breaker to do during a fault is to keep its contacts closed. In addition to the instantaneous override, some MCCBs are equipped with an adjustable instantaneous trip.

These devices are typically found downstream in the power distribution system, closer to the load and further away from the utility. The circuit breakers in Figure 4.2.6.5.a could be found at any point in the power distribution system, with their application driven by the needs of the loads served, as well as the performance for selectivity. Selecting the device frame ratings and amp ratings shown in Figure 4.2.6.5.a for any given installation are typically based upon the load, available fault currents, the circuit-breaker selective coordination tables and TCC curves. The larger the MCCB frame, the higher the instantaneous current pickup values are to address the higher fault current values to which they will selectively coordinate with downstream devices.

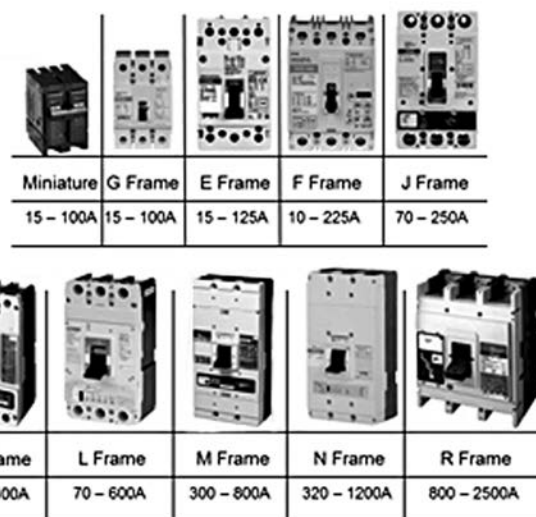


Figure 4.2.6.5.a

Within these frame ratings, Eaton manufactures special circuit breakers to provide a cost-effective thermal magnetic solution to help meet selective coordination needs by lowering the long time pickup to protect smaller conductors, and increase the instantaneous pickup values to provide selective coordination with higher fault current levels. The L and N frame circuit breakers were selected providing the LHH and NHH circuit breakers for these applications. These devices are available for applications from 125 A to 400 A, with instantaneous pickup values as high as 93 times their handle rating, depending upon the device's continuous current rating. For circuit breaker selective coordination purposes, the larger the window between continuous current rating and instantaneous pickup values, the better for MCCB applications. For smaller amp rated MCCBs, typical instantaneous pickup values are anywhere from 10 to 12 times the continuous current rating. Larger MCCBs can have higher multipliers for instantaneous pickup values in the range of 20 times their continuous current rating or higher.

MCCB TCC curve characteristics

- **Continuous current:** Long time pickup values ranging from 15 A through 2500 A
- **Instantaneous pickup:** Pickup values from 10 times as a minimum to very high maximums dependent upon the selected device. The TCC curves for individual MCCBs should be consulted.
- **Short time delays:** Standard thermal magnetic solutions do not provide the ability to offer short time delay settings. Electronic trip units, when equipped on MCCBs, have the ability to offer delay from 2.5 to 18 cycles for currents from 2 to 8 times or even 12 times the MCCB's continuous current rating.

Insulated case circuit breakers (ICCB)

The insulated case circuit breaker is a bridge between an MCCB and the Power Circuit Breaker (PCB), offering higher instantaneous pickup values and longer short time delay capabilities in a more economical package than a power circuit breaker. ICCBs can be found much closer to the service entrance, if not the service main, depending upon the application and selective coordination needs.

Molded case circuit breakers and insulated case circuit breakers typically comply with UL 489 (the standard for molded case circuit breakers) or UL 1066 (the UL standard for low-voltage AC and DC power circuit breakers). These circuit breakers employ a two-step stored energy mechanism and are found in draw-out construction enclosures, such as switchboards and Motor Control Centers (MCCs). They're available from 800 A to 6000 A with interrupting ratings from 35 kA to 150 kA.

The largest difference between ICCBs, and PCBs and MCCBs is their interrupting and withstand capabilities. All ICCBs will be equipped with electronic trip units that provide a high degree of flexibility with regard to selective coordination and equipment protection.

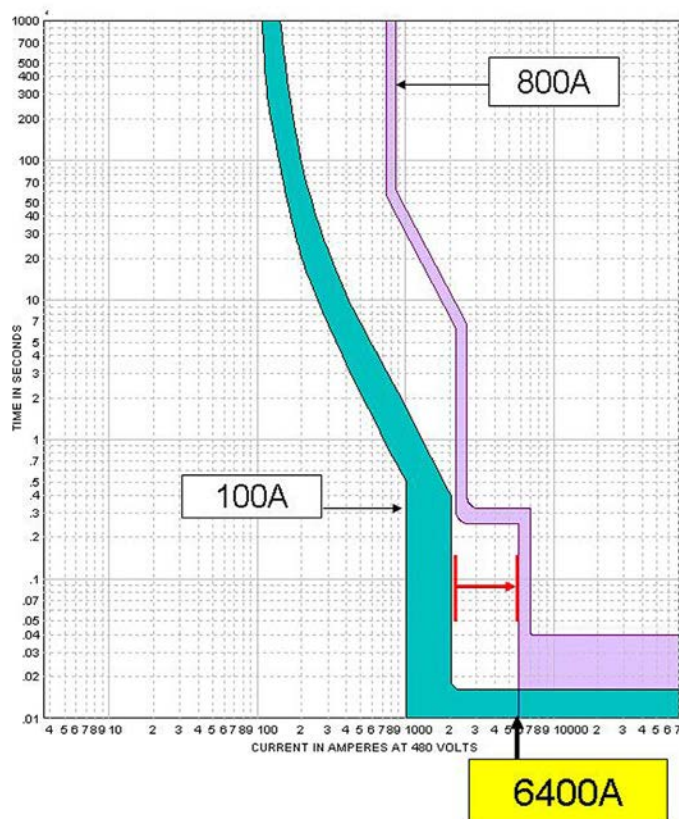


Figure 4.2.6.5.b

ICCB TCC curve characteristics

- **Continuous current:** Long time pickup values ranging from 800 A through 6000 A
- **Instantaneous pickup:** Pickup values from 2 to 12 times the continuous current rating. The TCC curves for individual ICCBs should be consulted.
- **Short time delays:** The flexibility of short time delay offered will depend upon the electronic trip unit solutions selected. ICCBs have the ability to offer delay from 2.5 to 30 cycles for currents from 2 to 10 times the continuous current rating of the MCCB.

Power circuit breakers (PCB)

The power circuit breaker is a full featured versatile device that offers a world of flexibility to meet a variety of power distribution system needs. These devices are equipped to provide delay up to 30 cycles for fault currents up to their interrupting ratings. All PCBs are equipped with electronic trip units and are listed to UL 1066 and ANSI/IEEE C37.

PCBs are typically found close to service entrance equipment, and in equipment such as switchboards, switchgear and MCCs. The enclosures that usually hold PCBs are of "drawout" construction. They are available from 800 A to 6000 A with interrupting ratings from 42 kA to 200 kA.

PCB TCC curve characteristics

- **Continuous current:** Long time pickup values ranging from 800 A through 6000 A
- **Instantaneous pickup:** Pickup values from 2 times the continuous current rating to the circuit breaker's interrupting rating.

- **Short time delays:** Delays from 2.5 to 30 cycles for currents from 2 times the continuous current rating of the PCB up to the PCB's interrupting rating.

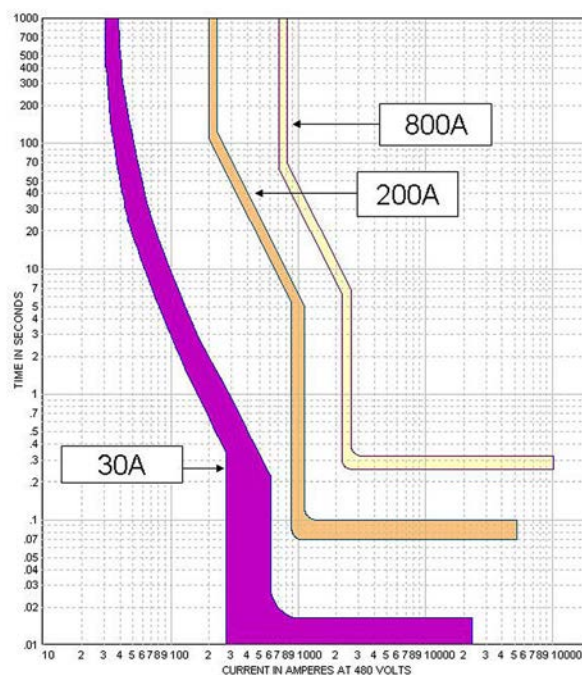


Figure 4.2.6.5.c

Figure 4.2.6.5.c illustrates a 30 A molded case circuit breaker fed by a 200 A LVPCB and 800 A LVPCB. The 200 A and 800 A circuit breakers have short-time delay (STD) settings that provide selective coordination. The 200 A circuit breaker has its STD set at 6 cycles and the 800 A circuit breaker has its STD set at 20 cycles.

4.2.6.6 Summary — circuit breaker selective coordination

It's possible to design electrical systems that selectively coordinate with circuit breakers. Applying circuit breakers requires analysis and specifying the proper circuit breaker types and settings. It's necessary to calculate the available fault currents at each circuit breaker's point of application, plot trip curves and/or review selective coordination tables to evaluate how devices will respond in relation to each other when compared to the maximum available fault currents.

The nature of applying circuit breakers to achieve selective coordination is using devices that can keep their contacts closed so that downstream devices can open and clear faults. This intentional delay will increase incident energy in these applications, and steps should be taken to mitigate these effects through employing arc energy reduction technologies. Section 4.3 of this document should be consulted.



4.2.7 Fuse and circuit breaker selective coordination

For downstream fuses and upstream circuit breakers, it's not a simple matter to determine if a fuse and circuit breaker will be selectively coordinated when tested pair tables, as shown in Figure 4.2.7.c, are not available. Even if the TCC curves plotted for a downstream fuse and an upstream circuit breaker show that the curves don't cross, selective coordination may not be possible for high fault currents that exceed a specific current value. Testing can be conducted to determine the selectivity level achieved between these two OCPD types. The Bussmann Division's Paul P. Gubany Center for High Power Technology is available to perform this testing. Look under Bussmann series Services at Eaton.com/bussmannseries.

Figure 4.2.7.a shows an example of a 400 A circuit breaker with a downstream 100 A fuse. Coordination is shown in the TCC curve up to about 3 kA, where the circuit breaker trip curve crosses the 0.01 second axis. Coordination cannot be ensured above this value without testing or further analysis because the fuse may not clear the fault prior to the upstream circuit breaker unlatching (the current axis is 10x).

If a fuse is upstream and a circuit breaker downstream, at some point the fuse's TCC curve will cross the circuit breaker's TCC curve. The general rule is that for fault currents at that crossover point and higher, the upstream fuse is not coordinated with the downstream circuit breaker. Figure 4.2.7.b shows a 400 A fuse upstream from a 100 A circuit breaker. Coordination is not possible above approximately 5 kA as shown in the overlapping time-current curves (the current axis is 10x).

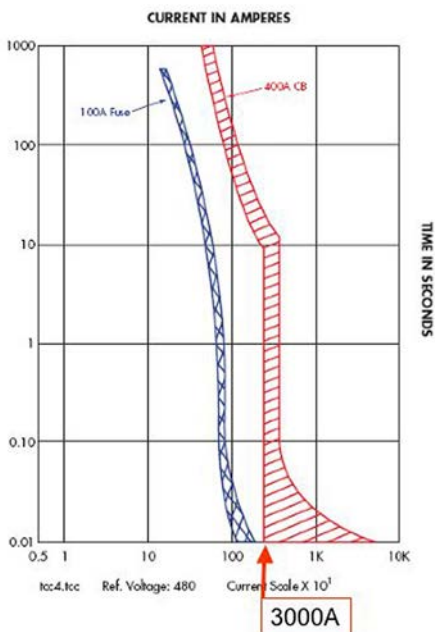


Figure 4.2.7.a

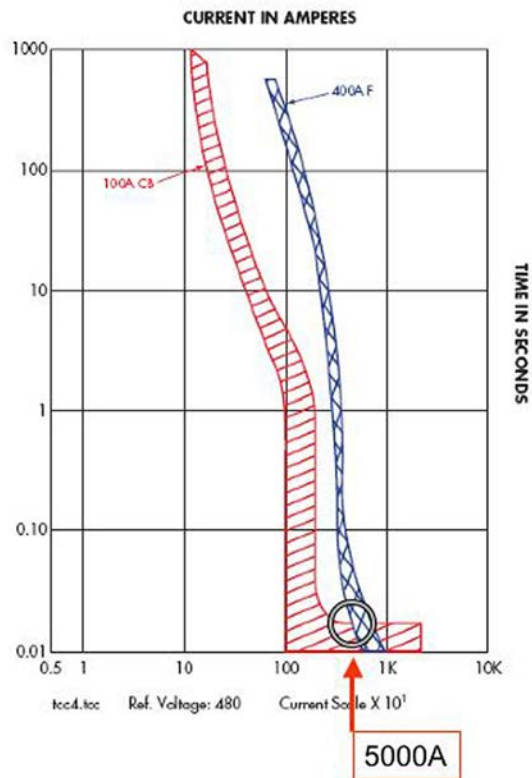


Figure 4.2.7.b



4.2.7.1 Circuit breaker and fuse selective coordination

In addition to the circuit breaker-to-circuit breaker selective coordination tables, Eaton provides circuit breaker-to-fuse selectivity tables leveraging the fuse's fast current-limiting operation when placed downstream of a circuit breaker*.

240 Vac Eaton thermal magnetic circuit breaker "quick pick" selective coordination with CUBEFuse amp ratings*

Eaton lineside circuit breakers				Max circuit fault current (kA)	Loadside TCF or FCF CUBEFuse (amps)**
Breaker frame	Breaker family	Min. amp rating	Max amp rating		
G Frame	GHB	100	100	65	15, 20, 25, 30, 35, 40, 50
E Frame	EGB	125	125	25	15, 20, 25, 30, 35, 40, 50, 60
F Frame	EHD	100	100	18	15, 20, 25, 30, 35, 40, 50
	FD	100	100	65	15, 20, 25, 30, 35, 40, 50
	FD	150	150	65	15, 20, 25, 30, 35, 40, 50, 60, 70
	FD	225	225	65	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
J Frame	JD	70	70	65	15, 20, 25, 30
	JD	150	150	65	15, 20, 25, 30, 35, 40, 50, 60, 70
K Frame	KD	200	400	65	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
	HKD	400	400	100	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100

* For circuit breakers with an adjustable instantaneous trip, selective coordination is based upon instantaneous trip set at maximum.

**TCF (time-delay) and FCF (fast-acting) fuses can be used on any 600 Vac or less system. The CUBEFuse has a 300 kA interrupting rating at 600 Vac or less.

480 Vac Eaton thermal magnetic circuit breaker "quick pick" selective coordination with CUBEFuse amp ratings*

Eaton lineside circuit breakers				Max circuit fault current (kA)	Loadside TCF or FCF CUBEFuse (amps)**
Breaker frame	Breaker family	Min. amp rating	Max amp rating		
G Frame	GHB	100	100	14†	15, 20, 25, 30, 35, 40, 50
E Frame	EGB	125	125	18	15, 20, 25, 30, 35, 40, 50, 60
F Frame	EHD	100	100	14	15, 20, 25, 30, 35, 40, 50
	FD	100	100	35	15, 20, 25, 30, 35, 40, 50
	FD	150	150	35	15, 20, 25, 30, 35, 40, 50, 60, 70
	FD	225	225	35	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
J Frame	JD	70	70	35	15, 20, 25, 30
	JD	150	150	35	15, 20, 25, 30, 35, 40, 50, 60, 70
K Frame	KD	200	400	35	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
	HKD	400	400	65	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100

* For circuit breakers with an adjustable instantaneous trip, selective coordination is based upon instantaneous trip set at maximum.

**TCF (time-delay) and FCF (fast-acting) fuses can be used on any 600 Vac or less system. The CUBEFuse has a 300 kA interrupting rating at 600 Vac or less.

† 480/277 Vac

600 Vac Eaton thermal magnetic circuit breaker "quick pick" selective coordination with CUBEFuse amp ratings*

Eaton lineside circuit breakers				Max circuit fault current (kA)	Loadside TCF or FCF CUBEFuse (amps)**
Breaker frame	Breaker family	Min. amp rating	Max amp rating		
F Frame	FD	100	100	18	15, 20, 25, 30, 35, 40, 50
	FD	150	150	18	15, 20, 25, 30, 35, 40, 50, 60, 70
	FD	225	225	18	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
J Frame	JD	70	70	18	15, 20, 25, 30
	JD	150	150	18	15, 20, 25, 30, 35, 40, 50, 60, 70
K Frame	KD	200	400	25	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
	HKD	400	400	35	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
L Frame	LD	300	600	25	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100
	HLD	300	600	35	15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100

* For circuit breakers with an adjustable instantaneous trip, selective coordination is based upon instantaneous trip set at maximum.

**TCF (time-delay) and FCF (fast-acting) fuses can be used on any 600 Vac or less system. The CUBEFuse has a 300 kA interrupting rating at 600 Vac or less.

Figure 4.2.7.c Circuit breaker-to-fuse selective coordination tables for 240, 480 and 600 V systems.

4.2.8 Code requirements

For building electrical systems, the topic of OCPD selective coordination can be segmented into two areas:

- A desirable design consideration
- An NEC requirement

In most cases, selective coordination is a desirable design consideration and not an NEC requirement. It's in the building owner's or tenants' best interest to have selectively coordinated overcurrent protection to avoid unnecessary blackouts. Selective coordination should be evaluated in the context of the reliability desired for the power system to deliver power to loads.

Because reliability is a key safety component, selective coordination is mandatory per the NEC for specific applications pertaining to life safety or national security.

The NEC has mandatory selective coordination requirements for these systems:

- Emergency Systems — Article 700: 700.32
- Legally Required Standby Systems — Article 701: 701.27
- Critical Operations Power Systems — Article 708: 708.54

Additionally, selective coordination is required in elevator circuits (620.62), in certain fire pump applications (695.3(C)(3), critical operations data systems (645.27) and for certain emergency system wiring schemes (700.10(B)(5)(b) which are not discussed in depth in this section.

Notice these requirements are not in NEC Chapters 1 through 4, (such as Articles 210 Branch Circuits, 215 Feeders, or 240 Overcurrent Protection)) that generally pertain to all premise electrical installations. Instead, these requirements are in Chapters 5 through 7, which are under special occupancies and special conditions, respectively.

The NEC gives these systems special attention because they have unique requirements. Articles 700, 701, and 708 cover circuits and systems intended to deliver reliable power for loads that are vital to life safety, public safety or national security. Reliability for these systems must be greater than normal systems covered in Chapters 1 through 4.

Articles 700, 701, 708 and 517 are unique and have more restrictive minimum requirements (versus the general requirements for normal systems) so that these systems provide more reliable power to vital loads, with selective coordination being one that supports higher reliability.

A few of the more restrictive minimum requirements in Article 700 are:

- Periodic testing, maintenance and record retention
- Alternate power sources
- Separate wiring from emergency source to emergency loads (separate from all other wiring)
- Special fire protection for wiring
- Locating wiring to avoid outage due to physical damage during fires, floods, vandalism, etc.
- Automatic transfer switches (ATS) with sophisticated sensors, monitors and controls
- Separate ATSs and load segmenting (emergency, legally required standby and optional standby) with sophisticated load shedding, if required

The reason these articles for special systems exist is that the electrical industry, the standard making bodies, the technical code panel members and Homeland Security believe special rules are needed to ensure minimum requirements for reliable power to designated vital loads.

To better understand why we have more restrictive requirements, it's important to understanding the loads being served by these special systems (vital loads that pertain to life safety, public safety and national security). For instance, the Informational Note found in 700.2 defines emergency systems as:

"Emergency systems are generally installed in places of assembly where artificial illumination is required for safe exiting and for panic control in buildings subject to occupancy by large numbers of persons, such as hotels, theaters, sports arenas, healthcare facilities and similar institutions. Emergency systems may also provide power for such functions as ventilation where essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious life safety or health hazards, and similar functions."

The NEC sections defining selective coordination, and those requiring the OCPDs in the circuit paths supplying these vital loads to be selectively coordinated, are as follows:

4.2.8.1 Article 100 definitions

NEC Article 100 contains only those definitions essential to the application of this Code. In general, only those terms used in two or more articles are defined in Article 100, where other definitions can be found in the specific Articles to which they apply. Because selective coordination is used in multiple NEC articles, its definition is included here.

"Coordination, selective (selective coordination)"

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the selection and installation of overcurrent protective devices and their ratings or settings for the full range of available overcurrents, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents (CMP-10)."

This definition establishes some very important criteria including these key points:

- **OCPD Selection.** The proper selection, installation and setting of the OCPDs in a power distribution system is critical to the devices' performance in practice. Once the fault current and selective coordination studies are completed, the OCPDs must be specified to achieve selective coordination at the designated fault current, and must also be the devices installed in the application. Some circuit breakers may require field adjustments to ensure selective coordination as dictated by the study.
- **Current levels.** The definition makes it clear that OCPDs must selectively coordinate for the full range of overcurrents, including overloads and maximum fault currents. As the definition states, the goal is to restrict outages to the circuit or equipment affected which can only be achieved by ensuring the downstream device clears overcurrents before the upstream devices for all overcurrent values up to and including the maximum fault current that the devices could see in the system.



4.2.8.2 Article 620 elevators

Article 620 covers electrical equipment installation and wiring used in connection with elevators, dumbwaiters, escalators, moving walks, platform lifts and stairway chairlifts. Quite often this equipment is used for safety related purposes, and selective coordination is important to their operation during emergencies. Section 620.62 was introduced in the 1990 NEC and it addresses the selective coordination requirements for these installations.

“620.62 Selective Coordination

Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified person engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain and operate the system.”

An important thing to highlight with regard to selective coordination is the NEC repeatedly establishes the need to ensure a professional engineer or a qualified individual is engaged in the OCPDs’ selection for selective coordination. This requirement was established in the 2014 NEC.

4.2.8.3. Article 645 information technology equipment

Article 645 covers equipment, power-supply wiring, equipment interconnecting wiring, and grounding of information technology equipment and systems in an information technology equipment room. Reliability is critical for this infrastructure and an important safety consideration. Section 645.27 provides the selective coordination requirements for this equipment and was introduced in the 2014 NEC.

“645.27 Selective Coordination

Critical operations data system(s) overcurrent protective devices shall be selectively coordinated with all supply-side overcurrent protective devices.”

This requirement applies to all OCPDs on the supply-side of the critical operations data system’s OCPDs.

4.2.8.4. Article 695 fire pumps

Article 695 covers the installation of electric power sources and interconnecting circuits (as well as switching and control equipment) dedicated to fire pump drivers. Fire pumps are critical for safety during emergencies and this equipment’s reliability drives the selective coordination requirements found in Section 695.3 and was introduced in the 2011 NEC.

“695.3 Power Source(s) for Electric Motor - Driven Fire Pumps

(C) Multi-building Campus-Style Complexes

If the sources in 695.3(A) are not practicable and the installation is part of a multi-building campus-style complex, feeder sources shall be permitted if approved by the authority having jurisdiction and installed in accordance within (C)(1) and (C)(3) or (C)(2) and (C)(3).

(3) Selective Coordination

The overcurrent protective device(s) in each disconnecting means shall be selectively coordinated with any other supply-side overcurrent protective device(s).”

4.2.8.5. Article 700 emergency systems

Article 700 applies to the electrical safety of emergency system installation, operation, and maintenance. This consist of circuits and equipment intended to supply, distribute and control electricity for illumination, power (or both) to required facilities when the normal electrical supply is interrupted. Requirements for selective coordination can be found in Section 700.32 that was introduced in the 2005 NEC, (which at that time was Section 700.27). Adding exceptions began as part of the 2008 NEC, recognizing that two OCPDs in series, such that when opening either device results in losing the same load, do not have to selectively coordinate. The requirement that selective coordination be addressed by a licensed professional engineer or other qualified person was introduced as part of the 2014 NEC.

“700.32 Selective Coordination

Emergency system(s) overcurrent devices shall be selectively coordinated with all supply-side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.”

4.2.8.6. Article 701 legally required standby systems

Article 701 applies to the electrical safety of the legally required standby system installation, operation and maintenance. This consist of circuits and equipment intended to supply, distribute and control electricity to required facilities for illumination or power (or both) when the normal electrical supply is interrupted. Requirements for selective coordination can be found in Section 701.27 and introduced in the 2005 NEC. Adding exceptions began as part of the 2008 NEC, recognizing that two OCPDs in series, such that when opening either device results in losing the same load, do not have to selectively coordinate. The requirement that selective coordination be addressed by a licensed professional engineer or a qualified person was introduced in the 20014 NEC.

“701.27 Selective Coordination

Legally required standby system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent protective devices located in series if no loads are connected in parallel with the downstream device.”



4.2.8.7 Article 708 critical operations power systems

Article 708 was introduced in the 2008 NEC. This article applies to the installation, operation, monitoring, control and maintenance of those portions of the premise's wiring system intended to supply, distribute, and control electricity to designated critical operations areas (DCOA) in the event of disruption to elements of the normal system.

A critical operations power system is one designated as such by municipal, state, federal or other codes by any government agency having jurisdiction, or by facility engineering documentation establishing the necessity for such a system. These systems include, but are not limited to designated critical operations areas including:

- Power systems
- HVAC
- Fire alarm
- Security
- Communications and signaling

The informational note number 1 to the scope of Article 708 provides useful information for understanding what critical operations power systems are. It states the following:

“Critical operations power systems are generally installed in vital infrastructure facilities that, if destroyed or incapacitated, would disrupt national security, the economy, public health or safety; and where enhanced electrical infrastructure for continuity of operation has been deemed necessary by governmental authority.”

As a result of such events as 9/11, and hurricane Katrina and Irma, Homeland Security requested NFPA to develop requirements for electrical systems that are vital to the public. Article 708 (COPS) includes selective coordination as a requirement; and is a minimum requirement for electrical systems that are important for national security and public safety. Selective coordination requirements can be found as part of 708.54 which was introduced in the 2008 NEC as part of the new Article 708. Adding exceptions began in the 2008 NEC recognizing that two OCPDs in series, such that when opening either device results in losing the same load, do not have to selectively coordinate. The requirement that selective coordination be addressed by a licensed professional engineer or a qualified person was introduced in the 2014 NEC.

“708.54 Selective Coordination

Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.”

4.2.9 Selective coordination design guide

Achieving a selectively coordinated power distribution system in the most cost effective manner is the goal of every power systems engineer. The power systems engineer must leverage all available tools to achieve this goal. The engineer must understand overcurrent protective device principles and functionality, and take into consideration some basic power system design principles to achieve the most cost effective and efficient life safety system possible. Sometimes the installation cost must also consider the cost of time and resources for the design itself.

The information provided here is meant to serve as a guide for consulting engineers when designing systems where selective coordination is desired or required. These basic principles can be applied by the consulting engineer for any part of the power distribution system to provide customers a well-engineered, selectively coordinated system.

4.2.9.1 Leveraging the fuse's power

When applying the fuse, maintaining an amp ratio from one fuse to another ensures selective coordination without regard to fault current levels. The value of this to the engineer is speed in achieving an effective design without calculating available fault currents nor plotting TCC curves. A reliable solution is also achieved for the power distribution system's life — even if available fault current changes. New technologies have reduced the fusible equipment's footprint, and the fuse itself provides an economical, logical choice — especially when selective coordination is a key design goal or Code requirement.

4.2.9.2 OCPDs that have to selectively coordinate

The Code text for the selective coordination requirements in 700.32 is carefully worded; stating that all emergency OCPDs shall selectively coordinate with all supply-side overcurrent devices. This helps ensure that these vital loads are not unnecessarily disrupted, whether fed from the normal source or the alternate source. Wording for 701.27 legally required standby systems and 708.54 critical operations power systems is similar, except for the system type nomenclature.

Figures 4.2.9.2.a and 4.2.9.2.b illustrate that all emergency overcurrent protective devices must selectively coordinate through to the alternate power source. Additionally, the emergency OCPDs on the transfer switch's loadside must selectively coordinate with the OCPDs in the normal circuit path.

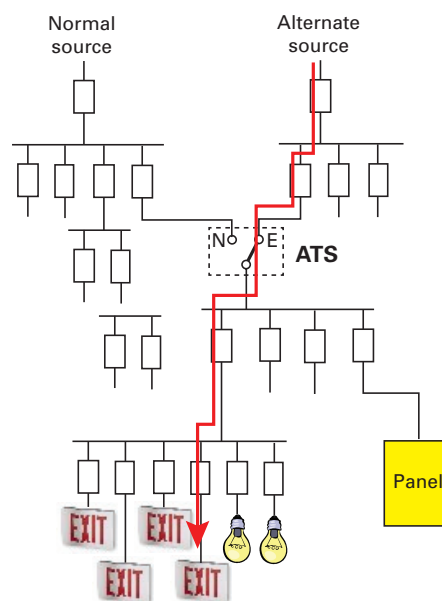


Figure 4.2.9.2.a

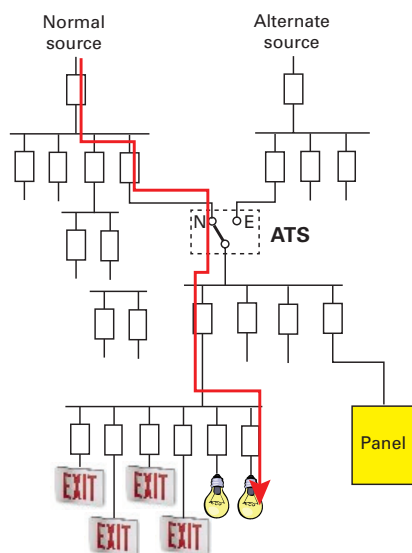


Figure 4.2.9.2.b

However, based on wording, there is a difference on the minimum requirement for the OCPDs in the normal source path located on the transfer switch's lineside.

The example in 4.2.9.2.c covers each OCPD in the system with a review of the selective coordination requirement.

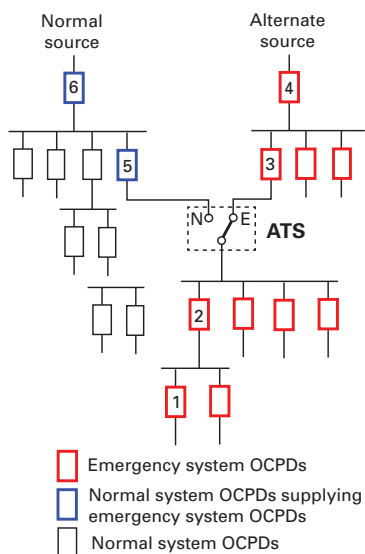


Figure 4.2.9.2.c

Practical requirement application example:

- OCPD 1 Must selectively coordinate with OCPD 2, 3, 4, 5 and 6
- OCPD 2 Must selectively coordinate with OCPD 3, 4, 5 and 6
- OCPD 3 Must selectively coordinate with OCPD 4
- OCPD 5 Does not have to selectively coordinate with OCPD 6 because OCPD 5 is not an emergency system OCPD.

Whether or not OCPD 5 selectively coordinates with OCPD 6 is a design decision. Although having OCPD 5 NOT selectively coordinate with OCPD 6 is permitted, the best practice is to have them selectively coordinated.

OCPDs that do not have to selectively coordinate

Sections 700.32, 701.27 and 708.54 have exceptions for selective coordination that's shown in Figure 4.2.9.2.d. The exception does not reduce life safety because there aren't any additional portions of the electrical system would be unnecessarily shut down. The red OCPDs in both circuits don't have to selectively coordinated with each other.

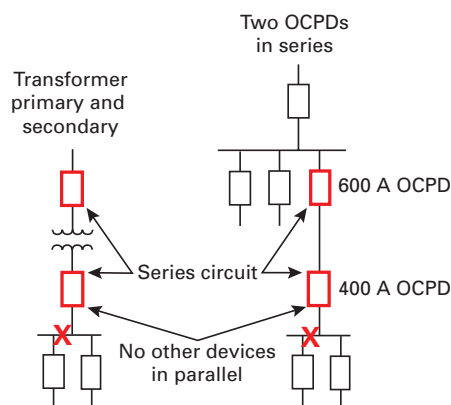


Figure 4.2.9.2.d

4.2.9.3. Worst case fault current

To assess whether the OCPDs selectively coordinated in the circuit path for these vital loads, it's important to consider the maximum available fault current, whether from the normal or alternate source (see Figure 4.2.9.3.a). This is required per 700.4(A) Capacity and Rating: "... The emergency system equipment shall be suitable for the maximum available fault current at its terminals." Generally, the normal source can deliver more fault current than the emergency generator/alternate source. If the alternate source can deliver more fault current, then it must be used for determining compliance with NEC 110.9 (interrupting rating) and 110.10 (short-circuit current rating).

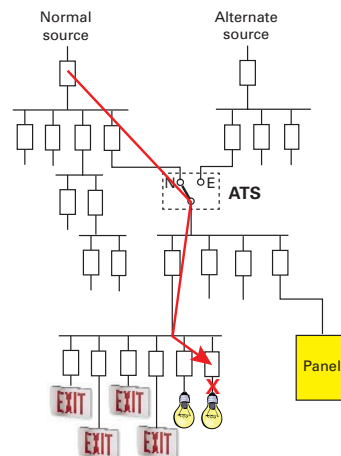


Figure 4.2.9.3.a

To ensure selective coordination, OCPDs must selectively coordinate for the full range of possible overcurrents. This includes overloads, faults, ground faults, arcing faults and bolted faults. Whether the OCPDs are current-limiting fuses or circuit breakers, they must be selectively coordinated for the maximum available fault current at each point of application in the system.

4.2.9.4 Ground fault protection relays

If a circuit path includes a ground fault protection relay (GFPR), then the selective coordination analysis should include the GFPR. One approach is to first perform the fuse or circuit breaker selective coordination analysis (as described in the previous sections and accounting for all overcurrent types). Then perform a separate analysis for how the fuse or circuit breaker and GFPR coordinate with each other for ground faults.

4.2.9.5 Panels in series

When designing a selectively coordinated system, it's important to minimize the number protective device "series levels." Figure 4.2.9.5.a illustrates a 400 A panelboard feeding a 200 A panelboard which, in turn, feeds a 175 A panelboard and then shows the same equipment arranged differently so that the 400 A panelboard now feeds both the 200 A and 175 A panelboard. By eliminating panelboard levels, the engineer effort needed to selectively coordinate the OCPDs is reduced.

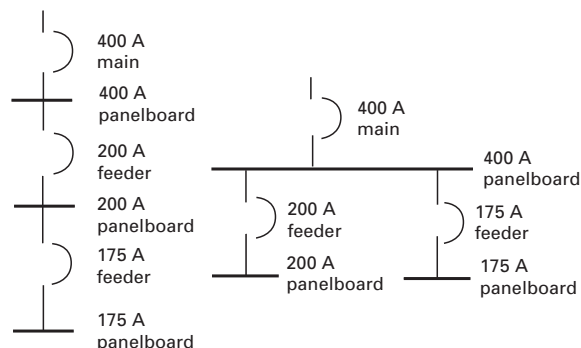


Figure 4.2.9.5.a

4.2.9.6 Fused branch and/or feeder panels

Achieving selective coordination relies heavily on how quickly a downstream OCPD can clear a fault, ensuring the upstream OCPDs can remain closed. Having a downstream device that can clear very quickly helps ensure the upstream OCPDs are the smallest devices possible for selective coordination. Current-limiting OCPDs will operate faster at high current, where the fuse operates fastest in its current-limiting region. Thus, applying a fuse close to the load allows for upstream OCPDs to be smaller and more effective.

By using selective coordination tables that have fuses as the downstream OCPD, engineers can achieve selective coordination to higher fault current levels with either upstream fuses or breakers.

4.2.9.7 480/277 V lighting loads

It's difficult to use single- and double-pole circuit breakers for feeding lighting loads from 277 V circuits, because the available fault current is typically higher than what's allowed for selectively coordinating the breakers per the selective coordination tables.

The Bussmann series Quik-Spec Coordination Panelboard (QSCP) is an ideal solution for these applications because a simple 2:1 amp ratio can be maintained in a footprint that's the same as a circuit breaker solution.

When using circuit breakers for supplying lighting loads, it's better to utilize smaller, kVA step-down transformers from the 480 V to 208 Y/120 V. This will result in low fault current levels at 208 Y/120 V and make it possible for the secondary main and branch breakers to selectively coordinate. Although the transformer's primary circuit breaker and secondary main circuit breaker need not selectively coordinate, the secondary branch devices must selectively coordinate with the transformer's primary circuit breaker. The maximum breaker size that can be placed on the transformer primary is determined by the NEC and the smallest breaker that can be placed on the transformer's primary is determined by inrush current levels and selective coordination needs.

The total cost of ownership and project cost must be considered when adding transformers just to achieve selective coordination. This increased cost and complexity can be avoided by installing fusible panelboards.

4.2.9.8 Automatic transfer switch withstand ratings

Automatic transfer switches (ATS) manufactured in accordance with UL 1008 have short-circuit withstand ratings of either 1.5 or 3 cycles.

Therefore, the upstream OCPD feeding the ATS must have an instantaneous element that clears a through-fault, downstream of the ATS, in less than the 1.5 or 3 cycle rating — or be a fuse. Because the fuse is not impacted as much by the available fault current, protecting the ATS is not a big concern, but should always be evaluated. Several ATS equipment manufacturers, including Eaton, have 30-cycle withstand ratings on their higher amp rated ATSs that's available upon request.

The following table illustrates the instantaneous trip requirements for protective devices feeding UL Listed ATSs.

ATS withstand	Required feeder protective device instantaneous clearing time	See note
1.5 cycles	≤ 1.5 cycles	1
3 cycles	≤ 3.0 cycles	2
30 cycles	≤ 30 cycles	3

- 1 ATSs with a 1.5-cycle withstand rating are typically rated 400 A or less and used in applications with a maximum available fault current of 10 kA.
- 2 ATSs with a 3-cycle withstand rating are typically rated greater than 400 A and used in applications with a maximum available fault current exceeding 10 kA.
- 3 ATSs with a 30-cycle withstand rating are typically used when there is a requirement for selective coordination. The upstream circuit breaker's instantaneous trip function can be disabled, as long as the available fault current is less than the 30-cycle withstand (short-time) rating of the ATS and circuit breaker.

Where the application requires selective coordination, it may be necessary to disable the instantaneous trip function on the power circuit breaker that's upstream from the ATS so that selective coordination with downstream devices is maintained. In this case, it's important to ensure the ATS has a 30-cycle withstand rating that's high enough for the system's available fault current.

4.2.9.9 Elevator disconnects

As defined in NEC 620.62, the selective coordination requirements for elevator circuits state that "...where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply-side overcurrent protective devices."

It's common practice to use fused elevator modules as the shunt-trip disconnecting means (circuit breakers may also be used). The following examples illustrate applying both equipment options.

Example 1: The one-line diagram in Figure 4.2.9.9.a illustrates a typical fused elevator module feeding two elevators.

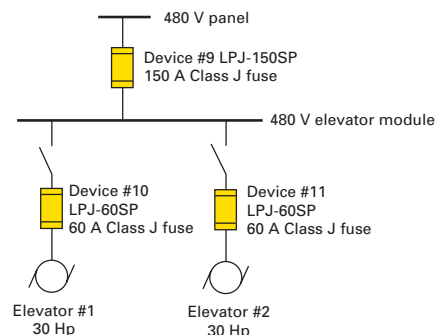


Figure 4.2.9.9.a

The fused elevator disconnects (Devices #10 and #11) selectively coordinate with the upstream feeder fuse (Device #9) provided a 2:1 ratio is maintained. There is no need to plot time current characteristic curves or know the available fault current.

Example 2: The one-line diagram in Figure 4.2.9.9.c illustrates a typical application of shunt-trip circuit breakers feeding two elevators.

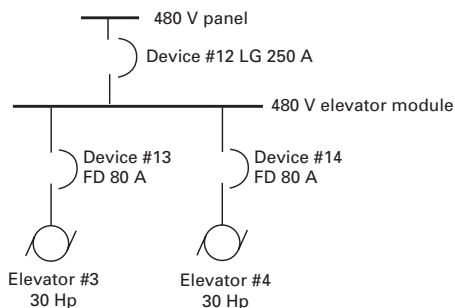


Figure 4.2.9.9.c

In the one-line diagram above, the circuit breaker elevator disconnects (Device #13 and #14) selectively coordinate with the upstream feeder circuit breaker (Device #12) per the time-current curve shown in Figure 4.2.9.9.d, provided Device #12's available fault current is below the instantaneous pickup setting, or that Device #12 and Device #13 or #14 have been tested to show they selectively coordinate for the available fault current levels.

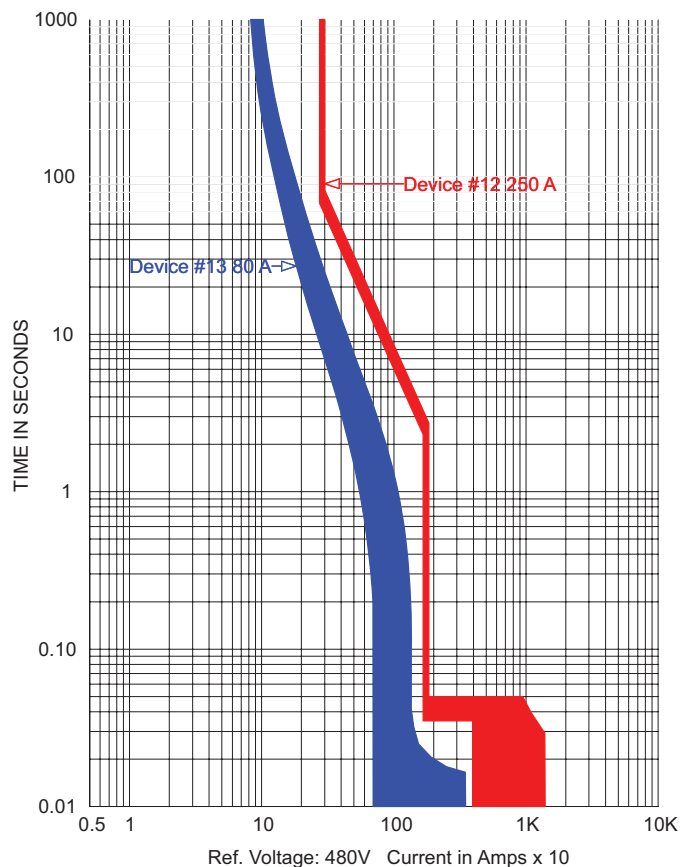


Figure 4.2.9.9.d

When only one elevator is present in an electrical system (or when multiple elevators are fed from separate sources), NEC 620.62 does not require selective coordination. Therefore, fused elevator modules or selectively coordinated circuit breakers are not required. However selective coordination may be required if the elevator is fed from an emergency or legally required standby source, as defined in NEC 700.32 and 701.27.

4.2.9.10 Main lug only (MLO) and through-feed lug (TFL) panels

When designing a selectively coordinated system, it's important to minimize the number OCPD "levels" that need coordinating. It's common practice to "daisy chain" panels (feed one sub-panel from another sub-panel). As shown in Figure 4.2.9.10.a, Devices #4 and #5 must selectively coordinate with Devices #2 and #3 and all downstream devices must selectively coordinate with Device #1.

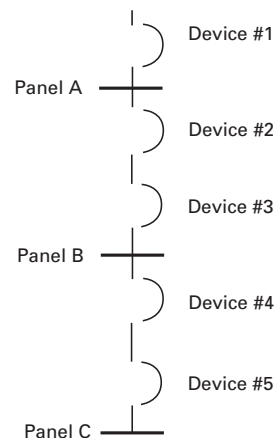


Figure 4.2.9.10.a

In lieu of sub-feed circuit breakers, using main lug only (MLO) panels with through-feed lugs (TFL) reduces the selective coordination requirement to just the branch circuit devices in Panels A, B and C, and the main device in Panel A. See Figure 4.2.9.10.b.

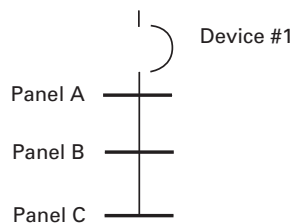


Figure 4.2.9.10.b

The conductor size for the feed through panels (Panels B and C in this example) must be the same size as those in through feed panel A. In addition, panelboards B and C must have a main lug and bus rating equal to Device #1. This will ensure that all cables and buses are protected by the upstream breaker, Device #1.

4.2.9.11 Generator breaker selection

Most fuse and circuit breaker manufacturers have performed testing to develop comprehensive selective coordination tables. However, no cross-manufacturer selective coordination testing has been performed. This becomes an issue when the entire electrical distribution system is comprised of one manufacturer's equipment and the generator protective device from another manufacturer. To avoid this, it's suggested that all protective devices be from the same manufacturer, including the generator protective device(s).

4.2.9.12 Series rated systems

The premise behind a series rated combination is that both the upstream and the downstream circuit breakers interrupt in the event of a fault. Since the objective of selective coordination is to localize the overcurrent event to just the affected equipment, series rated systems are not allowed where selective coordination is required. System designs must use fully rated equipment to meet selective coordination.

4.2.9.13 Zone selective interlock (ZSI)

A circuit breaker zone selectively interlocked system's goal is to reduce incident energy. ZSI is not a tool for selective coordination. Two circuit breakers that are zone selectively interlocked must first selectively coordinate for all fault currents as required by the NEC, or by the design goals. ZSI is put in place to ensure the upstream circuit breaker trips without an intentional delay should a fault occur between the two connected devices. ZSI does NOT provide selective coordination.

4.2.10 Coordination

2017 NEC introduced in Article 517 the concept of "coordination" for healthcare systems instead of "selective coordination." The change made in the NEC aligned with a change made in NFPA 99, "Healthcare Facilities Code," which has purview over healthcare facility performance. The NFPA 99 technical panel reduced the selectivity level to address the circuit breaker's increased incident energy due to the fact that the circuit breaker's instantaneous pickup will require increasing to achieve selective coordination.

517.31(G) requires that the OCPDs serving the essential electrical system shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.

"517.31 Essential Electrical Systems for Hospitals

(G) Coordination — Overcurrent protective devices serving the essential electrical system shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.

Exception No. 1: Between transformer primary and secondary overcurrent protective devices, where only one overcurrent protective device or set of overcurrent protective devices exists on the transformer secondary.

Exception No. 2: Between overcurrent protective devices of the same size (ampere rating) in series.

Informational Note: The terms coordination and coordinated as used in this section do not cover the full range of overcurrent conditions."

The minimum performance level required in 517.31(G) is less restrictive. The "coordination" of OCPDs disregards fault current that the OCPDs see during a fault to determine selectivity. The 517.31(G) informational note establishes the fact that fault currents are not considered.

To ensure a higher level of reliability for vital loads, many system designs will continue incorporating selective coordination in essential electrical systems. Also, there are some healthcare facilities or parts of facilities, such as administrative buildings, which are required to comply with the NEC and its requirements for:

- Elevators (620.62)
- Critical operations data systems (645.27)
- Emergency systems (700.32)
- Legally required standby systems (701.27)
- Critical operations power systems (708.54).

4.2.11 Summary

Selective coordination is a desirable design goal, and for some installations a Code requirement. The NEC provides the minimum requirements for special systems that are essential for life safety, public safety and national security. For any system where reliability is of utmost importance, selective coordination should be used to increase the reliability of delivering power to vital loads. Selective coordination can be achieved with fuses, circuit breaker or fuse/circuit breaker solutions, but attention to details and being designed by a qualified individual is essential.

4.3 Arc flash

Contents

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4.3.1 Overview

Understanding what incident energy levels are at various locations in an electrical distribution system is important for electrical safety. This information can also be input into a reliability review that indicates the extent of damage to expect should an arc flash event occur. An important arc flash analysis output is guidance on the requisite PPE when justified, energized work is conducted. The correct PPE selection and other safe work practices are covered in Section 6.

The steps necessary to conduct an arc flash study starts with these steps:

Step 1: Collect system information. Information accuracy is important for any analysis. Whether it be an existing installation or new construction, the power distribution system must be properly evaluated and documented. The foundation of power systems analysis studies is collected information accuracy and the conservative nature of any assumptions made. New and existing systems present challenges unique to each, with existing installations, that have not been maintained, posing the biggest challenge.

Existing facilities may need to receive a walk down of the facility to update or verify one-line diagrams. New facilities under construction may go through study phases; the first of which is based upon many conservative assumptions until as-built drawings are obtained after the construction is complete.

Step 2: Operation modes. Once the system configuration is understood, one-line diagrams are updated and accurate, a review must be made to determine the various power distribution system configurations that will impact the available fault currents.

Examples of the varying configurations include:

- Number of utility feeders that are, or could be, in and out of service
- Unit substations that can be supplied by one or two primary feeders
- MCCs with more than one feeder having the ability to energize one or two feeders
- Large motors that may or may not be running during fault conditions
- Generators running in parallel with the utility supply ,or in standby.

Step 3: Fault current study. The fault current study is critical to the incident energy calculation (Ref. 4.1). This fault study must include both maximum and minimum expected fault currents at each major piece of electrical distribution equipment. When performing incident energy calculations, minimum fault currents (when no motors are connected as an example) could result in higher incident energy values due to longer clearing times at lower fault currents.

Step 4: Coordination study. The coordination study is critical because arcing fault current clearing times are determined by comparing the arcing currents with the TCC curves of the OCPDs in the system. The TCC curve is selected as part of the selective coordination study.

Note: Steps 5, 6 and 7 reference IEEE 1584-2002 and system limitations covering:

- 0.208 kV to 15 kV, three-phase
- 50 Hz to 60 Hz
- 700 A to 106,000 A available short-circuit current
- 13 mm to 152 mm conductor gaps

Step 5: Calculating arcing currents. Arcing currents are calculated based on the equations of IEEE 1584-2002, "IEEE Guide for Performing Arc-Flash Hazard Calculations". The total arcing current at each piece of equipment must be determined, as well as the arcing current level that passes through the upstream OCPD. The total arcing current is used to calculate the incident energy. The arcing current that will pass through the upstream OCPD is used to determine that upstream device's clearing time.

Step 6: Calculating incident energy. Equations available from IEEE 1584-2002 are used with the assembled information. Multiple calculations are made for the various identified power system configurations to determine which configuration provides the highest calculated incident energy. The calculated incident energy will depend upon voltage, equipment type and working distances.

Step 7: Determine flash-protection boundary. The flash-protection boundary is determined through iterative calculations based on the same equations used to calculate incident energy. The iterations are designed to determine the distance from the arcing source at which the onset of a second degree burn could occur. Most programs include the flash-protection boundary based on an incident energy of 5.0 J/cm² (1.2 cal/cm²). To convert from J/cm² to cal/cm² divide J/cm² by 4.184.

4.3.2 Arcing current

Arcing current is a fault current flowing through an electrical arc plasma. This is commonly referred to as arc fault current and/or arc current. Once the three-phase arcing current is calculated, the operating time for the OCPDs at that arcing current can be determined for incident energy calculations.

The equations for the arcing current are based on actual test data. Lab testing was conducted under specific conditions with critical data points recorded. Equation derivations were made to mathematically replicate what was witnessed in the lab. The following includes the equations for calculating arcing current.

4.3.2.1 System voltage under 1000 V

This is the equation to use for applications where system voltage is less than 1000 V:

$$I_g I_a = K + (0.662) (I_g) (I_{bf}) + (0.0966) (V) + (0.000526) (G) + (0.5588) (V) (I_g) (I_{bf}) - 0.00304 (G) (I_g) (I_{bf})$$

Where:

I_g = The log10

I_a = Arcing current (kA)

K = -0.153 for open configurations, or -0.097 for enclosed equipment

I_{bf} = Bolted fault current for three-phase faults (RMS Sym.) (kA)

V = System voltage (kV)

G = The gap between conductors, in millimeters, see Table 4.3.2.1.a

System voltage (kV)	Equipment type	"G" typical conductor gap (mm)	Distance "x" factor (mm)
0.208 to 1	Open air	10-40	2.000
	Switchgear	32	1.473
	MCCs and panels	25	1.641
	Cable	13	2.000
>1 to 5	Open air	102	2.000
	Switchgear	13-102	0.973
	Cable	13	2.000
>5 to 15	Open air	13-153	2.000
	Switchgear	153	0.973
	Cable	13	2.000

Table 4.3.2.1.a

4.3.2.2 System voltage 1000 V to 15 kV

This is the equation to use for applications where system voltage is 1000 V to 15 kV:

$$I_g I_a = 0.00402 + 0.983 (I_g I_{bf})$$

There aren't any box configuration specifications when applying the high voltage equations to determine arcing current.

To arrive at I_a , the log10 must be addressed and the following equation used:

$$I_a = 10^{I_g} I_a$$

IEEE 1584-2002 also advises that two arcing current values are to be calculated in preparation for the calculating two incident energy values based on both of these arcing currents' clearing time. The second arcing current calculation is 85% of the original calculation's arcing current.

The reason for the second arcing current calculation is due to the OCPD trip curve characteristics. Depending where on the curve the arcing current lies, small changes in arcing current can cause a large increase in clearing time which will have a very big impact on incident energy.



4.3.3 Incident energy

Once the arcing current has been determined and the coordination study or TCC curve is obtained, the input information for the incident energy equations is available for calculating incident energy.

Incident energy is defined by IEEE 1584-2002 as: "The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is measured in joules per centimeter squared (J/cm²). To convert from J/cm² to cal/cm² one must divide J/cm² by 4.184.

Calculating incident energy is a three-step process. The first is to calculate the log₁₀ of incident energy normalized for a 0.2 second arc clearing time at a 610 mm working distance. The next step is to convert the Log 10 to an incident energy value. The final step is an equation that considers the arcing current's actual clearing time, working distance and other variables.

4.3.3.1 Step 1: Normalized equation

$$I_g E_n = K_1 + K_2 + 1.081 I_g I_a + 0.0011 G$$

Where:

E_n = Incident energy in Joules/cm² normalized for time and distance

K_1 = -0.792 for open configurations, or -0.555 for enclosed equipment

K_2 = 0 for ungrounded and high resistance grounded systems, or -0.113 for grounded systems

G = The gap between conductors which is dependent upon the equipment type being applied

4.3.3.2 Step 2: Converting from log₁₀

Use the following equation to convert from the LOG base and provide an energy value used in the next step.

$$E_n = 10^{I_g E_n}$$

Where $I_g E_n$ is the calculated value from Section 4.3.3.1.

4.3.3.3 Step 3: Calculating incident energy

The final step in the process is to actually calculate the incident energy value based on more detailed parameters specific to the application, using this equation:

$$E = C_f E_n \left(\frac{t}{0.2} \right) \left(\frac{610}{D} \right)^2 \text{ cal/cm}^2$$

Where:

E = Incident energy (cal/cm²)

C_f = A constant, 1.0 for voltage above 1 kV and 1.5 for voltage at or below 1000 volts

E_n = Normalized incident energy calculated as part of 4.3.3.2

t = Arcing time in seconds determined from the upstream OCPD's TCC curve

D = Working distance from the arcing point to the person, in mm

The parameter "D" is the working distance from the arcing point to the person measured in millimeters. Typical working distances are shown in the following table. Working distance accounts for the distance between the worker and the arc source.

Equipment class	"D" (mm)
15 kV switchgear	910
5 kV switchgear	910
Low voltage switchgear	610
Low voltage MCCs and panelboards	455
Cable	455
Other	To be determined in field

Table 4.3.3.3a

x = A distance value dependent upon the equipment type

The parameter "x" accounts for the gaps between buses in the panel. The equipment's construction plays a role in the incident energy amount that can be expected. Typical gaps to be used for the "x" value in the equation can be obtained from table 4.3.2.1.a.

4.3.4 Fuse equations

Equations have been developed to calculate incident energy when the arcing currents are in the specific fuse's current limiting region. These formulae were developed based upon testing at 600 V and a 455 mm distance using one manufacturer's fuses.

The common variables included in these equations are:

- I_{bf} is bolted fault current for three-phase faults (kA RMS Sym.)
- E is incident energy (cal/cm²)

The equations for each fuse class and size can only be used in the current ranges specified for each. Incident energy for currents outside the specified ranges must be calculated as per 4.3.3.

Class L and RK1 fuse incident energy equations

Bolted fault current range (kA)	Incident energy cal/cm ²
Class L 1601-2000 A	
$22.6 \leq I_{bf} \leq 65.9$	$-0.1284 I_{bf} + 32.262$
$65.9 < I_{bf} \leq 106$	$-0.5177 I_{bf} + 57.917$
Class L 1201-1600 A	
$15.7 \leq I_{bf} \leq 31.8$	$-0.1863 I_{bf} + 27.926$
$31.8 < I_{bf} < 44.1$	$-1.5504 I_{bf} + 71.303$
$44.1 \leq I_{bf} \leq 65.9$	2.9398
$65.9 < I_{bf} \leq 106$	$-0.0631 I_{bf} + 7.0878$
Class L 801-1200 A	
$15.7 \leq I_{bf} \leq 22.6$	$-0.1928 I_{bf} + 14.226$
$22.6 < I_{bf} \leq 44.1$	$0.0143 I_{bf}^2 - 1.3919 I_{bf} + 34.045$
$44.1 < I_{bf} \leq 106$	0.3896
Class L 601-800 A	
$15.7 \leq I_{bf} \leq 44.1$	$-0.0601 I_{bf} + 2.8992$
$44.1 < I_{bf} \leq 106$	0.25
Class RK1 401-600 A	
$8.5 \leq I_{bf} \leq 14$	$-3.0545 I_{bf} + 43.364$
$14 < I_{bf} \leq 15.7$	0.599
$15.7 < I_{bf} \leq 22.6$	$-0.0507 I_{bf} + 1.3964$
$22.6 < I_{bf} \leq 106$	0.25
Class RK1 201-400 A	
$3.16 \leq I_{bf} \leq 5.04$	$-19.053 I_{bf} + 96.808$
$5.04 < I_{bf} \leq 22.6$	$-0.0302 I_{bf} + 0.9321$
$22.6 < I_{bf} \leq 106$	0.25
Class RK1 101 A—200 A	
$1.16 \leq I_{bf} \leq 1.60$	$-18.409 I_{bf} + 36.355$
$1.60 < I_{bf} \leq 3.16$	$-4.2628 I_{bf} + 13.721$
$3.16 < I_{bf} \leq 106$	0.25
Class RK1 up to 100 A	
$0.65 \leq I_{bf} \leq 1.16$	$-11.176 I_{bf} + 13.565$
$1.16 < I_{bf} \leq 1.40$	$-1.4583 I_{bf} + 2.2917$
$1.40 < I_{bf} \leq 106$	0.25

4.3.4.1. Arc flash incident energy table

The incident energy table in this section can be used to determine incident energy let-through for current-limiting fuses. The data points within this table are based upon the equations above and the following assumptions:

- Electrode spacing: 32 mm (1-1/4")
- Enclosure: 20" x 20" x 20" box
- 600 V, 3 Ø ungrounded system
- Working distance: 18"
- Arc flash boundary is based on 1.2 cal/cm², the threshold for a second-degree "just curable" burn

The data is based upon tests conducted at various fault currents for each Bussmann series Low-Peak KRP-C-SP and LPS-RK-SP fuse in the table. These tests were used to develop the formulas as shown in NFPA 70E Annex D.7.6 and 2002 IEEE 1584. Actual results from incidents could be different for the following reasons:

- System voltage
- Short-circuit power factor
- Distance from the arc
- Arc gap
- Enclosure size
- Fuse manufacturer
- Fuse class
- Orientation of the worker
- Grounding scheme
- Electrode orientation

100 A LPS-RK-SP fuses were the smallest fuses tested. Data for smaller fuses is based upon the 100 A data. Arc flash values for actual 30 and 60 A fuses would be considerably less than 100 A fuses. However, it does not matter since the values for the 100 A fuses are already so low.

The fuse incident energy values were chosen not to go below 0.25 cal/cm², even though many actual values were below 0.25 cal/cm². This was chosen to keep from encouraging work on energized equipment without PPE because of a low AFB.

This arc flash incident energy table can also be used for LPJ-SP, TCF, FCF, JJS and LP-CC fuses to determine the available incident energy and AFB.

These values from fuse tests take into account the translation from available 3-phase bolted fault current to the arcing fault current.

To determine the AFB and incident energy for applications with other fuses, use the basic equations in 2002 IEEE 1584 or NFPA 70E Annex D.7.

Where the arcing current is less than the fuse's current-limiting range when calculated per NFPA 70E Annex D.7.6, and 2002 IEEE 1584, the value for incident energy is given as >100 cal/cm². For the incident energy and arc flash boundary in these cases, use 2002 IEEE 1584 basic equation methods with the fuse time-current curve.

The steps necessary to conduct an arc flash hazard analysis using this table are:

1. Determine the available bolted fault current on the lineside terminals of the equipment that will be worked upon.
2. Identify the amp rating of the upstream Low-Peak fuse that's protecting the equipment where work is to be performed.
3. Consult the table to determine the incident energy exposure and the arc flash boundary (AFB).
4. Identify the minimum requirements for PPE when work is to be performed inside the AFB by consulting the requirements found in NFPA 70E.



Bolted fault current (kA)	1-100 A		101-200 A		201-400 A		401-600 A		601-800 A		801-1200 A		1201-1600 A		1601-2000 A	
	IE	AFB	IE	AFB	IE	AFB	IE	AFB	IE	AFB	IE	AFB	IE	AFB	IE	AFB
1	2.39	29	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
2	0.25	6	5.20	49	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
3	0.25	6	0.93	15	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
4	0.25	6	0.25	6	20.60	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
5	0.25	6	0.25	6	1.54	21	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
6	0.25	6	0.25	6	0.75	13	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
8	0.25	6	0.25	6	0.69	12	36.85	>120	>100	>120	>100	>120	>100	>120	>100	>120
10	0.25	6	0.25	6	0.63	12	12.82	90	75.44	>120	>100	>120	>100	>120	>100	>120
12	0.25	6	0.25	6	0.57	11	6.71	58	49.66	>120	73.59	>120	>100	>120	>100	>120
14	0.25	6	0.25	6	0.51	10	0.60	11	23.87	>120	39.87	>120	>100	>120	>100	>120
16	0.25	6	0.25	6	0.45	9	0.59	11	1.94	25	11.14	82	24.95	>120	>100	>120
18	0.25	6	0.25	6	0.39	8	0.48	10	1.82	24	10.76	80	24.57	>120	>100	>120
20	0.25	6	0.25	6	0.33	7	0.38	8	1.70	23	10.37	78	24.20	>120	>100	>120
22	0.25	6	0.25	6	0.27	7	0.28	7	1.58	22	9.98	76	23.83	>120	>100	>120
24	0.25	6	0.25	6	0.25	6	0.25	6	1.46	21	8.88	70	23.45	>120	29.18	>120
26	0.25	6	0.25	6	0.25	6	0.25	6	1.34	19	7.52	63	23.08	>120	28.92	>120
28	0.25	6	0.25	6	0.25	6	0.25	6	1.22	18	6.28	55	22.71	>120	28.67	>120
30	0.25	6	0.25	6	0.25	6	0.25	6	1.10	17	5.16	48	22.34	>120	28.41	>120
32	0.25	6	0.25	6	0.25	6	0.25	6	0.98	16	4.15	42	21.69	>120	28.15	>120
34	0.25	6	0.25	6	0.25	6	0.25	6	0.86	14	3.25	35	18.58	116	27.90	>120
36	0.25	6	0.25	6	0.25	6	0.25	6	0.74	13	2.47	29	15.49	102	27.64	>120
38	0.25	6	0.25	6	0.25	6	0.25	6	0.62	11	1.80	24	12.39	88	27.38	>120
40	0.25	6	0.25	6	0.25	6	0.25	6	0.50	10	1.25	18	9.29	72	27.13	>120
42	0.25	6	0.25	6	0.25	6	0.25	6	0.38	8	0.81	14	6.19	55	26.87	>120
44	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.49	10	3.09	34	26.61	>120
46	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.36	>120
48	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.10	>120
50	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.84	>120
52	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.59	>120
54	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.33	>120
56	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.07	>120
58	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.81	>120
60	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.56	>120
62	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.30	>120
64	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.04	>120
66	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.92	33	23.75	>120
68	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.80	32	22.71	>120
70	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.67	31	21.68	>120
72	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.54	30	20.64	>120
74	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.42	29	19.61	120
76	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.29	28	18.57	116
78	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.17	27	17.54	111
80	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.04	26	16.50	107
82	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.91	25	15.47	102
84	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.79	24	14.43	97
86	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.66	22	13.39	93
88	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.54	21	12.36	88
90	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.41	20	11.32	83
92	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.28	19	10.29	77
94	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.16	18	9.25	72
96	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.03	16	8.22	66
98	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.90	15	7.18	61
100	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.78	13	6.15	55
102	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.65	12	5.11	48
104	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.53	10	4.08	41
106	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.40	9	3.04	34

Table 4.3.4.1.a Arc flash incident energy table*.

* Bussmann series 1-600 A Low-Peak LPS-RK-SP fuses and 601-2000 A Low-Peak KRP-C-SP fuses, Incident Energy (IE) values expressed in cal/cm², Arc Flash Boundary (AFB) expressed in inches.

4.3.5 Circuit breaker example

An electrical panel is supplied from a 1200 A circuit breaker with the TCC curve shown in Figure 4.3.5.a. The available fault current at the downstream electrical panel is 51,907 A. The system is a solidly grounded system and the enclosure to be labeled is a 208 V panelboard. Determine the incident energy label for this service entrance equipment.

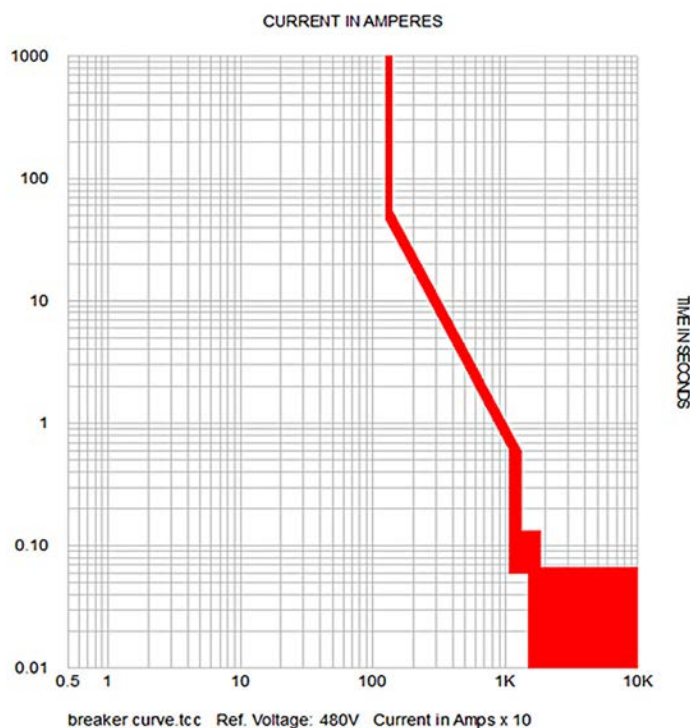


Figure 4.3.5.a

The arcing current is the first value to calculate. The variables to use in the equation of 4.3.2.1 include:

$K = -0.097$ as this is a panelboard

$I_{bf} = 51.97$ kA as defined in the problem statement

$V = 0.208$ V

$G = 25$ mm as obtained from Table 4.3.2.1.a

$I_g I_a = -0.097 + (0.662) (I_g 51.97) + (0.0966) (0.208) + (0.000526) (25) + (0.5588) (0.208) (I_g 51.97) - 0.00304 (25) (I_g 51.97)$

$I_g I_a = 1.1411$

$I_a = 10^{1.1411}$

$I_a = 13.84$ kA

85 percent of the calculated arcing current provides the second arcing current value to be considered when calculating incident energy.

$I_a (85\%) = 0.85 \times 13.84 = 11.76$ kA

Incident energy calculation

Step 1: The variables to use in the equation from section 4.3.3.1 include:

$I_a = 11.76$ kA and 13.84 kA. Two incident energy values will be calculated

$K_1 = -0.555$ for enclosed equipment (this is panelboard application)

$K_2 = -0.113$ as this example has a solidly grounded system

$G = 25$ as the gap determined as per Table 4.3.2.1.a for panelboards

The equation of 4.3.3.1 is solved as follows for each value of I_a :

For $I_a = 13.84$ kA:

$$I_g E_n = (-0.555) + (-0.113) + 1.081 (I_g 13.84) + (0.0011) (25)$$

$$I_g E_n = 0.5931$$

For $I_a = 11.76$ kA:

$$I_g E_n = (-0.555) + (-0.113) + 1.081 (I_g 11.76) + (0.0011) (25)$$

$$I_g E_n = 0.5166$$

Step 2: The previous values of $I_g E_n$ for both values of I_a are converted from log10 base as:

For $I_a = 13.84$ kA:

$$E_n = 10^{0.5931}$$

$$E_n = 3.918$$

For $I_a = 11.76$ kA:

$$E_n = 10^{0.5166}$$

$$E_n = 3.2856$$

Step 3: This calculation is done in two parts for both arcing current values. The information that must first be determined includes the OCPD's clearing time based upon each arcing current value. The TCC curve in Figure 4.3.5.a is used to determine the clearing times.

The clearing times for each arcing current value is taken by following the X-axis in Figure 4.3.5.a up to where the circuit breaker curve's top band is intersected and then following it left on the Y-axis to determine the time in seconds. This is an approximation process with more precise results obtainable using a software application.

Arcing current (kA)	E_n	t (seconds)
13.84	3.918	0.6
11.76	3.2856	0.85

Table 4.3.5.b

The following equation for incident energy from 4.3.3.3 is used for the arcing currents and clearing times shown in the table above:

$$E = C_f E_n \left(\frac{t}{0.2} \right) \left(\frac{610^x}{D^x} \right)$$

Where:

$C_f = 1.5$ (this equipment's voltage is below 1 kV)

$E_n = 3.918$ and 3.2856 (from Table 4.3.5.b)

$t = 0.6$ and 0.85 (from Table 4.3.5.b)

$D = 455$ mm (from Table 4.3.3.3.a, this equipment is a panelboard)

$x = 1.641$ (from Table 4.3.2.1.a, this equipment is a panelboard)

For the 11.76 kA arcing current:

$$E = 1.5 \times 3.2856 \times \left(\frac{0.85}{0.2} \right) \times \left(\frac{610^{1.641}}{455^{1.641}} \right)$$

$$E = 33.89 \text{ cal/cm}^2$$

For the 13.84 kA arcing current:

$$E = 1.5 \times 3.918 \times \left(\frac{0.6}{0.2}\right) \times \left(\frac{610^{1.641}}{455^{1.641}}\right)$$

$$E = 28.5237 \text{ cal/cm}^2$$

The higher incident energy is calculated from the lower arcing fault current. For this application the label incident energy should be 33.89 cal/cm².

4.3.6 Fuse example

The following is a simple method when using certain Bussmann series fuses and based on actual data from arcing fault tests (and resulting simplified formulas shown in 2018 NFPA 70E Annex D.4.6 and IEEE 1584-2002) with Bussmann series current-limiting fuses. Using this simple method, the first thing is to determine the incident energy exposure. This process is simplified when using Low-Peak LPS-RK-SP, LPJ-SP, TCF, LP-CC or KRP-C-SP fuses or JJS Limitron and Class CF FCF fuses. In some cases the results are conservative.

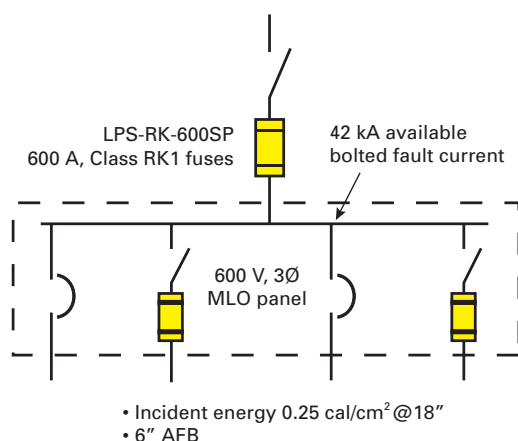


Figure 4.3.6.a

In this example, the lineside OCPD in Figure 4.3.6.a is a Low-Peak LPS-RK-600SP current-limiting fuse. Simply take the available 3 Ø bolted fault current at the panel, in this case 42,000 A, and locate it on the vertical column in the arc flash incident energy Table 4.3.4.1.a. Then proceed directly to the right to the 401-600 A fuse column and identify the IE (Incident Energy) and AFB (Arc Flash Boundary).

With 42 kA of 3 Ø bolted available fault current, Table 4.3.4.1.a shows that when relying on the Low-Peak LPS-RK-600SP fuse to interrupt an arcing fault, the incident energy is 0.25 cal/cm². Notice the variables required are the available 3 Ø bolted fault current and the Low-Peak current-limiting fuse's amp rating (see 4.3.4.1.).

The next step in this simplified arc flash hazard analysis is to determine the AFB. With an incident energy of 0.25 cal/cm² and using the same table, the AFB is approximately 6 inches, which is found next to the incident energy value previously located (see 4.3.4.1.). This AFB distance means that anytime work is performed inside this distance, including voltage testing to verify that the panel is de-energized, the worker must wear the appropriate PPE.

The last step in the arc flash hazard analysis is to determine the appropriate PPE. To select the proper PPE, utilize the incident energy exposure values and the requirements from NFPA 70E. NFPA 70E 130.7(C)(1) through (C)(16) for the PPE level based upon the incident energy. The 2018 NFPA 70E Annex H is a resource for guidance in selecting PPE, specifically Tables H.3(a) and (b).

When selecting PPE, keep in mind that the requirements from NFPA 70E are minimum requirements. Having additional PPE, above what is required, can further assist in minimizing an arc flash incident's affects. Another thing to keep in mind is that PPE available on the market today does not protect a person from the pressures, shrapnel and toxic gases that can result from an arc-blast (referred to as "physical trauma" in NFPA 70E). Existing PPE is only tested to minimize the potential for burns from the arc flash.

This information is not to be used as a recommendation to work on energized equipment. This information is to help assist in determining the PPE to help safeguard a worker from the burns that can be sustained from an arc flash incident. This information does not take into account the effects of pressure, shrapnel, molten metal spray or the toxic vapor resulting from an arc-fault. This information does not address the maintenance conditions of the overcurrent protective device.

This data is based upon the simplified fuse formulas in NFPA 70E Annex D.4.6 and 2002 IEEE 1584 guide for arc flash hazard analysis.

For a more complete presentation on this subject, see Section 3.1.5.3 "The OCPD's role in electrical safety."



5 Maintenance

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5.1 Overview

Overcurrent protection is similar to auto insurance. When a person buys auto insurance, they hope they never have to submit an accident claim. Should they have a major accident, they're grateful the insurance company financially protects them. The insurance for electrical systems and equipment are overcurrent protective devices (OCPDs), which are intended to protect against overload and short-circuit (fault) conditions that may arise. People install OCPDs hoping there will never be an overcurrent condition requiring them to open — especially due to a fault.

NFPA 70E 225.3 has a very specific requirement pertaining to fault currents and circuits breakers. It reads:

"225.3 Circuit Breaker Testing After Electrical Faults.

Circuit breakers that interrupt faults approaching their interrupting ratings shall be inspected and tested in accordance with the manufacturer's instructions."

Should an overcurrent event occur, the OCPD needs to operate as originally specified. If the OCPD does not operate as fast as it should, or fails to operate, the OCPD investment is nullified and property damage, lost business time/production, and possible harm to property and people can occur. In addition, arc flash mitigation for electrical safe work practices typically relies on overcurrent protective devices operating as intended.

Reliability may be the most important criteria for OCPD type evaluation and selection. What good is an OCPD that may not function, or not function properly, when needed? For a particular circuit, an overcurrent event that must be cleared by the OCPD can occur from the day it's installed, to decades later, or never. Whether a 1000 A or a 20 A circuit, the OCPD reliability is important for fire safety, life safety, and worker safety.

In the design stage, OCPD maintenance should be considered and recommendations made to the owner on the necessary periodic inspections, testing, maintenance and documentation over the electrical system's life-cycle.

Modern current-limiting fuses are inherently reliable in terms of overcurrent interruption over the product's life, with life cycle maintenance requirements a primary consideration when deciding whether to use fuses.

The NEC is predominantly an installation standard and has few OCPD maintenance requirements. However, the NEC recognizes that proper installation alone is not adequate for safety; maintenance during the system's life is also necessary.

NEC 90.1(B) Adequacy — This contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard, but not necessarily efficient, convenient, or adequate for good service or electrical system's future expansion.

NFPA 70E-2018 Standard for Electrical Safety in the Workplace does have OCPD maintenance requirements. A few important requirements are:

130.5(B) Estimate of Likelihood and Severity — The estimate of the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health shall take into consideration the following:

- (1) The design of the electrical equipment, including its overcurrent protective device and its operating time.
- (2) The electrical equipment operating condition and condition of maintenance.

IN No. 1 — Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

205.4 General Maintenance Requirements — Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards. Maintenance, tests, and inspections shall be documented.

210.5 Protective Devices — Protective devices shall be maintained to adequately withstand or interrupt available fault current..

IN — Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

5.2 Maintenance frequency and procedures

Important OCPD decision factors include reliability, maintenance frequency and procedures, and cost (including downtime) required to retain the original specified protection level.

The best sources for OCPD maintenance frequency, necessary tests and specific methods include OCPD manufacturer's instructions, NFPA 70B-2016 Recommended Practice for Electrical Equipment Maintenance, and ANSI/NETA MTS-2015, Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems.

NFPA 70B provides maintenance frequency guidelines, as well as guidelines for setting up an electrical preventative maintenance (EPM) program, including sample forms and requirements for electrical system maintenance. ANSI/NETA MTS-2015 is more prescriptive about what maintenance and testing is required for electrical power system devices and equipment. Visual, mechanical, and electrical inspections and tests are specified by equipment type, as well as what results are acceptable. This standard includes guidelines for maintenance frequency required for electrical system power equipment in Appendix B, Frequency of Maintenance Tests.



2016 NFPA 70B OCPD Frequency of Maintenance

The complete NFPA 70B text has more comprehensive practices and annex information than shown here. This is merely a representation of what's provided by NFPA 70B. NFPA 70B stresses that for specific situations the frequency of maintenance is dependent upon many variables such as environmental conditions and operating conditions.

11.4 Frequency of Tests — Most routine testing can best be performed concurrently with routine preventive maintenance, because a single outage will serve both procedures. For that reason, the testing frequency generally coincides with maintenance frequency. The optimum cycle depends on the use to which the equipment is put, and the equipment's operating and environmental conditions. In general, this frequency can range from six (6) months to three (3) years, depending on conditions and equipment use. The difficulty in scheduling an outage for testing and maintenance should never be a factor in performing these two vital procedures. Equipment for which an outage is difficult to obtain is usually the most vital equipment in the electrical system's operation. Consequently, this "equipment failure" would most likely create the most problems relative to continued system operation. In addition to routine testing, tests should be performed any time equipment has been subjected to conditions that could possibly cause it to be unable to continue performing its design function properly.

Below are considerations for low-voltage fuses.

Annex L Maintenance Intervals (partial extract)

Item/equipment	Task/function	Interval	Reference
Fuses, 1000 V or less			
Fuse terminals and fuseclips	Visual inspection/clean	3 years	18.1.2
	Clip contact pressure	3 years	18.1.3
	Cleaning of contact surfaces	3-5 years	18.1.3
Fuses	Visual inspection for discoloration and damage	3 years	18.1.3

18.1.2 Inspection — Fuse terminals and fuseclips should be examined for discoloration caused by heat from poor contact or corrosion. Early detection of overheating is possible through the use of infrared examination. If evidence of overheating exists, the cause should be determined.

18.1.3 Cleaning and Servicing — The power source to fuse holders should be disconnected before servicing. All fuse holder connections should be tightened. All connections to specifications should be torqued where available. Fuseclips should be checked to ascertain that they exert sufficient pressure to maintain good contact. Clips making poor contact should be replaced or clip clamps used. Contact surfaces of fuse terminals and clips that have become corroded or oxidized should be cleaned. Silver-plated surfaces should not be abraded. Contact surfaces should be wiped with a noncorrosive cleaning agent. Fuses showing signs of deterioration, such as discolored or damaged casings or loose terminals, should be replaced.

5.3 MCCB maintenance example

This example uses ANSI/NETA MTS-2011 Appendix B: Frequency of Maintenance Tests tables. Assume a molded case circuit breaker (MCCB) in average condition. The condition has been established by prior maintenance, retaining records, and trending the data. Since workers rely on this circuit breaker for arc flash protection, "high reliability" is desired. Referencing the Maintenance Frequency Matrix (shown in reprinted ANSI/NETA MTS table) using average condition and high reliability, results in a 0.50 multiplier. Then referencing the Inspections and Tests, Frequency in Months table for a molded case circuit breaker (left Section column denoted as 7.6.1.1) the following are

prescribed frequencies for inspections and tests: visual every one (1) month; visual and mechanical every 12 months; and visual, mechanical and electrical every 36 months. Then, the 0.50 multiplier is applied to these with these results:

- Visual — every two weeks
- Visual and mechanical — every six months
- Visual, mechanical and electrical — every 18 months

ANSI/NETA MTS-2011 in Section 7.6.1.1 Circuit Breaker

Air, Insulated-Case/Molded Case provides lists of prescribed inspections and test procedures including references to tables in the standard with acceptable test values. Item five of nine in the visual and mechanical inspection list is "Operate the circuit breaker to insure smooth operation," which is a procedure to exercise the circuit breaker. There is a list of thirteen electrical tests procedures which are reprinted below.

ANSI/NETA-2011 Section 7.6.1.1

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.1.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
4. (Optional) Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts DC for 300-volt rated cable and 1000 volts DC for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
5. Determine long-time pickup and delay by primary current injection.
6. Determine short-time pickup and delay by primary current injection.
7. Determine ground-fault pickup delay by primary current injection.
8. Determine instantaneous pickup current by primary injection.
9. (Optional) Test functions of the trip unit by means of secondary injection.
10. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 100.20.
11. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, ant pump function, and trip unit battery condition.
12. Reset all trip logs and indicators.
13. Verify operation of charging mechanism.

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5.4 Circuit breaker testing considerations

Maintenance files should be kept, and record the "as found" condition/performance and the "as left" condition/performance, as well as key trending data. Over time, these maintenance files and trending data will often indicate when a circuit breaker's declining and needs replacement. Low voltage power circuit breakers are designed to be reconditioned, if necessary. Molded case and insulated case circuit breakers are not intended to be internally examined and maintained/reconditioned. Instead a replacement device should be supplied if they are shown to be out of calibration or inoperative. Circuit breaker testing, maintenance and reconditioning should be performed by persons qualified for this work. Circuit breaker testing equipment is available in the market as well as companies that specialize in testing and maintenance, and reconditioning circuit breakers and other components.



Bussmann™ series clip clamps can be used to help restore fuse contact weakened fuseclips.

5.5 OCPD servicing and maintenance

NFPA 70B-2016 has guidelines for testing fuses:

21.18.1 — Fuses can be tested with a continuity tester to verify that the fuse is not open. Resistance readings can be taken using a sensitive 4 wire instrument such as a Kelvin bridge or micro-ohmmeter. Fuse resistance values should be compared against values recommended by the manufacturer.

21.18.2 — Where manufacturer's data is not readily available, resistance deviations of more than 15 percent for identical fuses in the same circuit should be investigated.

Normally on low voltage systems, a simple fuse continuity test is sufficient. Low resistance denotes a fuse is good and extremely high resistance indicates a fuse is open and needs replacing. For some applications, such as high speed fuses used in large power electronic applications and medium voltage fuse applications, maintenance contractors performing periodic shut down maintenance often will check the fuses' resistance. This requires using sensitive resistance measurement instruments such as a Kelvin bridge or micro-ohmmeter.

5.6 Testing knifeblade fuses

Contrary to popular belief, fuse manufacturers do not generally design their knifeblade fuses to have electrically energized fuse caps during normal fuse operation. The caps' electrical inclusion into the circuit results from the coincidental mechanical contact between the fuse cap and terminal extending through it. In most knifeblade fuse brands, this mechanical contact is not guaranteed; therefore, electrical contact is not guaranteed. Thus, a resistance reading or voltage measurement taken across the fuse caps does not indicate whether or not the fuse is open.

In an effort to promote safer work environments, Bussmann series Fusetron (Class RK5) and Low-Peak (Class RK1) knifeblade fuses feature insulated end caps to reduce the possibility of accidental contact with a live part (see Figure 5.6.a). With these fuses, the informed electrician knows that the end caps are isolated. With older style knifeblade fuses, with non-insulated end caps, the electrician using the caps for testing doesn't really know if the fuse is energized or not.



Figure 5.6.a

5.7 After an OCPD opens

Other important considerations for selecting the OCPD type is servicing and trouble shooting. This is an area where misinformation exists and often, a lack of proper safe work practices.

When an OCPD device opens due to a fault, OSHA and NFPA 70E do not permit circuit breakers to be re-closed or fuses to be replaced until it is safe to do so.

2018 NFPA 70E 130.6(M) and OSHA 1910.334(b)(2)* Re-closing Circuits After Protective Device Operation

After a circuit is de-energized by the automatic operation of a circuit protective device, the circuit shall not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or re-energizing circuits through replaced fuses shall be prohibited. When it is determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, examination of the circuit or connected equipment shall not be required before the circuit is re-energized.

* Shown is wording from 2018 NFPA 70E. The OSHA wording is different, but has the same meaning.

This is an important safety practice. If an OCPD opened under a fault condition, damage may have resulted. If the fault's cause is not identified and rectified, re-energizing the circuit again into the fault condition might result in an even more severe fault event than the first.

What constitutes "can be safely energized?" First, ensuring the fault's cause has been properly repaired, but that is not sufficient. When fault current flows through the distribution system to the fault's location, damage to circuit components carrying the fault can occur. Inspect and test the circuit to ensure that the fault current did not damage circuit components that now are or soon could be the source of another fault. If all the components check out as in good condition, the circuit may still not be safely re-energize. The OCPD(s) must be verified as safe to re-energize. New fuses of the proper type and amp rating must be inserted and the circuit re-energized by closing the disconnect.

A continuity test across any knifeblade fuse should be taken ONLY across the fuse blades.

Do NOT test a knifeblade fuse with meter probes to the fuse caps.

5.8 Calibration decal on equipment

A best practice after conducting periodic maintenance, or maintenance after fault interruption on OCPDs is to apply a decal on the equipment's outside. The decal is color coded and can be an aid for hazard identification and risk assessment for electrical safety. NFPA 70B Recommended Practice for Electrical Equipment Maintenance makes this recommendation in 11.27 Test or Calibration Decal System.

See Figures 5.8.a to 5.8.c for a decal system example. This maintenance decal system complies with NFPA 70B 11.27. After the technician performs inspections and tests, and, if necessary, remedial measures, one of three color coded decals is affixed to the equipment.

The decal and test records can communicate the OCPD's condition of maintenance. This is especially important for arc flash risk assessment. For instance, NFPA 70E 130.5 Arc Flash Risk Assessment requires the OCPD's design, opening time and condition of maintenance be considered. When an OCPD is not properly maintained and an arcing fault occurs, the resulting arc flash incident energy may be much greater than calculated because the OCPD is not clearing the arcing current in the time indicated by its published data. The possible result: a worker is wearing PPE with a certain arc rating based on an incident energy calculation, but the arc flash incident energy is actually much greater than calculated.

TESTED	
Project No.:	_____
Test Date:	_____
Tested By:	_____ (Technician)
	_____ (Company)

Figure 5.8.a White decal communicates the OCPD is electrically and mechanically acceptable, and it should perform to the manufacturer's original specification.

LIMITED SERVICE	
Project No.:	_____
Test Date:	_____
Tested By:	_____ (Technician)
	_____ (Company)

Figure 5.8.b Yellow decal communicates the OCPD may have minor deficiencies, but is electrically and mechanically acceptable. A trip indicator (indicating whether the overcurrent interrupted was an overload or fault) that does not function properly is an example of such a minor deficiency.

DEFECTIVE	
Project No.:	_____
Test Date:	_____
Tested By:	_____ (Technician)
	_____ (Company)

Figure 5.8.c Red decal communicates the OCPD has not passed one or more inspections, or tests and it is not suitable to be in service. Example deficiencies are failure to trip on calibration test or unacceptable high values during a contact resistance test.

The International Electrical Testing Association (NETA) has numerous articles and papers on this subject. The NETA contractors conduct maintenance on electrical equipment including OCPDs. For several years, the NETA has been surveying its members regarding equipment maintenance and associated reliability.

Pertinent quotes from NETA Maintenance Testing Research on Electrical Power System Equipment Performance, by Kerry Heid, Magna Electric Corporation and Ron Widup, Shermco Industries, 2012 PowerTest Conference:

"Surveys on electrical power distribution equipment and systems indicate a high number of equipment failures that directly impact personnel safety and intensify equipment damage."

"The 2008 paper focused on data obtained during electrical maintenance testing activities, indicating that 23% of service-aged electrical power systems equipment did not operate within the initial design parameters and 10.5% had serious issues affecting equipment performance and safety. These are alarming results when one considers that even a few milliseconds of operating lag in a power system protection scheme can mean drastic increases in energy levels released during a fault."

"In general terms of reliability, fuses were ranked as having the lowest failure rate with molded case breakers showing the highest level of failure rate amongst the survey participants. The survey indicated the following ranking for failures: molded-case or insulated-case breakers, low voltage air circuit breakers, medium-voltage relay breaker combo, and fuses."

"A few respondents indicate that a high amount of failures occur with breakers, particularly molded case breakers during acceptance testing. This is due to a number of factors such as operation, adjustment and settings issues typically found with circuit breakers."

Kerry Heid, Magna Electric Corporation, summarized the NETA 2008 survey results in Summer 2011 NETA World article, Survey Says! Maintenance is Critical as Part of Your Electrical Safety Program.

"A 2008 survey was conducted by NETA on the performance of electrical protective devices. A national survey of field performance on approximately 340,000 protective devices was reviewed, and the results of those findings are quite alarming."

"Based on the results of the survey, approximately 23 percent of the circuit breakers tested had an issue affecting the protective device operation. This data closely correlates with failure data presented in IEEE Std. 493-2007, Table 5-1 in the fair (18.1%) to poor (32.8%) maintenance quality category. With percentages in these ranges, approximately one in four of the devices in the field will not operate as indicated on the time current curves. The impact to personnel in the field is that in most cases incident energies will significantly increase due to the defective equipment."

"Another alarming statistic was the fact that on average 10.5 percent of the devices did not function at all when tested. This means that when overload or short-circuit current is applied to the device, it was found to be inoperable. If a fault were to occur, it would severely impact personnel safety when working on or near that particular piece of equipment. Of the units with issues affecting performance, 42.8 percent were mechanical issues, and 26.7 percent had issues related to electrical diagnostic testing. Lubrication issues were the predominant mechanical failure at 51.4 percent."



6 Electrical safe work practices

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6.1 Overview

There is a great deal of activity in the electrical industry concerning electrical safety. A culture change is underway and the electrical worker is at its center. Effectively implementing electrical safe work practices mandates that owners, employers and employees work together because safety is a shared responsibility. Electrical hazards include shock, arc flash and arc blast. Significant knowledge has been gained through testing and analysis concerning arc flash hazards. The 2018 edition of NFPA 70E, the “Standard for Electrical Safety in the Workplace,” is the foremost consensus standard on electrical safety. References to NFPA 70E are to the 2018 edition.

This standard was formed in 1976 when NFPA received a formal request from the Occupational Safety and Health Administration (OSHA). The request recognized the need for a consensus document to address electrical safe work practices that was fully compliant with the NEC. The committee on Electrical Safety Requirements for Employee Workplaces, NFPA 70E, was needed for a number of reasons, including:

- The NEC is an installation standard. OSHA addresses employee safety in the workplace through both installation requirements and safe work practices
- Most NEC sections do not relate directly to task-based worker safety
- Safety related work and maintenance practices are generally not covered, or not adequately covered, in the NEC
- A national consensus standard on electrical safety for workers did not exist, but was needed — an easy to understand document that addresses worker electrical safety

The first 1978 edition of NFPA 70E was published in 1979. In most cases, OSHA regulations can be viewed as the “Shall” and NFPA 70E as the “How.” In most cases, OSHA requirements are written in performance style while NFPA 70E is always written as prescriptive text. All OSHA requirements for electrical safe work practices are included in NFPA 70E. Compliance with 70E translates directly to compliance with OSHA, with NFPA 70E going beyond minimum OSHA compliance.

6.2 The electrical safety program

An employer must implement and document an overall electrical safety program that directs activity appropriate to the risk associated with electrical hazards. The electrical safety program, when a part of the employer’s overall occupational health and safety management system, is an important tool that’s helping change the industry’s safety culture.

NFPA 70E, through the requirements of 110.1, provides a detailed outline for this electrical safety plan covering:

- Inspection (110.1(B))
- Condition of maintenance (110.1(C))
- Awareness and self-discipline (110.1(D))
- Electrical safety program
- Principles (110.1(E))
 - Controls (110.1(F))
 - Procedures (110.1(G))
- Risk assessment procedure (110.1(H))
- Job Safety planning and job briefing (110.1(I))
- Incident investigations (110.1(J))
- Auditing (110.1(K))

Before work that involves exposure to electrical hazards is performed, a job safety plan must be completed. Before work is performed, all of the associated tasks with the job safety plan must be understood with an identification of shock and arc flash hazards. The tasks to be performed are reviewed to assess the risk involved with respect to the identified hazards. The next step is to implement risk control according to a hierarchy of risk control methods provided in section 110.1(H)(3). The hierarchy of risk control methods is comprised of six levels with the first being most effective and the last, least effective.

Hierarchy of Risk Control (110.1(H)(3) and information from Annex Table F.3) covers:

1. **Elimination** — creation of an electrically safe work condition
2. **Substitution** — reduce energy by using 24 volt control circuits instead of line voltage at 120, 277, etc.
3. **Engineering controls** — guarding of exposed energized conductors or circuit parts, remote switching, racking, etc.
4. **Awareness** — warning signs, identifying potential hazards
5. **Administrative controls** — verification of proper maintenance and installation, alerting techniques, auditing requirements, and training requirements
6. **PPE** — appropriate PPE used for shock and arc flash hazards

The first three steps (Elimination, Substitution, and Engineering controls) are considered to be the most effective methods for reducing risk because they are typically applied at the source of possible injury, or damage to health, and are **less likely** to be affected by human error.

The last three steps (Awareness, Administrative controls and PPE) are considered to be the least effective methods for reducing risk because they are not applied at the source of possible injury, or damage to health, and are **more likely** to be affected by human error.

The goal of NFPA 70E is to eliminate the hazard. The OSHA general industry standard was modified to parallel 70E requirements. Section 1910.333(a)(1) requires live parts to be de-energized before an employee works on or near them except for two demonstrable reasons by the employer:

1. De-energizing introduces additional or increased hazards (such as cutting ventilation to a hazardous location) or
2. Infeasible due to equipment design or operational limitations (such as when voltage testing is required for diagnostics).

Similarly, NFPA 70E 130.2 requires energized electrical conductors and circuit parts to be put in an electrically safe work condition before an employee works within the Limited Approach Boundary (LAB) of those conductors or parts, or the employee interacts with equipment without exposed energized parts, but an increased likelihood of an arc flash hazard exist. Energized work is only permitted where it is justified in accordance with NFPA 70E 130.2(A). NFPA 70E, Article 100, defines an electrically safe work condition as: "A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to verify the absence of voltage, and if necessary, temporarily grounded for personnel protection."

NFPA 70E 130.3(A)(2) requires work on electrical conductors or circuit parts not in an electrically safe work condition to be performed only by qualified persons. In some situations, an arc flash hazard may exist beyond the LAB.

NFPA 70E 130.2(A)(1) permits energized work if the employer can demonstrate energized work introduces additional or increased risk or per NFPA 130.2(A)(2) i.e., if the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations. Financial considerations are not an adequate reason to perform energized work. Not complying with these regulations and practices violates federal law in the form of OSHA regulations.

When energized work is justified per NFPA 70E 130.2(A)(1) or (A)(2), a shock hazard analysis, in accordance with NFPA 70E 130.4 and an arc flash risk assessment, which may include determining the arc flash PPE if an arc flash hazard exists, in accordance with NFPA 70E 130.5, is required. When an energized electrical work permit is required, it must include items from NFPA 70E 130.2(B)(2). Some key items of the energized electrical work permit include:

- Determining the limited approach and restricted approach shock protection boundaries in accordance with NFPA 70E 130.4
- The arc flash boundary in accordance with NFPA 70E 130.5
- The necessary protective clothing and other Personal Protective Equipment (PPE) in accordance with both NFPA 70E 130.4 and 130.5

Similarly, OSHA 1910.132(d)(2) requires the employer to verify that the required workplace hazard assessment has been performed through a written certification that states:

- The workplace evaluated
- The person certifying that the evaluation has been performed
- The date(s) of the hazard assessment
- Identifies the document as a certification of hazard assessment

Note: de-energized electrical parts are considered as energized until all steps of the lockout/tagout procedure are successfully completed per OSHA 1910.333(b)(1). Similarly, all electrical conductors and circuit parts are not considered to be in an electrically safe work condition until all the requirements of Article 120 have been met per NFPA 70E.

Verifying the absence of voltage is a critical step in the implementing an electrically safe work condition. All required PPE must be worn by qualified persons when verifying the absence of voltage. This means that the equipment is considered energized until the verification is complete. Adequate PPE may also be required during load interruption and the visual inspection that verifies all disconnecting devices are open.

6.3 Shock hazard

NFPA 70E defines a shock hazard as "A source of possible injury or damage to health associated with current through the body caused by contact or approach to energized electrical conductors or circuit parts." At higher voltages, the worker doesn't have to come in contact with energized conductors or circuit parts, close proximity could be enough.

Injury and damage to health resulting from shock is primarily dependent on:

- **Current magnitude** — amount of current flowing through the body, influenced both by the magnitude of the driving voltage and the total resistance of the path that current takes through your body
- **Current path** — the path the current flows through the body with current flowing through the chest cavity is more likely to cause harm than current flowing through an extremity
- **Time current flows** — Length of time the body is in the circuit.

Current magnitude depends upon the circuit's impedance and the impedance of those parts of the human body that come in contact with an energized conductor. The table below shows the human body's resistance based upon various conditions.

Condition	Resistance, (ohms)	
	Dry	Wet
Finger Touch	40,000 to 1,000,000	4000 to 15,000
Hand holding wire	15,000 to 50,000	3000 to 6000
Finger-thumb grasp	10,000 to 30,000	2000 to 5000
Hand holding pliers	5000 to 10,000	1000 to 3000
Palm touch	3000 to 8000	1000 to 2000
Hand around 1-1/2" pipe	1000 to 3000	500 to 1500
Two hands around 1-1/2" pipe	500 to 1500	250 to 750
Hand immersed	—	200 to 500
Foot immersed	—	100 to 300
Human body, internal, excluding skin	200 to 1000	

This table was compiled from data developed by Kouwenhoven and Milnor.

The path current takes through the body is important as the chest cavity, which contains the heart and lungs, is the most severe path current can take (see Figure 6.3a).

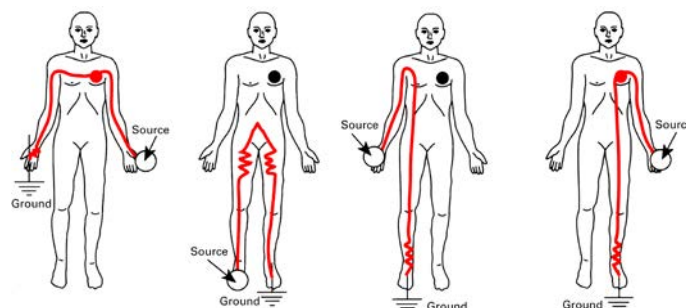


Figure 6.3a



The length of time that current flows through the body is dependent upon the OCPD's clearing time or other protective device in the circuit. Ground-fault circuit interrupters (GFCI) are designed to limit the time a person is exposed to ground fault currents. The UL category code for a GFCI circuit breaker is DKUY, the UL category code for a GFCI receptacle is KCXS, with both listed to the UL 943 standard titled "Ground-Fault Circuit Interrupters."

The physiological reaction to current passing through the body ranges from perception to muscular contractions, inability to let go, ventricular fibrillation, tissue burns to death. From research conducted in the 1960's and 1970's, the current levels in the table below provide the physiological reaction to current.

Current level	Physiological reaction
0.5 — 3 mA	Tingling Sensation
3 — 10 mA	Muscle contractions and pain
10 — 40 mA	"Let-go" threshold
30 — 75 mA	Respiratory paralysis
100 — 200 mA	Ventricular fibrillation
200 — 500 mA	Heart clamps tight
1500 + mA	Tissue and organs start to burn

6.3.1 Shock risk assessment

The shock risk assessment per NFPA 70E 130.4 requires the identifying the shock hazard, estimating the likelihood of injury or damage to health, including the potential severity and determining additional protective measures required, including PPE. A shock hazard analysis consists of the following:

- Determine if work is being conducted on exposed energized conductors or equipment greater than 50 volts. Where lower voltages exist, the system capacity and overcurrent protection must be evaluated to determine if an increased exposure exists.
- Identify and understand the shock hazards
- Estimate the likelihood of injury or damage to health and their potential severity
- Determine if additional protective measures are required, including the use of PPE

If additional protective measures are required, they must be selected and implemented according to the risk controls hierarchy in the following order: elimination, substitution, engineering controls, awareness, administrative controls and PPE.

When additional protective measures include PPE, the following must be determined:

- The voltage to which personnel will be exposed
- The boundary requirements
- The personal and other protective equipment required by this standard to protect against the shock hazard

Any equipment above 50 volts presents a potential shock hazard to the electrical worker when exposed energized conductors, parts, or components are present.

The LAB is the distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists. The RAB is a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement. The distances for both of these boundaries related to shock are found in Tables 130.4(D)(a) for AC systems and 130.4(D)(b) for DC systems.

For AC fixed electrical equipment systems, the LAB is established at three feet, six inches (3 ft. 6 in.) for all equipment from 50 to 750 volts. The RAB for AC fixed electrical equipment systems from 50 to 150 volts is to just avoid contact but for 151 to 750 volts is the restricted approach is one foot (1 ft.).

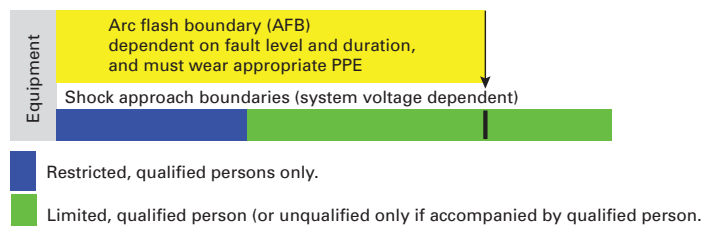


Figure 6.3.1.a

Figure 6.3.1.a is a graphic depiction of the two shock approach boundaries. For electrical hazard analysis and worker protection, it's important to observe the shock approach boundaries together with the arc flash boundary.

6.3.2 Shock risk control solutions

The risk assessment procedure must require implementing preventive and protective risk control methods.

The most effective methods to reduce risk include:

- Elimination
- Substitution
- Engineering controls

The least effective methods to reduce risk include:

- Awareness
- Administrative controls
- PPE

This section will focus on the most effective methods to reduce the risk of shock.

6.3.2.1 Finger-safe solutions

Finger-safe products help reduce the chance that shock can occur. When all components in a panel are finger-safe or covered, a worker has a much lower chance of coming in contact with energized parts.

Shown below is the finger-safe CUBEFuse (a very current-limiting protective device). Also shown are SAMI™ fuse covers, Safety J™ fuse holders for LPJ fuses, CH fuse holders, new modular fuse blocks with optional, finger-safe covers, a variety of Bussmann series fused disconnect switches (with fuse and terminal shrouds). All these devices can reduce the chance that a worker, tool or other conductive item will come in contact with a live part.



6.3.2.2 Barriers

Equipment that employ barriers designed to prevent the electrical worker from coming in contact with energized conductors or parts decrease the likelihood of contact. Barriers come in many different forms; from those that engulf lugs and exposed conductors to those that “barrier off” portions of the enclosure. The risk analysis must consider if these barriers must be removed in order to conduct justified energized work.

Electrical distribution equipment, such as panelboards, employ deadfront barriers that permit the portions of the equipment to which access is needed (for example switch handles) to protrude through the dead-front barrier while keeping energized parts unexposed. The QSCP panelboard below is an example of such a fused solution; it enables the UL 98 switch to be turned ON and OFF and fuse replacement without exposing any energized parts.



Figure 6.3.2.2.a

The 2017 NEC introduced a new requirement for service entrance panelboards to have a lineside barrier to protect workers from exposed, energized lugs and conductors from where the lineside conductors are landed on the main switch. (NEC Section 408.3(A)(2)) This requirement does not apply to those service entrance panels that are leveraging the 6-disconnect rule as permitted in 408.36 as part of the exceptions.



Figure 6.3.2.2.b

6.3.3 Ground-fault circuit-interrupters

GFCI protection is the last line of defense when it comes to shock protection. A ground fault device operates off the basic principal of differential current; that current that flows out to the load through the line conductor has to come back from the load over the neutral conductor. The conductors involved are the expected current paths.

A ground fault device employs two key components that work together to determine if ground fault current is flowing. The system is comprised of sensing equipment and relaying equipment. The sensing equipment is in the form of a current transformer that can be placed at various locations within the circuit.



Figure 6.3.3.a

6.4 Arc flash hazard

NFPA 70E defines an arc flash hazard as “a source of possible injury or damage to health associated with the release of energy caused by an electric arc.” If an arcing fault occurs, the tremendous energy released in a fraction of a second can result in tremendous heat, clothing ignition, severe burns or death.

The likelihood of an arc flash is increased in some cases when personnel interact with energized electrical equipment. Table 130.5(C) provides examples of tasks that increase the likelihood of an arc flash incident. When conductors or circuit parts are exposed, and when personnel are interacting with the equipment, taking measurements or other similar justified energized work, an arc flash is possible.

An arc flash incident is not likely to occur under normal operating conditions when enclosed energized equipment has been properly installed and maintained.

Where work is performed inside the LAB and arc flash boundary (AFB), shock and arc flash hazards exist.

The arc temperature can reach approximately 35,000°F, or about four times as hot as the sun’s surface. These temperatures can cause serious or fatal burns and/or ignite flammable clothing.

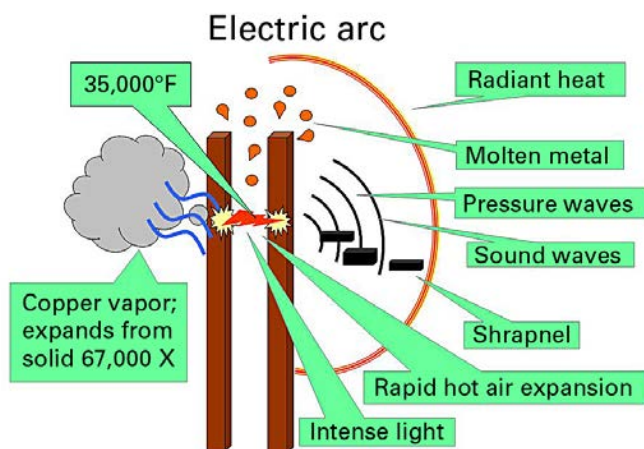


Figure 6.4.a

Figure 6.4.a is a model of an arc fault and the physical consequences that can occur. The unique aspect of an arcing fault involves the fault current flowing through the air between conductors, or the air between a conductor(s) and a grounded part. The arc has an associated arc voltage because there is arc impedance.

The concentration of fault current and arc voltage at one point results in releasing tremendous energy that takes several forms. The high arc temperature vaporizes the conductors and results in an explosive change in state (vaporized, copper expands to 67,000 times its original volume, e.g., **one cubic inch** of copper expands to **38.8 cubic feet**!). With the expansive vaporizing of conductive metal, a line-to-line or line-to-ground arcing fault can escalate into a three-phase arcing fault in less than a thousandth of a second. This event can be so rapid that the human system can’t react quickly enough to take corrective measures. If an arcing fault occurs while a worker is in close proximity, the worker’s survivability depends mostly upon (1) system design aspects (such as OCPD characteristics) and (2) precautions the worker has taken prior to the event (such as wearing PPE that’s appropriate for the hazard).

The arc flash severity depends upon the amount of incident energy available at the location where work will be performed. Incident energy, per NFPA 70E, “is the amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm²).” The incident energy amount at any given location depends upon the amount of arcing fault current magnitude and the time that the arcing current is permitted to flow. Section 4.3 is a resource to on how to calculate arcing current and incident energy.

To demonstrate the relationship between arcing current and time, with regard to incident energy, testing was conducted on the same electrical circuit set-up with different OCPDs. An ad hoc electrical safety working group, within the IEEE Petroleum and Chemical Industry Committee, conducted these tests to investigate arc fault hazards. These and other tests are detailed in Staged Tests Increase Awareness of Arc-Fault Hazards in Electrical Equipment, IEEE Petroleum and Chemical Industry Conference Record, September, 1997, pp. 313-322. One finding in this IEEE paper is that current-limiting OCPDs reduce damage and arc-fault energy (provided the fault current is within the current-limiting range). To better assess the benefit of limiting the current of an arcing fault, it is important to note some key human injury thresholds.

Injury	Threshold
Just curable burn	80°C / 175°F (0.1 sec)
Incurable burn	96°C / 205°F (0.1 sec)
Eardrum rupture	720 lbs/ft²
Lung damage	1728 — 2160 lbs/ft²
OSHA required ear protection	85 db (for sustained time period)
Note: a 3 dB increase is equivalent to doubling the sound level	

Test results were recorded by sensors on mannequins for comparison to these parameters.

All three tests shown in Figures 6.4.b through 6.4.d were conducted on the same electrical circuit that included:

- Available bolted three-phase, fault current of 22,600 symmetrical RMS amps
- Voltage: 480 V, three-phase
- An arcing fault was initiated in a Size 1 combination motor controller enclosure with the door open, as if an electrician were working on a “live unit” or before it was placed in an electrically safe work condition.

Test 4 and Test 3 were identical except for the OCPD protecting the circuit. In Test 4, a 640 A OCPD protecting the circuit interrupts the fault current in 6 cycles. In Test 3, a KRP-C-601SP, 601 amp, current-limiting Class L fuses protecting the circuit cleared the fault current in less than 1/2 cycle and limited the current. The arcing fault was initiated on the lineside of the motor branch circuit device in both Test 4 and Test 3, making the fault on the feeder circuit but within the controller enclosure.

In Test 1, the arcing fault was initiated on the loadside of the branch circuit overcurrent protective devices, LPS-RK-30SP, 30 A current-limiting Class RK1 fuses. These fuses limited the fault current to a much lower value and cleared the fault in approximately 1/4 cycle or less.

Figures 6.4.b through 6.4.d are results recorded from the various sensors on the mannequin closest to the arcing fault. T1 and T2 recorded the temperature on the bare hand and neck respectively. The hand with T1 sensor was very close to the arcing fault. T3 recorded the temperature on the chest under the shirt. P1 recorded the pressure on the chest. And the sound level was measured at the ear. Some results “pegged the meter” meaning the actual values were unable to be recorded because the actual level exceeded the sensor/recorder setting range. These values are shown as “>” indicating that the actual value is greater, but it’s unknown how much greater than the actual value attained.

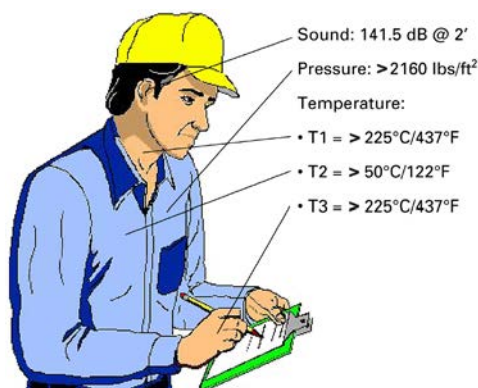

Figure 6.4.b Test 4

Figure 6.4.b are Test 4 results, the staged test protected by an OCPD that interrupted the fault current in six cycles (0.1 second). This is not a current-limiting OCPD. It should be noted that there was an additional, unexpected fault in the wireway and the blast caused the cover to hit the mannequin's head. An analysis shows this test's incident energy was 5.8 cal/cm² at an 18 inch working distance, with a resulting 47 inch arc flash boundary per IEEE 1584-2002 (basic equations).

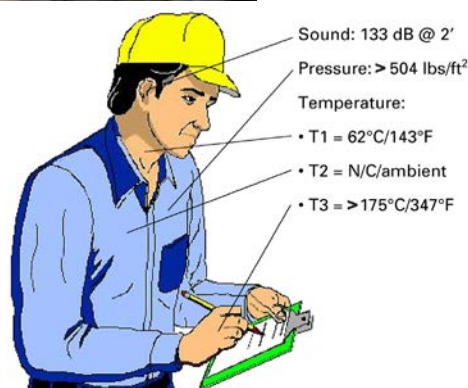

Figure 6.4.c Test 3

Figure 6.4.c are Test 3 results, the staged test protected by KRP-C-601SP Low-Peak™ current-limiting Class L fuses. These fuses operated in their current-limiting range clearing the fault in less than a 1/2 cycle (0.008 second). An analysis showed this test's calculated incident energy was 1.58 cal/cm² at an 18 inch working distance with a 21 inch arc flash boundary per IEEE 1584-2002 (simplified fuse equations).



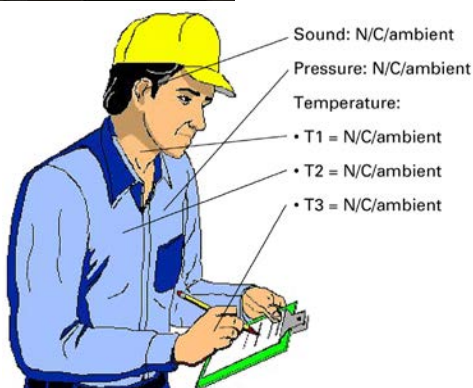


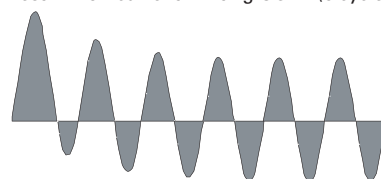
Figure 6.4.d Test 1

Figure 6.4.d are Test 1 results, The staged test protected by LPS-RK-30SP, Low-Peak current-limiting Class RK1 fuses). These fuses were in their current-limiting range and cleared the fault in approximately 1/4 cycle (0.004 second). An analysis showed this test's calculated incident energy was less than 0.25 cal/cm² at an 18 inch working distance with a less than 6 inch arc flash boundary per IEEE 1584-2002 (simplified fuse equations).

Conclusions that can be drawn from these tests include:

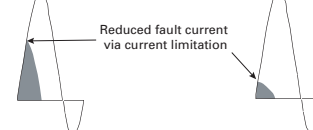
- (1) Arcing faults can release tremendous amounts of energy in many forms in a very short time period.
- (2) The OCPD's characteristics have a significant impact on the results.
 - A 601 amp, current-limiting OCPD reduced (limited) the current peak and clearing time. The clearing time was 1/2 cycle or less.
 - The measured Test 1 results are significantly less than those in Test 4, and even those in Test 3. The reason is Test 1 utilized a much smaller (30 amp), current-limiting OCPD.
 - Test 3 and Test 1 both show the benefits of using current-limiting OCPDs. Test 1 results demonstrate that the greater the current-limitation, the more the arcing fault energy may be reduced.
 - Both Test 3 and Test 1 utilized very current-limiting fuses, but the lower amp rated fuses limit the fault current more than the larger amp rated fuses (Note, the fault current must be in the OCPD's current-limiting range to receive the benefit of the lower current let-through). See the oscillographs below depicting Test 4, Test 3 and Test 1.

Test 4: Non-current limiting OCPD (6 cycles)



Test 3: current limiting KRP-C-601SP

Test 1: current limiting LPS-RK-30SP



6.4.1 Arc flash risk assessment

In all justified energized work, an arc flash risk assessment is an important part. This includes the process for determining if equipment has been placed into an electrically safe work condition. As per NFPA 70E, the following aspects of an arc flash risk assessment must be established:

- Estimate of likelihood and severity (130.5(B))
- Determine additional protective measures (130.5(C))
- Documentation of the risk assessment (130.5(D))
- Establish an arc flash boundary (130.5(E))
- Determine arc flash PPE (130.5(F))
- Incident energy analysis method (130.5(G))
- Equipment labeling (130.5(H))

6.4.2 Incident energy analysis method

One method for determining the proper PPE to wear, as well as the arc flash boundary, is the incident energy analysis method of 130.5(G). There are several incident energy calculation methods within IEEE 1584-2002 commonly used for 15 kV or less. The IEEE 1584-2002 basic equation method has these steps:

- Complete a fault current study that calculates the available fault currents throughout the power distribution system (see Section 4.1)
- Calculate arcing currents at each piece of electrical distribution equipment based upon IEEE 1584-2002 (see Section 4.3)

- Document a selective coordination study establishing OCPD trip curves. For existing systems, visually verify the settings of all OCPDs in the system. For new systems, the OCPD settings or proper selection must be verified to have been implemented in the final design (see Section 4.2).
- For each location within the power distribution system where justified energized work may be performed, the incident energy must be calculated for the task working distance (based upon IEEE 1584-2002 equations) along with the available arcing currents and their respective clearing times for the protecting overcurrent protective device (see section 4.3)
- The arc flash boundary (AFB) must be determined based upon the distance where the incident energy is limited to 1.2 cal/cm². (130.5(E))
- Repeat calculating the incident energy and AFB for 85% of the available arcing current. In the next step, use the higher incident energy resulting from the 100% and 85% arcing fault current calculations.
- The correct arc-rated clothing/PPE is selected from Table 130.5(G)

NFPA 70E Annex D provides information on calculating both the arc flash boundary and incident energy.

IEEE 1584-2002 is the foremost industry consensus standard for calculations on 15 kV or less systems for faults in a box or in the open. This guide has the basic calculation methods; simplified fuse method, and simplified circuit breaker method.

It is important to note that current-limiting OCPDs (when the fault current is in their current-limiting range) can reduce the required AFB and the required arc-rated PPE as compared to non-current limiting OCPDs. In addition, once the arcing current is in the current-limiting range of a specific fuse type/amp rating, the incident energy is very low (typically 0.25 cal/cm²) and remains at this low level even for higher available arcing fault currents.

There are various resources and tools available in the industry to aid in performing the IEEE 1584-2002 calculations. Section 4.3 includes a table method derived using the IEEE 1584-2002 simplified methods for fuses.

6.4.3 Arc flash PPE category method

The second method offered in 130.5(F) is the arc flash PPE category method in accordance with 130.7(C)(15) which is titled “Arc Flash PPE Category Method.” 130.7(C)(15) includes references to two tables:

Table 130.7(C)(15)(a), Arc-Flash PPE Categories for Alternating Current (AC) Systems

Table 130.7(C)(15)(b), Arc-Flash PPE Categories for Direct Current (DC) Systems

These tables offer the PPE category as well as arc-flash boundary based upon the equipment and various parameters. The arc flash PPE category method can be used for many situations provided all table parameters are met. The conditions of use (as to when Tables 130.7(C)(15)(a) and 130.7(C)(15)(b) are permitted to be used) are a part of Section 130.7(C)(15)(a) and 130.7(C)(15)(b). If all the use conditions are not satisfied, the tables cannot be used and an incident energy method must be used.

Table conditions of use

Using the NFPA 70E tables has its limitations. The following conditions that must be satisfied in order to use this table to perform the PPE category method:

- Limited to AC systems for Table 130.7(C)(15)(a) and DC systems for Table 130.7(C)(15)(b)
- Limited to equipment types and voltage ratings listed in table
- Parameters under the specific equipment type being evaluated
 - Available fault current at equipment installation cannot exceed the parameter maximum value in the table
 - The clearing time for the OCPD type at the given value of maximum available, bolted short-circuit current in the table cannot exceed the parameter maximum fault clearing time value the in table
 - The working distance cannot be less than the parameter value in the table

If all conditions are met, the PPE category and arc flash boundary can be used in conjunction with Table 130.7(C)(15)(c) to select PPE. The PPE categories are 1, 2, 3, and 4.

Table 130.7(C)(15)(a) has notes at the end that are important to its application.

The first note acknowledges the fast acting nature of current-limiting fuses and current-limiting circuit breakers. For equipment rated 600 volts and less that are protected by an upstream current-limiting OCPD sized at 200 A or less, the arc flash PPE category is permitted to be reduced by one realizing that the lowest PPE category is 1.

An informational note provides typical OCPD type fault clearing times. They are:

Device	Cycles
Current-limiting fuses when the fault current is within the current-limiting range	0.5
Molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip	1.5
Insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.	3.0
Relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”)	5.0
Low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush	20
Voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip	30

In addition, NFPA 70E 130.5(H) requires that the calculations and data used for the information on the equipment label be reviewed for accuracy at intervals not to exceed 5 years. Where this review results in a change that renders the equipment label inaccurate, the label must be updated with the correct information.



6.4.4 Equipment labeling

Labeling is an important method for raising the awareness of hazards. Electrical distribution equipment labeling requirements can be found in the NEC as well as NFPA 70E.

NEC 110.16, "Arc-Flash Hazard Warning," includes labeling requirements for two important areas. 110.16(A) includes the general requirements that specify a label for electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, in other than dwelling units. This label's application is limited to equipment that's likely to require examination, adjustment, servicing, or maintenance while energized. The required label can be field or factory installed because it's very general and designed to warn qualified persons of potential electric arc flash hazards. The marking must also meet the requirements found in section 110.21(B), and must be located on the equipment such that it is clearly visible to the electrical worker. Figure 6.4.4.a is an example of this label.



Figure 6.4.4.a Label complying with NEC 110.16(A)

NEC section 110.16(B) now requires service equipment rated at 1200 amps or more to be labeled in a manner that provides information help determination the arc rated PPE. This requirement applies to:

- **That equipment in other than dwelling units**
A dwelling unit is defined in the NEC Article 100 as "a single unit, providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking, and sanitation." 110.16(B) requirements would apply to any structure other than a single family dwelling unit, as it's the only structure that is specified as a dwelling unit. Most single family dwelling units would not meet the next requirement.
- **Service equipment rated 1200 amps or larger**
This stipulation pertains to the equipment and not the OCPDs within. The information to determine if the service equipment is impacted by this requirement is found on the manufacturer's equipment label / nameplate as shown in Figure 7.3.4.b.

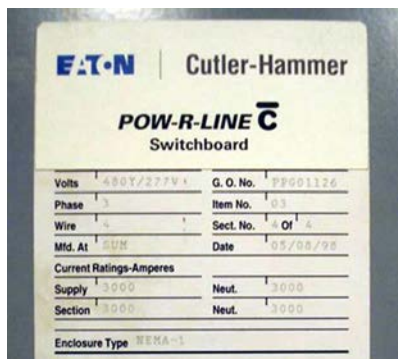


Figure 6.4.4.b

As with 110.16(A), the label must meet the requirements of 110.21(B). This label must also contain the following:

- (1) Nominal system voltage
- (2) Available fault current at the service OCPDs
- (3) The service equipment OCPDs' clearing time based on the available fault current at the service equipment
- (4) The date the label was applied

The nominal system voltage is obtained from the equipment nameplate information as shown in Figure 6.4.4.b. The available fault current is that which is at the service OCPD. The clearing time required in (3) is the clearing time of the available fault current required to be shown as part of (2). This exercise must leverage the OCPD's TCC curve and the current value to determine the clearing time.

This label information correlates with the PPE category method described in 6.4.3 and is enough to establish a PPE category when performing energized work.

The exception to 110.16(B) permits the application of a label as outlined in NFPA 70E. It can be marked with any of the approved methods in NFPA 70E section 130.5(H). The required information includes:

1. Nominal system voltage
2. Arc flash boundary
3. At least one of the following:
 - Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b) for the equipment, but not both
 - Minimum clothing arc rating
 - Site-specific PPE level

Additional information is often included on the label, such as the values determined by the shock approach boundaries.

Figure 6.4.4.c is an example of a label required by NFPA 70E 130.5(H).



Figure 6.4.4.c

The last paragraph of 130.5(H) requires the calculation method and data to support this information shall be documented. For instance, in both the incident energy method and arc flash PPE category method, the available fault current must be determined in the analysis process. The fault current calculating method and the results must be documented and retained. This information may be required for a future OSHA inspection/investigation. Also, if future system changes occur, this documentation will assist in determining whether the arc flash hazard results changed.

6.4.5 Personal Protective Equipment (PPE)

Employees must wear appropriate protective equipment and be trained in its use for the possible electrical hazards they may face. PPE is the last line of defense for the electrical worker. PPE examples could include a hard hat, face shield, neck protection, hearing protection, arc rated (AR) clothing, arc flash suit, insulated rubber gloves with leather protectors, and insulated leather footwear. Selecting the required arc-rated PPE will be driven by either the PPE category method or the incident energy analysis method previously covered in 6.4.2 and 6.4.3.

As stated previously, the common working distance used for most low voltage incident energy measurement research and testing is 18 inches from the arcing fault source. The closer the worker is to the arcing fault, the higher the incident energy and arc blast energy. This means that when the arc flash hazard analysis results in relatively high incident energy at 18 inches from the arcing fault source, the incident energy and arc blast energy at the arcing fault's point can be considerably greater. Put another way, even if the body has sufficient PPE for an 18 inch working distance, severe injury can still result for any part of the body closer than 18 inches to the arc source. The incident energy is approximately inversely proportional to the distance squared. That is, if the incident energy is 8 cal/cm² at 18 inches working distance, the incident energy at 9 inches is approximately 32 cal/cm² and at 4.5 inches approximately 128 cal/cm².

6.4.6 Arc flash risk control solutions

Preventative and protective risk control methods should be implemented to help reduce electrical worker risk. Section 110.1(H)(3) of NFPA 70E provides a control method hierarchy with elimination, substitution and engineering controls at the top of the list. The following solutions can be used to help reduce the risk for arc flash hazards.

6.4.6.1 Local disconnects

Adding a local disconnect to end use equipment where most maintenance and troubleshooting will occur provides the electrical worker multiple benefits. Having a disconnect close to the load to be serviced can increase the likelihood that work will be performed in an electrically safe state. Figure 6.4.6.1.a illustrates HVAC equipment with local disconnects.

When a local disconnect is provided for specific equipment, the ability to apply current-limiting fuses is in place to provide that equipment the most effective means possible to reduce incident energy. Fuses working in their current-limiting range can be sized closer to the load and provide an effective means to ensure any justified energized work is done so with the lowest possible incident energy.

The installing horsepower-rated disconnects (with a permanently installed lockout/tagout provision) within sight and within 50 feet of every motor or driven machine can help increase electrical safety. Doing this fosters safer work practices and can be used for an emergency disconnect if there is an incident as well as promoting electrically safe work habits.

When selecting fusible OCPDs, the fuse holder or switch type is very important for determining proper application. The most economical solution is often a standard UL 4248 Listed fuse holder, but it does not offer a disconnecting means for the fuses, which is required, in most cases, per NEC 240.40. A disconnecting means can be ahead of the fuse holder or a fused UL 98 disconnect or UL 508 disconnect can be selected. The UL 98 fused disconnect offers the widest application range, since it can be used in all locations whether as the motor branch circuit disconnect, controller disconnect, or within sight motor disconnect. UL 508 disconnects can only be used in motor branch circuits on the motor branch circuit OCPD's loadside.

The Compact Circuit Protector (CCP) is the smallest, most economical UL 98 Listed fusible disconnect switch available. There are two CCP types: one for Class CC and UL supplemental fuses that's available as a 30 A disconnect, accepting fuses up to 30 A, the other for the UL Class CF CUBEFuse that's available in ratings up to 400 A.



Figure 6.4.6.1.a

6.4.6.2 Lockout/tagout

The use of lockout/tagout methods is vital for establishing an electrically safe work condition as mandated in Article 120 of NFPA 70E. The general requirement in this Article is that each employer establish, document, and implement a lockout/tagout program.

The solutions shown in Figures 6.4.6.2.a through 6.4.6.2.c include those that would meet the NEC requirements and have permanent provisions to receive a lock to meet the work practices required by 70E.



Figure 6.4.6.2.a



Figure 6.4.6.2.b



Figure 6.4.6.2.c

6.4.6.3 Maintenance

Maintenance plays an important role in any electrical distribution system's life. NFPA 70E uses the term "condition of maintenance" throughout the document and it refers to the electrical equipment's state with regard to the manufacturers' instructions and recommendations, and applicable industry codes, standards, and recommended practices. The proper operation of OCPDs, switches, transfer switches, GFCIs and other safety related solutions depends upon a rigorous and vigilant maintenance program.

The condition of maintenance is critical for OCPDs being relied upon to mitigate incident energy if an arcing fault incident occurs when a worker is working on equipment not in an electrically safe work condition. If the OCPD does not operate as intended, or does not operate when an incident occurs, the actual incident energy impressed on the worker may be much greater. NFPA 70E 205.4 requires OCPDs to be maintained and the inspections, tests and maintenance to be documented.

If the electrical system is an existing fusible system, consideration should be given to upgrading the installed fuse base to Bussmann series Low-Peak fuses. If the installed fuses are not the most current-limiting type fuses, upgrading to those in the Low-Peak family may reduce the hazards associated with arc flash. Visit Eaton.com/bussmannseries to review the Low-Peak Fuse Upgrade Program.

6.4.6.4 Ratings

The proper electrical equipment and component application within their ratings is very important for safety. OCPDs must have interrupting ratings and electrical distribution equipment must have the short-circuit current ratings equal to or greater than the available fault current at their lineside terminals. An OCPD subjected to interrupting a fault current beyond its interrupting rating can violently rupture. Electrical distribution equipment applied beyond its SCCR can also result in an unintended rapid disassembly. Consideration for interrupting ratings and SCCR should be for the system's life. System changes, such as when transformers are replaced or systems are upgraded and the available short-circuit currents increase, must initiate equipment evaluations. Modern fuses have interrupting ratings of 200 kA and 300 kA, which virtually eliminates this hazard contributor.

6.4.6.5 Current limiting OCPDs

Current limitation can play an important role in reducing incident energy. Current-limiting fuses are the industry's fastest devices when the arcing current is in their current-limiting region. Current limitation is discussed in depth as part of Sections 3.1 and 3.2 of this handbook.

Systems should leverage the most current-limiting OCPDs possible. There are many OCPD choices in the market and many are not marked as "current-limiting" and can't be considered current-limiting. For those that are marked current-limiting, there are different current-limitation degrees to consider. The brand to use for 600 V and less, electrical distribution applications and general equipment circuit protection are the Bussmann series Low-Peak fuses. The Low-Peak fuse family is the most current-limiting fuse family type for general and motor circuit protection.

If the actual, maximum full load current on an existing main, feeder or branch circuit is significantly below its designed circuit amp rating, replace existing fuses with lower amp rated Low-Peak fuses, e.g., an industrial found that many of the 800 amp feeders to their MCCs were lightly loaded; for better arc flash protection they installed 400 and 600 amp current-limiting fuses and switches in the feeders.



Figure 6.4.6.5.a

6.4.6.6 Arcflash Reduction Maintenance System (ARMS)

The ARMS is a device that places the circuit into a maintenance mode to reduce the system's incident energy for the time period that work is being performed. This arc reduction method is the fastest solution in the circuit breaker offering for incident energy reduction.



Figure 6.4.6.6.a

6.4.6.7 Zone Selective Interlocking (ZSI)

Zone selective interlocking provides incident energy reduction when the arcing fault occurs within the protection zone as shown in Figure 6.4.6.7.a. ZSI equipped circuit breakers work in pairs consisting of an upstream and a downstream circuit breaker. These devices are connected together via a control circuit to provide the upstream device with the ability to know if the downstream device sees a detected fault. This connection is usually referred to as a restraining signal, as when the downstream device sees a fault, the restraining signal sent to the upstream device prevents it from tripping instantaneously and instructs it to trip per its programmed settings for selective coordination. The result is the downstream device will clear the fault per its programmed trip settings for selective coordination.

Should the fault occur between the two devices, the upstream device would not receive the restraining signal and would trip without an intentional time-delay. Circuit breakers equipped with this feature reduce the damage at the fault's point if it occurs at a location within the zone of protection.

It is important to understand the zone of protection provided as a fault on the upstream device's lineside or the downstream device's loadside would not be met with incident energy reduction for the electrical worker.

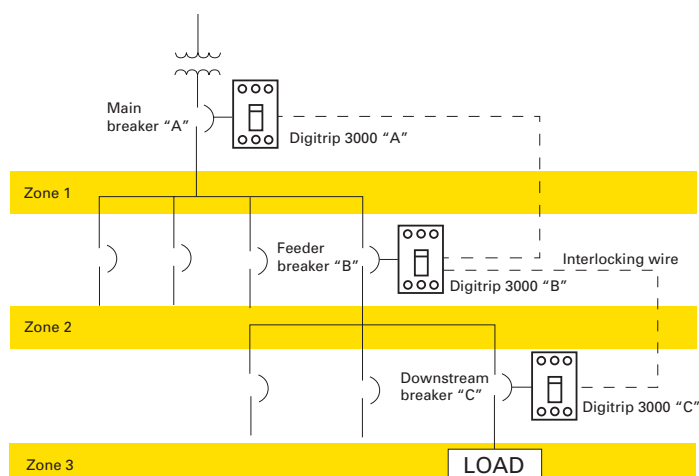


Figure 6.4.6.7.a



Figure 6.4.6.7.b

6.4.6.8 Active arc flash mitigation systems

Active arc flash mitigation systems employ technologies beyond just looking at current flow to detect when an arcing event has occurred within a specific piece of electrical equipment. The arc detection process will typically involve:

- An arc is detected by light sensors and lineside CTs
- The arc flash relay sends a signal to trigger an arc quenching device
- The arc quenching device will create a lower-impedance arc event across all 3 phases which are contained inside a sacrificial pressure vessel
- The arcing fault is quickly extinguished inside the switchgear

This process occurs in approximately 53 milliseconds reducing the time and incident energy.

Again, it's important to understand the limitations to these solution types as they only work on the electrical equipment within which they are installed. And it is vital to note some technologies do not work when the enclosure doors are open and justified energized work is performed.

6.4.6.9 Remote operation

Placing electrical workers outside the arc flash boundary (while performing such tasks as racking in or out a circuit breaker) places them at a safe distance from the equipment. There are many methods currently on the market that make remote operation a reality for the electrical installation. These include but are not limited to:

- Communications: OCPDs and other solutions exist that have the ability to communicate electronically with computers. These communication methods make it possible to open switches or circuit breakers remotely from a computer in an office or from a touch screen display outside the electrical room.
- Remote operation accessories: Solutions exist that can be placed on electrical equipment to mechanically operate handles via a remote location through a long umbilical cord. This method places the worker outside the arc flash boundary while circuit operations are made.



Figure 6.4.6.9.a

6.4.6.10 Barriers

Doing more with the doors closed is a significant trend in equipment development. There are more solutions on the market than ever before that enable racking electrical components in and out with the protective doors closed. Switchgear, switchboards, motor control centers and even circuit breaker panelboards are offered with this functionality.

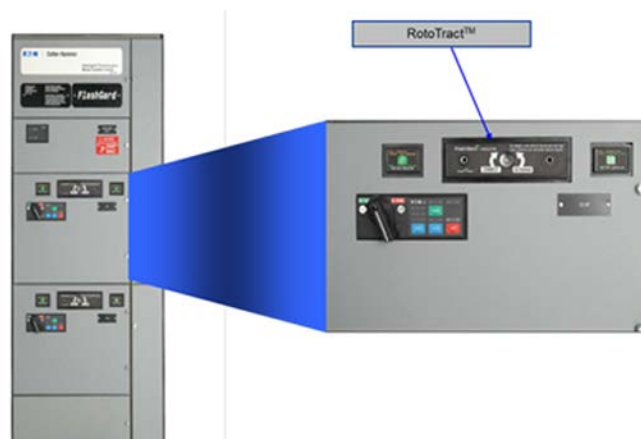


Figure 6.4.6.10.a



Figure 6.4.6.10.b

6.5 Maintenance

Electrical distribution system maintenance can take many forms, all of which are important for system safety over its lifetime. Electrical equipment maintenance should be performed based on manufacturer requirements. Maintenance must also be performed to ensure all equipment is working together correctly as a system.

The OCPD reliability can directly impact arc flash hazards. Poorly maintained OCPDs may result in higher arc flash hazards. Devices, such as GFCLs, if not tested per manufacturers' instructions may not provide the required protection when needed. Smoke detectors and similar equipment, too, have life limitations beyond which they must be replaced. Manufacturer instructions are important to keep on file and read with regard to recommended maintenance practices.

NFPA 70E 130.5(B) reads in part:

The estimate of the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health must take into consideration:

1. The design of the electrical equipment, including its overcurrent protective device and its operating time
2. The electrical equipment operating condition and condition of maintenance.

130.5 has two Informational Notes (IN) concerning the importance of overcurrent protective device maintenance:

IN No. 1: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

IN No. 2: For additional direction for performing maintenance on overcurrent protective devices see Chapter 2, Safety-Related Maintenance Requirements.

The 130.5 requirement to take into consideration the maintenance condition of OCPDs is very relevant to arc flash hazards. Their reliability can directly impact the incident energy. Poorly maintained OCPDs may take longer to clear or not clear at all, resulting in higher arc flash incident energies.

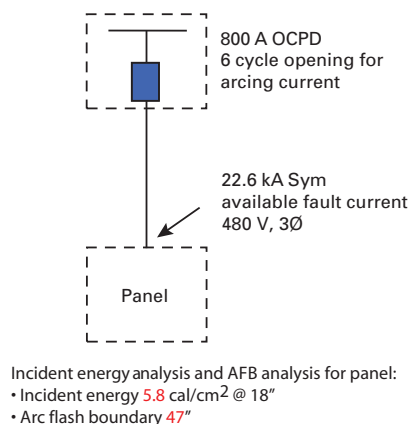


Figure 6.5.a

Figure 6.5.a illustrates an arc flash hazard analysis calculation assuming the OCPD has been maintained and operates as specified by the manufacturer's performance data. In Figure 6.5.b illustrates that the actual arc flash event can be significantly higher if the lack of maintenance causes the OCPD clearing time to be greater than its specified performance data. Calculations are per IEEE 1584-2002.

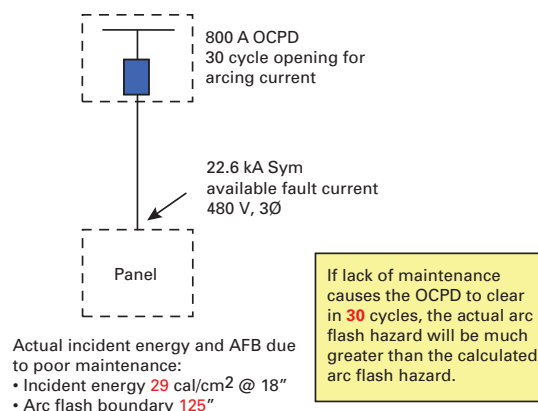


Figure 6.5.b

6.5.1 OCPD maintenance

The OCPD is a critical component in the power system that's necessary to reduce incident energy for the electrical worker. NFPA 70E includes references to OCPD maintenance that recognizes their significance in the system.

The following are the NFPA 70E references for OCPD maintenance:

- 205.4: Requires OCPDs to be maintained per manufacturers' instructions or industry consensus standards. "Maintenance, tests, and inspections shall be documented."
- 210.5: Requires OCPDs to be maintained to safely withstand or be able to interrupt the available fault current. Informational Note makes mention that improper or lack of maintenance can increase arc flash incident energy.
- 225.1: Requires fuse body and fuse mounting means to be maintained. Mountings for current-limiting fuses cannot be altered to allow for insertion of non-current-limiting fuses.
- 225.2: Requires molded cases circuit breaker cases and handles to be maintained properly.
- 225.3: Requires circuit breakers that interrupt faults approaching their interrupting rating be inspected and tested in accordance with the manufacturer's instructions.

OSHA 1910.334(b)(2) Use of Equipment

Re-closing circuits after protective device operation — after a circuit is de-energized by a circuit protective device — the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual re-closing of circuit breakers or reenergizing circuits through replaced fuses is prohibited.

Note: When it can be determined from the circuit design and the OCPDs involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.

A key phrase in the regulation is "circuit can be safely energized." When complying with NFPA 70E 225.3 it's impractical, if not impossible, to determine the fault level interrupted by a circuit breaker.

Sources for guidance in setting up maintenance programs, determining the maintenance frequency and providing prescriptive procedures include:

1. Equipment manufacturer's maintenance manuals
2. NFPA 70B Recommended Practice for Electrical Equipment Maintenance
3. ANSI/NETA MTS-2011, Standard for Maintenance Testing Specifications for Electrical Distribution Equipment and Systems. This standard includes guidelines for the required maintenance frequency for electrical system power equipment in Appendix B, Frequency of Maintenance Test, as well as prescriptive inspections and tests in the standard.

Maintenance calibration decal systems (Figure 6.5.1.a) can assist in evaluating the OCPD maintenance condition required in NFPA 70E 130.5.

TESTED	
Project No.:	_____
Test Date:	_____
Tested By:	_____ (Technician)
	_____ (Company)

Figure 6.5.1.a

The internal parts of current-limiting fuses do not require maintenance for arc flash protection considerations. However, it's important to periodically check fuse bodies and mountings.

In addition, periodically check conductor terminations for signs of overheating, poor connections and/or insufficient conductor ampacity. Infrared thermographic scans are one method for monitoring these conditions. Records on maintenance tests and conditions should be retained and trended.

The NEMA document pertinent to the subject of maintenance include "Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications" is the industry reference for molded case circuit breaker maintenance.

6.5.2 Risk control solutions

A maintenance program that is formalized and comprehensive can go a long way towards reducing risk for those electrical professionals working on the power distribution system.

Using OCPDs that are reliable and do not require maintenance to ensure performance per the original specifications is a wise choice. Modern fuses are reliable and retain their ability to react quickly under fault conditions. When a fuse is replaced, a new, factory-calibrated replacement is put back into service and the circuit retains reliable protection with performance equal to the original specifications. When an arc fault or overcurrent occurs, the OCPD must be able to operate as intended.



7 Equipment application/protection

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Introduction

All electrical distribution system components work together to deliver or utilize electric power, and they must be applied within their listing and protected according to the minimum National Electrical Code (NEC) requirements.

The fundamental principles behind proper equipment protection lies in the magnitude and time duration that current flows in a power distribution system. The overcurrent protective device's (OCPD) role is twofold:

1. Control the amount of time that current is permitted to flow when its magnitude is outside the equipment's safe operating limits.
2. Limit the magnitude of high-level, destructive currents that can inflict damage to system components due to magnetic forces and thermal energy.

The fuse's current-limiting nature is a powerful feature that can limit the amount of damage caused to the distribution system when faults occur. This section provides guidance to ensure maximum electrical system protection.

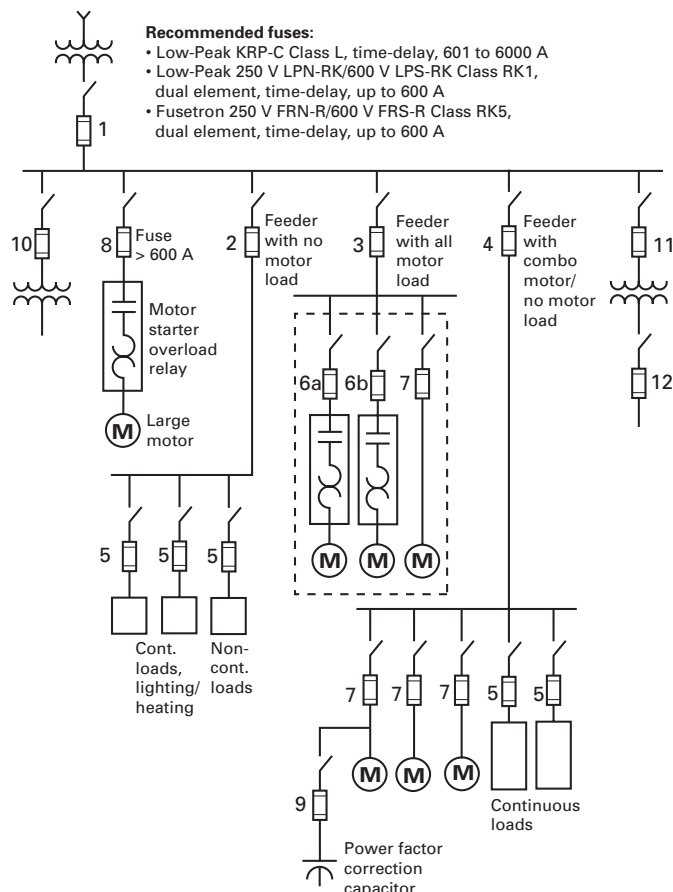
This section pertains to the two roles OCPDs perform when called upon to protect specific applications.

This section starts with covering fuse sizing and conductor ampacity for building electrical systems that are up to 600 V. This provides a context for the applications covered in this section as they are almost always connected to a building's electrical system for their power.



Fuse sizing for 600 V building electrical systems

General guidelines are given for selecting fuse amp ratings for most circuits. For specific applications warranting other fuse sizing, the load characteristics and appropriate NEC sections should be considered. The selections shown here are not, in all cases, the maximum or minimum amp ratings permitted by the NEC. Demand factors as permitted by the NEC are not included. Study the pertinent NEC sections noted by “()” and reference pertinent footnotes.



Dual-element, time-delay fuses

Class CF (up to 400 A), and J, RK1 and RK5 (up to 600 A)

For fuses above 600 A, use Class L time-delay fuses with ratings from 601-6000 A. While these fuses are not dual-element construction, the Bussmann series KRP-C-SP is a time-delay fuse.

- 1. Main service.** Size fuse according to method in 4 below.
- 2. Feeder circuit with no motor loads.** (215.3) The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than the conductor's ampacity*.
- 3. Feeder circuit with all motor loads.** (430.62) Size the fuse at 150% to 175% of the largest motor's full load current** plus the full-load current** of all other motorsΔ.
- 4. Feeder circuit with mixed loadsΔ.** (430.63) Size fuse at sum of:
 - 150% to 175%†† of the largest motor's full-load current**, plus
 - 100% of all other motors' full-load current**, plus
 - 125% of the continuous, non-motor load†, plus
 - 100% of the non-continuous, non-motor load
- 5. Branch circuit with no motor load.** (210.20) The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than the conductor's ampacity*.

- 6. Motor branch circuit with overload relays.** Where overload relays are sized per 430.32 for motor running overload protection, there are various alternatives:

6a. Motor branch circuit short-circuit and ground fault protection. (430.52) (most common).

Size the fuse between 150 to 175%†† of the full load current.** Provides branch circuit short-circuit and ground fault protection only.

6b. Motor branch circuit short-circuit and ground fault protection (430.52) as well as backup overload protection.

Size FRN-R and FRS-R Class RK5 dual-element, time-delay fuses at 125% and LPN-RK-SP and LPS-RK-SP Class RK1 dual-element, time-delay fuses at 130% of motor full-load current or next higher size. This results in closer fuse sizing and provides some backup running overload protection. In addition, it provides motor branch circuit short-circuit and ground fault protection. Sizing in this manner may result in better motor protection if the overload relays are not properly sized or calibrated.

- 7. Motor branch circuit with only fuse protection.** Where the fuse is the only motor protection, the following FRS-R and FRN-R, Class RK5, fuses provide motor running overload protection (430.32) and short-circuit protection (430.52):

- Motor 1.15 service factor or 40°C rise. Size the fuse at 110% to 125% of the motor full-load current on the name plate [430.6(a)(2)].
- Motor less than 1.15 service factor or over 40°C rise. Size fuse at 100% to 115% of motor full-load current on the name plate [430.6(a)(2)].

- 8. Large motor branch circuit.** Fuse larger than 600 A. [436.52(c) and 430.52(c)(1) Exceptions 2(d)]. For large motors, size Low-Peak KRP-C-SP time-delay fuse at 175% to 300% of the motor full-load current**, depending on the starting method; i.e., part-winding starting, reduced voltage starting, etc.

- 9. Power factor correction capacitors.** [460.8(b)]. Size dual-element fuses as low as practical, typically 150% to 175% of capacitor rated current.

- 10. Transformer primary fuse (without secondary fuse protection).** [450.3(b)] When transformer primary current is equal to or greater than 9 amps, the dual-element, time-delay fuse should be sized at 125% of transformer primary current or the next size larger if 125% does not correspond to a standard fuse size. Note: Secondary conductors must be protected from overcurrent damage per Article 240.

- 11. Transformer primary fuse (with secondary fuse protection).** [450.3(b)] May be sized at 250% of transformer primary current if the secondary is fused per 12 below.

- 12. The secondary fuse is sized at no more than 125% of secondary full-load current.** [450.3(b)] Note: Secondary conductors must be protected at their ampacities per Article 240.

Non-time delay and all Class CC fuses

(FCF, JKS, KTN-R, KTS-R, JJN, JJS, LP-CC, KTK-R and FNQ-R)

1. **Main service.** Size fuse according to method in 4.
2. **Feeder circuit with no motor loads.** (215.3) The fuse size must be at least 125% of the continuous load[†] plus 100% of the non-continuous load. Do not size larger than the conductor's ampacity.*
3. **Feeder circuit with all motor loads.** (430.62) Size the fuse at 300% of the largest motor's full-load current** plus the full-load current** of all other motors.
4. **Feeder circuit with mixed loads.** (430.62) Size fuse at sum of:
 - a. 300% of the full-load current** of the largest motor, plus
 - b. 100% of the full-load current** of all other motors, plus
 - c. 125% of the continuous, non-motor load[†], plus
 - d. 100% of the non-continuous, non-motor load
5. **Branch circuit with no motor loads.** (210.20) The fuse size must be at least 125% of the continuous load[†] plus 100% of the non-continuous load. Do not size larger than the conductor's ampacity.*
- 6a. **Motor branch circuit with overload relays.** (430.52) Size the fuse at 300% of the full load current**. Provides branch circuit short-circuit and ground fault protection only. Other means must be utilized to provide motor overload protection (see 430.32). (If 300% is not a standard fuse amp rating, 430.52(C)(1) Exception 1 permits the next standard fuse amp rating. If the motor cannot start with this size fuse, 430.52(C)(1) Exception 2 permits increasing the fuse size up to 400% provided the fuse rating does not exceed 600 A.)
- 6b. **Motor branch circuit short-circuit and ground fault protection (430.52) as well as backup overload protection.** Not applicable for non-time-delay fuses; use FRN-R and FRS-R, Class RK5, dual-element time-delay fuses or LPN-RK-SP and LPS-RK-SP Class RK1, dual-element, time-delay fuses (see 6b under dual-element time-delay fuse selection). Non-time-delay fuses cannot be sized close enough to provide motor running backup overload protection. If sized for motor overload backup protection, non-time-delay fuses would open due to motor starting current.
7. **Motor branch circuit with only fuse protection.** Not applicable for non-time-delay fuses; use FRN-R and FRS-R, Class RK5, dual-element time-delay fuses (see 7 under dual-element time-delay fuse selection). Non-time-delay fuses cannot be sized close enough to provide motor running overload protection. If sized for motor overload protection, non-time-delay fuses would open due to motor starting current.
8. **Power factor correction capacitors.** [460.8(B)] Size non-time-delay fuses as low as practical, typically 250% to 300% of capacitor rated current.



Conductor ampacity selection

1. **Feeder circuit and main circuit with mixed loads.** (430.24) conductor ampacity at least sum of:
 - a. 100%^{††} of the full-load current** of the largest motor, plus
 - a. 100% of the full-load current** of all other motors, plus
 - c. 125% of the continuous, non-motor load[†], plus
 - d. 100% of the non-continuous, non-motor load
2. **Feeder circuit with no motor load.** [215.2(a)(1)] Conductor ampacity at least 125% of the continuous load plus 100% of the non-continuous load.
3. **Feeder circuit with all motor loads.** (430.24) Conductor ampacity at least 125% of the largest motor full-load amps plus 100% of all other motors' full-load amps.
4. **Feeder circuit with mixed loads.** (430.24) Size according to method 1 above.
5. **Branch circuit with no motor load.** [210.19(a)(10)] Conductor ampacity at least 125% of the continuous load plus 100% of the non-continuous load.
- 6, 7 and 8. **Motor branch circuits.** (430.22) Conductor ampacity at least 125% of the motor full-load current.
9. **Capacitor connected to motor branch circuit.** (460.8) Conductor ampacity at least 135% of capacitor rated current, and at least 1/3 the motor circuit conductors' ampacity.
- 10, 11. **Conductor ampacity minimum 125% of transformer full-load current.**
12. **Conductor ampacity per 1 above.**

- [†] 100% of the continuous load can be used rather than 125% when the switch and fuse are listed for 100% continuous operation as an assembly (e.g., 215.3 Exc 1). Some bolted pressure switches and high pressure contact switches 400 A to 6000 A with Class J and L fuses in specified assemblies are listed for 100% continuous operation.
- * Where conductor ampacity does not correspond to a standard fuse amp rating, the next higher amp rating fuse is permitted when 800 A or less [(240.4(B)). Above 800 A the conductor ampacity must be equal or greater than the fuse amp rating [(240.4(C)). However, per 240.91(B), when above 800 A for supervised industrial installations, the conductor ampacity is permitted to be 95% of the fuse amp rating as long as the equipment is listed for that size conductor and the conductor is protected within its time vs. current limits [240.4 Informational Note].
- Δ In many motor feeder applications dual-element fuses can be sized at ampacity of feeder conductors.
- Available short-circuit current and the clearing time of the overcurrent device must be considered so that the conductor's ICEA (P32.382) withstand rating is not exceeded.
- ** On general motor applications, motor full load amps for calculating conductor ampacity and for calculating fuse amp ratings for motor branch circuit short-circuit and ground fault protection (430.52) are selected from NEC Tables 430.247 through 430.250 per 430.6(A)(1). However, the motor nameplate current rating is used for sizing motor overload protection (430.32) per 430.6(A)(2).
- †† 430.52(C)(1) allows a maximum of 175% for time-delay fuses, for all but wound rotor and DC motors. A range of 150% to 175% was used for these guidelines, even though 430.52(C)(1) allows a maximum of 175% for time-delay fuses as stated above. The reason for showing this range is to highlight the possibility for application selection. In some situations, there may be a difference in the switch amp rating or fuse block amp rating in selecting 150% versus 175%. Using 175% is permitted and is suggested for heavy starting current or longer starting time applications. Further note: the NEC permits larger sizing via two exceptions. 430.52(C)(1) Exception 1 permits the next standard size if 175% does not correspond with a standard fuse amp rating. If the motor cannot start with this size fuse, 430.52(C)(1) Exception 2 permits increasing a time-delay fuse size up to 225%.
- (Note that while a time-delay fuse may not exceed 225% when using Exception 2, using a time-delay fuse could exceed 225% when applying Exception 1. For example, assume a motor with a FLA of 1.0 amp. 430.52(C)(1) would allow a 1.75 amp fuse. Exception 1 would allow a 3 amp time-delay fuse per 240.6(A). Exception 2 limits the time-delay fuse to 2.25 amps as a maximum, but Exception 2 is not utilized or needed if Exception 1 is adequate.)
- *** The conductor ampacity may have to be greater due to using adjustment or correction factors per 210.19(A)(1) and 215.2(A)(1).

7.1 Appliances

The NEC defines an appliance as “utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth.” Appliance branch circuits must be protected in accordance with NEC 240.5. If an OCPD amp rating is marked on an appliance, the branch circuit OCPD amp rating cannot exceed that rating marked as per 422.11(A). Section 430.6(A)(1) exception No. 3 addresses situations where the appliance is marked with both a horsepower rating and an amp rating.

For branch circuits which supply a single non-motor operated appliance rated more than 13.3 A, the fuse rating must not exceed 150% of the appliance rating [422.11(E)(3)].

Electric resistance element heating appliances rated more than 48 A must have the heating elements subdivided such that each subdivision does not exceed 48 A and each subdivision must be protected by a branch circuit listed fuse not to exceed 60 A. These fuses must be factory installed by the manufacturer, be accessible, and be suitable for branch circuit protection [422.11(F)(1)].

Fixed appliances are considered protected when supplied from a 15, 20, 25, or 30 A branch circuit. Fixed cooking appliances are permitted to be protected by 40 or 50 A branch circuits (210.23(C)). Household appliances with surface heating elements that have a maximum rating greater than 60 A must be divided into two or more circuits, each of which is protected by a fuse of no greater than 50 A [422.11(B)].

For “equipment not fastened in place,” NEC 210.23(A)(1) requires any one cord-and-plug-connected utilization equipment to not exceed 80 percent of the branch circuit’s amp rating.

7.2 Ballasts

NEC 410.130(E) requires integral thermal protection for ballasts, except where used for egress lighting. Testing agencies list ballasts for general use in lighting fixtures that pass specific thermal and short-circuit tests. The ballast must have a thermal protector to sense certain over temperature conditions and must also be able to withstand a 200 A fault current when tested with a 20 A fuse. See the Figure 7.2.a for a typical ballast test.

Most electrical systems today will deliver a fault current greater than 200 A to a row of fixtures (see Figure 7.2.b). In order to comply with the last sentence in NEC 110.10 (equipment short-circuit current rating), it’s necessary to have ballasts applied in accordance with their listing and therefore the fixtures must be specified to incorporate individual ballast fusing within the fixture and external to the ballast.

Fusing each fixture also provides for isolating any faulted ballast and reducing costly and dangerous blackouts. When a ballast does fail, only the fuse protecting that individual fixture opens - the remaining fixtures continue in normal operation. Without individual ballast protection, a faulted ballast could cause the branch circuit OCPD to open and shut off all the lights. With individual fusing, the maintenance electrician can troubleshoot the problem much more quickly because only one fixture is “out.” And this troubleshooting can be performed as part of a scheduled maintenance procedure. Adding external fuses avoids an “emergency” situation where employees are left in the dark.

Note: Refer to the fixture manufacturer for recommended fuse size. Bussmann series in-line fuses and holder are made specifically for light fixtures.

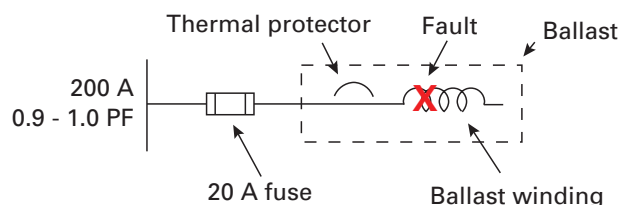


Figure 7.2.a UL 935 short-circuit test for ballast protectors.

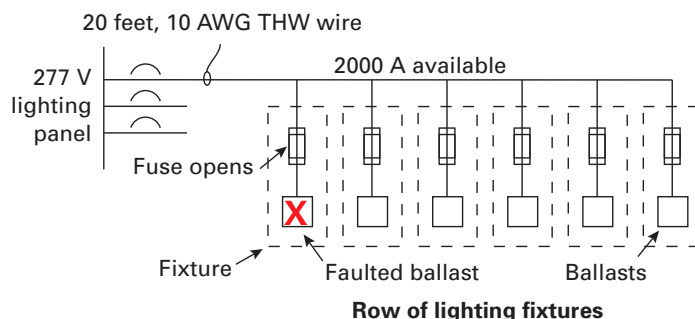


Figure 7.2.b Individual ballast fusing.

Ballasts fuse selection

Location	Type	Notes	Fuse recommendation	Fuse holder recommendation
Indoor	Fluorescent	Consult fixture manufacturer for size and type	GLR, GMF, GRF	HLR
			GLQ, GMQ	HLQ
	All other (mercury, sodium, etc.)	Consult fixture manufacturer for size and type	BAF, KTK, FNM, FNQ	HPF, HPS
			KTK-R, FNQ-R, LP-CC	HPS-RR, HPF-RR
			BBS	HPS-L, HPF-L
			SC up to 15 A	HPF-EE, HPS-EE
			SC 20 A	HPF-JJ, HPS-JJ
			SC 25-30 A	HPF-FF, HPS-FF
Outdoor	Mercury, sodium, etc.	Consult fixture manufacturer for size and type.	BAF, KTK, FNM, FNQ	HEB, HEX, HPC-D
			KTK-R, FNQ-R, LP-CC	HEY, HEZ

7.3 Batteries/battery charging

Batteries can be a part of an overall system to supply electrical power. The components that comprise this system include an inverter, a battery management system and batteries. Just as with any power distribution system, all these components must be protected from the ill effects of current under abnormal or fault conditions.

The NEC defines the battery system as an “Interconnected battery subsystem consisting of one or more storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment.”

The current a battery provides is “direct current” (DC) and not a sinusoidal alternating current (AC). The battery’s DC current supplied at a specific DC voltage is much different than an AC current as there are no “zero crossings” with DC. Overcurrent protective devices leverage the AC system’s zero crossings to interrupt the flow of current. The overcurrent protective devices used in DC systems must be listed for these systems and/or they require testing to ensure they can safely interrupt DC current at specified DC voltages. In most cases, especially in higher current applications, high speed, electric vehicle (EV) or photovoltaic (PV) fuses are selected. Bussmann series product application engineers can assist in evaluating AC-rated fuses for battery applications. Otherwise, only those devices listed for DC systems should be used in DC systems.

Fuses and circuit breakers provide short-circuit and overload protection for batteries, conductors and the other distribution equipment within the system. Not all battery systems are equal and each should be understood from a system perspective. The battery ancillary equipment, as well as the battery itself, can be simple or complex, depending upon the function that they serve.

As with all power distribution systems, there are three competing objectives when designing the battery system protection scheme:

- Minimize the risk of equipment damage during electrically faulted conditions.
- Limit the battery system’s number and duration of service interruptions.
- Cost.

Protective devices serve to minimize the damage to the battery. High currents of sufficient duration may cause damage to cable insulation, conductor material, battery posts, battery intercell connectors, battery post seals and battery cell covers.

Batteries are a part of many different system types that provide energy storage and ride-through energy. The following NEC Articles include requirements pertaining to batteries and battery charging systems based on their application.

- Article 480, Storage Batteries
- Article 706, Energy Storage Systems
- Article 500, Hazardous (Classified) Locations, Classes I, II, and III, Divisions 1 and 2
- Article 503, Class III Locations
- Article 505, Zone 0, 1, and 2 Locations
- Article 511, Commercial Garages, Repair and Storage
- Article 513, Aircraft Hangars
- Article 517, Health Care Facilities
- Article 551, Recreational Vehicles and Recreational Vehicle Parks
- Article 552, Park Trailers
- Article 600, Electric Signs and Outline Lighting
- Article 625, Electric Vehicle Charging System
- Article 640, Audio Signal Processing, Amplification, and Reproduction Equipment
- Article 645, Informational Technology Equipment
- Article 646, Modular Data Centers
- Article 680, Swimming Pools, Fountains, and Similar Installations
- Article 690, Solar Photovoltaic (PV) Systems
- Article 691, Large-Scale Photovoltaic (PV) Electric Power Production Facility
- Article 692, Fuel Cell Systems
- Article 694, Wind Electric Systems
- Article 695, Fire Pumps
- Article 700, Emergency Systems
- Article 701, legally Required Standby Systems
- Article 705, Interconnected Electric Power Production Sources
- Article 706, Energy Storage Systems
- Article 708, Critical Operations Power Systems (COPS)
- Article 712, Direct Current Microgrids
- Article 760, Fire Alarm Systems

7.4 Busway

NEMA standards require that busways have a symmetrical short-circuit withstand rating at least as great as the average available symmetrical fault current. NEMA established a minimum three-cycle short-circuit rating, tested as three cycles of peak current (I_p).

“Busways may be used on circuits having available fault currents greater than the three cycle rating of the busway rating when properly coordinated with current-limiting devices (NEMA Publication no. BU1).”

If a busway is listed or labeled for a maximum short-circuit current with a specific overcurrent device, it cannot be used where greater fault currents are available. If a busway is listed or labeled for a maximum short-circuit current without a specific overcurrent device (i.e., for three cycles), current-limiting fuses can be used to reduce the fault current to within the busway’s withstand rating.

Refer to Figure 7.4.a for an analysis of the short-circuit rating requirements for the 800 A plug-in bus.

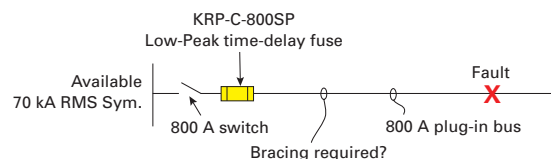


Figure 7.4.a Analysis of the short-circuit rating requirements.

Determining a busway’s short-circuit current rating

The 800 A plug-in bus could be subjected to a 70 kA fault current on its lineside; however, the 800 A Low-Peak Class L KRP-C-800SP time-delay fuse would limit this available current. When protected by a KRP-C-800SP fuses, the 800 A bus need only be braced for 19 kA RMS Sym. This is derived by using the KRP-C-SP fuse let-through chart (see current-limiting fuse let-through data in Section 3). Table 7.4.c on the following page illustrates the minimum required bracing to be 20 kA RMS Sym. when protected by KRP-C-800SP fuses with 80 kA available fault current.

This would allow a standard 22 kA RMS Sym. (three-cycle) rated bus to be specified, whereas, if a non-current limiting OCPD were specified, the bracing requirements would be 70 kA for three cycles.

“Current limiting fuses generally reduce bus bracing requirements to allow a standard short-circuit rated busway to be specified.”

The busway short-circuit, short time rating has a mechanical limit. Exceeding this limit invites physical damage from the high magnetic forces associated with a fault's peak current. The mechanical limit typically applies for high faults near and below the busway short-circuit current rating. Allowable durations of short-circuit current longer than the three-cycles at 60 Hz (0.05 second) required at the maximum short-circuit rating are obtained from a constant I^2t “mechanical damage limit” curve.

Typically, for currents below one-half of the short-circuit current rating, where mechanical stresses are reduced to one-quarter of the maximum rating, the mechanical strength becomes less important than the thermal capability. The lower limit duration at one-half the busway rating is determined by the busway thermal (I^2t) capabilities.

The following example shows busway fault current protection with current-limiting fuses (see Figure 7.4.b). This study looks at the development of the busway mechanical withstand curves and the fuses' time-current curves (a busway used as a branch circuit must be protected against overcurrent in accordance with NEC 210.20).

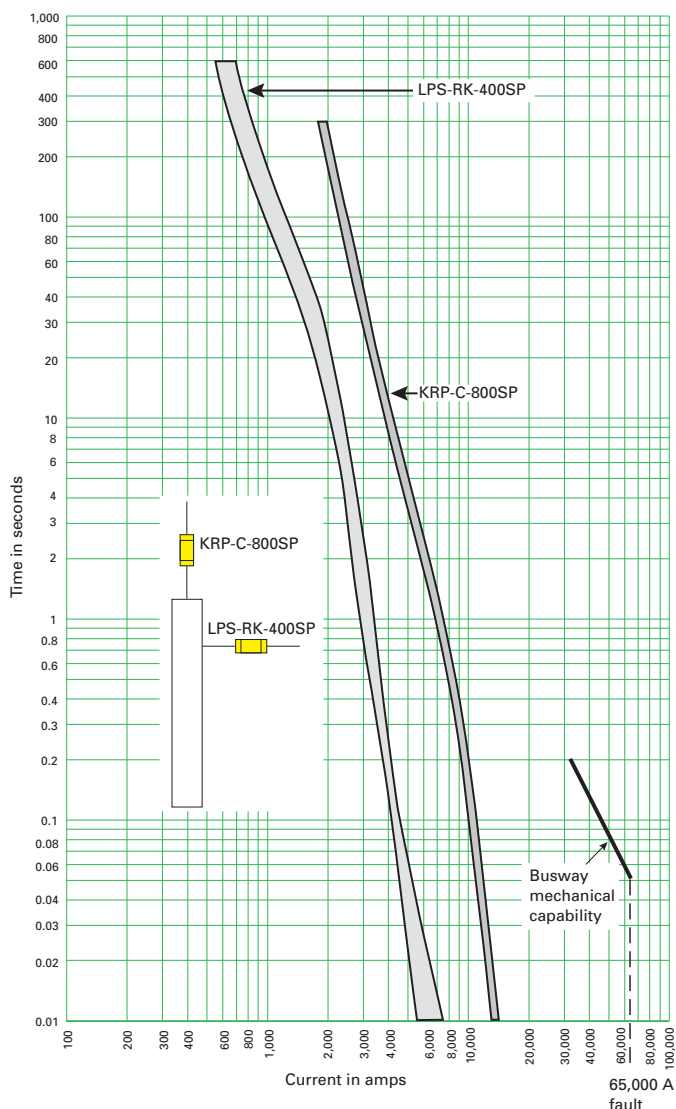


Figure 7.4.b Busway fault current protection with current-limiting fuses.

In this example, the 800 A plug-in busway has a 70 kA short-circuit current rating for three cycles.

A plot of the busway mechanical limit characteristic on log-log paper passes through the short-circuit rating at (70 kA, 0.05 second) and is a constant I^2t down to 32.5 kA (one-half the short-circuit current rating of 70 kA).

Assume the available fault current at the busway is equal to its 70 kA rating. The OCPD is assumed to have the proper interrupting rating.

Shown is the system's plot using Low-Peak Class L and Class RK1 fuses. Current limitation by the KRP-C800SP will offer the busway short-circuit protection, as it lets-through current is 19 kA in less than 1/2 cycle.

Note: The busway is protected by the fast response in the high fault current region. Protection is achieved, as is selective coordination, with the downstream LPS-RK-400SP fuse.

Busway amps	Fuse amps*	Available fault current — amps RMS Sym.				
		25 kA	50 kA	75 kA	100 kA	200 kA
100	100	3400	4200	4800	5200	6500
225	225	6000	7000	8000	9000	12,000
400	400	9200	11,000	13,000	14,000	17,000
600	600	12,000	15,000	17,000	19,000	24,000
601	601	11,000	14,500	17,000	18,000	24,000
800	800	14,200	17,500	20,000	23,000	29,000
1200	1200	16,000	22,500	26,000	28,000	39,000
1600	1600	22,500	28,500	33,000	36,000	46,000
2000	2000	25,000	32,000	37,000	40,000	52,000
3000	3000	25,000	43,000	50,000	58,000	73,000
4000	4000	25,000	48,000	58,000	68,000	94,000

* Fuses are:

- 100 to 600 A Low-Peak dual-element, current-limiting fuses; LPS-RK-SP (Class RK1) or LPJ-SP (Class J)
- 800 to 4000 A Low-Peak time-delay, current-limiting fuses; KRP-C-SP (Class L)

Table 7.4.c Minimum required bracing for bus structures up to 600 V.

UL Standard 891 details fault current durations for busway within switchboards for a minimum of three cycles, unless the main OCPD clears the short in less than three cycles.



7.5 Capacitors

The reason for fusing capacitors is short-circuit protection. A capacitor fails when the dielectric is no longer able to withstand the applied voltage and it “shorts out.” Proper fusing is intended to remove the shorted capacitor from the circuit, prevent it from rupturing and protect the conductors from damage due to fault current. However, proper fusing must also be sized such that the capacitor can operate normally; that is the fuse should not open under the normal, steady state current, or the inrush current when voltage is applied. For example, when a capacitor’s circuit is energized, the capacitor can draw a very high inrush current for a very brief time. Therefore, a capacitor fuse must have the characteristics to not open during the initial current inrush. Also, the capacitor’s steady state current is directly proportional to the applied voltage; when the voltage increases the capacitor current increases.

Capacitors are rated in reactive kilovolt-amperes (kilovars or kVAr) or kilovolt-amperes capacitive (kVAc). Both ratings are synonymous.

Fuse sizing per NEC 460

Protected by	Sizing	Fuse/volt recommendation
Time-delay fuses	150% to 175% of Full Load Current (FLC)	Up to 250 V: LPN-RK-SP, FRN-R Up to 600 V: LPS-RK-SP, FRS-R, LPJ-SP, LP-CC, FNQ-R, TCF
Non time-delay fuses	250% to 300% of Full Load Current (FLC)	Up to 250 V: KTN-R Up to 300 V: JJN Up to 600 V: KTS-R, JKS, KTK-R, JJS, FCF-RN
On loadside of motor running overcurrent device	Protection recommended as shown, but not required —	

The current corresponding to the kVAr rating of a 3-phase capacitor (ic) is computed using this formula:

$$i_c = \text{kVAr} \times 1000\sqrt{3} \times V$$

$$1 \text{ kVAr} = 1000 \text{ VA (reactive)}$$

In a typical capacitor bank configuration there will be a fuse in line with an overload relay and a capacitor. A fuse must be provided on each ungrounded conductor (no protection is required for a capacitor connected on the loadside of a motor running overcurrent device). The fuse rating must be as low as practical [460.8(B)].

Generally, size dual element, current-limiting fuses from 150% to 175% of the capacitor’s rated current and size non-time delay, fast-acting, current-limiting fuses from 250% to 300% of the capacitor’s rated current.

Conductor ampacity must be at least 135% of the capacitor rated current [460.8(A)]. The conductor ampacity for a capacitor connected to a motor circuit must be at least 1/3 the motor circuit conductor ampacity [460.8(A)].

7.6 Circuit breakers

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7.6.1 Overview

A circuit breaker should not be applied where the available short-circuit current at its lineside terminals exceeds its interrupting rating. This is an NEC 110.9 requirement. However, 240.86 contains allowances for protecting downstream circuit breakers with fuses or circuit breakers where the available short-circuit current exceeds the downstream circuit breaker’s interrupting rating.

The terms for this protection is “series rated combination,” “series rating” or “series combination rating.” Properly applying series ratings has many technical limitations and additional NEC requirements that must be met. Series rated combinations allowed per 240.86 should be used sparingly. The series rating requirements are different for new installations versus existing installations.

Starting on page 7-13 are tables for commercially available fuse/circuit breaker series rated combinations published by panelboard and switchboard manufacturers. These tables, along with a compliance check list for evaluating a series rated combination for a specific installation can be viewed or downloaded from Eaton.com/bussmannseries.

Systems can be either fully rated or series rated. As far as interrupting ratings are concerned, fully rated systems are recommended with the benefit that they can be used everywhere.

Fully rated system

A fully rated system is one that has all the individual OCPD individual interrupting ratings equal to or greater than the available short-circuit current at their line terminals per 110.9. Fully rated systems can be protected by all fuses, all circuit breakers, or fuse/circuit breaker combinations. The interrupting rating is required by 240.60(C) to be marked on the branch circuit fuse (unless its interrupting rating is 10 kA). The interrupting rating is required by 240.83(C) to be marked on the branch circuit circuit breaker (unless its interrupting rating is 5 kA). In this section, “individual” or “stand-alone” interrupting rating is used to denote the fuses’s or circuit breaker’s interrupting rating. It’s the “individual” or “stand-alone” interrupting rating that is marked on a fuse or circuit breaker (see Figure 7.6.a). A major advantage with modern current-limiting fuses is that they have 200 kA or 300 kA interrupting ratings that can protect against virtually any fault current level.

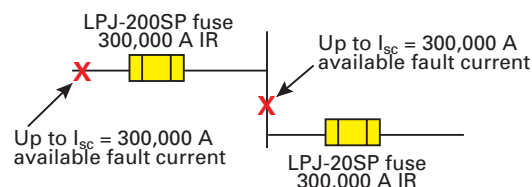


Figure 7.6.1.a Current-limiting fuses with up to 300 kA IR can protect against virtually any fault.

Series rated system

A series rated combination is a specific circuit breaker/circuit breaker combination or fuse/circuit breaker combination that can be applied at available short-circuit current levels above the loadside (protected) circuit breaker's interrupting rating, but not above the lineside (protecting) device's interrupting rating.

A series rated combination can consist of:

- Fuses protecting circuit breakers
- Circuit breakers protecting circuit breakers

With the stipulations that a fuse cannot protect a fuse, and a circuit breaker cannot protect a fuse.

Figure 7.6.1.b illustrates a fuse/circuit breaker series rated combination. While there are common series rated requirements for new and existing installations, each has additional, specific requirements. The following addresses the common and specific requirements for new and existing installations.

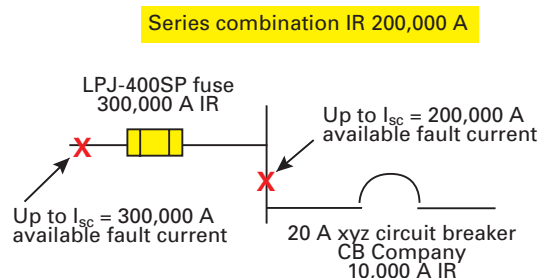


Figure 7.6.1.b A fuse/circuit breaker combination can achieve a high IR.

Fully rated vs. series rated systems

Fully rated systems are the preferred choice for many reasons. If fully rated fuses are used and the proper choices are made, the systems will not have any limitations as described in the previous paragraphs. In addition, if a fully rated system uses modern current-limiting fuses with 200 kA or higher interrupting ratings, the system will likely remain fully rated over its life — even if changes or additions occur that increase the available short-circuit current.

Series rated combinations should be used sparingly. The most suitable application for series rated combinations is for branch circuit, lighting panel circuit breaker protection. Lighting panels typically do not have significant motor loads, so the motor contribution limitation [240.86(C)] is not an issue for series rated combinations. However, series rated combinations used for power panel or main/feeder applications can pose a problem upon initial installation or if future loads change.

A recommendation is to use fully rated fuses for all lighting panelboards, power panelboards, distribution panelboards, motor control centers, motor branch circuits, emergency circuits, elevator circuits and switchboards.

Most series rated combinations cannot be selectively coordinated. This is a major limitation that most building owners or tenants do not want. Unnecessary blackouts in an electrical system is unacceptable in today's business environment, technology driven healthcare systems, or emergency circuits. Consider the consequences if there is a disaster to a portion of the building; it is important for safety egress to have as much of the electrical system in service as possible.

7.6.2 Tested series rated combinations

The industry has devised a method for a Nationally Recognized Testing Laboratory (NRTL) to test a manufacturer's specific type and size circuit breaker combination beyond its marked interrupting rating when protected by specific type lineside fuses or circuit breakers of a maximum amp rating. An NRTL does not list the fuse/circuit breaker combination by itself as a series rated combination.

The series combination has to be evaluated and found suitable for a specific manufacturer's panelboard, loadcenter, switchboard or other equipment. Section 240.86(B) requires that when a series rating is used, the switchboard, panelboard, loadcenter, or other equipment be marked by the manufacturer for use with the specific series rated combinations, indicating they've been investigated for such use with those specific series rated combinations. For instance, the series rated combination shown in Figure 7.6.1.b is tested and marked for use in a particular manufacturer's panelboard as shown in Figure 7.6.2.a. Notice in these two figures that the loadside circuit breaker has an individual marked 10 kA interrupting rating. However, with the series rated combination testing and marking, it may be possible to use it where there is 200 kA available fault current. Also, note that this rating applies to:

1. A specific manufacturer's type and size circuit breaker.
2. When used in a specific manufacturer's type panelboard, switchboard or other equipment.
3. When protected on the lineside by a specific OCPD maximum amp rating.
4. The panelboard is factory marked with the necessary series combination rating specifics.

The lineside (protecting) fuse or circuit breaker can be installed in the same panelboard or a separate enclosure.

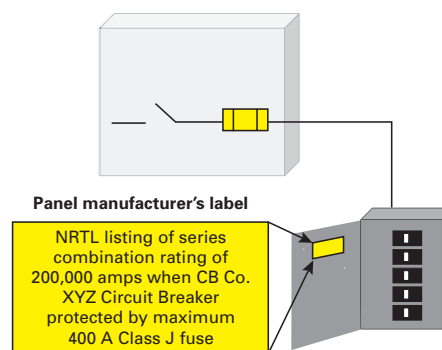


Figure 7.6.2.a NEC 240.86(B) labeling.

Because there is often not enough room in the equipment to show all of the legitimate series rated combinations, UL 67 (panelboards) allows for a bulletin to be referenced and supplied with the panelboard. These bulletins typically provide all the acceptable series rated combinations for that panelboard.

Bussmann has researched the major manufacturers' application literature and published the tables starting on page 7-13. These tables show, by manufacturer, the various series rated fuses and breakers combinations that are acceptable by panelboard and switchboard type. Note that more combinations may be available for loadcenters and metercenters; refer to the equipment manufacturer's literature.

Although series rated combinations save a little on the initial equipment costs, there are many issues involved with designing and utilizing series rated combinations. If series rated combinations are considered for use, there are other NEC requirements that must be met. Since series rated combinations are evaluated by laboratory testing under specific conditions, these other requirements are extremely important in order to make sure a series rated combination is, in fact, applied per its testing, listing and marking [110.3(B)].

7.6.3 Series rated systems — new installations

For new installations, the series rated combinations must be tested and marked on specific panelboards and switchboards [240.86(B)]. While testing determines the series combination rating, that rating is not marked on circuit breakers or fuses.

As will be shown in this section, the manufacturer of the panelboard, loadcenter, switchboard or other equipment in which the protected circuit breaker is installed must mark the equipment with the tested series rated combination details. In a later section, field labeling per NEC 110.22 and motor contribution limitation requirements are discussed.

A series rated combination compliance checklist for new installations is available in the Inspection Checklist section of this publication.

Labeling requirements:

- Factory label: the switchboard, panelboard or other equipment is required to be tested, listed and factory marked for use with series rated combination to be utilized per 240.86(B).
- Field label: installer (electrical contractor) to affix labels on the equipment enclosures, which note the series combination rating and call out the specific replacement OCPDs to be utilized. If the upstream OCPD protecting the downstream circuit breaker is in a different enclosure, then both enclosures need to have field-installed labels affixed.

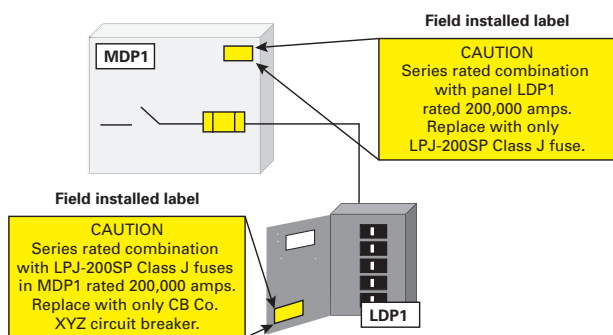


Figure 7.6.3.a New installation labeling per 240.86(B) and 110.22(C).

7.6.4 Series rated systems — existing installations

For existing installations, NEC 240.86(A) permits licensed professional engineers to select series rated combinations by other means than testing by an NRTL.

When buildings undergo improvements, or when new transformers are installed, the new available fault currents can exceed the existing circuit breakers' interrupting ratings. This is a serious safety hazard and does not comply with NEC 110.9. In the past, an owner in this situation faced the possibility of replacing the existing circuit breaker panel with a new circuit breaker or fusible panel with OCPDs having sufficient interrupting ratings for the new available fault currents. This could be very expensive and disruptive.

Now, for existing systems, a licensed professional engineer can determine if a lineside fuse or circuit breaker upgrade can constitute a sufficient series rated combination with existing loadside breakers. This option may represent a significant cost savings versus replacing the existing gear.

The professional engineer must be qualified by primarily working in the design or maintenance of electrical installations. Documents on the selection must be stamped and available to all necessary parties. The series rated combination must also be labeled in the field, including upstream OCPD identification.

There may be several analysis options for a licensed professional engineer to comply with 110.9 where existing circuit breakers have inadequate interrupting ratings. In some cases, a suitable method may not be feasible.

Methods

1. Check to see if a new fused disconnect can be installed ahead of the existing circuit breakers utilizing a tested series rated combination. Even though the existing system may not take advantage of series ratings, the panel manufacturer may have a table or booklet that provides all the possible tested fuse-circuit breaker series ratings combinations.

2. If the existing system used series ratings with Class R fuses, analyze whether a specific Bussmann series Class RK1, J or T fuse may provide the protection at the higher short-circuit current level. The series ratings for panelboards that use lineside Class R fuses have been determined with special, commercially unavailable* Class RK5 umbrella fuses. Actual, commercially available Bussmann series Class RK1, J or T fuses will have current-limiting let-through characteristics considerably better than the Class RK5 umbrella fuse limits.

* Commercially unavailable umbrella fuses are only sold to electrical equipment manufacturers in order to perform equipment short-circuit testing.

3. Supervise lineside current-limiting fuse short-circuit testing to verify that protection is provided to circuit breakers that are identical to the existing, installed circuit breakers.
4. Perform an analysis to determine if current-limiting fuses installed on the existing circuit breakers, lineside provides adequate protection for the circuit breakers. For instance, if the existing equipment is passive during the interruption period, such as with low voltage power circuit breakers (approximately 3-cycle opening time), then the lineside fuse short-circuit let-through current (up, over and down method) must be less than the circuit breaker's interrupting rating.

7.6.5 Labeling requirements

Field labeling: for engineered series ratings (see Figure 7.6.5.a), affix labels on the equipment enclosures, which note engineered series rating, the series combination rating and call out the specific replacement OCPDs. If the upstream OCPD protecting the downstream circuit breaker is in a different enclosure, then both enclosures need to have field installed labels affixed. 240.86(A) and 110.22(B).

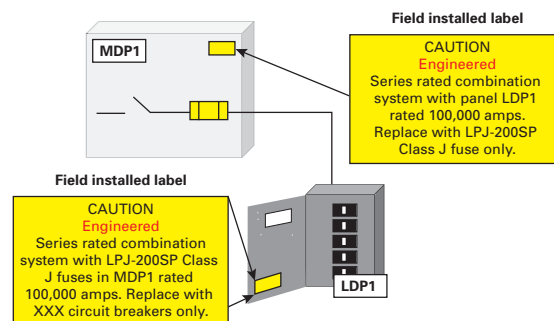


Figure 7.6.5.a Existing installation labeling per 240.86(A) and 110.22(B).



7.6.6 Motor contribution and limitation

Where motors are connected between the lineside (protecting) device and the loadside (protected) circuit breaker, 240.86(C) has a critical limitation on series rated combination use. This section requires that a series rated combination must not be used where the motor full load current sum exceeds 1% of the loadside (protected) circuit breaker's individual interrupting rating (see Figure 7.6.f). The reason is that when a fault occurs, running motors momentarily contribute current to the short-circuit (usually about four to six times their full load rating). This added motor contribution may result in short-circuit current that exceeds what the loadside (protected) circuit breaker was tested to handle per the series rated combination testing. Motor contribution is critical for initial installations, but in addition, future system changes can negate the series combination rating.

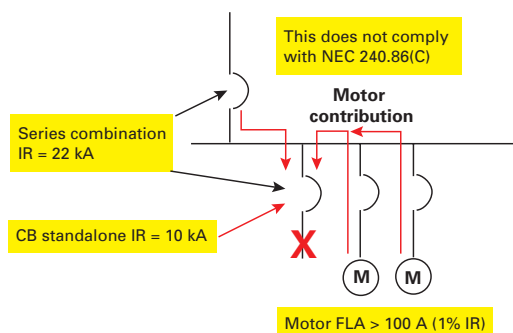


Figure 7.6.6.a Motor contribution considerations.

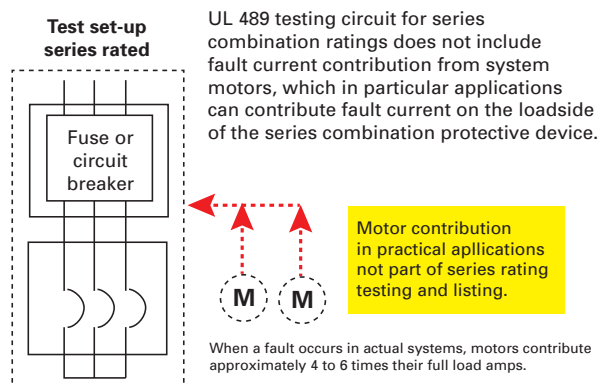


Figure 7.6.6.b UL 489 testing configuration.

This is one of the major reasons that series rated combinations are generally recommended only for lighting panel applications. Lighting panels typically do not have significant motor loads, so the motor contribution between the feeder overcurrent device and lighting panel branch circuit breakers is not an issue upon initial installation, or in the future. However, series rated combinations used for power panel or main/feeder applications can often pose a problem upon initial installation or if future loads change.

7.6.7 Examples

Example 1

The implications of 240.86(C) are contained in Figure 7.6.7.a. With an installation having a 1000 A total load, 50% motor load (500 A motor load), the motor contribution could be an issue in selecting a series rated combination. If a main/feeder series rating were to be considered, the feeder circuit breaker must have at least a 50 kA individual or standalone interrupting rating per 240.86(C) (1% of 50,000 = 500). If the protected circuit breaker needs at least a 50 kA individual interrupting rating, it negates the reason that series rated combinations are utilized for most applications.

Total calculated load: 1000 amps
System motor load (MCC1 and MCC2): 500 amps

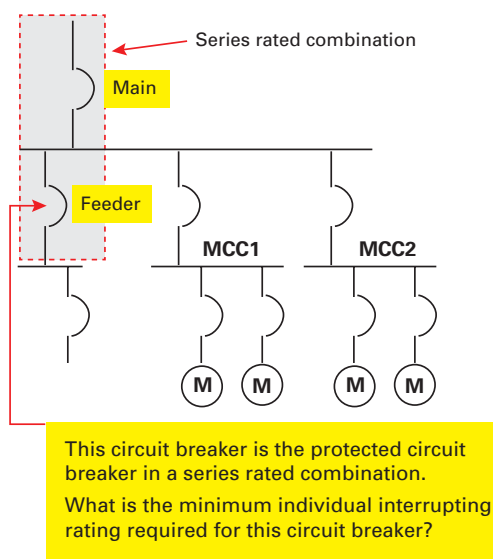


Figure 7.6.7.a Example 1 diagram.

Example 2

Use Table 7.6.7.b to evaluate the “protected” (loadside) circuit breaker in a series rated combination for meeting the motor contribution limits in 240.86(C). In Figure 7.6.7.a, the connected motors could contribute current where the feeder circuit breaker (“protected” device of the “series combination”) would have to interrupt, but that the main circuit breaker (“protecting” device of the “series combination”) would not have to interrupt is represented by normal full load current of 500 A. In column A of the table below, the 500 A full load motor current exceeds 420 A. Therefore, a series rating with a “protected” circuit breaker having a standalone interrupting rating of 42 kA AIR is insufficient to meet 240.86(C). A series combination that uses a “protected” circuit breaker with a standalone interrupting rating of at least 50 kA would be required to meet 240.86(C).

Note: Do not confuse the “protected” circuit breaker’s standalone interrupting rating with the series combination rating. The series combination rating is the rating for both devices working together to interrupt fault currents. The series combination rating is much greater than the “protected” circuit breaker’s standalone interrupting rating.

Motor full load amps must not exceed this value, If using series combination with “protected” circuit breaker having standalone interrupting rating in Column B	“Protected” circuit breaker standalone interrupting rating in series combination
(A)	(B)*
75 A	7500 AIR
100 A	10,000 AIR
140 A	14,000 AIR
180 A	18,000 AIR
200 A	20,000 AIR
220 A	22,000 AIR
250 A	25,000 AIR
300 A	30,000 AIR
350 A	35,000 AIR
420 A	42,000 AIR
500 A	50,000 AIR
650 A	65,000 AIR

* Some possible circuit breaker interrupting ratings per UL 489, Table 8.1.

Table 7.6.7.b Example 2 motor contribution table.

Example 3

Assessing the series combination rating for motor contribution limits in the following system (see.

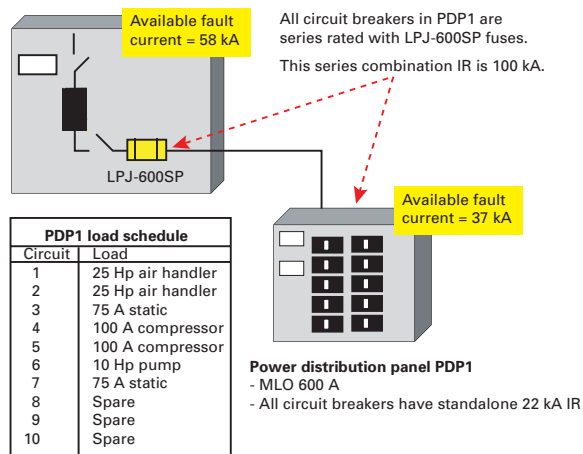


Figure 7.6.7.c Example 3 diagram.

Step 1: Determine total motor load

Quantity	Component	Amps
2	100 A compressors	200
2	25 Hp motors @ 34 A each	68
1	10 Hp pump @14 A	14
Total motor load connected between series rated devices		282

Step 2: Is the series rated combination shown acceptable?

No. The series combination shown has a 100 kA series combination rating, which is sufficient for the 37 kA available short-circuit current at PDP1. The 600 amp LPJ-600SP fuses have a 300 kA interrupting rating, which is sufficient for the 58 kA available short-circuit current at the main switchboard. However, the series combination “protected” circuit breakers, which are located in PDP1, have a standalone or individual 22 kA interrupting rating. The motor load connected between the protecting and protected devices in the series rated combination cannot exceed 1% of the protected circuit breaker’s standalone interrupting rating. The motor load is 282 A, which exceeds 1% of 22 kA (220 A), making this series rated combination non-compliant with 240.86(C).

Then consider the building’s uncertain future. Many buildings, such as office buildings, manufacturing facilities, institutional buildings and commercial spaces, by their nature, incur future changes. A properly designed and initially installed series combination rating could be compromised should building loads change to a larger percentage of motor loads.

As just illustrated, it’s not enough to just check the available short-circuit current against the series combination rating. 240.86(C) also requires the designer, contractor and AHJ to investigate the protected circuit breaker’s individual or standalone interrupting rating in the series combination. This is necessary for series rated combinations used in new installations as well as existing series rated combinations, when refurbishing or upgrading existing systems.

7.6.8 Selective coordination

In most applications, series rated combinations cannot be selectively coordinated. In order to protect the loadside circuit breaker, the lineside (protecting) device must open in conjunction with the loadside (protected) circuit breaker. This means the entire panel can lose power because the device feeding the panel must open under short-circuit conditions.

When applying series rated combinations, it’s difficult to meet the selective coordination requirements for:

- Elevator circuits (620.62)
- Critical operations data systems (645.27)
- Emergency systems (700.28)
- Legally required standby systems (701.27)
- Critical operations power systems (708.54)

Applying series rated combinations reduces overall emergency circuit reliability caused by the inherent lack of selective coordination (see Figure 7.6.8.a).

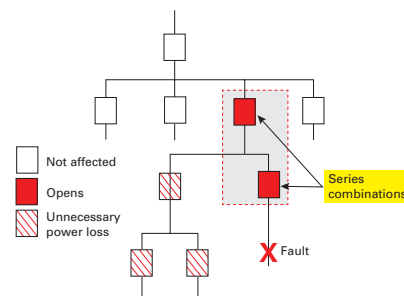


Figure 7.6.8.a Selective coordination and series ratings.

7.6.9 Component protection

Using series rated combinations does not assure circuit component protection. The series rating only pertains to the OCPDs. Specifically, it means a lower interrupting rating loadside circuit breaker can be used in an application with higher available fault currents. In practical applications, the other circuit components (conductors, busway, contactors, etc.) should be independently assessed for protection under the worst case short-circuit conditions.

7.6.10 Recommended solution

If a series rated combination is to be used, the designer and contractor should select the tested and marked lineside protection that will assure reliable performance over the electrical system’s lifetime. If the lineside (protecting) OCPD does not function as intended, due to lack of maintenance or loss of calibration, the original protection level is lost.

Fuses are recommended when using series rated combinations. Modern current-limiting fuses are the most reliable OCPDs available. While periodic fuse maintenance is not required, it’s recommended that disconnects, and all conductor and fuse terminations be periodically inspected and maintained. Regardless, whether it’s the first day of service or years later, modern current-limiting fuses will respond to protect the circuit components as originally designed.



If and when fuses are called upon to open on an overcurrent, installing the same type and amp rated fuses provides the circuit with new, factory-calibrated fused protection. The original design integrity can be maintained throughout the electrical system's life. With fuses there is typically no worry about replacing an incorrect one in per the series rating. Modern current-limiting fuses have mountings that only accept the same fuse class and case size. All the testing, listing and marking of series rated combinations that utilize fuses as the lineside (protecting) device are tested with the maximum fuse amp rating that fits into the fuse mounting. For instance, all the series ratings with lineside fuses are at the maximum amp ratings for 30, 60, 100, 200, 400, 600 amp standard fuse mounting.

Per UL/CSA/ANCE 248 fuse standards, the lineside fuses used in testing for series rated combinations are special "umbrella" fuses that intentionally exceed the maximum short-circuit current let-through values for specific fuse classes and amp ratings. These special "umbrella" fuses add an extra safety factor that ensures the short-circuit current let-through energy represents the worst case for all the commercially available fuses for that fuse class and amp rating. As mentioned previously, it is an umbrella fuse with the highest amp rating that fits in a standard fuse mounting. In addition, the commercially available fuses undergo periodic follow up testing witnessed by the listing agency to verify that the products continue to have short-circuit let-through values under the umbrella limits.

7.6.11 Example of practical series rated combination application

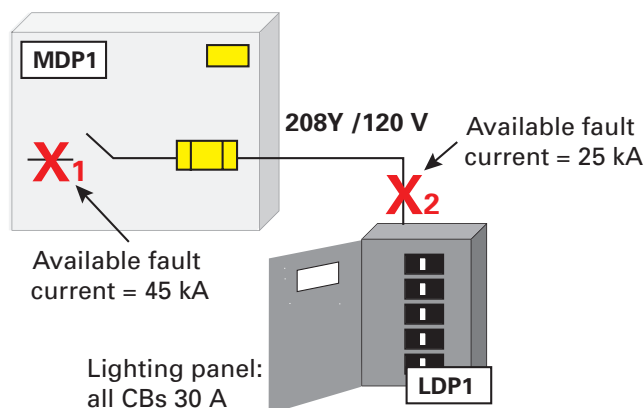


Figure 7.6.11.a Series rated combination application.

In Figure 7.6.11.a, the 208Y/120 V, 200 A lighting panel LDP1 has 25 kA available short-circuit current. The distribution panel MDP1 has 45 kA available. The lighting panel has all single-pole, 20 A circuit breakers. The typical standard 20 A lighting panel circuit breaker has a 10 kA interrupting rating, which is insufficient for the 25 kA available fault current. The options are:

1. Use a higher interrupting rated circuit breaker for the lighting panel, which may cost more and require more space
2. Use a series rated combination. The series rated combination option can be investigated by looking at the fuse/circuit breaker tables by panelboard manufacturer that are in this handbook's appendix.

Every major panelboard manufacturer has a suitable fuse/circuit breaker series rated solution. The example that follows uses Eaton equipment (the table on page 7-13). The selected Eaton panelboard is a type PRL1A with BA single-pole, 20 A, circuit breakers (which have a 10 kA individual interrupting rating) protected by 200 amp Bussmann series LPJ-200SP fuses (which have a 300 kA interrupting rating). From the table, this series combination rating is 200 kA. That means if all the other requirements are met, the BA circuit breakers in this type panelboard can be applied in a system having an available short-circuit current up to 200 kA at the point where the panelboard is installed. The requirements that must be met are:

1. The series combination rating must be equal to or greater than the available short-circuit current at the circuit breaker location(X2). Remember, the loadside circuit breaker in a series rated combination can be applied beyond its individual interrupting rating (a BA circuit breaker in this case has a 10 kA individual interrupting rating).
2. In this example, the series rated combination interrupting rating is 200 kA and there is 25 kA available short-circuit current. The protecting overcurrent protective device's interrupting rating must have an individual interrupting rating equal to or greater than the available short-circuit current at its point of application (X1). In this example, the 200 amp LPJ-200SP fuses have a 300 kA individual interrupting rating and there is 45 kA available short-circuit current.
3. The loadside (protected) circuit breaker's individual interrupting rating must meet the minimum required in 240.86(C) due to motor contribution. In this case, it's a lighting panel application and there aren't any motor loads on the LPJ-200SP fuses' loadside.
4. Selective coordination in this application is not required per the NEC as this is not a healthcare application, an elevator circuit, nor a part of an emergency legally required standby, or critical operations power system circuit. However, the owner and designer should consider the consequences of not having selective coordination. If selective coordination were deemed necessary, another approach would have to be taken.
5. The panelboard must be marked by the manufacturer and provide sufficient details about the tested series combination rating. The installer must field install a label on the panelboard and the distribution panelboard providing specific details for the installed series combination rating, the devices and their respective locations. These are critical to verify the proper ratings for the initial installation and during the system's life.

See the following series rating tables.



7.6.12 Series combination ratings tables

Eaton series ratings

Switchboards: PRL-C / PRL-i

Panelboards: PRL 5P, PRL 4, PRL 3A and Pow-R-Command Panelboards

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
120/240 Vac	100	LPN-RK	200	GB, GHB	All	1, 2
		JJN, LPJ	400	BA, BAB, HQP, QBHW, QPHW	All	1, 2
	200	LPN-RK	100	BA, BAB, HQP, QBHW, QPHW, GB, GHB	All	1, 2
		JJN, LPJ	200	BA, BAB, HQP, QBHW, QPHW	All	1, 2
		JJN, LPJ	400	GB, GHB	All	1, 2
240 Vac	100	LPN-RK	200	GHB	All	1, 2, 3
				GB, CA	All	2, 3
		JJN, LPJ	400	BAB_H, QBHW_H, HQP_H, QPHW_H	All	2, 3
		JJN	600	CA, CAH, HCA	All	2, 3
		KRP-C	4000	EHD, FD	All	1, 2, 3
	200	KRP-C	4000	FDB, ED, JDB, JD, DK, KDB, KD	All	2, 3
		LPN-RK	100	GHB	All	1, 2, 3
				BAB_H, QBHW_H, HQP_H, QPHW_H, CAH, HCA, GB	All	2, 3
		LPN-RK	200	GHB	All	2, 3
		JJN, LPJ	200	BAB_H, QBHW_H, HQP_H, QPHW_H, CAH, HCA	All	2, 3
		JJN, LPJ	400	GHB	All	1, 2, 3
				GB	All	2, 3
	65	JJS, LPJ	200	GHBS	All	1, 2, 3
		JJS, ;PJ	100	GHBS	All	2, 3
	100	LPS-RK	200	GHB	All	1, 2
		LPJ	600	EHD, FD, HFD, FDC	All	1, 2
		JJS	600	GHB, EHD, FD, HFD, FDC, JD, HJD, JDC	All	1, 2, 3
480/277 Vac	200	LPS-RK	100	GHB	All	2, 3
		JJS, LPJ	400	GHB	All	2, 3
	100	LPS-RK	100	EHD	All	1, 2, 3
		JJS, LPJ	200	EHD, FD, HFD, FDC	All	2, 3
		KRP-C	1200	MC, HMC, NC, HNC	All	2, 3
480 Vac	200	KRP-C	800	MC, HMC	All	2, 3
			100	FD, HFD, FDC	All	2, 3
	100	LPS-RK	200	JD, HJD, JDC	All	2, 3
			400	KD, HKD, KDC	All	2, 3
			600	LC	All	2, 3
		JJS, LPJ	200	FD, HFD, FDC	All	2, 3
			400	JD, HJD, JDC	All	2, 3
			1200	LC	All	2, 3
	200	LSP-RK	400	LC	All	2, 3
		JJS, LPJ	600	KD, HKD, KDC, LC	All	2, 3

* Series combination rating

Table notes:

1. The data in these tables was compiled from information in Eaton, Series Rating Information Manual, catalog reference number 1C96944Ho1 Rev. E, pages 18-24, and Eaton, Consulting Application Catalog 12th Edition, pages F1-11 - F1-12. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
2. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
3. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.

Eaton series ratings

Panelboards: PRL 1A, PRL 2A, PRL 1A-LX, PRL 2A-LX

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Load side		
				Circuit breaker	Amps	Poles
120/240 Vac	100	LPN-RK	200	GB, GHB	All	1, 2
		JJN, LPJ	400	BA, BAB, HQP, QBHW, QPHW	All	1, 2
	200	LPN-RK	100	BA, BAB, HQP, QBHW, QPHW, GB, GHB	All	1, 2
		JJN, LPJ	200	BA, BAB, HQP, QBHW, QPHW	All	1, 2
		JJN, LPJ	400	GB, GHB	All	1, 2
240 Vac	100	LPN-RK	200	GHB	All	1, 2, 3
				GB, CA	All	2, 3
		JJN, LPJ	400	BAB_H, QBHW_H, HQP_H, QPWH_H	All	2, 3
		JJN	600	CA, CAH, HCA	All	2, 3
		KRP-C	6000	EHD, FD	All	1, 2, 3
	200	KRP-C	6000	FDB, ED, JDB, JD, DK, KDB, KD	All	2, 3
		LPN-RK	100	GHB	All	1, 2, 3
				BAB_H, QBHW_H, HQP_H, QPHW_H, CAH_H, HCA, GB	All	2, 3
		LPN-RK	200	GB, GBH	All	2, 3
		JJN, LPJ	200	BAB_H, HQP_H, QBHW_H, QPHW_H, CA, CAH, HCA	All	2, 3
		JJN, LPJ	400	GHB	All	1, 2, 3
480/277 Vac	65			GB	All	1, 2
		JJS, LPJ	200	GHBS	All	1, 2
	100	JJS, LPJ	100	GHBS	All	1, 2
		LPS-RK	200	GHB	All	1, 2, 3
		LPJ	600	EHD, FD, HFD, FDC	All	2, 3
		JJS	600	GHB, EHD, FD, HFD, FDC, JD, HJD, JDC	All	2, 3
	200	LPS-RK	100	GHB	All	1, 2, 3
		JJS, LPJ	400	GHB	All	1, 2, 3

* Series combination rating.

Table notes:

1. The HQP and QPHW are not listed for use in the PRL1A-LX panel.
2. PRL 1A and PRL 1A-LX are for use at 240 V maximum
3. Branch breakers for maximum 120/240 V systems include BAB, HQP, QBHW and QPHW.
4. Branch breakers for maximum 240 V systems include BAB_H, HQP_H, QBHW_H and QPHW_H.
5. PRL 2A and PRL 2A-LX, branch breakers include GHB, GHBS and GB.
6. PRL 1A-LX and PRL 2A-LX main and sub-feed breakers include ED, FD, HFD, FDC.
7. PRL 1A and PRL 2A main and sub-feed breakers include CA, CAH, HCA, ED, FD, HFD, FDC, JD, HJD, JDC, KD, HKD and KDC.
8. The data in these tables was compiled from information in Eaton, Series Rating Information Manual, catalog reference number 1C96944Ho1 Rev. E, pages 18-24, and Eaton, Consulting Application Catalog 12th Edition, pages F1-11 - F1-12. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
9. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
10. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.



Eaton series ratings

Triple series rating - switchboards: PRL-C and PRL-i

Panelboard types: PRL 5P, PRL 4, PRL 3A, PRL 2A, PRL 2A-LX, PRL 1A, PRL 1A-LX and Pow-R-Command panels

Max system Volts	SCIR* (kA)	Lineside fuse	Tenant main type	Branch type		
				Circuit breaker	Amps	Poles
120/240 Vac	100	KRP-C (6000 A max)	DK, KDB, KD	GB, GHB	All	1, 2
			JD, JDB	GB, GHB	All	1, 2
			FD	GB, GHB	All	1, 2
			FD, FDB	HQP	15-70	1, 2
				BA, BAB	All	1, 2
			EHD	BA, BAB, HQP	All	1, 2
				GHB	All	1, 2, 3
				GB, EHD	All	2, 3
			DK, KDB, KD	CA, CAH, HCA	All	2, 3
				FD, FDB	All	2, 3
240 Vac	100	KRP-C (6000 A max)		JD, JDB	All	2, 3
			JD, JDB	GHB	All	1, 2, 3
				GB	All	2, 3
			FD	GHB	All	1, 2, 3
				GB	All	2, 3
			FD, FDB	BAB_H, QBHW_H, HQP_H, QPHW_H	All	2,3
			EHD	BAB_H, HQP_H	All	2, 3

* Series combination rating.

Table notes:

1. The data in these tables was compiled from information in Eaton, Series Rating Information Manual, catalog reference number 1C96944Ho1 Rev. E, pages 18-24, and Eaton, Consulting Application Catalog 12th Edition, pages F1-11 - F1-12. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
2. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
3. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.



General Electric series ratings

Spectra Series (see notes on page 7-20)

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside						
				Circuit breaker	Amps	Poles				
240 Vac	42	LPJ, JJN	600	TJD	250-400	2, 3				
		KRP-C	2000	TJD	250-400	2, 3				
	100	JJN, LPJ	400	TQD	125-225	2, 3				
			600	THHQB	40-100	3				
				TQD	100-225	2				
				TQD	125-225	3				
		JJN	800	TJD	250-400	2, 3				
			1200	SFH	70-250	2, 3				
			KRP-C	2000	TJD	250-400	2, 3			
				2500	THJK	250-600	2, 3			
	200	LPN-RK	200	TEB, TED	15-100	1, 2, 3				
				SFH, SFL	70-250	2, 3				
				SED, SEH, SEL	15-150	2, 3				
		JJN, LPJ	400	TEB	15-100	1, 2				
				TEB, TED	15-100	2, 3				
				TJD	250-400	2, 3				
				SFH, SFL	70-250	2, 3				
			600	SED, SEH, SEL	15-150	2, 3				
				KRP-C	2000	SGD, SGH, SGL	125-600	2, 3		
					277 Vac	100	LPS-RK	100	TED	15-50
				200				THED	15-30	1
TEY	15-100	1								
JJS, LPJ	400	SED, SEH, SEL	15-150				2, 3			
	600	TEY	15-100	1						
		TED	15-50	1						
480 Vac	65	LPJ	400	TED		15-50	1			
			200	THED		15-30	1			
				SED, SEH, SEL		15-150	2, 3			
		LPS-RK		600		TEY	15-100	1		
			100	JJS, LPJ	SED, SEH, SEL	15-150	2, 3			
					TEY	15-100	1			
	SED, SEH, SEL				15-150	2, 3				
	200	KRP-C	800	SKH, SKL	300-1200	2, 3				
			1200	THJK	125-600	2, 3				
			KRP-C	2000	SKH, SKL	300-1200	2, 3			
SGH, SGL				125-600	2, 3					
200		KRP-C	2000	TPV, THPV	800 A FRAME**	3				
			2500	TPV, THPV	2500 A FRAME**	3				
		600 Vac	200	KRP-C	2000	TPV, THPV	800 A FRAME**	3		
					2500	TPV, THPV	2500 A FRAME**	3		

* Series combination rating.

**Includes all sensor/rating plug or setting values within stated frame size.

General Electric series ratings

AL / AQ Panelboard (see notes on page 7-20)

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
240 Vac	42	JJN	600	THQL-GF	15-30	1
				THQL	15-100**	1, 2, 3
		JJN, LPJ	600	TJD	250-400	2, 3
		KRP-C	2000	TJD	250-400	2, 3
	65	JJN	600	THHQL	15-70	1
				THHQL	15-125	2
		JJN, LPJ, LPN-RL	600	TFJ	70-225	2, 3
		KRP-C	3000	TFJ	70-225	2, 3
		LPN-RK	200	THQL	15-100**	1, 2, 3
		JJN	200	THQP	15-50	1, 2
			400	THQL	15-100**	1, 2, 3
				TQD	125-225	2, 3
	100	JJN, LPJ	600	THHQL, THHQB	40-100	3
				TFJ	70-225	2, 3
				TQD	100-225	2
				TQD	125-225	3
		JJN	800	TJD	250-400	2, 3
				TFJ	70-225	2, 3
		KRP-C	1200	SFH	70-250	2, 3
				TJD	250-400	2, 3
				THQL	15-100**	1, 2
				TFJ	70-200	2, 3
	200	LPN-RK	200	SFH, SFL	70-250	2, 3
				SED, SEH, SEL	15-150	2, 3
				THQL	15-100**	1, 2
				TFJ	70-225	2, 3
		JJN, LPJ	400	TJD	250-400	2, 3
				SFH, SFL	70-250	2, 3
				SED, SEH, SEL	15-150	2, 3
				SGD, SGH, SGL	125-600	2, 3
		KRP-C	2000			

* Series combination rating.

**THQL 1-pole rating is 70 A maximum. Maximum system voltage is 120/240 Vac., THQL 2 pole 110-125 A ratings are also series rated on 120/240 Vac maximum services.



General Electric series ratings

ALC / AQC Panelboard (see notes on page 7-20)

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside			
				Circuit breaker	Amps	Poles	
240 Vac	42	JJN	600	THQL-GF	15-30	1	
				THQL	15-100**	1, 2, 3	
	65	JJN	600	THHQL	15-70	1	
				THHQL	15-125	2	
		JJN, LPJ, LPN-RL	600	TFJ	70-225	2, 3	
				KRP-C	3000	TFJ	70-225
		LPN-RK	200	THQL	15-100**	1, 2, 3	
				JJN	200	THQP	15-50
	100	JJN, LPJ	400	THQL	15-100**	1, 2, 3	
				TQD	125-225	2, 3	
			600	THHQL, THHQB	40-100	3	
				TFJ	70-225	2, 3	
				TQD	100-225	2	
				TQD	125-225	3	
		KRP-C	1200	TFJ	70-225	2, 3	
				SFH	70-250	2, 3	
		200	LPN-RK	200	THQL	15-100**	1, 2
					TFJ	70-200	2, 3
	SFH, SFL				70-250	2, 3	
	SED, SEH, SEL				15-150	2, 3	
	JJN, LPJ		400	THQL	15-100**	1, 2	
				TFJ	70-225	2, 3	
			600	SFH, SFL	70-250	2, 3	
				SED, SEH, SEL	15-150	2, 3	

* Series combination rating.

**THQL 1-pole rating is 70 A maximum. Maximum system voltage is 120/240 Vac. THQL 2-pole 110-125 A ratings are also series rated on 120/240 Vac maximum services.



General Electric series ratings

AE / AD Panelboard (see notes on page 7-20)

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
277 Vac	100	LPS-RK	100	TED	15-50	1
				THED	15-30	1
				TEY	15-100	1
			200	SED, SEH, SEL	15-150	2, 3
				TEY	15-100	1
				TED	15-50	1
		JJS, LPJ	400	TED	15-50	1
				THED	15-30	1
				SED, SEH, SEL	15-150	2, 3
			600	TEY	15-100	1
				SED, SEH, SEL	15-150	1
				SED, SEH, SEL	15-150	1
480 Vac	100	LPJ	600	TED, THED	15-150	2, 3
			100	TED, THED6	15-100	2, 3
		LPS-RK	200	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
			400	TED	15-50	1
				TED, THED6	15-100	2, 3
				TFJ	70-225	2, 3
				TJJ	125-400	2, 3
				SFH, SFL	70-250	2, 3
				SGH, SGL	125-600	2, 3
			600	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
		JJS	800	SKH, SKL	300-1200	2, 3
		KRP-C	1200	TJL	125-400	2, 3
			2000	SKH, SKL	300-1200	2, 3
				SGH, SGL	125-600	2, 3

* Series combination rating.

AEC Panelboard (see notes on page 7-20)

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
277 Vac	100	LPS-RK	100	TED	15-50	1
				TEY	15-100	1
				SED, SEH, SEL	15-150	2, 3
			200	TEY	15-100	1
				TED	15-50	1
				TED	15-50	1
		JJS, LPJ	400	SED, SEH, SEL	15-150	2, 3
			600	TEY	15-100	1
				SED, SEH, SEL	15-150	
	65	LPJ	600	TED	15-150	2, 3
			100	TED	15-100	2, 3
		LPS-RK	200	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
			400	TED	15-50	1
				TED	15-100	2, 3
				TFJ	70-225	2, 3
				SFH, SFL	70-250	2, 3
				SGH, SGL	125-600	2, 3
			600	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3

* Series combination rating.

General Electric series ratings

The following circuit breakers may be substituted for the circuit breakers shown in the series rating tabulations. Devices with MicroVersaTrip Plus and PM trip units may also be substituted, provided the short-circuit rating is equal to or greater than series connected rating. Reference. GE publication DET-008A.

Circuit breaker	Substitute circuit breakers
THQL	THQB, THQC, THQE, THHQL, THHQB, THHQC
THHQL	THHQB, THHQC
THQL-GF	THQB-GF, THQC-GF
TED	THED
SED	SEH, SEL, SEP
SEH	SEL, SEP
SEL	SEP
TQD	THQD
TFJ	TFK, THFK
SFH	SFL, SFP
SFL	SFP
TJJ	TJK, THJK, TJ4V, THJ4V, THJ9V, TJH
THJK	THJ4V, THJ9V, TJH, TJL
SGD	SGH, SGL, SGP
SGH	SGL, SGP
SGL	SGP
SKH	SKL, SKP
SKL	SKP
TPV	SS, SH, TP, TCV, THP, THC, THCV
THPV	SH, THP, THC, THCV

Table notes:

1. The data in these tables was compiled from information in GE Electrical Distribution and Control publication, catalog reference number GEP-11OOP and GE Electrical Distribution and Control publication - UL Component Recognized Series Ratings, publication reference number DET-008A. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
2. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
3. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.



Siemens series ratings

Switchboards SB1, SB2, SB3

Panelboard S1

Max system volts	SCIR*	Lineside fuse	Max fuse amps	Loadside						
				Circuit breaker	Amps	Poles				
120/240 Vac	65	LPJ, LPN-R	600	QPH, BQH, BLH	15-70	1 (120 V)				
		JJN	1200		15-125	2				
		KRP-C	6000		15-100	3				
	100	JJN	200	QP, BQ, BL	15-70	1 (120 V)				
					15-125	2				
					15-100	3				
				HQP, HBQ, HBL, QPH, BQH, BLH	15-100	3				
				QPF, BQF, BLF, QE, BE, BLE, QEH, BLEH, BLHF, QPHF, BQHF	15-30	1 (120 V)				
				QEH, BLEH, QE, QPHF, BLHF, BLE, QPF, BLF	15-60	2				
			QT	15-50	1 (120 V), 2					
			600	QPH, BQH, BLH, HQP, HBQ, HBL	15-70	1 (120 V)				
					15-125	2				
					15-100	3				
				240 Vac				ED4, HED4	15-100	1 (120 V)
								ED4, ED6, HED4, HED6	15-125	2, 3
FD6-A, FXD6-A	70-250	2, 3								
JD6-A, JXD6-A, JXD2-A, SJD6-A	200-400	2, 3								
LD6-A	200-600	2, 3								
SLD6-A	300-600	3								
LXD6-A	450-600	2, 3								
JJN	1200	ED4, HED4	15-100					1 (120 V)		
		ED4, ED6, HED4, HED6	15-125					2, 3		
		FD6-A, FXD6-A	70-250					2, 3		
		JD6-A, JXD6-A, JXD2-A, SJD6-A	200-400					2, 3		
		LD6-A	200-600					2, 3		
		SLD6-A	300-600					3		
LXD6-A	450-600	2, 3								
KRP-C	6000	ED4, HED4	15-100					1 (120 V)		
		ED4, ED6, HED4, HED6	15-125	2, 3						
		FD6-A, FXD6-A	70-250	2, 3						
		JD6-A, JXD6-A, JXD2-A, SJD6-A	200-400	2, 3						
		LD6-A	200-600	2, 3						
		SLD6-A	300-600	3						
		LXD6-A	450-600	2, 3						
		SMD6	500-800	3						
		SND6	500-1200	3						
		PD6, PXD6, SPD6	1200-1600	3						
		RD6, RXD6	1600-2000	3						
		200	LPN-RK	200	QJH2, QJ2H, QJ2	125-200	2, 3			
JJN	400				QJ2	125-225	2, 3			
LPJ	600				QJH2, QJ2H	125-225	2, 3			
LPJ, LPN-RK	600				HFD6, HFXD6	70-250	2, 3			
JJN	1200				HFD6, HFXD6	70-250	2, 3			
KRP-C	6000		HFD6, HFXD6	70-250	2, 3					
			MD6, MXD6, HMD6, HMXD6	500-800	2, 3					
			ND6, NXD6, HND6, HNXD6	500-1200	2, 3					

* Series combination rating.

Table notes:

- The data in these tables was compiled from information in Siemens SpeedFax 2000 Electrical Products publication, catalog reference number GNPC-01000. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
- The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
- Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.

Siemens series ratings

Switchboards SB1, SB2, SB3

Panelboards 82, SE, S3, S4, 85

Max system volts	SCIR*	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
480 Vac	50	LPJ	400	ED4	60-100	1 (277 V)
					15-100	2, 3
					5-50	1 (277 V)
					70-250	2, 3
	100	LPJ	400	ED4	70-250	2, 3
			600	FD6-A, FXD6-A	70-250	2, 3
		LPJ, LPS-RK	600	HFD6, HFXD6	200-600	2, 3
				JD6-A, JXD6-A, HJD6-A, HJXD6-A 200-400 2,3 LD6-A, HLD6-A	450-600	2, 3
		JJS, LPJ, LPS-RK	600	LXD6-A, HLXD6-A	70-250	2, 3
				JJS	200-400	2, 3
		JJS	800	HFD6, HFXD6	200-600	2, 3
				JD6-A, JXD6-A, HJD6-A, HJXD6-A	70-250	2, 3
				LD6-A, HLD6-A	200-600	2, 3
				LXD6-A, HLXD6-A	450-600	2, 3
480/277 Vac	200	KRP-C	6000	HFD6, HFXD6	70-250	2, 3
				MD6, MXD6, HMD6, HMXD6	500-800	2, 3
				ND6, NXD6, HND6, HNXD6	500-1200	2, 3
				BQD, CQD	15-100	1 (277 V)
		LPS-RK	100	BQD**, CQD**	20-30	2, 3
				BQD, CQD	15-100	1 (277 V)
		JJS, LPJ	200	BQD**, CQD**	20-30	2, 3

* Series combination rating.

**BQD and CQD circuit breakers are series rated from 15-100 A for Series 7A, S2 and S3 panelboard applications only.

Table notes:

1. The data in these tables was compiled from information in Siemens SpeedFax 2000 Electrical Products publication, catalog reference number GNPC-01000. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
2. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
3. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.



Square D series ratings

I-Line Switchboard/Panelboard

Max system volts	SCIR*	Lineside fuse	Max fuse amps	Loadside		
				Circuit breaker	Amps	Poles
240 Vac	100	LPN-RK	600	FH, KA, KH, LA, LH, MA, MH, MX	All	2, 3
		JJS	600	FA	All	2, 3
		JJS	800	FH, KA, KH, LA, LH, MA, MH, MX	All	2, 3
		LPJ	600	FA, FH, KA, KH, LA, LH, MA, MH, MX	All	2, 3
		KRP-C	800	KA	All	2, 3
		KRP-C	1200	FH, LA, LH	All	2, 3
		KRP-C	2000	KH, MA, MH, MX	All	2, 3
	200	LPN-RK	600	FH, FC, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		JJS	600	FA	All	2, 3
		JJS	800	FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		LPJ	600	FA, FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		KRP-C	800	FH, LA, LH	All	2, 3
		KRP-C	1200	FC, KH, KC, LC, LX, MA, MH, MX	All	2, 3
		KRP-C	2000	NA, NC, NX	All	2, 3
480 Vac	100	LPS-RK	600	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	All	2, 3
		JJS	600	FA, FH	All	2, 3
		JJS	800	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	All	2, 3
		LPJ	600	FA, FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	All	2, 3
		KRP-C	800	KA		
		KRP-C	1200	KH, LA, LH		
		KRP-C	1600	MA		
	200	KRP-C	2000	FC, KC, LC, LX, MH, MX, NA		
		LPS-RK	600	FC, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		JJS	400	FA, FH	All	2, 3
		JJS	800	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		LPJ	400	FA, FH	All	2, 3
		LPJ	600	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	All	2, 3
		KRP-C	800	LA, LH	All	2, 3
		KRP-C	1200	FC, KC, LC, LX, MA, MH, MX	All	2, 3
		KRP-C	2000	NA, NC, NX	All	2, 3

* Series combination rating.

Table notes:

1. The data in these tables was compiled from information in Square D, Series Rating Data Bulletin No. 2700DB9901 and Square D Digest 171. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
2. The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
3. Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.

Square D series ratings

Max system volts	SCIR* (kA)	Lineside fuse	Max fuse amps	Loadside	Amps	Poles
				Circuit breaker		
NQOD Panelboards						
240 Vac	200	JJS, LPJ	200	QO, QOB	All	1, 2, 3
				QO, QOB (AS)	All	1, 2, 3
				QO, QOB (GF I)	All	1, 2, 3
		JJN	400	QO, QOB	All	1, 2, 3
				QO, QOB (AS)	All	1, 2, 3
				QO, QOB (GF I)	All	1, 2, 3
Note for NQOD panelboards: 1P for use at 120 V only						
NEHB Panelboards						
480Y/277 Vac	100	JJS, LPJ	200	EH, EHB	All	1, 2, 3
Note for NEHB Panelboards: 1P for use at 277 V only						
NF panelboard						
480Y/277 Vac	100	JJS, LPJ	400	EDB, EGB, EJB	All	1, 2, 3
	200	JJS, LPJ	200			
Note for NF Panelboards: 1P for use at 277 V only						
SF switchboards with I-Line or NQOD distribution						
120/240 Vac	42	JJS	400	QO-VH, QOB-VH	All	1 (120 V)
240 Vac	42	JJS	800	QO-VH, QOB-VH, FA, Q4	All	2, 3
				Q2-H	All	2
480 Vac	50	JJS	800	FA, FH	All	2, 3
	65	JJS	800	KA, KH, LA, LH	All	

* Series combination rating.

Table notes:

- The data in these tables was compiled from information in Square D, Series Rating Data Bulletin No. 2700DB9901 and Square D Digest 171. The Bussmann Division assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.
- The lineside fused switch may be in a separate enclosure or in the same enclosure as the loadside circuit breaker. A lineside fused switch may be integral or remote.
- Max fuse current rating denotes the largest amp fuse that may be used for that series rated combination. A lower amp fuse may be substituted for the listed fuse.



7.7 Conductors

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7.7.1 NEC Article 100 definitions

“Ampacity: The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Continuous load: A load where the maximum current is expected to continue for 3 hours or more.

Informational Note: A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations.

Neutral conductor: The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.

Overcurrent: Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short-circuit, or ground fault.

Overload: Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short-circuit or ground fault, is not an overload.”

7.7.2 General

The basic conductor selection and protection process includes the following:

1. Calculate the load current: The load amps for the branch and feeder circuits must be calculated taking into consideration continuous and non-continuous loads.

- Find calculated load for continuous amps
 - Apply 1.25 multiplying factor
 - Apply 1.00 multiplying factor for fully rated conductors
- Find calculated load for non-continuous amps
 - Apply 1.00 multiplying factor in all applications
- Find total calculated load
 - Add calculated continuous and non-continuous loads

2. Select the conductor: Select the conductor that has an ampacity to handle the load calculated as per 210.19 or 215.2. The conductor size will either be based upon the continuous plus non-continuous loads or be based upon the conditions of use, after adjustment and correction factors.

- Continuous plus non-continuous (No adjustments and correction factors)
 - Use rated ampacity of the conductor based on table 310.15(B)(16)
 - Ambient temperature is greater than 77°F and less than 87°F
 - No more than three current carrying conductors in a raceway, cable or Earth (direct buried)
- Conditions of use (adjustment and correction factors)
 - Adjustment factor - more than three current carrying conductors in raceway, cable, or Earth (direct buried)
 - Obtain multiplier from Table 310.15(B)(3)(a) adjustment factors
 - Correction factor — ambient temperature less than 78°F and greater than 86°F
 - Obtain multiplier from Table 310.15(B)(2)(a) ambient temperature correction factors
 - Add 60°F to ambient temperature if installed in conduit on a roof in direct sunlight less than 7/8" from the rooftop
- Total Adjustment — number of conductors + ambient
 - The conductor's new ampacity is:

$$MF_{NoC} \times MF_{Temp} \times \text{Rated ampacity} = \text{Adjusted ampacity}$$

3. Termination consideration: Depending upon the size of conductor landed on a specific termination with a temperature rating, the maximum amps the termination is rated for is shown in Table 7.7.6.a.

- If the adjusted ampacity of the conductor is less than that shown in the table of Figure 7.7.6.a, use the adjusted ampacity
- If the adjusted ampacity of the conductor is greater than that shown in the table of Figure 7.7.6.a, use the value shown in the table of Figure 7.7.6.a.

4. Voltage drop considerations: The voltage at the load must be adequate for the application. If it isn't, make necessary adjustments in conductor size.

5. OCPD selection: The overcurrent protective device selected must protect the conductor from overcurrents. This may require resizing the conductor so it may be protected by the OCPD.

Branch and feeder conductors must be sized appropriately for the load. Section 210.19 of the NEC, “Conductors — Minimum Ampacity and Size,” requires as part of 210.19(A)(1) branch circuit conductors to have an ampacity not less than the maximum load that it will serve. A similar requirement is found for feeders as part of Section 215.2, “Minimum Rating and Size.” It is 215.2(A)(1) that requires feeder conductors to have an ampacity that is not less than that which is required to supply the calculated load.

Conductors that are of an appropriate ampacity that can carry the calculated load must then be afforded protection from overcurrents as per 240.4, “Protection of Conductors.” Per the definition of overcurrent found in Article 100 of the NEC, for a conductor an overcurrent is any current in excess of the ampacity of the conductor. Per Article 100 an overcurrent may result from overloads, short-circuits, or ground faults.

NEC 110.10 requires that conductors must also be protected from the effects of short-circuit current damage. For these high fault currents, no device is faster than the current-limiting fuse which removes the most stress and heat from the distribution system in the safest most economical way possible.

The proper selection and application of the conductor is as much a part of its adequate protection as is the overcurrent protective device selection.

7.7.3 Conductor ampacity tables

The NEC includes six tables that provide allowable ampacity of conductors. These tables provide the rated amps for the conductors which is the amount of current that each conductor can carry indefinitely and continuously.

Just as in any rating of a product, there are stipulations on how they achieved their rating. These stipulations are also included within the table. As an example, let’s review the most commonly used table providing allowable ampacities in the NEC, Table 310.15(B)(16). This table provides the rated ampacity for conductors that meet the following qualifications:

- Insulated conductors
- Rated up to and including 2000 V
- Insulation rating of 60°C through 90°C (140°F through 194°F)
- When not more than three current-carrying conductors are in raceway, cable, or earth (directly buried),
- When in an ambient temperature of 30°C (86°F)

Addressing each qualification:

- **Insulated conductors:** this table addresses conductors that are insulated. Insulation is the outer coating on the copper conductors.
- **Rated up to and including 2000 volts:** All products must be applied within their rating. The ampacities in this table apply to conductors with a voltage rating of 2000 volts and less. Each conductor is listed and tested and labeled with a voltage rating.
- **Insulation rating of 60°C through 90°C (140°F through 194°F):** A conductor will be tested and listed at a specific insulation rating. A conductor will be marked with the temperature at which it was evaluated. Conductors will have a dry or wet conductor rating. For example, THHN in Table 7.7.5.a has a 90°C rating dry only.
- **Not more than three current-carrying conductors:** The rated ampacity listed in this table is achieved under specific conditions one of which is having not more than three current-carrying conductors in a raceway. If a raceway has more than three current carrying conductors the ampacity must be adjusted. For that adjustment, reference 310.15(B)(3)(a). See 310.15(B)(5) to determine if any neutral conductors present are current carrying.

- **Ambient of 30°C (86°F):** The rated ampacity in this table is achieved under specific conditions one of which is having an ambient temperature of 30°C (86°F). For those conductors routed in areas in temperatures that exceed or are less than 30°C (86°F), adjustment factors must be used to adjust the ampacity in this table. For this adjustment activity, reference 310.15(B)(2).

As an example, a 1/0 copper conductor of insulation type THHW can carry 170 amps indefinitely when not more than three current-carrying conductors are in a raceway, cable, or direct buried in earth and when the ambient temperature is 30°C (86°F). This information is obtained from the 90°C column of Table 310.15(B)(16).

The other tables in Section 310.15 address the ampacity rating of other conductor configurations and include:

- Table 310.15(B)(17) (formerly Table 310.17) allowable ampacities
 - Single, insulated conductors
 - Rated up to and Including 2000 V
 - In free air
 - Based on ambient temperature of 30°C (86°F)
- Table 310.15(B)(18) (formerly Table 310.18) allowable ampacities
 - Insulated conductors
 - Rated up to and Including 2000 V
 - Insulation rating of 150°C through 250°C (302°F through 482°F).
 - Not more than three current-carrying conductors in raceway or cable
 - Based on ambient air temperature of 40°C (104°F)
- Table 310.15(B)(19) (formerly Table 310.19) allowable ampacities
 - Single, insulated conductors
 - Rated up to and Including 2000 V
 - Insulation rating of 150°C through 250°C (302°F through 482°F), in free air
 - Based on ambient air temperature of 40°C (104°F)
- Table 310.15(B)(20) (formerly Table 310.20) ampacities
 - Not more than three single insulated conductors
 - Rated up to and including 2000 V
 - Supported on a messenger
 - Based on ambient air temperature of 40°C (104°F)
- Table 310.15(B)(21) (formerly Table 310.21) ampacities
 - Bare or covered conductors
 - In free air
 - Based on 40°C (104°F) ambient, 80°C (176°F), total conductor temperature, 610 mm/sec (2 ft/sec) wind velocity

7.7.4 Determining load amps

The first step in the process of selecting a conductor is understanding the current it will be called upon to carry. This section will address branch circuits and feeder circuits.

Branch circuits

NEC Article 100 defines a branch circuit as the circuit conductors between the final overcurrent protective device protecting the circuit and the outlet(s). Refer to Figure 7.7.4.a for various examples of branch circuit and feeder circuits.

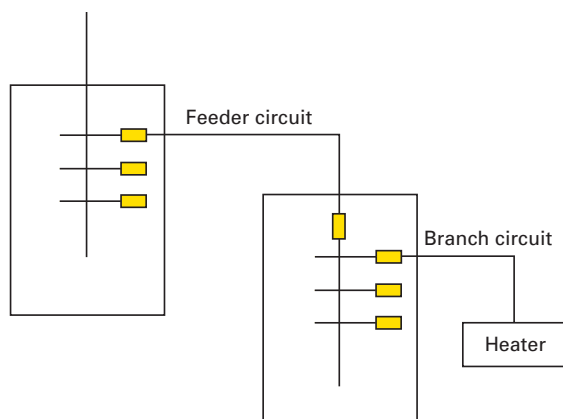


Figure 7.7.4.a Feeder and branch circuits.

Section 210.19 addresses conductor minimum ampacity and size. This section tells us that the branch circuit conductor must have an ampacity not less than the maximum load that is served by the branch circuit. To determine this maximum load consideration must be given to whether a load is continuous or not. The NEC defines a continuous load as that load where the maximum current is expected to continue for three hours or more. In determining the amp load for the branch circuit the following equation is leveraged:

$$\text{Calculated branch circuit amps} = I_{NC} + (1.25 \times I_C)$$

Where:

I_{NC} = Non-continuous current

I_C = Continuous current

Once the load amps that the circuit must supply indefinitely is determined, conductor selection can proceed.

Example: A branch circuit supplies 20 heaters that have four fluorescent bulbs (F54T5HO) per fixture. Manufacturer information tells us that each heater draws 0.84 amps at 277 volts. This is a warehouse and these heaters will be on 24 hours per day and 7 days a week. What is the minimum ampacity for this branch circuit?

The total amps for this circuit is calculated as:

$$\text{Heater amps} = 20 \times 0.84 \text{ A} = 16.8 \text{ A}$$

The heater load must be treated as a continuous load when sizing the branch circuit. The branch circuit minimum ampacity is calculated as:

$$\text{Branch circuit amps} = 1.25 \times 16.8 \text{ A} = 21 \text{ A}$$

The branch circuit must be sized per a minimum ampacity of 21 A and be able to continuously serve a load of 16.8 A indefinitely.

Feeder circuits

NEC Article 100 defines a feeder as all circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. Refer to Figure 7.7.4.a for various examples of branch circuit and feeder circuits. Section 215.2 addresses minimum conductor rating and size. This section tells us that the branch circuit conductor must have an ampacity not less than that required to serve the load as calculated per specific Parts of Article 220.

- Part III, Feeder and Service Load Calculations
- Part IV, Optional Feeder and Service Load Calculations
- Part V, Farm Load Calculations
- To determine the maximum load, 215.2 requires consideration be given to whether a load is continuous or not. The NEC defines a continuous load as that load where the maximum current is expected to continue for three hours or more. In determining the amp load for the feeder circuit the following equation is leveraged:

$$\text{Calculated feeder amps} = I_{NC} + (1.25 \times I_C)$$

Where:

I_{NC} = Non-continuous current

I_C = Continuous current

Once the amps that the circuit must supply indefinitely is determined, conductor selection can proceed.

Example: A feeder circuit supplies a 200 A panel. The panel was sized to be able to supply the load calculated as per Parts III, IV, and V of Article 220. The loads on this panel are heating loads for a warehouse and will be on 24 hours per day and 7 days a week. What is the minimum ampacity for this feeder circuit?

The total amps for this circuit is given by the panel size for this application. The panel size of 200 A was determined based upon the loads being treated as continuous loads and multiplying those load amps by 1.25. The engineer has added additional room for growth and so the 200 A panel is oversized from the standard load calculations of Article 220. The feeder circuit for this application is a 200 A feeder. It must be capable of supplying 200 A continuously and indefinitely.

7.7.5 Conductor selection

Proper selection of a conductor for an application must take into consideration where and how the conductor will be routed to serve the load. Table 310.104(A) provides information to help understand the construction of conductors and their application provisions. If for example a conductor will be in a wet or damp location, this table can provide guidance on which conductors are rated for that application. Chapter 3 of the NEC includes detailed information important for proper selection and application of various types of conductors for many different applications.

Example: A branch circuit includes 20 heaters that have 4 heating elements per fixture. Per manufacturer information, each heater draws 0.84 A at 277 V. This is a warehouse and the heaters will be on 24 hours per day and 7 days a week. The ampacity of this branch circuit is calculated to be 21 A which is $1.25 \times (20 \times 0.84 \text{ A})$. The majority of this circuit will be routed in a raceway in a part of the building that is 115°F. What conductor type would fit this application?

Based on Table 310.104(A), an insulation with 90°C for dry and damp locations is selected. Heat-resistant thermoplastic type THHN conductor is selected for this application. This conductor has an insulation temperature of 90°C. Based on manufacturer information this conductor is rated for 600 V. These conductors have multiple ratings. Depending upon the product application, allowable temperatures are shown in Table 7.7.5.a.

Insulation	Applications/max. temperatures
THHN or T90 Nylon	Dry locations not to exceed 90°C
THWN-2	Wet or dry locations not to exceed 90°C or locations not to exceed 75°C when exposed to oil
THWN	Wet locations not to exceed 75°C or dry locations not to exceed 90°C or locations not to exceed 75°C when exposed to oil
TWN75	Wet locations not to exceed 75°C
MTW	Wet locations or when exposed to oil at temperatures not to exceed 60°C or dry locations not to exceed 90°C (with ampacity limited to that for 75°C conductor temperature per NFPA 79)
AWM	Dry locations not to exceed 105°C only when rated and used as appliance wiring material

Table 7.7.5.a

Example: A feeder circuit supplies a 200 A panel that was sized as per the load calculations in Parts III, IV, and V of Article 220. The loads on this panel are heater loads for a warehouse and will be on 24 hours per day and 7 days a week. It was determined that the ampacity of this feeder is 200 A. The feeder will be routed in a raceway with other conductors such that there are nine current carrying conductors in the raceway. The temperature in the portion of the building where the majority of the length of this feeder circuit is routed is 115°F. What conductor type would fit this application?

Based on Table 310.104(A), select an insulation with 90°C for dry and damp locations. Heat-resistant thermoplastic type THHN conductor is selected. This conductor has an insulation temperature of 90°C. Manufacturer information states it is rated for 600 V. The manufacturer information notes that there are multiple options for this conductor. Depending upon the product application, allowable temperatures are shown in Table 7.7.5.a.

7.7.6. Conductor termination considerations

Both ends of a conductor whether in a branch circuit or feeder circuit will be terminated on a terminal. The temperature rating of the terminal will be a limiting factor as to the amount of current that the conductor is permitted to carry. Figure 7.7.6.a is a table developed from 310.15(B)(16) that illustrates the maximum current permitted for each termination with the specified temperature rating and conductor size. This is a limiting factor in the determination of the ampacity of the circuit that has nothing to do with the capability of the conductor but rather the limitations of the electrical equipment.

Section 110.14 is that area of the NEC that speaks to electrical connections. This section of the NEC reminds us to be aware of dissimilar metals and other details important to ensure proper termination of conductors. Section 110.14(C), "Temperature Limitations," requires that the temperature rating associated with the ampacity of a conductor must be selected and coordinated so as not to exceed the lowest temperature rating of any connected termination, conductor, or device. Conductors with temperature ratings higher than those specified for terminations must be permitted to be used for ampacity adjustment, correction, or both. It is also permitted to land a conductor with a higher temperature rated insulation but it is not permitted to use the ampacity at that higher temperature rated insulating ampacity rating. This is true even when adjusting or correcting the ampacity of this higher insulation rated conductor. Any adjustment or correction factors that arrive upon an ampacity that is greater than that which is established by the lowest temperature rated termination cannot be used. Section 310.15(B) requires that a conductor ampacity adjustment can be taken from the ampacity based on the insulation rating and can be used as the ampacity of the conductor only if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

It is also not permissible to replace a lug/terminal on equipment with higher temperature rated terminals that have not been tested with those lugs at the higher temperature ratings.

Section 110.14(C)(1) provides termination temperature ratings when the equipment is not available for inspection to determine the actual rating of the termination. Figure 7.7.6.a simplifies the requirements of 110.14(C)(1) in table format.

Unless the equipment is listed and marked otherwise, conductor ampacities must be limited by the termination temperature ratings. Section 110.14(C)(1) addresses two types of equipment:

1. Termination provisions of equipment for circuits rated 100 amperes or less, or marked for 14 through 1 AWG conductors
 - a. Conductors rated at 60°C (140°F) can be used with ampacity determined based on 60°C (140°F)
 - b. Conductors with higher temperature ratings can be used, provided the ampacity of such conductors is determined based on the 60°C (140°F) ampacity of the conductor size used
 - c. Conductors with higher temperature rating can be used at their higher temperature ampacity as long as the product is listed as such
 - d. Conductors for motors marked with design letters B, C, or D, that have an insulation rating of 75°C (167°F) or higher can be used as long as their ampacity doesn't exceed the 75°C (167°F) ampacity
2. Termination provisions of equipment for circuits rated over 100 amps, or marked for conductors larger than 1 AWG
 - a. Conductors must be rated for 75°C (167°F) and the ampacity at that temperature rating can be used
 - b. Conductors with higher temperature ratings can be used, provided the ampacity of such conductors is determined based on the 75°C (167°F) ampacity of the conductor size used
 - c. Conductors with higher temperature rating can be used at their higher temperature ampacity as long as the product is listed as such

Example: A THWN-2 4 AWG conductor is terminated on a circuit breaker which has a lug rated for 75°C at one end and an industrial control panel at the other. What is the ampacity of this conductor based on Table 310.15(B)(16)?

As per Table 310.104(A), a THWN-2 conductor is rated for 90°C. Section 110.14 requires that the ampacity be limited to the temperature rating that aligns with the temperature rating of the terminals upon which this conductor is landed. Both ends of the this conductor have to be considered. One end of the conductor is terminated on a circuit breaker which, based on the information provided, is rated for 75°C. The other end of the conductor is terminated on an industrial control panel for which no information is available. Based on 110.14(C)(1) and because this conductor is not larger than a 1 AWG, the assumed temperature rating of the termination is 60°C.

Based on this information the 60°C column of Table 7.7.6.a or the 60°C column of NEC Table 310.15(B)(16) is used to determine the maximum current that can be used for a 4 AWG conductor which is 70 A.



Size AWG/ kcmil	60°C (140°F)	75°C (167°F)	60°C (140°F)	75°C (167°F)
	Copper		Aluminum or copper-clad aluminum	
18	—	—	—	—
16	—	—	—	—
14	15*	20	—	—
12	20*	25	15*	20
10	30*	35	25*	30
8	40*	50	35*	40
6	55*	65	40*	50
4	70*	85	55*	65
3	85*	100	65*	75
2	95*	115	75*	90
1	110*	130	85*	100
1/0	—	150*	—	120*
2/0	—	175*	—	135*
3/0	—	200*	—	155*
4/0	—	230*	—	180*
250	—	255*	—	205*
300	—	285*	—	230*
350	—	310*	—	250*
400	—	335*	—	270*
500	—	380*	—	310*
600	—	420*	—	340*
700	—	460*	—	375*
750	—	475*	—	385*
800	—	490*	—	395*
900	—	520*	—	425*
1000	—	545*	—	445*
1250	—	590*	—	485*
1500	—	625*	—	520*
1750	—	650*	—	545*
2000	—	665*	—	560*

* Default minimum value when equipment terminal rating is unknown.

Table 7.7.6.a Maximum equipment termination current.



7.7.7 Conductor and termination considerations



Figure 7.7.7.a This disconnect's middle, lineside conductor became loose and created an excessive thermal condition that damaged the terminal, along with the middle and the adjacent conductors.

A fuse, as well as a circuit breaker, is part of a system where there are electrical, mechanical and thermal considerations. All three are interrelated. If there is too much electrical current for the circuit, the components will overheat. If a conductor termination is not properly torqued, it can be a "hot spot" and contribute excess heat that's detrimental to the termination, conductor insulation and even the OCPD. If the conductor size is too small for the circuit load, or for the fuse/termination or circuit breaker/termination rating, the undersized conductor will create excess heat, which can damage the device.



Figure 7.7.7.b

Both the proper conductor size and termination method are critical! Many so called OCPD "nuisance" openings or failures can be traced to improper termination methods or conductor sizing as the root cause. Poorly made or improper electrical connections can result in fire or other damage to property, and can cause injury and death. If there are loose terminal connections, then:

- The conductor overheats and the conductor insulation may break down that can lead to a fault; typically line-to-ground. If conductors with different potentials are touching, the insulation of both may deteriorate, and a phase-to-neutral or phase-to-phase fault occurs.
- Arcing can occur between the conductor and lug. Since a poor connection is not an overload or a short-circuit, the OCPD does not operate.
- The excessive heat at the conductor's termination increases the temperature beyond the fuseclip material's thermal rating and can result in the fuseclip losing its spring tension and creating a hot spot at the interface between the fuse and clip. See Figure 7.7.7.c.
- The excessive thermal conditions described above may cause a device's (block, switch, fuse, circuit breaker, etc.) insulating system to deteriorate and result in a mechanical and/or electrical breakdown. For instance, the excessive thermal condition of a conductor termination at a circuit breaker can degrade the insulating case material or fuse block material may carbonize.

Normally, a fuse is mounted in a fuseclip or bolted to a metal surface. It's important that the fuse-to-clip/metal surfaces are clean and mechanically tight to minimize electrical resistance. If not, this interface will be a high resistance connection, which can lead to a hot spot.



With a fuseclip application, the temperature rise from a poor fuse/clip connection can cause even further clip tension deterioration causing the hot spot condition getting worse.

Figure 7.7.7.c The fuse clip on the right has excellent tension that provides a good mechanical and electrical interface (low resistance) between the fuse and clip. The clip on the left experienced excessive heat caused by an improper conductor termination or undersized conductor and lost its tension as a result. Consequently, the mechanical and electrical interface between the fuse and clip was inadequate which further accelerated the unfavorable thermal condition.

Loose terminal and connection causes

Below are some possible loose terminal connection causes for various termination methods that can result in excessive OCPD/termination/conductor heating:

- **The copper or aluminum conductor's gauge and type must be within the connector's specifications.** Terminals are rated to accept a specific conductor type(s) and size(s). A conductor that's too large or small for the connector will result in a poor connection. Additionally, it must be verified that the terminal is suitable for aluminum, copper or both. Usually the termination means is rated for acceptable conductor type(s) and size range, with these ratings marked on the device (block, switch, circuit breaker, etc.) or specified in the device's data sheet.
- **The connector is not torqued to the manufacturer's specification.** Conductors expand and contract with temperature changes caused by load fluctuations. If the connections are not torqued correctly, loose connections may result after a number of expansion/contraction cycles. For a mechanical screw, nut, bolt or box lug type connection, follow the manufacturer's specified torque that's typically marked on the device. For a specific connector, the specified torque may be different for different wire sizes.
- **The conductor is not properly crimped. A poor crimp connection could be between a conductor and a ring terminal, quick-connect terminal or an in-line device.** If using a crimp/compression connection, use the manufacturer's recommended crimp tool with the designated die location and number of crimps.
- **The quick-connect terminal is not seated properly.** If the male-female connections are not fully seated, a hot spot may result.
- **The quick-connect terminal is being used beyond its amp rating.** Quick-connects typically have limited continuous current ratings that must not be exceeded. Typical possible maximum quick-connect ratings are 16 or 20 A (some are less) and are also based on a specified conductor size. If a quick-connect is used beyond its amp rating, excessive temperature will result which can degrade its tension properties, leading to ever increasing temperatures until the connection fails.
- **The conductor is not properly soldered to a solder terminal.** Again, if there isn't a good connection between the two, a hot spot will result.

- **The terminal is rated to only accept one conductor, but multiple conductors are being used.** Again, the product specifications must be checked to see if the terminal is rated for dual conductors. If the product is not marked suitable for dual conductors, then only one conductor can be used for the terminal. Inserting too many conductors will cause a poor connection, which can result in overheating at the connector.
- **The terminal is not rated for a finely stranded conductor.** The common electrical connectors and terminals for electrical equipment are rated to accept conductors with the number of strands not exceeding Class B and Class C stranding. If conductors with finer stranding are used, the connectors and terminals must be suitable and identified for the specific stranded conductor class(es). See NEC 110.14 for the requirement and NEC Chapter 9, Table 10 for the number of strands for Class B and Class C conductors.

Properly torque terminations

Proper conductor installation and maintenance practices are to properly torque the termination during initial installation and then to periodically conduct visual and thermal inspections (such as infrared scan).

When installing a conductor into a termination, applying the device manufacturer's specified torque for the type and size conductor is critical. The specified torque value ensures the proper force is being applied on the conductor in the termination with a resulting low contact resistance. Applying a torque value below the manufacturer's specification can result in a higher resistance at the conductor termination that may result in excessive heat and causes damage to the conductor and device. Applying a torque value exceeding the specification can result in damaging the termination device and/or the conductor.

The conductor termination torque values are part of the testing and listing procedures when a manufacturer's device is evaluated for compliance to product standards by a nationally recognized testing laboratory. NEC 110.3(B) requires installing the equipment to the torque values that were used in the listing or product labeling. Therefore, when installing conductors it's important to use a calibrated torque tool and torque to the device manufacturer's specification. A device's conductor termination specified torque values typically are on the device label as shown in Figure 7.7.7.d. However, these specifications may be in the instructions or data sheet.

18-10 AWG (1-2.5 mm²) Single & Dual 20 in-lb (2.26 N•m)
8-6 AWG (3.15-4 mm²) Single & Dual 35 in-lb (3.95 N•m)
4 AWG (5 mm²) Single 35 in-lb (3.95 N•m)
75°C, CU ONLY, SAME AWG & TYPE FOR DUAL

Figure 7.7.7.d Terminal torque specifications are generally marked on the device's label or may be found in its instructions or data sheet.

If all connections were properly torqued, many electrical device failures would not occur. The installer needs to ensure a proper conductor termination by using a calibrated torque measurement tool and the device manufacturer's specified torque value for the conductor type and gauge. Through recent surveys conducted at various electrical industry events, it was found that approximately 75% of the terminations made without a torque measuring tool do not come within plus or minus 20% of the manufacturer's specifications. These findings reinforce the point that there is a need to ensuring proper termination methods by using installation tools that measure torque.

Some maintenance practices involve periodically checking the conductor termination by checking the torque or just retightening. This should not be done and is affirmed in the NEC Informative Annex I: "Because it is normal for some relaxation to occur in service, checking torque values sometime after installation is not a reliable means of determining the values of torque applied at installation."

Often it's assumed that terminations inevitably become loose after a system's extended cycling or just through time in service. After all, every metal has the physical property that it will experience a certain amount of relaxation, and it's perceived that this relaxation is a cause of concern. However, manufacturers have taken these physical properties into account through their product design and testing. If equipment, conductors and terminations are used in applications for which they are designed and listed, and the terminations are made with the proper torque value during installation, then the connection will remain within its required values. All this requires that conductor termination devices used are suitable for their application. By contrast, many common conductor termination devices are not suitable for applications with vibrations, such as at a generator's terminals.

When a loose conductor termination has resulted in thermal damage to the conductor at and near the termination, remove the conductor from the terminal. First, determine if the terminal is suitable for continued use. Stripped threads make terminals unsuitable for use and terminal discoloration may indicate it isn't suitable for further use, either. If the terminal is deemed suitable for further use, cut the conductor's damaged portion and reinstall it using a calibrated torque tool set to the proper value.

Improper overcurrent protection can be a root cause of conductor termination damage. Conductors can become loose under screws or lugs if they have carried excessive amounts of short-circuit current. High fault current can result in high mechanical forces causing conductor movement which degrades the contact points between the conductors and terminal devices. In addition, the excessive heat generated by the fault current contributes to the problem. Since the conductor is deformed during termination, the portion at the termination that's damaged by fault current needs to be cut off and the conductor properly re-terminated so that new and correct contact points are created. Unfortunately, terminated conductor damage due to fault current may not manifest itself as a problem until long after the fault's cause has been corrected. Properly applied current-limiting fuses can prevent terminated conductor damage caused by fault currents.

7.7.8 Ampacity adjustments

Each conductor used must be reviewed to ensure the ampacity of the conductor can serve the connected load and is protected at its ampacity by an overcurrent protective device. Section 310.15 addresses ampacities for conductors and reminds us that conductors must not be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved. (310.15(A)(3))

Once a conductor has been selected to be used in an application, the correct size must be determined and will be dependent upon the ampacity taking into consideration the environment in which it will be applied. The ampacity of the conductor must be greater than the current it must carry to serve the load.

There are requirements in the NEC for adjusting and determining the conductor's ampacity, including:

1. Ampacity limitations due to terminations
2. Ambient temperature
3. Number of conductors in a raceway or cable

There are code requirements that affect the size of conductor to be used (e.g., motor circuits or continuous loads) but only items 2 and 3 shown above are used to regulate ampacity to keep the conductor within its maximum temperature rating.

NEC 310.10 contains the basic rule that, in effect, requires an ampacity adjustment for ambient temperature and number of conductors in a raceway or cable.

Temperature considerations for a conductor that impact its ampacity include:

1. Ambient temperature
2. Heat generated internally in the conductor as a result of current flow
3. The rate at which generated heat dissipates from the conductor, and
4. Adjacent current-carrying conductors

Items (1) and (4) are the two that require attention and for which guidance is provided by NEC Section 310.15.

7.7.8.1. Ambient temperature adjustment

All ampacity tables must use some ambient temperature as a basis and NEC Table 310.15(B)(16) uses 30°C (86°F). At the bottom of this table, direction is provided to Section 310.15(B)(2) for ampacity correction factors where the ambient temperature is other than 30°C (86°F). Use of these factors is fairly straightforward. As per the parent text of 310.15(B), the temperature correction and adjustment factors are permitted to be applied to the ampacity for the temperature rating of the conductor as long as the corrected and adjusted ampacity is not greater than the ampacity for the termination's temperature rating in accordance with 110.14(C).

The temperature adjustment factors are found in Table 7.7.8.1.a (NEC 310.15(B)(2)(a)) and 7.7.8.1.b (NEC 310.15(B)(2)(b)). The first table aligns with ampacity tables 310.15(B)(16) and 310.15(B)(B)(17). The second table aligns with ampacity tables 310.15(B)(18), 310.15(B)(19), and 310.15(B)(20).

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature rating of conductor			Ambient temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11-15	1.22	1.15	1.12	51-59
16-20	1.15	1.11	1.08	60-68
21-25	1.08	1.05	1.04	69-77
26-30	1.00	1.00	1.00	78-86
31-35	0.91	0.94	0.96	87-95
36-40	0.82	0.88	0.91	96-104
41-45	0.71	0.82	0.87	105-113
46-50	0.58	0.75	0.82	114-122
51-55	0.41	0.67	0.76	123-131
56-60	-	0.58	0.71	132-140
61-65	-	0.47	0.65	141-149
66-70	-	0.33	0.58	150-158
71-75	-	-	0.50	159-167
76-80	-	-	0.41	168-176
81-85	-	-	0.29	177-185

Table 7.7.8.1.a NEC Table 310.15(B)(2)(a) ambient temperature correction factors based on 30°C (86°F).



For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient temperature (°C)	Temperature rating of conductor						Ambient temperature (°F)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11-15	1.50	1.31	1.22	1.11	1.08	1.06	51-59
16-20	1.41	1.25	1.18	1.09	1.06	1.05	60-68
21-25	1.32	1.20	1.14	1.07	1.05	1.04	69-77
26-30	1.22	1.13	1.10	1.04	1.03	1.02	78-86
31-35	1.12	1.07	1.05	1.02	1.02	1.01	87-95
36-40	1.00	1.00	1.00	1.00	1.00	1.00	96-104
41-45	0.87	0.93	0.95	0.98	0.98	0.99	105-113
46-50	0.71	0.85	0.89	0.95	0.97	0.98	114-122
51-55	0.50	0.76	0.84	0.93	0.95	0.96	123-131
56-60	-	0.65	0.77	0.90	0.94	0.95	132-140
61-65	-	0.53	0.71	0.88	0.92	0.94	141-149
66-70	-	0.38	0.63	0.85	0.90	0.93	150-158
71-75	-	-	0.55	0.83	0.88	0.91	159-167
76-80	-	-	0.45	0.80	0.87	0.90	168-176
81-90	-	-	-	0.74	0.83	0.87	177-194
91-100	-	-	-	0.67	0.79	0.85	195-212
101-110	-	-	-	0.60	0.75	0.82	213-230
111-120	-	-	-	0.52	0.71	0.79	231-248
121-130	-	-	-	0.43	0.66	0.76	249-266
131-140	-	-	-	0.30	0.61	0.72	267-284
141-160	-	-	-	-	0.50	0.65	285-320
161-180	-	-	-	-	0.35	0.58	321-356
181-200	-	-	-	-	-	0.49	357-392
201-225	-	-	-	-	-	0.35	393-437

Figure 7.7.8.1.b NEC Table 310.15(B)(2)(b) ambient temperature correction factors based on 40°C (104°F).

Example: What is the ampacity of a 1/0 AWG, aluminum, type THHN conductor when the ambient temperature is 100°F?

The process for adjustment is:

1. THHN is an insulated conductor rated 600 V and is not in free air. Table 310.15(B)(16) for the rated ampacity of the conductor is used.
2. Table 310.104(A) shows that the THHN conductor has an insulation rating of 90°C.
3. Because this is a 90°C insulated aluminum conductor, adjustments are made for temperature based on the 90°C column of Table 310.15(B)(16). The starting ampacity is 135 amps.
4. Table 310.15(B)(2)(a) is next consulted to determine the ampacity adjustment factor for a conductor applied at 100°F. This table shows for a temperature range of 96 to 104°F the multiplier to be used for a 90°C temperature rated conductor is 0.91.
5. Finally enough information is obtained to determine the ampacity of this 1/0 AWG conductor in an ambient of 100°F with this calculation: Adjusted ampacity = $0.91 \times 135 \text{ A} = 122.85 \text{ A}$

7.7.8.2 Number of conductors adjustment

As noted above, the rated ampacity tables 310.15(B)(16) and 310.15(B)(18) are applicable when not more than three current carrying conductors are in the raceway. For those installations where there are more than three current carrying conductors ampacity adjustment must be addressed through application of multiplying factors shown in Table 310.15(B)(3)(a).

Number of current-carrying conductors*	% values in NEC ampacity tables 310.16 to 310.19 as adjusted for ambient temperature if necessary
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and greater	35

* Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count must be adjusted in accordance with 310.15(B)(5) and (A). The count must not include conductors that are connected to electrical components that cannot be simultaneously energized.

Table 7.7.8.2.a NEC Table 310.15(B)(3)(a) adjustment factors for more than three current-carrying conductors.

Example: What is the ampacity of eight 12 AWG copper THHN conductors installed in one conduit?

The process for adjustment is:

1. THHN is an insulated conductor rated 600 V and is not in free air. Table 310.15(B)(16) is the applicable table for the rated ampacity of the conductor.
2. Table 310.104(A) shows that the THHN conductor has an insulation rating of 90°C.
3. Because this is a 90°C insulated copper conductor, adjustments for temperature can be made based on the 90°C column of Table 310.15(B)(16). The starting ampacity is 30 A.
- Note:** This No. 12 copper THHN conductor in Table 310.15(B)(16) has two stars next to it which per the foot note references 240.4(D) for conductor overcurrent protection limitations. Section 240.4(D) requires that the OCPD protecting a 12 AWG aluminum and copper-clad aluminum conductor not exceed 15 A unless specifically permitted in 240.4(E) or (G). The requirements of 240.4(D) do not impact the ampacity determination of a conductor, it only impacts the sizing of the overcurrent protective device for that conductor. For this ampacity adjustment, it is permitted to use the 90°C column but the adjusted ampacity cannot be more than what 240.4(D) requires unless the application falls under the provisions of 240.4(E) or 240.4(G).
4. Table 310.15(B)(3)(a) is next consulted to determine the adjustment factor for an application with eight current-carrying conductors in a single raceway. Per this table for 7 to 9 current-carrying conductors in the same raceway the adjustment factor is 0.70.
5. Finally enough information is available to determine the ampacity of this 12 AWG copper THHN conductor in a raceway that has a total of eight current-carrying conductors with this calculation: Adjusted ampacity = $0.70 \times 30 \text{ A} = 21 \text{ A}$

The adjusted ampacity is 21 A. The requirement of Section 240.4(D)(5) is such that, as long as this application does not fall under the provisions of 240.4(E) or 240.4(G), this circuit must be protected by a maximum of a 20 A OCPD. If the demands of the load is such that a 20 A OCPD would be too small, a larger size conductor must be used.

7.7.8.3 Ambient temperature and number of conductors adjustment

For those applications where a conductor will be routed in an ambient outside of its rating and in a raceway with more conductors than with which it was rated, both adjustment calculations are made and their impact is cumulative.

Example: What is the ampacity of four 1/0 THW copper conductors when the ambient temperature is expected to reach 110°F?

The process for adjustment is:

1. THW is an insulated conductor rated 600 V and is not in free air. Table 310.15(B)(16) is used for the rated ampacity of the conductor.
2. Table 310.104(A) shows that the THW conductor is available with insulation ratings of both 75°C and 90°C. Table 310.15(B)(16) has THW under the 75°C column only.
3. Because this is a 75°C insulated copper conductor, adjustments for temperature are made based on the 75°C column only of Table 310.15(B)(16) and not the 90°C column. Starting ampacity is 150 A for both ambient and number of conductor adjustment factors.
4. Table 310.15(B)(2)(a) is next consulted to determine the ampacity adjustment factor for a conductor applied at 110°F. This table shows for a temperature range of 105 to 113°F the multiplier to be used for a 75°C temperature rated conductor is 0.82.
5. Table 310.15(B)(3)(a) is next consulted to determine the adjustment factor for an application with four current-carrying conductors in a single raceway. Per this table for 4 to 6 current-carrying conductors in the same raceway the adjustment factor is 0.80.
6. Finally enough information is obtained to determine the ampacity of this 1/0 AWG THW conductor in a raceway that has four current-carrying conductors and in an ambient of 110°F using this calculation: Adjusted ampacity = $0.80 \times 0.82 \times 150 \text{ A} = 98.4 \text{ A}$

7.7.9 Voltage drop considerations

A power distribution system should be capable of providing power to all equipment within their published voltage limits under all normal operating conditions. In addition, voltage considerations should also include motor voltage drop during starting and restrictions placed on the user by the utility company to prevent disturbances to their system when starting large motors.

The National Electrical Code has many Informational Notes throughout the document in various areas that speak to recommended voltage drop maximums. There are a few specific requirements that place required do not exceed percentage voltage drop values for an application.

Branch circuits 210.19(A): “Branch Circuits Not More Than 600 Volts.” Informational Note No. 4 recommends branch circuits be sized to prevent a voltage drop exceeding 3% at the farthest outlet and a maximum of 5% voltage drop on both feeders and branch circuits.

Feeder circuits 215.2(A)(1): Informational Note No. 2 recommends feeders be sized to prevent a voltage drop exceeding 3% at the farthest outlet and a maximum of 5% voltage drop on both feeders and branch circuits.

Ampacity calculations 310.15(A)(1): Section 310.15 focuses on ampacities for conductors rated 0-2000 volts. Informational note #1 makes the user of the NEC aware that the conductor ampacities and adjustments addressed by Section 310.15 do not take into consideration voltage drop. The user is referenced to Sections 210.19(A) for branch circuits and 215.2(A) for feeder circuits when it comes to voltage drop considerations.

Ampacity calculations 310.60(C) Tables: Conductors Rated 2001 to 35,000 Volts. Informational Note No. 2 makes the user of the NEC aware that the conductor ampacities and adjustments provided by Section 310.60, which is titled “Conductors Rated 2001 to 35,000 Volts,” do not take into consideration voltage drop. The user is referenced to Sections 210.19(A) for branch circuits and 215.2(A) for feeder circuits when it comes to voltage drop considerations.

Phase converters 455.6(A): The informational note for this section recommends a maximum voltage drop of 3% for the single-phase conductors from the source of supply to the phase converter. This maximum value is established to help ensure proper starting and operation of the motor loads.

Storage batteries 480.4(B): “Intercell and Intertier Conductors and Connections.” The Informational note for this section recommends a maximum voltage drop of 3% when supplying the maximum anticipated load and a maximum of 5% to the furthest point of connection. This informational note also advises that these values of voltage maximums may not be appropriate for all battery applications. Reference is made to IEEE 1375-2003, “Guide for the Protection of Stationary Battery Systems” for more information.

Agricultural buildings 547.9(C): “Service Disconnecting Means and Overcurrent Protection at the Distribution Point.” The informational note for this section recommends a maximum voltage drop of 2% and connecting loads line-to-neutral to help reduce neutral-to-earth voltages in livestock facilities.

Recreational Vehicles and Recreational vehicle parks 551.72(D): “Neutral Conductors.” The informational note to this section tells the user of the NEC that circuit lengths will typically be very long in recreational vehicle parks. It reminds one of the fact that the ampacity information provided as part of Article 310 does not take into consideration voltage drop noting that selection based on Article 310 alone may be inadequate for the installation. Informational note #2 provides insight to what voltage drop is and what current should be used when calculating voltage drop. The suggested current to be used here is based on the calculated load with appropriate demand factors as per Section 551.73(A).

Electric welders 630.31: “Ampacity of Supply Conductors.” The informational note for this section of the NEC simply advises that the voltage drop should be limited to a value that is satisfactory for the performance of the welder. The informational note reads “The ampacity of the supply conductors for resistance welders necessary to limit the voltage drop to a value permissible for the satisfactory performance of the welder is usually greater than that required to prevent overheating.”

Sensitive electronic equipment 647.4(D): “Voltage Drop.” This section of the NEC specifies a not to exceed voltage drop percentage for branch circuits of 1.5% and a not to exceed combined voltage drop of feeder and branch-circuit conductors of 2.5%. Special consideration is given for cord-connected equipment in an effort to limit voltage to 1.5% where portable cords may be used as a means of connecting equipment. These requirements, found in 647.4(D)(2) require that the voltage drop on branch circuits supplying receptacles are not to exceed 1%. Additional information is provided with regard to the load current that should be used when calculating voltage drop. This section sets the minimum current to be 50% of the branch-circuit rating. In addition, the maximum voltage drop for the feeder and branch circuit combined cannot exceed 2.0%.

Code reference is 647.6(B), Grounding Conductors Required. Informational Note No. 1 to this section reminds the user of the NEC that when the current carrying conductors are increased in size for voltage drop considerations, Section 250.122 should be consulted to make the appropriate adjustments to the equipment grounding conductor.

Solar photovoltaic (PV) systems 690.45 “Size of Equipment Grounding Conductors.” This section of the NEC tells us that for PV systems, when the current carrying conductors are increased in size to account for voltage drop, the requirements of Section 250.122 are not required to be met with regard to the equipment grounding conductor sizing.

Fire pumps, Article 695.6(B): “Conductor Size.” This section provides guidance on sizing the conductors supplying the fire pump motor and reminds the user of the NEC that the voltage drop requirements of Section 695.7 must also be met.

“Voltage Drop.” requirements for fire pumps in 695.7 focuses more on not exceeding a percent voltage drop for a normal starting condition of the fire pump motor. 695.7(A) titled “Starting” notes that the voltage at the fire pump controller line terminals must not drop more than 15% below the normal voltage when the motor is starting under normal conditions.

Energy storage systems 706.31(B): “Intercell and Intertier Conductors and Connections” The informational note to this section recommends a maximum voltage drop of 3% calculated based on maximum anticipated load. In addition a recommendation is made of not exceeding 5% for total voltage drop to the furthest point of connection. This informational note also reminds the user of the NEC that these voltage drop maximums may not be appropriate for all battery applications. Reference is made to IEEE 1375-2003, Guide for the Protection of Stationary Battery Systems, for further guidance for overcurrent protection and associated cable sizing.

Conductor impedance, Chapter 9 Table 9: It's Table 9, “Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-phase, 60 Hz, 75°C (167°F) — Three Single Conductors in Conduit” of the NEC where guidance on the impedance values is found to use in voltage drop calculations. Note 2 to this table tells us that leveraging the effective impedance Z in voltage drop calculations provides a decent approximation for line-to-neutral voltage drop.

When circuit changes are made to reduce voltage drop, the impact to the available fault current must also be reviewed. Reducing voltage drop is primarily achieved through increasing the size of the current carrying conductors. As conductors sizes get larger conductor impedances get smaller. Lower impedance results in higher fault currents. The effects of increasing fault currents must not be overlooked and include SCCR and selective coordination for circuit breaker applications.

Single-phase calculations

The calculation of voltage drop is a simple basic equation based upon the circuit in Figure 7.7.9.a.

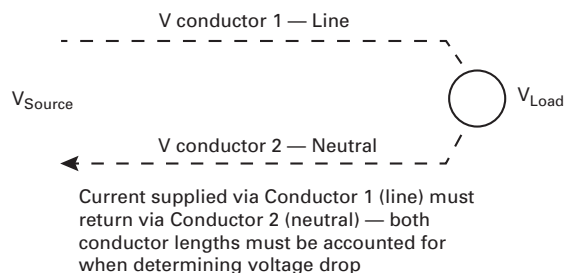


Figure 7.7.9.a Line and neutral conductors must both be considered for voltage drop calculations.

Kirchoff's Voltage Law tells us that the algebraic sum of all voltages in a loop must equal zero. The following equation is constructed:

$$0 = V_{\text{source}} - V_{\text{Conductor 1}} - V_{\text{Conductor 2}} - V_{\text{Load}}$$

$$V_{\text{Load}} = V_{\text{source}} - V_{\text{Conductor 1}} - V_{\text{Conductor 2}}$$

The voltage across the conductor is determined by multiplying the load current by the impedance. As per Note 2 of Table 9, the effective impedance Z of the conductor can be used as the conductor impedance. One can obtain the current used for these calculations a few different ways depending upon the application and the anticipated application:

- 1. Ampacity of the conductor:** This assumption will provide the worst case voltage drop for the circuit as the highest load current would be used resulting in the most voltage drop across the conductor.
- 2. 80% of the conductor's ampacity:** This assumption is more close to those applications that leverage the sizing of conductors based on 1.25 times the calculated continuous load currents.
- 3. 50% of the conductor's ampacity:** This assumption is used in Article 647 for sensitive electronic loads.
- 4. Maximum anticipated load:** This recommendation is used in Articles 706 for Energy Storage Systems and Article 551 for Recreational Vehicles and Recreational Parks.
- 5. Actual load:** The actual load on the circuit in question can be used.

The basic equation for calculating voltage drop across a conductor for a two wire DC circuit, a two wire AC circuit, or a three wire AC single-phase circuit is as follows:

$$\text{Voltage drop} = 2 \times L \times Z_{\text{Conductor}} \times I_{\text{Load}} \div 1000$$

Where:

L = The one way length of the conductor. The factor of 2 in the numerator takes into consideration the entire circuit length including the return path.

Z_{Conductor} = Conductor impedance in Ω/1000 ft. This information is from NEC Chapter 9 Table 9

I_{Load} = The current selected at which the voltage drop must be determined for the application. The value here may vary depending upon application.

Percent voltage drop is calculated as:

$$\% \text{ Voltage drop} = V_{\text{Load}} - V_{\text{Source}} \div V_{\text{Source}}$$

Example 1: For a 120 V circuit, what is the voltage drop of a 12 AWG conductor that supplies a 15 A load located 100 feet from the power supply?

$$\begin{aligned} \text{VD} &= 2 \times L \times Z_{\text{Conductor}} \times I_{\text{Load}} \div 1000 \\ &= 2 \times 100 \text{ ft.} \times 1.7 (\Omega \div 100 \text{ ft.}) \times 15 \text{ A} \div 1000 = 5.1 \text{ volts} \end{aligned}$$

The percent voltage drop assuming a source of 120 V is calculated as:

$$\begin{aligned} \% \text{ Voltage drop} &= V_{\text{Load}} - V_{\text{Source}} \div V_{\text{Source}} \\ &= 5.1 \text{ V} \div 120 \text{ V} \times 100\% = 4.25\% \end{aligned}$$

The voltage at the load assuming a source voltage of 120 V is equal to 120 V - 5.1 V or 114.9 V.

Example 2: For a 240 V circuit, what is the voltage drop of a 6 AWG conductor that supplies a 45 A load located 120 ft. from the power supply?

$$\begin{aligned} \text{VD} &= 2 \times L \times Z_{\text{Conductor}} \times I_{\text{Load}} \div 1000 \\ &= 2 \times 120 \text{ ft.} \times 0.29 (\Omega \div 1000 \text{ ft.}) \times 45 \text{ A} \div 1000 = 3.132 \text{ V} \end{aligned}$$

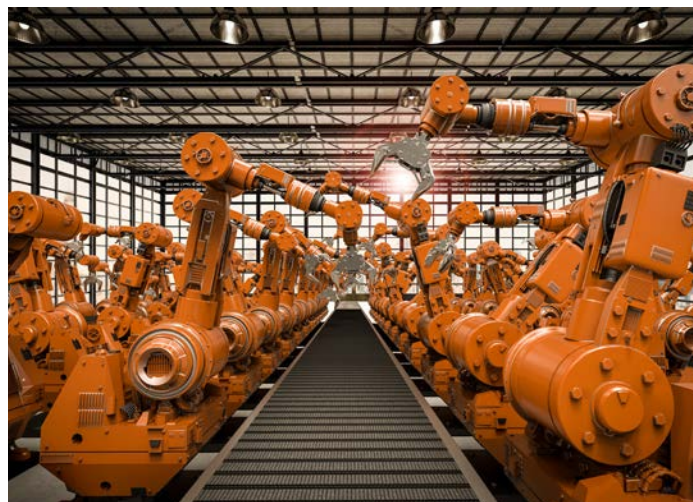
The percent voltage drop assuming a source of 240 V is calculated as:

$$\begin{aligned} \% \text{ Voltage drop} &= V_{\text{Load}} - V_{\text{Source}} \div V_{\text{Source}} \\ &= 3.132 \text{ V} \div 240 \text{ V} \times 100\% = 1.3\% \end{aligned}$$

The voltage at the load assuming a source voltage of 240 V is equal to 240 V - 3.132 V or 236.9 V.

Three-phase calculations

Three-phase systems have to be treated differently than single-phase systems.



Copper conductors — ratings and volt loss†

Ampacity/type					Volt loss									
					Three-phase (60 cycle, lagging power factor)					Single-phase(60 cycle, lagging power factor)				
Wire size	T, TW (60°C)	RH, THWN, RHW, THW (75°C)	RHH, THHN, XHHW (90°C)	Direct current	100%	90%	80%	70%	60%	100%	90%	80%	70%	60%
Steel conduit														
14	20*	20*	25*	6140	5369	4887	4371	3848	3322	6200	5643	5047	4444	3836
12	25*	25*	30*	3860	3464	3169	2841	2508	2172	4000	3659	3281	2897	2508
10	30	35*	40*	2420	2078	1918	1728	1532	1334	2400	2214	1995	1769	1540
8	40	50	55	1528	1350	1264	1148	1026	900	1560	1460	1326	1184	1040
6	55	65	75	982	848	812	745	673	597	980	937	860	777	690
4	70	85	95	616	536	528	491	450	405	620	610	568	519	468
3	85	100	110	490	433	434	407	376	341	500	501	470	434	394
2	95	115	130	388	346	354	336	312	286	400	409	388	361	331
1	110	130	150	308	277	292	280	264	245	320	337	324	305	283
0	125	150	170	244	207	228	223	213	200	240	263	258	246	232
00	145	175	195	193	173	196	194	188	178	200	227	224	217	206
000	165	200	225	153	136	162	163	160	154	158	187	188	184	178
0000	195	230	260	122	109	136	140	139	136	126	157	162	161	157
250	215	255	290	103	93	123	128	129	128	108	142	148	149	148
300	240	285	320	86	77	108	115	117	117	90	125	133	135	135
350	260	310	350	73	67	98	106	109	109	78	113	122	126	126
400	280	335	380	64	60	91	99	103	104	70	105	114	118	120
500	320	380	430	52	50	81	90	94	96	58	94	104	109	111
600	335	420	475	43	43	75	84	89	92	50	86	97	103	106
750	400	475	535	34	36	68	78	84	88	42	79	91	97	102
1000	455	545	615	26	31	62	72	78	82	36	72	84	90	95
Non-magnetic conduit (lead covered cables or installation in fiber or other non-magnetic conduit, etc.)														
14	20*	20*	25*	6140	5369	4876	4355	3830	3301	6200	5630	5029	4422	3812
12	25*	25*	30*	3464	3464	3158	2827	2491	2153	4000	3647	3264	2877	2486
10	30	35*	40*	2420	2078	1908	1714	1516	1316	2400	2203	1980	1751	1520
8	40	50	55	1528	1350	1255	1134	1010	882	1560	1449	1310	1166	1019
6	55	65	75	982	848	802	731	657	579	980	926	845	758	669
4	70	85	95	616	536	519	479	435	388	620	599	553	502	448
3	85	100	110	470	433	425	395	361	324	500	490	456	417	375
2	95	115	130	388	329	330	310	286	259	380	381	358	330	300
1	110	130	150	308	259	268	255	238	219	300	310	295	275	253
0	125	150	170	244	207	220	212	199	185	240	254	244	230	214
00	145	175	195	193	173	188	183	174	163	200	217	211	201	188
000	165	200	225	153	133	151	150	145	138	154	175	173	167	159
0000	195	230	260	122	107	127	128	125	121	124	147	148	145	140
250	215	255	290	103	90	112	114	113	110	104	129	132	131	128
300	240	285	320	86	76	99	103	104	102	88	114	119	120	118
350	260	310	350	73	65	89	94	95	94	76	103	108	110	109
400	280	335	380	64	57	81	87	89	89	66	94	100	103	103
500	320	380	430	52	46	71	77	80	82	54	82	90	93	94
600	335	420	475	43	39	65	72	76	77	46	75	83	87	90
750	400	475	535	34	32	58	65	70	72	38	67	76	80	83
1000	455	545	615	26	25	51	59	63	66	30	59	68	73	77

* The overcurrent protection for conductor types marked with an (*) must not exceed 15 A for 14 AWG, 20 A for 12 AWG, and 30 A for 10 AWG copper; or 15 A for 12 AWG and 25 A for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phases.

Aluminum conductors — ratings and volt loss†

Ampacity/type					Volt loss									
					Three-phase (60 cycle, lagging power factor)					Single-phase(60 cycle, lagging power factor)				
Wire size	T, TW (60°C)	RH, THWN, RHW, THW (75°C)	RHH, THHN, XHHW (90°C)	Direct current	100%	90%	80%	70%	60%	100%	90%	80%	70%	60%
Steel conduit														
12	20*	20*	25*	6360	5542	5039	4504	3963	3419	6400	5819	5201	4577	3948
10	25	30*	35*	4000	3464	3165	2836	2502	2165	4000	3654	3275	2889	2500
8	30	40	45	2520	2251	2075	1868	1656	1441	2600	2396	2158	1912	1663
6	40	50	60	1616	1402	1310	1188	1061	930	1620	1513	1372	1225	1074
4	55	65	75	1016	883	840	769	692	613	1020	970	888	799	708
3	65	75	85	796	692	668	615	557	497	800	771	710	644	574
2	75	90	100	638	554	541	502	458	411	640	625	580	529	475
1	85	100	115	506	433	432	405	373	338	500	499	468	431	391
0	100	120	135	402	346	353	334	310	284	400	407	386	358	328
00	115	135	150	318	277	290	277	260	241	320	335	320	301	278
000	130	155	175	259	225	241	234	221	207	260	279	270	256	239
0000	150	180	205	200	173	194	191	184	174	200	224	221	212	201
250	170	205	230	169	148	173	173	168	161	172	200	200	194	186
300	190	230	255	141	124	150	152	150	145	144	174	176	173	168
350	210	250	280	121	109	135	139	138	134	126	156	160	159	155
400	225	270	305	106	95	122	127	127	125	110	141	146	146	144
500	260	310	350	85	77	106	112	113	113	90	122	129	131	130
600	285	340	385	71	65	95	102	105	106	76	110	118	121	122
750	320	385	435	56	53	84	92	96	98	62	97	107	111	114
1000	375	445	500	42	43	73	82	87	89	50	85	95	100	103
Non-magnetic conduit (lead covered cables or installation in fiber or other non-magnetic conduit, etc.)														
12	20*	20*	25*	6360	5542	5029	4490	3946	3400	6400	5807	5184	4557	3926
10	25	30*	35*	4000	3464	3155	2823	2486	2147	4000	3643	3260	2871	2480
8	30	40	45	2520	2251	2065	1855	1640	1423	2600	2385	2142	1894	1643
6	40	50	60	1616	1402	1301	1175	1045	912	1620	1502	1357	1206	1053
4	55	65	75	1016	883	831	756	677	596	1020	959	873	782	668
3	65	75	85	796	692	659	603	543	480	800	760	696	627	555
2	75	90	100	638	554	532	490	443	394	640	615	566	512	456
1	85	100	115	506	433	424	394	360	323	500	490	455	415	373
0	100	120	135	402	346	344	322	296	268	400	398	372	342	310
00	115	135	150	318	277	281	266	247	225	320	325	307	285	260
000	130	155	175	252	225	234	223	209	193	260	270	258	241	223
0000	150	180	205	200	173	186	181	171	160	200	215	209	198	185
250	170	205	230	169	147	163	160	153	145	170	188	185	177	167
300	190	230	255	141	122	141	140	136	130	142	163	162	157	150
350	210	250	280	121	105	125	125	123	118	122	144	145	142	137
400	225	270	305	106	93	114	116	114	111	108	132	134	132	128
500	260	310	350	85	74	96	100	100	98	86	111	115	115	114
600	285	340	385	71	62	85	90	91	91	72	98	104	106	105
750	320	385	435	56	50	73	79	82	82	58	85	92	94	95
1000	375	445	500	42	39	63	70	73	75	46	73	81	85	86

* The overcurrent protection for conductor types marked with an (*) must not exceed 15 A for 14 AWG, 20 A for 12 AWG, and 30 A for 10 AWG copper; or 15 A for 12 AWG and 25 A for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phases.

7.7.10 Overcurrent protective device selection

Once a conductor has been selected considering ampacity as well as considerations for voltage drop, selecting the OCPD can proceed. The basic premise to selecting the overcurrent protective device is that the amp rating of the OCPD must not be greater than the ampacity of the conductor. The conductor's ampacity must also include any adjustments due to temperature or number of current carrying conductors in a raceway.

Section 240.4(B) provides an allowance to go to the next larger fuse size when the ampacity of the conductor does not correspond to a standard size fuse. This is only applicable when its rating does not exceed 800 A and the conductor is not part of a multi-outlet branch circuit supplying receptacles for cord and plug connected portable loads.

Standard fuse sizes per NEC 240.6 are: 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000 and 6000 A.

Note: The small fuse amp ratings of 1, 3, 6 and 10 were added to provide more effective short-circuit and ground-fault protection for motor circuits, in accordance with 430.40 and 430.52 and listing agency requirements for protecting the overload relays in controllers for very small motors.

For fuse amp ratings over 800 A, per 240.4(C), the ampacity of the conductor must be equal to or greater than the rating of the fuse as required in 240.6. For supervised industrial installations, see 240.91.

7.7.11 Tap conductors and OCPDs

Fuses must be installed at the point where the conductor receives its supply, i.e., at the beginning or lineside of a branch circuit or feeder, NEC 240.21.

- (B)(1) OCPDs are not required at the conductor supply if a feeder tap conductor is not over ten feet long; is enclosed in raceway; does not extend beyond the switchboard, panelboard or control device which it supplies; and has an ampacity not less than the combined computed loads supplied, and not less than the rating of the equipment containing an overcurrent device(s) supplied, unless the tap conductors are terminated in a fuse not exceeding the tap conductor ampacity. For field installed taps, the ampacity of the tap conductor must be at least 10% of the overcurrent device protecting the feeder conductors [240.21(B)(1)].
- (B)(2) OCPDs are not required at the conductor supply if a feeder tap conductor is not over 25 feet long; is suitably protected from physical damage by being enclosed in an approved raceway or other approved means; has an ampacity not less than 1/3 that of the device protecting the feeder conductors and terminate in an overcurrent device sized not more than the tap conductor ampacity [240.21(B)(2)].
- (B)(3) OCPDs are not required at the conductor supply if a transformer feeder tap has primary conductors at least 1/3 the ampacity of the overcurrent device protecting the feeder, and secondary conductors are at least 1/3 the ampacity of the overcurrent device protecting the feeder, when multiplied by the transformer turns ratio. The total length of one primary plus one secondary conductor (excluding any portion of the primary conductor that is protected at its ampacity) is not over 25 feet in length; the secondary conductors terminate in an OCPD rated at the ampacity of the tap conductors; and if the primary and secondary conductors are suitably protected from physical damage [240.21(B)(3)].
- (B)(4) OCPDs are not required at the conductor supply if a feeder tap is not over 25 feet long horizontally and not over 100 feet long total length in high bay manufacturing buildings where only qualified persons will service such a system. Also, the ampacity of the tap conductors is not less than 1/3 of the fuse rating from which they are supplied. The size of the tap conductors must be at least 6 AWG copper or 4 AWG aluminum. They may not penetrate walls, floors, or ceilings, and the taps are made no less than 30 feet from the floor.

The tap conductors terminate in an OCPD that limit the load to the tap conductors' ampacity. They are physically protected by being enclosed in an approved raceway or other approved means and contain no splices. [240.21(B)(4)].

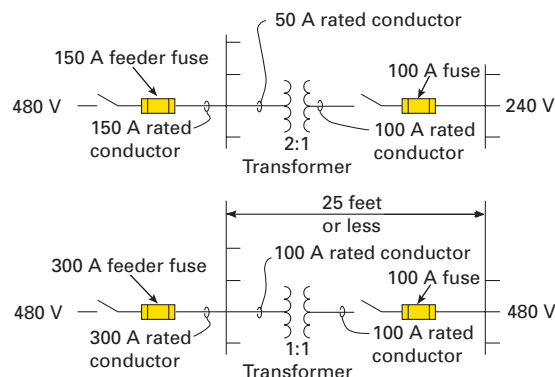


Figure 7.11.a

Note: Smaller conductors tapped to larger conductors can be a serious hazard. If not adequately protected against short-circuit conditions (as required in NEC 110.10 and 240.1(FPN)), these unprotected conductors can vaporize or incur severe insulation damage. Molten metal and ionized gas created by a vaporized conductor can envelop other conductors (such as bare bus), causing equipment burndown. Adequate short-circuit protection is recommended for all conductors. When a tap is made to a switchboard bus for an adjacent panel, such as an emergency panel, the use of Busssmann series cable limiters is recommended for protection of the tapped conductor. These current-limiting cable limiters are available in sizes designed for short-circuit protection of conductors from 12 AWG to 1000 kcmil. Busssmann series cable limiters are available in a variety of terminations to make application to bus structures or conductors relatively simple.

- (B)(5) OCPDs are not required at the supply for an outside tap of unlimited length where all of the following are met:
 - The conductors are outdoors except at the point of load termination.
 - The conductors are protected from physical damage in an approved manner.
 - The conductors terminate in an OCPD that limits the load to the ampacity of the conductors.
 - The fuses are a part of or immediately adjacent to the disconnecting means.
 - The disconnecting means is readily accessible and is installed outside or inside nearest the point of entrance or where installed inside per 230.6 nearest the point of conductor entrance [240.21(B)(5)]. See the Figure 7.11.b.

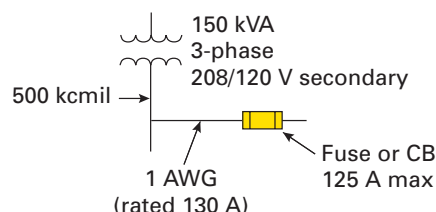


Figure 7.11.b

- (C)(1) OCPDs are not required on the secondary of a single-phase two-wire or three-phase, three-wire, Delta-Delta transformer to provide conductor protection where all of the following are met:
 - The transformer is protected in accordance with 450.3.

- The overcurrent protective device on the primary of the transformer does not exceed the ampacity of the secondary conductor multiplied by the secondary to primary voltage ratio. [240.21(C)(1)]. Selecting the next higher standard size overcurrent protective device is NOT allowed.
- (C)(2) OCPDs are not required on the secondary of a transformer to provide conductor protection where all of the following are met:
 - The secondary conductors are not over 10 feet long.
 - The secondary conductors' ampacity is not less than the combined computed loads.
 - The secondary conductor ampacity is not less than the rating of the device they supply or the rating of the overcurrent device at their termination. Selecting the next higher standard size overcurrent protective device is NOT allowed.
 - The secondary conductors do not extend beyond the enclosure(s) of the equipment they supply and they are enclosed in a raceway.
 - For field installations where the secondary conductors leave the enclosure or vault from where they receive their supply, the secondary conductor ampacity is not less than 1/10 of the rating of the OCPD protecting the transformer's primary multiplied by the turns ratio. [240.21(C)(2)].
- (C)(3) Transformer secondary conductors do not require fuses at the transformer terminals when all of the following conditions are met.
 - Must be an industrial location.
 - The conditions of maintenance and supervision in a given industrial location ensure that only qualified personnel service the system.
 - Secondary conductors must not be more than 25 feet long.
 - Secondary conductor ampacity must be at least equal to the secondary full-load current of transformer and sum of terminating, grouped, overcurrent devices. Selecting the next higher standard size overcurrent protective device is NOT allowed.
 - Secondary conductors must be protected from physical damage in an approved raceway or other approved means. [240.21(C)(3)].

Note: Switchboard and panelboard protection (408.36) and transformer protection (450.3) must still be observed.
- (C)(4) Outside conductors that are tapped to a feeder or connected to the secondary terminals of a transformer do not require OCPD protection when all of the following are met:
 - The conductors are protected from physical damage in an approved means.
 - The conductors terminate in an OCPD, no larger than the ampacity of the conductors.
 - The conductors are outside, except for point of load termination.
 - The overcurrent device is near or a part of the disconnecting means.
 - The disconnecting means is readily accessible outdoors or, if indoors, nearest the point of the entrance of the conductors or where installed inside per 230.6 nearest the point of conductor entrance [240.21(C)(4)].

7.7.12 Small conductors

NEC 240.4(D) determines protection of small conductors. The overcurrent protective device is required to not exceed the following, unless specifically permitted by 240.4(E) for tap conductors or 240.4(G) for specific conductor applications:

- 18 AWG Copper — 7 A or less provided continuous loads do not exceed 5.6 A and overcurrent protection is provided by one of the following:
 - Class CC, J, or T fuses

- Branch circuit-rated fuses or circuit breakers listed and marked for use with 18 AWG copper wire
- 16 AWG copper — 10 A or less provided continuous loads do not exceed 8 amps and overcurrent protection is provided by one of the following:
 - Class CC, J, or T fuses
 - Branch circuit-rated fuses or circuit breakers listed and marked for use with 16 AWG copper wire
- 14 AWG copper or 12 AWG aluminum and copper-clad aluminum — 15 A or less
 - 12 AWG copper - 20 A or less
 - 10 AWG aluminum and copper-clad aluminum - 25 A or less
 - 10 AWG copper - 30 A or less

It's important to note that 310.106 (and Table 310.106(A)) lists the minimum size conductor as 14 AWG. 16 and 18 AWG conductors can only be used provided they are permitted elsewhere in the Code. In addition to allowances for small motors per 430.22(G) 16 and 18 AWG conductors are permitted for power circuits in industrial machinery per NFPA 79 and UL 508A. However, there are strict limitations on the overcurrent protection. See NFPA 79 for more information.

7.7.13 Flexible cords

Per NEC 240.5 flexible cords and extension cords must have overcurrent protection rated at their ampacities. Supplementary fuse protection is an acceptable method of protection. For 18 AWG fixture wire of 50 feet or more, a 6 A fuse would provide the necessary protection. For 16 AWG fixture wire of 100 feet or more, an 8 A fuse would provide the necessary protection.

For 18 AWG extension cords, a 10 A fuse would provide the necessary protection for a cord where only two conductors are carrying current, and a 7 amp fuse would provide the necessary protection for a cord where only three conductors are carrying current.

7.7.14 Exception for listed surge protective devices

Exceptions to 240.21(B)(1)(1)b and 240.21(C)(2)(1)b permits sizing of tap conductors for listed surge protective devices and other listed non-energy consuming devices to be based on the manufacturer's instructions.

This surge protective device is prewired with specific conductors that are shown in the device's instructions. Surge protective devices are non-energy consuming devices that do not have a calculated load as referenced by 240.21(B)(1)(1)b and 240.21(C)(2)(1)b. For surge protective devices visit Eaton.com/bussmannseries.



7.7.15 Battery conductors

Conductors connected to storage battery systems must be protected in accordance with their ampacity per 240.4. For non-hazardous environments the location of the overcurrent protective device must be as close as practicable to the storage battery terminals in accordance with 240.21(H). The installation of overcurrent protective devices on battery systems in hazardous locations is permitted. However, the additional requirements for hazardous locations must be followed.

7.7.16 Branch circuits — lighting and/or appliance load (no motor load)

The branch circuit rating must be classified in accordance with the rating of the overcurrent protective device. Classifications for those branch circuits other than individual loads must be: 15, 20, 30, 40 and 50 A (210.3).

Branch circuit conductors must have an ampacity of the rating of the branch circuit and not less than the load to be served (210.19).

The minimum size branch circuit conductor that can be used is 14 AWG (210.19). For exceptions to minimum conductor size, see 210.19.

Branch circuit conductors and equipment must be protected by a fuse with an amp rating which conforms to 210.20. Branch circuit conductor ampacity must be at least the larger of two calculations (a) or (b):

- The sum of non-continuous load plus 125% of the continuous load.
- Maximum load to be served after applying adjustment or correction factors (as calculated per Article 220).

An example calculation is shown in NEC Information Annex D, Example D3(a). The fuse size must not be greater than the conductor ampacity (for exceptions, see 210.20). Branch circuits rated 15, 20, 30, 40 and 50 A with two or more outlets (other than receptacle circuits of 210.11(C)(1) and (C)(2) must be fused at their rating and the branch circuit conductor sized according to Table 210.24 (see 210.24).

7.7.17 Feeder circuits (no motor load)

The feeder fuse amp rating and feeder conductor ampacity minimum size must be at least the larger of two calculations (a) or (b): (a) the sum of non-continuous load plus 125% of the continuous load or (b) maximum load to be served after applying adjustment or correction factors (as calculated per Article 220). An example calculation is shown in NEC Information Annex D, Example D3(a). The feeder conductor can be protected by an OCPD the next higher standard overcurrent device rated (above the ampacity of the conductors being protected) as long as the OCPD size is rated 800 A or less. If the OCPD size is greater than 800 A, the conductor must be protected by an OCPD not greater than the conductor ampacity (for exceptions, see 240.3). Motor loads must be computed in accordance with Article 430; Conductors for motor branch and feeder circuits in Section 7.14.5.

7.7.18 Service conductors

Each ungrounded service entrance conductor must have a fuse in series with an amp rating not higher than the ampacity of the conductor (for exceptions, see 230.90(A) which permits the use of 240.4(B) or (C) and 240.6. The service fuses must be part of the service disconnecting means or be located immediately adjacent thereto (230.91).

Service disconnecting means can consist of one to six switches for each service (230.71) or for each set of service entrance conductors permitted in 230.2. When more than one switch is used, the switches must be grouped together (230.71).

Service equipment must have adequate short-circuit ratings for the available fault current.

110.24 requires the maximum available fault current and date of calculation to be field marked on the service equipment. This is to ensure that the overcurrent protective devices have sufficient interrupting rating and that the service equipment short-circuit current rating are equal to or exceed the available short-circuit current. If electrical installation modifications are made the maximum available fault current should be recalculated and new field marking for the service equipment. It should be verified that the service equipment short-circuit current rating and overcurrent protective devices' interrupting ratings are adequate for the new available fault current. 110.24 is not required for dwelling units or certain industrial installations.

7.7.19 Wire and cable short-circuit protection

The circuit shown originates at a distribution panel where 40 kA RMS Sym. fault current is available. To determine the proper fuse, first establish the short-circuit withstand data for the 10 AWG THW copper cable shown in Figure 7.7.19.a

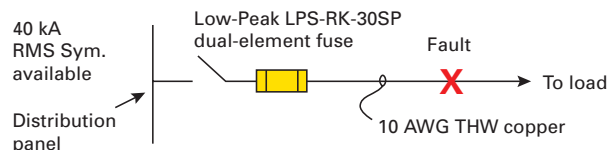


Figure 7.7.19.a.

The following table shows the short-circuit withstand of copper cable with 75°C thermoplastic insulation based on Insulated Cable Engineers Association (ICEA) formulas.

The short-circuit withstand of the 10 AWG THW copper conductor is 4300 A for one cycle (0.0167 seconds). This conductor's short-circuit protection requires selecting an OCPD that will limit the 40 kA RMS Sym. available to a value less than 4300 A, and clear the fault in one cycle or less.

The Low-Peak LPS-RK30SP dual-element fuse let-through graph in Section 3 shows that it will let-through an apparent prospective RMS current that's less than 1800 A, when 40 kA is available (and would clear the fault in less than 1/2 cycle).

Fault currents for insulated cables

Increases in power distribution system kVA capacity have resulted in the potential for extremely high magnitude fault currents that can seriously damage conductor insulation from the induced, high conductor temperatures. As a guide in preventing such serious damage, maximum allowable short-circuit temperatures, which begin to damage conductor insulation, have been established for various insulation types as follows:

- Paper, rubber and varnished cloth, 200°C
- Thermoplastic, 150°C

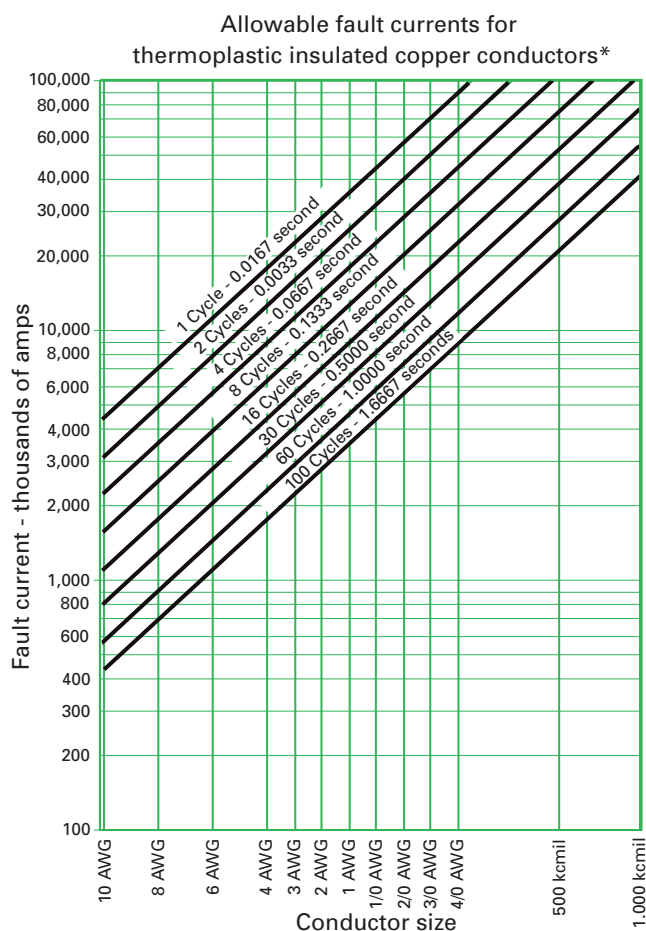
The graph in Figure 7.7.19.c shows the currents which, after flowing for the times indicated, will produce these maximum temperatures for each conductor size. The system short-circuit capacity, conductor cross-sectional area and OCPD opening time should be such that these maximum allowable fault currents are not exceeded.

Using the formula shown on the ICEA protection table will allow calculating conductor withstand ratings. It may be advantageous to calculate withstand ratings below one cycle, when the opening time of the current-limiting device is known; see table below. See Bussmann series current-limiting fuse let-through data to obtain LPS-RK data in Section 3.

Copper wire size, 75°C thermoplastic	Maximum fault current withstand in amps					
	1/8 cycle*	1/4 cycle*	1/2 cycle*	1 cycle	2 cycles	3 cycles
18*	1850	1300	900	700	500	400
16*	3000	2100	1500	1100	700	600
14*	4800	3400	2400	1700	1200	1000
12*	7600	5400	3800	2700	1900	1550
10	12,000	8500	6020	4300	3000	2450
8	19,200	13,500	9600	6800	4800	3900
6	30,400	21,500	16,200	10,800	7600	6200
4	48,400	34,200	24,200	17,100	12,100	9900

* Extrapolated data.

Table 7.7.19.b Copper, 75° thermoplastic insulated cable damage at 60 Hz.



* © 1969 (reaffirmed March, 1992) by the Insulated Cable Engineers Association (ICEA).
Permission has been given by ICEA to reprint this chart.

Figure 7.7.19.c Short-circuit current withstand graph for copper cables with thermoplastic insulation.

Protecting equipment grounding conductors

Safety issues arise when the equipment grounding conductor analysis (EGC) is discussed. NEC Table 250.122 offers minimum sizing for equipment grounding conductors.

Equipment grounding conductors are much more difficult to protect than phase conductors because the OCPD is most often several sizes larger than the equipment grounding conductor's ampacity.

The equipment grounding conductor protection problem was recognized decades ago when Eustace Soares, wrote his famous book "Grounding Electrical Distribution Systems for Safety." In his book he states that the "validity" rating corresponds to the amount of energy required to cause the copper to become loose under a lug after the conductor has had a chance to cool down. This validity rating is based upon raising the copper temperature from 75°C to 250°C.

In addition to this and the ICEA charts, a third method promoted by Onderdonk allows for calculating the energy necessary to cause the conductor to melt (75°C to 1083°C).

Table 7.7.19.d summarizes the values associated with various size copper conductors.

The word "Minimum" in the heading of NEC Table 250.122 means just that - the values are minimums - they may need increasing due to the available fault current and the OCPD's current-limiting, or non-current-limiting ability. 250.4(A)(5) and 250.4(B)(4) require grounding conductors sized adequately for the fault current that could be let-through. This means that based on the available fault current and the OCPD characteristics (let-through current), the grounding conductor may have to be sized larger than the minimum in Table 250.122.

Good engineering practice requires calculating available fault currents (three-phase and phase-to-ground values) wherever equipment grounding conductors are used. OCPD manufacturers' literature must be consulted. Let-through energy for these devices should be compared with the equipment grounding conductor's short-circuit current withstand. Wherever let-through current exceeds the "minimum" equipment grounding conductor withstand, the equipment grounding conductor size must be increased until the withstand is not exceeded.



Conductor size	5 Sec. rating (amps)			I ² t rating x10 ⁶ (amps squared seconds)		
	ICEA P32-382 insulation damage	Soares 1 amp/30cm validity	Onderdonk melting point	ICEA P32-382 insulation damage	Soares 1 amp/30cm validity	Onderdonk melting point
	150°C	250°C	1083°C	150°C	250°C	1083°C
18	38	55	99	0.007	0.015	0.049
16	61	88	158	0.019	0.039	0.124
14	97	137	253	0.047	0.094	0.320
12	155	218	401	0.120	0.238	0.804
10	246	346	638	0.303	0.599	2.03
8	391	550	1015	0.764	1.51	5.15
6	621	875	1613	1.93	3.83	13.0
4	988	1391	2565	4.88	9.67	32.9
3	1246	1754	3234	7.76	15.4	52.3
2	1571	2212	4078	12.3	24.5	83.1
1	1981	2790	5144	19.6	38.9	132.0
1/0	2500	3520	6490	31.2	61.9	210.0
2/0	3150	4437	8180	49.6	98.4	331.0
3/0	3972	5593	10,313	78.9	156.0	532.0
4/0	5009	7053	13,005	125.0	248.0	845.0
250	5918	8333	15,365	175.0	347.0	1180.0
300	7101	10,000	18,438	252.0	500.0	1700.0
350	8285	11,667	21,511	343.0	680.0	2314.0
400	9468	13,333	24,584	448.0	889.0	3022.0
500	11,835	16,667	30,730	700.0	1389.0	4721.0
600	14,202	20,000	36,876	1008.0	2000.0	6799.0
700	16,569	23,333	43,022	1372.0	2722.0	9254.0
750	17,753	25,000	46,095	1576.0	3125.0	10,623.0
800	18,936	26,667	49,168	1793.0	3556.0	12,087.0
900	21,303	30,000	55,314	2269.0	4500.0	15,298.0
1000	23,670	33,333	61,460	2801.0	5555.0	18,867.0

Table 7.7.19.d Comparison of equipment grounding conductor fault current withstands.

Take the example in Figure 7.17.19.e. The EGC to be protected can withstand 4300 A for 1 cycle. A current-limiting fuse will limit the current to within the EGC's withstand rating. An LPS-RK60SP will limit the line-to-ground current to approximately 3300 A and provide sufficient protection.

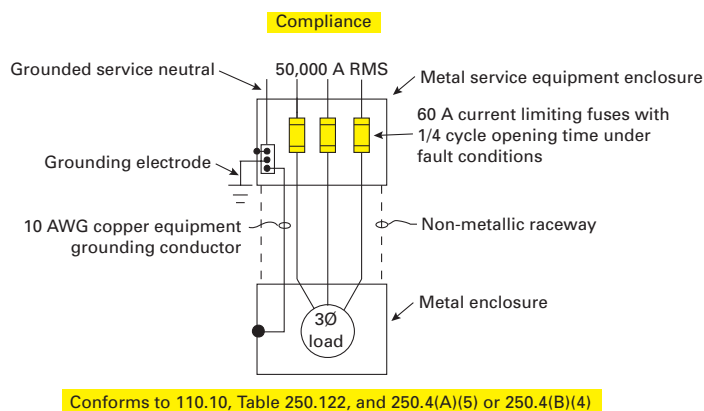


Figure 7.7.19.e

Tap conductor sizing by the engineering method

The NEC has additional sizing latitude for feeder tap conductors used in supervised industrial installations. Tap conductors are now considered protected under short-circuit current conditions by using an engineering method to select the conductor size based on the proper feeder OCPD characteristics. This allowance can only be used in supervised industrial installations.

Per 240.2, three conditions must be met to be qualified as a supervised industrial installation:

- The maintenance crew must be qualified and under engineering supervision.
- The premises wiring system load (based on industrial process(es) and manufacturing activities) must be 2500 kVA or greater as calculated in accordance with Article 220.
- There must be at least one service at 277/480 or 480 volts or higher.

The physics formulas shown in Table 240.92(B) are the same as in the ICEA protection table, and can be used to find the maximum short-circuit current and time for proper conductor protection under short-circuit conditions.

Table 240.92(B) tap conductor short-circuit current ratings.

Tap conductors are considered to be protected under short-circuit conditions when their short-circuit temperature limit is not exceeded. Conductor heating under short-circuit conditions is determined by the short-circuit formula for:

(1) Copper conductors $(I^2/A^2)t = 0.0297 \log_{10} [(T2 + 234)/(T1 + 234)]$

(2) Aluminum conductors $(I^2/A^2)t = 0.0125 \log_{10} [(T2 + 228)/(T1 + 228)]$

Where:

I = Short-circuit current in amps

A = Conductor area in circular mils

t = Time of short-circuit in seconds (for times ≤ to 10 seconds)

T1 = Initial conductor temperature in °C (conductor insulation rating)

T2 = Final conductor temperature in °C (threshold for insulation damage, see Table 7.7.19.e)

Conductor	Insulation	T2 (°C)
Copper	Paper, rubber, varnished cloth	200
	Thermoplastic	150
	Cross-linked polyethylene	250
	Ethylene propylene rubber	250
Aluminum	Paper, rubber, varnished cloth	200
	Thermoplastic	150
	Cross-linked polyethylene	250
	Ethylene propylene rubber	250

Table 7.7.19.e

The change in 240.92(B) allows supervised industrial installations increased flexibility for feeder tap conductor where protection can be proven by physics formulas, in lieu of the simple ratios in 240.21(B)(2), (B)(3) and (B)(4). Thus, feeder tap conductor sizing can be accomplished using formulas for selecting OCPDs based on conductor insulation thermal damage levels and the OCPD's let-through energy under short-circuit conditions. Previous tap conductor sizing did not take into consideration any fault current or OCPD current-limiting characteristics, only the amp rating ratios that may result in overly conservative tap conductor sizing.

16 and 18 AWG conductors for industrial machinery power circuits

Typically 14 AWG or larger conductors are required for power circuits. However, per 430.22(G), 240.4(D), NFPA 79 (12.6.1.1 and 12.6.1.2) and UL 508A (66.5.4 Exception and Table 66.1A) 16 and 18 AWG conductors are permitted for motor and non-motor circuits under specified conditions. Using 16 and 18 AWG conductors reduces wiring costs in industrial machinery. The Table below illustrates where Class CC, J and T fuses can be used to protect 16 and 18 AWG conductors in power circuits per NFPA 79 and UL 508A.

Sizing Table 7.7.19.f for LP-CC (Class CC) and LPJ (Class J time-delay) fuse protection for 16 and 18 AWG conductors in industrial machinery power circuits per 430.22(G), 240.4(D) NFPA 79 and UL 508A

16 and 18 AWG conductors are easily damaged by fault currents. Many OCPDs are unable to protect these small conductors. However, the Small Wire Working Group of the NFPA 79 technical committee performed tests and evaluated criteria to demonstrate that Class CC or J fuses are among those able to provide protection. Other branch-circuit rated fuses or circuit breakers can only be used if marked for protecting 16 and 18 AWG conductors.

UL issued a special service investigation to look into using 16 and 18 AWG conductors for power branch circuits in industrial machinery applications (file number E4273) to verify the test results. The analysis, test program and results can be viewed in an IEEE paper presented at the 2002 IEEE Industrial and Commercial Power Systems Technical Conference, titled "An Investigation of the Use of 16 AWG and 18 AWG Conductors for Branch Circuits in Industrial Machinery Built to NFPA 79 2002."

Conductor size (AWG)	Max load amps	Load type	Max LP-CC amps	Max LPJ or TCF amps	Motor overload relay trip class
16	8	Non-motor	10	10	—
	8	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 10
	5.5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 20
18	5.6	Non-motor	7	7	—
	5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 10
	3.5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 20

* Standard fuse sizes are 1, 3, 6, 10, 15, 20, 25 and 30. Where the motor's starting current opens the fuse, the maximum setting can be increased, but not exceed 400% for LP-CC or 225% for LPJ.

Table 7.7.19.f

7.7.20 Cable limiters



Cable limiters are distinguished from fuses by their application for providing only short-circuit protection. They are not designed to provide overload protection. Typically, cable limiters are selected based on conductor size. They are available in a wide range to accommodate the many copper or aluminum conductor sizes and termination methods. There are two broad cable limiter categories:

- 600 V or less rated for large commercial, institutional and industrial applications
- 250 V or less rated for residential and light commercial applications

In institutional, commercial and industrial systems, cable limiters are used at both ends of each cable on three or more cables-per-phase applications, and located between the transformer and switchboard as shown in Figure 7.7.20.a. For residential systems, the limiters are generally applied on single cables as shown in Figure 7.7.20.b.

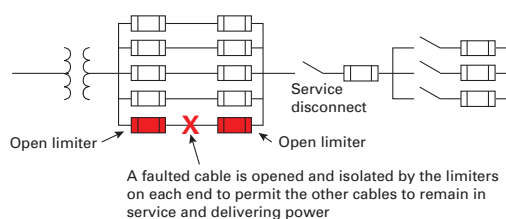


Figure 7.7.20.a Multi cable-per-phase commercial/industrial service entrance

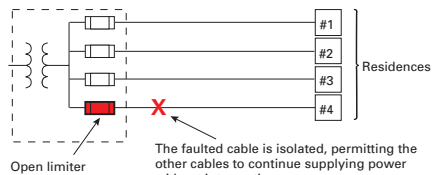


Figure 7.7.20.b Single cable-per-phase basis for residential applications have limiters applied at the lateral feeder source end.

Cable limiters may be located on the supply side of the service disconnecting means, and provide these advantages:

- Isolating one or more faulted cables so that only the affected cable(s) are isolated by the cable limiters opening at each end (assuming three or more cables per phase, with cable limiters on each end).
- Isolating a faulted cable permits more convenient repair service scheduling.
- Equipment burndown hazards caused by a fault on the main OCPD's lineside is greatly reduced. Typically, without cable limiters, a fault between the transformer and service switchboard is given little or no protection.
- Their current-limiting ability can minimize arc flash hazards by reducing the arc flash current's magnitude and exposure duration. There are many different limiters available for cables from 12 AWG to 1000 kcmil and many different termination types. Below are the available Bussmann series 600 V and 250 V cable limiters.

600 V limiters

Catalog no.	Cable size (AWG/kcmil)	Catalog no.	Cable size (AWG/kcmil)
Tubular terminals*			
KCY	4	KCF	4/0
KCZ	3	KCH	250
KCA	2	KCJ	350
KCB	1	KCM	500
KCC	1/0	KCV	600
KCD	2/0	KCR	750
KCE	3/0	KCS	1000
Tubular terminal and offset bolt-type terminal*			
KQV	12	KDD	2/0
KQT	10	KDE	3/0
KFZ	8	KDF	4/0
KIG	6	KDH	250
KDY	4	KDJ	350
KDA	2	KDM	500
KDB	1	KDU	600
KDC	1/0	KDR	750
Compression connector rod terminal and tubular terminal*			
KEX	4/0	KQO	350
KFH-A	250	KDT	500
Center bolt-type terminal and offset bolt-type terminal**			
KPF	4/0	KDP	500
KFT	250	KFM	750
KEW	350		

* Copper conductors only.

**Copper or aluminum conductors.

250 V limiters

Catalog no.	Cu cable size (AWG/kcmil)	Al cable size (AWG/kcmil)
UHA	3/0	4/0
UHH-M	3/0	250
UHH-T	350	500
UHH-W	600	800

7.7.21 Transformer secondary conductors

Secondary conductors need to be protected from damage by the proper overcurrent protective device. Although 240.4(F) provides an exception for conductors supplied by a single-phase transformer with a two-wire secondary, or a three-phase delta-delta transformer with a three-wire, single voltage secondary, it is recommended that these conductors be protected by fuses on the secondary sized at the secondary conductor ampacity. Due to energizing the transformer's primary windings inrush current, overcurrent protective devices on the primary may not be able to be sized low enough to meet the requirements of 450.3 and provide protection to the secondary conductors.

7.7.22 Motor circuit conductor protection



Motors and motor circuits have unique operating characteristics and circuit components, and therefore must be dealt with differently than other load types. Generally, two levels of overcurrent protection are required for motor branch circuits:

- **Overload protection:** Motor running overload protection is intended to protect the system components and motor from damaging overload currents.
- **Short-circuit protection (includes ground fault protection):** Short-circuit protection is intended to protect the motor circuit components such as the conductors, switches, controllers, overload relays, etc., against fault currents. This level of protection is commonly referred to as motor branch circuit protection.

Frequently, due to inherent limitations in various OCPD types for motor applications, two or more separate protective devices are used to provide overload and short-circuit protection. An exception is the dual-element fuse. For most motor applications, the benefits of dual-element fuse characteristic allow sizing the Fusetron™ Class RK5 fuses to provide both protection functions for motor circuits.

7.8 Electric heat

Resistance type electric space heating equipment rated more than 48 A must have its heating elements subdivided. Each subdivided load must not exceed 48 A, and the fuse for each load should not exceed 60 A [424.22(B)]. If a subdivided load is less than 48 A, the fuse rating must be 125% of that load.

Exception: Boilers employing resistance type immersion electric heating elements in an ASME rated and stamped vessel may be subdivided into circuits not exceeding 120 A, and protected by a fuse at not more than 150 A [424.22(B) and 424.72(A)]. If a subdivided load is less than 120 A, the fuse rating must be 125% of that load.

Fuse sizing per NEC 424

Heating type	Sizing	Fuse/volt recommendation
Space heating	125% or next size larger but in no case larger than 60 amps for each subdivided load	Up to 250 V: LPN-RK-SP, FRN-R, NON Up to 300 V: JJN
Boilers (ASME rated and stamped vessel)	125% or next size larger but in no case larger than 150 amps for each subdivided load	Up to 480 V: SC 25 to SC 60 Up to 600 V: LPS-RK-SP, FRS-R, NOS, JJS, LPJ_SP, LP-CC, FNQ-R, JKS, KTK-R, TCF, SC 1/2 to SC 20, FCF_RN

7.9 Elevators

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7.9.1 Overview

Where the elevator shaft and/or equipment room has a sprinkler fire suppression system installed, the elevator Code (ANSI/ASME A17.1) requires main line power to the elevator be removed prior to the application of water. This is typically accomplished via a shunt trip device. NEC 620.51(B) allows this requirement to be implemented at the elevator disconnecting means.

There are options available to achieve this depending upon the customer's needs. The simplest option is to use a shunt trip circuit breaker in either the feeder supplying the elevator or the elevator disconnect. For elevators with battery lowering systems, an additional contact is required per NEC 620.91(C) to disable the battery lowering system when the elevator disconnect is manually operated for maintenance. NFPA 72 requires the control circuit between the Fire Alarm System and the shunt trip be monitored for integrity. In addition, the shunt-trip voltage must also be monitored by the Fire Alarm System. Loss of voltage to the control circuit for the disconnecting means must cause a supervisory signal to be indicated at the control unit and required remote annunciation. In some cases, it may require a means to test the shunt trip operation or have one contact operate the shunt trip of more than one elevator. Per the 2017 NEC, if the elevator is designated as an emergency system load, the disconnect must be protected by a surge protective device (SPD). All of these options and special wiring can be challenging depending upon the location of the shunt trip circuit breaker as well as who has responsibility for providing these additional options. Because of this, several manufacturers offer an all-in-one shunt trip elevator disconnect switch that includes all the prewired accessories needed to comply with the various Code sections.

The Bussmann series Power Module™ is a simple solution available to engineering consultants, contractors and inspectors to help comply with all of these requirements in one enclosure.

Electric resistance heating appliances using elements rated more than 48 A must have the heating elements subdivided such that each subdivision does not exceed 48 A, and each subdivision must be protected by a branch circuit listed fuse not to exceed 60 A. These fuses must be factory installed by the manufacturer, be accessible and be suitable for branch circuit protection [422.11(F)(1)].

The Power Module contains a shunt trip molded case switch with trailing fuses together with the components necessary to comply with the fire alarm system requirements and shunt trip control power all in one package. This greatly simplifies the specification for engineering consultants. This also greatly simplifies installation for contractors because it only requires connecting the appropriate wires. This simplifies things for inspectors, too, because everything is in one place with the same wiring every time. The Power Module utilizes Low-Peak LPJ-SP fuses to protect the elevator branch circuit from the damaging effects of fault currents as well as helping to provide an easy selective coordination method when supplied with upstream Low-Peak fuses with at least a 2:1 amp rating ratio. More information about the Bussmann series Power Module can be found at Eaton.com/bussmannseries.

Typical elevator installations

The architect has a choice of either traction or hydraulic elevators. Traction elevators are typically faster and more energy efficient than hydraulic elevators, and are often used for high-rise buildings. Hydraulic elevators are typically more cost effective and used for buildings up to 5-6 stories. Traction elevators are typically installed in a "bank of elevators" where fused switches, or circuit breakers in a panelboard are located in the machine room serving the bank of elevators. Each fused switch or circuit breaker in the panelboard is used as an elevator disconnect. Hydraulic elevator installations are typically supplied from the main switchboard and have an elevator fused switch or circuit breaker in the machine room that serves as the elevator disconnect.

As mentioned, traditional installations of a traction or hydraulic elevator include a separate machine room. The vast majority of equipment serving the elevator is located within this room (i.e., elevator control panel). Also located in this room might be, but not limited to: exhaust fan, cooling unit (depending on local requirements and/or requirements set forth by the individual elevator supplier), lighting, voice and/or data drop serving the elevator cab emergency phone, elevator control panel primary fused disconnect, elevator feeder shunt-trip circuit (i.e., shunt-trip circuit breaker), elevator cab lighting fused switch, and convenience receptacle(s).

Machine room less (MRL) elevator installations incorporate the elevator control panel and often the primary disconnecting means in a convenient package that is located within the elevator shaft. However, space is frequently limited within the shaft and as such many ancillary components (shunt trip circuit breakers, fused disconnects) may need to be located outside of the elevator shaft. It is important for design engineers to communicate this with the architect and owner during the design phase, as it will impact space needs elsewhere in the facility to accommodate electrical equipment.

A traditional elevator installation (which includes a machine room) requires access inside the elevator shaft. Convenience receptacles and lighting for maintenance purposes are required at the base of the pit and, in some instances (elevator manufacturer dependent), at the top of the elevator shaft. It is important for the design engineer to coordinate with the architect to determine the elevator manufacturer basis of design to determine if and when additional power and lighting is required.

It is of great importance for the design engineer to communicate with their local authority having jurisdiction (AHJ) to determine fire alarm requirements for the respective elevator installation. While machine roomless designs have been commercially available for many years, their use may still be unknown to some AHJs. Design practices that are acceptable in some jurisdictions may not be in others. As always, the best advice in all instances — do your homework, communicate often, and document decisions made. Years may lapse between the design and installation stages of a project. Good documentation is of key importance to recalling what decisions were made and why.

7.9.2 NEC 620.62 requirements

NEC 620.62, “Selective Coordination,” requires that where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means must be selectively coordinated with any other supply side overcurrent protective devices.

A design engineer must specify and the contractor must install main, feeder, sub-feeder and branch circuit protective devices that are selectively coordinated for all overload and fault current values.

7.9.2.1 Example 1

To better understand how to assess selectively coordinated overcurrent protective devices in an electrical system refer to this publication's section on selective coordination. Figure 7.9.2.1.a offers a brief elevator system coordination assessment using fuses in Power Module elevator disconnects with upstream fuses in the feeders and main.

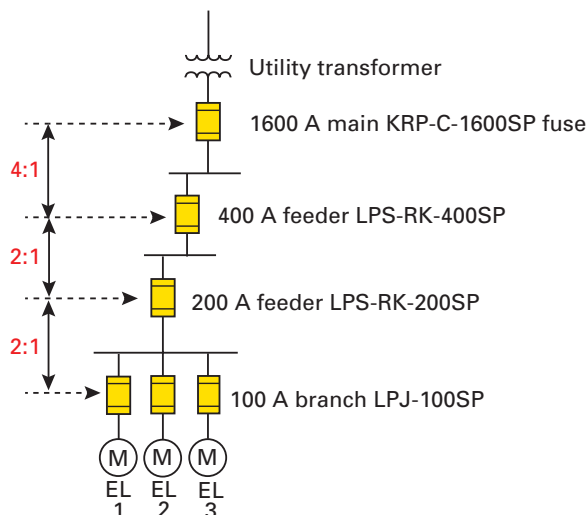


Figure 7.9.2.1.a Coordination assessment using fuses.

Using the one-line diagram of Figure 7.9.2.1.a, perform a coordination study to determine if the system complies with the 620.62 selective coordination requirements. EL-1, EL-2, and EL-3 are elevator motors.

Section 4.2 offers a more in-depth discussion on how to analyze systems to determine if selective coordination can be achieved.

In this example, LPJ-100SP fuses are used for the branch protection, LPS-RK-200SP and LPS-RK-400SP fuses for the feeder protection, and a KRP-C-1600SP fuse for the main protection.

The fuse selectivity ratio guide is all that's needed to ensure selectivity for any fault current in this system. To assure selective coordination, the Low-Peak fuses selected require only a minimum 2:1 amp rating ratio. In this example, there is a 4:1 ratio between the 1600 A main fuse and the first level 400 A feeder fuse, and a 2:1 ratio between the first level 400 A feeder fuse and the 200 A second level feeder fuse. There is a 2:1 ratio between the second level 200 A feeder fuse and the 100 A branch circuit fuse. Since a minimum of a 2:1 ratio is satisfied at all levels for this system, selective coordination is achieved and 620.62 is met.

Because the ratio tables were utilized, drawing fuse time-current curves was not necessary to assess selective coordination. The fuse time-current curves for this example are shown as Figure 7.9.2.1.b.

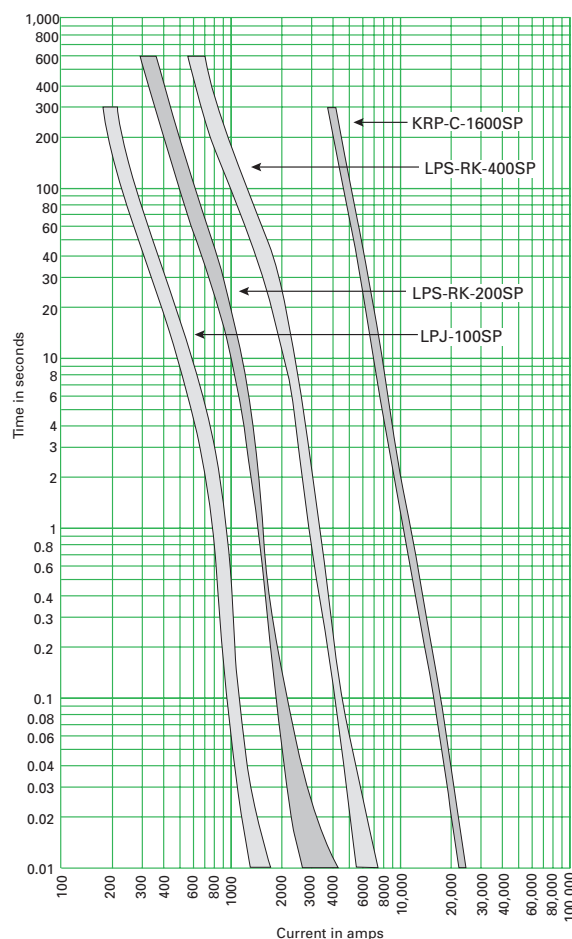


Figure 7.9.2.1.b A selectively coordinated system using fuses.



Power Module switch

The Bussmann series Power Module™ switch (PS) and Power Module Panel (PMP) come factory configured and only require electrical connection for installation



Power Module panel

Elevator control panels

Traditionally, the electrical system design engineer has given little attention to the elevator control panel. In fact, an entire elevator system for a project is most often designed and specified by the architect who has little understanding of the electrical distribution system. Because of this, there is often a communications gap between the electrical system designer, whose design typically stops at the required elevator disconnecting means, and the architect who designs the elevator system. To address this issue, new requirements have been added to the 2017 NEC that deal with the proper installation of elevator control panels.

These requirements were added to the 2017 NEC due to the concern that elevator control panels can be installed in locations where the available fault current can be high and the inspector may not be able to clearly determine the SCCR of the elevator control panel unless it is marked on the equipment. In addition, The 2017 NEC now requires the elevator control panel marked SCCR value must be adequate for the available fault current to ensure a safe installation. In order to aid enforcement, the 2017 NEC additionally requires marking the available fault current at the elevator control panel. Below is a summary of these new 2017 NEC sections:

- 620.16(A) Manufacturers must mark their elevator control panels with an equipment short-circuit current rating (SCCR). The SCCR can be based on an assembly product standard listing and labeling, or an approved analysis method, such as UL 508A, Supplement SB.
- 620.16(B) If the elevator control panel SCCR is not equal to or greater than the available fault current, the elevator control panel must not be installed.
- 620.51(D)(2) An elevator control panel must now be field marked with the maximum available fault current along with the date the calculation was made. Further, if there is a change to the available fault current, then this field marking must be revised.

Complying with these new requirements

In order to comply with these requirements a chain of events must occur.

1. The electrical system designer calculates the maximum available fault current at the elevator control panel.
2. The electrical system designer needs to communicate this information to the person responsible for specifying the elevator control panel, which is most often the architect.
3. The party responsible for procuring the elevator control panel must state the minimum acceptable SCCR or the maximum available fault current where the controller will be installed.
4. The elevator control panel manufacturer must determine the required elevator control panel SCCR as stated in the elevator control panel specification and provide an elevator control panel SCCR that is equal to or greater than the available fault current that's indicated in the design documents where there are multiple elevator control panels at different locations.

With these new NEC requirements, there is now the potential that an elevator control panel SCCR may be required that's higher than what elevator manufacturers have historically furnished. As such, elevator controller manufacturers should make the effort to rethink their designs to avoid costly system design changes. For instance, a typical elevator control panel may traditionally have SCCR ratings from 5 to 10 kA. However, it is likely that for many elevator control panels, this may not be high enough for the available fault current where they will eventually be installed. Some elevator control panel manufacturers believe this is an issue for the electrical system designer and installer to address and remedy by adding impedance to the system for lowering the available fault current. This, however, can result in a dramatic increase in cost, space availability (lack thereof), and reduced efficiency. For instance, one method to reduce the available fault current is to add an isolation transformer ahead of the elevator control panel.

Many new buildings are incorporating an elevator design that does not include an equipment room (sometimes called MRL elevators). All equipment in a MRL design is installed within the elevator shaft or exterior compartment near the elevator shaft, including the elevator control panel and the elevator disconnecting means. In these installations, it is best to design the elevator control panel so the elevator control panel SCCR is adequate for the available fault current. This is something that can be easily accomplished if the elevator control panel manufacturer uses components in combination with OCPDs that are tested and listed with high combination SCCRs. In many cases, the OCPDs that are suitable for this level of protection are current-limiting fuses rather than a traditional circuit breaker. In this case, it may be best if the elevator control panel manufacturer does not include the elevator disconnecting means (often offered as a circuit breaker) but instead have the installer provide a separate fused disconnect to comply with NEC 620.51(A) and also achieve a high SCCR for the elevator control panel when fuses are provided as specified by the elevator control panel and marked on the elevator control panel nameplate.

7.9.3 2017 NEC and SCCR marking requirements

These are to be found in NEC Chapter 6 Special Equipment, Article 620 Elevators, Dumbwaiters, Escalators, Moving Walks, Platform Lifts, and Stairway Chairlifts and pertain to:

- Part II. Conductors, 620.16 Short-Circuit Current Rating
- Part VI. Disconnecting Means and Control
 - 620.51 Disconnecting Means
 - 620.51(D)(2) Available Short-Circuit Current Field Marking

Significance of the additions

These new requirements (see Figure 7.9.c for marking examples) make it easier for inspectors to verify elevator control panels have sufficient equipment SCCR for the available short-circuit current.

- 620.16(A) - manufacturers must mark their elevator control panels with an equipment short-circuit current rating (SCCR). The SCCR can be based on an assembly product standard listing and labeling, or an approved analysis method, such as UL 508A, Supplement SB.
- 620.51(D) - An elevator control panel must now be field marked with the maximum available short-circuit current along with the date the calculation was made.
- 620.16(B) - if the SCCR of an elevator control panel is not equal to or greater than the available short-circuit current, the elevator control panel must not be installed.
- With the marked SCCR and marked available short-circuit current on the elevator control panel, an inspector can easily check for compliance.

The person responsible for the specifications or for ordering the elevator controls needs to communicate the minimum elevator control panel SCCR level that is required for a specific installation to the equipment supplier. This requires knowing the available short-circuit current. Elevator control suppliers should require customers to provide the minimum SCCR level as necessary in their specification data.

If there is a change to the available short-circuit current, then 620.51(D)(2) requires revising the field marking. Then the equipment SCCR must be verified that it is not less than this revised available short-circuit current.

Changes to the electrical distribution system can increase the available short-circuit current when a larger kVA or lower percent impedance transformer is installed, or premise wiring changes.



Nidec MCE		Sample Label
Model: SCE-AC-0X	Date: 08/25/2016	Serial #: 8001424
Job #: XXXXXXXXXX		
Input: XXXV rms, 3Ø, 50/60Hz, XXXA rms		
Output: Motor: XXX hp, XXX Vac, X phase, XX.X Hz, XXXXX FLA		
Brake: XXXXVdc XXX Amps DC		
Suitable for use on a circuit capable of delivering not more than 10,000 rms Symmetrical Amperes, 600 Volts		
CONVIENT À CIRCUIT POUVANT DÉBITER UN COURANT DE DÉFAUT MAXIMAL EST DE 10,000 AMPÈRES EFFICACES SYMÉTRIQUES SOUS UNE TENSION MAXIMALE DE 600 V.		
		
46-03-0129 R1 Motion Control Engineering A Nidec Kinetek Company www.nidec-MCE.com MADE IN USA		

EAT•N BUSSMANN SERIES		FC ² available fault current calculator
Project Name:	Office Building A	
Fault Name:	Elevator Tower B	
System:	Three-Phase	
Avail. Fault Current L-L (Amps):	9,055	
Voltage L-L (Volts):	480	
Calculation Performed On:	Sep 2, 2016 @ 10:20am	
Calculation performed via Eaton's Bussmann Series Available Fault Current Calculator v1.5		

Figure 7.9.c Elevator control panel has a manufacturer's nameplate SCCR of 10 kA and is field marked with available short-circuit current 9055 A. Photo courtesy of MCE.

What to look for:

- The elevator control panel's manufacturer nameplate is marked with its SCCR.
- The control panel is field marked with the available short-circuit current and documentation supporting the calculation is available.
- If the control panel's SCCR is equal to or greater than the marked available short-circuit current.



7.10 Generator protection

If a short-circuit is applied directly to a synchronous generator's output terminals, it will initially produce an extremely high current, then gradually decay to a steady-state value. This change is represented by a varying reactive impedance. Three specific reactances are used for short-circuit fault currents:

- Subtransient reactance X_d'' , which is used to determine the fault current during the first 1 to 5 cycles
- Transient reactance X_d' , which is used to determine the fault current during the next 5 to 200 cycles
- Synchronous reactance X_d , which is used to determine the steady-state fault current

The subtransient reactance X_d'' will range from a minimum of approximately 9% for a two-pole, wound-rotor machine to approximately 32% for a low-speed, salient-pole, hydro-generator. The initial symmetrical fault current can be as much as 12 times full load current.

Generator short-circuit current is determined using this equation:

$$I_{sc} = \text{Voltage} \div X_d'$$

NEC 445.11 requires that a generator be provided with a nameplate with the following information:

- Manufacturer's name
- Rated frequency
- Number of phases if AC
- Rating in kilowatts or kilovolt-amperes
- Power factor
- Normal volts and amps corresponding to the rating
- Rated ambient temperature
- Rated temperature rise

Nameplates or manufacturer's instructions must provide the following information for all stationary generators and portable generators rated more than 15 kW:

1. Subtransient, transient, synchronous, and zero sequence reactances
2. Power rating category
3. Insulation system class
4. Indication if the generator is protected against overload by inherent design, an overcurrent protective relay, circuit breaker, or fuse
5. Maximum short-circuit current for inverter-based generators, in lieu of the synchronous, subtransient and transient reactances

Depending on the generator type, the zero sequence impedance may be less than the subtransient reactance, and the ground fault current substantially higher than the three-phase short-circuit current. For example, a 2500 kVA, 480/277 V, four-pole, 2/3 pitch standby generator has: a 0.1411 per unit subtransient reactance X_d'' and a 0.033 per unit zero sequence X_0 reactance. The ground fault current is approximately a third larger than the three-phase fault current. The ground fault current can be reduced to the three-phase level by simply adding a small reactance between the generator's neutral and ground while still being considered solidly grounded.

The electric power system analysis must be performed based on the worst case operating conditions. Typically this is when all sources are paralleled.

If the system can operate with both the utility and generator supply in parallel, then the equipment must be rated for the combined fault current plus motor contribution. If the generator and utility will not be paralleled, then both cases will need to be looked at independently and the worst case used for selecting the equipment ratings.

Generator protection will vary and depend on the size of the generator, system type and the generator's importance. Generator sizes are defined as: small, 1000 kVA maximum up to 600 V (500 kVA maximum when above 600 V); medium over 1000 kVA to 12,500 kVA maximum regardless of voltage; large, from 12,500-50,000 kVA. The simplest is a single generator system used to feed emergency and/or standby loads. In this case, the generator is the only source available when it's operating and it must keep operating until the normal source is restored.

7.11 Ground fault protection of equipment

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7.11.1 Overview

This section covers the NEC requirements for ground fault protection of equipment (GFPE), how to comply with fusible equipment, options to design systems without GFPE and selective coordination considerations for circuits with GFPE.

The NEC defines Ground Fault Protection of Equipment (GFPE) as "a system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device."

The pertinent NEC requirements for ground fault protection of equipment (GFPE) are located in 230.95, 210.17, 215.10, 240.13, 517.17, 695.6(G), 700.31, 701.26, and 708.52. A few key requirements are:

- GFPE is required on 1000 A or greater service disconnects for 480/277 V, solidly grounded Wye systems
- If a GFPE is located on the service or feeder of a healthcare or COPS facility, then GFPE must be on the next level of feeders, per 517.17(B) and 708.52(B) respectively
- GFPE is not required for the alternate source of emergency systems (700.31) and legally required standby systems per 701.26
- GFPE is not allowed on the circuit paths for fire pumps per 695.6(G)
- For healthcare essential electrical systems, additional levels of GFPEs cannot be located on the loadside of certain transfer switches, per 517.17(B)

GFPE is only required in a few, certain applications. If the use of GFPE is not desired, in some cases, there may be design options in which GFPE is not required, such as impedance grounded systems.

7.11.2 Ground-fault protection of equipment (GFPE)

A ground fault protection relay in conjunction with a sensor are used with a fusible switch to provide the addition of GFPE. The switch needs to be listed as suitable with the GFPR. When the ground fault current magnitude and time reach the GFPR's pick-up setting (amp and time-delay setting), the control scheme signals the circuit disconnect to open. GFPRs only monitor and respond to ground fault currents.

Fuses and circuit breakers respond to any overcurrent condition type: overloads and short-circuit currents, including ground faults. Per the NEC, for most premise circuits, the service, feeder, and branch circuit OCPDs (fuses or circuit breakers) provide protection for all overcurrent types, including ground faults. However, for some very high amp circuits, the NEC requires the addition of GFPE, which is intended to provide equipment protection from lower magnitude ground fault currents.

GFPE typically provides only equipment protection from low magnitude ground faults. GFPE and disconnecting means typically are too slow for higher magnitude ground faults. Equipment protection against higher magnitude ground faults depends on the conventional OCPD response speed (fuses or circuit breakers).

Providing ground fault protection of equipment with a GFPR requires a sensor, monitor, shunt trip and circuit disconnecting means. A fusible switch with shunt trip capability can be equipped with GFPR. Figure 7.11.2.a shows a bolted pressure switch with GFPR.

Circuit breakers with shunt trip capability also can be equipped in a similar manner. Some electronic trip circuit breakers have the GFPE option built into the electronic trip unit.

GFPE limitations

People protection. These devices are not intended to protect people from electric shock hazards. Ground fault circuit interrupters (GFCIs) perform this function and are required for certain branch circuits, and are intended to protect people from line-to-ground shock hazards.

Ground fault prevention. GFPE and OCPDs can minimize the damage to equipment caused by ground faults, but they do not protect against a ground fault event. There are other methods recommended to prevent the ground fault, such as insulated bus or barriers.

Other than zero sequence currents. The GFPE cannot provide protection from faults of any magnitude that stay within the intended current path such as 3-phase, phase-phase, or phase-neutral faults. Detecting these faults is typically left to the fuse or circuit breaker.

Non-Current limitation. A GFPE in itself will not limit the line-to-ground or phase-to-phase short-circuit current. Therefore, it's recommended that current-limiting OCPDs be used in conjunction with a GFPE. Using current-limiting fuses offers:

- Some degree of arcing and low magnitude ground fault protection by the GFPR operating the switch
- Limiting current for high magnitude ground faults and short-circuits with current-limiting fuses provides component protection for the switchgear

GFPE characteristics and settings

GFPEs typically have adjustable trip settings and various shaped time-current characteristic curves. Manufacturers typically ship GFPEs with these set to the minimum which leads to many nuisance trips. To ensure best possible circuit coordination, these should be field adjusted to the desired setting.

The trip setting generally consists of an amp setpoint and a time setpoint, both selected from a range. Understanding a GFPE's characteristics is important in assessing the equipment's protection and coordination levels. Too often a GFPE on a service is adjusted to a low amp and instantaneous trip setting. With this setting, a ground fault on a 20 A branch circuit may cause a GFPE to unnecessarily open the service disconnect. If the GFPE is set properly, a fault on a 20 A branch circuit would be interrupted by the 20 A fuse or circuit breaker.

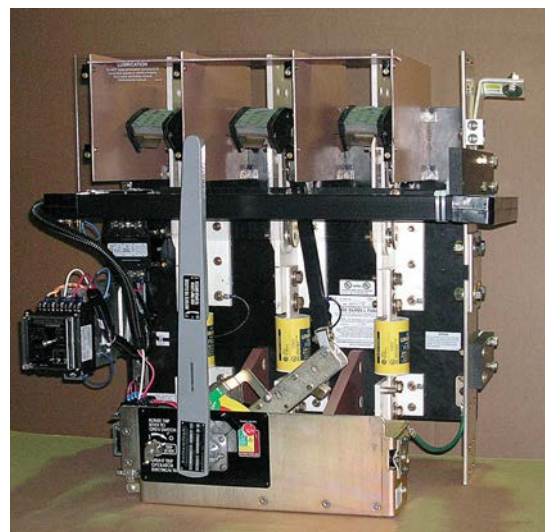


Figure 7.11.2.a Fusible bolted pressure switch equipped with ground fault protection relay and sensor. Courtesy of Boltswitch, Inc.

NEC 230.95 has a maximum 1200 A current limit for GFPE characteristics and an operational limit of 1 second at 3000 A. GFPEs are available with various time-current shaped characteristics; some with a step function and others with an inverse time function as shown in Figure 7.11.4.c. A GFPE's time-current characteristic curve shape, various amp and time-delay setpoints permit selecting time-current characteristics that provide the needed equipment protection level along with the desired coordination level.

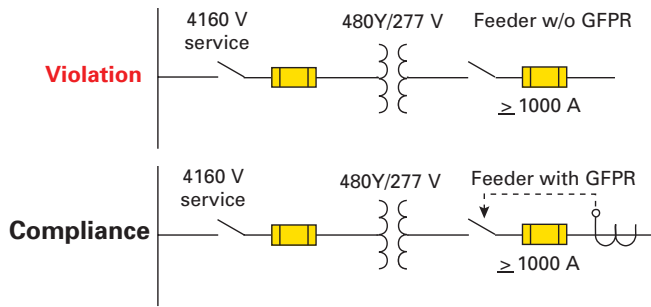
7.11.3 NEC requirements

The pertinent NEC sections with requirements for ground fault protection of equipment (GFPE) include:

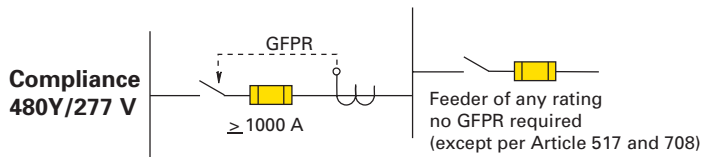
230.95. Ground-fault protection of equipment must be provided for solidly grounded Wye electric services of more than 150 volts to ground but not exceeding 1000 volts phase-to-phase for each service disconnect rated 1000 amperes or more.

480Y/277 V, solidly grounded Wye only connected service disconnects, 1000 A and larger must have GFPE in addition to conventional overcurrent protection. However, a GFPE is not required on a service disconnect for a continuous process where its opening will increase hazards (240.13). All Delta connected or impedance grounded services are not required to have GFPE. The maximum setting for the GFPE can be set to pick up ground faults at a 1200 A maximum and actuate the main switch or circuit breaker to disconnect all phase conductors. A GFPE with a deliberate time-delay characteristic up to 1 second, may be specified for currents greater than or equal to 3000 A. (The use of such a GFPE greatly enhances system coordination and minimizes power outages - see Figure 7.11.4.c).

215.10. "Each feeder disconnect rated 1000 A or more and installed on solidly grounded wye electrical systems of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase, shall be provided with ground-fault protection of equipment in accordance with the provisions of 230.95." There are two exceptions. Exception No. 2: GFPE is not required on feeder equipment when GFPE is provided on the feeder's supply side and on the transformer's loadside supplying the feeder (except for certain healthcare and COPS facilities, Article 517 and 708). Note: 210.13 and 215.10 are only valid if there isn't any upstream GFPE.



215.10. Exception No. 2



210.13. “Each branch-circuit disconnect rated 1000 A or more and installed on solidly grounded wye electrical systems of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase, shall be provided with equipment ground-fault protection in accordance with the provisions of 230.95.” There are two exceptions which are the same as those for 215.10.

Additional required levels

517.17(B). If GFPE is provided on the service or feeder as specified in 230.95 or 215.10 of a healthcare facility, GFPE must be provided in all next level feeder disconnecting means downstream toward the load. This is done so that selective coordination can minimize the outage should a ground fault occur downstream. Merely providing coordinated GFPE does not prevent a main service blackout caused by feeder or branch circuit ground faults. The phase OCPDs must also be selectively coordinated. Selective coordination by definition requires that the phase OCPDs working in conjunction with the GFPE be selectively coordinated for all values of current, including medium and high magnitude ground fault currents. This is because the conventional phase OCPDs may operate at these higher levels.

708.52(B). If GFPE is provided on the service or feeder as specified in 230.95 or 215.10 of a COPS, GFPE must be provided in all next level feeder disconnecting means downstream toward the load. For COPS, the separation between GFPE time bands for any feeder and main GFPE must be at least six cycles in order to achieve coordination between these two GFPEs. If the requirements of 230.95, 240.13, or 215.10 do not require a GFPE, and no GFPE is utilized on the main service disconnect or feeder disconnect, then no GFPE is required on the next level downstream. See Figure 7.11.2.a.

Load/application specific requirements

426.28. Ground-fault protection of equipment must be provided for fixed outdoor electric deicing and snow-melting equipment.

427.22. GFPE for electric heat tracing and heating panels.

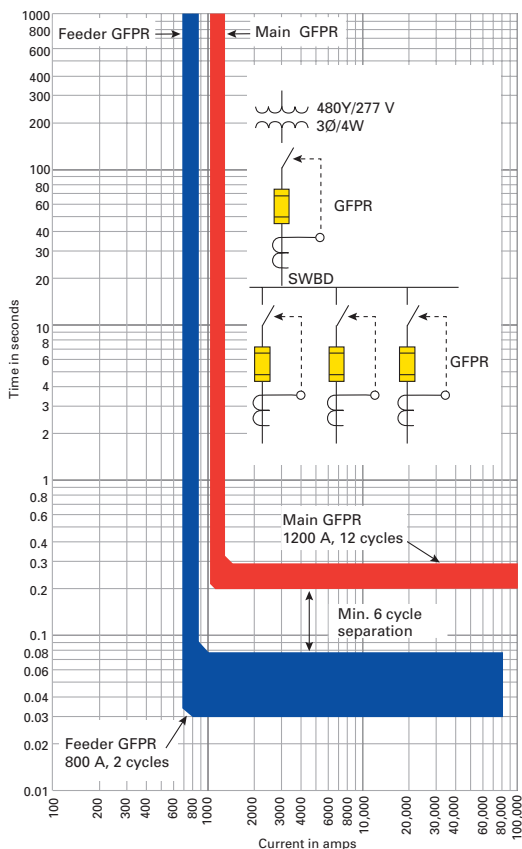
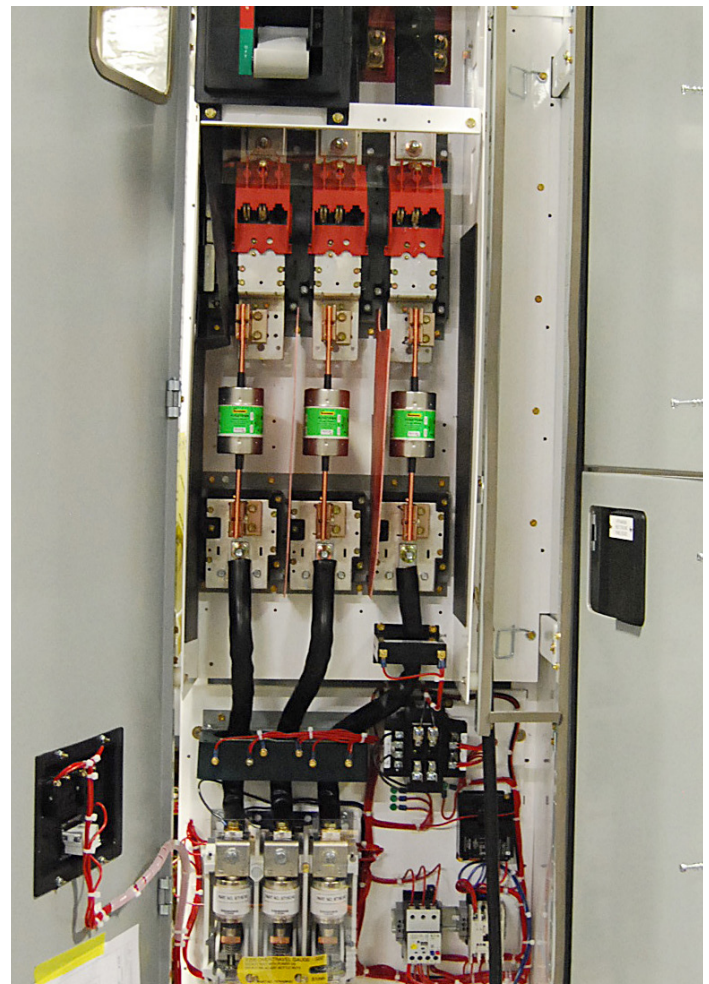


Figure 7.11.2.a Main and feeder GFPR curves

240.13. Ground-fault protection of equipment must be provided in accordance with the provisions of 230.95 for solidly grounded Wye electrical systems of more than 150 volts to ground but not exceeding 1000 volts phase-to-phase for each individual device used as a building or structure main disconnecting means rated 1000 amperes or more.



Eaton fusible vacuum starter in a motor control center protected by Bussmann series dual-element, time-delay, current-limiting Fusetron FRN-R fuses.

Where GFPE is not required

There are many branch, feeder and services, and others that do not require or permit GFPE. The general rules for where GFPE is not required are determined based on the boundaries of the NEC requirements including:

- Service, feeder or branch disconnects less than 1000 A
- 208Y/120 V, 3 Ø, services or feeders do not require GFPE
- Single-phase services or feeders including 240/120 V
- Resistance or impedance grounded systems, such as 480 V, high resistance grounded Wye systems.
- High or medium voltage services or feeders; greater than 1000 V. (See NEC 240.13 and 215.10 for feeder requirements.)
- Services or feeders on Delta systems (grounded or ungrounded) such as 480 V, 3 Ø, 3 W Delta, or 240 V, 3 Ø, 4 W Delta with midpoint tap
- Services with six or less disconnects (Section 230.71) where each disconnect is less than 1000 A. A 4000 A service could be split into five 800 A switches

230.95. This section's GFPE provisions must not apply to a service disconnect for a continuous industrial process where a non-orderly shutdown will introduce additional or increased hazards.

240.13. The provisions of 240.13 must not apply to the disconnecting means for:

- Continuous industrial processes where a non-orderly shutdown will introduce additional or increased hazards
- Installations where GFPE is provided by other requirements for services or feeders
- Fire pumps

517.17(B). For healthcare essential electrical systems, additional levels of GFPEs can't be on the Loadside of certain transfer switches

695.6(G). Ground-fault protection of equipment must not be installed in any fire pump power circuit

700.31. Ground-Fault Protection of Equipment. The alternate source for emergency systems must not be required to provide ground-fault protection of equipment with automatic disconnecting means. Ground-fault indication at the emergency source must be provided in accordance with 700.6(D) if ground-fault protection of equipment with automatic disconnecting means is not provided.

701.26. The alternate source for legally required standby systems must not be required to provide ground-fault protection of equipment with automatic disconnecting means. Ground-fault indication at the legally required standby source must be provided in accordance with 701.6(D) if ground-fault protection of equipment with automatic disconnecting means is not provided.

708.52. Critical operations (including multiple occupancy buildings) with critical operation areas. Where GFPE is provided for operation of the service disconnecting means or feeder disconnecting means as specified by 230.95 or 215.10, an additional step of ground-fault protection must be provided in all next-level feeder disconnecting means downstream toward the load. Such protection must consist of overcurrent devices and current transformers or other equivalent protective equipment that causes the feeder disconnecting means to open. When GFPE is first installed, each level must be tested to ensure that GFPE is operational. GFPE for operation of the service and feeder disconnecting means must be fully selective such that the feeder device, but not the service device, must open on ground faults on the loadside of the feeder device. Separation of GFPE time-current characteristics must conform to the manufacturer's recommendations and must consider all required tolerances and disconnect operating time to achieve 100 percent selectivity.

7.11.4 Selective coordination

GFPEs should be included in a selective coordination analysis. If a particular GFPE use causes a lack of selective coordination, there may be other GFPE options available, or there may be alternate design options.

The following content on ground fault protection provides more information on the requirements and considerations for applying GFPEs.

Analysis of GFPE curves and overcurrent device curves

To a fuse or circuit breaker, ground fault current is sensed just as any other current. If the ground fault current is high enough, the fuse or circuit breaker responds before the GFPE (depending on the GFPE setting, OCPD characteristics and response speed and ground fault current magnitude). Therefore, when analyzing ground fault protection, it's necessary to study the GFPE and OCPD characteristics as a combination.

The GFPE and OCPD combination has a ground fault "effective curve." This is a composite of the GFPE and OCPD curves. When analyzing line-to-ground faults, the "effective" GFPE and OCPD curve must be examined (see Figure 7.11.b).

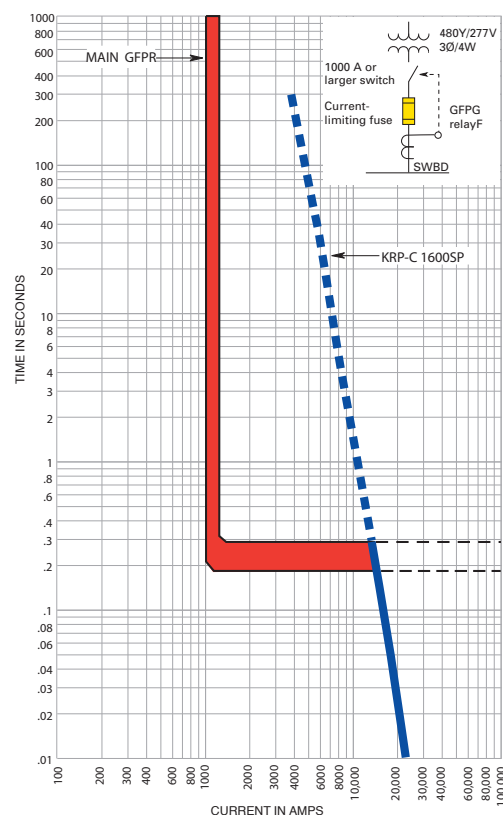


Figure 7.11.4.a "Effective" time-current curve for line-to-ground fault with a 1600 A fuse and GFPE set at 1200 A.

Figure 7.11.4.a is the "effective" ground fault curve for a 1600 A fuse in combination with a GFPE set at 1200 A pickup and 12-cycle delay.

Figure 7.11.4.b is the "effective" ground fault curve for a 1600 A circuit breaker in combination with a GFPE set at 1200 A and 12-cycle delay.

Notice in Figures 7.11.4.a and 7.11.4.b that for ground fault current less than approximately 14,000 A, the GFPE sensor responds and signals the bolted pressure switch (Figure 7.11.4.a) or circuit breaker (Figure 7.11.4.b) to open. For ground fault current greater than approximately 14,000 A in Figure 7.11.4.a the fuses will respond faster than the GFPE, and in Figure 7.11.4.b the circuit breaker phase overcurrent sensors will respond faster than the GFPE. In Figure 7.11.4.a, the fuses become current-limiting above approximately 22,000 A regardless of whether the fault is a ground fault or other fault type.

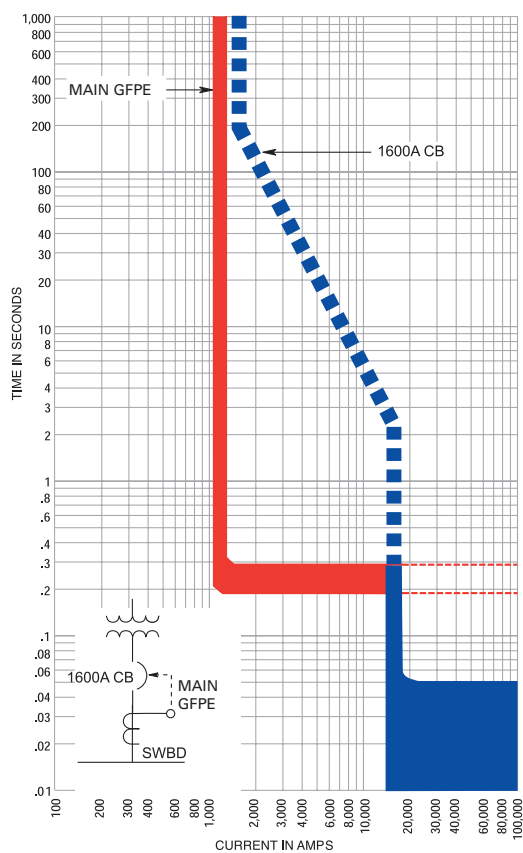


Figure 7.11.4.b “Effective” time-current curve for line-to-ground fault with 1600 A circuit breaker and GFPE set at 1200 A.

7.11.5 GFPE considerations

When GFPE is used in a system, selective coordination should include an analyzing the ground fault circuit paths.

As previously mentioned, GFPE only monitors and responds to ground fault currents. Branch circuit fuses and circuit breakers sense and respond to all overcurrent types. Therefore, when analyzing a circuit path for selective coordination, GFPEs should be included. For circuit paths with GFPEs, there are two components in a coordination analysis:

1. Analyze only the circuit paths, considering the fuses or circuit breakers for all overcurrent types. Previous sections in this publication cover this in depth.
2. Analyze the circuit paths for just ground faults. In this case, the GFPE characteristics and the fuse or circuit breaker characteristics must be considered together. Remember, fuses and circuit breakers monitor and respond to any overcurrent type, so they should also be factored in. The following are some important considerations for this analysis.

One step GFPE

When a ground fault occurs on a feeder or branch circuit, it's highly desirable for the feeder or branch circuit OCPD to open and clear that fault before the main device opens, thus preventing an unnecessary system blackout. However, this is not always the case when GFPE is located on the main or when the OCPDs are not selectively coordinated.

To avoid unnecessary service disruptions or blackouts:

1. The main OCPD characteristics must be analyzed with relation to the feeder and branch circuit OCPDs.
2. The feeder and/or branch circuit OCPDs' characteristics must be analyzed with relation to the main GFPE characteristics, and with the next lower GFPE level, if provided.

Selective coordination should be investigated for low and high magnitude ground faults. Generally on low magnitude ground faults, the feeder OCPD must be selective with the main GFPE. For high magnitude ground faults, it's necessary also to consider selective coordination between the main phase OCPD and downstream phase OCPDs.

Two step GFPE

Two step ground fault relaying includes ground fault relays on the main service and feeders.

In many instances, this procedure can provide a higher degree of ground fault coordination to prevent unnecessary service blackouts. Yet it's mistakenly believed by many that two step GFPE ensures total ground fault coordination.

For complete selective coordination of all ground faults, the conventional phase OCPDs must be selectively coordinated, as well as the GFPE. The fact is that even with this two-step GFPE provision, ground fault coordination is not assured on many systems where the main fuses or circuit breakers are not selectively coordinated with the feeder fuses or circuit breakers. The analysis must also include the phase OCPDs since they also respond to all fault current types, including ground faults.

In many cases, two step relays do provide a higher degree of ground fault coordination. When properly selected, the main fuse can be selectively coordinated with the feeder fuses. Thus, on all feeder ground faults or short-circuits, the feeder fuse will always open before the main fuse.

When selectively coordinated main and feeder GFPEs are combined with selectively coordinated main and feeder GFPE, ground fault coordination between the main and feeder is predictable.

Figures 7.11.5.a and 7.11.5.b illustrate a selectively coordinated main and feeder for all ground fault, overload and short-circuits levels. Any fault on the feeder will not disrupt the main service.

This system offers full selective coordination for all ground fault or short-circuit levels.

1. The feeder GFPE is set at a lower time band than the main GFPE, therefore they are coordinated.
2. The feeder fuses are selectively coordinated with the main fuses for all ground faults, short-circuits or overloads on the feeder's loadside. The feeder fuses would open and clear the fault before the main fuses open.

If downstream circuits must be selectively coordinated with the feeder GFPE and OCPDs, the analysis needs to include the downstream OCPDs.

For healthcare facilities (517.17) and Critical Operations Power Systems (708.52), the main and feeders are required to be 100% selectively coordinated for all ground fault current magnitudes, including low, medium and high ground fault currents. The system shown in Figures 7.11.5.a and 7.11.5.b comply with 517.17 and 708.52.

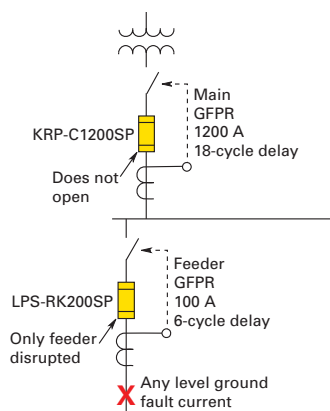


Figure 7.11.5.a Mains and feeders selectively coordinated for all ground faults.

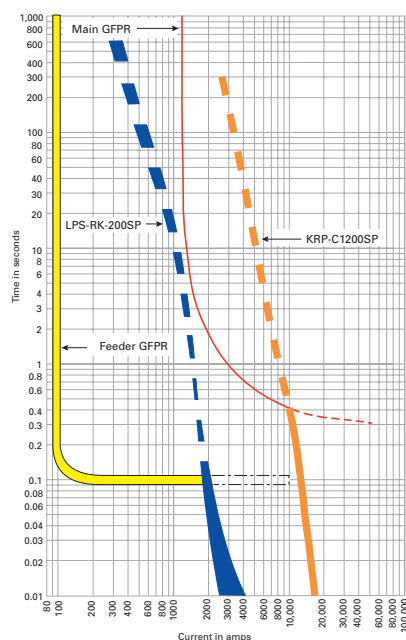


Figure 7.11.5.b Time-current curve comparisons for a selective coordinated fused system with GFPR.

Low magnitude ground faults on feeders — one step GFPE

For low magnitude feeder ground faults, the feeder OCPD can open and clear the circuit without disrupting the main service if the feeder OCPD curve lies to the left of the GFPE curve and they do not cross each other at any point.

In Figures 7.11.5.c and 7.11.5.d, the GFPE located on the main has an 18-cycle operating time-delay and 1200 A pickup. Its inverse-time characteristic with the maximum 1 second opening time at 3000 A improves selective coordination with downstream devices.

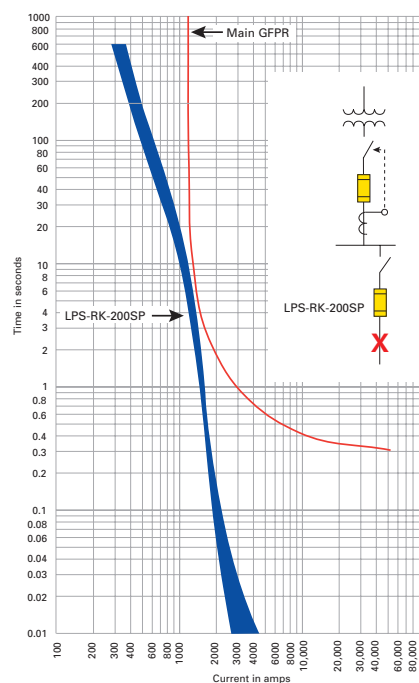


Figure 7.11.5.c Selective coordination considerations for low magnitude feeder ground faults. Longer GFPR delay permits larger feeder fuse to coordinate with main relay.

Figure 7.11.5.c illustrates that an inverse-time main ground fault relay may permit a larger size feeder fuse to selectively coordinate with the ground fault relay. In this case, the inverse time ground fault relay is set at 1200 A and an 18-cycle delay. A 200 amp LPS-RK-200SP feeder fuse coordinates with this main ground fault relay. A 400 A JKS-400 non-time delay fast-acting feeder fuse coordinates with this same main GFPR (figure not included).

High magnitude ground faults on feeders — one step GFPE

For higher magnitude ground faults, it's generally necessary to consider the main OCPD characteristics as well as the GFPE. Conventional phase OCPDs (fuses or circuit breakers) operate the same way for high magnitude ground faults or high magnitude phase-to-phase short-circuits. Therefore, when a high magnitude feeder ground fault occurs, the main OCPD must be considered in relation to the feeder OCPD. To achieve selective coordination and prevent a blackout for high magnitude ground faults, the feeder OCPD must be selective with the main OCPD.

Selective coordination considerations for high magnitude feeder ground faults involve analyzing the main and feeder OCPDs. In this case, the fuses are selectively coordinated so that an unnecessary blackout does not occur.

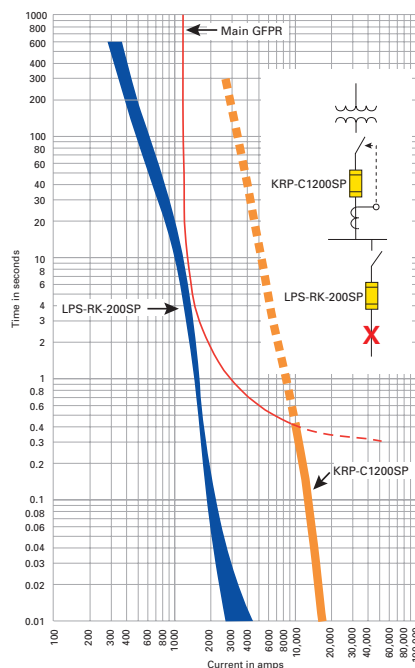


Figure 7.11.5.d Selective coordination considerations for high magnitude feeder ground faults involves analysis of main and feeder OCPDs. In this case the fuses are selectively coordinated so that an unnecessary blackout does not occur.

Figure 7.11.5.d illustrates that the 200 amp feeder LPS-RK-200SP fuse selectively coordinates with the inverse-time main GFPR for all ground fault levels. Also, for any overcurrent type, including low level and high level ground faults, the LPS-RK-200SP fuse selectively coordinates with the 1200 amp main KRP-C-1200SP fuses. Figure 7.11.5.a fuse time-current curves show coordination for the curve portions shown (up to approximately 17,000 A). For currents greater than 17,000 A, using the Selectivity Ratio Guide presented in the section on selection coordination shows that LPS-RK-200SP fuses selectively coordinate with KRP-C-1200SP fuses up to 200 kA for any overcurrent type, including ground fault currents.

7.11.6 Design options

GFPEs are only required in certain applications. If using GFPEs causes selective coordination issues, or isn't desired, there are design options to resolve the issues, including:

- Use inverse-time ground fault relays and set the amp and time delay setpoints as high as practical.
- Utilize a 480 V high resistance grounded Wye system. This system type does not require GFPEs. This system also reduces the probability of a hazardous arcing-fault starting from line-to-ground faults and enhances worker safety. Loads requiring neutrals must be fed from downstream transformers, which can be 208Y/120 V solidly grounded Wye systems or 480Y/277 V solidly grounded Wye systems with 800 A or less secondary feeder disconnects.
- Design 480Y/277 V solidly grounded Wye services using up to six 800 A or less disconnects (230.71).
- For circuits supplying loads having alternate sources, place the automatic transfer switches close to the loads. Use smaller transfer switches placed closer to the final panelboard or large branch circuit loads. This option requires more transfer switches and longer cable runs. However, it enhances power to vital load reliability.
- Some municipalities enforce selective coordination only between the OCPD's rated current setting and not through the GFPE ground fault current and time settings. Consult your AHJ for local requirements.



7.12 Industrial control panels

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7.12.1 Overview

NEC Article 409 covers the installation requirements for industrial control panels. As indicated in the Informational Note in 409.1, UL 508A is the product safety standard for industrial control panels.

The NEC defines an industrial control panel in Article 100 as an assembly of two or more components consisting of one of the following:

- Power circuit components only
- Control circuit components only
- Combination of power and control circuit components

The components, and associated wiring and terminals are mounted on a subpanel or contained in an enclosure. Generally, industrial control panels do not include the controlled equipment.

Power circuit components, such as motor controllers, overload relays, fused disconnect switches, and circuit breakers carry main power to loads such as motors, lighting, heating, appliances and general use receptacles. Control circuits, as defined in Article 100, carry the electric signals directing the performance of the controller, but do not carry the main power current. Common control circuit components include push buttons, pilot lights, selector switches, timers, switches, and control relays.

Per NEC 409.21, overcurrent protection is required to be provided ahead of the industrial control panel or by a single main OCPD within the panel. The rating of the OCPD supplying the industrial control panel is required to not be greater than the sum of the largest rating or setting of the branch-circuit short-circuit and ground-fault protective device provided with the industrial control panel, plus 125 percent of the full-load current rating of all resistance heating loads, plus the sum of the full-load currents of all other motors and apparatus that could be in operation at the same time. 409.110 requires the industrial control panel to be marked with:

- Manufacturer name
- Voltage, number of phases, frequency and full-load current for each supply circuit
- Short-circuit current rating (SCCR)

The SCCR is based on assembly listing and labeling or an approved method such as UL 508A, Supplement SB. If the panel only contains control circuit components (i.e., no power circuit components), an SCCR marking is not required.

NEC 409.22 prohibits installing industrial control panels where the available fault current exceeds the SCCR as marked in accordance with 409.110. Additionally, where an industrial control panel is marked with an SCCR, the available fault current at the industrial control panel's install location and the date the fault current calculation was performed is required to be documented and made available to those authorized to inspect the installation. Typically, where the available fault current exceeds 5000 A, the designer and installer need to advise the industrial control panel manufacturer of the available fault current so industrial control panels with adequate SCCR can be designed/manufactured. This may require the use of current-limiting fuses to achieve an SCCR adequate for the installation.

See the Industrial Control Panel - SCCR section in this publication.

Although a main disconnect is not required to be installed in the industrial control panel's feeder or branch circuits per NEC 409.30, if disconnecting means are used to supply motors, they must comply with Part IX of Article 430.

7.12.1 Assembly SCCR

Prior to the 2011 NEC there was no definition of SCCR (sometimes referred to as "withstand rating"), although it was referenced in several sections on the marking and proper application of various types of equipment. Because the term is referenced in multiple locations of the Code, it was necessary to add a definition to Article 100 of the NEC.

Article 100 definition

"Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria."

What's an SCCR?

SCCR is the maximum short-circuit (fault) current a component or assembly can safely withstand when protected by a specific overcurrent protective device(s) or for a specified time. Adequate equipment SCCR is required per NEC 110.10.



Figure 7.12.2.a

AWG range	Max. Class J fuse amps	Resulting SCCR (kA)
2-6	400	200
2-14	200	50
2-14	175	100

This finger-safe power distribution block, protected with Class J fuses, is rated for use on a circuit capable of delivering no more than the SCCR shown (kA RMS Sym. or DC amps 600 V maximum).

Figure 7.12.a is a power distribution block (PDB) that has a default SCCR of 10 kA per UL 508A Table SB4.1. However, this PDB has been combination tested and UL Listed with higher SCCR when in combination with specific types and maximum amp rating current-limiting fuses. The label is marked with a 200 kA SCCR when protected by 400 A or less Class J fuses and the conductors on the lineside and loadside are in the range of 2 to 6 AWG.

"Short-circuit current rating" is not the same as "interrupting rating" and the two must not be confused. Interrupting rating is the highest current at rated voltage that a device is identified to interrupt under standard test conditions; it does not ensure protection of the circuit components or equipment. Adequate interrupting rating is required per NEC 110.9. The fuse in Figure 7.12.2.b has a UL Listed interrupting rating of 300 kA @ 600 Vac or less.

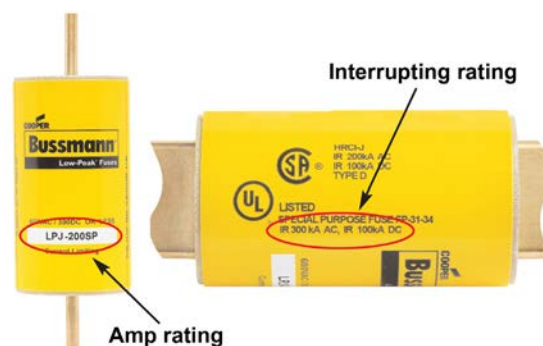


Figure 7.12.2.b Fuse with 300 kA IR at 600 Vac.

When analyzing assemblies for SCCR, the interrupting rating of overcurrent protective devices and the SCCR of all other components affect the overall equipment/assembly SCCR. For instance, the SCCR for an industrial control panel typically cannot be greater than the lowest interrupting rating of any fuse or circuit breaker, or the lowest SCCR of all other components in the enclosure.

The importance of SCCR

SCCRs establish the level of fault current that a component or piece of equipment can safely withstand (based on a shock or fire hazard external to the enclosure). Without knowing the available fault current and SCCR, it is impossible to determine if components or equipment can be safely installed.

Specification and installation of new equipment with higher SCCRs, such as 200,000 amps, makes it easy to meet the requirements of the NEC. In addition, when equipment is later moved within a facility or from plant to plant, equipment with the highest ratings can be moved without worrying about unsafe situations that might arise from placing the equipment in a new location where the available fault current is higher than the old location and now above the rating of the equipment.

Complying with the code

To assure proper application, the designer, installer and inspector must ensure that the marked SCCR of a component or equipment is greater than the calculated available fault current.

In order to ensure compliance, it's necessary to:

1. Determine the available fault current at the point of installation of the component or equipment.
2. Ensure the component or equipment marked SCCR is equal to or greater than the available fault current.

Figure 7.12.c illustrates SCCR compliance from a system perspective. Any installation where the equipment marked SCCR is less than the available fault current is a lack of compliance, a safety hazard, and violates NEC 110.10. In these cases, the equipment cannot be installed until the component or equipment SCCR is sufficient or the fault current is reduced to an acceptable level..

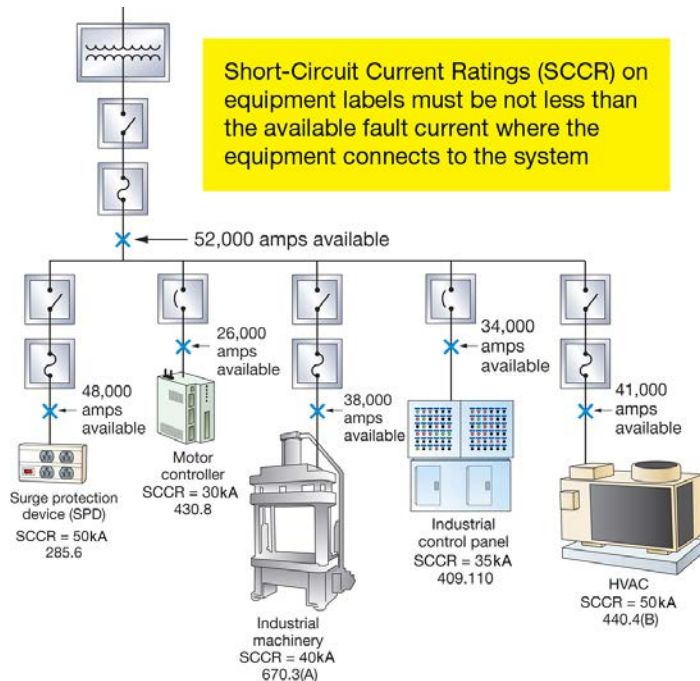


Figure 7.12.c Courtesy NJATC.

Using current-limiting fuses and assembly SCCR

Current-limiting fuses are an effective means used by equipment manufacturers to increase the equipment SCCR per methods in accordance with product standards such as UL 508A. Therefore, it may not be appropriate to utilize the let-through current of externally field installed fuses to reduce the available fault current level below an equipment inadequate SCCR. Use of manufacturer specific published let-through current of externally mounted fuses is not in compliance with these methods. UL 508A Supplement SB uses UL 248 documented peak let-through limits that apply for all manufacturers fuses and not the RMS let-through of a specific manufacturer.

When marked properly per UL procedures, peak let-through limits of externally mounted fuses may be used to increase branch components SCCR but they cannot increase the overcurrent protective device interrupting rating or combination motor controller SCCR found inside the panel.

If the equipment has an SCCR less than the available fault current, and does not contain overcurrent protective devices with inadequate interrupting ratings or combination motor controllers with inadequate SCCRs, the authority having jurisdiction (AHJ) may allow the use of fuse manufacturer published let-through RMS data. For installations where the fault current exceeds the marked equipment SCCR and interrupting rating of overcurrent devices or SCCR of combination motor controller in the equipment, other methods should be explored such as adding impedance to reduce the fault current or redesigning and evaluating the existing equipment SCCR based on field inspection by a nationally recognized testing laboratory (NRTL).

Independent of connected downstream equipment, upstream current-limiting fuses will reduce the available fault current per manufacturer's publish data and provide many benefits including:

- Potentially reducing arc flash hazards at downstream equipment
- Simple selective coordination with upstream current-limiting fuses in feeders or mains using published amp rating ratios
- Superior short-circuit protection for any Loadside-connected conductors and busway
- Maintain protection level by reducing maintenance beyond periodically checking conductors and terminations

Determining assembly SCCR: "Two Sweep" method and procedures

How to determine assembly SCCR

For components, the Short-Circuit Current Rating (SCCR) is typically determined by product testing. For assemblies, the SCCR can be determined through the equipment product listing standard or by an approved method. UL 508A is the standard for Safety for Industrial Control Panels. UL 508A, Supplement SB, provides an analytical method to determine the SCCR of an industrial control panel. This method is based upon the "weakest link" approach. In other words, the assembly marked SCCR is limited to the lowest rated component SCCR or the lowest rated overcurrent protective device interrupting rating. Since testing is not required with this method, it is typically the preferred method to use in determining the assembly SCCR and approved by the NEC.

There are two basic concepts that must be understood and identified before analyzing the assembly SCCR per UL 508A, Supplement SB. The first is power circuit versus control circuit. The second is branch circuit versus feeder circuit. The differences and importance of these concepts are detailed as follows:

1. A power circuit is defined as the conductors and components of branch and feeder circuits. A branch and feeder circuit carries main line power current to external loads such as motors, lighting, heating, appliances and general use receptacles. A control circuit is a circuit that carries the electric signals directing the performance of a controller, and which does not carry the main power current. Only devices in power circuits and overcurrent devices protecting control circuits or power supplies (see Note 1) affect the assembly SCCR.

Note 1: Supplement SB3.2.1: For control circuits tapped from the feeder circuit, the overcurrent protection for the common control circuit or for the primary of a control transformer or power supply must be a branch circuit protective devices having a short-circuit current rating not less than the overall panel short-circuit current rating. For control circuits tapped from the load-side of a motor branch circuit protective device, the overcurrent protection for the common control circuit or for the primary of a control transformer or power supply, the short-circuit current rating of the overcurrent protection must be included in the determination of the branch circuit short-circuit current rating.

Note 2: There are some devices that are applied in power circuits but do not affect the assembly SCCR. These include:

- Power transformers, reactors, current transformers, dry-type capacitors, resistors, and voltmeters (deletion of “varistors” is a proposed revision so that SPDs affect the SCCR, not currently in UL 508A).
- The “S” contactor of a Wye-Delta motor controller
- Enclosure air conditioners that are cord-and-attachment-plug connected
- Wiring ferrules
- Line filters used with power conversion equipment (proposed revision, not currently in UL 508A)

2. Per UL 508A: a branch circuit is defined as the conductors and components following the final branch circuit overcurrent protective device protecting a load. A feeder circuit is the conductors and circuitry on the supply side of the branch circuit overcurrent protective device(s).

Note: In some cases, current-limiting devices in the feeder circuit can be used to increase the SCCR of branch circuit components. In addition, larger spacings are required for components used in feeder circuits versus when used in branch circuits. This is especially important for power distribution and terminal blocks, if used in feeder circuits.

Using the “Two Sweep” method based on UL 508A

After all the power circuit components and overcurrent devices protecting control circuits and power supplies have been identified, the “Two Sweep” method based on UL 508A can be used to determine the assembly Short-Circuit Current Rating (SCCR). The purpose of performing two sweeps in this method is to ensure that the overcurrent protective device interrupting rating (or SCCR for combination motor controllers) are never increased by an upstream overcurrent protective device. UL 508A strictly prohibits any overcurrent protective device interrupting rating (or SCCR for combination motor controllers) from being raised beyond the marked interrupting rating or SCCR by an upstream overcurrent protective device. Hence, series rating of overcurrent devices (combination of an under rated circuit breaker applied at higher fault currents when provided with an appropriately tested or selected upstream fuse or circuit breaker) is prohibited. Series ratings, per NEC 240.86 are applicable for panelboards and switchboards, not industrial control panels, industrial machinery or motor control centers.

Sweep 1: The component protection sweep

The first sweep reviews all components in the branch, feeder, sub-feeder and supply circuits, and determines the component with the lowest SCCR. It is important to note these components can have either standard or high fault SCCRs. Per UL 508A Supplement SB2.2 and SB2.3, they are defined per below:

STANDARD FAULT SHORT-CIRCUIT CURRENT RATING — Short-circuit current rating of a component as specified in Table SB4.1 (default values).

HIGH FAULT SHORT-CIRCUIT CURRENT RATING — Marked short-circuit current rating of a component that is greater than the standard fault short-circuit current rating.

Note: There are exceptions where the overcurrent device required to achieve a high fault SCCR may not be required per UL 508A Supplement SB4.2.3, these include:

- When the specified branch circuit protection related to the high fault short-circuit current rating is a Class CC, G, J, L, RK1, RK5, or T fuse, a fuse of a different class is able to be used at the same high fault rating where the peak let-through current and I^2t of the new fuse is not greater than that of the specified fuse. See Table SB4.2 for maximum let-through currents and I^2t .

- The specified branch circuit protection is able to be provided in the field when the panel is marked in accordance with SB5.1.2. SB5.1.2 requires the industrial control panel to be marked with the required branch circuit protective device type and size required to be installed in the field.
- When the specified branch circuit protection related to the high fault short-circuit current rating is a listed circuit breaker marked “current-limiting”, a different current-limiting circuit breaker is able to be used at the same high fault rating where the peak let-through current and I^2t of the new current-limiting circuit breaker is not greater than that of the specified circuit breaker. Refer to published let-through values for current-limiting circuit breakers provided by the manufacturer. Figure SB4.1 is provided to assist in determining the peak let-through current and I^2t from the manufacturers data sheets.
- When the specified branch circuit protection related to the high fault SCCR is a non-current limiting overcurrent device, a current-limiting fuse according to Table SB4.2 can be used at the same high fault rating where the interrupting rating of the current-limiting fuse is equal to or greater than the specified overcurrent device, and where the rated current of the fuse is equal to or less than the specified overcurrent device.

Sweep 2: The overcurrent protection sweep

The second sweep reviews all overcurrent protective devices in the branch, feeder and supply circuits, and determines the lowest interrupting rating (or SCCR for combination motor controllers).

The lowest rating from Sweep 1 and Sweep 2 identifies the assembly SCCR. Because this method determines the assembly SCCR, it may be referred to as the “FIND IT”.

Note: It is necessary to complete both sweeps and all steps to determine an assembly’s SCCR marking. If an assembly SCCR marking is inadequate, then see the “FIX IT” portion at the end of this section for suggestions on how to increase an assembly’s marked SCCR.

Procedures for the “Two Sweep” method

Each sweep of this method is broken down into steps:

- Sweep 1 has five steps
- Sweep 2 has three steps

The following shows the procedure for completing the steps of both sweeps.

Sweep 1: Verifying assembly component SCCRs

Step 1: Determine the component SCCR for each branch circuit:

- Identify all component SCCRs and any special conditions that exist to utilize the ratings by one of the following methods:
 1. The SCCR based on the default ratings per UL 508A Table SB4.1 (see Table 7.12.e SCCR1 - default SCCR Ratings).
 2. The SCCR marked on the component or instruction sheet provided with the component.
 3. The SCCR based on testing with a specific overcurrent protective device and/or combination of components in accordance with product standards and documented by the manufacturer. Example: a motor controller may have a high fault SCCR of 100 kA with a 30 A Class J fuse, but only 5 kA with a 30 A non-current-limiting overcurrent protective device.
- Apply the lowest SCCR of any component used in a branch circuit as the SCCR for that branch circuit. Repeat this for each branch circuit in the assembly.
- Note the lowest branch circuit SCCR for every branch circuit in the assembly or panel.

Step 2: Determine the component SCCR for each feeder circuit (includes supply, feeders and sub-feeders):

- Identify all component SCCRs and any special conditions that exist to utilize the ratings by one of the following methods:
 - The SCCR based on the default ratings per UL 508A Table SB4.1 (see Table 7.12.e SCCR1 - Default SCCR Ratings).
 - The SCCR marked on the component or instruction sheet provided with the component.
 - The SCCR based on testing with a specific overcurrent protective device and/or combination of components in accordance with product standards and documented by the manufacturer. Example: a power distribution block may have a high fault SCCR of 100 kA with a 200 A Class J fuse, but only 10 kA with a 200 A non-current-limiting overcurrent protective device.
- Apply the lowest SCCR of any component used in the feeder circuit as the SCCR of the feeder circuit.
- Note the lowest feeder circuit SCCR.

Step 3: If using a power transformer (a transformer that supplies loads) in a feeder circuit, modify the transformer circuit SCCR, if possible, as follows:

- Determine if the SCCR of the downstream components or interrupting rating of overcurrent devices can be increased by applying the following procedure:
 - Determine the let-through short-circuit current based upon calculation using the formulas in SB4.3.1(a) or use of Tables of SB4.3 or SB4.4 provided the impedance of the transformer is at least 2.1% or higher (see Table 7.12.d for Transformer1).
 - On the transformer secondary, identify the lowest component SCCR or overcurrent protective device interrupting rating.
 - If the lowest component SCCR or overcurrent protective device interrupting rating is greater than the let-through short-circuit current, apply the transformer's primary overcurrent protective device interrupting rating to the entire transformer circuit. Otherwise apply the lowest downstream component SCCR or overcurrent protective device interrupting rating to the transformer circuit.

Single-phase transformer secondary available short-circuit currents (A)†								
Min. transformer secondary voltage (V)								
Trans. max kVA	120	240††	208	240	277	347	480	600
1	400	300	230	200	180	140	100	80
3	1200	900	690	600	520	420	300	240
5	1990	1490	1150	1000	860	690	500	400
10	3970	2980	2290	1990	1720	1380	1000	800
15	5960	4470	3440	2980	2580	2060	1490	1200
25	9930	7450	5730	4970	4300	3440	2490	1990
37.5	14,890	11,170	8590	7450	6450	5150	3730	2980
50	19,850	14,890	11,450	9930	8600	6870	4970	3970
75	29,770	22,330	17,180	14,890	12,900	10,300	7450	5960

† Z assumed to be 2.1%. All values are rounded up.

††Short-circuit current shown is line-to-neutral. (1.5 times line-to-line.)

Table 7.12.2.d Transformer1: Single-phase transformer secondary short-circuit current (UL 508A SB4.3).

Three-phase transformer secondary available short-circuit currents (A)†							
Min. transformer secondary voltage (V)							
Trans. max kVA	208Y/120††	208	240	480Y/277††	480	600Y/347††	600
5	830	670	580	360	290	290	230
10	1660	1330	1150	720	580	580	460
15	2480	1990	1720	1080	860	860	690
20	3310	2650	2300	1440	1150	1150	920
25	4140	3310	2870	1800	1440	1440	1150
30	4960	3970	3440	2150	1720	1720	1380
45	7440	5950	5160	3230	2580	2580	2070
75	12,400	9920	8600	5370	4300	4300	3440
100	16,530	13,220	11,460	7160	5730	5730	4590

† Z assumed to be 2.1%. All values are rounded up.

††Short-circuit current shown is line-to-neutral (1.25 times line-to-line).

Table 7.12.2.e Transformer2: Three-phase transformer secondary short-circuit current (UL 508A SB4.4).

Step 4: If using a current-limiting overcurrent protective device in the feeder circuit, modify branch circuit component SCCRs other than the interrupting rating of branch circuit overcurrent protection devices such as fuses and circuit breakers or, the SCCR of Type A (fusible combination motor controllers), Type C (circuit breaker combination motor controllers), Type D combination motor controllers (instantaneous trip circuit breakers/motor circuit protectors [MCPs]) and Type E or F (self-protected) combination motor controllers, if possible, as follows:

- Determine the peak let-through value of the current-limiting overcurrent protective devices at a given prospective fault current.
 - If the overcurrent protective device is a current-limiting fuse, determine the peak let-through umbrella value dictated by the product standard for the fuse class and amp rating utilized at the level of fault current desired (50, 100, 200 kA). See Table 7.12.g for SCCR2 - UL Umbrella Limits at Rated Voltage (based on UL 508A Table SB4.2).
 - If the overcurrent protective device is a marked current-limiting circuit breaker, manufacturer's let-through curves can be used to determine the peak let-through value at a given prospective fault current.
- Ensure that the peak let-through value is less than any of the SCCRs determined for the branch circuit in Step 1.
- If condition "2" above is met, apply a SCCR to branch circuit components fed by the feeder based upon the value of the prospective fault current used to determine the peak let-through value of the current-limiting overcurrent protective device.

Note 1: Per SB4.3.4, the specified circuit breaker marked "current-limiting" or current-limiting Class of fuse supplied in the feeder circuit that limits the peak let-through current available in accordance with SB4.3.2 and SB4.3.3 is able to be provided in the field when the panel is marked in accordance with SB5.1.3.

Note 2: Per SB5.1.3, an industrial control panel marked with a high fault short-circuit current rating and is not provided with the required feeder circuit protective device as specified in the SB4.3.4 must be marked with the type and size of feeder circuit protection required to be installed in the field. This marking must be included as part of the marking in SB5.1.1.

Step 5: Determine the assembly SCCR for Sweep 1

- Determine the Sweep 1 assembly SCCR by utilizing the lowest rated branch or feeder circuit component SCCR.

Sweep 2: Verify assembly SCCR based upon overcurrent protective device interrupting rating (or SCCR for combination motor controllers)

Step 1: Determine the interrupting ratings (or SCCR of combination motor controllers) of all the overcurrent protective devices used in feeder (includes supply, feeders and sub-feeders) and branch circuits, including those overcurrent protective devices protecting control circuits and power supplies.

Step 2: Identify the lowest overcurrent protective device interrupting rating or SCCR for combination motor controllers.

Step 3: Compare the lowest overcurrent protective device interrupting rating or SCCR with the component SCCRs from Sweep 1, Step 5. The lowest rating encountered is the assembly SCCR.

This SCCR is then marked on the assembly. If this SCCR is not sufficiently high enough, there are "FIX IT" solutions at the end of this section that can be investigated to achieve a higher SCCR.

Note 1: Per SB5.1.1 the nameplate rating of an industrial control panel must include: "Short-circuit current rating: ____kA rms symmetrical, ____V maximum" or the equivalent.

Note 2: Per UL 508A 49.5 if multiple sources of supply to the industrial control panel are present, each set of input terminals must have a short-circuit current rating.

Note 3: Per UL 508A Table 52.1, the short-circuit current rating marking location must be visible without opening the enclosure's door or cover.

Note 4: Per UL 508A 49.6 when an industrial control panel contains slash voltage rated components, such as 120/240 V, 480Y/277 V, or 600Y/347 V, the voltage rating of the industrial control panel must be the complete slash voltage rating, when intended for connection to the higher voltage, or not more than the lower voltage rating.

Component	Default SCCR (kA)
Busbars	10
Circuit breaker (including GFCI type)	5
Current meters	*
Current shunt	10
Fuse holder	10
Industrial control equipment	
a. Auxiliary devices (overload relay)	5
b. Switches (other than mercury tube type)	5
c. Mercury tube switches rated:	
Over 60 amps or over 250 volts	5
250 volts or less, 60 amps or less and over 2 kVA	3.5
250 volts or less and 2 kVA or less	1
Motor controller, rated in horsepower (kW)††	
a. 0-50 (0-37.3)	5**
b. 51-200 (38-149)	10**
c. 201-400 (150-298)	18**
d. 401-600 (299-447)	20**
e. 601-900 (448-671)	42**
f. 901-1500 (672-1193)	85**
Meter socket base	10
Miniature or miscellaneous fuse	10†
Receptacle (GFCI type)	2
Receptacle (other than GFCI)	10
Supplementary protector	0.2
Switch unit	5
Terminal block or power distribution block	10
Multi-point interconnection power cable assembly	10
Cable assemblies and fittings for industrial control and signal distribution	10
Multi-wire (power distribution) lug	10

* An SCCR is not required when connected via a current transformer or current shunt. A directly connected current meter must have a marked SCCR.

**Standard short-circuit current rating for motor controller rated within specified horsepower range.

† The use of a miniature fuse is limited to 125 V circuits.

††Includes combination motor controllers, float and pressure operated motor controllers, power conversion equipment and solid state motor controllers. Highest rated horsepower of motor controller.

Table 7.12.2.f SCCR1 - Default SCCR Ratings (UL 508A Table SB4.1)

Umbrella fuse limits

UL / CSA / ANCE Fuse Standards set maximum I_p and I^2t let-through limits for short-circuit current performance of current-limiting fuses. The limits vary by fuse class, amp rating and available short-circuit current. To receive a listing, a commercially available current-limiting fuse must be tested and evaluated under short-circuit current tests per the applicable standard and witnessed by a National Recognized Testing Laboratory (NRTL). One evaluation criteria of the testing is that the fuse's I_p and I^2t let-through measured during the short-circuit tests cannot exceed the Standard's "umbrella limits" for I_p and I^2t let-through established for that fuse class, amp rating, and available short-circuit current*. See Table 7.12.g SCCR2 - UL Umbrella Limits at Rated Voltage for the umbrella limits applicable to most of the current-limiting fuses.

* NOTE: These tests are performed at the fuse's rated voltage, with only one fuse in the circuit and by controlled closing of the test circuit so that the fuse "starts to arc" between 60 and 90 degrees on the voltage waveform. These test conditions are the most severe for fuse interruption. In addition, current-limiting fuses are required to have periodic NRTL witnessed follow-up testing in the same manner. The fuses for NRTL witnessed follow-up testing are pulled from inventory.

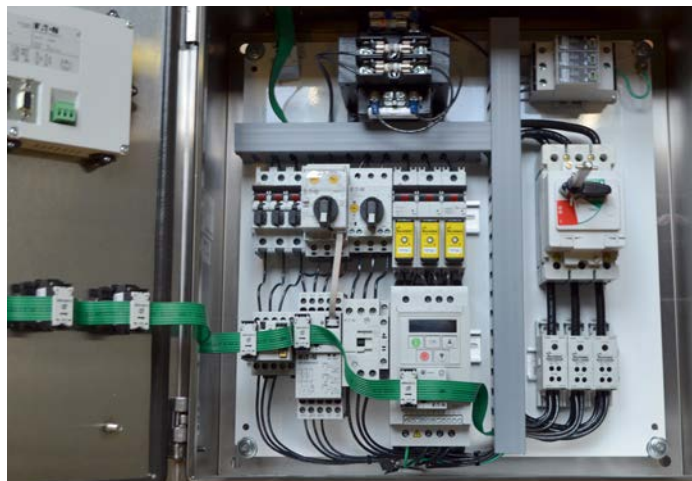
Umbrella fuses

An umbrella fuse is a special fuse that is designed to have short-circuit current I_p and I^2t let-through that are at least equal to or greater than the fuse standard limit. Umbrella fuses are not intended to be sold as commercially available fuses.

These devices fall under UL 248-16 Test Limiters. UL uses the term "test limiters" interchangeably as umbrella fuses. UL 248-16 states:

"...test limiters are calibrated to specific limits of peak let-through current and clearing I^2t at 250, 300, 480, or 600 Vac. Test limiters are non-renewable and current-limiting, with test current ratings up to 200,000 A. They are calibrated to maximum peak let-through current and clearing I^2t limits for the fuses specified in this Standard and are used for withstand testing of equipment designed to accept those fuses."

Umbrella fuses are used for test purposes in qualifying a combination SCCR with a specific component. For instance, a controller manufacturer wants the controller to be marked with a 100,000 A SCCR at 600 V when protected by 60 A Class J fuses. The NRTL witnessed tests would be with 60 A Class J umbrella fuses in combination with the controller on a test circuit of 100,000 A at 600 V. If the results satisfy the UL 508 Industrial Control Standard evaluation criteria, the controller can be labeled with a 100,000 A, 600 V SCCR when protected by Class J fuses 60 A (or less). Another use of umbrella fuses is for series rated fuse/circuit breaker panelboard and switchboard combinations per NEC 240.86. For more information on series ratings see the section on Series Rating: Protecting Circuit Breakers. However, UL 508A Supplement SB4 does not permit series rated combinations for use in establishing the SCCR for industrial control panels. Therefore, the interrupting rating of overcurrent devices cannot be raised by another upstream overcurrent device.



Fuse type	Amp rating	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$ (kA)	$I^2t \times 10^3$	$I_p \times 10^3$ (kA)	$I^2t \times 10^3$	$I_p \times 10^3$ (kA)
Class CC	15	2	3	2	3	3	4
	20	2	3	3	4	3	5
	30	7	6	7	7.5	7	12
Class G	15			3.8	4		
	20			5	5		
	30	—	—	7	7	—	—
	60			25	10.5		
Class RK1	30	10	6	10	8.7	11	12
	60	40	10	40	12	50	16
	100	100	14	100	16	100	20
	200	400	18	400	22	400	30
	400	1200	33	1200	35	1600	50
	600	3000	45	3000	50	4000	70
Class RK5	30	50	11	50	11	50	14
	60	200	20	200	21	200	26
	100	500	22	500	25	500	32
	200	1600	32	1600	40	2000	50
	400	5200	50	5000	60	6000	75
	600	10000	65	10000	80	12000	100
Class T, 300 V*	1			0.4	0.8		
	3			0.6	1.3		
	6			1	2		
	10	—	—	1.5	3	—	—
	15			2	4		
	20			2.5	4.5		
	25			2.7	5.5		
	30	3.5	5.0	3.5	7	3.5	9
	35			6	7		
	40	—	—	8.5	7.2	—	—
	45			9	7.6		
	50			11	8		
	60	15	7	15	9	15	12
	70			25	10		
	80	—	—	30	10.7	—	—
	90			38	11.6		
	100	40	9	40	12	40	15
	110			50	12		
	125	—	—	75	13	—	—
	150			88	14		
	175			115	15		
	200	150	13	150	16	150	20
	225			175	21		
	250	—	—	225	22	—	—
	300			300	24		
	350			400	27		
	400	550	22	550	28	550	35
	450	—	—	600	32	—	—
	500			800	37		
	600	1,000	29	1,000	37	1,000	46
	700	—	—	1,200	45	—	—
	800	1,500	37	1,500	50	1,500	65
	1000	—	—	3,500	65	—	—
	1200	3,500	50	3,500	65	4,000	80

* When values at 50 kA and 200 kA are needed, the standard case size must be used.

Note: Values shown are UL umbrella limits.

Table 7.12.g SCCR2 - UL umbrella limits at rated voltage (UL 508A Table SB4.2)

Fuse type	Amp rating	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$ (kA)	$I^2t \times 10^3$	$I_p \times 10^3$ (kA)	$I^2t \times 10^3$	$I_p \times 10^3$ (kA)
Class CF (up to 400 A), J and T 600 V*	1			0.8	1		
	3			1.2	1.5		
	6			2	2.3		
	10	—	—	3	3.3	—	—
	15			4	4		
	20			5	5		
	25			5.5	6		
	30	7	6	7	7.5	7	12
	35			12	7.5		
	40			17	8		
	45	—	—	18	8.5	—	—
	50			22	9		
	60	30	8	30	10	30	16
	70			50	11.5		
	80	—	—	60	12.5	—	—
	90			75	12.5		
	100	60	12	80	14	80	20
	110			100	14.5		
	125			150	15.5		
	150	—	—	175	17	—	—
	175			225	18.5		
	200	200	16	300	20	300	30
	225			350	22.5		
	250			450	24		
	300	—	—	600	26	—	—
	350			800	29		
	400	1000	25	1,100	30	1100	45
	450			1,500	36		
	500	—	—	2,000	42	—	—
	600	2500	35	2500	45	2500	70
Class L	700**	—	—	3,500**	50**	—	—
	800**	4000**	50**	4000**	55**	4000**	75**
	800	10,000	80	10,000	80	10,000	80
	1200	12,000	80	12,000	80	15,000	120
	1600	22,000	100	22,000	100	30,000	150
	2000	35,000	110	35,000	120	40,000	165
	2500			75,000	165	75,000	180
	3000			10,000	175	100,000	200
	4000	—	—	15,000	220	150,000	250
	5000			35,000	—	350,000	300
	6000			35,000		500,000	350

* When values at 50 kA and 200 kA are needed, the standard case size must be used.

**Value applies to Class T fuses. Values at 700 A are included per UL 248, but have not been added to UL 508A Supplement SB.

Note: Values shown are UL umbrella limits.

Table 7.12.g SCCR2 - UL umbrella limits at rated voltage (UL 508A Table SB4.2)



Example using the “Two Sweep” method: “FIND IT”

The following example illustrates the procedures outlined for the two sweep method to determine the assembly SCCR. The example is based on the industrial control panel shown in Figures 7.12.1.h and 7.12.1.i.

Figure 7.12.1.h shows the graphical representation of the industrial control panel while Figure 7.12.1.i is its the one-line diagram that details each power circuit component and their ratings.

This example illustrates how each sweep and their steps are performed and documented in the tables. After both sweeps and all steps have been completed, the result identifies the assembly SCCR or “FIND IT.” Later, methods are outlined to increase the assembly SCCR or “FIX IT.”

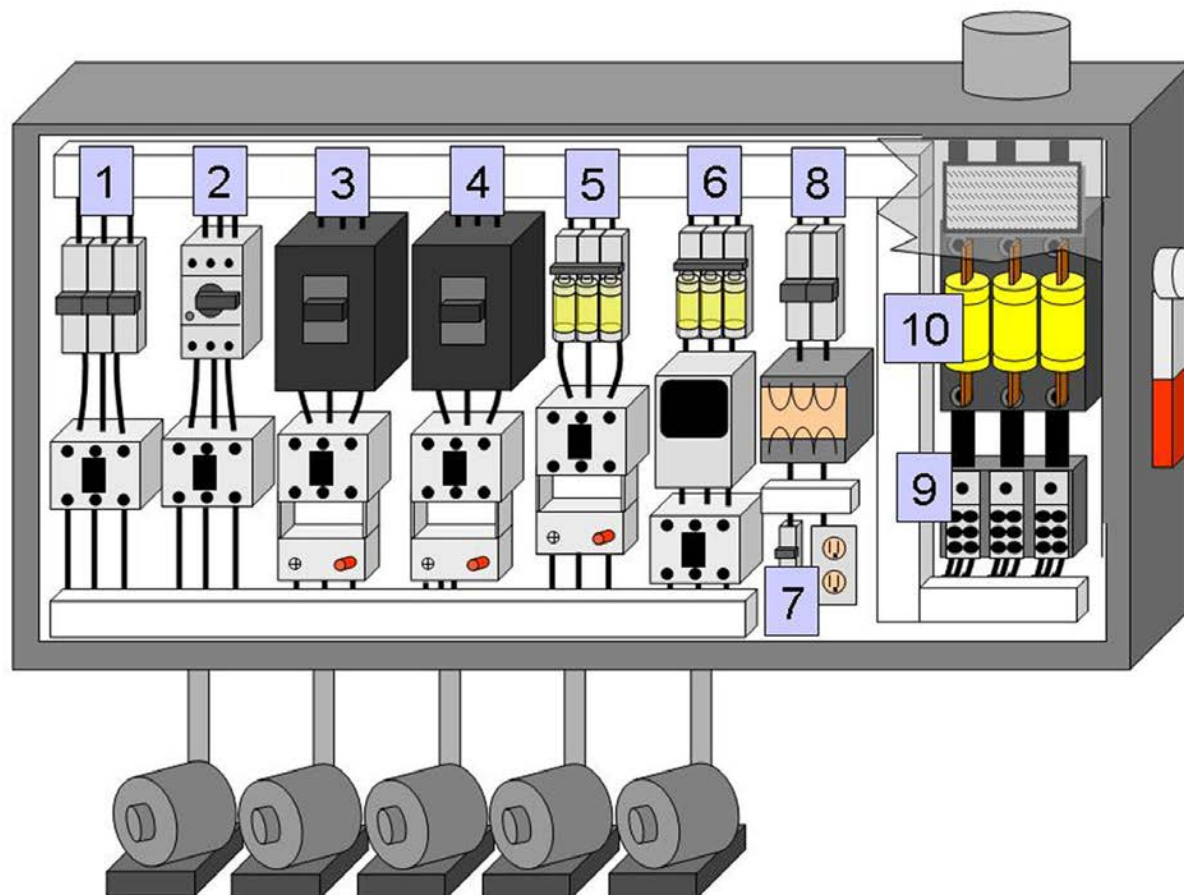
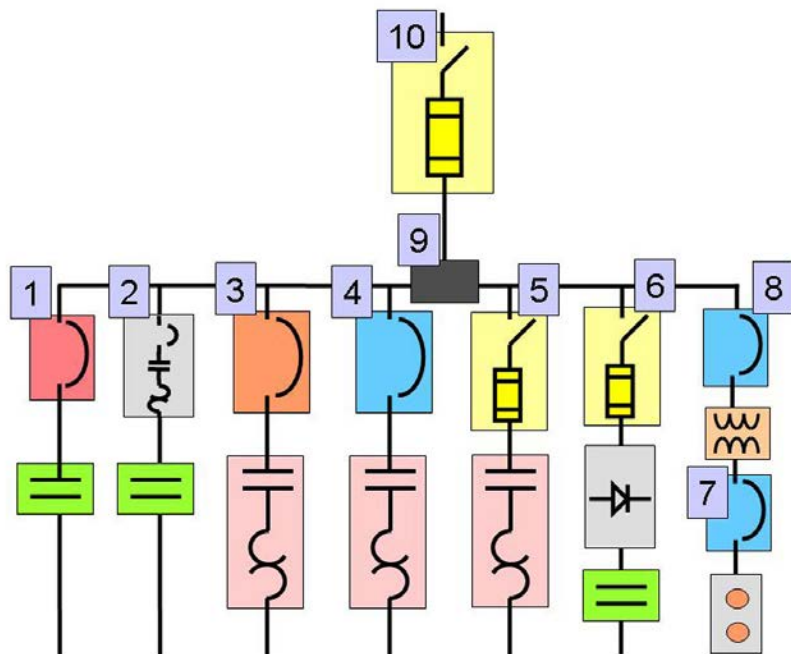


Figure 7.12.1.h Industrial control panel graphical representation.

Circuit number	Device description
1	Molded case circuit breaker protecting an IEC contactor
2	Self-protected Type E combination motor controller protecting an IEC contactor (Type F combination motor controller, additional components may be required)
3	Instantaneous trip circuit breaker (MCP) protecting an IEC starter (Type D combination motor controller) special assembly conditions required)
4	Molded case circuit breaker protecting an IEC starter contactor (Type C combination motor controller)
5	Class CC fused switch protecting an IEC starter
6	Class CC fused switch protecting variable frequency drive and contactor
7	Molded case circuit breaker and GFCI receptacle
8	Molded case circuit breaker protecting power transformer
9	Power distribution block
10	Class J fused switch

Example using the “two sweep” method: “FIND IT”



Note: It is important to record the voltage ratings for all components and overcurrent protective devices. The assembly is marked based upon the lowest or most restrictive device voltage rating. If there are devices with slash voltage ratings (such as 480/277 V), these are more limiting than straight or full voltage ratings (such as 480 V). Assemblies with 480/277 V devices are suitable for only 480/277 V solidly grounded Wye systems. These assemblies cannot be applied on 480 V ungrounded, resistance grounded or corner grounded systems. (See slash voltage rated devices in Section 3 for more information.)

Figure 7.12.1.i Industrial control panel one-line diagram.

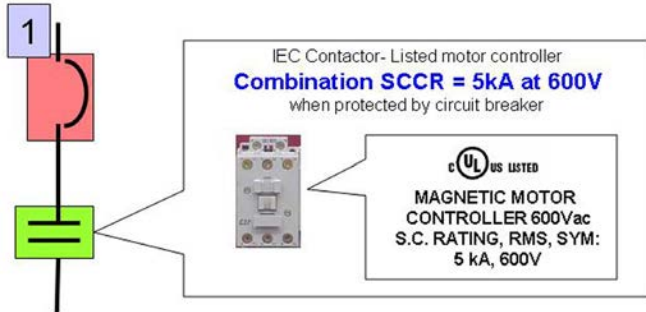
Circuit number	Type	Device descriptions
1	Branch	- Molded case circuit breaker: IR = 14 kA @ 480/277 V - IEC contactor: SCCR = 5 kA @ 600 V
2	Branch	- Self-protected Type E combination motor controller with lineside terminal kit: SCCR = 65 kA @ 480/277 V - IEC contactor: SCCR = 5 kA @ 600 V
3	Branch	- Instantaneous trip circuit breaker (MCP): unmarked IR - IEC starter: SCCR = 5 kA @ 600 V
4	Branch	- Molded case circuit breaker: IR = 14 kA @ 480 V - IEC starter: SCCR = 5 kA @ 600 V
5	Branch	- Bussmann series Class CC Compact Circuit Protector (CCP): SCCR = 200 kA @ 600 V - Bussmann series LP-CC fuses: IR = 200 kA @ 600 V - IEC starter: SCCR = 5 kA @ 600 V
6	Branch	- Bussmann series Class CC Compact Circuit Protector (CCP): SCCR = 200 kA @ 600 V - Bussmann series LP-CC fuses: IR = 200 kA @ 600 V - Variable frequency drive: SCCR = 5 kA @ 480 V - IEC contactor: SCCR = 5 kA @ 600 V
7	Branch	- Molded case circuit breaker: IR = 10 kA @ 120 V - GFCI receptacle: unmarked SCCR
8	Sub-feeder	- Molded case circuit breaker: IR = 14 kA @ 480/277 V - 3 kVA 480 V-120 V secondary power transformer (does not affect SCCR)
9	Feeder	- Power distribution block: unmarked SCCR
10	Supply	- Bussmann series 100 A Class J fused switch: SCCR = 200 kA @ 600 V - Bussmann series 100 A LPJ fuses: IR = 300 kA @ 600 V

“Two sweep” method: Sweep 1, Step 1 - branch circuit components

Sweep 1: Verifying component SCCRs

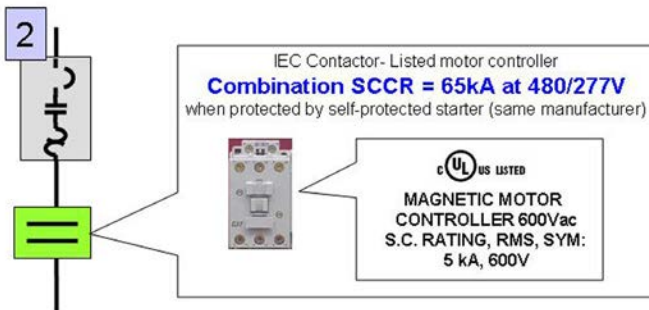
Step 1: Determine the lowest rated component in each branch circuit.

Note: Determine only component SCCRs. OCPD interrupting ratings and SCCRs are ignored in this step.



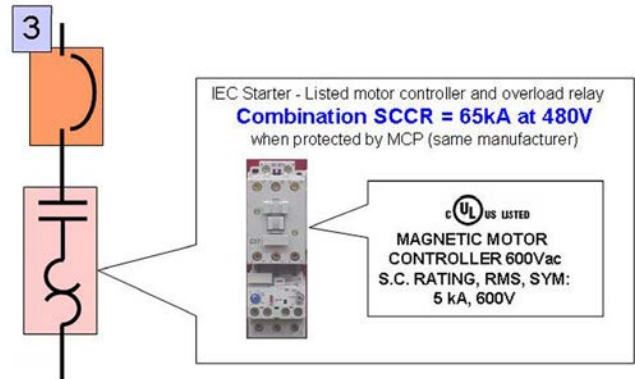
Branch circuit 1

- IEC contactor: SCCR = 5 kA @ 600 V
- High fault SCCR as Type C combination motor controller (with a circuit breaker) does not exist
- SCCR = 5 kA @ 600 V



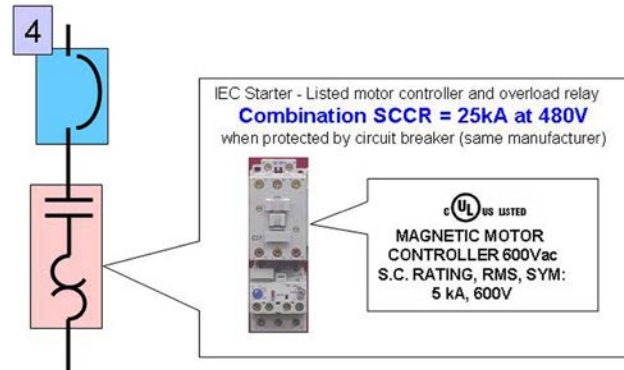
Branch circuit 2

- IEC contactor: SCCR = 5 kA @ 600 V
- High fault short-circuit current rating as Type F Combination motor controller rating with self-protected starter (only with same manufacturer) = 65 kA @ 480/277 V
- SCCR = 65 kA @ 480/277 V



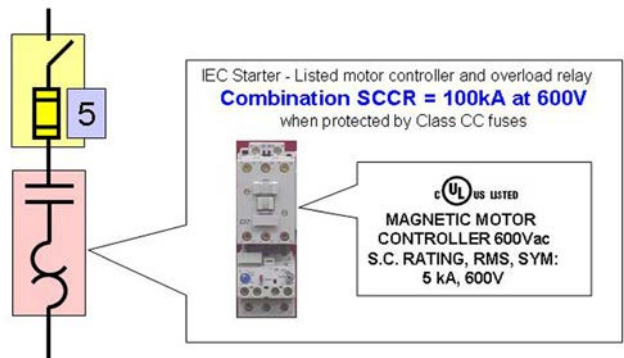
Branch circuit 3

- IEC Starter: SCCR = 5 kA @ 600 V
- High fault short-circuit current rating as Type D combination motor controller rating with MCP (only with same manufacturer) = 65 kA @ 480 V
- SCCR = 65 kA @ 480 V



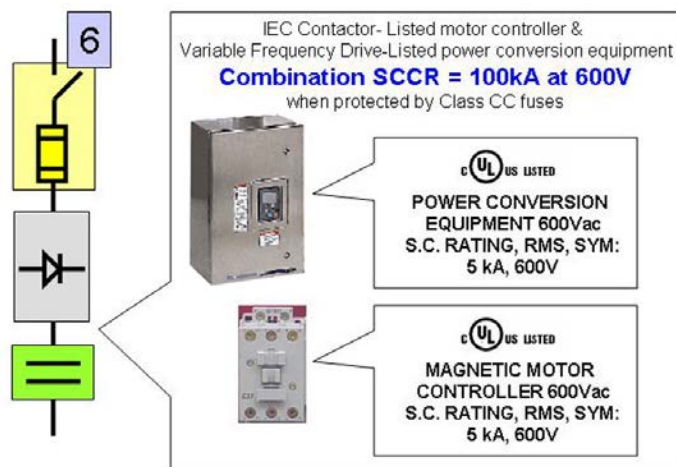
Branch circuit 4

- IEC starter: SCCR = 5 kA @ 600 V
- High fault short-circuit current rating as Type C combination motor controller rating with circuit breaker (only with same manufacturer) = 25 kA @ 480 V
- SCCR = 25 kA @ 480 V



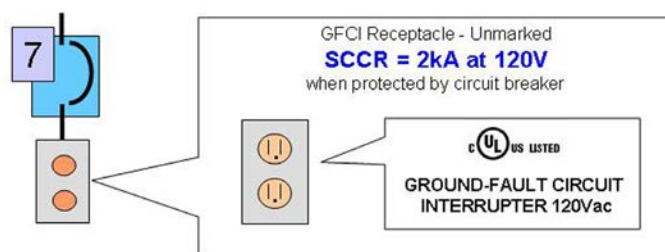
Branch circuit 5

- IEC starter: SCCR = 5 kA @ 600 V
- High fault short-circuit current rating with Class CC fuses = 100 kA @ 600 V
- SCCR = 100 kA @ 600 V



Branch circuit 6

- Variable Frequency Drive: SCCR = 5 kA @ 480 V
- IEC contactor: SCCR = 5 kA @ 600 V
- High fault short-circuit current rating with Class CC fuses:
 - 200 kA @ 600 V for variable frequency drive
 - 100 kA @ 600 V for IEC contactor
- SCCR = 100 kA @ 600 V



Branch circuit 7

- GFCI Receptacle: unmarked SCCR (2 kA per Table 7.12.e Default SCCR Ratings)
- Higher combination rating with circuit breaker does not exist
- SCCR = 2 kA @ 120 V (does not affect panel voltage rating)

Results of Sweep 1, Step 1: SCCR = 2 kA @ 480/277 V

Summary

- Lowest Step 1 SCCR is 2 kA @ 480/277 V

Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results			
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		Sweep 2-Steps 1 and 2 (overcurrent device)	
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V								
Branch circuit 2	65 kA	480/277 V								
Branch circuit 3	65 kA	480 V								
Branch circuit 4	25 kA	480 V								
Branch circuit 5	100 kA	600 V								
Branch circuit 6	100 kA	600 V								
Branch circuit 7	2 kA	—								
Sub-feeder circuit 8	—	—								
Feeder circuit 9	—	—								
Supply circuit 10	—	—								

“Two sweep” method: Sweep 1, Step 2 - feeder circuit components

Sweep 1: Verifying component SCCRs

Step 2: Determine the component SCCR for each feeder, sub-feeder and supply circuit.

Sub-feeder circuit 8

- This is a transformer circuit and is covered by Sweep 1, Step 3



Feeder circuit 9

- Power distribution block (PDB): unmarked SCCR (10 kA per Table 7.12.e SCCR1 - Default SCCR Ratings)
- SCCR = 10 kA @ 600 V

Note: PDB must have proper spacings for feeder application per UL 508A.



Supply circuit 10

- Bussmann series 100 A Class J fused switch: SCCR = 200 kA @ 600 V
- SCCR = 200 kA @ 600 V

Results of Sweep 1, Step 2: SCCR = 2 kA @ 480/277 V

Summary

- Lowest Step 2 SCCR is 10 kA @ 600 V.
- Lowest Step 1 or Step 2 SCCR is 2 kA @ 480/277 V.

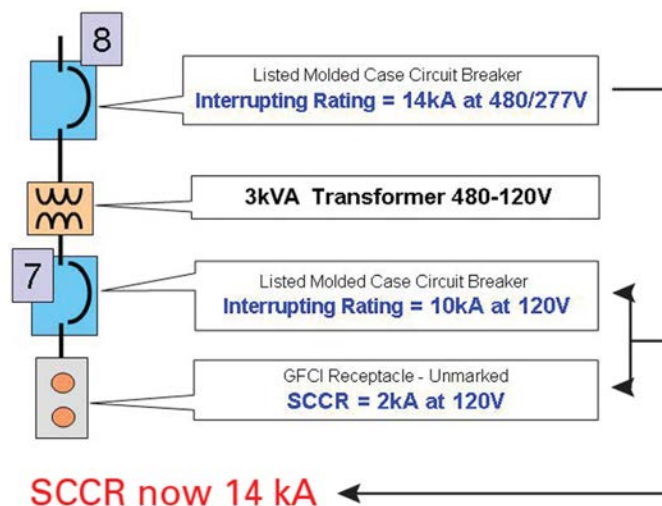
Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results		
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		Sweep 2-Steps 1 and 2 (overcurrent device)
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR Volts
Branch circuit 1	5 kA	600 V	—	—					
Branch circuit 2	65 kA	480/277 V	—	—					
Branch circuit 3	65 kA	480 V	—	—					
Branch circuit 4	25 kA	480 V	—	—					
Branch circuit 5	100 kA	600 V	—	—					
Branch circuit 6	100 kA	600 V	—	—					
Branch circuit 7	2 kA	—	—	—					
Sub-feeder circuit 8	—	—	—	—					
Feeder circuit 9	—	—	10 kA	600 V					
Supply circuit 10	—	—	200 kA	600 V					

“Two Sweep” method: Sweep 1, Step 3 - components/transformers

Sweep 1: Verifying equipment component SCCRs

Step 3: Determine if power transformers in the feeder, sub-feeder or supply circuit can raise the interrupting rating of branch circuit overcurrent protective devices and branch circuit component SCCRs (circuit breaker and GFCI receptacle):



Sub-feeder circuit 8

- 3 kVA sub-feeder transformer with a 120 V secondary can be used to raise the secondary components SCCR since the transformer's let-through current is 1.2 kA. Refer to table transformer1.
- Since all 120 V secondary branch circuit overcurrent protective devices and components have an interrupting rating/SCCR (circuit breaker IR = 10 kA) or SCCR (GFCI receptacle SCCR = 2 kA) of 1.2 kA or higher, the interrupting rating of the transformer primary overcurrent protective device (sub-feeder circuit 8) can be assigned to the entire branch circuit 7 (circuit breaker and GFCI receptacle).
- Revised branch circuit 7 **SCCR = 14 kA**

Results of Sweep 1, Step 3: SCCR = 5 kA @ 480/277 V

Summary

- Branch circuit 7 SCCR was raised to 14 kA
- Branch circuit 1 is still the limiting SCCR factor

Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results			
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		Sweep 2-Steps 1 and 2 (overcurrent device)	
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V	—	—	—	—	—	—	—	—
Branch circuit 2	65 kA	480/277 V	—	—	—	—	—	—	—	—
Branch circuit 3	65 kA	480 V	—	—	—	—	—	—	—	—
Branch circuit 4	25 kA	480 V	—	—	—	—	—	—	—	—
Branch circuit 5	100 kA	600 V	—	—	—	—	—	—	—	—
Branch circuit 6	100 kA	600 V	—	—	—	—	—	—	—	—
Branch circuit 7	2 kA	—	—	—	14 kA	—	—	—	—	—
Sub-feeder circuit 8	—	—	—	—	—	—	—	—	—	—
Feeder circuit 9	—	—	10 kA	600 V	—	—	—	—	—	—
Supply circuit 10	—	—	200 kA	600 V	—	—	—	—	—	—

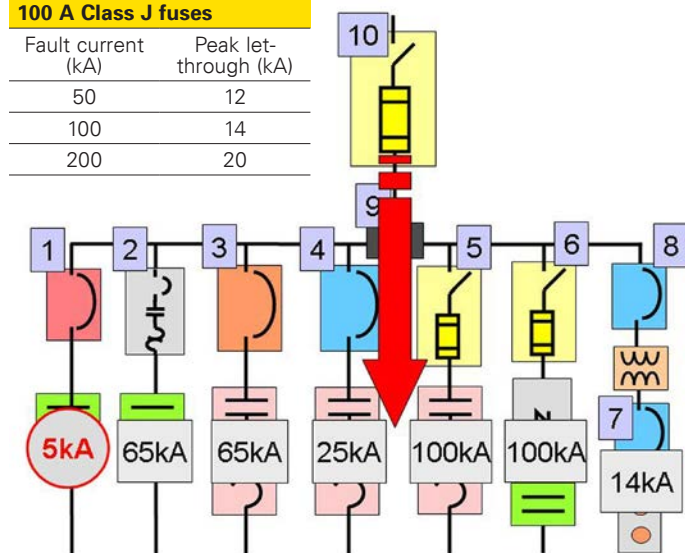
“Two sweep” method: Sweep 1, Step 4 - current-limiting overcurrent devices

Sweep 1: Verifying assembly component SCCRs

Step 4: Determine if current-limiting overcurrent protective devices (C-L OCPDs) are used in the feeder, sub-feeder or supply circuit that can raise branch circuit component ratings (other than devices that provide branch circuit overcurrent protection or combination motor controllers).

100 A Class J fuses

Fault current (kA)	Peak let-through (kA)
50	12
100	14
200	20



Supply circuit 10

The 100 A Class J fuse in supply circuit 10 is a current-limiting device. Use Table 7.12.g SCCR2 - UL Umbrella Limits at Rated Voltage to identify the peak let-through values:

- Compare the peak let-through values with result of Step 1 and increase branch circuit component ratings where possible.

Note: Since the 100 A Class J fuse peak let-through of 20 kA at a fault current of 200 kA is less than the SCCR of Step 1 for branch circuits 2 through 6, the SCCR is raised to 200 kA (contactor or variable frequency drive SCCR only). The SCCR of components in feeder circuit 9, sub-feeder circuit 8 or supply circuit 10 cannot be raised per UL 508A.

Results of Sweep 1, Step 4: SCCR = 5 kA @ 480/277 V

Summary

- Branch circuit 1 SCCR cannot be raised.
- Increased SCCR of branch circuits 2 through 6 to 200 kA (contactor or variable frequency drive SCCR only)
- Branch circuit 7 SCCR cannot be raised in this step because it was raised by Step 3
- Feeder circuit 9, sub-feeder circuit 8 or supply circuit 10 cannot be raised in this step (only branch circuit components can be raised)

Note: Red table cells denote limiting components and voltages for each step.

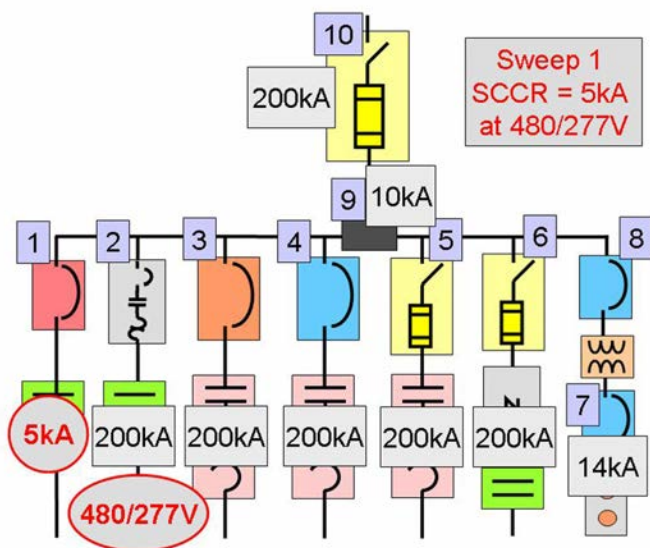
	Assessment		SCCR Revisions				Sweep 1 Results			
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		Sweep 2-Steps 1 and 2 (overcurrent device)	
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V	—	—	—	—	—	—	—	—
Branch circuit 2	65 kA	480/277 V	—	—	—	200 kA	—	—	—	—
Branch circuit 3	65 kA	480 V	—	—	—	200 kA	—	—	—	—
Branch circuit 4	25 kA	480 V	—	—	—	200 kA	—	—	—	—
Branch circuit 5	100 kA	600 V	—	—	—	200 kA	—	—	—	—
Branch circuit 6	100 kA	600 V	—	—	—	200 kA	—	—	—	—
Branch circuit 7	2 kA	—	—	—	14 kA	—	—	—	—	—
Sub-feeder circuit 8	—	—	—	—	—	—	—	—	—	—
Feeder circuit 9	—	—	10 kA	600 V	—	—	—	—	—	—
Supply circuit 10	—	—	200 kA	600 V	—	—	—	—	—	—

Sweep 1: Verifying assembly component SCCRs

Step 5: Determine the lowest branch or feeder circuit component SCCR based on all steps in Sweep 1 and retain for Sweep 2.

- Lowest SCCR resulted from branch circuit 1 in Step 1
- Branch circuit 2 limited voltage in Step 1
- Sweep 1 Lowest SCCR = 5 kA @ 480/277 V

Note: Sweep 2 must still be completed to determine SCCR marking.



Results of Sweep 1, Step 5: SCCR = 5 kA @ 480/277 V

Summary

- After completing all five steps in Sweep 1, the resulting SCCR remains at a low 5 kA @ 480/277 V due to the 5 kA rated contactor in Branch Circuit 1 and the slash voltage rated contactor in Branch Circuit 2 (when protected by a slash voltage rated self-protected Type E combination motor controller).

Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results		Sweep 2-Steps 1 and 2 (overcurrent device)	
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V	—	—	—	—	5 kA	600 V		
Branch circuit 2	65 kA	480/277 V	—	—	—	200 kA	200 kA	480/277 V		
Branch circuit 3	65 kA	480 V	—	—	—	200 kA	200 kA	480 V		
Branch circuit 4	25 kA	480 V	—	—	—	200 kA	200 kA	480 V		
Branch circuit 5	100 kA	600 V	—	—	—	200 kA	200 kA	600 V		
Branch circuit 6	100 kA	600 V	—	—	—	200 kA	200 kA	600 V		
Branch circuit 7	2 kA	—	—	—	14 kA	—	14 kA	—		
Sub-feeder circuit 8	—	—	—	—	—	—	—	—		
Feeder circuit 9	—	—	10 kA	600 V	—	—	10 kA	600 V		
Supply circuit 10	—	—	200 kA	600 V	—	—	200 kA	600 V		

Sweep 2: Verifying assembly SCCR based upon overcurrent protective device interrupting rating (or SCCR for combination motor controllers)

Step 1: Determine overcurrent protective device interrupting rating or SCCR:



Branch circuit 1

- Molded case circuit breaker
- IR = 14 kA @ 480/277 V



Branch circuit 2

- High fault short-circuit current rating as Self-protected Type E combination motor controller (with lineside terminal kit)
- SCCR = 65 kA @ 480/277 V

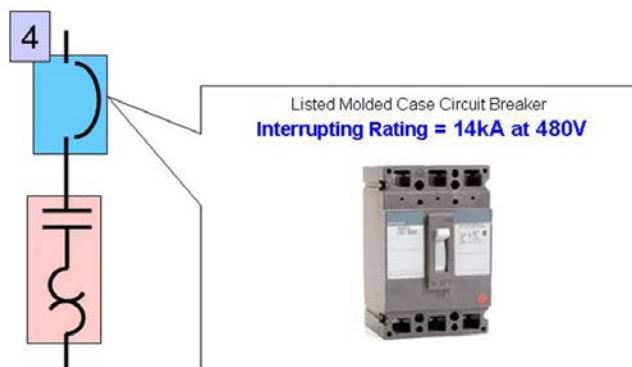
Note: Self-protected Type E combination motor controllers are not rated with an interrupting rating. So for this Step 1, its SCCR is used per UL 508A.



Branch circuit 3

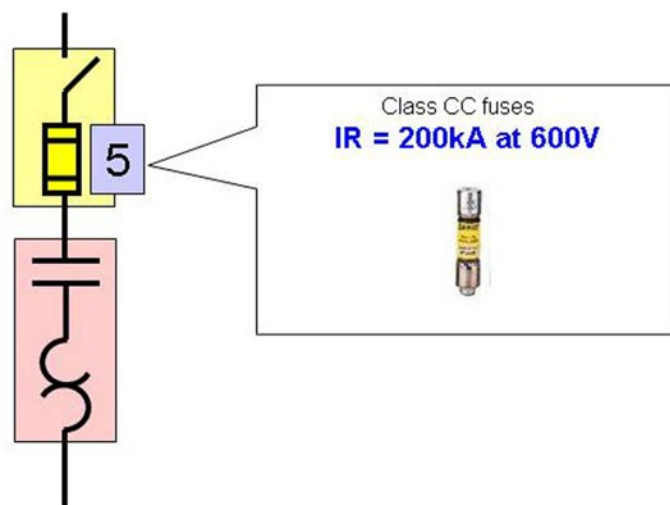
- MCP — High fault short-circuit current rating as Type D combination motor controller rating with IEC Starter (same manufacturer)
- SCCR = 65 kA @ 480 V

Note: Per UL 508A, in order to ensure proper application in industrial control panels, the MCP must be procedure described to verify use as part of a listed Type D combination motor controller and the corresponding SCCR.



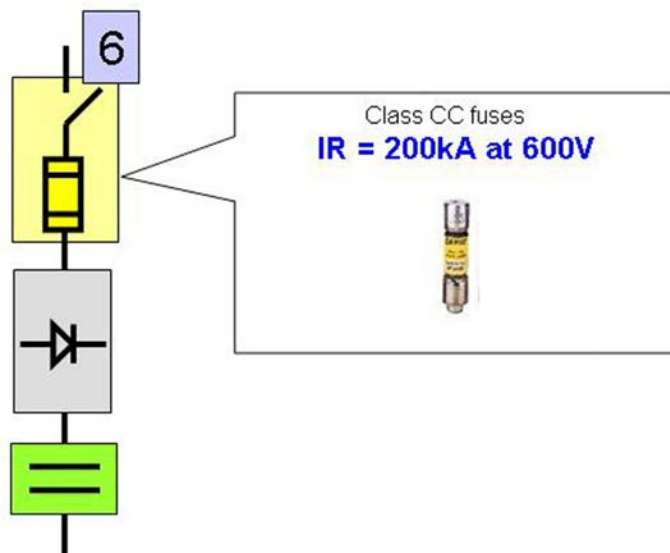
Branch circuit 4

- Molded case circuit breaker
- IR = 14 kA @ 480 V



Branch circuit 5

- Bussmann series LP-CC fuses
- IR = 200 kA @ 600 V

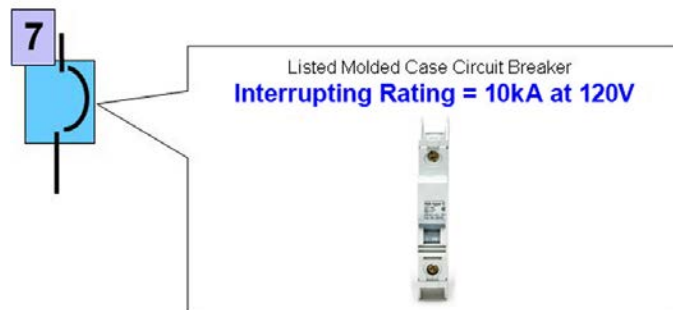


Branch circuit 6

- Bussmann series LP-CC fuses
- IR = 200 kA @ 600 V

Verifying assembly overcurrent protective device interrupting rating or SCCR of combination motor controller

Step 2: Identify the lowest overcurrent protective device interrupting rating or SCCR of combination motor controller.



Branch circuit 7

- Molded case circuit breaker analyzed in Sweep 1, Step 3
- IR = 10 kA, but raised to 14 kA due to transformer and interrupting rating of sub-feeder circuit 8 molded case circuit breaker



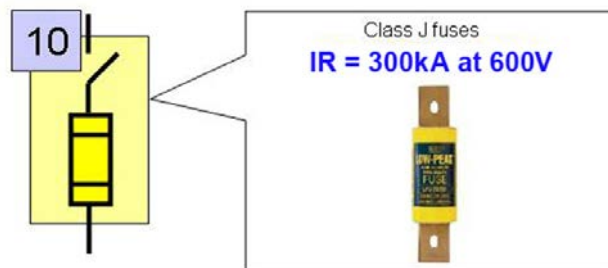
Sub-feeder circuit 8

- Molded case circuit breaker
- IR = 14 kA @ 480/277 V



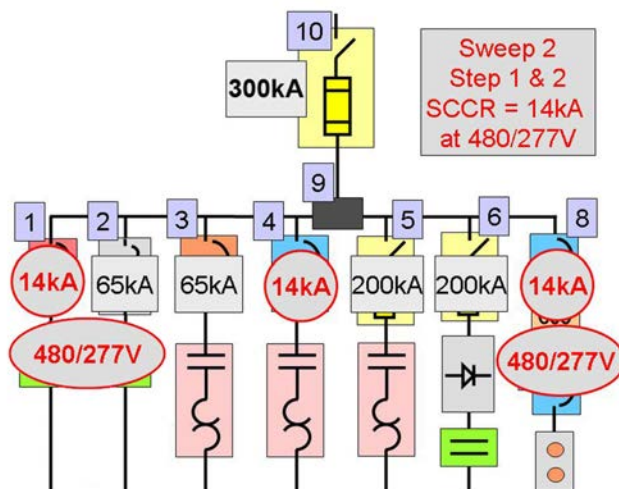
Feeder circuit 9

- No overcurrent protective device in this circuit



Supply circuit 10

- Bussmann series 100 A LPJ fuses
- IR = 300 kA @ 600 V



Results of Sweep 2, Steps 1 and 2: SCCR = 14 kA @ 480/277 V (Sweep 2, Step 2 only)

Summary

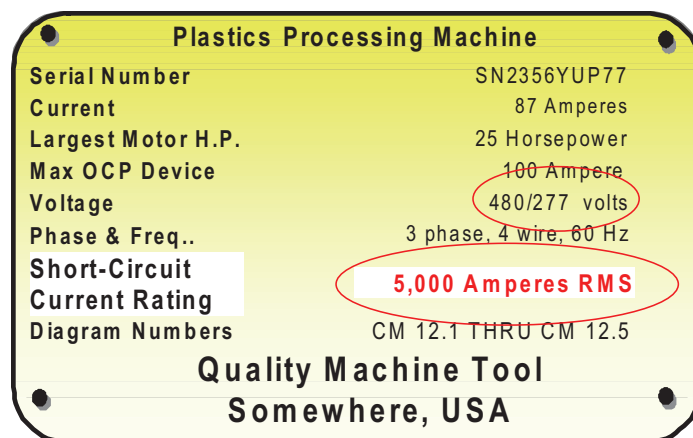
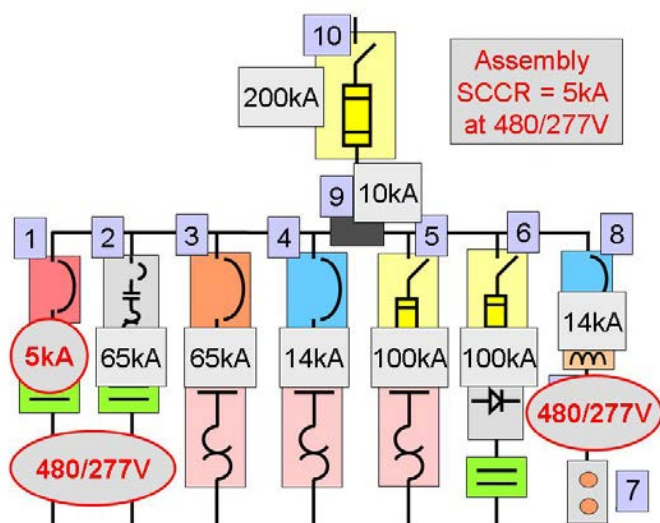
- The lowest overcurrent protective device interrupting rating or SCCR of combination motor controllers in this Step is 14 kA @ 480/277 V based upon the interrupting rating of branch circuits 1, 2, 4 and sub-feeder circuit 8

Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results		Sweep 2-Steps 1 and 2 (overcurrent device)	
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V	—	—	—	—	5 kA	600 V	14 kA	480/277 V
Branch circuit 2	65 kA	480/277 V	—	—	—	200 kA	200 kA	480/277 V	65 kA	480/277 V
Branch circuit 3	65 kA	480 V	—	—	—	200 kA	200 kA	480 V	65 kA	480 V
Branch circuit 4	25 kA	480 V	—	—	—	200 kA	200 kA	480 V	14 kA	480 V
Branch circuit 5	100 kA	600 V	—	—	—	200 kA	200 kA	600 V	200 kA	600 V
Branch circuit 6	100 kA	600 V	—	—	—	200 kA	200 kA	600 V	200 kA	600 V
Branch circuit 7	2 kA	—	—	—	14 kA	—	14 kA	—	—	—
Sub-feeder circuit 8	—	—	—	—	—	—	—	—	14 kA	480/277 V
Feeder circuit 9	—	—	10 kA	600 V	—	—	10 kA	600 V	—	—
Supply circuit 10	—	—	200 kA	600 V	—	—	200 kA	600 V	300 kA	600 V

Step 3: Determine final assembly SCCR based upon results of Sweep 1 (component SCCR) and Sweep 2 (overcurrent protective device interrupting rating or SCCR for combination motor controller).

- Sweep 1 lowest SCCR = 5 kA @ 480/277 V
- Sweep 2 lowest IR or SCCR = 14 kA @ 480/277 V
- Resulting assembly SCCR = 5 kA @ 480/277 (see figure below)



Example of assembly SCCR label marking based on the "2 Sweep" method.

Note: The assembly would have to be marked with 5 kA SCCR and 480/277 V. Equipment with 480/277 V devices are suitable for only 480/277 V solidly grounded Wye systems and cannot be applied on 480 V ungrounded, resistance grounded or corner grounded systems. See the section on Slash Voltage Ratings for more information.)

Results of Sweep 2, Step 3: assembly SCCR = 5 kA, voltage = 480/277

Summary

- The lowest SCCR of both Sweep 1 and Sweep 2 is 5 kA @ 480/277 V
- The 5 kA SCCR is based on the contactor in branch circuit 1, analyzed in Sweep 1 - Step 1
- The 480/277 V slash voltage rating is from multiple components in Sweep 1 - Steps 1 and 5, and Sweep 2, Steps 1, 2 and 3
- The assembly SCCR is 5 kA @ 480/277 V

Note: Red table cells denote limiting components and voltages for each step.

	Assessment		SCCR Revisions				Sweep 1 Results		Sweep 2-Steps 1 and 2 (overcurrent device)	
	Sweep 1-Step 1 (branch)		Sweep 1-Step 2 (feeder)		Sweep 1-Step 3 (trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Volts	SCCR	Volts	SCCR	SCCR	SCCR	Volts	IR/SCCR	Volts
Branch circuit 1	5 kA	600 V	—	—	—	—	5 kA	600 V	14 kA	480/277 V
Branch circuit 2	65 kA	480/277 V	—	—	—	200 kA	200 kA	480/277 V	65 kA	480/277 V
Branch circuit 3	65 kA	480 V	—	—	—	200 kA	200 kA	480 V	65 kA	480 V
Branch circuit 4	25 kA	480 V	—	—	—	200 kA	200 kA	480 V	14 kA	480 V
Branch circuit 5	100 kA	600 V	—	—	—	200 kA	200 kA	600 V	200 kA	600 V
Branch circuit 6	100 kA	600 V	—	—	—	200 kA	200 kA	600 V	200 kA	600 V
Branch circuit 7	2 kA	—	—	—	14 kA	—	14 kA	—	—	—
Sub-feeder circuit 8	—	—	—	—	—	—	—	—	14 kA	480/277 V
Feeder circuit 9	—	—	10 kA	600 V	—	—	10 kA	600 V	—	—
Supply circuit 10	—	—	200 kA	600 V	—	—	200 kA	600 V	300 kA	600 V

Increasing assembly SCCR — “FIX IT”

What follows are methods to increase, or “FIX,” a low assembly SCCR using the appropriate overcurrent protective devices with higher interrupting ratings and components with high fault SCCR.

To increase the assembly SCCR, identify the “weak links” and determine alternatives to increase the SCCR. Industrial control panels are required to be marked with an SCCR. NEC 409.22 requires the industrial control panel SCCR to be not less than the available fault current. Many OEMs and end users are finding that SCCR ratings of 65 kA, 100 kA, or higher with full voltage ratings (480 V in lieu of 480/277 V) are often needed to ensure NEC compliance and provide flexibility for future changes to the system or when moving the assembly to another location. The process to “FIX” these “weak links” follows.

“Weak link” 1 — Branch circuit 1: SCCR = 5 kA and slash voltage rated devices

The first “weak link” from the “Two Sweep” example is the IEC contactor (5 kA SCCR) and the slash voltage rated circuit breaker (480/277 V) from branch circuit 1. As shown in Figure 7.12.1.j, not only does the circuit breaker have a low interrupting rating (14 kA) and is slash voltage rated (480/277 V), but the other circuit components, such as the IEC contactor (5 kA), can additionally limit the SCCR since high fault SCCR are not available.

The solution is to use a fully rated overcurrent protective device with a high interrupting rating and a high fault SCCR combination rating with the IEC contactor. In this example, the circuit breaker can be replaced with the Bussmann series Compact Circuit Protector (CCP) with Class CC fuses rated 600 V and 200 kA. Since the Class CC CCP utilizes Class CC fuses, and since the IEC contactor in this example had a high fault SCCR of 100 kA with Class CC fuses, the SCCR is now 100 kA. An additional benefit of the CCP saves space when compared to typical lighting and industrial style circuit breakers.

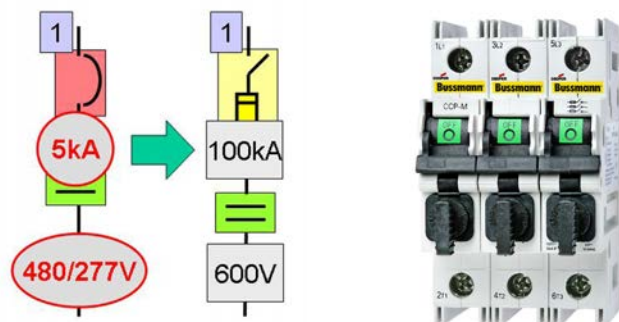


Figure 7.12.1.j The Bussmann series CCP with Class CC fuses can easily increase SCCR by replacing low IR and slash rated OCPDs.

“Weak link” 2 — Feeder circuit 9: SCCR = 10 kA

The next “weak link” is the unmarked power distribution block. The easy solution to this is to find a power distribution block that has a high SCCR when protected by a specific overcurrent device upstream. Since the overcurrent device upstream is a Class J fuse, the solution would be to use a Bussmann series high fault SCCR power distribution block or terminal block. This is important to note, as many power distribution blocks and terminal blocks require a current-limiting fuse to achieve a high fault SCCR. In addition, since the power distribution block is in the feeder circuit, feeder circuit spacings are also required per UL 508A. The Bussmann series PDB (open style) or PDBFS (enclosed style) Series of power distribution blocks are Listed to UL 1953 ensuring compliance with feeder circuit spacing requirements in UL 508A and are UL Listed with high fault SCCR with Class J fuses as shown in Figure 7.12.1.k.

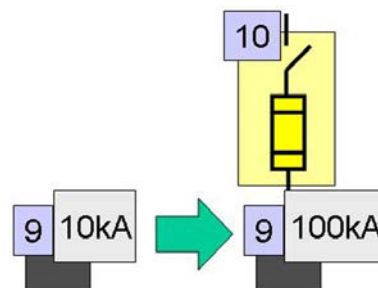


Figure 7.12.1.k

High fault SCCR PDBs

Often the power distribution block is the “weak link” keeping assembly SCCR low. Using high fault SCCR PDBs protected with Class J fuses can deliver a high fault SCCR. The table below shows the possible high fault SCCR.

AWG wire range	Class J fuse max. amps (A)	Combination SCCR (kA)
2-6	400	200
2-14	200	50
	175	100

This power distribution block is rated for use on a circuit capable of delivering no more than the SCCR shown (kA RMS Sym. or DC amps 600 V maximum). For other SCCR options, see Bussmann series data sheet no 10536.



Figure 7.12.1.l power distribution block and power distribution fuse block.

Bussmann series PDBFS's SCCR is only 10 kA with a circuit breaker, unless otherwise indicated in Bussmann series data sheet no 10536.

Enhanced SCCR and component protection is easily achieved by using Bussmann series power distribution fuse blocks that combine the power distribution block and fuse block into one unit. They feature SCCR up to 200 kA, fuse amp ratings up to 400 A and are available in 1-, 2- and 3-pole versions for UL supplemental, Class CC, H(K), J and R fuses.

“Weak Link” 3 — Branch circuit 4: SCCR = 14 kA and sub-feeder circuit 8: SCCR = 14 kA and slash voltage rating

The next “weak link” is the 14 kA circuit breaker in branch circuit 4 and the 14 kA slash rated (480/277 V) circuit breaker in sub-feeder circuit 8. There are two possible solutions for this, either increase the interrupting rating of both circuit breakers and change to a full or straight voltage rated circuit breaker in sub-feeder circuit 8 or change to the Bussmann series CCP (or modular fuse holder if a branch circuit disconnect is not required) as shown in “Weak Link 1.” An economical solution is to change to the Bussmann series CCP or modular fuse holder with Class CC fuses. In branch circuit 4, this change increases the interrupting rating to 200 kA as well as the IEC starter’s SCCR to 100 kA (high fault SCCR) through the use of Class CC fuses so that branch circuit 4 is now rated 100 kA. The change to sub-feeder circuit 8 not only increases the interrupting rating to 200 kA, but also improves the voltage rating from 480/277 V (limits the assembly) to 600 V (not limited). This remedy is shown in Figure 7.12.1.m.

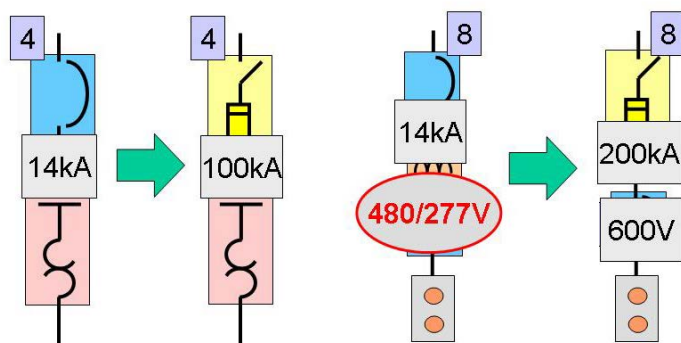


Figure 7.12.1.m

“Weak Link” 4 — Branch circuit 2: slash voltage rated components

The next “weak link” is the slash voltage rating in branch circuit 2. While the self-protected Type E combination motor controller is compact in size and has a relatively high fault SCCR (65 kA), it typically comes with a slash voltage rating. The solution is to either add an overcurrent device with a high interrupting rating ahead of the self-protected Type E combination motor controller (changing this device’s application to a manual motor controller) or change to the CCP or modular fuse holder with Class CC fuses and a magnetic starter. The most economical solution to achieve a high SCCR and full voltage rating is to change to the CCP or modular fuse holder with Class CC fuses and a magnetic starter. With this change the circuit is rated 100 kA @ 600 V. This remedy is shown in Figure 7.12.1.n.

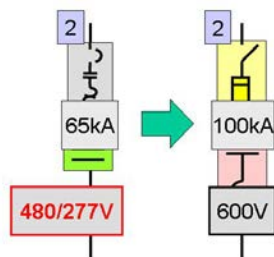


Figure 7.12.1.n

“Weak Link” 5 — Branch circuit 2, 3 and 4: manufacturer limitation

Where fusible devices are used in motor circuits, high fault SCCR with motor circuit components from multiple manufacturers are available increasing an OEMs’ flexibility in sourcing components. This typically reduces costs and provides alternatives during extended product delivery situations. For instance, fuses protecting motor circuit components listed at 100 kA high fault SCCR generally are available from several motor circuit component manufacturers. In contrast, the self-protected Type E combination motor controller and contactor in branch circuit 2 requires the same manufacturer for each component to be selected if high fault SCCRs are desired. This remedy is shown in Figure 7.12.1.o.

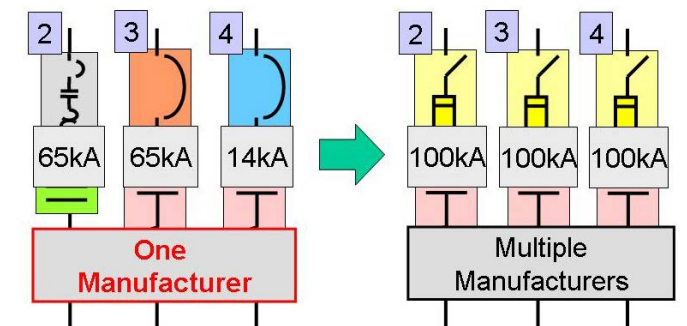


Figure 7.12.1.o

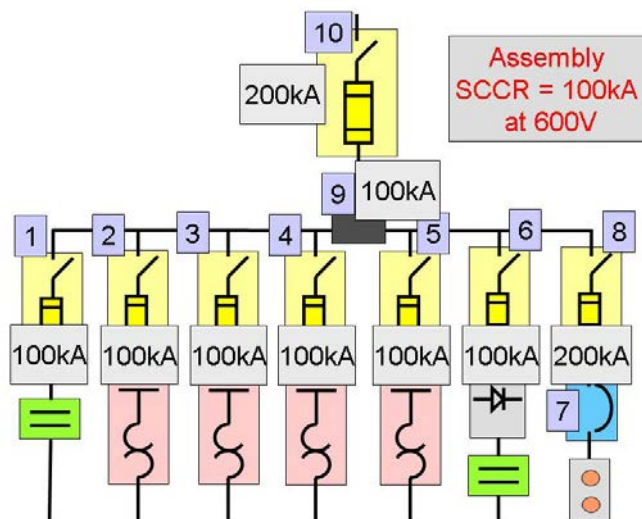
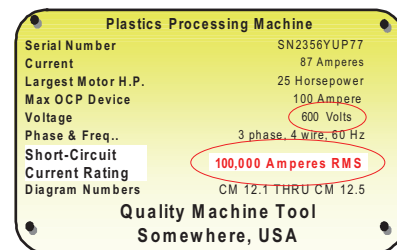


Figure 7.12.1.p

“FIX IT” Summary

The Figure 7.12.1.p shows the solutions to the “weak links.” The panel now has a high assembly SCCR with a full voltage rating.

Increasing assembly SCCR: “FIX IT” — typical “weak links” and improving SCCR

The following table highlights the typical “weak links” in industrial control panels and provides Bussmann series product solutions, along

with the added benefits that these solutions can provide for industrial control panels.

“Weak link”		“FIX IT”	
UL 1077 supplemental protectors		Increase the interrupting rating	
 Limiting factors: - Some may have an interrupting rating of 5 kA to 10 kA. Default rating is 200 A if unmarked. - Not permitted for feeder or branch circuit protection.		 Use Bussmann series current-limiting fuses and the CCP (Class CC or CUBEFuse) or modular fuse holder to achieve high fault SCCRs by replacing the low interrupting rated UL 1077 supplementary protector with modern current-limiting fuses with high IRs of up to 300 kA and UL 4248 modular fuse holders or UL 98 disconnects with SCCR of 200 kA.	
UL 489 instantaneous trip circuit breaker (MCP)		Increase the interrupting rating	
 Limiting factors: - SCCR is dependent upon Type D combination motor controller high fault SCCR when used with a listed combination motor controller. Default rating can be as low as 5 kA. Varies by manufacturer. - Procedure described to verify proper application.		 Use Bussmann series current-limiting fuses and the CCP (Class CC or CUBEFuse) or modular fuse holder to achieve high fault SCCR. Modern current-limiting fuses are available with high interrupting ratings of up to 300 kA and UL 4248 modular fuse holders or UL 98 disconnects are available with SCCR of 200 kA.	
Power distribution block in feeder circuit		Use power distribution blocks with high SCCR	
 Limiting factors: - If the power distribution block is not marked (or indicated in instruction sheets) with a high fault SCCR, the 10 kA default rating must be used. - For feeder circuit applications, power distribution blocks must have feeder spacings per UL 508A. - Power distribution blocks recognized to UL 1059 typically do not comply.		 Bussmann series PDBs Listed to UL 1953 with high SCCRs up to 200 kA when protected by Class J and CF fuses. By replacing a low rated PDB with a finger-safe PDBFS a panel can achieve the high fault SCCR and proper spacings needed for feeder circuit applications. Also consider using power distribution fuse blocks that simplify wiring, reduce components and deliver up to 200 kA SCCR with amp ratings up to 400 A.	
UL 489 molded case circuit breakers with low interrupting ratings		Increase the interrupting rating	
 Assembly limiting factor: - Typically have interrupting ratings of 10 kA to 14 kA. - Higher interrupting ratings are available at increased cost.		 Use Bussmann series current-limiting fuses and the CCP (Class CC or CUBEFuse) or modular fuse holder to achieve high fault SCCR by replacing the low interrupting rated circuit breaker with modern current-limiting fuses which are available with high interrupting ratings of up to 300 kA. UL 4248 modular fuse holders or UL 98 disconnects are available with SCCR of 200 kA.	
Self-protected Type E combination motor controller		Use a device with a straight voltage rating	
 Assembly limiting factor: - Slash voltage rating (480/277 V) limits the application options for the assembly to only a solidly grounded Wye system. - Line-to-ground interrupting capability is limited. - SCCR at 600/347 V is typically limited. - May require additional lineside adapter accessory to be used as a self-protected Type E combination motor controller.		 Use Bussmann series current-limiting fuses and the CCP (Class CC or CUBEFuse) or modular fuse holder with high fault SCCR and straight voltage rated motor controller to allow for installation on any type of system grounding.	

Additional SCCR resources

FC² Available Fault Current Calculator

Bussmann series FC² Available Fault Current Calculator is the online and mobile app that makes it easy to calculate fault current levels and generates NEC 110.24 compliant labels and one-line diagrams. Knowing available fault current is vital for compliance with NEC and OSHA SCCR requirements. This free mobile (Apple and Android devices) can be downloaded at the app store, or use the web-based version.

The SCCR Protection Suite

The SCCR Protection Suite provides OEM designers an easy means to fix weak links. This online application provides access to a comprehensive product portfolio of circuit protection and wiring distribution/termination/switching devices (and their component SCCRs) to meet SCCR needs up to 200 kA.

OSCAR™ SCCR online compliance software

Bussmann series OSCAR SCCR online compliance software easily guides subscribers through entering an electrical panel's components to calculate the equipment SCCR, provide a one-line diagram and detailed documentation. This online application is a quick and accurate means for compliance with 2017 NEC and UL 508A Supplement SB equipment SCCR marking requirements. Request a free 7-day trial.

7.13 Industrial machinery



NEC 670 covers the installation requirements for industrial machinery and NFPA 79 is the electrical standard for industrial machinery.

670.2 defines industrial machinery as a power driven machine (or group of machines), not portable by hand while working, which is used to process material. It can include associated equipment used to transfer material or tooling, to assemble/disassemble, to inspect or test, or to package. The associated electrical equipment is considered as part of the industrial machine.

670.3(A) requires the industrial machinery to be marked with the following:

- Voltage, number of phases, frequency and full-load current for each supply circuit
- Maximum amp rating of the short-circuit and ground-fault protective device
- Amp rating of the largest motor
- Short-circuit current rating (SCCR) based on the assembly's listing and labeling or an approved method such as UL 508A, Supplement SB.

To determine the SCCR of an industrial machine control panel, follow the procedure for industrial control panel SCCR in this publication.

Unlike industrial control panels, 670.4(B) requires a disconnecting means. If overcurrent protection is included with the disconnecting means, it is required to be marked as such per 670.3(B). Overcurrent protection is required to be provided and sized in accordance with 670.4(C) ahead of the industrial control panel, or by a single main OCPD within the panel.

Similar to industrial control panels, the overcurrent protection is required to not be greater than the sum of the largest rating or setting of the branch-circuit short-circuit and ground-fault protective device provided with the industrial control panel, plus 125 percent of the full-load current rating of all resistance heating loads, plus the sum of the full-load currents of all other motors and apparatus that could be in operation at the same time.

NEC 670.5 prohibits installing industrial machinery where the available fault current exceeds the SCCR as marked in accordance with 670.3(A). It also requires industrial machinery to be marked in the field with the maximum available fault current at the point of installation. This marking is required to include the date the fault current calculation was performed and withstand the environment involved. Typically where fault currents exceed 5000 A, the designer and installer need to advise the industrial machinery's manufacturer of the available fault current so industrial machinery with adequate SCCR can be designed/manufactured. The use of current-limiting fuses may be required to achieve an SCCR adequate for the installation.

In addition, NEC 670.6 requires industrial machinery with safety interlock circuits to have surge protection installed.

7.14 Motor/motor circuit protection

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Overview

Of all the branch circuits encountered in the electrical industry, motor branch circuits remain the most unique. Listed here are a few reasons why:

- The harsh demand of motor loads, such as inrush and locked rotor currents
- The desire for various functionality, such as remote push button and automatic control
- The multitude of potential device types used in motor circuits and associated permitted functions for different parts of the motor circuit
- Combination of higher probability to incur faults and many motor circuit components such as starters, overload heaters, and contactors that have low short-circuit current ratings (SCCRs) or may not be completely protected from damage under short-circuit conditions (See Type 2 "No Damage" protection)

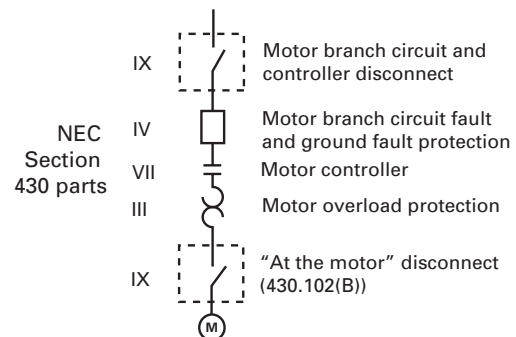


Figure 7.14.a NEC 430 parts.



In order to provide reliable motor branch circuit protection, a thorough understanding of the requirements for various functional motor branch circuits parts and their intended purpose is required. Motor branch circuits can be broken down into 4 and sometimes 5 major functional blocks as shown in Figure 7.14.a. (This figure is a subset of NEC 430.1 found at the beginning of Article 430.)

They include:

1. Motor branch-circuit and controller disconnect
2. Motor branch-circuit short-circuit and ground fault protection
3. Motor controller
4. Motor overload protection
5. Sometimes an additional motor disconnect, often referred to as the “at the motor” or “in sight from motor” disconnect may be required if the motor branch-circuit and controller disconnect is not in sight of the motor and driven machinery location

Overcurrent protection for motor circuits can be broken into two parts:

1. Motor overload protection (430.32)
2. Motor branch circuit short-circuit and ground fault protection (430.52)

Motor overload protective devices provide protection from low-level, long time overcurrent conditions which generally cause motor or motor branch circuit components to overheat over a long period of time (10 seconds or longer). Motor branch circuit devices provide short-circuit and ground fault protection for motor branch circuits and the components of the circuit (i.e. motor starters, conductors, equipment grounding conductors, etc.). Proper OCPD selection is extremely important. If not properly protected from fault currents, motor circuit components can be extensively damaged. It's possible for the component to violently rupture and emit conductive gases that present safety hazards and can lead to other faults.

The motor branch-circuit and controller disconnect and the “at the motor” disconnect provide a means to isolate the motor circuit or motor from the supply source supply for maintenance work (electrically safe work condition) and serves as an emergency disconnect. Motor controllers can be manual or automatic and serve as an ON/OFF function for the motor and, as the name implies, control the motor's operation.

In addition to these functional blocks, there are various requirements for motor control circuit components and other specialized components. This discussion will focus on the motor (power) branch circuit requirements and the devices corresponding thereto. Various devices are available on the market to provide these functions. Some devices perform only one of these functions and some combine multiple functions. Some devices, such as UL 508 disconnects (manual motor controllers) and Manual Motor Protectors (MMPs) have spacing requirements that are less than UL 98 disconnects or UL 489 molded case circuit breakers, and, therefore have limitations on their application.

Suitability for use of motor branch circuit devices

Two of this section's main objectives are to provide an understanding of devices that can be used in motor branch circuits, and then understand how each device must be judged as suitable per the NEC for specific motor circuit functions. Device product listing or recognition is one means to judge suitability for use. However, these facts are often overlooked or ignored, and devices get applied in applications beyond their intended use and listing and posing a safety hazard. It's important for designers and installers to recognize and understand the various NEC motor circuit functions and requirements. Additionally, one needs to know how to read device labeling, markings, and instructions in order to determine the proper applications for devices based on this information and the NEC requirements. NEC 110.3(A) and (B) identify the proper examination, identification, installation and use of equipment. The text of NEC 110.3(A) and (B) is partially reprinted here.

110.3 Examination, Identification, Installation, Use, and Listing (Product Certification) of Equipment.

(A) Examination. In judging equipment, considerations such as the following must be evaluated:

- (1) Suitability for installation and use in conformity with the provisions of this Code

Informational Note 1: Equipment may be new, reconditioned, refurbished or remanufactured.

Informational Note 2: Suitability of equipment use may be identified by a description marked on or provided with a product to identify the suitability of the product for a specific purpose, environment, or application. Special conditions of use or other limitations and other pertinent information may be marked on the equipment, included in the product instructions, or included in the appropriate listing and labeling information. Suitability of equipment may be evidenced by listing or labeling.

(B) Installation and Use. Listed or labeled equipment must be installed and used in accordance with any instructions included in the listing or labeling.

(C) Listing. Product testing, evaluation, and listing (product certification) must be performed by recognized qualified electrical testing laboratories and must be in accordance with applicable product standards recognized as achieving equivalent and effective safety for equipment installed to comply with this Code.

In addition, the specific application must comply with NEC 110.9 and 110.10. This means each OCPD must have an interrupting rating equal to or greater than the available fault current, and the SCCR for each component must be equal to or greater than the available fault current.

Table 7.14.b summarizes the suitability of some common devices for the five possible NEC motor branch circuit functions. The device suitability should be evidenced by its product listing mark and any instructions included in the listing or labeling. The NEC requirements for each function are found in Article 430 under their respective parts as shown in Figure 7.14.b. Remember, for specific applications all OCPD interrupting ratings (NEC 110.9) and all component SCCRs (NEC 110.10) must be equal to or greater than the available fault current at the point of installation.



	UL 248 fuses and disconnect	UL 489 circuit breaker	Instantaneous trip circuit breaker	Self protected combination starter (Type E starter)	IEC manual motor controller (manual motor protector)	Magnetic motor starter	Manual motor Controller (UL 508 switch)	UL 1077 supplemental protector
Allowed uses per NFPA 79 and NEC								
Motor branch circuit and controller disconnect	Yes ¹	Yes	Yes ^{5,6}	Yes ^{6,7}	No	No	No	No
Motor branch circuit fault and ground fault protection	Yes	Yes ⁸	Yes ^{5,6}	Yes ^{6,8}	No	No	No	No
Motor controller Motor overload protection	Yes ²	Yes	No	Yes ⁹	Yes ⁹	Yes	Yes ⁹	No
"At the motor" disconnect (430.102(B))	Yes ²	Yes	No	Yes ¹⁰	Yes ¹⁰	Yes	No	No
"At the motor" disconnect (430.102(B))	Yes ²	Yes	No	Yes	Yes ⁴	No	Yes ⁴	No

Figure 7.14.b

- When used in conjunction with a UL 98 fusible switch.
- Where used in conjunction with a UL 98 or UL 508 fusible switch. If UL 508 switch, see footnote 4.
- Often cannot be sized close enough.
- Must be located on the Loadside of motor branch short-circuit protective device, marked "Suitable as Motor Disconnect," and be provided with a lockable handle.

- When used in conjunction with a motor starter as part of a listed and labeled combination motor controller.
- Limited to single motor circuit applications.
- Additional terminal kit often required.
- If slash voltage rated, limited to solidly grounded Wye systems ONLY.
- Additional contactor required for remote control.
- Class 10 overload protection only.

7.14.1 Motor branch circuit devices

Branch circuit fuses as listed to UL/CSA/ANCE 248 Standards

Branch circuit fuses cannot be replaced with fuses having a lower voltage rating, and current-limiting branch circuit fuses installed in rejection-style clips cannot be replaced with non-current-limiting fuses. UL branch circuit fuses are Class CC, CF, G, H, J, K1, K5, L, RK1, RK5 and T, and plug fuses. These fuses are listed for branch, feeder, and main protection and have interrupting ratings that range from 10 kA to 300 kA. In a motor circuit they provide branch circuit, short-circuit, and ground fault protection. In addition, enhanced overcurrent protection such as back-up overload and Type 2 "No Damage" protection can be provided by selecting certain fuse types and ratings.

Allowed uses

- Motor branch short-circuit and ground fault protection
- Motor overload protection (some fuse types based upon their amount of time delay)
- Group motor protection as the short-circuit and ground fault protective device per NEC 430.53
- Motor branch circuit and "at-the-motor" disconnecting means when used in conjunction with a UL 98 fusible switch
- Motor controller when used in conjunction with a UL 98 fusible switch, UL 508 manual motor controller, or UL 1429 pullout switches

Identification

Fuses listed to UL/CSA/ANCE 248 will contain a marking near the agency symbol. This marking should read "Listed Fuse."



Disconnect switches (fused and non-fused) listed to UL 98

Disconnect switches from 30 to 6000 A that may be used in mains, feeders and branch-circuits for service equipment, panelboards, switchboards, industrial control equipment and motor control centers. They may also be used as a motor controller (ON/OFF function) to meet NEC Article 430, Part VII, and may be used as both a motor branch-circuit disconnect (NEC 430.109) or "at-the-motor" disconnect and a motor controller (NEC 430.111).



Allowed uses

- Motor branch circuit and controller disconnect or "at-the-motor" disconnect
- Motor controller

Identification

Disconnect switches as listed to UL 98 will contain a marking near the agency symbol. This marking should read "Listed Misc. Sw." or "Open Type Switch."



Pullout switches listed to UL 1429

Fused and non-fused switches ranging from 30 to 400 A at 600 V or less. Pullout switches with horsepower ratings are suitable for branch-circuit and controller disconnect or “at-the-motor” disconnect to meet NEC 430.109, as motor controllers to meet NEC Article 430 Part VII (if rated 100 Hp or less. Per UL 1429, pullout switches are not permitted to be used as a motor controller for motors above 100 Hp), and in general use for panelboards, switchboards, etc. They may be used as both a motor branch circuit and controller disconnect or “at-the-motor” disconnect, and a motor controller to meet NEC 430.111. Pullout switches with only amp ratings (no Hp ratings) are suitable only for general use, not motor circuits. If they are marked “Motor Circuit Pullout Switch,” they may only be used in a motor circuit. When used with properly sized branch circuit fuses, pullout switches may be used for motor, motor circuit and group motor protection.

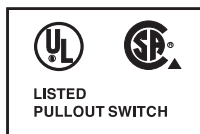


Allowed uses

- Motor branch circuit and controller disconnect or “at-the-motor” disconnecting means
- Motor controller

Identification

Pullout switches listed to UL 1429 will contain a marking near the agency symbol. This marking should read “Listed Pullout Switch.”



Motor switches (manual motor controllers) listed to UL 508

UL 508 switches may be used as a motor controller (ON/OFF function) to meet NEC Article 430 Part VII. As motor controllers, they have creepage and clearance distances that are less than those required by UL 98. As a result, they can’t be used as a motor branch circuit and controller disconnect to meet NEC 430.109. If the device is listed as a “Manual Motor Controller” and is additionally marked “Suitable As Motor Disconnect,” it’s permitted to serve as an “at-the-motor” disconnect if it’s located between the final motor branch circuit short-circuit and ground fault protective device, and the motor. This listing is optional; verification will be required if it’s intended to be used for this purpose.

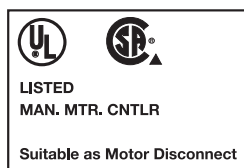


Allowed uses

- Motor controller
- “At the Motor” disconnect if marked “Suitable as Motor Disconnect” and located between the final motor branch-circuit short-circuit and ground fault protective device and the motor.

Identification

Motor switches/manual motor controllers listed to UL 508 will contain a marking near the agency symbol. This marking should read “Listed Manual Motor Controller” or an abbreviation such as “Man. Mtr. Cntrl.” Manual motor controllers listed for use as an “at-the-motor” disconnect means will be marked “Suitable as Motor Disconnect.”



Fuse holders listed to UL 4248

When used with a motor branch-circuit and controller disconnect, and properly sized branch-circuit fuses, fuse holders may provide main, feeder, branch circuit, motor circuit, and group motor protection. They can’t be used alone as a motor branch circuit and controller disconnect or as an “at-the-motor” disconnect to meet NEC 430.109, nor can they be used alone as a motor controller (ON/OFF function) to meet NEC Article 430, Part VII.



Identification

Fuse holders listed to UL 4248 will contain a marking near the agency listing symbol. This marking should read “Listed Fuse Holder.”



Thermal-magnetic (inverse time) circuit breakers listed to UL 489

Circuit breakers listed to UL 489 are intended to provide branch, feeder and main protection, with interrupting ratings from 5 kA to 200 kA. Properly sized inverse time circuit breakers provide motor branch circuit short-circuit and ground fault protection. They may be used for group motor protection and are suitable for use as a motor branch circuit and controller disconnect or “at-the-motor” disconnect per NEC 430.109, as a motor controller (ON/OFF function) per NEC Article 430 Part VII, and as both a motor branch circuit and controller disconnect, or “at-the-motor” disconnect and motor controller per NEC 430.111.



Allowed uses

- Motor branch circuit short-circuit and ground fault protection
- Motor overload protection
- Group motor protection as the short-circuit and ground fault protective device per NEC 430.53
- Motor branch circuit and controller disconnect or “at-the-motor” disconnect
- Motor controller

Identification

Circuit breakers listed to UL 489 will contain a marking near the agency symbol. This marking should read “Listed Circuit Breaker” or an abbreviation such as “Cir. Bkr.”



Instantaneous trip circuit breakers (MCPs) recognized to UL 489

Circuit breakers without overload (thermal) protection capability are known as MCPs. They're intended to provide only branch circuit short-circuit and ground fault protection for individual motor branch circuits. They may not be used to provide main, motor feeder, motor overload, general branch circuit or group motor protection. Because they're only recognized and not listed, they can't be used with any manufacturer's control equipment. NEC 430.52 requires that MCPs must only be used as part of a listed combination controller (typically from the same manufacturer). MCPs are only short-circuit tested in combination with a motor controller and overload device. As a result, they're not labeled with an interrupting rating by themselves. Per NEC 430.109, they may be used as a motor branch circuit and controller disconnect or "at-the-motor" disconnect only as a part of a listed combination motor controller.

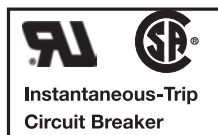


Allowed uses

- Motor branch circuit short-circuit and ground fault protection only when part of a listed combination motor controller
- Motor branch circuit and controller disconnect or "at-the-motor" disconnect only when part of a listed combination motor controller
- Motor controller

Identification

Instantaneous trip circuit breakers recognized to UL 489 will contain a UL recognition or CSA component acceptance marking. This marking indicates that the product can't be used "stand alone" and is limited to certain conditions of use.



Molded case switches listed to UL 489

Molded case switches can be used with fuses and are very similar to molded case thermal magnetic circuit breakers, except they don't have any thermal overload protection, and may or may not be equipped with a "magnetic" instantaneous trip as a self-protect mechanism. They may be used in mains, feeders and branch circuits for service equipment, panelboards, switchboards, industrial control equipment, motor control centers and motor branch circuits. They are suitable for use as a motor branch circuit and controller disconnect or "at-the-motor" disconnect per NEC 430.109. They may be used as a motor controller (ON/OFF function) to meet NEC Article 430 Part VII and as both a motor branch circuit and controller disconnect or "at-the-motor" disconnect and motor controller to meet NEC 430.111.



Allowed uses

- Motor branch circuit and controller disconnect or "at-the-motor" disconnect
- Motor controller

Identification

Molded case switches listed to UL 489 will contain a marking near the agency symbol. This marking should read "Listed Molded Case Switch."



Self-protected combination starters (Type E) listed to UL 508

Self-protected combination starters could be referred to as "coordinated protected starters," "self-protected starters," "self-protected combination controllers," "Type E combination starters" or "Type E starters." In some cases, self-protected combination starters can be marked and applied as either self-protected combination starters or manual motor controllers. However, the device ratings will typically be much more restrictive when applied as a self-protected combination starter. Self-protected combination starters are intended to provide motor overload and motor branch circuit short-circuit and ground fault protection by combining a magnetic short-circuit trip and adjustable motor overload in one package. A self-protected combination starter is a listed combination starter suitable for use without additional motor branch circuit overcurrent protection, and is limited to single motor circuits. Type E starters have additional test requirements for low level short-circuit interrupting tests followed by endurance tests that are not required for other combination motor controllers. Self-protected starters can be either manual or electro-mechanical.



A slash voltage rated self-protected combination starter is limited to use only on solidly grounded Wye systems. They can't be used on ungrounded, corner grounded or impedance grounded systems. Creepage and clearance on the line terminals must be the same as UL 489 and UL 98 devices. Because of this, a self-protected combination starter that's marked for use with a terminal kit must be installed with a terminal kit to ensure lineside terminal spacings are adequate. Additional accessories, such as lockable handles, may be needed in order for the device to be suitable for use. Self-protected combination starters are suitable for use as a motor branch circuit and controller disconnect or "at-the-motor" disconnect per NEC 430.109, as a motor controller (ON/OFF function) per NEC Article 430, Part VII, and as both a motor branch circuit disconnect or "at-the-motor" disconnect and motor controller per NEC 430.111. These devices are only permitted on single motor branch circuits.

Allowed uses

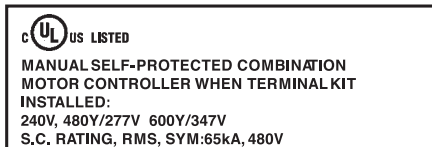
- Motor branch circuit short-circuit and ground fault protection
- Motor overload protection
- Motor branch circuit and controller disconnect or "at-the-motor" disconnect
- Motor controller

Identification

Self-protected combination starters as listed to UL 508 will contain a marking near the agency symbol. For factory-assembled units, this marking should read "Listed Self-Protected Combination Motor Controller." If separate components are used, the manual self-protected combination starter must be marked "Self-Protected Combination Motor Controller when used with (manufacturer and loads side component catalog number or "Motor Controllers Marked For Use With This Component"). If not marked with manufacturer and catalog number, the other assembly components must be marked "Suitable For Use On Loadside Of (manufacturer and catalog number) Manual Self-Protected Combination Motor Controller."

Additionally, self-protected combination starters which are limited in application to only solidly grounded Wye systems will be marked as slash voltage rated, e.g., 480Y/277 V or 600Y/347 V.

When marked as slash voltage rated, they can't be used on ungrounded, corner grounded, or impedance grounded systems.



Type F combination starters listed to UL 508

An IEC contactor combined with a self-protected combination starter, may be referred to as a "Type F" starter. However, this does not make it a "self-protected" starter unless tested and listed as a "Type E" starter. If listed as a Type F combination starter, the additional tests required for Type E starter status have not been performed.

Allowed uses

- Motor branch circuit short-circuit and ground fault protection
- Motor overload protection
- Motor branch circuit and controller disconnect or "at-the-motor" disconnect
- Motor controller

Identification

Type F combination starters listed to UL 508 will contain a marking near the agency symbol. For factory assembled units, this marking should read "Combination Motor Controller." If separate components are used, the manual self-protected combination starter must be marked "Combination Motor Controller when used with (manufacturer's loadside component and catalog number or "Motor Controllers Marked For Use With This Component". If not marked with manufacturer and catalog number, the other assembly components must be marked "Suitable For Use On Loadside Of (manufacturer and catalog number) Manual Self-Protected Combination Motor Controller."

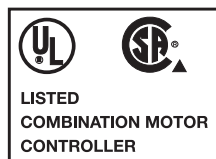
Additionally, Type F combination starters which are limited in application to only solidly grounded Wye type systems will be slash voltage rated marked, e.g., 480Y/277 V or 600Y/347 V. When slash voltage rated marked, they can't be used on ungrounded, corner grounded, or impedance grounded systems.

Manual motor controllers (manual motor protectors) listed to UL 508

Manual motor starters, sometimes called MMPs, are permitted to provide motor overload protection as required per NEC 430.32, and to provide motor control. MMPs are not listed nor permitted to provide motor branch circuit short-circuit and ground fault protection.

Their creepage and clearance distances are typically not as great as required in UL 489, and, therefore, they cannot be tested and listed as a circuit breaker. They require a motor branch circuit overcurrent protective device and a motor branch circuit and controller disconnect on the lineside for both single motor and group motor applications.

Some IEC manual motor protectors have been tested and listed for group motor applications. This allows several of them to be protected by a single motor branch circuit overcurrent protective device, such as an upstream fuse provided it doesn't exceed the maximum size allowed per the device listing. In group motor applications, other limitations such as horsepower ratings and tap rule restrictions must also be investigated. Devices listed for use in group motor installations will be marked to indicate that they have undergone the appropriate testing, and are suitable for such use.



The slash voltage rating (480Y/277 V) limits their use to only solidly grounded Wye systems. Manual motor controllers may be used as a motor controller (ON/OFF function) to meet NEC Article 430 Part VII. Unless otherwise marked, MMPs do not meet requirements for a motor branch circuit and controller disconnect or "at-the-motor" disconnect as required in NEC 430.109. If it is marked "Suitable as Motor Disconnect," it's permitted to serve as an "at-the-motor" disconnect if it is located between the final motor branch circuit short-circuit and ground fault protective device and the motor. If investigated for tap conductor protection in group motor installations, they can be additionally marked "Suitable for Tap Conductor Protection in Group Installations." These additional markings and listings are optional, so a device marking review will be required if it is intended to be used for this purpose.

Allowed uses

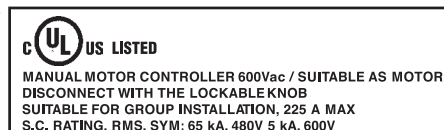
- Motor overload protection
- Group motor applications only as the protected (downstream) device when it's tested, listed and marked, and the upstream fuse (protecting device) is sized within the maximum allowed per the device's listing and other limitations, such as horsepower ratings and tap rules are met.
- Motor controller
- "At-the-motor" disconnect if marked "Suitable as Motor Disconnect" and located between the final motor branch circuit short-circuit and ground fault protective device and the motor.
- Protecting tap conductors in group installations if marked "Suitable for Tap Conductor Protection in Group Installations" and located on the loadside of the final motor branch circuit short-circuit and ground fault protective device.

Identification

Manual motor protectors listed to UL 508 will contain a marking near the agency symbol. This marking should read "Listed Manual Motor Controller" or an abbreviation such as "Man. Mtr. Cntrl."

Manual motor controllers listed for use within group motor applications, as the protected overload/controller device, will be marked for such use along with the required maximum upstream fuse size. Manual motor controllers additionally listed for use as an "at-the-motor" disconnect will be marked "Suitable as Motor Disconnect." Manual motor controllers additionally listed for use to protect tap conductors

in group installations will be marked "Suitable for Tap Conductor Protection in Group Installations."



Integrated starters listed to UL 508

Integrated starters are a modular type motor starter. They consist of an IEC manual motor controller and an IEC contactor. Various controller types, control units, communication modules and accessories are available. Users can select from different components to meet their specific application needs. These starters may be factory assembled units or assembled in the field.

Application requirements are the same as manual motor controllers, including the need for motor branch circuit overcurrent protective device and a lineside disconnect suitable for motor branch circuits and motor controllers upstream.

In some cases, integrated starters may be additionally tested and listed as a self-protected Type E or Type F starter when the appropriate components and accessories are installed. When applied as a self-protected Type E or Type F starter, the device ratings are usually limited compared to the device ratings when applied as a manual motor controller or motor starter.



Magnetic motor starters

Magnetic motor starters combine a magnetic contactor and overload relay. The magnetic starter's overload relay is intended to provide single motor overload protection per NEC 430.32. The magnetic motor starter's horsepower rated magnetic contactor is intended for use as a motor controller (ON/OFF function) to meet NEC Article 430 Part VII. The horsepower rated magnetic contactor also allows for remote motor operation. Available in NEMA or IEC, magnetic motor starters must be protected by a separate motor branch circuit overcurrent protective device per NEC 430.52. A lineside disconnecting means suitable for a motor branch circuit NEC 430.109 must also be installed.

Allowed uses

- Motor overload protection
- Motor controller

Identification

Magnetic motor starters listed to UL 508 will contain a marking near the agency symbol. This marking should read "Listed Industrial Control Equipment" or an abbreviation such as "Ind. Cont. Eq."



7.14.2 Supplemental overcurrent protective devices for use in motor control circuits

Branch circuit vs. supplemental overcurrent protective devices (OCPDs)

Branch circuit OCPDs can be installed anywhere overcurrent protection is needed, from protecting motors and motor circuits, control circuits and group motor circuits, to protecting distribution and utilization equipment. Supplemental OCPDs can only be used where proper overcurrent protection is already being provided by a branch circuit OCPD, by exception (430.72(A)), or if additional overcurrent protection is not required, but desired for increased overcurrent protection and isolating loads. Supplemental OCPDs can often be used to protect motor control circuits, but they can't be used to protect motors or motor branch circuits. A very common misapplication is using a supplemental OCPD, such as a UL Recognized 1077 supplemental overcurrent protective device, for motor branch circuit short-circuit and ground fault protection, and motor branch circuit and controller disconnect or "at-the-motor" disconnect. Supplemental OCPD testing is inferior to the more stringent requirements of branch circuit devices, such as UL Listed 489 circuit breakers. IT'S A SERIOUS MISAPPLICATION AND SAFETY CONCERN to apply these devices beyond their ratings! Caution should be taken to ensure that the proper OCPD is being used for the application. Supplemental OCPDs are described below.

Most supplemental OCPDs have very low interrupting ratings, and caution must be taken to ensure the interrupting rating is equal to or greater than the available short-circuit current.

Supplemental fuses as listed or recognized to the UL/CSA/ANCE 248-14 Standard

Supplemental fuses can have varying voltage and interrupting ratings within the same case size. Supplemental fuse examples are 13/32" x 1-1/2", 5x20 mm and 1/4" x 1-1/4" fuses. Interrupting ratings range from 35 A to 100 kA.



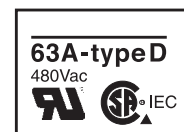
Supplemental protectors ("mini-breakers") recognized to UL 1077

Supplemental protectors (often referred to as mini-circuit breakers) are not permitted for use as a branch circuit OCPD. They are not permitted to provide motor circuit or group motor protection and can only be used for protecting an appliance or other electrical equipment where branch circuit overcurrent protection is already provided, or is not required. Creepage and clearance distances that are less than those required in UL 489, and therefore they can't be listed as a circuit breaker or used as a motor branch circuit and controller disconnect or "at-the-motor" disconnect to meet the requirements of NEC 430.109. Interrupting ratings are typically very low and those devices that are short-circuit tested in series with a fuse must be applied with a branch circuit rated fuse on their lineside.



Identification

Supplemental protectors marked recognized to UL 1077 will contain a recognized symbol rather than a listed symbol.



Warning — Supplemental protectors are NOT suitable for motor branch circuit protection

In numerous applications throughout the industry, supplemental protectors are being improperly used for motor branch circuit overcurrent protection and as motor branch circuit and controller disconnects or "at-the-motor" disconnects. These are MISAPPLICATIONS and their prevalence has prompted numerous safety notices, articles and technical bulletins to alert users to the danger of this practice.

Why supplemental OCPDs are misapplied

Top reasons for misapplication include:

- Supplemental protectors look very similar to molded case circuit breakers leading to the assumption they provide the same protection
- Supplemental protectors are often labeled as circuit breakers or miniature circuit breakers (MCB) in literature
- Per IEC standards, many devices are rated as a circuit breaker and creates confusion between North American and IEC ratings that leads to misapplication

Avoiding misapplication

For correct OCPD application, suitable protection for the motor branch circuit needs to be specified and installed. The simplest correction to any misapplication is to replace a misapplied supplemental OCPD with one that's suitable for branch circuit protection.

How to confirm proper application

NEC 430.52 lists acceptable motor branch circuit short-circuit and ground fault protection devices. Time-delay and non-time delay (fast-acting) branch circuit fuses used in conjunction with a disconnect are acceptable for reliable and safe protection.

Summary

Many reasons lead to misapplication, including mistaking supplemental protectors for North American circuit breakers. The key to properly identifying supplemental protectors is to look for the "recognized" symbol on its marking. If the device is marked "recognized," more than likely it's a supplemental protector and should be replaced with a branch circuit OCPD.

7.14.3 Branch circuit OCPDs and disconnects

Fuse solutions

When selecting fuses, the fuse holder or switch type is very important in determining proper application. While the most economical solutions are often standard UL 4248 Listed fuse holders, they don't offer a fuse disconnecting means as required per NEC 240.40. A disconnecting means can be ahead of the fuse holder or a UL 98 or UL 508 fused disconnect switch can be selected. UL 98 fused disconnects offer the widest range of applications, while UL 508 disconnects are limited to only motor circuit applications with additional restrictions as noted in Figure 7.14.3.a.

The Bussmann series Compact Circuit Protector (CCP) is the smallest, most economical UL 98 Listed fusible disconnect switch available. There are two CCP types: one with Class CC fuses, the other with Class CF fuses. The Class CC CCP is full voltage rated and available up to 30 A. The Class CF CCP (uses the UL Class CF CUBEFuse) is available in DIN-Rail mount and bolt mount versions that are full voltage rated and available up to 100 A.

Red text indicates applications that are limited or restricted.

	UL 98 Listed CCP with Class CC fuses or Class CF CUBEFuse™	UL 4248 Listed fuse holder with Class CC fuses or CUBEFuse with holder	UL 4248 Listed holder with Class CC fuses and UL 508 Listed disconnect (manual motor controller)	UL 508 Listed disconnect (manual motor controller) with integral Class CC fuses	UL 98 Listed disconnect with UL 4248 Listed fuse holder with Class CC fuses	UL 98 Listed fusible disconnect with Class CC or J fuses
Visual reference						
Branch circuit overcurrent protection	Yes	Yes	Yes	Yes	Yes	Yes
Branch circuit disconnect	Yes	No	No	No	Yes	Yes
At the motor circuit disconnect	Yes	No	Yes*†	Yes*	Yes	Yes
Feeder circuit overcurrent protection	Yes	Yes	N/A**	N/A**	Yes	Yes
Feeder circuit disconnect	Yes	No	No	No	Yes	Yes
Cost	\$\$-\$\$\$	\$-\$\$	\$\$\$	\$\$\$	\$\$\$\$	\$\$\$\$\$

* Manual motor controller must be additionally marked "Suitable as Motor Disconnect" and be installed on the loadside of the final branch circuit overcurrent protective device.

**Class CC fuse can provide feeder circuit overcurrent protection but UL 508 manual motor controller cannot be applied in a feeder circuit.

† The manual motor controller is the "at the motor" disconnect, not the fuse holder. Table 1 — CCP compared to fuse holders, disconnects with fuses and fused disconnects

Figure 7.14.3.a CCP compared to fuse holder, disconnect with fuses, and fusible disconnect.

Fuse and circuit breaker solutions

To provide branch or feeder circuit overcurrent protection, the OCPD must be either a UL Listed 248 “Class” fuse or a UL Listed 489 circuit breaker. To provide a branch or feeder circuit disconnect, a UL 98 Listed fused disconnect switch or a UL Listed 489 circuit breaker must be selected. The CCP can replace low-rated circuit breakers or misapplied supplemental protectors in branch circuit applications, and provide a higher short-circuit current rating at a similar or lower cost. The CCP is a cost-effective solution similar in size to a supplemental protector

or lighting-style circuit breaker, but has higher voltage and interrupting ratings with better short-circuit component protection. Compared to a similarly rated industrial circuit breaker, the CCP is one-third the size. Figure 7.14.3.b shows the rating differences between the CCP and a supplemental protector, lighting circuit breaker (240 V and 480Y/277 V) and fully rated (600 V) industrial circuit breaker.

Red text indicates applications that are limited or restricted.

	UL 98 Listed CCP with Class CC or Class CF CUBEFuse	UL 1077 Recognized supplemental protector	UL 489 Listed circuit breaker	UL 489 Listed circuit breaker	UL 489 Listed circuit breaker
Visual representation					
Branch or feeder circuit overcurrent protection	Yes	No	Yes	Yes	Yes
Branch or feeder circuit disconnect	Yes	No	Yes	Yes	Yes
Voltage rating (AC)	600 V	Typically 277 V or less	Typically 240 V or less	Typically 480/277 V† or 600/347 V†	Typically 600 V or less
Interrupting rating	200 kA	Typically 5-10 kA	Typically 10-14 kA	Typically 14-18 kA	Varies 14-100 kA*
Overcurrent protection method	Class CC fuse or CUBEFuse	Thermal magnetic trip	Thermal magnetic trip	Thermal magnetic trip	Thermal magnetic trip
Cost	\$\$\$-\$\$\$\$	\$	\$\$	\$\$\$	\$\$\$\$

* Cost increases as interrupting rating increases.
† Limits application to solidly grounded wye systems only, not permitted on ungrounded, resistance grounded or corner grounded systems.

Figure 7.14.3.b CCP Compared to supplemental protector, lighting circuit breakers and fully rated industrial circuit breakers.

Motor circuit solution comparisons

There are many options available for motor circuits with the CCP along with a magnetic starter providing a very compact, cost-effective solution. Figure 7.14.3.c is an application comparison for the CCP/magnetic starter combination when compared to other viable solutions.

Red text indicates applications that are limited or restricted.

	UL 98 Listed CCP with Class CC or Class CF (CUBEFuse) fuses and magnetic starter	UL 4248 Listed fuse holder with Class CC fuses or CUBEFuse with holder and magnetic starter	UL 508 Listed self-protected starter (SPS) and magnetic contactor	UL 4248 Listed CCP with Class CC or Class CF (CUBEFuse) fuses and manual motor protector (MMP) and magnetic contactor	UL 489 Recognized motor circuit protector (MCP) and magnetic starter**	UL 489 Listed circuit breaker and magnetic starter
Visual representation						
Branch circuit overcurrent protection	Yes	Yes	Yes†††	Yes	Yes**	Yes
Motor circuit disconnect	Yes	No	Yes	Yes*	Yes**	Yes
Voltage rating (AC)	600 V	600 V	Typically 480/277 V† or 600/347 V†	Typically 480 V or 600 V	Typically 600 V	Typically 600 V
SCCR	Typically 100 kA	Typically 100 kA	Typically 30 kA or 65 kA††	Typically 30 kA or 65 kA††	Varies 14 kA to 100 kA***	Varies 14 kA to 100 kA***
High SCCR with multiple manufacturers	Yes	Yes	No	No	No	No
Cost	\$\$-\$\$\$	\$-\$\$	\$-\$\$	\$\$\$-\$\$\$\$	\$\$\$\$\$	\$\$\$\$

* If on loadside of the final branch circuit overcurrent device and MMP is marked "Suitable as Motor Disconnect."

** Must be part of a listed combination, typically from same manufacturer.

*** Cost increases as interrupting rating increases.

† Limits application to solidly grounded wye systems only, not permitted on ungrounded, resistance grounded or corner grounded systems.

†† SCCR is lower at higher voltage rating.

††† May require additional accessories such as lineside terminals, to be used as a self-protected starter.

7.14.3.c CCP Class CC or Class CF and magnetic starter compared to other motor circuit protective devices.

7.14.4 Overload protection

Overcurrents

An overcurrent exists when the normal load current for a circuit is exceeded and can be either an overload or short-circuit. When applied to motor circuits, an overload is any current flowing within the normal circuit path that's higher than the motor's normal Full Load Amps (FLA). A short-circuit (fault) is an overcurrent which greatly exceeds the circuit's normal full load current. Also, as its name infers, a short-circuit leaves the circuit's normal current carrying path and takes a "short cut" around the load and back to the power source. Motors can be damaged by both overcurrent types.

A careful choice of OCPD can protect motors against single-phasing, overworking and locked rotor conditions, to name a few. If left unprotected, motors will continue to operate even under abnormal conditions with the excessive current causing the motor to overheat which, in turn, causes the motor winding insulation to deteriorate and ultimately fail. Good motor overload protection can greatly extend the motor's useful life. Because of a motor's unique operating characteristics, many common OCPD actually offer limited or no protection.

Motor starting currents

When an AC motor is energized, a high inrush current occurs. Typically, during the initial half cycle, the inrush current is often higher than 20 times the normal full load current. After the first half-cycle the motor begins to rotate and the starting current subsides to 4 to 8 times the normal current for several seconds. As a motor reaches running speed, the current subsides to its normal running level. Typical motor starting characteristics are shown in Figure 7.14.4.a.

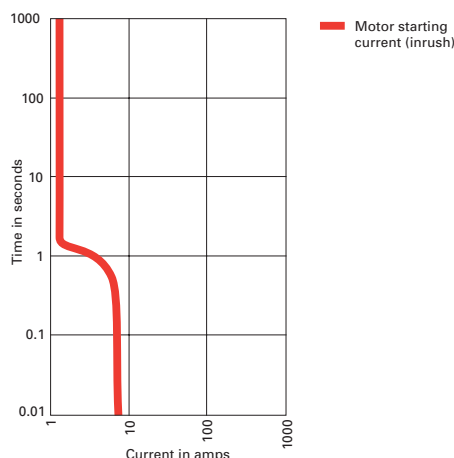


Figure 7.14.4.a

Because of this inrush, motors require special overload protective devices that can withstand the temporary overload surge associated with starting and yet protect the motor from sustained overloads. There are four major types. Each offers varying degrees of protection.

Non-time delay (fast-acting) fuses

To offer overload protection, an OCPD, depending on its application and the motor's Service Factor (SF), should be sized at 115% or less of the motor's FLA for 1.0 SF or 125% or less of motor FLA for 1.15 or greater SF. However, as shown in Figure 7.14.4.b, when fast-acting, non-time-delay fuses are sized to the recommended level, the motor's inrush current will cause nuisance openings.

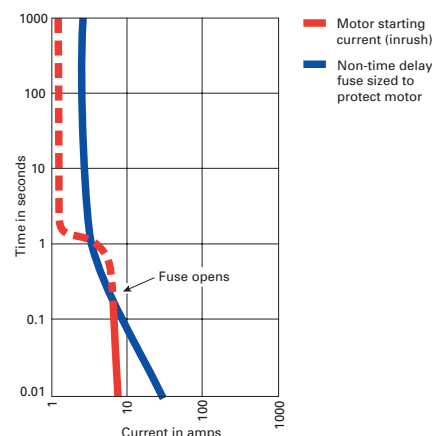


Figure 7.14.4.b

A fast-acting, non-time-delay fuse sized at 300% will withstand the inrush current and allow the motor to start, but sacrifices the motor's overload protection. As shown by Figure 7.14.4.c, a sustained overload will damage the motor before the fast-acting fuse sized at 300% can open.

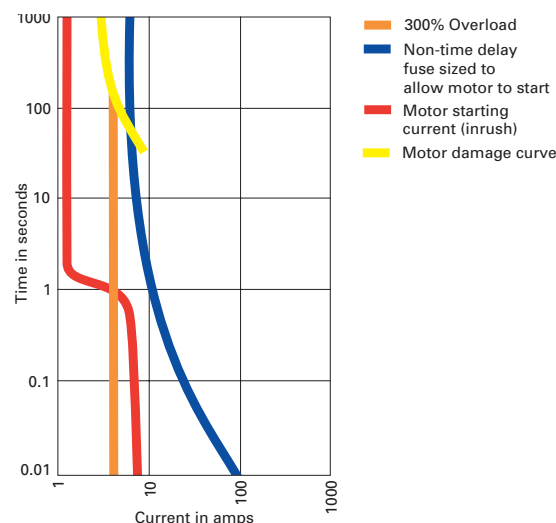


Figure 7.14.4.c

MCPs and thermal magnetic breakers

Magnetic only breakers (MCPs) and thermal magnetic breakers are also unsatisfactory for protecting motors. Once again, to properly safeguard motors from overloads, these devices should be sized at 115% or less of motor FLA for 1.0 SF, or 125% or less of motor FLA for 1.15 or greater SF. When sized this close to the FLA the inrush current will cause these breakers to needlessly open.

Figure 7.14.4.d shows an MCP opening from motor inrush current and an unaffected 15 amp thermal magnetic circuit breaker (the minimum standard size).

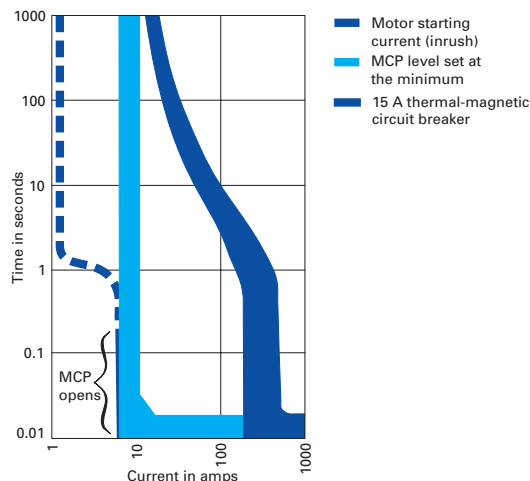


Figure 7.14.4.d

To withstand the inrush current and allow the motor to start, the MCP must be sized at about 700-800% of the FLA, and the thermal magnetic breaker must be sized at about 250% of FLA. Figure 7.14.4.e clearly shows that breakers sized to these levels are unable to protect motors against overloads.

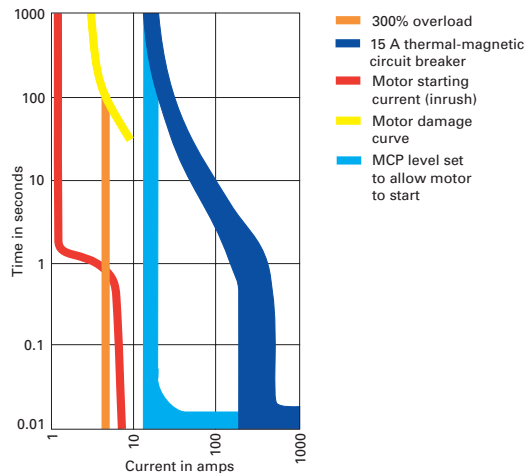


Figure 7.14.4.e

Overload Relays

Overload relays, or heaters, installed in motor starters are usually the melting alloy or bimetallic type. When properly sized and maintained, the relay can offer good overload protection. When operating properly, overload relays allow the motor to start, but when a sustained overload occurs, the overload relays will cause the contacts to open (see Figure 7.14.4.f)

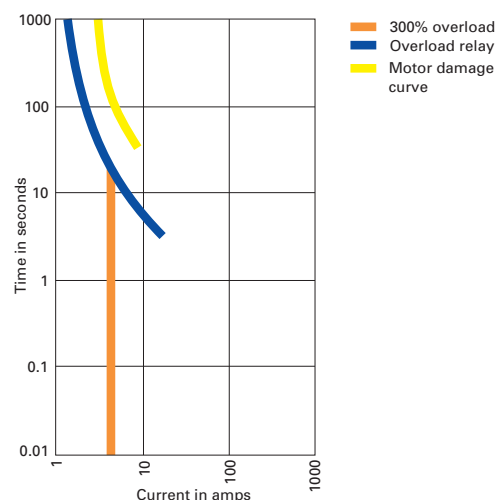


Figure 7.14.4.f

However, if the overload relays are oversized or if the contacts fail to open for any reason (e.g., welded contacts), the motor is left unprotected. Also, overload relays cannot offer any protection against short-circuits, and, in fact, must be protected by fuses or circuit breakers under short-circuit conditions (see Figure 7.14.4.g).

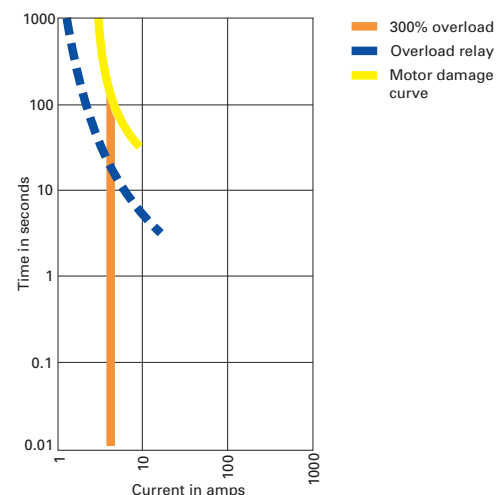


Figure 7.14.4.g

Dual-element time-delay fuses

The dual-element time-delay fuse is unaffected by the motor inrush current (Figure 7.14.4.h), but opens before a sustained overload can reach the motor damage curve (Figure 7.14.4.i).

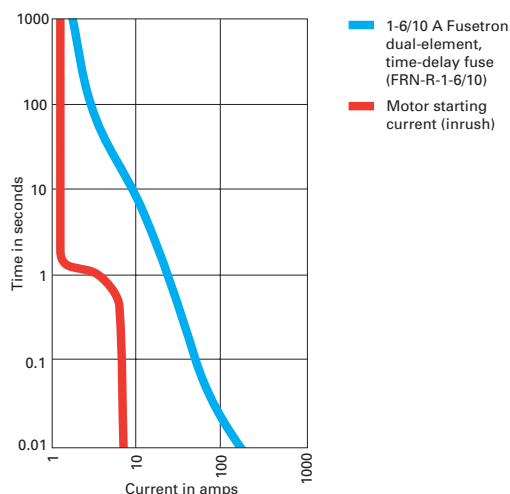


Figure 7.14.4.h

The NEC allows dual-element time-delay fuses to be used by themselves for both overload and short-circuit protection, (see NEC 430.36, 430.55, 430.57, and 430.90). Figure 7.14.4.i shows that the dual-element time-delay fuse offers excellent motor overload protection.

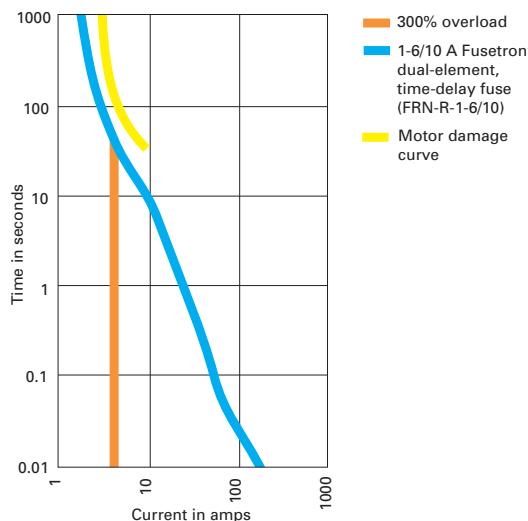


Figure 7.14.4.i

Motor overload protection

Given a motor with 1.15 service factor or greater, size the FRN-R or FRS-R fuse at 125% of the motor full load current or the next smaller, available fuse size. With a motor having a service factor of less than 1.15, size these same fuses at 115% of the motor's FLA or the next smaller size.

Motor backup overload protection

By using the following "backup" method of fusing, it is possible to have two overload protection levels. Begin by sizing the overload relays according to the manufacturer's directions. Then, size the fuse at 125%-130% or the next larger size. With this combination you have the convenience of being able to quickly reset the overload relay after solving a minor problem, while the fuses remain unopened. However, if the overload relays are sized too large, the contacts fail to open or the heaters lose calibration, the fuses will open before the motor damage curve is reached.

Typically LPN-RK-SP, and LPS-RK-SP or FRN-R, and FRS-R fuses have sufficient delay and thermal capacity to be sized for motor backup overload protection.

Figure 7.14.4.j shows the backup protection available with this method.

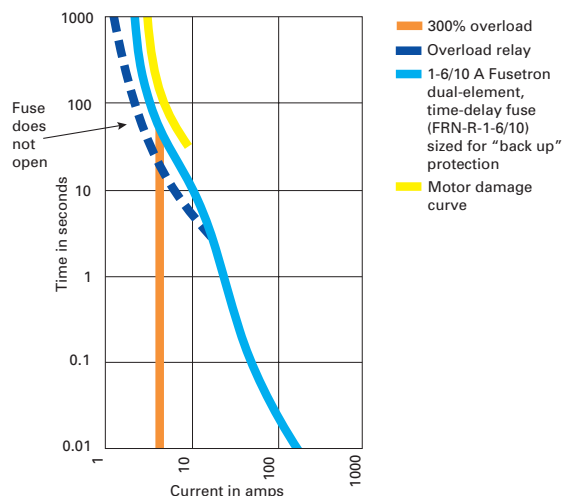


Figure 7.14.4.j

NEC 430.52 explanation

Motor circuit protection

Motor circuit protection describes the short-circuit protection of conductors supplying power to the motor, the motor controller, and motor control circuits/conductors.

430.52 provides the maximum sizes or settings for OCPD protecting the motor branch circuit. A branch circuit is defined in Article 100 as "The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s)."

NEC motor circuit protection requirements

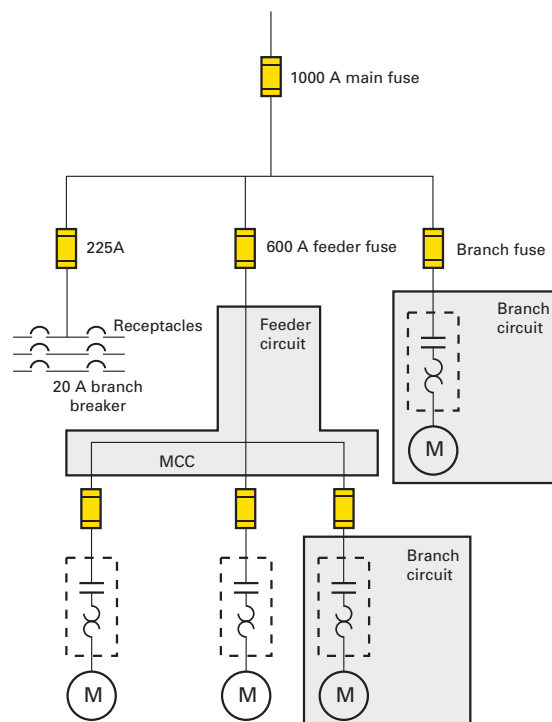


Figure 7.14.4.k

Note that the branch circuit in Figure 7.14.4.k extends from the last branch circuit OCPD to the load.

NEC Table 430.52 lists the maximum sizes for non-time delay fuses, dual-element (time-delay) fuses, instantaneous trip circuit breakers, and inverse time circuit breakers. Sizing is based on full load amp values shown in Table 430.247 through 430.250, not motor nameplate values.

For example, the maximum dual-element time-delay fuse for a 10 Hp, 460 V, three-phase motor with a nameplate FLA of 13 A would be based on 175% of 14 A, not 175% of 13 A.

For certain exceptions to these values, see 430.52 through 430.54.

Motor type	Percent of full-load current			
	Non-time delay fuse**	Dual-element, time-delay fuse**	Instantaneous trip breaker	Inverse time breaker*
Single-phase	300	175	800	250
AC polyphase other than wound-rotor				
Squirrel cage:				
Other than Design E	300	175	800	250
Design E	300	175	1100	250
Synchronous†	300	175	800	250
Wound Rotor	150	150	800	150
Direct-current (constant voltage)	150	150	250	150

* The values given in the last column also cover the ratings of non-adjustable inverse time types of circuit breakers that may be modified as in 430.52.

**The values in the Non-time delay fuse column apply to time-delay Class CC fuses.

† Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

NEC Table 430.52 maximum rating or setting of motor branch circuit, short-circuit and ground fault protective devices

Standard amp ratings for fuses and fixed trip circuit breakers, per 240.6, are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000 5000, and 6000 amps. Additional standard fuse amp ratings are 1, 3, 6, 10, and 601 amps.

The exceptions in 430.52 allow the user to increase the OCPD size if the motor is not able to start. All Class CC fuses can be increased to 400%, along with non-time delay fuses not exceeding 600 amps. Time-delay (dual-element) fuses can be increased to 225%. All Class L fuses can be increased to 300%. Inverse time (thermal-magnetic) circuit breakers can be increased to 400% (100 amp and less) or 300% (larger than 100 amps). Instant trip circuit breakers may be adjusted to 1300% for other than Design B motors, and 1700% for energy efficient Design B motors.

430.52(C)(2) reminds the user that the maximum device ratings which are shown in a manufacturer's overload relay table must not be exceeded even if higher values are allowed by other parts of 430.52.

430.52(C)(3) details the requirements that an instantaneous-trip circuit breaker can only be used if it is part of a listed combination motor controller.

7.14.5 Disconnecting means for motor circuits

Notes:

1. A disconnecting means must be located in sight from the controller (430.102). For exceptions see 430.102.
2. "In Sight From" means that the motor must be visible and not more than 50 feet distant. (Definitions in Article 100.)
3. "Controller" includes any switch or device normally used to start or stop a motor by making and breaking the motor circuit current (430.82)(A)).
4. A switch can serve both as a controller and disconnecting means if properly rated in accordance with 430.111 and 430.83.

Switches for motor circuits

The Code requirements for switches used as controllers and disconnect switches are as follows (430.81, 430.82, 430.83, 430.109, 430.110, 430.111):

- For up to 300 V stationary motors
 - 2 Hp or Less — use horsepower rated switch, or general use switch having amp rating at least twice the amp rating of the motor, or general use AC (only) snap switch having amp rating at least 125% of motor current rating
 - Greater than 2 Hp to 100 Hp — switch must have horsepower rating
 - Larger than 100 Hp — disconnect purposes—switch must have an amp rating at least 115% of the motor full load current from Tables 430.247 through 430.250
 - Controller purposes — switch must have horsepower rating
- For 301 to 600 V stationary motors
 - Less than 100 Hp — switch must have horsepower rating.
 - Larger than 100 Hp — disconnect purposes — switch must have an amp rating at least 115% of the motor full load current from Tables 430.247 through 430.250
 - Controller purposes — switch must have horsepower rating
- For portable motors
 - An attachment plug and receptacle may serve as disconnect on all sizes
 - 1/3 Hp or Less — an attachment plug and receptacle may serve as controller
 - Larger than 1/3 Hp — controller must meet requirements as outlined for stationary motors (shown above)

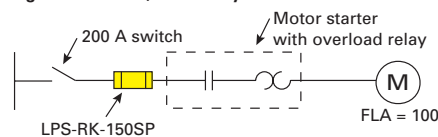
Size of Hp rated switches (switch size savings)

Low-Peak and Fusetron dual-element, time-delay fuses, rather than non-time delay fuses, are recommended for motor branch circuit protection because normally dual-element, time-delay fuses permit using a smaller switch size (and less cost), give better protection, and require less space.

For motors, oversized switches must be used with non-time delay fuses because this fuse type has very little time-lag. Non-time delay fuses are generally sized at 300% of the motor rating to hold normal motor starting inrush current. Consequently, the switch also has to be oversized to accommodate these fuses.

The dual-element, time-delay fuse can be sized close to the motor full-load amps and a smaller switch used, as shown in Figures 7.14.5.a to 7.14.4.d.

Using dual-element, time-delay fuses



Using non-time delay fuses

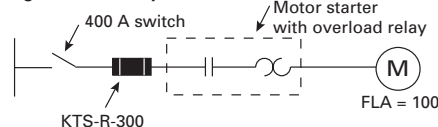


Figure 7.14.5.a

Branch circuit short-circuit protection can be provided for the given motor by either a 150 A dual-element, time-delay fuse or a 300 A non-time delay fuse. The dual-element time-delay fuse selection above provides these advantages: (1) Backup overload protection, (2) smaller switch size, resulting in lower cost/requires less space, (3) smaller fuse amp case size, resulting in lower cost, (4) short-circuit protection that is comparable or better than non-time delay (fast-acting) fuse.

Most switches are listed with two Hp ratings. The Standard horsepower rating is based on the largest non-time delay (non-dual element) fuse rating (1) which can be used in the switch, and (2) which will normally permit the motor to start. The maximum horsepower rating is based on the largest rated dual-element time-delay Bussmann series Low-Peak or Fusetron dual-element time-delay fuse (1) which can be used in the switch, and (2) which will normally permit the motor to start. Thus when Bussmann series Low-Peak or Fusetron dual-element time-delay fuses are used, smaller size switches can be used (430.57 Exception).

Conductors for motor branch and feeder circuits

The ampacity of branch circuit conductors supplying a single motor must be at least 125% of the motor full-load current rating [430.22].

Exceptions for conductors supplying motors include motors used for short-time, intermittent, periodic, or varying duty (refer to 430.22(E)).

Any motor application must be considered continuous duty unless the nature of the apparatus it drives is such that the motor will not operate continuously with load under any conditions of use.

Requirements for 18 and 16 AWG individual copper conductors supplying small motors are found in 430.22(G).

Feeder circuits for motors

Feeder conductor ampacity

The ampacity of a conductor supplying two or more motors must be at least equal to the sum of (1) 125% of the largest motor (if there are two or more motors of the largest size, one of them is considered to be the largest), and (2) the total of the full-load amp ratings for all other motors and other loads.

Where different voltages exist, the current determined per the above must be multiplied by the ratio of output to input voltage.

Feeder fuse size

On normal installations, size Bussmann series Fusetron Low-Peak dual-element time-delay fuses equal to the combined amp rating of (1) 150% to 175% FLA of the largest AC motor (if there are two or more motors of the same size, one of them is considered to be the largest), and (2) the sum of all the FLA for all other motors.

This dual-element time-delay fuse size should provide feeder protection without unnecessary fuse openings on heavy motor starts.

Where conditions are severe, as where a high percentage of motors connected must be started at one time, a larger size may be necessary. In that event, use the maximum size permitted by the Code as detailed in the maximum motor circuit feeder fuse (430.62) under motor circuit protection.

Group switching

Motors served by a single disconnecting means (group switching)

430.112 covers the requirements for serving two or more motors with the same disconnecting means. Each motor must be provided with an individual disconnecting means unless:

- all motors drive parts of a single machine
- all motors are 1 Hp or less as permitted by 430.53(A)
- all motors are in a single room and within sight from (visible and not more than 50 feet) the disconnecting means.

See Figure 7.14.5.b for the applicable NEC sections.

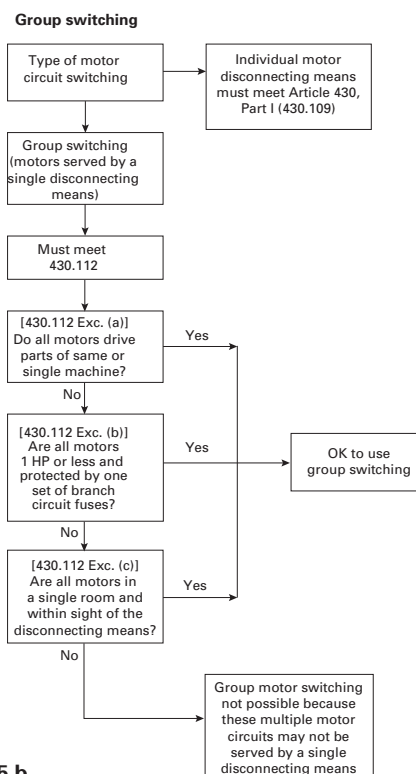
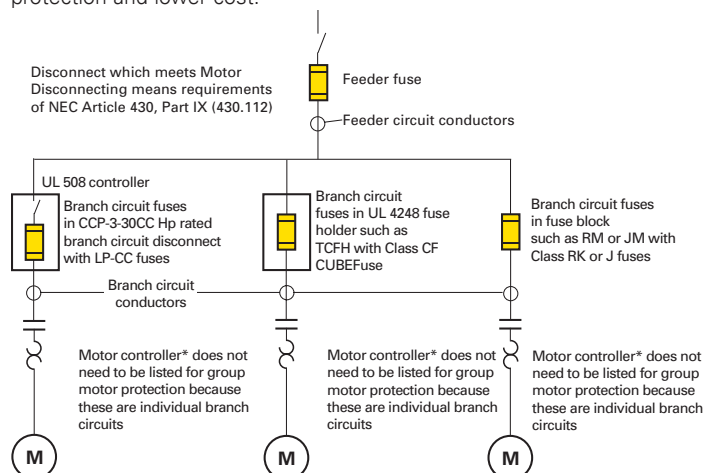


Figure 7.14.5.b

Group switching application

The preferred method, shown in Figure 7.14.5.c, can achieve excellent protection and lower cost.

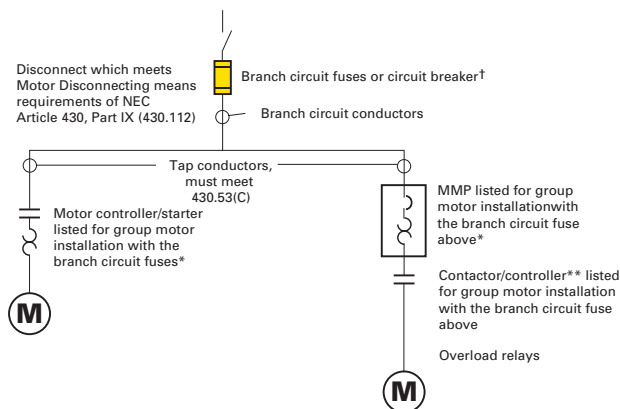


* Must be within sight of the branch circuit disconnecting means.

Figure 7.14.5.c

Group motor installation

Must meet both group motor installation (430.53(C)) and group switching requirements (430.112), often limited.



† Must be a inverse time circuit breaker.

* Must be within sight of the branch circuit disconnecting means.

** Often used in addition to MMP for automatic/remote control.

Figure 7.14.5.d

NEC Article 430 and table explanations

These explanations provide information necessary for a more complete understanding of the fuse sizing information presented in the motor protection tables on pages 7-93 through 7-109.

Columns 1 and 2

Motor horsepower ratings are listed in Column 1. Full load amps from Tables 430.247 through 430.250 are provided in Column 2.

Column 3

Below are the Bussmann series time-delay fuse types are listed in Column 3.

Catalog symbol	Volts AC	Amp range	UL fuse class	Fuse family	Interrupting rating (kA)
LPJ-SP	600	0-600	J	Low-Peak	300
TCF	600	1-100	CF finger-safe	Low-Peak	300
LP-CC	600	0-30	CC	Low-Peak	200
LPN-RK-SP	250	0-600	RK1	Low-Peak	300
LPS-RK-SP	600	0-600	RK1	Low-Peak	300
FRN-R	250	0-600	RK5	Fusetron	200
FRS-R	600	0-600	RK5	Fusetron	200
KRP-C-SP	600	601-6000	L	Low-Peak	300

The DC ratings for these fuses are below.

Catalog symbol	Amp range	DC volts	Catalog symbol	Amp range	DC volts
LPJ	1-600	300	LPS-RK	1/10-600	300
TCF	1-100	300		1/10-60	125
	1/2 to 2-1/2	300	FRN-R	110-200	125
LP-CC	2-8/10 to 15	150		225-600	250
	20-30	125		1/10-30	300
LPN-RK	1-60	125	FRS-R	35-60	250
LPN-RK	70-600	250		65-600	300

Column 4: optimal branch circuit protection

There are two distinct levels of protection provided in this column.

LPS-RK-SP, LPN-RK-SP, FRS-R and FRN-R fuses are sized for motor running "back-up" protection and provide superb short-circuit protection at the same time.

LPJ-SP, TCF, and LP-CC fuses are sized a little larger, but are even more current-limiting to provide an even greater degree of short-circuit protection.

All fuses selected from this column provide short-circuit and ground fault protection for motor branch circuits (430.52), but typically are not the maximum allowed. Fuses sized in accordance with Column 4 must be used in conjunction with properly sized motor overload protection, such as overload relays or solid state motor controllers (430.32). This fuse sizing is normally large enough to allow the overload protective device to operate on overloads without opening the fuse. Yet for many cases, this fuse amp rating selection is smaller than the maximums allowed per Columns 5 or 6 (430.52). In some cases, this smaller amp rating selection may provide the benefits of a smaller size disconnect and better short-circuit protection. If a motor has a long starting time, high starting current profile or is cycled frequently, it may be necessary to use Column 5 or 6.

The LPS-RK-SP, LPN-RK-SP, FRS-R and FRN-R fuses sized per this column provide short-circuit and ground fault protection for motor branch circuits (430.52). Additionally, these dual-element fuses exhibit longer time-delay characteristics and can therefore be sized to provide back-up motor overload protection. The fuse sizing in Column 4 for LPS-RK-SP, LPN-RK-SP, FRS-R and FRN-R fuses provides a degree of motor and circuit overload protection to back-up the normal motor overload protective device. This level of protection requires a well-designed, true dual-element fuse. The Fusetron FRS-R and FRN-R, and Low-Peak LPS-RK-SP and LPN-RK-SP, are the industry leading dual-element fuses with excellent overload time-delay characteristics and current-limiting short-circuit ability. The Low-Peak dual-element fuse has better current-limiting ability than the Fusetron dual-element fuse.

The amp ratings in Column 4 are determined by using Column 2 motor current values and the following:

- LPJ-SP and TCF: 150% or the next larger amp rating if 150% does not correspond to a standard fuse amp rating.
- LP-CC 1/2 to 15 A: 200% (150% for DC) or the next larger size if 200% (150% for DC) does not correspond to a standard fuse amp rating.
- LP-CC 20 to 30 A: 300% (150% for DC) or the next larger size if 300% (150% for DC) does not correspond to a standard fuse amp rating.
- LPS-RK-SP and LPN-RK-SP: 130% or the next larger amp rating if 130% does not correspond to a standard fuse amp rating.
- FRS-R and FRN-R: 125% or the next larger amp rating if 125% does not correspond to a standard fuse amp rating.



Column 5: branch circuit protection, max. general applications

Fuses selected from this column are intended to provide short-circuit and ground fault protection. Fuses sized in accordance with Column 5 must be used in conjunction with properly sized motor overload protection such as overload relays or solid state motor controllers (430.32). Column 5 fuse sizing provides the maximum NEC 430.52 amp ratings for general purpose applications. It takes into account 430.52(C) (1) Exception No. 1, which allows the next standard fuse amp rating (per standard fuse amp ratings in 240.6) to be used if the maximum percentage in Table 430.52 does not correspond to a standard fuse amp rating. If this Column 5 fuse sizing does not allow the motor to start, then Column 6 may provide a larger amp rating.

The amp ratings in Column 5 are determined by using Column 2 motor current values and the following:

- LPJ-SP, TCF, LPS-RK-SP, LPN-RK-SP, FRS-R, FRN-R and KRP-C-SP: 175% (150% for DC motors) or the next larger 240.6 standard fuse amp rating if 175% (150% for DC motors) does not correspond to a standard fuse amp rating.
- LP-CC: 300% (150% for DC motors) or the next larger 240.6 standard fuse amp rating if 300% (150% for DC motors) does not correspond to a standard fuse amp rating.

Sizes shown for the LP-CC can also be used for fast-acting fuses such as FCF, JKS, KTN-R, KTS-R, JJN, JJS and KTK-R.

Column 6: branch circuit protection, max. heavy start

When the amp rating shown in Column 5 is not sufficient to start a motor, a larger amp rating is often available by utilizing 430.52(C)(1) Exception No. 2. The amp ratings in Column 6 are the larger of the amp rating allowed by 430.52(C)(1) Exception No. 1, or 430.52(C)(1) Exception No. 2. These amp ratings will often be required when:

- Acceleration times are greater than 5 seconds
- Plugging or jogging applications exist
- There are high inrush currents (such as energy efficient Design B motors).

In a few cases, the amp rating in Column 6 may be smaller than the maximum permitted due to the fuse type's limitation, such as LP-CC, Class CC fuses that are only available in ratings up to 30 A. In these cases, if the amp rating shown is not sufficient to start the motor, select a different fuse family that meets the requirements. The amp ratings in Column 6 are determined by using Column 2 motor current values and the following:

- LPJ-SP, TCF, LPS-RK-SP, LPN-RK-SP, FRS-R, and FRN-R: 225% or the next smaller rating if 225% does not correspond to a standard fuse amp rating.
- LP-CC: 400% or the next smaller fuse amp rating if 400% does not correspond to a standard fuse amp rating.
- KRP-C-SP: 300% or the next smaller amp rating, if 300% does not correspond to a standard amp rating.

Sizes shown for the LP-CC can also be used for fast-acting fuses such as FCF, JKS, KTN-R, KTS-R, JJN, JJS and KTK-R.

Column 7

Horsepower-rated switch sizes given in Column 7 are based on 115% (430.110) of Column 2. Switch sizes need to be increased when the fuses are sized above the switch rating shown in this column due to starting requirements.

Column 8

Sizes listed are for general-purpose magnetic controllers (single speed, full-voltage for limited plugging and jogging-duty) as shown in NEMA Standards Publication ICS-2-2000.

Column 9

Copper wire sizes are based upon 125% (430.22) of values shown in Column 2 and ampacities listed in Table 310.15(B)(16) for 75°C terminals. Although the NEC allows 60°C terminations for equipment rated 100 A or less, most equipment terminations have been rated for 75°C conductors. If equipment terminations are rated for 60°C conductors only, the 60°C ampacities must be utilized; and larger conductor sizes may be required than those shown in this column. See 110.14(C)(1)(a). Where utilized in industrial machinery, per the requirements in NFPA 79 and 430.22(G), smaller conductors (18-16 AWG) may be used.

Column 10

The rigid metallic conduit sizes are based upon copper conductors with THWN or THHN insulation, Table C8 of Annex C, and 75°C equipment terminals.

Conduit sizes are for three conductors per circuit for three-phase motors and two conductors per circuit for single-phase and DC motors. Conduit sizes may need increasing if equipment grounding conductors or neutrals are also installed (310.15(B)(3)).

If equipment terminations are rated for 60°C conductors only, the 60°C ampacities must be utilized and therefore larger conductor sizes and conduit sizes may be required.

Conductors operated in a high ambient temperature (greater than 30°C) may need derating (310.15(B)(2).)



200 Vac three-phase motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA			NEC max for gen. applic	NEC max for heavy start			Min copper wire THWN or THHN	Min ridgid metallic conduit	
Table 430.250	Table 430.250	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size	AWG or kcmil Table 310.15(B) (16) size	Annex C Table C8 inches
1/2	2.5	LPJ-SP	J	4	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	5	10	10				
		LPN-RK-SP	RK1	3-1/2	6	6				
		FRN-R	RK5	3-2/10	6	6				
3/4	3.7	LPJ-SP	J	5-6/10	10	10	30	00	14	1/2
		TCF	CF	6	10	10				
		LP-CC	CC	7-1/2	15	15				
		LPN-RK-SP	RK1	5	10	10				
		FRN-R	RK5	5	10	10				
1	4.8	LPJ-SP	J	8	10	10	30	00	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	15	15				
		LPN-RK-SP	RK1	6-1/4	10	10				
		FRN-R	RK5	6	10	10				
1-1/2	6.9	LPJ-SP	J	12	15	15	30	00	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK-SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
2	7.8	LPJ-SP	J	12	15	17-1/2	30	0	14	1/2
		TCF	CF	15	15	17-1/2				
		LP-CC	CC	25	25	30				
		LPN-RK-SP	RK1	12	15	17-1/2				
		FRN-R	RK5	10	15	17-1/2				
3	11	LPJ-SP	J	17-1/2	20	20	30	0	14	1/2
		TCF	CF	17-1/2	20	20				
		LP-CC	CC	25	—	—				
		LPN-RK-SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
5	17.5	LPJ-SP	J	30	35	35	30*	1	12	1/2
		TCF	CF	30	35	35				
		LPN-RK-SP	RK1	25	35	35				
		FRN-R	RK5	25	35	35				
		LPJ-SP	J	40	45	50				
7-1/2	25.3	TCF	CF	40	45	50	60	1	10**	1/2**
		LPN-RK-SP	RK1	35	45	50				
		FRN-R	RK5	35	45	50				
		LPJ-SP	J	50	60	70				
		TCF	CF	50	60	70				
10	32.2	LPN-RK-SP	RK1	45	60	70	60*	2	8**	1/2**
		FRN-R	RK5	45	60	70				
		LPJ-SP	J	80	90	100				
		TCF	CF	80	90	100				
		LPN-RK-SP	RK1	70	90	100				
15	48.3	FRN-R	RK5	70	90	100	100	3	6**	3/4**
		LPJ-SP	J	100	110	125				
		TCF	CF	100	110	125				
		LPN-RK-SP	RK1	90	110	125				
		FRN-R	RK5	80	110	125				
20	62.1	LPJ-SP	J	100	110	125	100*	3	4**	1
		TCF	CF	100	110	125				
		LPN-RK-SP	RK1	90	110	125				
		FRN-R	RK5	80	110	125				
		LPJ-SP	J	100	110	125				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

200 Vac three-phase motors and circuits continued

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA				NEC max for gen. applic	NEC max for heavy start		Min copper wire THWN or THHN	Min ridgid metallic conduit	
Table 430.250	Table 430.250	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size	AWG or kcmil Table 310.15(B) (16) size	Annex C Table C8 inches
25	78.2	LPJ-SP	J	125	150	175	100*	3	3**	1**
		TCF	CF	125	150	175				
		LPN-RK-SP	RK1	110	150	175				
		FRN-R	RK5	100	150	175				
30	92	LPJ-SP	J	150	175	200	200	4	2**	1**
		TCF	CF	150	175	200				
		LPN-RK-SP	RK1	125	175	200				
		FRN-R	RK5	125	175	200				
40	120	LPJ-SP	J	200	225	250	200*	4	1/0	1-1/4
		TCF	CF	200	225	250				
		LPN-RK-SP	RK1	175	225	250				
		FRN-R	RK5	150	225	250				
50	150	LPJ-SP	J	225	300	300	200*	5	3/0	1-1/2
		TCF	CF	225	300	300				
		LPN-RK-SP	RK1	200	300	300				
		FRN-R	RK5	200	300	300				
60	177	LPJ-SP	J	300	350	350	400	5	4/0	2
		TCF	CF	300	350	350				
		LPN-RK-SP	RK1	250	350	350				
		FRN-R	RK5	225	350	350				
75	221	LPJ-SP	J	350	400	450	400*	5	300	2
		LPN-RK-SP	RK1	300	400	450				
		FRN-R	RK5	300	400	450				
		KRP-C-SP	L	—	—	650				
100	285	LPJ-SP	J	450	500	600	400*	6	500	3
		LPN-RK-SP	RK1	400	500	600				
		FRN-R	RK5	400	500	600				
		KRP-C-SP	L	—	—	800				
125	359	LPJ-SP	J	600	—	—	600*	6	4/0 2/phase	(2)2
		LPN-RK-SP	RK1	500	—	—				
		FRN-R	RK5	450	—	—				
		KRP-C-SP	L	—	700	1000				
150	414	LPN-RK-SP	RK1	600	—	—	600*	6	300 2/phase	(2)2
		FRN-R	RK5	600	—	—				
		KRP-C-SP	L	—	800	1200				
		KRP-C-SP	L	—	1000	1600				
200	552	KRP-C-SP	L	—	1000	1600	1200	7***	500 2/phase	(2)3

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

*** These sizes are typical. They are not shown in NEMA ICS 2-2000.



208 Vac three-phase motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size Table 430.250 Hp	Motor FLA Table 430.250 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	NEC max for gen. applic. 430.52(C)(1) exc. no. 1 amps†	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size††	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
1/2	2.4	LPJ-SP	J	4	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	5	10	10				
		LPN-RK-SP	RK1	3-1/2	6	6				
		FRN-R	RK5	3	6	6				
3/4	3.5	LPJ-SP	J	5-6/10	10	10	30	00	14	1/2
		TCF	CF	6	10	10				
		LP-CC	CC	7	15	15				
		LPN-RK-SP	RK1	5	10	10				
		FRN-R	RK5	4-1/2	10	10				
1	4.6	LPJ-SP	J	7	10	10	30	00	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	15	15				
		LPN-RK-SP	RK1	6	10	10				
		FRN-R	RK5	6	10	10				
1-1/2	6.6	LPJ-SP	J	10	15	15	30	00	14	1/2
		TCF	CF	10	15	15				
		LP-CC	CC	15	20	25				
		LPN-RK-SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.



208 Vac three-phase motors and circuits continued

1	2	3	4	5	6	7	8	9	10
Motor size Table 430.250 Hp	Motor FLA Table 430.250 Amps	UL branch circuit fuse class Bussmann series fuse symbol	Optimal branch ckt protection amps†	NEC max for gen. applic. 430.52(C) (1) exc. no. 1 amps†	NEC max for heavy start 430.52(C) (1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size††	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B)(16) size	Min rigid metallic conduit Annex C Table C8 inches
2	7.5	LPJ-SP	J	12	15	30	0	14	1/2
		TCF	CF	15	15				
		LP-CC	CC	15	25				
		LPN-RK-SP	RK1	10	15				
		FRN-R	RK5	10	15				
3	10.6	LPJ-SP	J	17-1/2	20	30	0	14	1/2
		TCF	CF	17-1/2	20				
		LPN-RK-SP	RK1	15	20				
		FRN-R	RK5	15	20				
		LPJ-SP	J	30	30				
5	16.7	TCF	CF	25	30	30*	1	12	1/2
		LPN-RK-SP	RK1	25	30				
		FRN-R	RK5	25	30				
		LPJ-SP	J	40	45				
		TCF	CF	40	45				
7-1/2	24.2	LPN-RK-SP	RK1	35	45	60	1	10**	1/2
		FRN-R	RK5	35	45				
		LPJ-SP	J	50	60				
		TCF	CF	50	60				
		LPN-RK-SP	RK1	45	60				
10	30.8	FRN-R	RK5	40	60	60	2	8	1/2**
		LPJ-SP	J	70	90				
		TCF	CF	70	90				
		LPN-RK-SP	RK1	70	90				
		FRN-R	RK5	60	90				
15	46.2	LPJ-SP	J	90	110	60*	3	6**	3/4**
		TCF	CF	90	110				
		LPN-RK-SP	RK1	80	110				
		FRN-R	RK5	80	110				
		LPJ-SP	J	125	150				
20	59.4	TCF	CF	125	150	100*	3	4**	1
		LPN-RK-SP	RK1	100	150				
		FRN-R	RK5	100	150				
		LPJ-SP	J	150	175				
		TCF	CF	150	175				
25	74.8	LPN-RK-SP	RK1	125	150	100*	3	3**	1**
		FRN-R	RK5	125	150				
		LPJ-SP	J	150	175				
		TCF	CF	150	175				
		LPN-RK-SP	RK1	125	150				
30	88	FRN-R	RK5	110	175	200	4	2**	1**
		LPJ-SP	J	175	200				
		LPN-RK-SP	RK1	150	200				
		FRN-R	RK5	150	200				
		LPJ-SP	J	225	300				
40	114	TCF	CF	225	300	200*	4	1/0	1-1/4
		LPN-RK-SP	RK1	200	300				
		FRN-R	RK5	200	300				
		LPJ-SP	J	300	350				
		TCF	CF	300	350				
50	143	LPN-RK-SP	RK1	225	300	200*	5	3/0	1-1/2
		FRN-R	RK5	200	300				
		LPJ-SP	J	300	350				
		TCF	CF	300	350				
		LPN-RK-SP	RK1	225	300				
60	169	FRN-R	RK5	225	300	400	5	4/0	2
		LPJ-SP	J	350	400				
		LPN-RK-SP	RK1	300	400				
		FRN-R	RK5	300	400				
		KRP-C-SP	L	—	—				
75	211	LPJ-SP	J	450	500	400*	5	300	2
		TCF	CF	450	500				
		LPN-RK-SP	RK1	400	500				
		FRN-R	RK5	350	500				
		KRP-C-SP	L	—	—				
100	273	LPJ-SP	J	600	—	400*	6	500	3
		TCF	CF	600	—				
		LPN-RK-SP	RK1	450	—				
		FRN-R	RK5	450	—				
		KRP-C-SP	L	—	—				
125	343	LPJ-SP	J	600	—	600*	6	4/0 2/phase	(2)2
		TCF	CF	600	—				
		LPN-RK-SP	RK1	450	—				
		FRN-R	RK5	450	—				
		KRP-C-SP	L	—	—				
150	396	LPJ-SP	J	600	—	600*	6	250 2/phase	(2)2
		TCF	CF	600	—				
		LPN-RK-SP	RK1	450	—				
		FRN-R	RK5	450	—				
		KRP-C-SP	L	—	—				
200	528	KRP-C-SP	L	—	1000	1200*	7	400 2/phase	(2)2-2-1/2

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

230 Vac three-phase motors and circuits (220-240 Vac systems)

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA		UL		NEC max for	NEC max for			Min rigid	
Table 430.250	Table 430.250	Bussmann series fuse symbol	branch circuit fuse class	Optimal branch ckt protection amps†	gen. applic. 430.52(C)(1) exc. no. 1 amps†	heavy start 430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B)(16) size	metallic conduit Annex C Table C8 inches
Hp	Amps									
1/2	2.2	LPJ-SP	J	3-1/2	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	4-1/2	10	10				
		LPN-RK-SP	RK1	3	6	6				
3/4	3.2	FRN-R	RK5	2-8/10	6	6	30	00	14	1/2
		LPJ-SP	J	5	6	7				
		TCF	CF	6	6	6				
		LP-CC	CC	7	10	12				
1	4.2	LPN-RK-SP	RK1	4-1/2	6	7	30	00	14	1/2
		FRN-R	RK5	4	6	7				
		LPJ-SP	J	7	10	10				
		TCF	CF	10	10	10				
1-1/2	6	LP-CC	CC	9	15	15	30	00	14	1/2
		LPN-RK-SP	RK1	5-6/10	10	10				
		FRN-R	RK5	5-8/10	10	10				
		LPJ-SP	J	9	15	15				
2	6.8	TCF	CF	10	15	15	30	0	14	1/2
		LP-CC	CC	12	20	20				
		LPN-RK-SP	RK1	8	15	15				
		FRN-R	RK5	7-1/2	15	15				
3	9.6	LPJ-SP	J	12	15	15	30	0	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK-SP	RK1	9	15	15				
5	15.2	FRN-R	RK5	9	15	15	30	1	14	1/2
		LPJ-SP	J	15	20	20				
		TCF	CF	15	20	20				
		LP-CC	CC	30	30	30				
7-1/2	22	LPN-RK-SP	RK1	15	20	20	30*	1	10	1/2
		FRN-R	RK5	12	20	20				
		LPJ-SP	J	25	30	30				
		TCF	CF	25	30	30				
10	28	LPN-RK-SP	RK1	20	30	30	60	2	10**	1/2
		FRN-R	RK5	20	30	30				
		LPJ-SP	J	35	40	45				
		TCF	CF	35	40	45				
15	42	FRN-R	RK5	30	40	45	60*	2	6	3/4
		LPJ-SP	J	45	50	60				
		TCF	CF	45	50	60				
		LPN-RK-SP	RK1	40	50	60				
20	54	FRN-R	RK5	35	50	60	100*	3	4	1
		LPJ-SP	J	70	80	90				
		TCF	CF	70	80	90				
		LPN-RK-SP	RK1	60	80	90				
25	68	FRN-R	RK5	60	80	90	100*	3	4**	1
		LPJ-SP	J	90	100	110				
		TCF	CF	90	100	110				
		LPN-RK-SP	RK1	80	100	110				
30	80	FRN-R	RK5	70	100	110	100*	3	3**	1**
		LPJ-SP	J	110	125	150				
		TCF	CF	110	125	150				
		LPN-RK-SP	RK1	90	125	150				
40	104	FRN-R	RK5	90	125	150	200*	4	1**	1-1/4**
		LPJ-SP	J	125	150	175				
		TCF	CF	125	150	175				
		LPN-RK-SP	RK1	110	150	175				
50	130	FRN-R	RK5	100	150	175	200*	4	2/0	1-1/2
		LPJ-SP	J	175	200	225				
		TCF	CF	175	200	225				
		LPN-RK-SP	RK1	150	200	225				
60	154	FRN-R	RK5	150	200	225	200*	5	3/0	1-1/2
		LPJ-SP	J	200	250	250				
		TCF	CF	200	250	250				
		LPN-RK-SP	RK1	250	300	300				
		FRN-R	RK5	250	300	300				
		LPJ-SP	J	250	300	300				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

230 Vac three-phase motors and circuits (220-240 Vac systems) continued

1	2	3	4	5	6	7	8	9	10	
Motor size Table 430.250 Hp	Motor FLA Table 430.250 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	NEC max for gen. applic. 430.52(C)(1) exc. no. 1 amps†	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
75	192	LPJ-SP	J	300	350	400	400	5	250	2
		TCF	CF	300	350	400				
		LPN-RK-SP	RK1	250	350	400				
		FRN-R	RK5	250	350	400				
100	248	LPJ-SP	J	400	450	500	400*	5	350	2-1/2
		LPN-RK-SP	RK1	350	450	500				
		FRN-R	RK5	350	450	500				
		KRP-C-SP	L	—	—	700				
125	312	LPJ-SP	J	500	600	—	400*	6	3/0 2/phase	(2) 1-1/2
		LPN-RK-SP	RK1	450	600	—				
		FRN-R	RK5	400	600	—				
		KRP-C-SP	L	—	—	900				
150	360	LPJ-SP	J	600	—	—	600*	6	4/0 2/phase	(2) 2
		LPN-RK-SP	RK1	500	6004	—				
		FRN-R	RK5	450	6004	—				
		KRP-C-SP	L	—	700	1000				
200	480	FRN-R	RK5	600	—	—	600*	6	350 2/phase	(2) 2-2-1/2
		KRP-C-SP	L	—	1000	1400				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.



460 Vac three-phase motors and circuits (440-480 Vac systems)

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA				NEC max for gen. applic.	NEC max for heavy start		Min copper wire THWN or THHN		
Table 430.250	Table 430.250	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection ampst†	430.52(C)(1) exc. no. 1 ampst†	430.52(C)(1) exc. no. 2 ampst†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 sizett††	Min rigid metallic conduit Annex C Table C8 inches	
1/2	1.1	LPJ-SP	J	1-8/10	3	3	30	00	14	1/2
		TCF	CF	3	3	3				
		LP-CC	CC	2-1/4	6	6				
		LPS-RK-SP	RK1	1-1/2	3	3				
		FRS-R	RK5	1-4/10	3	3				
3/4	1.6	LPJ-SP	J	2-1/2	3	3-1/2	30	00	14	1/2
		TCF	CF	3	3	3				
		LP-CC	CC	3-2/10	6	6-1/4				
		LPS-RK-SP	RK1	2-1/4	3	3-1/2				
		FRS-R	RK5	2	3	3-1/2				
1	2.1	LPJ-SP	J	3-2/10	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	4-1/2	10	10				
		LPS-RK-SP	RK1	2-8/10	6	6				
		FRS-R	RK5	2-8/10	6	6				
1-1/2	3	LPJ-SP	J	4-1/2	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	6	10	12				
		LPS-RK-SP	RK1	4	6	6-1/4				
		FRS-R	RK5	4	6	6-1/4				
2	3.4	LPJ-SP	J	5-6/10	6	7	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	7	15	15				
		LPS-RK-SP	RK1	4-1/2	6	7				
		FRS-R	RK5	4-1/2	6	7-1/2				
3	4.8	LPJ-SP	J	8	10	10	30	0	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	15	15				
		LPS-RK-SP	RK1	6-1/4	10	10				
		FRS-R	RK5	6	10	10				
5	7.6	LPJ-SP	J	12	15	15	30	0	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	25	25	30				
		LPS-RK-SP	RK1	10	15	15				
		FRS-R	RK5	10	15	15				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.



460 Vac three-phase motors and circuits (440-480 Vac systems) continued

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA		UL		NEC max for gen. applic.			Min copper wire THWN or THHN		
Table 430.250	Table 430.250	Bussmann series fuse	branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter ICS 2-2000 size††	AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
Hp	Amps	symbol								
7-1/2	11	LPJ-SP	J	17-1/2	20	20	30	1	14	1/2
		TCF	CF	17-1/2	20	20				
		LPS-RK-SP	RK1	15	20	20				
		FRS-R	RK5	15	20	20				
10	14	LPJ-SP	J	25	25	30	30	1	14	1/2
		TCF	CF	25	25	30				
		LPS-RK-SP	RK1	20	25	30				
		FRS-R	RK5	17-1/2	25	30				
15	21	LPJ-SP	J	35	40	45	30*	2	10	1/2
		TCF	CF	35	40	45				
		LPS-RK-SP	RK1	30	40	45				
		FRS-R	RK5	30	40	45				
20	27	LPJ-SP	J	45	50	60	60	2	10**	1/2
		TCF	CF	40	50	60				
		LPS-RK-SP	RK1	40	50	60				
		FRS-R	RK5	35	50	60				
25	34	LPJ-SP	J	60	60	70	60*	2	8**	1/2**
		TCF	CF	60	60	70				
		LPS-RK-SP	RK1	45	60	70				
		FRS-R	RK5	45	60	70				
30	40	LPJ-SP	J	60	70	90	60*	3	8**	1/2**
		TCF	CF	60	70	90				
		LPS-RK-SP	RK1	60	70	90				
		FRS-R	RK5	50	70	90				
40	52	LPJ-SP	J	80	100	110	100*	3	6**	3/4**
		TCF	CF	80	100	110				
		LPS-RK-SP	RK1	70	100	110				
		FRS-R	RK5	70	100	110				
50	65	LPJ-SP	J	100	125	125	100*	3	4**	1
		TCF	CF	100	125	125				
		LPS-RK-SP	RK1	90	125	125				
		FRS-R	RK5	90	125	125				
60	77	LPJ-SP	J	125	150	150	100*	4	3**	1**
		TCF	CF	125	150	150				
		LPS-RK-SP	RK1	110	150	150				
		FRS-R	RK5	100	150	150				
75	96	LPJ-SP	J	150	175	200	200	4	1**	1-1/4**
		TCF	CF	150	175	200				
		LPS-RK-SP	RK1	125	175	200				
		FRS-R	RK5	125	175	200				
100	124	LPJ-SP	J	200	225	250	200*	4	2/0	1-1/2
		TCF	CF	200	225	250				
		LPS-RK-SP	RK1	175	225	250				
		FRS-R	RK5	175	225	250				
125	156	LPJ-SP	J	250	300	350	200*	5	3/0	1-1/2
		TCF	CF	250	300	350				
		LPS-RK-SP	RK1	225	300	350				
		FRS-R	RK5	200	300	350				
150	180	LPJ-SP	J	300	350	400	400	5	4/0	2
		TCF	CF	300	350	400				
		LPS-RK-SP	RK1	250	350	400				
		FRS-R	RK5	225	350	400				
200	240	LPJ-SP	J	400	450	500	400*	5	350	2-1/2
		LPS-RK-SP	RK1	350	450	500				
		FRS-R	RK5	300	450	500				
		KRP-C-SP	L	—	—	700				
250	302	LPJ-SP	J	500	600	—	400*	6	3/0 2/phase	(2) 1-1/2
		LPS-RK-SP	RK1	400	600	—				
		FRS-R	RK5	400	600	—				
		KRP-C-SP	L	—	—	900				
300	361	LPJ-SP	J	600	—	—	600*	6	4/0 2/phase	(2) 2
		LPS-RK-SP	RK1	500	6004	—				
		FRS-R	RK5	500	6004	—				
		KRP-C-SP	L	—	700	1000				
350	414	LPS-RK-SP	RK1	600	—	—	600*	6	300 2/phase	(2) 2
		FRS-R	RK5	600	—	—				
		KRP-C-SP	L	—	800	1200				
		KRP-C-SP	L	—	1000	1400				
400	477	FRS-R	RK5	600	—	—	600*	6	350 2/phase	(2) 2-1/2
450	515	KRP-C-SP	L	—	1000	1500	1200*	7	400 2/phase	(2) 2-1/2
500	590	KRP-C-SP	L	—	1200	1600	1200*	7	500 2/phase	(2) 3

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

575 Vac three-phase motors and circuits (550-600 Vac systems)

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA		UL		NEC max for	NEC max for		Min copper wire		
Table 430.250	Table 430.250	Bussmann series fuse	branch circuit	Optimal	gen. applic.	heavy start		THWN or THHN		
Hp	Amps	symbol	branch circuit fuse class	branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size††	THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
1/2	0.9	LPJ-SP	J	1-4/10	3	3	30	0	14	1/2
		TCF	CF	3	3	3				
		LP-CC	CC	1-8/10	3	3-1/2				
		LPS-RK-SP	RK1	1-1/4	3	3				
		FRS-R	RK5	1 1/8	3	3				
3/4	1.3	LPJ-SP	J	2	3	3	30	0	14	1/2
		TCF	CF	3	3	3				
		LP-CC	CC	2-8/10	6	6				
		LPS-RK-SP	RK1	1-8/10	3	3				
		FRS-R	RK5	1-8/10	3	3				
1	1.7	LPJ-SP	J	2-8/10	3	3-1/2	30	0	14	1/2
		TCF	CF	3	3	3				
		LP-CC	CC	3-1/2	6	6-1/4				
		LPS-RK-SP	RK1	2-1/4	3	3-1/2				
		FRS-R	RK5	2-1/4	3	3-1/2				
1-1/2	2.4	LPJ-SP	J	4	6	6	30	0	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	5	10	10				
		LPS-RK-SP	RK1	3-2/10	6	6				
		FRS-R	RK5	3	6	6				
2	2.7	LPJ-SP	J	4-1/2	6	6	30	0	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	5-6/10	10	10				
		LPS-RK-SP	RK1	4	6	6				
		FRS-R	RK5	3-1/2	6	6				
3	3.9	LPJ-SP	J	6	10	10	30	0	14	1/2
		TCF	CF	6	10	10				
		LP-CC	CC	8	15	15				
		LPS-RK-SP	RK1	5-6/10	10	10				
		FRS-R	RK5	5	10	10				
5	6.1	LPJ-SP	J	10	15	15	30	0	14	1/2
		TCF	CF	10	15	15				
		LP-CC	CC	15	20	20				
		LPS-RK-SP	RK1	8	15	15				
		FRS-R	RK5	8	15	15				
7-1/2	9	LPJ-SP	J	15	20	20	30	1	14	1/2
		TCF	CF	15	20	20				
		LP-CC	CC	30	30	30				
		LPS-RK-SP	RK1	12	20	20				
		FRS-R	RK5	12	20	20				
10	11	LPJ-SP	J	17-1/2	20	20	30	1	14	1/2
		TCF	CF	17-1/2	20	20				
		LPS-RK-SP	RK1	15	20	20				
		FRS-R	RK5	15	20	20				
		LPJ-SP	J	30	30	35				
15	17	TCF	CF	30	30	35	30*	2	12	1/2
		LPS-RK-SP	RK1	25	30	35				
		FRS-R	RK5	25	30	35				
		LPJ-SP	J	35	40	45				
		TCF	CF	35	40	45				
20	22	LPS-RK-SP	RK1	30	40	45	30*	2	10	1/2
		FRS-R	RK5	30	40	45				
		LPJ-SP	J	45	50	60				
		TCF	CF	45	50	60				
		LPS-RK-SP	RK1	40	50	60				
25	27	FRS-R	RK5	35	50	60	60	2	10**	1/2**
		LPJ-SP	J	50	60	70				
		TCF	CF	50	60	70				
		LPS-RK-SP	RK1	45	60	70				
		FRS-R	RK5	40	60	70				
30	32	LPJ-SP	J	70	80	90	60*	3	8	1/2
		TCF	CF	70	80	90				
		LPS-RK-SP	RK1	60	80	90				
		FRS-R	RK5	60	80	90				
		LPJ-SP	J	80	100	110				
40	41	TCF	CF	80	100	110	60*	3	6	3/4
		LPS-RK-SP	RK1	60	80	90				
		FRS-R	RK5	60	80	90				
		LPJ-SP	J	80	100	110				
		TCF	CF	80	100	110				
50	52	LPS-RK-SP	RK1	70	100	110	100*	3	6**	3/4**
		FRS-R	RK5	70	100	110				
		LPJ-SP	J	70	100	110				
		TCF	CF	70	100	110				
		LPS-RK-SP	RK1	70	100	110				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

575 Vac three-phase motors and circuits (550-600 Vac systems) continued

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA				NEC max for gen. applic.	NEC max for heavy start		Min copper wire THWN or THHN		
Table 430.250	Table 430.250	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size††	AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
Hp	Amps									
60	62	LPJ-SP	J	100	110	125	100*	4	4**	1
		TCF	CF	100	110	125				
		LPS-RK-SP	RK1	90	110	125				
		FRS-R	RK5	80	110	125				
75	77	LPJ-SP	J	125	150	150	100*	4	3**	1**
		TCF	CF	125	150	150				
		LPS-RK-SP	RK1	110	150	150				
		FRS-R	RK5	100	150	150				
100	99	LPJ-SP	J	150	175	200	200	4	1**	1-1/4**
		TCF	CF	150	175	200				
		LPS-RK-SP	RK1	150	175	200				
		FRS-R	RK5	125	175	200				
125	125	LPJ-SP	J	200	225	250	200*	5	2/0	1-1/2
		TCF	CF	200	225	250				
		LPS-RK-SP	RK1	175	225	250				
		FRS-R	RK5	175	225	250				
150	144	LPJ-SP	J	225	300	300	200*	5	3/0	1-1/2
		TCF	CF	225	300	300				
		LPS-RK-SP	RK1	200	300	300				
		FRS-R	RK5	200	300	300				
200	192	LPJ-SP	J	300	350	400	400	5	250	2
		TCF	CF	300	350	400				
		LPS-RK-SP	RK1	250	350	400				
		FRS-R	RK5	250	350	400				
250	242	LPJ-SP	J	400	450	500	400*	6	350	2-1/2
		LPS-RK-SP	RK1	350	450	500				
		FRS-R	RK5	350	450	500				
		KRP-C-SP	L	—	—	700				
300	289	LPJ-SP	J	450	600	600	400*	6	500	3
		LPS-RK-SP	RK1	400	600	600				
		FRS-R	RK5	400	600	600				
		KRP-C-SP	L	—	—	800				
350	336	LPJ-SP	J	600	600	—	600*	6	4/0 2/phase	(2) 2
		LPS-RK-SP	RK1	450	600	—				
		FRS-R	RK5	450	600	—				
		KRP-C-SP	L	—	601	1000				
400	382	LPJ-SP	J	600	—	—	600*	6	250 2/phase	(2) 2
		LPS-RK-SP	RK1	500	—	—				
		FRS-R	RK5	500	—	—				
		KRP-C-SP	L	—	700	1100				
450	412	LPS-RK-SP	RK1	600	—	—	600*	7	300 2/phase	(2) 2
		FRS-R	RK5	600	—	—				
		KRP-C-SP	L	—	800	1200				
500	472	FRS-R	RK5	600	—	—	600*	7	350 2/phase	(2) 2-1/2
		KRP-C-SP	L	—	1000	1400				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

115 Vac single-phase motors and circuits (110-120 Vac systems)

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA				NEC max for gen. applic.	NEC max for heavy start		Min copper wire THWN or THHN		
Table 430.250	Table 430.250	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size††	AWG or kcmil Table 310.15(B) (16) size	
Hp	Amps								Min rigid metallic conduit Annex C Table C8 inches	
1/6	4.4	LPJ-SP	J	8	10	10	30	00	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	9	15	15				
		LPN-RK-SP	RK1	6	10	10				
		FRN-R	RK5	5-6/10	10	10				
1/4	5.8	LPJ-SP	J	9	15	15	30	00	14	1/2
		TCF	CF	10	15	15				
		LP-CC	CC	12	20	20				
		LPN-RK-SP	RK1	8	15	15				
		FRN-R	RK5	7-1/2	15	15				
1/3	7.2	LPJ-SP	J	12	15	15	30	00	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK-SP	RK1	10	15	15				
		FRN-R	RK5	9	15	15				
1/2	9.8	LPJ-SP	J	15	20	20	30	0	14	1/2
		TCF	CF	15	20	20				
		LP-CC	CC	30	30	30				
		LPN-RK-SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
3/4	13.8	LPJ-SP	J	25	25	30	30	0	14	1/2
		TCF	CF	25	25	30				
		LPN-RK-SP	RK1	20	25	30				
		FRN-R	RK5	17-1/2	25	30				
		LPJ-SP	J	25	30	35				
1	16	TCF	CF	25	30	35	30*	0	14	1/2
		LPN-RK-SP	RK1	25	30	35				
		FRN-R	RK5	20	30	35				
		LPJ-SP	J	30	35	45				
		TCF	CF	30	35	45				
1-1/2	20	LPN-RK-SP	RK1	30	35	45	30*	1	12	1/2
		FRN-R	RK5	25	35	45				
		LPJ-SP	J	40	45	50				
		TCF	CF	40	45	50				
		LPN-RK-SP	RK1	35	45	50				
2	24	FRN-R	RK5	30	45	50	30*	1	10	1/2
		LPJ-SP	J	60	60	70				
		TCF	CF	50	60	70				
		LPN-RK-SP	RK1	45	60	70				
		FRN-R	RK5	45	60	70				
3	34	LPJ-SP	J	90	100	125	60*	2	8**	1/2**
		TCF	CF	90	100	125				
		LPN-RK-SP	RK1	80	100	125				
		FRN-R	RK5	70	100	125				
		LPJ-SP	J	125	150	175				
5	56	TCF	CF	125	150	175	100*	3	4	3/4**
		LPN-RK-SP	RK1	110	150	175				
		FRN-R	RK5	100	150	175				
		LPJ-SP	J	150	175	225				
		TCF	CF	150	175	225				
7-1/2	80	LPN-RK-SP	RK1	150	175	225	100*	3	3**	1**
		FRN-R	RK5	100	150	175				
		LPJ-SP	J	150	175	225				
		TCF	CF	150	175	225				
		LPN-RK-SP	RK1	150	175	225				
10	100	FRN-R	RK5	125	175	225	200*	42	1	1-1/4
		LPJ-SP	J	150	175	225				
		TCF	CF	150	175	225				
		LPN-RK-SP	RK1	150	175	225				
		FRN-R	RK5	125	175	225				

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

230 Vac single-phase motors and circuits (220-240 Vac systems)

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA			NEC max for gen. applic.	NEC max for heavy start		Min NEMA starter	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches	
Table 430.250 Hp	Table 430.250 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps†	430.52(C)(1) exc. no. 1 amps†	430.52(C)(1) exc. no. 2 amps†	Min switch size 430.110 amps	NEMA ICS 2-2000 size††		
1/6	2.2	LPJ-SP	J	3-1/2	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	4-1/2	10	10				
		LPN-RK-SP	RK1	3	6	6				
		FRN-R	RK5	2-8/10	6	6				
1/4	2.9	LPJ-SP	J	4-1/2	6	6	30	00	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	6	10	10				
		LPN-RK-SP	RK1	4	6	6-1/4				
		FRN-R	RK5	4	6	6-1/4				
1/3	3.6	LPJ-SP	J	5-6/10	10	10	30	00	14	1/2
		TCF	CF	6	10	10				
		LP-CC	CC	7	15	15				
		LPN-RK-SP	RK1	5	10	10				
		FRN-R	RK5	4-1/2	10	10				
1/2	4.9	LPJ-SP	J	8	10	10	30	00	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	15	15				
		LPN-RK-SP	RK1	8	10	10				
		FRN-R	RK5	6-1/4	10	10				
3/4	6.9	LPJ-SP	J	12	15	15	30	00	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK-SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
1	8	LPJ-SP	J	12	15	17-1/2	30	00	14	1/2
		TCF	CF	15	15	17-1/2				
		LP-CC	CC	25	25	30				
		LPN-RK-SP	RK1	12	15	17-1/2				
		FRN-R	RK5	10	15	17-1/2				
1-1/2	10	LPJ-SP	J	15	20	20	30	0	14	1/2
		TCF	CF	15	20	20				
		LP-CC	CC	30	30	30				
		LPN-RK-SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
2	12	LPJ-SP	J	20	25	25	30	0	14	1/2
		TCF	CF	20	25	25				
		LP-CC	CC	25	—	—				
		LPN-RK-SP	RK1	17-1/2	25	25				
		FRN-R	RK5	15	25	25				
3	17	LPJ-SP	J	30	30	35	30*	1	12	1/2
		TCF	CF	30	30	35				
		LPN-RK-SP	RK1	25	30	35				
		FRN-R	RK5	25	30	35				
		LPJ-SP	J	45	50	60				
5	28	TCF	CF	45	50	60	60	2	10**	1/2
		LPN-RK-SP	RK1	40	50	60				
		FRN-R	RK5	35	50	60				
		LPJ-SP	J	60	70	90				
		TCF	CF	60	70	90				
7-1/2	40	LPN-RK-SP	RK1	60	70	90	60*	2	8**	1/2**
		FRN-R	RK5	50	70	90				
		LPJ-SP	J	80	90	110				
		TCF	CF	80	90	110				
		LPN-RK-SP	RK1	70	90	110				
10	50	FRN-R	RK5	70	90	110	100*	3	6**	1/2**

† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

†† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

90 Vdc† motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size Table 430.247 Hp	Motor FLA Table 430.247 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps††	NEC max for gen. applic. 430.52(C)(1) exc. no. 1 amps††	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps††	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size†††	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
1/4	4.0	LPJ-SP	J	6	6	6	30	1	14	1/2
		TCF	CF	6	6	6				
		LPC-CC	CC	6	6	15				
		LPN-RK-SP	RK1	6	6	9				
		FRN-R	RK5	5	6	9				
1/3	5.2	LPJ-SP	J	8	10	10	30	1	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	10	20				
		LPN-RK-SP	RK1	8	10	10				
		FRN-R	RK5	7	10	10				
1/2	6.8	LPJ-SP	J	12	15	15	30	1	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	15	25				
		LPN-RK-SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
3/4	9.6	LPJ-SP	J	15	15	20	30	1	14	1/2
		TCF	CF	15	15	20				
		LP-CC	CC	15	15	30				
		LPN-RK-SP	RK1	15	15	20				
		FRN-R	RK5	12	15	20				

† All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

†† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

††† These sizes are typical. They are not shown in NEMA ICS 2-2000.



120 Vdc† motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size Table 430.247 Hp	Motor FLA Table 430.247 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps††	NEC max for gen. applic. 430.52(C)(1) exc. no. 1 amps††	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps††	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size†††	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
1/4	3.1	LPJ-SP	J	5	6	6	30	1	14	1/2
		TCF	CF	6	6	6				
		LP-CC	CC	6	6	12				
		LPN-RK-SP	RK1	4-1/2	6	6-1/4				
		FRN-R	RK5	4	6	6-1/4				
1/3	4.1	LPJ-SP	J	7	10	10	30	1	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	9	10	15				
		LPN-RK-SP	RK1	5-6/10	10	10				
		FRN-R	RK5	5-6/10	10	10				
1/2	5.4	LPJ-SP	J	9	10	12	30	1	14	1/2
		TCF	CF	10	10	10				
		LP-CC	CC	10	10	20				
		LPN-RK-SP	RK1	7-1/2	10	12				
		FRN-R	RK5	7	10	12				
3/4	7.6	LPJ-SP	J	12	15	15	30	1	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	15	15	30				
		LPN-RK-SP	RK1	10	15	15				
		FRN-R	RK5	10	15	15				
1	9.5	LPJ-SP	J	15	15	20	30	1	14	1/2
		TCF	CF	15	15	20				
		LP-CC	CC	15	15	30***				
		LPN-RK-SP	RK1	15	15	20				
		FRN-R	RK5	12	15	20				
1-1/2	13.2	LPJ-SP	J	20	20	25	30	1	14	1/2
		TCF	CF	20	20	25				
		LP-CC	CC	20	20	30***				
		LPN-RK-SP	RK1	17-1/2	20	25				
		FRN-R	RK5	17-1/2	20	25				
2	17	LPJ-SP	J	30	30	35	30*	1	12	1/2
		TCF	CF	30	30	35				
		LP-CC	CC	30	30	30***				
		LPN-RK-SP	RK1	25	30	35				
		FRN-R	RK5	25	30	35				
3	25	LPJ-SP	J	40	40	50	60	1	10**	1/2
		TCF	CF	40	40	50				
		LPN-RK-SP	RK1	35	40	50				
		FRN-R	RK5	35	40	35				
		LPJ-SP	J	60	60	90				
5	40	TCF	CF	60	60	60	60*	2	8**	1/2**
		LPN-RK-SP	RK1	60	60	90				
		FRN-R	RK5	50	60	90				
		LPJ-SP	J	90	90	125				
		TCF	CF	90	90	—				
7-1/2	58	LPN-RK-SP	RK1	80	90	125	100*	3	4**	3/4**
		FRS-R	RK5	80	90	125				
		LPJ-SP	J	125	125	150				
		LPN-RK-SP	RK1	100	125	150				
		FRS-R	RK5	100	125	150				

† All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

†† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

††† Reduced voltage magnetic controller ratings.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

*** Largest LP-CC fuse 30 A. With other type fuse, could use larger amp rating in this application.

180 Vdc† motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size	Motor FLA			NEC max for gen. applic.	NEC max for heavy start			Min copper wire THWN or THHN	Min rigid metallic conduit	
Table 430.247 Hp	Table 430.247 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal branch ckt protection amps††	430.52(C)(1) exc. no. 1 amps††	430.52(C)(1) exc. no. 2 amps††	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size†††	AWG or kcmil Table 310.15(B) (16) size	Annex C Table C8 inches
1/4	2.0	LPJ-SP	J	3	3	4-1/2	30	1	14	1/2
		TCF	CF	3	3	3				
		LPS-RK-SP	RK1	2-8/10	3	4-1/2				
		FRS-R	RK5	2-1/2	3	4-1/2				
1/3	2.6	LPJ-SP	J	4	6	6	30	1	14	1/2
		TCF	CF	6	6	6				
		LPS-RK-SP	RK1	3-1/2	6	6				
		FRS-R	RK5	3-1/2	6	6				
1/2	3.4	LPJ-SP	J	5-6/10	6	6	30	1	14	1/2
		TCF	CF	6	6	6				
		LPS-RK-SP	RK1	4-1/2	6	6-1/4				
		FRS-R	RK5	4-1/2	6	7-1/2				
3/4	4.8	LPJ-SP	J	8	10	10	30	1	14	1/2
		TCF	CF	10	10	10				
		LPS-RK-SP	RK1	6-1/4	10	10				
		FRS-R	RK5	6	10	10				
1	6.1	LPJ-SP	J	10	10	12	30	1	14	1/2
		TCF	CF	10	10	10				
		LPS-RK-SP	RK1	8	10	12				
		FRS-R	RK5	8	10	12				
1-1/2	8.3	LPJ-SP	J	15	15	17-1/2	30	1	14	1/2
		TCF	CF	15	15	15				
		LP-CC	CC	—	—	30				
		LPS-RK-SP	RK1	12	15	17-1/2				
2	10.8	FRS-R	RK5	12	15	17-1/2	30	1	14	1/2
		LPJ-SP	J	15	20	20				
		TCF	CF	15	20	20				
		LP-CC	CC	20	20	30				
3	16	LPS-RK-SP	RK1	15	20	20	30*	1	14	1/2
		FRS-R	RK5	15	20	20				
		LPJ-SP	J	25	25	35				
		TCF	CF	25	25	35				
5	27	LP-CC	CC	25	25	30	60	2	10**	1/2
		LPS-RK-SP	RK1	20	25	35				
		FRS-R	RK5	20	25	35				
		LPJ-SP	J	40	45	60				
		TCF	CF	40	45	60	60	2	10**	1/2
		LPS-RK-SP	RK1	40	45	60				
		FRS-R	RK5	35	45	60				

† All equipment manufacturers should be consulted about their equipment DC voltage ratings.

†† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

††† These sizes are typical. They are not shown in NEMA ICS 2-2000.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

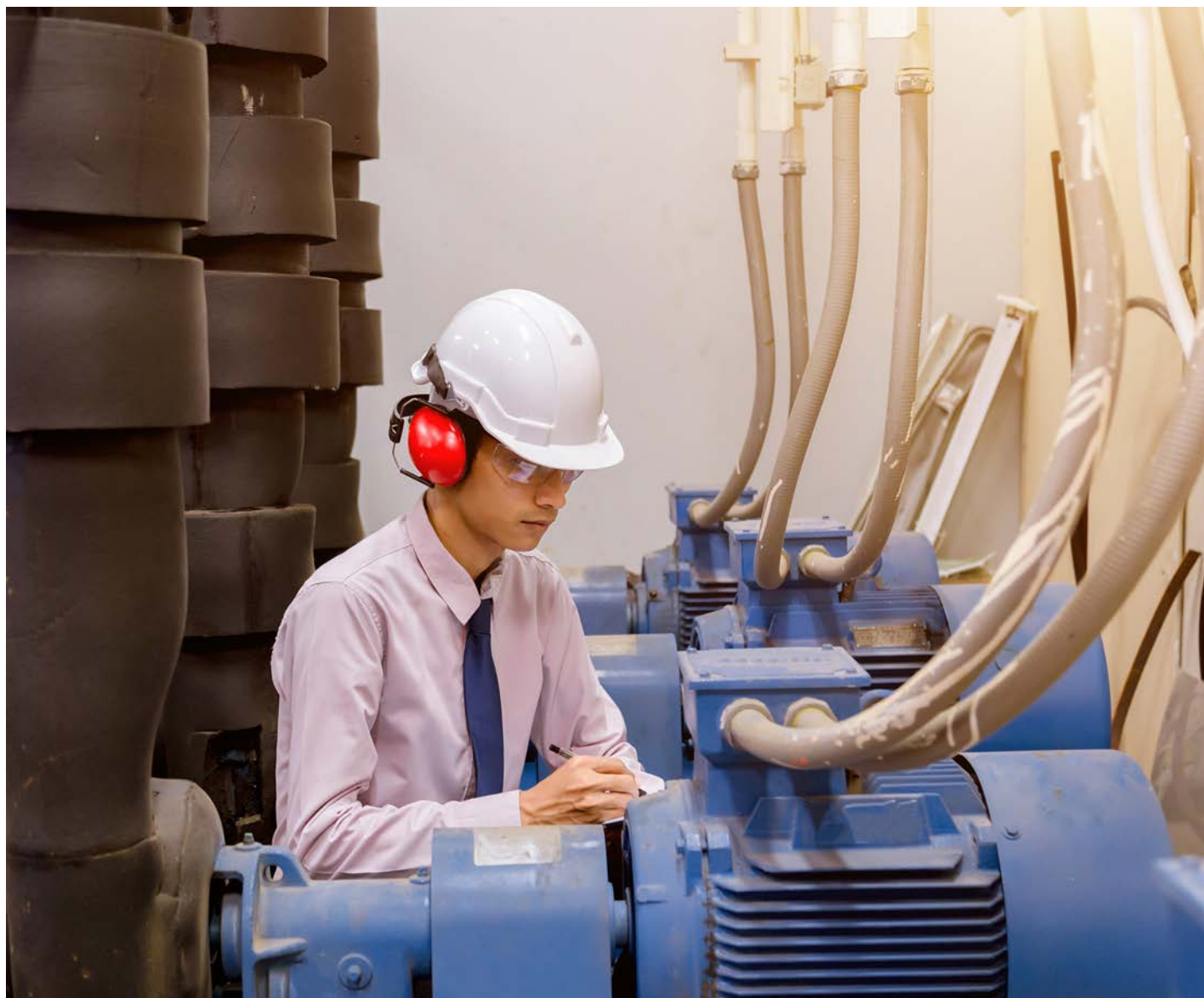
240 Vdc† motors and circuits

1	2	3	4	5	6	7	8	9	10	
Motor size Table 430.247 Hp	Motor FLA Table 430.247 Amps	Bussmann series fuse symbol	UL branch circuit fuse class	Optimal Branch ckt protection amps††	NEC max for gen. applic. 430.52(C)(1) exc. no. 1 amps††	NEC max for heavy start 430.52(C)(1) exc. no. 2 amps††	Min switch size 430.110 amps	Min NEMA starter NEMA ICS 2-2000 size†††	Min copper wire THWN or THHN AWG or kcmil Table 310.15(B) (16) size	Min rigid metallic conduit Annex C Table C8 inches
1/4	1.6	LPJ-SP	J	2-1/2	3	3-1/2	30	1	14	1/2
		TCF	CF	3	3	3				
		LPN-RK-SP	RK1	2-1/4	3	3-1/2				
		FRS-R	RK5	2	3	3-1/2				
1/3	2.0	LPJ-SP	J	3	3	4-1/2	30	1	14	1/2
		TCF	CF	3	3	3				
		LPS-RK-SP	RK1	2-8/10	3	4-1/2				
		FRS-R	RK5	2-1/2	3	4-1/2				

† All equipment manufacturers should be consulted about their equipment DC voltage ratings.

†† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

††† Reduced voltage magnetic DC controller ratings.



240 Vdc† motors and circuits continued

1	2	3	4	5	6	7	8	9	10
Motor size	Motor FLA			NEC max for	NEC max for			Min copper	
Table 430.247	Table 430.247	Bussmann series fuse	UL branch circuit fuse	Optimal branch ckt protection	430.52(C)(1) exc. no. 1	430.52(C)(1) exc. no. 2	Min NEMA starter ICS 2-2000 size†††	wire THWN or THHN AWG or kcmil Table 310.15(B)(16) size	Min rigid metallic conduit Annex C Table C8 inches
Hp	Amps	symbol	class	ampst†	ampst†	ampst†	430.110 amps		
1/2	2.7	LPJ-SP	J	4-1/2	6	6	30	1	14
		TCF	CF	6	6	6			
		LPS-RK-SP	RK1	4	6	6			
		FRS-R	RK5	3-1/2	6	6	30	1	14
		LPJ-SP	J	6	6	8			
		TCF	CF	6	6	6			
3/4	3.8	LP-CC	CC	—	—	15	30	1	14
		LPS-RK-SP	RK1	5	6	8			
		FRS-R	RK5	5	6	8			
		LPJ-SP	J	8	10	10	30	1	14
		TCF	CF	10	10	10			
		LPS-RK-SP	RK1	6-1/4	10	10			
1	4.7	FRS-R	RK5	6	10	10	30	1	14
		LPJ-SP	J	10	10	12			
		TCF	CF	10	10	10			
1-1/2	6.6	LPS-RK-SP	RK1	9	10	12	30	1	14
		FRS-R	RK5	9	10	12			
		LPJ-SP	J	15	15	17-1/2			
		TCF	CF	15	15	15	30	1	14
		LPS-RK-SP	RK1	12	15	17-1/2			
		FRS-R	RK5	12	15	17-1/2			
2	8.5	LPJ-SP	J	20	20	25	30	1	14
		TCF	CF	20	20	25			
		LP-CC	CC	20	20	30			
3	12.2	LPS-RK-SP	RK1	17-1/2	20	25	30	1	14
		FRS-R	RK5	17-1/2	20	25			
		LPJ-SP	J	30	30	45			
		TCF	CF	30	30	45	30*	1	12
		LP-CC	CC	30	30	30			
		LPS-RK-SP	RK1	30	30	45			
5	20	FRS-R	RK5	25	30	45	30*	1	12
		LPJ-SP	J	45	45	60			
		TCF	CF	45	45	60			
7-1/2	29	LPS-RK-SP	RK1	40	45	60	60	2	8
		FRS-R	RK5	40	45	60			
		LPJ-SP	J	60	60	80			
10	38	TCF	CF	60	60	60	60*	2	8**
		LPS-RK-SP	RK1	50	60	80			
		FRS-R	RK5	50	60	80			
15	55	LPJ-SP	J	90	90	110	100*	3	4
		TCF	CF	90	90	—			
		LPN-RK-SP	RK1	80	90	110			
20	72	FRS-R	RK5	70	90	110	100*	3	3**
		LPJ-SP	J	110	110	150			
		LPN-RK-SP	RK1	100	110	150			
25	89	FRS-R	RK5	90	110	150	200	3	2**
		LPJ-SP	J	150	150	200			
		LPN-RK-SP	RK1	125	150	200			
30	106	FRS-R	RK5	125	150	200	200*	4	1/0**
		LPJ-SP	J	175	175	225			
		LPN-RK-SP	RK1	150	175	225			
40	140	FRS-R	RK5	150	175	225	200*	4	2/0**
		LPJ-SP	J	225	225	300			
		LPN-RK-SP	RK1	200	225	300			
50	173	FRS-R	RK5	175	225	300	400	5	4/0**
		LPJ-SP	J	300	300	350			
		LPN-RK-SP	RK1	225	300	350			
60	206	FRS-R	RK5	225	300	350	400*	5	300**
		LPJ-SP	J	350	350	450			
		LPN-RK-SP	RK1	300	350	450			
75	255	FRS-R	RK5	300	350	450	400*	5	400**
		LPJ-SP	J	400	400	500			
		LPN-RK-SP	RK1	350	400	500			
100	341	FRS-R	RK5	350	400	500	600	6	4/0 2/phase
		LPJ-SP	J	600	600	—			
		LPN-RK-SP	RK1	450	600	—			
		FRS-R	RK5	450	600	—			(2) 1-1/2**

† All equipment manufacturers should be consulted about their equipment DC voltage ratings.

†† Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

††† Reduced voltage magnetic DC controller ratings for 230 V circuits.

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

7.14.6 Motor starter protection

Motor controllers are highly susceptible to damage from short-circuits. Even for moderate or low-level faults, extensive damage may occur if the short-circuit protective device is not carefully selected. The most vulnerable parts are the starter's contacts and heater elements. Fault currents can weld the contacts and cause the heater elements to vaporize or be critically damaged. The metallic vapors from such damage then can initiate further starter destruction in the enclosure.

Often, after a fault, no apparent damage is visible (i.e., the contacts are not welded and the heater elements are not burnt up). However, the heat energy from the fault may have caused too high of a heat excursion for the heater elements or overload relay sensing element to withstand, with the result being a permanently altered and degraded level of overload protection.

The question is, what can be done to obtain the highest degree of short-circuit protection for motor controllers? The solution is to use current-limiting short-circuit protective devices that are sized as close as practical. A current-limiting fuse can cut off the short-circuit current before it reaches damaging levels. Even for potentially high fault currents, the fuse's quick clearing can limit the current passed through the starter to safe levels. Dual-element time-delay Class RK5 and RK1 fuses are recommended since they can be sized at 125% or 130% respectively of the motor full-load current, rather than 300% sizing for non-time delay fuses.

The branch circuit protective device size cannot exceed the maximum rating shown on equipment labels or controller manufacturer's tables. NEC 430.53 requires observing the requirements of 430.52 plus, for circuits under 430.53(C) the motor running overload device and controller must be listed for group installation with a specified maximum rating protective device. Under 430.54, for multi-motor and combination-load equipment, the branch circuit protective device rating cannot exceed the rating marked on the equipment. Therefore, be sure to check labels, controller overload relay tables, equipment nameplates, etc. In no case can the manufacturer's specified rating be exceeded. This would constitute a violation of NEC 110.3(B). When the label, table, etc. is marked with a "Maximum Fuse Amp Rating" rather than marked with a "Maximum Overcurrent Device" this then means only fuses can be used for the branch circuit protective device.

Achieving short-circuit protection

In order to properly select an overcurrent device for a motor starter, four areas require particular attention:

1. Contactor withstand rating
2. Wire damage
3. Fuse and relay curve crossover point
4. Motor damage

Please refer to the graphs in Figure 7.14.6.a.

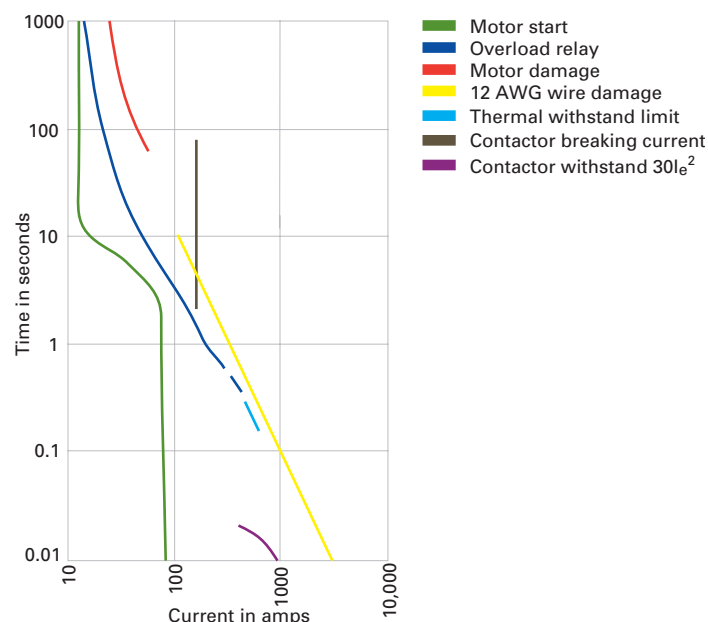


Figure 7.14.6.a Motor and motor circuit damage protection, 10 Hp @ 480 V.

Contactor withstand rating

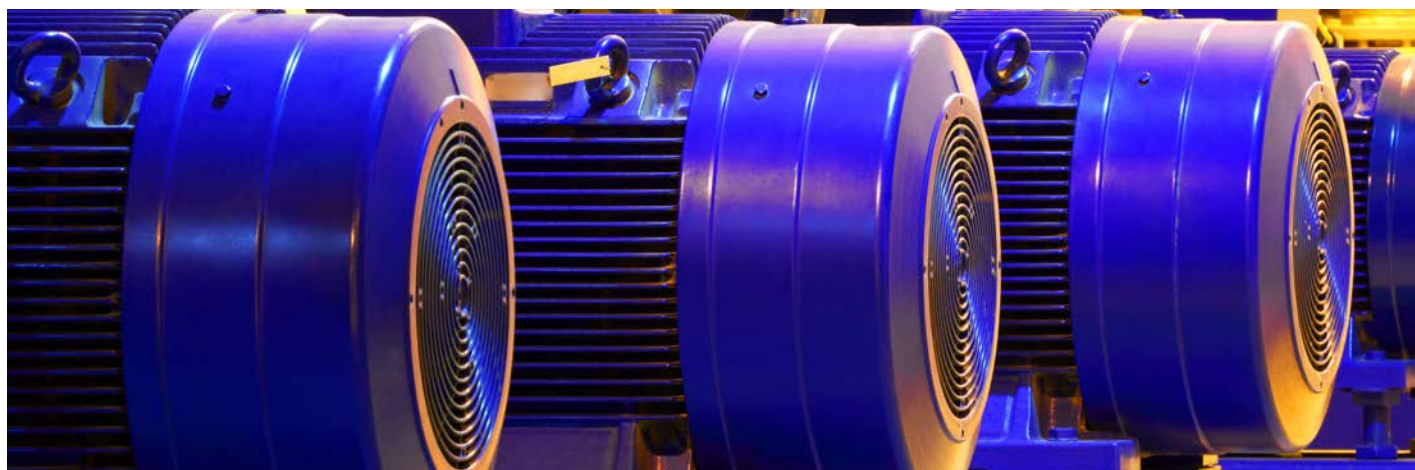
The first area of concern is the contactor's withstand rating. In order to prevent contactor damage, the maximum peak let-through current (I_p) and maximum clearing energy (I^2t) (amps² seconds) of the fuse must be less than the equivalent contactor ratings. The fuse's clearing time and let-through characteristics must be considered when verifying adequate contactor protection.

Wire damage

Secondly, motor circuit conductors have a withstand rating that must not be exceeded. If the OCPD is not capable of limiting the fault current to a value below the wire withstand, the wire may be damaged, or destroyed.

Fuse and relay crossover point

Thirdly, the crossover point (I_c) is the point where the fuse curve intersects the overload relay curve. For current levels less than the crossover point the overload relay opens the circuit. For current values greater than the crossover point the fuses open the circuit and prevent thermal damage to the overload relay, contacts, and the motor circuit. This point of intersection should be approximately 7 to 10 times I_e , where I_e is rated current. Ideally the fuse should allow the overload relay to function under overload conditions and operate before the overcurrent reaches the contactor's breaking capacity.



7.14.7 Group motor protection

Group fusing

NEC 430.53 covers the requirements for group motor installations. Two or more motors, or one or more motors and other loads may be protected by the same branch circuit fuse or inverse time circuit breaker if:

- (A) All motors are 1 Hp or less, protected at not over 20 A at 120 V or at 15 A at 600 V or less, the full load amp rating of each motor does not exceed 6 A, the device rating marked on the controller is not exceeded, and individual overload protection conforms to 430.32.
- or
- (B) The circuit for the smallest motor is protected per 430.52; i.e. the branch circuit overcurrent protective device protecting the group meets 430.52 for the circuit with the smallest motor.
- or
- (C) The complete assembly of properly sized branch circuit overcurrent protective device, controller and overload devices is tested, listed, and marked for a group installation. The overload device or motor controller does not need to be listed for group installation if the branch circuit, short-circuit and ground fault protective device provides protection for the overload device/motor controller per 430.52.

And one of the following:

- (D)(1) The motor conductor ampacity is not less than the branch circuit conductor ampacity
- or
- (D)(2) The conductors to motors have at least 1/3 the ampacity of the branch circuit conductors, are protected from physical damage and are not more than 25 feet long before being connected to the motor overload device.
- or
- (D)(3) The tap conductors from the branch circuit OCPD to each manual motor controller* marked "Suitable for Tap Conductor Protection in Group Installations" must have an ampacity of at least 1/10** the branch circuit OCPD's amp rating. These tap conductors must be 10 feet or less, enclosed and protected from physical damage; if not, then these conductors must have an ampacity of at least the same as the branch circuit conductors. The conductor ampacity from the controller to the motor must be per 430.22.

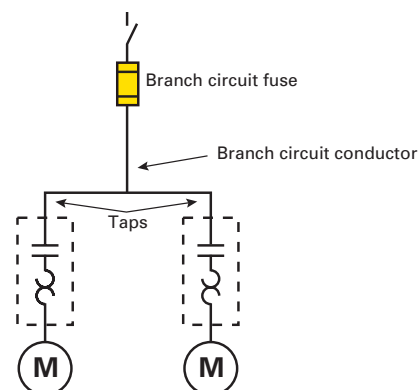
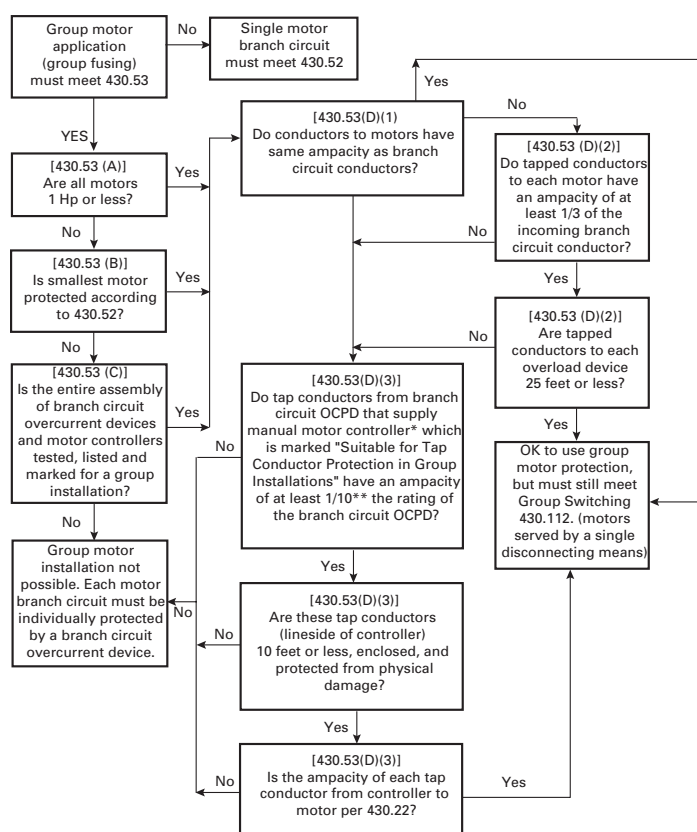


Figure 7.14.7.a Group motor installation (group fusing) NEC 430.53



Another approach

Typically, group motor installations protected by one branch circuit OCPD and group switching are considered. However, caution should be taken where a conductor is to be protected by an OCPD sized significantly larger than the conductor's ampacity. The NEC implies this caution in 430.53(C) IN, referring back to 110.10 and 240.4 IN which references ICEA P-32-382-2007 for conductor insulation damage under short-circuit conditions. Smaller conductors are difficult to protect under short-circuit conditions, especially by non-current limiting OCPDs. Also, group protection sacrifices selective coordination; a fault on one circuit may shut down all the loads on the group circuit. As a better alternative, consider group switching with fuses/fuse holders protecting each motor or other type load. See information on group switching. Use holders such as OPM-NG, OPM1038SW, OPM1038, CH, JT or TCFH with finger-safe TCF CUBEFuse.

* If a manual motor controller is utilized for this application, it must:

1. Be marked "Suitable for Tap Conductor Protection in Group Installations."
2. Be applied within its voltage limitations (slash voltage rating), if applicable.
3. Be protected by a branch circuit protective device that meets all limitations of the manual motor controller listing criteria. For instance, it may be required to be protected by a fuse no greater than a specified amp rating.

**Even though permitted by this section, the branch circuit overcurrent protective device may not be able to provide adequate short-circuit protection for a conductor having an ampacity 1/10 the rating of the branch circuit overcurrent protective device. This is especially the case with non current-limiting branch circuit protective devices. It is suggested an engineering conductor protection analysis be conducted for this application (110.10) and (240.4 IN).

Figure 7.14.7.b Group motor protection decision tree.

The maximum motor circuit feeder fuse (430.62)

1. For the one motor in the group with the highest starting current; Find the largest fuse permitted for branch circuit protection using Table 430.52 or 440.22(A). The fuse capacity permitted for the motor with the heaviest starting current may be considered for only one motor. If two or more motors can each have a fuse of the same maximum size, only one of them can be considered. Then add:
2. The amp rating for all other motors on that feeder.

Feeder motor schedule example - 480 V, 3-phase motors

Number of units	Hp	Amps*	Multiplier†
1	3	4.8	1.75
	5	7.6	
	15	21	
	40	52	
	75	96	

* Per Table 430.150.

† Per Table 430.52.

Calculations, maximum for dual-element, time-delay fuses:

1. Largest motor (96 A x 1.75 = 168 A) use either 175 A or 200 A fuse.
 - a. Next standard fuse amp rating: Since 168 A is not standard fuse rating, permitted to use 175 A, per 430.52(C) Exception No. 1.
 - b. Heavy start: if the above sizing is not sufficient for the motor starting current, 430.52(C) Exception No. 2 (b) permits a larger fuse amp rating, but it can not exceed 2.25 times the motor full-load current.
 2. FLA all other motors (85.4 A).
 3. Total (175 A + 85.4 A = 260.4 A) 250 A feeder fuse (round down).
- Total (200 A + 85.4 A = 285.4 A) 250 A feeder (round down).
- Choose 250 amp dual-element fuse.

Feeder circuit-combination motor, power and lighting loads

Where a feeder supplies motor load and power and/or lighting load, the permitted feeder fuse size calculation is the sum of the calculated motor load (in accordance with 430.62), plus the calculated other loads (in accordance with Articles 210 and 220 (430.63)). The conductor ampacity supplying motors and other loads must be at least the sum of that calculated for the motor load in accordance with 430.22 and 430.24, plus that calculated for the other loads in accordance with Article 220 (430.25). (For exceptions see 430.25.)

Sizing example for dual-element fuses used in a combination load feeder

Motor load (use “Feeder motor schedule” table above)

Continuous heating and lighting load = 135 A

Non-continuous loads = 110 A

Calculations:

1. Motor load: (from preceding example) 260.4 A
 2. Continuous non-motor load 135 A x 125% 168.8 A
 3. Non-continuous, non-motor load 110.0 A
- Total = 539.2 A

Round down to 500 A and choose a 500 A dual-element fuse.

7.14.8 Motor control circuit protection

General

A motor control circuit is an apparatus or system circuit that carries the electric signal directing the controller's performance (430.2). It does not carry the main power current.

A control circuit tapped on the loadside of the motor branch circuit fuse (which controls the motor on that branch circuit) must be protected against overcurrent as in 430.72. Such a circuit is not considered a branch circuit and may be protected by a supplemental or branch circuit fuse as shown in Figure 7.14.8.a. In either case, the fuse must have an adequate interrupting rating for the fault current at its point of application.

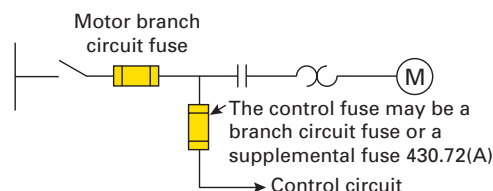


Figure 7.14.8.a Supplemental or branch circuit fuse protection for a control circuit

A standards requirement pertinent to motor controllers listed for available fault currents greater than 10 kA, states that the control circuit fuse must be a branch circuit fuse with a sufficient interrupting rating. (Using Bussmann series KTK-R, FNQ-R, LP-CC, JJS, JJN, TCF, or LPJ-SP fuses is recommended. These are UL Listed branch circuit fuses with high interrupting ratings and small size.)

Motor control circuit conductors

Control circuits tapped on the branch circuit fuse's loadside [430.72(B)]

1. Control circuit conductors 18 AWG and larger must be protected against overcurrent in accordance with Table 430.72(B), Column A, as applicable. 430.72(B)(2) as shown in Figure 7.14.8.b.

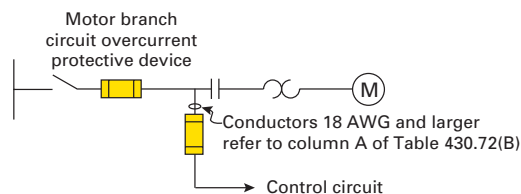


Figure 7.14.8.b Control circuit conductor sizes to be 18 AWG or larger.

Control conductors not extending beyond the enclosure must be considered protected by the branch circuit fuse if in accordance with Table 430.72(B), Column B as shown in Figure 7.14.8.c.

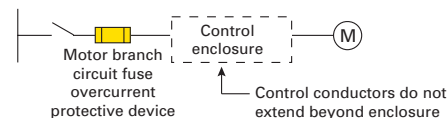


Figure 7.14.8.c Control circuit conductors not extending beyond the enclosure.

For control conductors extending beyond the enclosure, the motor branch circuit overcurrent device must be considered to protect the conductors if in accordance with Table 430.72(B), Column C as shown in Figure 7.14.8.d.

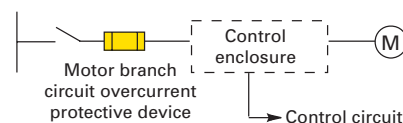


Figure 7.14.8.d Control circuit conductors extending beyond the enclosure.

Table 430.72(B) Maximum OCPD ratings (amps)

Control circuit conductor size AWG	Column A basic rule		Column B exception no. 1		Column C exception no. 2	
	Copper	Aluminum or copper clad aluminum	Copper	Aluminum or copper clad aluminum	Copper	Aluminum or copper clad aluminum
18	7	—	25	—	7	—
16	10	—	40	—	10	—
14	Note 1	—	100	—	45	—
12	Note 1	Note 1	120	100	60	45
10	Note 1	Note 1	160	140	90	75
Larger than 10	*	*	**	**	†	†

* Value specified in Section 310-15, as applicable.

**400 percent of value specified in Table 310-17 for 60°C conductors.

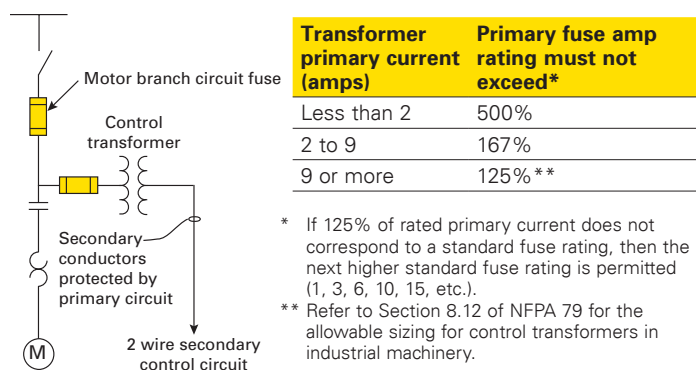
† 300 percent of value specified in Table 310-16 for 60°C conductors.

NEC 430.72(C)

Single-phase transformer secondary conductors having only a 2 wire secondary are protected by the primary fuse (600 V or less) if the primary fuse rating is:

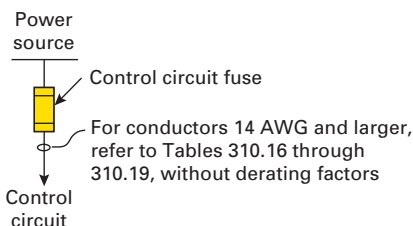
- Not larger than that determined in Table 430.72(B), multiplied by secondary-to-primary voltage ratio
- Not more than the following percent of transformer rated primary current

Control conductors are permitted to be protected by the motor branch circuit OCPD where the control circuit opening would create a hazard.

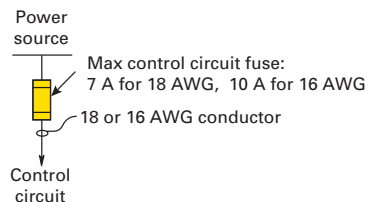


Class 1 power limited, and Class 2 and 3 remote motor control circuits

1. Control circuit conductors must be protected from overcurrent in accordance with 725.43 or the notes to Table (11A) and (B) in NEC Chapter 9 as shown in Figure 7.14.8.e.


Figure 7.14.8.e Control circuit conductor 14 AWG and larger protection.

2. Control circuit conductors 18 AWG and 16 AWG, must be protected by a control circuit fuse not to exceed 7 and 10 amps respectively as shown in Figure 7.14.8.f.


Figure 7.14.8.f Fuse amp limits for protecting 18 and 16 AWG control circuit conductors.

Exception No. 2 relative to transformer protection

Refer to Exception 2, [430.72(B)], covered in preceding paragraphs.

Motor control circuit transformers [430.72(C)]

430.72(C)(3): Control circuit transformers rated less than 50 VA can be protected by a primary fuse, impedance limiting means, or other inherent means. The transformer must be an integral part of the motor controller, and be located within the controller.

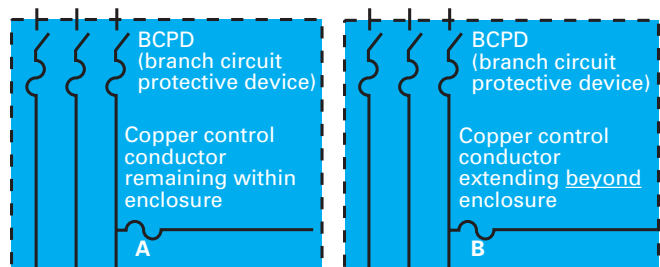
430.72(C)(4): Allows transformers with primary currents less than 2 amps to be protected with primary fuses at 500% or less of primary full-load amps.

430.72(C)(1): Allows the control transformer to be protected by the motor branch circuit OCPD when the transformer supplies a Class 1 power-limited circuit [see 725.41] Class 2, or Class 3 remote control circuit conforming with the requirements of Article 725.

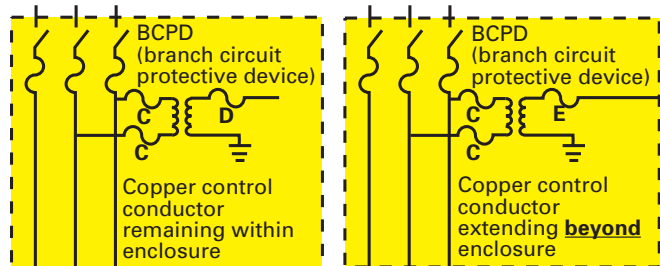
430.72(C)(5): Allows the control transformer to be protected by the motor branch circuit overcurrent device where protection is provided by other approved means.

430.72(C) Exception: States that overcurrent protection must be omitted where the opening of the control circuit would create a hazard, as for example, the control circuit of a fire pump motor.

The following tables simplify and permit easy fuse application for protecting motor control circuits in accordance with the NEC.


Circuit 1
Circuit 2

For a control circuit without a control transformer that conforms to either circuit 1 or 2 above, apply fuses per Table 1.


Circuit 3
Circuit 4

For a control circuit with a control transformer that conforms to either circuit 3 or 4 above, apply fuses per Table 2.

Amp rating of branch circuit protective device (BCPD)	Circuit 1 — Control conductor (AWG) not extending beyond enclosure				Circuit 2 — Control conductor (AWG) extending beyond enclosure			
	18 AWG	16 AWG	14 AWG	12 AWG	18 AWG	16 AWG	14 AWG	12 AWG
Fuse size (amps)	7 A	10 A	15 A	20 A	7 A	10 A	15 A	20 A
Requirements for control circuit protection (see footnotes)								
1/10 to 7	1	1	1	1	1	1	1	1
7-1/2 to 10	1	1	1	1	2	1	1	1
12 to 25	1	1	1	1	2	2	1	1
30 to 40	2	1	1	1	2	2	1	1
45	2	2	1	1	2	2	1	1
50 to 60	2	2	1	1	2	2	2	1
65 to 100	2	2	1	1	2	2	2	2
110	2	2	2	1	2	2	2	2
125 and up	2	2	2	2	2	2	2	2

1 Control circuit fuse protection required

2 Protection recommended but not mandatory when BCPD is a Class CC, CF, G, J, R or T fuse Protection is mandatory when BCPD is a thermal magnetic or a magnetic-only circuit breaker (MCP), and available fault current exceeds the values in the table below.

Control circuit conductor (AWG copper)	Available fault current at branch circuit protective device (BCPD)	
	1 cycle clearing time† (amps)	1/2 cycle clearing time† (amps)
18	660	940
16	1050	1500
14	1700	2400
12	2700	3800

* Thermoplastic insulation.

† Based on ICEA conductor withstand data.

Table 1. Fuse selection for control circuits without a control transformer (see circuit diagrams 1 and 2 on the previous page).

Control Xfm rating	V _{pri} /V _{sec} (volts)	I _{pri} (amps)	I _{sec} (amps)	1 Fuse C		Fuse D or E					Recommended amps	
				2 Req'd. If BCPD exceeds these amp values	4,5 Max amps	Required if BCPD and Fuse C (when provided) exceed these amp values				1 Time-delay	3 Non-Time delay	
						8 AWG	16 AWG	14 AWG	12 AWG			
25 VA	480/120	0.05	0.21	6 See 430.72(C)(3) Except. 1	0.25	0.25	0.25	0.25	0.25	0.25	0.60	
	480/24	0.05	1.00		0.25	0.25	0.25	0.25	0.25	1.25	3.0	
	240/120	0.10	0.21		0.50	0.50	0.50	0.50	0.50	0.25	0.60	
	240/24	0.10	1.00		0.50	0.50	0.50	0.50	0.50	1.25	3.0	
50 VA	480/120	0.10	0.42	0.5	0.50	0.50	0.50	0.50	0.50	0.50	1.0	
	480/24	0.10	2.10	0.5	0.50	0.50	0.50	0.50	0.50	2.5	6.0	
	240/120	0.21	0.42	1.0	1.0	1.0	1.0	1.0	1.0	0.50	1.0	
	240/24	0.21	2.10	1.0	1.0	1.0	1.0	1.0	1.0	2.5	6.0	
100 VA	480/120	0.21	0.83	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	
	480/24	0.21	4.20	1.0	1.0	1.0/0.35 ⁹	1.0/0.50 ⁹	1.0	1.0	5.0	12.0 ⁷	
	240/120	0.42	0.83	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	
	240/24	0.42	4.20	2.0	2.0	2.0/0.70 ⁹	2.0/1.0 ⁹	2.0	2.0	5.0	12.0 ⁷	
150 VA	480/120	0.31	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.50	3.50	
	480/24	0.31	6.25	1.5	1.5		1.5/0.5 ⁹	1.5	1.5	7.50	15.0 ⁷	
	240/120	0.62	1.25	3.0	3.0	3.0	3.0	3.0	3.0	1.50	3.50	
	240/24	0.62	6.25	3.0	3.0		3.0/1.0 ⁹	3.0	3.0	7.50	15.0 ⁷	
200 VA	480/120	0.42	1.67	2.0	2.0	2.0/1.75 ⁹	2.0	2.0	2.0	2.0	5.0	
	480/24	0.42	8.33	2.0	2.0			2.0	2.0	10.0	20.0 ⁸	
	240/120	0.84	1.67	4.0	4.0	4.0/3.5 ⁹	2.0	4.0	4.0	2.0	5.0	
	240/24	0.84	8.33	4.0	4.0			4.0	4.0	10.0	20.0 ⁸	

1. Time-delay fuses: FNQ, FNM, FNA (supplemental fuses); FNO-R, FRN-R, FRS-R, LPN-RK-SP, LPS-RK-SP, LPJ-SP, LP-CC, SC 6 amps and above (rejection type branch circuit fuses).

2. For exceptions, see 430.72(C).

3. Non-time delay fuses: KTK, BAN, BAF, MIC supplemental fuses or; KTK-R, JJN, JJS, SC (SC fast-acting 1/2 - 5 A only) rejection type branch circuit fuses.

4. These are maximum values as allowed by 430.72(C). Closer sizing at 125%-300% may be possible for better overload protection using time-delay branch circuit fuses.

5. Fuse must be a rejection type branch circuit fuse when controller withstand rating is greater than 10 kA RMS Sym.

6. Transformers less than 50 VA still need protection - either primary overcurrent protection, inherent protection, or the equivalent. Note that the primary conductors may be protected as shown in Circuit 1, Table 1.

7. Minimum copper secondary control conductor for this application is 14 AWG.

8. Minimum copper secondary control conductor for this application is 12 AWG.

9. Smaller value applied to fuse "E."

Table 2. Fuse selection for control circuits with a control transformer (see circuit diagrams 3 and 4 on the previous page).

Motor control circuit transformer fuse amp rating selection guide (based on the NEC) using Bussmann series FNO-R Class CC fuses.

XFMR VA	600 V	550 V	480 V	460 V	415 V	380 V	277 V	240 V	230 V	208 V
50	4/10	4/10	1/2	1/2	6/10	6/10	8/10	1	1	1-1/8
75	6/10	6/10	3/4	8/10	8/10	8/10	1-3/10	1-1/2	1-6/10	1-8/10
100	8/10	8/10	1	1	1-1/8	1-3/10	1-8/10	2	2	2-1/4
150	1-1/4	1-3/10	1-1/2	1-6/10	1-8/10	1-8/10	2-1/2	3	3-2/10	3-1/2
200	1-6/10	1-8/10	2	2	2-1/4	2-1/2	3-1/2	4	4	4-1/2
250	2	2-1/4	2-1/2	2-1/2	3	3-2/10	4-1/2	5	5	6
300	2-1/2	2-6/10	3	3-2/10	3-1/2	3-1/2	5	6-1/4	6-1/4	7
350	2-8/10	3	3-1/2	3-1/2	4	4-1/2	6-1/4	7	7-1/2	8
500	4	4-1/2	5	5	6	6-1/4	9	3-2/10††	3-1/2††	4††
750	6-1/4	6-1/4	7-1/2	8	9	9	4-1/2†	5††	5††	6††
1000	8	9	3-2/10†	3-1/2†	4†	4†	6†	6-1/4††	7††	8††
1500	4†	4-1/2†	5†	5†	6†	6-1/4†	9†	10††	10††	12††
2000	5†	6†	6-1/4†	7†	8†	8†	12†	12††	12††	15††

† For increased time-delay, use FRS-R, LPS-RK-SP, LPJ-SP or TCF.

†† For increased time-delay, use FRN-R, LPN-RK-SP.

Other available Bussmann series fuses

Supplemental fuses (13/32" x 1-1/2" — all voltages and interrupting ratings are AC)

	Fast-acting				Time-delay			
Catalog symbol								
	BAF	BBS	KLM	MIC	FNA	FNM	FNQ	KTK
Amps/volts	2-30@250	1/10-6@600 7-10@250 12-30@48	1/10-30@600	1-15@250 20-30@32	1/10-6@250 6-1/4-15@125 20-30@32	1/10-30@250	1-30@500	1/10-30@600

Branch circuit fuses (all voltage and interrupting ratings are AC)

	Class R dual-element, time-delay				Class G*	Class CC			Class CF
						Fast-acting	Time-delay	Time-delay	Time-delay
Catalog symbol									
	LPN-RK-SP	FRN-R	FRS-R	LPS-RK-SP	SC	KTK-R	FNQ-R	LP-CC	TCF
Amps/volts	1/10-30@250	1/10-30@250	1/10-30@600	1/10-30@600	1/2-20@600 25-30@480	1/10-30@600	1/4-30@600	1/2-30@600	1-30@600
IR	300 kA	200 kA	200 kA	300 kA	100 kA	200 kA	200 kA	200 kA	300 kA

* 1/2 to 6 A are non-time delay, 7 to 60 A are time-delay.

Busmann series fuse catalog symbols and their applicable fuse block catalog symbols.

Catalog symbol	UL fuse type/class	Amp rating	Single pole	Double pole	
Supplemental fuses (13/32" x 1-1/2")					
BAF	Supplemental	Up to 30	BMM603-(poles)_*	See footnote *	
FNM					
FNQ					
KLM					
KTK					
Branch circuit fuses					
FRN-R	RK5	Up to 30	RM25030-(poles)_*	See footnote *	
LPN-RK-SP	RK1		RM60030-(poles)_*		
FRS-R	RK5				
LPS-RK-SP	RK1				
FRN-R	RK5	35 to 60	RM25060-(poles)_*		
LPN-RK-SP	RK1		RM60060-(poles)_*		
FRS-R	RK5				
LPS-RK-SP	RK1				
SC	G	Up to 15	BG3011_	BG3012_	
		20	BG3021_	BG3022_	
		25 to 30	BG3031_	BG3032_	
		35 to 60	G30060-1CR	G30060-2CR	
KTK-R	CC	Up to 30	BCM603-(poles)_*	See footnote *	
FNQ-R					
LP-CC					
LPJ	J	Up to 30	JM60030-(poles)_*	See footnote *	
JKS		35 to 60	JM60060-(poles)_*		
TCF	CF	Up to 30	TCFH30N**	N/A	
		1 to 60	TCFH60N**		
		1 to 100	TCFH100N**		

* Modular design. Blocks may be dovetailed together to create the desired number of poles. Available as factory configured 1-, 2- and 3-pole blocks along with various terminal options. DIN-Rail or panel mount.

**Finger-safe fuse amp rating rejection blocks. Each will hold all fuse ratings up to the block's amp rating. All blocks, regardless of amp rating will dovetail together. DIN-Rail or panel mount.



Motor damage

Finally, all motors have an associated motor damage curve. Single phasing, overworking, and locked rotor conditions are just a few of the conditions that cause excessive currents in motor circuits. Excessive currents cause motors to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Overload relays and dual-element, time-delay fuses are designed to open the motor circuit before current levels reach the motor damage curve.

IEC and UL standards for allowable damage

IEC 947-4-1 and UL 508E differentiate between two different types of coordination, or damage levels.

Type 1 Considerable damage, requiring replacement. No external damage to the enclosure. Short-circuit protective devices interrupt intermediate to high fault currents which exceed the withstand rating of the motor starter. A non-current-limiting device will interrupt these high currents, but this type of damage will typically result.

Type 2 “No Damage” is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable. (Note: If access is not possible and the contacts cannot be separated, Type 2 protection cannot be achieved.) This protection level typically can only be provided by a current-limiting device (one which limits the available short-circuit current to a significantly lower value).

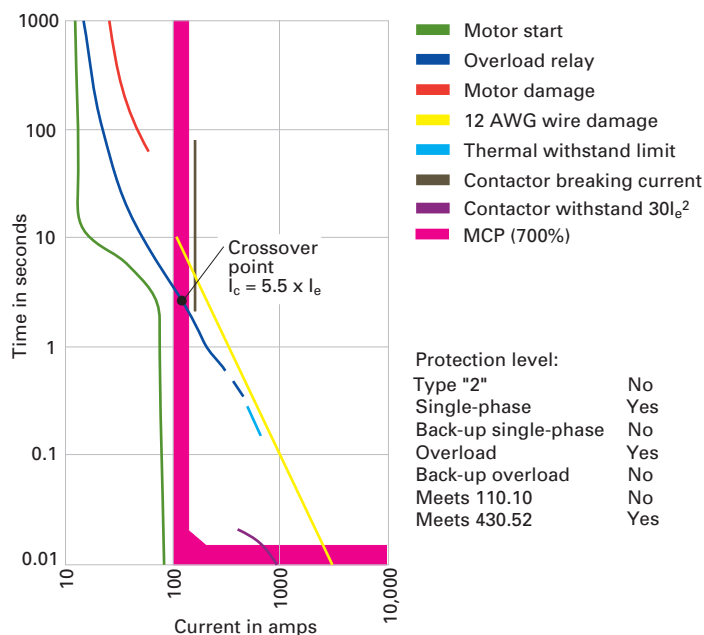
Five choices with one Solution

IEC Motor starter protection

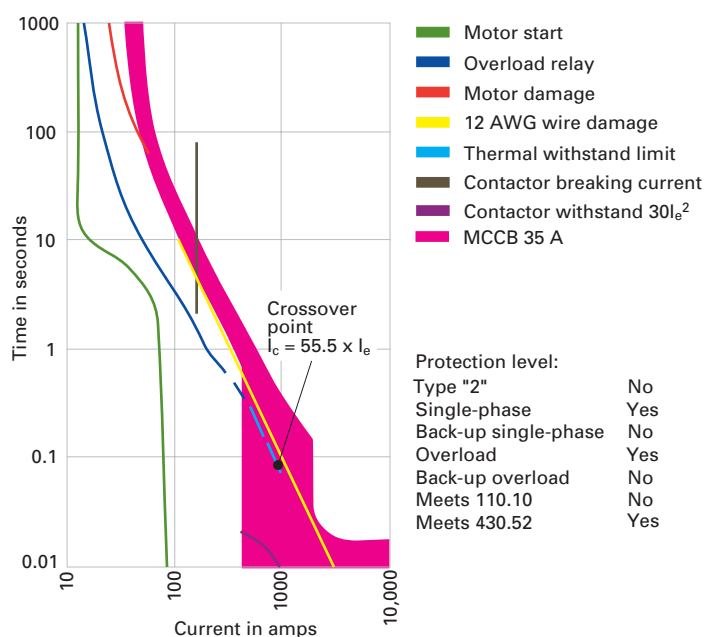
Five methods for motor starter overcurrent protection are delineated in the examples that follow. In noting the protection levels provided by each, it becomes apparent that using dual-element time-delay fuses (Example 5) is the only one that gives Type 2 “No Damage” starter protection” “back-up overload protection,” “back-up single-phase protection,” etc.

These examples are based on a typical motor circuit consisting of an IEC starter, and a 10 Hp, 460 V motor (Service factor = 1.15). These “Protection Level” examples reflect the branch circuit protective device operating in combination with the IEC starter overload relays sized at approximately 115% of motor FLA and contactor $I_e = 18$ amps.

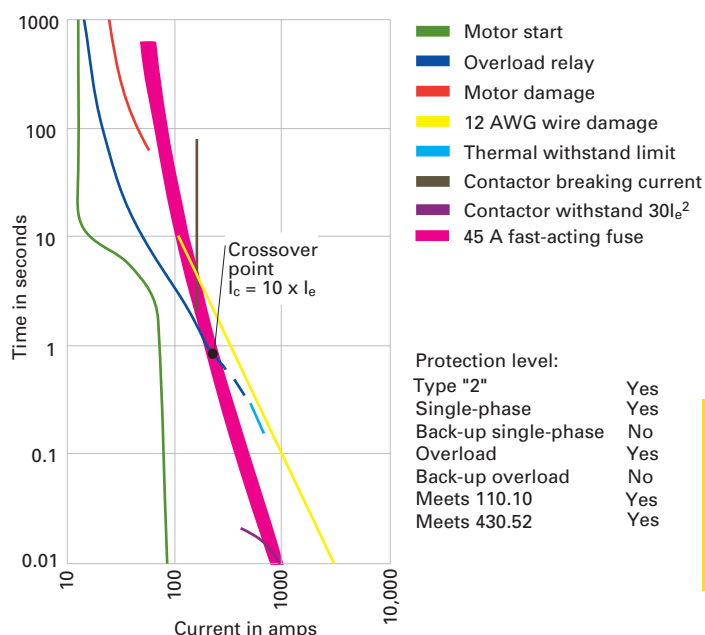
Choice 1 — Motor circuit protector (700% FLA)



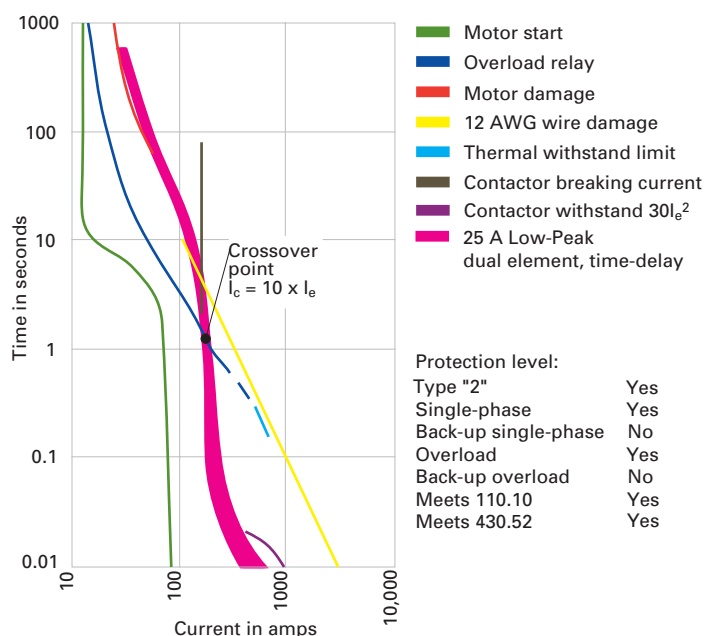
Choice 2 — Molded case circuit breaker (250% FLA)



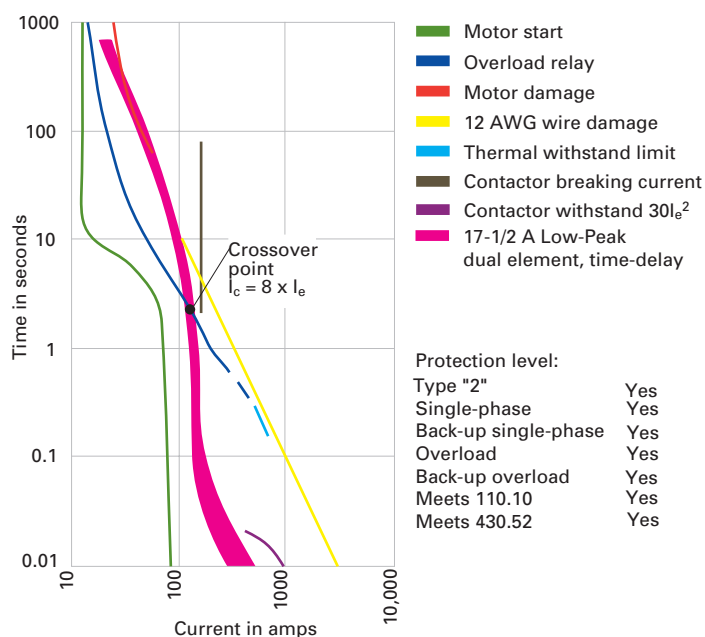
Choice 3 — Fast-acting fuse (300% FLA)



Choice 4 — Dual-element, time-delay fuse (175% FLA)



Choice 5 — Dual-element, time-delay fuse (125%, Class J or RK1)



Tips for electricians and maintenance crews

Often motors are oversized for applications. For instance, a 5 Hp motor is installed when the load demand is only 3 Hp. In these cases a much higher degree of protection can be obtained by sizing the overload relay elements and/or Bussmann series Fusetron (FRN-R/FRS-R) and Low-Peak (LPN-RK-SP/LPS-RK-SP) dual-element, time-delay fuses based on the actual full-load current draw.

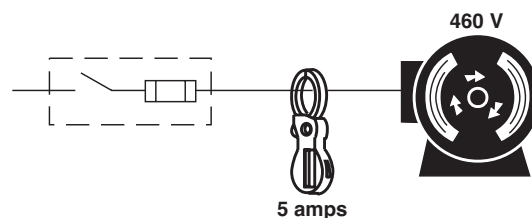


Figure 7.14.6.b

1. Preferable — With a clamp-on meter, determine running RMS current when the motor is at normal full-load. (Be sure this current does not exceed nameplate current rating.) This method's advantage is realized when a lightly loaded motor (especially those over 50 Hp) experiences a single-phase condition. Even though the relays and fuses may be sized correctly based on motor nameplate, circulating currents within the motor may cause damage.

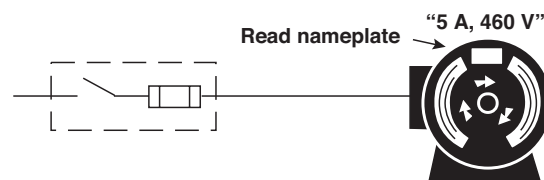


Figure 7.14.6.c

Alternate — If unable to secure a meter reading for the motor current, then take the current rating off the nameplate.

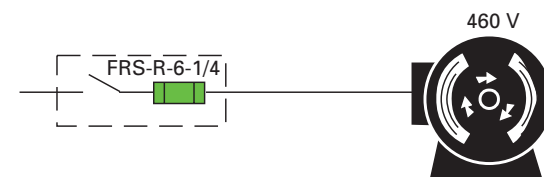


Figure 7.14.6.d

2 Then size the overload relay elements and Bussmann series Fusetron FRS-R and FRN-R or Low-Peak LPS-RK-SP and LPN-RK-SP dual-element, time-delay fuses based on this current. For optimum motor circuit protection offering a high degree of "back-up overload" protection, use the table that follows to assist in sizing dual-element time-delay fuses. The other Bussmann series fuses in the table (LPJ-SP, TCF and LP-CC) can provide excellent short-circuit protection when sized for Optimum Motor Circuit Protection. However, they typically can't be sized close enough to provide motor back-up overload protection.

3. Use a labeling system to mark the fuse type and amp rating that should be in the fuse clips, such as Bussmann series FRS-R 6 1/4. This simple step makes it easy to run spot checks for proper fuse replacement. When installing the proper fuses in the switch to give the desired protection level, it's advisable to leave spare fuses on top of the disconnect, the starter enclosure or in a cabinet adjacent to the motor control center. By doing this, should the fuses open, the problem can be corrected and proper size fuses quickly and easily reinstalled.

Selection of Fusetron or Low-Peak dual-element fuses based upon motor FLA for optimum motor circuit protection*

Fuse amps	Motor current			
	Fusetron FRN-R/FRS-R RK5	LPN-RK-SP/ LPS-RK-SP RK1	LPJ-SP Class J	LP-CC Class CC
1/10	0-0.08	0.0000-0.0769	—	—
1/8	0.09-0.10	0.0770-0.0961	—	—
15/100	0.11-0.12	0.0962-0.1153	—	—
2/10	0.13-0.16	0.1154-0.1538	—	—
1/4	0.17-0.20	0.1539-0.1923	—	—
3/10	0.21-0.24	0.1924-0.2307	—	—
4/10	0.25-0.32	0.2308-0.3076	—	—
1/2	0.33-0.40	0.3077-0.3846	—	0.0000-0.2500
6/10	0.41-0.48	0.3847-0.4615	—	0.2501-0.3000
8/10	0.49-0.64	0.4616-0.6153	—	0.3001-0.4000
1	0.65-0.80	0.6154-0.7692	0.0-0.6666	0.4001-0.5000
1-1/8	0.81-0.90	0.7693-0.8653	0.6667-0.7500	0.5001-0.5625
1-1/4	0.91-1.00	0.8654-0.9615	0.7501-0.8333	0.5626-0.6250
1-4/10	1.01-1.12	0.9616-1.076	0.8334-0.9333	0.6251-0.7000
1-1/2	1.13-1.20	1.077-1.153	0.9334-1.000	0.7001-0.7500
1-6/10	1.21-1.28	1.154-1.230	1.001-1.066	0.7501-0.8000
1-8/10	1.29-1.44	1.231-1.384	1.067-1.200	0.8001-0.9000
2	1.45-1.60	1.385-1.538	1.201-1.333	0.9001-1.000
2-1/4	1.61-1.80	1.539-1.730	1.334-1.500	1.001-1.125
2-1/2	1.81-2.00	1.731-1.923	1.501-1.666	1.126-1.250
2-8/10	2.01-2.24	1.924-2.153	1.667-1.866	1.251-1.400
3	2.25-2.40	2.154-2.307	1.867-2.000	1.401-1.500
3-2/10	2.41-2.56	2.308-2.461	2.001-2.133	1.501-1.600
3-1/2	2.57-2.80	2.462-2.692	2.134-2.333	1.601-1.750
4	3.81-3.20	2.693-3.076	2.334-2.666	1.751-2.000
4-1/2	3.21-3.60	3.077-3.461	2.667-3.000	2.001-2.250
5	3.61-4.00	3.462-3.846	3.001-3.333	2.251-2.500
5-6/10	4.01-4.48	3.847-4.307	3.334-3.733	2.501-2.800
6	4.49-4.80	4.308-4.615	3.734-4.000	2.801-3.000
6-1/4	4.81-5.00	4.616-4.807	—	3.001-3.125
7	5.01-5.60	4.808-5.384	4.001-4.666	3.126-3.500
7-1/2	5.61-6.00	—	—	3.501-3.750
8	6.01-6.40	5.385-6.153	4.667-5.333	3.751-4.000
9	6.41-7.20	6.154-6.923	5.334-6.000	4.001-4.500
10	7.21-8.00	6.924-7.692	6.001-6.666	4.501-5.000
12	8.01-9.60	7.693-9.230	6.667-8.000	5.001-6.000
15	9.61-12.00	9.231-11.53	8.001-10.00	6.001-7.500
17-1/2	12.01-14.00	11.54-13.46	10.01-11.66	4.37-5.83
20	14.01-16.00	13.47-15.38	11.67-13.33	5.84-6.67
25	16.01-20.00	15.39-19.23	13.34-16.66	6.68-8.33
30	20.01-24.00	19.24-23.07	16.67-20.00	8.34-15.00
35	24.01-28.00	23.08-26.92	20.01-23.33	—
40	28.01-32.00	26.93-30.76	23.34-26.66	—
45	32.01-36.00	30.77-34.61	26.67-30.00	—
50	36.01-40.00	34.62-38.46	30.01-33.33	—
60	40.01-48.00	38.47-46.15	33.34-40.00	—
70	48.01-56.00	46.16-53.84	40.01-46.66	—
75	56.01-60.00	—	—	—
80	60.01-64.00	53.85-61.53	46.67-53.33	—
90	64.01-72.00	61.54-69.23	53.34-60.00	—
100	72.01-80.00	69.24-76.92	60.01-66.66	—
110	80.01-88.00	76.93-84.61	66.67-73.33	—
125	88.01-100.00	84.62-96.15	73.34-83.33	—
150	100.01-120.00	96.16-115.3	83.34-100.0	—
175	120.01-140.00	115.4-134.6	100.1-116.6	—
200	140.01-160.00	134.7-153.8	116.7-133.3	—
225	160.01-180.00	153.9-173.0	133.4-150.0	—
250	180.01-200.00	173.1-192.3	150.1-166.6	—
300	200.01-240.00	192.4-230.7	166.7-200.0	—
350	240.01-280.00	230.8-269.2	200.1-233.3	—
400	280.01-320.00	269.3-307.6	233.4-266.6	—
450	320.01-360.00	307.7-346.1	266.7-300.0	—
500	360.01-400.00	346.2-384.6	300.1-333.3	—
600	400.01-480.00	384.7-461.5	333.4-400.0	—

* Abnormal installations may require larger size Bussmann series Fusetron or Low-Peak dual-element time-delay fuses than shown and provide only short-circuit protection. These applications include:

- Bussmann series Fusetron or Low-Peak dual-element time-delay fuses in high ambient temperature environments.
- A motor started frequently, rapidly reversed or subject to jogging.
- Motor is directly connected to a machine that cannot be brought up to full speed quickly (large fans, centrifugal machines such as extractors and pulverizers, machines having large fly wheels such as large presses.)
- Motor has a high Code Letter (or possibly no Code Letter) with full voltage start.
- VVw/Delta open transition start.
- Motor has a large inrush current, such as a Design B.

Low voltage motor controllers

Motor controller marking

NEC 430.8 requires that most motor controllers be marked with their short-circuit current rating (SCCR). Controller manufacturers have the discretion to test, list, and mark their controllers at the standard fault levels of UL 508 (shown in the table below) or the manufacturer can choose to test, list and mark for higher fault current levels. A controller with a marked SCCR makes it easier to establish the short-circuit current rating for an industrial control panel as is now required in NEC 409.110.

Motor controller protection

Figure 7.14.v shows a Size 2, combination motor controller supplying a 460 volt, 3 Ø, 20 Hp motor. The short-circuit withstand of this and other motor controllers are established so that they may be properly protected from short-circuit damage.

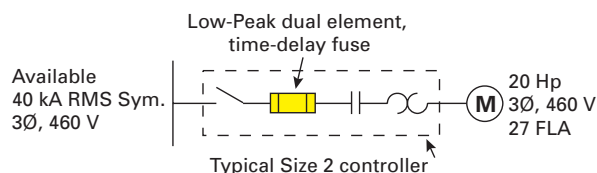


Figure 7.14.6.e Motor controller short-circuit protection

There are several independent organizations engaged in regular testing of motor controllers under short-circuit conditions. One of these, Underwriter's Laboratories (UL®), tests controllers rated one horsepower or less and 300 V or less with 1000 A fault current available to the controller test circuit. Controllers rated 50 Hp or less are tested with 5000 A available and controllers rated above 50 Hp to 200 Hp are tested with 10 kA available. See the table below for these values.*

Motor controller Hp rating	Available test short-circuit current (A)
1 Hp or less and 300 V or less	1000
50 Hp or less	5000
Greater than 50, less than 200 Hp	10,000
201 to 400 Hp	18,000
401 to 600 Hp	30,000
601 to 900 Hp	42,000
901 to 1600 Hp	85,000

* From Industrial Control Equipment, UL 508.

It should be noted that these are basic short-circuit requirements. Higher, combination ratings are attainable if tested to an applicable standard. However, damage is usually allowed.

NEC 430.52 allows dual-element, time-delay fuses and other overcurrent protective devices to be sized for branch circuit protection (short-circuit protection only). Controller manufacturers often affix labels to the inside of the motor starter cover which recommend the maximum size fuse for each overload relay size. NEC 430.52 states:

430.52(C)(2) Overload Relay Table.

Where maximum branch circuit short-circuit and ground fault protective device ratings are shown in the manufacturer's overload relay table for use with a motor controller or are otherwise marked on the equipment, they must not be exceeded even if higher values are allowed as shown above.**

** "Above" refers to other portions of 430.52 not shown here.

This paragraph means that the branch circuit overcurrent protection for overload relays in motor controllers must be no greater than the maximum size as shown in the manufacturer's overload relay table. These maximum branch circuit sizes must be observed even though other portions of 430.52 allow larger sizing of branch circuit overcurrent protection.

The reason for this maximum overcurrent device size is to provide short-circuit protection for the overload relays and motor controller.

Type 2 protection is better than Type 1

UL developed a short-circuit test procedure to verify that motor controllers will not be a safety hazard or cause a fire.

Compliance to the standard allows deformation of the enclosure, but the door must not be blown open and it must be possible to open the door after the test. In the standard short-circuit tests, the contacts must not disintegrate, but welding of the contacts is considered acceptable. Tests allow the overload relay to be damaged with current element burnout completely acceptable. For short-circuit ratings exceeding the standard levels listed in UL 508, the damage allowed is even more severe. Welding or complete disintegration of contacts is acceptable and complete overload relay burnout is allowed. Therefore, a user cannot be certain if the motor starter will not be damaged just because it has been UL Listed for use with a specific branch circuit protective device. UL tests are for safety, with the doors closed, but do allow significant damage as long as it's contained within the enclosure. Figures 7.14.6.f to 7.14.6.h show the results for two tests with different OCPDs.

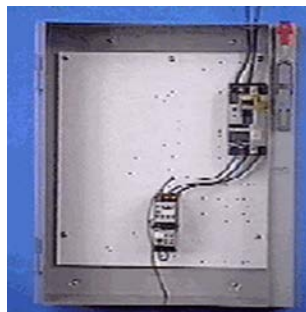


Figure 7.14.6.f: Before test with an OCPD that only provides Type 1 protection as motor branch circuit protection for 10 Hp, IEC starter with 22 kA available at 480 V.



Figure 7.14.6.g: Same test as Figure 7.14.w, showing the heater elements vaporizing and contacts severely welding. Extensive starter repair or total starter replacement is required. This level of damage is permitted by UL 508 or UL 508E/IEC60947-4-1 Type 1 protection.

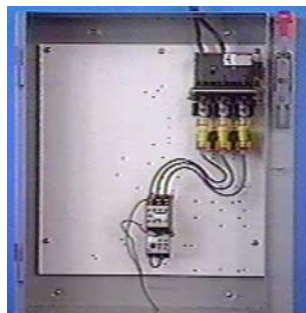


Figure 7.14.6.h: Using the same test circuit and starter as Figure 7.14.w during short-circuit interruption. The difference is current-limiting fuses provide the motor branch circuit protection. This illustrates the protection level required by UL 508E and IEC 60947-4-1 for Type 2 "No Damage" protection. The heaters and overload relays maintained calibration, retaining the extremely important circuit overload protection. This starter could be put back into service without any repair.

In order to properly select a branch circuit protective device that not only provides motor branch circuit protection, but also protects the circuit components from damage, the designer must look beyond mere safety standards. Coordination (protection) of the branch circuit protective device and the motor starter is necessary to ensure that there will be no damage or danger to either the starter or the surrounding equipment. There is an "Outline of Investigation," (UL 508E) and an IEC (International Electrotechnical Commission) Standard IEC Publication 60947, "Low Voltage Switchgear and Control, Part 4-1: Contactors and Motor Starters," that offer guidance in evaluating the level of damage likely to occur during a short-circuit with various branch circuit protective devices. These standards address the coordination (protection) between the branch circuit protective device and the motor starter. They provide a method to measure the performance of these devices should a short-circuit occur. They define two levels of protection (coordination) for the motor starter:

Type 1. Considerable damage to the contactor and overload relay is acceptable. Replacement of components or a completely new starter may be needed. There must be no discharge of parts beyond the enclosure.

Type 2. No damage is allowed to either the contactor or over-load relay. Light contact welding is allowed, but must be easily separable.

Where Type 2 protection is desired, the controller manufacturer must verify that Type 2 protection can be achieved by using a specified protective device. US manufacturers have both their NEMA and IEC motor controllers verified to meet the Type 2 requirements outlined in UL 508E and IEC 60947-4. As of this writing only current-limiting devices have been able to provide the current limitation necessary to provide verified Type 2 protection. In many cases, Class J, Class CF, Class RK1, or Class CC fuses are required, because Class RK5 fuses and other OCPD(s) aren't fast enough under short-circuit conditions to provide Type 2 protection.

More resources

For tables containing tested and verified motor starters that have Type 2 "No Damage" protection when protected by Bussmann series fuses, see the "Type 2 motor starter/Bussmann series fuses tables" on pages 7-121 through 7-132.

Type 2 "No Damage" protection and Bussmann series fuses

The following pages have tables listing the motor starters from several manufacturers that have been verified by testing for Type 2 protection when the maximum size listed fuses are used. For specific applications, it may be desirable to size closer. In some cases, the fuse type/amp rating shown is greater than what's permitted for branch circuit protection for a single motor per 430.52 (footnoted).

Regardless, the size may be applicable for group motor protection applications. In a few cases, the fuse type/amp rating may be too small for typical motor starting applications (footnoted). It's recommended to use these fuse types/amp ratings in conjunction with the fuse type/sizing covered for backup motor overload, optimal or maximum branch circuit protection. See the explanations (based on data obtained from the manufacturers or their web sites) in the motor protection tables found in the section on motor circuit protection.

Eaton Freedom Series — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Starter number*	Heater element	Max fuse	
			LPJ-SP Class J	LP-CC Class CC
200 Volt, three-phase motors				
0.5 (2.5)	AE16ANSO_C	H2106B-3	6	6
0.75 (3.7)	AE16ANSO_C	H2107B-3	6	6†
1 (4.8)	AE16ANSO_C	H2108B-3	10	15
1.5 (6.9)	AE16ANSO_C	H2109B-3	15	20
2 (7.8)	AE16BNSO_C	H2110B-3	17.5	25
3 (11.0)	AE16CNSO_C	H2111B-3	20	
5 (17.5)	AE16DNSO_C	H2112B-3	35	
7.5 (25.3)	AE16ENSO_B	H2114B-3	50	
10 (32.2)	AE16HNSO_B	H2115B-3	70	
15 (48.3)	AE16JNSO_B	H2116B-3	100	
20 (62.1)	AE16KNSO_B	H2117B-3	110	
25 (78.2)	AE16LNSO_	H2022-3	150	
30 (92.0)	AE16MNSO_	H2023-3	200	
40 (119.6)	AE16NNSO_	H2024-3	200	
230 Volt, three-phase motors				
0.5 (2.2)	AE16ANSO_C	H2106B-3	6	6
0.75 (3.2)	AE16ANSO-C	H2107B-3	6	6†
1 (4.2)	AE16ANSO-C	H2108B-3	10	15
1.5 (6.0)	AE16ANSO-C	H2109B-3	15	20
2 (6.8)	AE16BNSO_C	H2109B-3	15	20
3 (9.6)	AE16BNSO_C	H2110B-3	20	
5 (15.2)	AE16DNSO_C	H2112B-3	30	
7.5 (22.0)	AE16ENSO_C	H2113B-3	45	
10 (28.0)	AE16FNSO_B	H2114B-3	50	
15 (42.0)	AE16HNSO_B	H2116B-3	90	
20 (54.0)	AE16JNSO_B	H2117B-3	110	
25 (68.2)	AE16KNSO_B	H2117B-3	110	
30 (80.0)	AE16LNSO_	H2022-3	150	
40 (104.0)	AE16MNSO_	H2023-3	200	
50 (130.0)	AE16NNSO	H2024-3	200	

Hp (FLA)	Starter number*	Heater element	Max fuse	
			LPJ-SP Class J	LP-CC Class CC
460 Volt, three-phase motors				
0.5 (1.1)	AE16ANSO_C	H2104B-3	3	3
0.75 (1.6)	AE16ANSO_C	H2105B-3	3	3†
1 (2.1)	AE16ANSO_C	H2106B-3	6	6
1.5 (3.0)	AE16ANSO_C	H2106B-3	6	6
2 (3.4)	AE16ANSO_C	H2107B-3	6	6†
3 (4.8)	AE16ANSO_C	H2108B-3	10	15
5 (7.6)	AE16BNSO_C	H2110B-3	15	25
7.5 (11.0)	AE16CNSO_C	H2111B-3	20	
10 (14.0)	AE16DNSO_C	H2111B-3	30	
15 (21.0)	AE16ENSO_C	H2113B-3	45	
20 (27.0)	AE16FNSO_B	H2114B-3	50	
25 (34.0)	AE16GNSO_B	H2115B-3	70	
30 (40.0)	AE16HNSO_B	H2116B-3	90	
40 (52.0)	AE16JNSO_B	H2116B-3	100	
50 (65.0)	AE16KNSO_B	H2117B-3	110	
60 (77.0)	AE16LNSO_	H2022-3	150	
75 (96.0)	AE16MNSO_	H2023-3	200	
100 (124.0)	AE16NNSO_	H2024-3	200	
575 Volt, three-phase motors				
0.75 (1.3)	AE16ANSO_C	H2104B-3	3	3
1 (1.7)	AE16ANSO_C	H2105B-3	3	3†
1.5 (2.4)	AE16ANSO_C	H2106B-3	6	6
2 (2.7)	AE16ANSO_C	H2107B-3	6	6
3 (3.9)	AE16ANSO_C	H2108B-3	10	15
5 (6.1)	AE16ANSO_C	H2109B-3	15	20
7.5 (9.0)	AE16BNSO_C	H2110B-3	20	
10 (11.0)	AE16CNSO_C	H2111B-3	20	
15 (17.0)	AE16DNSO_C	H2112B-3	35	
20 (22.0)	AE16ENSO_C	H2113B-3	45	
25 (27.0)	AE16FNSO_B	H2114B-3	50	
30 (32.0)	AE16GNSO_B	H2115B-3	70	
40 (41.0)	AE16HNSO_B	H2116B-3	90	
50 (52.0)	AE16KNSO_B	H2116B-3	100	
60 (62.0)	AE16LNSO_	H2021-3	110	
75 (77.0)	AE16LNSO_	H2022-3	150	
100 (99.0)	AE16MNSO_	H2023-3	200	
125 (125.0)	AE16NNSO_	H2024-3	200	

* Empty space designates where coil suffix must be added.

† May be too small to allow some motors to start.



Eaton Freedom Series — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Starter number (fixed heaters)*	Max fuse	
		LPJ-SP Class J	LP-CC Class CC
200 Volt, three-phase motors			
0.5 (2.5)	AE17ANSO_FJ	6	6
0.75 (3.7)	AE17ANSO_FK	6	6
1 (4.8)	AE17ANSO_FL	10	15
1.5 (6.9)	AE17ANSO_FM	15	15
2 (7.8)	AE17BNSO_FP	17.5	25
3 (11.0)	AE17CNSO_FQ	20	20†
5 (17.5)	AE17DNSO_FR	35	
7.5 (25.3)	AE17FNSO_FT	50	
10 (32.2)	AE17HNSO_KC	70	
15 (48.3)	AE17JNSO_KE	100	
20 (62.1)	AE17KNSO_KF	110	
230 Volt, three-phase motors			
0.5 (2.2)	AE17ANSO_FH	3†	3†
0.75 (3.2)	AE17ANSO_FK	6	6†
1 (4.2)	AE17ANSO_FK	6†	6†
1.5 (6.0)	AE17ANSO_FM	15	15
2 (6.8)	AE17BNSO_FN	15	15
3 (9.6)	AE17CNSO_FP	20	20†
5 (15.2)	AE17DNSO_FR	30	30†
7.5 (22.0)	AE17ENSO_FS	45	
10 (28.0)	AE17FNSO_FT	60	
15 (42.0)	AE17HNSO_KD	90	
20 (54.0)	AE17JNSO_KE	110	
25 (68.2)	AE17KNSO_KF	110	
460 Volt, three-phase motors			
0.5 (1.0)	AE17ANSO_FF	2	2
0.75 (1.6)	AE17ANSO_FG	3	3
1 (2.1)	AE17ANSO_FH	3	3†
1.5 (3.0)	AE17ANSO_FJ	6	6
2 (3.4)	AE17ANSO_FK	6	6†
3 (4.8)	AE17ANSO_FM	10	15
5 (7.6)	AE17BNSO_FN	15	15
7.5 (11.0)	AE17CNSO_FQ	20	20†
10 (14.0)	AE17DNSO_FR	30	30†
15 (21.0)	AE17ENSO_FS	45	
20 (27.0)	AE17FNSO_FT	60	
25 (34.0)	AE17GNSO_KC	70	
30 (40.0)	AE17HNSO_KD	90	
40 (52.0)	AE17JNSO_KE	110	
50 (65.0)	AE17KNSO_KF	110	
575 Volt, three-phase motors			
0.75 (1.3)	AE17ANSO_FF	2	2†
1 (1.7)	AE17ANSO_FG	3	3†
1.5 (2.4)	AE17ANSO_FH	3†	3†
2 (2.7)	AE17ANSO_FJ	6	6
3 (3.9)	AE17ANSO-FL	10	15
5 (6.1)	AE17ANSO_FM	15	15
7.5 (9.0)	AE17BNSO-FP	20	20†
10 (11.0)	AE17CNSO_FQ	20	20†
15 (17.0)	AE17DNSO_FR	35	
20 (22.0)	AE17ENSO_FS	45	
25 (27.0)	AE17FNSO_FT	60	
30 (32.0)	AE17GNSO_KC	70	
40 (41.0)	AE17HNSO_KD	90	
50 (52.0)	AE17KNSO_KE	110	

* Empty space designates where coil suffix must be added.

† May be too small to allow some motors to start.



Eaton Freedom Series — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Size	Starter number*	Heater element	Max fuse LPN-RK-SP Class RK1
200 Volt, three-phase motors				
0.5 (2.5)	00	AN16ANO_C	H2006B-3	4.5
0.75 (3.7)	00	AN16ANO_C	H2008B-3	8
1 (4.8)	00	AN16ANO_C	H2009B-3	10
1.5 (6.9)	0	AN16NDO_C	H2010B-3	15
2 (7.8)	0	AN16BNO_C	H2010B-3	17.5
3 (11.0)	0	AN16BNO_C	H2011B-3	20
7.5 (25.3)	1	AN16DNO_B	H2013B-3	45
10 (32.2)	2	AN16GNO_B	H2015B-3	70
15 (48.3)	3	AN16KNO_	H2021-3	100
20 (62.1)	3	AN16KNO_	H2021-3	110
25 (78.2)	3	AN16KNO_	H2022-3	175
40 (119.6)	4	AN16NNO_	H2024-3	200
50 (149.5)	5	AN16SNO_B	H2007B-3	300
60 (166.8)	5	AN16SNO_B	H2007B-3	350
75 (220.8)	5	AN16SNO_B	H2008B-3	400
230 Volt, three-phase motors				
0.5 (2.2)	00	AN16ANO_C	H2006B-3	4.5
0.75 (3.2)	00	AN16ANO_C	H2007B-3	5.6
1 (4.2)	00	AN16ANO_C	H2008B-3	8
1.5 (6.0)	00	AN16ANO_C	H2009B-3	12
2 (6.8)	0	AN16BNO_C	H2009B-3	12
3 (9.6)	0	AN16BNO_C	H2011B-3	20
5 (15.2)	1	AN16DNO_B	H2012B-3	30
7.5 (22.0)	1	AN16DNO_B	H2013B-3	45
7.5 (22.0)	2	AN16GNO_B	H2013B-3	45
10 (28.0)	2	AN16GNO_B	H2014B-3	60
15 (42.0)	2	AN16GNO_B	H2015B-3	70
20 (54.0)	3	AN16KNO_	H2021-3	110
25 (68.2)	3	AN16KNO_	H2022-3	150
30 (80.0)	3	AN16KNO_	H2022-3	175
30 (92.0)	4	AN16NNO_	H2023-3	200
40 (104.0)	4	AN16NNO_	H2023-3	200
50 (130.0)	4	AN16NNO_	H2024-3	200
60 (145.0)	5	AN16SNO_B	H2007B-3	300
75 (192.0)	5	AN16SNO_B	H2007B-3	400
100 (248.0)	5	AN16SNO_B	H2008B-3	400

Hp (FLA)	Size	Starter number*	Heater element	Max fuse LPN-RK-SP Class RK1
460 Volt, three-phase motors				
0.5 (1.1)	00	AN16ANO_C	H2004B-3	2
0.75 (1.6)	00	AN16ANO_C	H2005B-3	2.8
1 (2.1)	00	AN16ANO_C	H2006B-3	4.5
1.5 (3.0)	00	AN16ANO_C	H2007B-3	5.6
2 (3.4)	00	AN16ANO_C	H2008B-3	7
3 (4.8)	0	AN16BNO_C	H2009B-3	10
5 (7.6)	0	AN16BNO_C	H2010B-3	15
7.5 (11.0)	1	AN16DNO_B	H2011B-3	20
10 (14.0)	1	AN16DNO_B	H2012B-3	30
15 (21.0)	2	AN16GNO_B	H2013B-3	45
20 (27.0)	2	AN16GNO_B	H2014B-3	60
25 (34.0)	2	AN16GNO_B	H2015B-3	70
30 (40.0)	3	AN16KNO_	H2020-3	80
40 (52.0)	3	AN16KNO_	H2021-3	110
50 (65.0)	3	AN16KNO_	H2022-3	125
60 (77.0)	4	AN16NNO_	H2022-3	150
75 (96.0)	4	AN16NNO_	H2023-3	200
100 (124.0)	4	AN16NNO_	H2024-3	200
125 (156.0)	5	AN16SNO_B	H2007B-3	350
150 (180.0)	5	AN16SNO_B	H2007B-3	400
200 (240.0)	5	AN16SNO_B	H2008B-3	400
575 Volt, three-phase motors				
0.75 (1.3)	00	AN16ANO_C	H2005B-3	2.8
1 (1.7)	00	AN16ANO_C	H2005B-3	2.8
1.5 (2.4)	00	AN16ANO_C	H2006B-3	4.5
2 (2.7)	00	AN16ANO_C	H2007B-3	5.6
3 (3.9)	0	AN16BNO_C	H2008B-3	8
5 (6.1)	0	AN16BNO_C	H2009B-3	12
7.5 (9.0)	1	AN16DNO_B	H2010B-3	17.5
10 (11.0)	1	AN16DNO_B	H2011B-3	20
15 (17.0)	2	AN16GNO_B	H2012B-3	35
20 (22.0)	2	AN16GNO_B	H2013B-3	45
25 (27.0)	2	AN16GNO_B	H2014B-3	60
30 (32.0)	3	AN16KNO_	H2019-3	60
40 (41.0)	3	AN16KNO_	H2020-3	80
50 (52.0)	3	AN16KNO_	H2021-3	110
60 (62.0)	4	AN16NNO_	H2021-3	110
75 (77.0)	4	AN16NNO_	H2022-3	150
100 (99.0)	4	AN16NNO_	H2023-3	200
125 (125.0)	5	AN16SNO_B	H2006B-3	250
150 (144.0)	5	AN16SNO_B	H2007B-3	300
200 (192.0)	5	AN16SNO_B	H2007B-3	400

* Empty space designates where coil suffix must be added.

General Electric Company — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Contactor	OLR	Max fuse LPJ-SP Class J
200 Volt, three-phase motors			
0.5 (2.5)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
0.5 (2.5)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
0.75 (3.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8
1 (4.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
1.5 (6.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
2 (7.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20†
3 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
5 (17.5)	CL02, CL03, CL04, CL25, CL45	RT*1S	35
5 (17.5)	CL06, CL07, CL08, CL09, CL10	RT*2B	35
5 (17.5)	CL03, CL04, CL45	RT*1T	45†
7.5 (25.3)	CL04, CL05	RT*1U	45
7.5 (25.3)	CL06, CL07, CL08, CL09, CL10	RT*2D	60†
7.5 (25.3)	CL04, CL45	RT*1V	60†
10 (32.2)	CL45	RT*1W	70
10 (32.2)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
15 (48.3)	CL07, CL08, CL09, CL10	RT*2G	100
20 (62.1)	CL08, CL09, CL10	RT*2H	125
20 (62.1)	CK08, CK09, CK95	RT*3B	125
25 (78.2)	CK08, CK09	RT*3C	150
230 Volt, three-phase motors			
0.5 (2.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
0.75 (3.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
1 (4.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
1.5 (6.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
2 (6.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
3 (9.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20
5 (15.2)	CL02, CL03, CL04, CL25, CL45	RT*1S	35†
5 (15.2)	CL06, CL07, CL08, CL09, CL10	RT*2B	35†
7.5 (22.0)	CL03, CL04, CL45	RT*1T	45
7.5 (22.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
7.5 (22.0)	CL03, CL04, CL45	RT*1U	45
10 (28.0)	CL04	RT*1V	60
10 (28.0)	CL45	RT*1V	60
10 (28.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
15 (42.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
20 (54.0)	CL07, CL08, CL09, CL10	RT*2G	100
20 (54.0)	CL07, CL08, CL09, CL10	RT*2H	125†
25 (68.0)	CK08, CK09, CK95	RT*3B	125
25 (68.0)	CL08, CL09, CL10	RT*2J	125
30 (80.0)	CK08, CK09, CK95	RT*3B	125
25 (68.0)	CK08, CK09	RT*3C	150

Hp (FLA)	Contactor	OLR	Max fuse LPJ-SP Class J
460 Volt, three-phase motors			
0.5 (1.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1F	1.5††
0.5 (1.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1G	2
0.75 (1.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1 (2.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
1.5 (3.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
2 (3.4)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
3 (4.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
5 (7.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20†
7.5 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
10 (14.0)	CL02, CL03, CL04, CL25, CL45	RT*1R	25
10 (14.0)	CL06, CL07, CL08, CL09, CL10	RT*2A	30
15 (21.0)	CL03, CL04, CL45	RT*1T	45
15 (21.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
20 (27.0)	CL04, CL45	RT*1V	60
20 (27.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
25 (34.0)	CL45	RT*1W	70
25 (34.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
30 (40.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
30 (40.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
40 (52.0)	CL07, CL08, CL09, CL10	RT*2G	100
50 (65.0)	CL08, CL09, CL10	RT*2H	125
50 (65.0)	CL08, CL09, CL10	RT*3B	125
50 (65.0)	CL08, CL09, CL10	RT*2J	125
60 (77.0)	CL09, CL10	RT*3B	125
60 (77.0)	CL09, CL10	RT*2K	150
575 Volt, three-phase motors			
0.5 (0.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1F	1.5
0.75 (1.3)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1G	2
0.75 (1.3)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1 (1.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1.5 (2.4)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
2 (2.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
2 (2.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
3 (3.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8
5 (6.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
5 (6.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
7.5 (9.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20
10 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
15 (17.0)	CL02, CL03, CL04, CL25, CL45	RT*1S	35
15 (17.0)	CL06, CL07, CL08, CL09, CL10	RT*2B	35
20 (22.0)	CL03, CL04, CL45	RT*1T	45
20 (22.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
20 (22.0)	CL03, CL04, CL45	RT*1U	45
25 (27.0)	CL04, CL45	RT*1V	60
25 (27.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
30 (32.0)	CL04, CL45	RT*1V	60
30 (32.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
30 (32.0)	CL45	RT*1W	70
30 (32.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
40 (41.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
40 (41.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
50 (52.0)	CL07, CL08, CL09, CL10	RT*2G	100
60 (62.0)	CL07, CL08, CL09, CL10	RT*2H	125
60 (62.0)	CK08, CK09, CK95	RT*3B	125
75 (77.0)	CK08, CK09, CK95	RT*3B	125
75 (77.0)	CK08, CK09	RT*3C	150

* Replace * with "A" or "M"

† Sized larger than code max for single motor.

General Electric Company — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	OLR	Max fuse LPJ-SP Class J
200 Volt, three-phase motors		
0.5 (2.5)	CR324CXE	6
0.5 (2.5)	CR123C326A	6
0.75 (3.7)	CR123C356A	8
0.75 (3.7)	CR324CXF	10
1 (4.8)	CR324CXF	10
1 (4.8)	CR123C526A	10
1.5 (6.9)	CR324CXG	15
1.5 (6.9)	CR123C778A	15
1.5 (6.9)	CR123C695A	15
2 (7.8)	CR324CXG	17.5
2 (7.8)	CR123C867A	17.5
3 (11.0)	CR324CXG	20
3 (11.0)	CR123C125B	20
5 (17.5)	CR234CXH	35
5 (17.5)	CR234FXK	35
5 (17.5)	CR123C180B	35
5 (17.5)	CR123C198B	35
5 (17.5)	CR123F233B	35
230 Volt, three-phase motors		
0.5 (2.2)	CR123C268A	5
0.5 (2.2)	CR324CXE	6
0.75 (3.2)	CR324CXF	7
0.75 (3.2)	CR123C356A	7
1 (4.2)	CR324CXF	10
1 (4.2)	CR123C466A	10
1.5 (6.0)	CR324CXF	15
1.5 (6.0)	CR123C695A	15
2 (6.8)	CR324CXG	15
2 (6.8)	CR324DXG	15
2 (6.8)	CR123C778A	15
3 (9.6)	CR324CXG	20
3 (9.6)	CR324DXG	20
3 (9.6)	CR123C104B	20
5 (15.2)	CR234CXH	30
5 (15.2)	CR234DXH	30
5 (15.2)	CR123C163B	30
7.5 (22.0)	CR324DXH	45
7.5 (22.0)	CR324FXK	45
7.5 (22.0)	CR123C228B	45
7.5 (22.0)	CR123C250B	45
7.5 (22.0)	CR123C270B	45

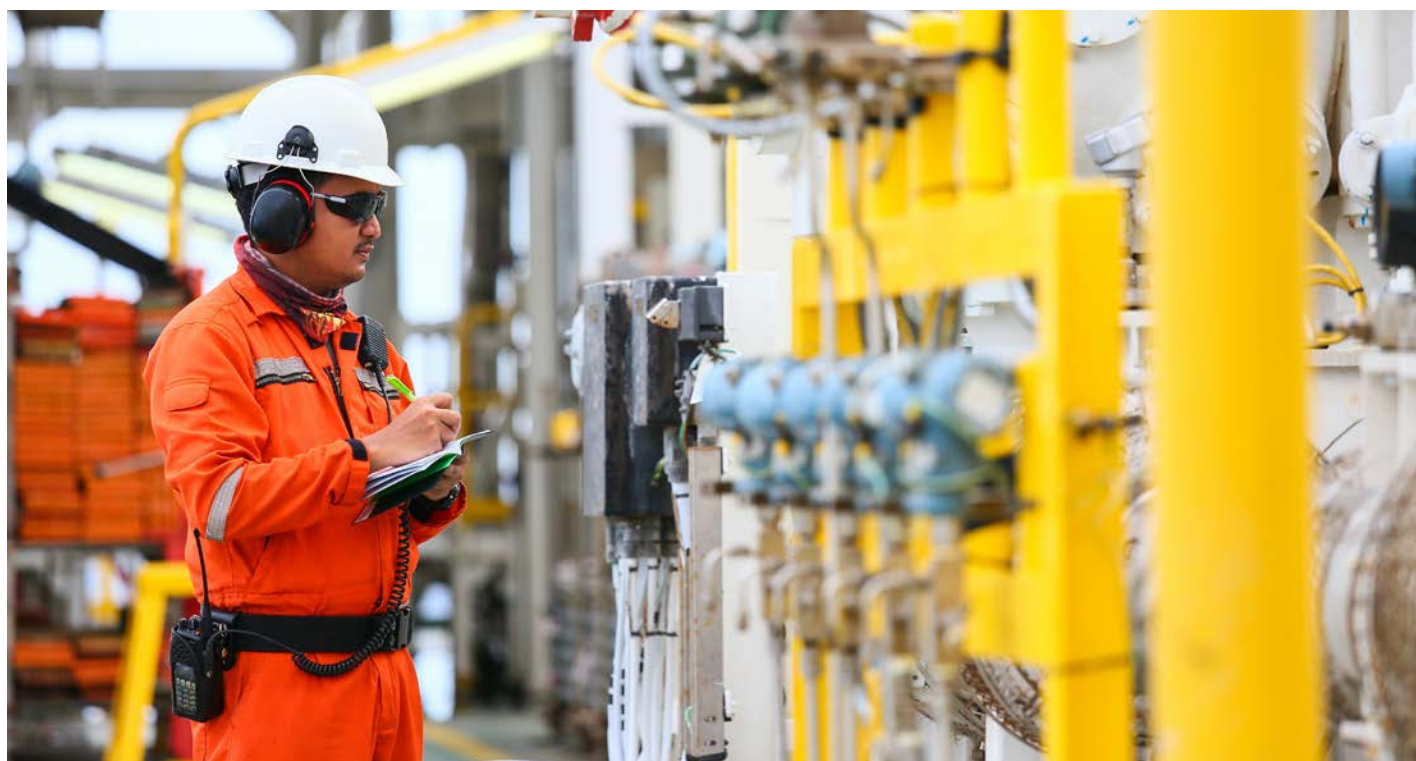
Hp (FLA)	OLR	Max fuse LPJ-SP Class J
460 Volt, three-phase motors		
0.5 (1.1)	CR123C131A	2.5
0.5 (1.1)	CR324CXD	3
0.75 (1.6)	CR324CXD	3.5
0.75 (1.6)	CR123C196A	3.5
1 (2.1)	CR123C268A	5
1 (2.1)	CR324CXE	6
1.5 (3.0)	CR324CXE	6
1.5 (3.0)	CR123C356A	6
2 (3.4)	CR324CXF	7
2 (3.4)	CR123C379A	7
3 (4.8)	CR324CXF	10
3 (4.8)	CR123C526A	10
5 (7.6)	CR324CXG	15
5 (7.6)	CR324DXG	15
5 (7.6)	CR123C867A	15
7.5 (11.0)	CR324CXG	20
7.5 (11.0)	CR324DXG	20
7.5 (11.0)	CR123C125B	20
10 (14.0)	CR234CXH	30
10 (14.0)	CR234DXH	30
10 (14.0)	CR123C163B	30
15 (21.0)	CR324CXH	45
15 (21.0)	CR324DXH	45
15 (21.0)	CR324FXK	45
15 (21.0)	CR123C228B	45
15 (21.0)	CR123F243B	45
575 Volt, three-phase motors		
0.5 (0.9)	CR123C109A	2
0.5 (0.9)	CR324CXD	3
0.75 (1.3)	CR324CXD	3
0.75 (1.3)	CR123C163A	3
1 (1.7)	CR324CXD	3.5
1 (1.7)	CR123C196A	3.5
1 (1.7)	CR324CXE	3.5
1.5 (2.4)	CR324CXE	6
1.5 (2.4)	CR123C301A	6
2 (2.7)	CR324CXE	6
2 (2.7)	CR123C326A	6
3 (3.9)	CR324CXF	10
3 (3.9)	CR123C419A	10
5 (6.1)	CR324CXF	15
5 (6.1)	CR123C695A	15
7.5 (9.0)	CR324CXG	20
7.5 (9.0)	CR324DXG	20
7.5 (9.0)	CR123C104B	20
7.5 (9.0)	CR123C955A	20
10 (11.0)	CR123C125B	20
10 (11.0)	CR324CXG	20
10 (11.0)	CR324DXG	20
15 (17.0)	CR234DXH	35
15 (17.0)	CR234FXK	35
15 (17.0)	CR123C180B	35
20 (22.0)	CR324DXH	45
20 (22.0)	CR324FXK	45
20 (22.0)	CR123C228B	45
20 (22.0)	CR123C250B	45
20 (22.0)	CR123C270B	45

General Electric Company — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	OLR	Max fuse	
		LPJ-SP Class J	KRP-C-SP Class L
200 Volt, three-phase motors			
7.5 (25.3)	CR324DXH	50	
7.5 (25.3)	CR324FXK	50	
7.5 (25.3)	CR123C273B	50	
7.5 (25.3)	CR123C303B	50	
7.5 (25.3)	CR123F300B	50	
10 (32.2)	CR324DXJ	70	
10 (32.2)	CR324FXK	70	
10 (32.2)	CR123C330B	70	
10 (32.2)	CR123F395B	70	
15 (48.3)	CR324DXJ	100	
15 (48.3)	CR324FXL	100	
15 (48.3)	CR123F614B	100	
20 (62.1)	CR324FXL	125	
20 (62.1)	CR123F772B	125	
25 (78.2)	CR234FXM	175	
25 (78.2)	CR324GXP	175	
25 (78.2)	CR123F104C	175	
30 (92.0)	CR234FXM	200	
30 (92.0)	CR324GXP	200	
30 (92.0)	CR123F118C	200	
40 (120.0)	CR234FXM	250	
40 (120.0)	CR324GXP	250	
40 (120.0)	CR123F161C	250	
50 (150.0)	CR324GXQ	300	
50 (150.0)	CR324HXS	300	
60 (177.0)	CR324GXQ	350	
60 (177.0)	CR324HXS	350	
75 (221.0)	CR324GXQ	450	
75 (221.0)	CR324HXS	450	
100 (285.0)	CR324HXT	600	
125 (359.0)	CR324HXT		1000
150 (414.0)	CR324HXT		1000

Hp (FLA)	OLR	Max fuse	
		LPJ-SP Class J	KRP-C-SP Class L
230 Volt, three-phase motors			
10 (28.0)	CR324DXJ	60	
10 (28.0)	CR324FXK	60	
10 (28.0)	CR123C303B	60	
10 (28.0)	CR123F327B	60	
15 (42.0)	CR324DXJ	90	
15 (42.0)	CR324FXL	90	
15 (42.0)	CR123F567B	90	
15 (42.0)	CR123F487B	90	
15 (42.0)	CR123F440B	90	
20 (54.0)	CR324FXL	110	
20 (54.0)	CR123F719B	110	
25 (68.2)	CR324FXL	150	
25 (68.2)	CR324FXM	150	
25 (68.2)	CR324GXP	150	
25 (68.2)	CR123F848B	150	
25 (68.2)	CR123F914B	150	
30 (80.0)	CR234FXM	175	
30 (80.0)	CR324GXP	175	
30 (80.0)	CR123F104C	175	
40 (104.0)	CR234FXM	225	
40 (104.0)	CR324GXP	225	
40 (104.0)	CR123F133C	225	
50 (130.0)	CR234FXM	250	
50 (130.0)	CR324GXP	250	
50 (130.0)	CR123F161C	250	
60 (145.0)	CR324GXQ	300	
60 (145.0)	CR324HXS	300	
75 (192.0)	CR324GXQ	400	
75 (192.0)	CR324HXS	400	
100 (248.0)	CR324GXQ	500	
100 (248.0)	CR324HXS	500	
125 (312.0)	CR324HXT		900
150 (360.0)	CR324HXT		1000
200 (480.0)	CR324HXT		1000



General Electric Company — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	OLR	Max fuse	
		LPJ-SP Class J	KRP-C-SP Class L
460 Volt, three-phase motors			
20 (27.0)	CR324DXH	60	
20 (27.0)	CR324DXJ	60	
20 (27.0)	CR324FXK	60	
20 (27.0)	CR123C303B	60	
20 (27.0)	CR123F327B	60	
20 (27.0)	CR123C330B	60	
25 (34.0)	CR324DXJ	70	
25 (34.0)	CR324FXK	70	
25 (34.0)	CR123C366B	70	
25 (34.0)	CR123F430B	70	
30 (40.0)	CR324DXJ	90	
30 (40.0)	CR324FXL	90	
30 (40.0)	CR123C400B	90	
30 (40.0)	CR123F487B (size 3)	90	
30 (40.0)	CR123F487B (size 4)	90	
40 (52.0)	CR324FXL	110	
40 (52.0)	CR123F658B (size 3)	110	
40 (52.0)	CR123F658B (size 4)	110	
50 (65.0)	CR324FXL	125	
50 (65.0)	CR123F772B	125	
50 (65.0)	CR324FXM	125	
50 (65.0)	CR324GXP	125	
50 (65.0)	CR123F848B	125	
60 (77.0)	CR324FXM	150	
60 (77.0)	CR324GXP	150	
60 (77.0)	R123F104C (size 3)	150	
60 (77.0)	R123F104C (size 4)	150	
75 (96.0)	CR234FXM	200	
75 (96.0)	CR324GXP	200	
75 (96.0)	CR123F118C	200	
100 (124.0)	CR234FXM	250	
100 (124.0)	CR324GXP	250	
100 (124.0)	CR123F161C	250	
125 (156.0)	CR324GXQ	350	
125 (156.0)	CR324HXS	350	
150 (180.0)	CR324GXQ	400	
150 (180.0)	CR324HXS	400	
200 (240.0)	CR324GXQ	500	
200 (240.0)	CR324HXS	500	
250 (302.0)	CR324HXT		900
300 (361.0)	CR324HXT		1000
350 (414.0)	CR324HXT		1000
400 (477.0)	CR324HXT		1000
450 (515.0)	CR324HXT		1000

		Max fuse	
		LPJ-SP Class J	KRP-C-SP Class L
Hp (FLA)	OLR		
575 Volt, three-phase motors			
25 (27.0)	CR324DXH	60	
25 (27.0)	CR324DXJ	60	
25 (27.0)	CR324FXK	60	
25 (27.0)	CR123C303B	60	
25 (27.0)	CR123F327B	60	
25 (27.0)	CR123C330B	60	
30 (32.0)	CR324DXJ	70	
30 (32.0)	CR324FXK	70	
30 (32.0)	CR123C330B	70	
30 (32.0)	CR123F395B	70	
40 (41.0)	CR324DXJ	90	
40 (41.0)	CR324FXL	90	
40 (41.0)	CR123C400B	90	
40 (41.0)	CR123F567B	90	
40 (41.0)	CR123F487B	90	
50 (52.0)	CR324FXL	110	
50 (52.0)	CR123F658B (size 3)	110	
50 (52.0)	CR123F658B (size 4)	110	
60 (62.0)	CR324FXL	125	
60 (62.0)	CR123F772B	125	
75 (77.0)	CR324FXM	150	
75 (77.0)	CR324GXP	150	
75 (77.0)	R123F104C (size 3)	150	
75 (77.0)	R123F104C (size 4)	150	
100 (99.0)	CR234FXM	200	
100 (99.0)	CR324GXP	200	
100 (99.0)	CR123F118C	200	
125 (125.0)	CR234FXM	250	
125 (125.0)	CR324GXP	250	
125 (125.0)	CR123F161C	250	
150 (144.0)	CR324GXQ	300	
150 (144.0)	CR324HXS	300	
200 (192.0)	CR324GXQ	400	
200 (192.0)	CR324HXS	400	
250 (242.0)	CR324GXQ	500	
250 (242.0)	CR324HXS	500	
300 (289.0)	CR324HXT		800
350 (336.0)	CR324HXT		1000
400 (382.0)	CR324HXT		1000
450 (412.0)	CR324HXT		1000
500 (472.0)	CR324HXT		1000

Rockwell Automation, Allen-Bradley — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Contactor basic catalog number (a)	Overload relay basic catalog number (b)	Max fuse	
			LPJ-SP Class J	LP-CC Class CC
200 Volt, three-phase motors				
0.5 (2.5)	100-C09	193-E**EB	6	6
0.75 (3.7)	100-C09	193-E**EB	10	10
1 (4.8)	100-C09	193-E**FB	15†	15
1.5 (6.9)	100-C09	193-E**FB	15	15
2 (7.8)	100-C09	193-E**FB	15	15††
3 (11)	100-C12	193-E**FB	20	20††
5 (17.5)	100-C23	193-E**GB	30	30††
7.5 (25.3)	100-C30	193-E**HC	40	
10 (32.2)	100-C37	193-E**HC	50	
15 (48.3)	100-C60	193-E**KE	80	
20 (62.1)	100-C72	193-E**KE	100	
25 (78.2)	100-C85	193-E**KE	100††	
230 Volt, three-phase motors				
0.5 (2.2)	100-C09	193-E**DB	6	6
0.75 (3.2)	100-C09	193-E**EB	10†	10
1 (4.2)	100-C09	193-E**FB	15†	15
1.5 (6)	100-C09	193-E**FB	15	15
2 (6.8)	100-C09	193-E**FB	15	15
3 (9.6)	100-C12	193-E**FB	20	20
5 (15.2)	100-C16	193-E**GB	20††	20††
7.5 (22)	100-C23	193-E**GB	30††	30††
10 (28)	100-C30	193-E**HC	40††	
15 (42)	100-C43	193-E**JD	50††	
20 (54)	100-C60	193-E**KE	80††	
25 (68)	100-C72	193-E**KE	100	
30 (80)	100-C85	193-E**KE	100††	

Hp (FLA)	Contactor basic catalog number (a)	Overload relay basic catatalog number (b)	Max fuse	
			LPJ-SP Class J	LP-CC Class CC
460 Volt, three-phase motors				
0.5 (1.1)	100-C09	193-E**DB	3	3
0.75 (1.6)	100-C09	193-E**DB	6†	6
1 (2.1)	100-C09	193-E**DB	6	6
1.5 (3)	100-C09	193-E**EB	10†	10
2 (3.4)	100-C09	193-E**EB	10†	10
3 (4.8)	100-C09	193-E**FB	15†	15
5 (7.6)	100-C09	193-E**FB	15	15††
7.5 (11)	100-C12	193-E**FB	20	20††
10 (14)	100-C16	193-E**GB	20††	20††
15 (21)	100-C23	193-E**GB	30††	30††
20 (27)	100-C30	193-E**HC	40	
25 (34)	100-C37	193-E**HC	50	
30 (40)	100-C43	193-E**JD	50††	
40 (52)	100-C60	193-E**KE	80	
50 (65)	100-C72	193-E**KE	100	
60 (77)	100-C85	193-E**KE	100††	
575 Volt, three-phase motors				
0.5 (0.9)	100-C09	193-E**DB	3	3
0.75 (1.3)	100-C09	193-E**DB	3	3
1 (1.7)	100-C09	193-E**DB	6†	6
1.5 (2.4)	100-C09	193-E**DB	6	6
2 (2.7)	100-C09	193-E**EB	10†	10
3 (3.9)	100-C09	193-E**FB	10	10
5 (6.1)	100-C09	193-E**FB	15	15
5 (7.6)	100-C09	193-E**FB	15	15††
7.5 (9)	100-C09	193-E**FB	15	15††
10 (11)	100-C12	193-E**FB	20	20††
15 (17)	100-C23	193-E**GB	30	30††
20 (22)	100-C30	193-E**HC	40	
25 (27)	100-C37	193-E**HC	50	
30 (32)	100-C37	193-E**HC	50	
40 (41)	100-C60	193-E**KE	80	
50 (52)	100-C72	193-E**KE	100	
60 (62)	100-C85	193-E**KE	100	

(a) Catalog number is not complete, add coil voltage code and auxiliary contact description.

(b) Catalog number is not complete, replace ** with trip class and reset mode.

†† May be too small to allow some motors to start.

† Sized larger than code max for single motor.



Rockwell Automation, Allen-Bradley — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Starter size†	Catalog number	Heater element number	Max fuse LPN-RK-SP/LPJ-SP Class RK1/J
200 Volt, three-phase motors				
1.5 (6.9)	0	509-A	W48	15
2 (7.8)	0	509-A	W50	15
3 (11.0)	0	509-A	W53	20
5 (17.5)	1	509-B	W59	30
7.5 (25.3)	2	509-C	W63	50
10 (32.2)	3	509-D	W65	60
15 (48.3)	3	509-D	W68	100
20 (62.1)	3	509-D	W71	100
25 (78.2)	3	509-D	W75	150
30 (92.0)	4	509-E	W77	175
40 (120.0)	4	509-E	W81	200
50 (150.0)	5	509-F	W37	200††
60 (177.1)	5	509-F	W39	250††
75 (221.0)	5	509-F	W41	350
230 Volt, three-phase motors				
2 (6.8)	0	509-A	W48	15
3 (9.6)	0	509-A	W52	20
5 (15.2)	1	509-B	W57	30
7.5 (22.0)	2	509-C	W61	45
10 (28.0)	3	509-C	W64	60
15 (42.0)	3	509-D	W66	90
20 (54.0)	3	509-D	W69	100
25 (68.2)	3	509-D	W73	100††
30 (80.0)	3	509-D	W75	150
40 (104.0)	4	509-E	W79	175
50 (130.0)	4	509-E	W83	200
60 (154.0)	5	509-F	W37	200††
75 (192.0)	5	509-F	W40	300
100 (248.0)	5	509-F	W43	400

Hp (FLA)	Starter size†	Catalog number	Heater element number	Max fuse LPN-RK-SP/LPJ-SP Class RK1/J
460 Volt, three-phase motors				
5 (7.6)	0	509-A	W49	15
7.5 (11.0)	1	509-B	W53	20
10 (14.0)	1	509-B	W56	30
15 (21.0)	2	509-C	W61	45
20 (27.0)	2	509-C	W63	60
25 (34.0)	3	509-D	W66	60
30 (40.0)	3	509-D	W66	90
40 (52.0)	3	509-D	W69	100
50 (65.0)	3	509-D	W72	100
60 (77.0)	4	509-E	W74	125
75 (96.0)	4	509-E	W77	175
100 (124.0)	4	509-E	W82	200
125 (156.0)	5	509-F	W37	200††
150 (180.0)	5	509-F	W39	250††
200 (240.0)	5	509-F	W42	400
575 Volt, three-phase motors				
5 (6.1)	0	509-A	W47	12
7.5 (9.0)	1	509-B	W51	20
10 (11.0)	1	509-B	W53	20
15 (17.0)	2	509-C	W58	35
25 (27.0)	2	509-C	W63	60
30 (32.0)	3	509-D	W64	70
40 (41.0)	3	509-D	W66	90
50 (52.0)	3	509-D	W69	100
60 (62.0)	4	509-E	W71	100
75 (77.0)	4	509-E	W74	125
100 (99.0)	4	509-E	W78	175
125 (125.0)	5	509-F	W35	200
150 (144.0)	5	509-F	W36	200††
200 (192.0)	5	509-F	W40	300

† Catalog number is not complete. Refer to Bulletin 509 Section of A-B Industrial Control Catalog to specify complete catalog starter number.

††May be too small to allow some motors to start.



Square D Company — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

			Max fuse		
			LPJ-SP	LPN-RK-SP	KRP-C-SP
Hp (FLA)	Contactor	OLR	Class J	Class RK1	Class L
200 Volt, three-phase motors					
0.5 (2.5)	LC1D09	LR2D1307	4		
0.75 (3.7)	LC1D09	LR2D1308	6		
1 (4.8)	LC1D09	LR2D1310	10		
1.5 (6.9)	LC1D09	LR2D1312	15		
2 (7.8)	LC1D09	LR2D1312	15		
2 (7.8)	LC1D09	LR2D1314	15		
3 (11.0)	LC1D012	LR2D1316	20		
5 (17.5)	LC1D018	LR2D1321	25††		
5 (17.5)	LC1D025	LR2D1322	35		
7.5 (25.3)	LC1D032	LR2D2353	40		
10 (32.2)	LC1D040	LR2D3355	60		
15 (48.3)	LC1D050	LR2D3357	70††		
15 (48.3)	LC1D050	LR2D3359	80		
15 (48.3)	LC1D065	LR2D3359	100		
20 (62.1)	LC1D050	LR2D3359	80††		
20 (62.1)	LC1D065	LR2D3359	100		
30 (92.0)	LC1F115	LR2F5367	200	200	
40 (120.0)	LC1F150	LR2F5569	250	250	
50 (150.0)	LC1F185	LR2F5569	300	250	
50 (150.0)	LC1F185	LR2F5571	300	300	
60 (177.0)	LC1F265	LR2F6573		350	
60 (177.0)	LC1F265	LR2F5571	350	350	
75 (221.0)	LC1F400	LR2F6575		450	
100 (285.0)	LC1F400	LR2F6575	500	500	
100 (285.0)	LC1F400	LR2F6577	600		601
125 (359.0)	LC1F500	LR2F6577	600		800
230 Volt, three-phase motors					
0.5 (2.2)	LC1D09	LR2D1307	4		
0.75 (3.2)	LC1D09	LR2D1308	6		
1 (4.2)	LC1D09	LR2D1310	10		
1.5 (6.0)	LC1D09	LR2D1310	10		
1.5 (6.0)	LC1D09	LR2D1312	15		
2 (6.8)	LC1D09	LR2D1312	15		
3 (9.6)	LC1D09	LR2D1314	15		
3 (9.6)	LC1D012	LR2D1316	20		
5 (15.2)	LC1D018	LR2D1321	25		
7.5 (22.0)	LC1D032	LR2D1322	35		
10 (28.0)	LC1D032	LR2D2353	40††		
15 (42.0)	LC1D050	LR2D3357	70		
20 (54.0)	LC1D050	LR2D3359	80††		
20 (54.0)	LC1D065	LR2D3359	100		
40 (104.0)	LC1F115	LR2F5367	225	200	
40 (104.0)	LC1F115	LR2F5369	225	225	
50 (130.0)	LC1F150	LR2F5569	250	250	
60 (154.0)	LC1F185	LR2F5569	300	250	
60 (154.0)	LC1F185	LR2F5571	300	300	
75 (192.0)	LC1F265	LR2F6571	400	350	
75 (192.0)	LC1F265	LR2F6573	400	400	
100 (248.0)	LC1F400	LR2F6575	500	500	
125 (312.0)	LC1F400	LR2F6575	500	500	
125 (312.0)	LC1F400	LR2F6577	600		700
150 (360.0)	LC1F500	LR2F6577	600		800
200 (480.0)	LC1F500	LR2F7579			1000
250 (600.0)	LC1F630	LR2F7581			1350
300 (720.0)	LC1F630	LR2F8583			1600

			Max fuse		
Hp (FLA)	Contactor	OLR	LPJ-SP Class J	LPN-RK-SP Class RK1	KRP-C-SP Class L
460 Volt, three-phase motors					
0.5 (1.1)	LC1D09	LR2D1306	3		
0.75 (1.6)	LC1D09	LR2D1306	3		
1 (2.1)	LC1D09	LR2D1307	4		
1.5 (3.0)	LC1D09	LR2D1308	6		
2 (3.4)	LC1D09	LR2D1308	6		
3 (4.8)	LC1D09	LR2D1310	10		
5 (7.6)	LC1D09	LR2D1312	15		
5 (7.6)	LC1D09	LR2D1314	15		
7.5 (11.0)	LC1D012	LR2D1316	20		
10 (14.0)	LC1D018	LR2D1321	25		
15 (21.0)	LC1D032	LR2D1322	35		
20 (27.0)	LC1D032	LR2D2353	40		
25 (34.0)	LC1D040	LR2D3355	60		
30 (40.0)	LC1D040	LR2D3355	60		
30 (40.0)	LC1D050	LR2D3357	70		
40 (52.0)	LC1D050	LR2D3359	80		
40 (52.0)	LC1D065	LR2D3359	100		
50 (65.0)	LC1D050	LR2D3359	80††		
50 (65.0)	LC1D065	LR2D3359	100		
75 (96.0)	LC1F115	LR2F5367	200	200	
100 (124.0)	LC1F150	LR2F5569	250	250	
125 (156.0)	LC1F185	LR2F5569	300	250	
125 (156.0)	LC1F185	LR2F5571	350	350	
150 (180.0)	LC1F265	LR2F6571	400	350	
150 (180.0)	LC1F265	LR2F6573	400	400	
200 (240.0)	LC1F400	LR2F6573	450	500	
200 (240.0)	LC1F400	LR2F6575	500	500	
250 (302.0)	LC1F400	LR2F6575	500	500	
250 (302.0)	LC1F400	LR2F6577	600		650
300 (361.0)	LC1F500	LR2F6577	600		800
350 (414.0)	LC1F500	LR2F7579			800
400 (477.0)	LC1F500	LR2F7579			1000
500 (590.0)	LC1F630	LR2F7581			1350
600 (720.0)	LC1F630	LR2F8583			1600
575 Volt, three-phase motors					
0.75 (1.3)	LC1D09	LR2D1306	3		
1 (1.7)	LC1D09	LR2D1306	3		
1.5 (2.4)	LC1D09	LR2D1307	4		
2 (2.7)	LC1D09	LR2D1308	6		
3 (3.9)	LC1D09	LR2D1308	6		
5 (6.1)	LC1D09	LR2D1312	10		
7.5 (9.0)	LC1D012	LR2D1314	15		
7.5 (9.0)	LC1D018	LR2D1316	20		
10 (11.0)	LC1D018	LR2D1316	20		
15 (17.0)	LC1D025	LR2D1321	25		
15 (17.0)	LC1D032	LR2D1322	35		
20 (22.0)	LC1D032	LR2D1322	35		
30 (32.0)	LC1D040	LR2D3355	45††		
40 (41.0)	LC1D050	LR2D3357	70		
50 (52.0)	LC1D065	LR2D3359	80		
50 (52.0)	LC1D080	LR2D3359	90		
60 (62.0)	LC1D065	LR2D3359	80††		
60 (62.0)	LC1D080	LR2D3359	90††		
75 (77.0)	LC1F115	LR2D3363	150	125	
100 (99.0)	LC1F115	LR2F5367	200	200	
125 (125.0)	LC1F150	LR2F5569	250	250	
150 (144.0)	LC1F185	LR2F5569	300	250	
150 (144.0)	LC1F185	LR2F5571	300	300	
200 (192.0)	LC1F265	LR2F5571	400	350	
200 (192.0)	LC1F265	LR2F6573	400	400	
250 (242.0)	LC1F400	LR2F6575	500	500	
300 (289.0)	LC1F400	LR2F6575	500	500	
300 (289.0)	LC1F400	LR2F6577	600		601
350 (336.0)	LC1F500	LR2F6577	600		700
400 (382.0)	LC1F500	LR2F6577	600		800
500 (472.0)	LC1F500	LR2F7579			1000
600 (576.0)	LC1F630	LR2F7581			1200
800 (770.0)	LC1F630	LR2F8583			1600

††May be too small to allow some motors to start.

Square D Company — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

			Max fuse		
			LP-CC	LPJ-SP	TCF CUBEFuse
Hp (FLA)	Contactor	OLR	Class CC	Class J	Class CF
200 Volt, three-phase motors					
0.5 (2.5)	LC1D09	LRD1508	8	6	6
0.75 (3.7)	LC1D09	LRD1508	8	6	6
1 (4.8)	LC1D09	LRD1510	25	20	20
1.5 (6.4)	LC1D09	LRD1512	25	20	20
2 (7.8)	LC1D09	LRD1512	25	20	20
3 (11.0)	LC1D12	LRD1516	25	20	20
5 (17.5)	LC1D18	LRD1522		25*	25*
7.5 (25.3)	LC1D40	LRD1530		50	50
10 (32.2)	LC1D40	LRD3555		60	60
15 (48.3)	LC1D50	LRD3557		70*	70*
20 (62.1)	LC1D65	LRD3559		100	100
25 (78.2)	LC1D80	LRD3563		125	
30 (92.0)	LC1D115	LRD5569		175	
40 (120)	LC1D150	LRD5569		200	
230 Volt, three-phase motors					
0.75 (3.4)	LC1D09	LRD1508	8	6	6
1 (4.2)	LC1D09	LRD1510	25	20	20
1.5 (6.0)	LC1D09	LRD1512	25	20	20
2 (6.8)	LC1D09	LRD1512	25	20	20
3 (9.5)	LC1D12	LRD1516	25	20	20
5 (15.2)	LC1D18	LRD1521		25	25
7.5 (22.0)	LC1D25	LRD1522		35	35
10 (28.0)	LC1D40	LRD1530		50	50
15 (42.0)	LC1D50	LRD3557		70	70
20 (54.0)	LC1D65	LRD3559		100	100
25 (68.0)	LC1D80	LRD3563		125	
30 (80.0)	LC1D80	LRD3560		125	
40 (104)	LC1D115	LRD5569		175	
460 Volt, three-phase motors					
1.5 (3.0)	LC1D09	LRD1508	8	6	6
2 (3.4)	LC1D09	LRD1508	8	6	6
3 (4.8)	LC1D09	LRD1510	25	20	20
5 (7.6)	LC1D09	LRD1512	25	20	20
7.5 (11.0)	LC1D12	LRD1516	25	20	20
10 (14.0)	LC1D18	LRD1521		25	25
15 (21.0)	LC1D25	LRD1522		35	35
20 (27.0)	LC1D40	LRD1530		50	50
25 (34.0)	LC1D40	LRD3555		60	60
30 (40.0)	LC1D40	LRD3555		60	60
30 (40.0)	LC1D50	LRD3557		70	70
40 (52.0)	LC1D50	LRD3559		80	80
50 (65.0)	LC1D65	LRD3559		80*	80*
50 (65.0)	LC1D65	LRD3559		100	100
60 (77.0)	LC1D80	LRD3563		125	
75 (96.0)	LC1D115	LRD5569		175	
100 (124)	LC1D125	LRD5569		200	
575 Volt, three-phase motors					
2 (2.7)	LC1D09	LRD1508	8	6	6
3 (3.9)	LC1D09	LRD1508	8	6	6
5 (6.1)	LC1D09	LRD1512	25	20	20
7.5 (9.0)	LC1D09	LRD1514	25	20	20
10 (11.0)	LC1D12	LRD1516	25	20	20
10 (11.0)	LC1D18	LRD1516	30	20	20
15 (17.0)	LC1D18	LRD1522		25	25
20 (22.0)	LC1D25	LRD1522		35	35
25 (27.0)	LC1D40	LRD1530		50	50
30 (32.0)	LC1D40	LRD3555		60	60
40 (41.0)	LC1D50	LRD3557		70	70
50 (52.0)	LC1D65	LRD3559		100	100
60 (62.0)	LC1D80	LRD3561		125	
75 (77.0)	LC1D115	LR9D5567		150	
100 (99.0)	LC1D115	LR9D5569		175	
125 (125)	LC1D150	LR9D5569		200	

* May be too small to allow some motors to start.

Square D Company — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Starter	Catalog number	Heater size	Max fuse	
				LPN-RK-SP Class RK1	LPJ-SP Class J
200 Volt, three-phase motors					
1.5 (6.9)	0	SB02V02S	B11.5*	12	15
2 (7.8)	0	SB02V02S	B12.8	15	15
3 (11.0)	0	SB02V02S	B19.5	17.5	20
5 (17.5)	1	SC03V02S	B32	25	30
7.5 (25.3)	1	SC03V02S	B50	40	45
10 (32.2)	2	SD01V02S	B62	50	60
15 (48.3)	3	SE01V02S	CC81.5	70	80
20 (62.1)	3	SE01V02S	CC112	100	100
25 (78.2)	3	SE01V02S	CC180	125	125
30 (92.0)	4	SF01V02S	CC156	150	150
40 (120.0)	4	SF01V02S	CC208	175	200
50 (150.0)	5	SG01V02S**	B3.70	225	250
60 (177.0)	5	SG01V02S**	B4.15	300	300
75 (221.0)	5	SG01V02S**	B5.50	350	400
230 Volt, three-phase motors					
1.5 (6.0)	0	SB02V02S	B10.2	10	12
2 (6.8)	0	SB02V02S	B11.5*	12	15
3 (9.6)	0	SB02V02S	B15.5	17.5	17.5
5 (15.2)	1	SC03V02S	B28.0	25	30
7.5 (22.0)	1	SC03V02S	B45	35	50†
10 (28.0)	2	SD01V02S	B50	45	50
15 (42.0)	3	SE01V02S	CC68.5	70	70
20 (54.0)	3	SE01V02S	CC94.0	80	90
25 (68.0)	3	SE01V02S	CC132	110	125
30 (80.0)	3	SE01V02S	CC196	125	150
40 (104.0)	4	SF01V02S	CC180	175	175
50 (130.0)	5	SG01V02S**	B3.30	200	200
60 (154.0)	5	SG01V02S**	B3.70	225	250
75 (192.0)	5	SG01V02S**	B4.15	300	300
100 (248.0)	5	SG01V02S**	B6.25	400	400
460 Volt, three-phase motors					
3 (4.8)	0	SB02V02S	B7.70*	8	9
5 (7.6)	0	SB02V02S	B12.8	15	15
7.5 (11.0)	1	SC03V02S	B19.5	17.5	20
10 (14.0)	1	SC03V02S	B25	20	25
15 (21.0)	2	SD01V02S	B36	30	35
20 (27.0)	2	SD01V02S	B45	40	45
25 (34.0)	2	SD01V02S	B70	50	60
30 (40.0)	3	SE01V02S	CC64.3	60	70
40 (52.0)	3	SE01V02S	CC87.7	80	90
50 (65.0)	3	SE01V02S	CC121	100	110
60 (77.0)	4	SF01V02S	CC121	125	125
75 (96.0)	4	SF01V02S	CC167	150	175
100 (124.0)	5	SG01V02S**	B3.00	200	200
125 (156.0)	5	SG01V02S**	B3.70	225	250
150 (180.0)	5	SG01V02S**	B4.15	300	300
200 (240.0)	5	SG01V02S**	B6.25	400	400
575 Volt, three-phase motors					
3 (3.9)	0	SB02V02S	B6.25	6	8
5 (6.1)	0	SB02V02S	B10.2	10	12
7.5 (9.0)	1	SC03V02S	B15.5	15	17.5
10 (11.0)	1	SC03V02S	B19.5	17.5	20
15 (17.0)	2	SD01V02S	B28.0	25	30
20 (22.0)	2	SD01V02S	B40	35	40
25 (27.0)	2	SD01V02S	B45	40	45
30 (32.0)	3	SE01V02S	CC50.1	50	50
40 (41.0)	3	SE01V02S	CC68.5	60	70
50 (52.0)	3	SE01V02S	CC87.7	80	90
60 (62.0)	4	SF01V02S	CC103	100	100
75 (77.0)	4	SF01V02S	CC121	125	125
100 (99.0)	4	SF01V02S	CC167	150	175
125 (125.0)	5	SG01V02S**	B3.00	200	200
150 (144.0)	5	SG01V02S**	B3.70	225	250
200 (192.0)	5	SG01V02S**	B4.15	300	300

* These overloads were not tested. Maximum fuse sizes are for the lower value of over-load which was tested.

**Y500

† Sized larger than code max for single motor.

Siemens — IEC

UL and CSA verified, Type 2 combination SCCR = 100 kA

			Max fuse		
Hp (FLA)	Starter	OLR	LPN-RK-SP	LPJ-SP	LP-CC
			Class RK1	Class J	Class CC
200 Volt, three-phase motors					
0.5 (2.5)	3TF30/40	3UA5000-1D	6	6	6
0.75 (3.7)	3TF30/40	3UA5000-1E	6	6	6††
1 (4.8)	3TF30/40	3UA5000-1F	8	8	10
1 (4.8)	3TF30/40	3UA5000-1G	10	10	10
1.5 (6.9)	3TF30/40	3UA5000-1H	15	15	20
2 (7.8)	3TF30/40	3UA5000-1J	15	15	20
3 (11.0)	3TF31/41	3UA5000-1K	20	20	30
3 (11.0)	3TF31/41	3UA5000-2S	25†	25†	30
5 (17.5)	3TF32/42	3UA5200-2B	30	30	30††
7.5 (25.3)	3TF34/44	3UA5500-2D	50	50	
10 (32.2)	3TF46	3UA5800-2E	60	60	
15 (48.3)	3TF46	3UA5800-2T	90	90	
20 (62.1)	3TF47	3UA5800-2V	125	125	
25 (78.2)	3TF48	3UA5800-8V	175	175	
30 (92.0)	3TF50	3UA6000-2X	200	200	
40 (120.0)	3TF50	3UA6000-3J	250	250	
50 (150.0)	3TF52	3UA6200-3L	300	300	
75 (221.0)	3TF54	3UA6600-3C	400	400	
75 (221.0)	3TF54	3UA6600-3D	450	450	
100 (285.2)	3TF56	3UA6600-3D	500	500	
125 (359.0)	3TF56	3UA6600-3E	500	500††	
230 Volt, three-phase motors					
0.5 (2.2)	3TF30/40	3UA5000-1C	2.8	3††	3††
0.75 (3.2)	3TF30/40	3UA5000-1E	6	6	6††
1 (4.2)	3TF30/40	3UA5000-1F	8	8	10
1.5 (6.0)	3TF30/40	3UA5000-1G	10	10	10††
2 (6.8)	3TF30/40	3UA5000-1H	15	15	20
3 (9.6)	3TF30/40	3UA5000-1J	15	15	20
3 (9.6)	3TF31/41	3UA5000-1J	15	15	20
5 (15.2)	3TF32/42	3UA5200-2A	25	25	30
7.5 (22.0)	3TF33/43	3UA5200-2C	40	40	30††
10 (28.0)	3TF34/44	3UA5500-2D	50	50	
15 (42.0)	3TF46	3UA5800-2F	70	70	
20 (54.0)	3TF46	3UA5800-2T	90	90	
25 (68.0)	3TF47	3UA5800-2V	125	125	
30 (80.0)	3TF48	3UA5800-8V	175	175	
40 (104.0)	3TF50	3UA6000-2X	200	200	
50 (130.0)	3TF50	3UA6000-3J	250	250	
60 (154.0)	3TF52	3UA6200-3L	300	300	
75 (192.0)	3TF54	3UA6600-3C	400	400	
100 (248.0)	3TF54	3UA6600-3D	450	450	
125 (312.0)	3TF56	3UA6600-3D	500	500	
150 (360.0)	3TF56	3UA6600-3E	500	500††	
460 Volt, three-phase motors					
0.5 (1.1)	3TF30/40	3UA5000-1A	1.6	2	2.25
0.75 (1.6)	3TF30/40	3UA5000-1A	1.6††	2††	2.25††
1 (2.1)	3TF30/40	3UA5000-1C	2.8	3††	3††
1.5 (3.0)	3TF30/40	3UA5000-1D	6	6	6
2 (3.4)	3TF30/40	3UA5000-1E	6	6	6††
3 (4.8)	3TF30/40	3UA5000-1F	8	8	10
3 (4.8)	3TF30/40	3UA5000-1G	10	10	10
5 (7.6)	3TF30/40	3UA5000-1H	15	15	20
5 (7.6)	3TF30/40	3UA5000-1J	15	15	20
7.5 (11.0)	3TF31/41	3UA5000-1K	20	20	30
7.5 (11.0)	3TF31/41	3UA5000-2S	25†	25†	30
10 (14.0)	3TF32/42	3UA5200-2A	25	25	30
15 (21.0)	3TF33/43	3UA5200-2C	40	40	30††
20 (27.0)	3TF34/44	3UA5500-2D	50	50	
25 (34.0)	3TF46	3UA5800-2E	60	60	
30 (40.0)	3TF46	3UA5800-2F	70	70	
40 (52.0)	3TF46	3UA5800-2T	90	90	
50 (65.0)	3TF47	3UA5800-2V	125	125	
60 (77.0)	3TF48	3UA5800-8V	175†	175†	
75 (96.0)	3TF50	3UA6000-2X	200	200	
100 (124.0)	3TF50	3UA6000-3J	250	250	
125 (156.0)	3TF52	3UA6200-3L	300	300	
150 (180.0)	3TF54	3UA6600-3B	300	300	
200 (240.0)	3TF54	3UA6600-3C	400	400	
250 (302.0)	3TF56	3UA6600-3D	500	500	
300 (361.0)	3TF56	3UA6600-3E	500	500††	

† Sized larger than code max for single motor.

††May be too small to allow some motors to start.

Siemens — NEMA

UL and CSA verified, Type 2 combination SCCR = 100 kA

Hp (FLA)	Starter	OLR	Max fuse		
			LPN-RK-SP Class RK1	LPJ-SP Class J	LP-CC Class CC
200 Volt, three-phase motors					
0.5 (2.5)	SXLA	3UA5000-1D	6	6	6
0.75 (3.7)	SXLA	3UA5000-1E	6	6	6††
1 (4.8)	SXLA	3UA5000-1F	8	8	10
1.5 (6.9)	SXLA	3UA5000-1H	15	15	20
2 (7.8)	SXLB	3UA5400-1J	15	15	20
3 (11.0)	SXLB	3UA5400-1K	20	20	30
5 (17.5)	SXLC	3UA5400-2B	30	30	30††
7.5 (25.3)	SXLC	3UA5400-2D	50	50	
10 (32.2)	SXLD	3UA5800-2E	60	60	
15 (48.3)	SXLE	3UA5800-2T	90	90	
20 (62.1)	SXLE	3UA5800-2V	125	125	
25 (78.2)	SXLE	3UA5800-8W	175	175	
30 (92.0)	SXLF	3UA6200-2X	200	200	
40 (120.0)	SXLF	3UA6200-3J	250	250	
50 (150.0)	SXLG	3UA6600-3B	300	300	
60 (177.0)	SXLG	3UA6600-3C	400†	400†	
75 (221.0)	SXLG	3UA6600-3D	500†	450	
230 Volt, three-phase motors					
0.5 (2.2)	SXLA	3UA5000-1C	2.8	3††	3††
0.75 (3.2)	SXLA	3UA5000-1E	6	6	6††
1 (4.2)	SXLA	3UA5000-1F	8	8	10
1.5 (6.0)	SXLA	3UA5000-1G	10	10	10††
2 (6.8)	SXLB	3UA5400-1H	15	15	20
3 (9.6)	SXLB	3UA5400-1K	20	20	30
5 (15.2)	SXLC	3UA5400-2B	30	30	30
7.5 (22.0)	SXLC	3UA5400-2C	40	40	30††
10 (28.0)	SXLD	3UA5800-2D	50	50	
15 (42.0)	SXLD	3UA5800-2F	70	70	
20 (54.0)	SXLE	3UA5800-2T	90	90	
25 (68.0)	SXLE	3UA5800-2U	150	150	
30 (80.0)	SXLE	3UA5800-8W	175	175	
40 (104.0)	SXLF	3UA6200-3H	225	225	
50 (130.0)	SXLF	3UA6200-3J	250	250	
60 (154.0)	SXLG	3UA6600-3B	300	300	
75 (192.0)	SXLG	3UA6600-3C	400	400	
100 (248.0)	SXLG	3UA6600-3D	500	450	
460 Volt, three-phase motors					
0.5 (1.1)	SXLA	3UA5000-1A	1.6	2	2.25
0.75 (1.6)	SXLA	3UA5000-1A	1.6	2††	2.25††
1 (2.1)	SXLA	3UA5000-1C	2.8	3††	3††
1.5 (3.0)	SXLA	3UA5000-1D	6	6	6
2 (3.4)	SXLA	3UA5000-1E	6	6	6††
3 (4.8)	SXLB	3UA5400-1G	10	10	10
5 (7.6)	SXLB	3UA5400-1H	15	15	20
7.5 (11.0)	SXLC	3UA5400-1K	20	20	30
10 (14.0)	SXLC	3UA5400-2A	25	25	30
15 (21.0)	SXLD	3UA5800-2C	40	40	30††
20 (27.0)	SXLD	3UA5800-2D	50	50	
25 (34.0)	SXLD	3UA5800-2E	60	60	
30 (40.0)	SXLE	3UA5800-2F	70	70	
40 (52.0)	SXLE	3UA5800-2T	90	90	
50 (65.0)	SXLE	3UA5800-2V	125	125	
60 (77.0)	SXLF	3UA6200-2W	175†	175†	
75 (96.0)	SXLF	3UA6200-2X	200	200	
100 (124.0)	SXLF	3UA6200-3J	250	250	
125 (156.0)	SXLG	3UA6600-3B	300	300	
150 (180.0)	SXLG	3UA6600-3C	400	400	
200 (240.0)	SXLG	3UA6600-3D	500	450	

† Sized larger than code max for single motor.

††May be too small to allow some motors to start.

7.14.9 The myth of OCPD resettability

Motor circuits — overcurrent protection choices

Motor circuits have unique characteristics and several functions that require short-circuit and overload protection, and perhaps automatic/remote start/stop. Engineers report owners prefer circuit breakers because they can restore power by simply resetting the device. Let's examine using circuit breakers or current-limiting fuses for motor branch circuit protection.

In this application, fuses and circuit breakers (includes magnetic only circuit breakers which are called MCPs or motor circuit protectors) are sized with the intent to provide only short-circuit and ground fault protection for the motor branch circuit protection per NEC 430.52. Other protective means, such as overload relays, only provide protection against overloads. Typical thermal magnetic circuit breakers can only be sized for motor branch circuit short-circuit protection which is typically 200% - 250% of motor current. If they are sized closer, the motor starting current (inrush current for inductive loads) will trip the circuit breaker's instantaneous mechanism. Magnetic only circuit breakers (MCPs) are intentionally provided without overload capability; they only operate on fault currents. There are some fuses, such as the FRS-R, FRN-R, LPN-RK and LPS-RK fuses, that pass normal, harmless inrush currents and can be sized close enough for motor running overload protection or backup motor running protection. For this examination, assume current-limiting fuses are sized only for motor short-circuit and ground fault protection.

It's important to note that for the protection level being discussed, circuit breakers or fuses should only open if there is a fault on the motor circuit. Any separate overload protective device, such as an overload relay, provides the motor overload protection per 430.32.

Important application considerations

1. OSHA regulation 1910.334(b)(2) Use of Equipment states:

"Reclosing circuits after protective device operation. After a circuit is de-energized by a circuit protective device, the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited. NOTE: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized."

The speed with which a circuit breaker can be reset after a fault is not an advantage. Federal law requires that if the condition is a fault (that is the only reason the circuit breakers or fuses should open on a motor circuit), then the fault must be corrected prior to fuse replacement or resetting the circuit breaker.

2. The typical short-circuit protection level provided by circuit breakers and MCPs for the motor starter is referred to as Type 1. For a loadside fault, the starter may sustain significant damage such as severe contact welding and heater element rupturing. In addition, the heater/overload relay system may lose calibration. Per UL 508, this is an acceptable level of protection. Current-limiting fuses can be selected and sized to provide Type 2 "No Damage" short-circuit protection for motor starters. For loadside fault, no damage is allowed to the contacts or overload relays.

After a fault occurs with circuit breaker protection, significant downtime and cost may be incurred in repairing or replacing the starter. With properly selected and sized fuses providing Type 2 protection, after the fault is repaired, only the fuses need replacing; the starter does not require repair or replacement.

3. Circuit breakers must be periodically operated (exercised) to verify they can mechanically open and close the circuit, and electrically tested to verify they're still properly calibrated to specification (see manufacturers' instructions for recommendations). Typically, circuit breakers should be mechanically operated at least every year and electrically tested every one to five years, depending on their service conditions. Modern current-limiting fuses do not require any maintenance, or electrical testing to verify they will operate as intended. The terminations for both circuit breakers and fusible devices must be periodically checked and maintained to prevent thermal damage. Fuse clips should be periodically inspected and maintained, if necessary.
4. After a circuit breaker interrupts a fault, it may not be suitable for further service. UL 489 only requires a circuit breaker to interrupt two fault currents at its interrupting rating. Circuit breakers that are rated 100 amps or less aren't required to operate after only one short-circuit operation under "busbar" short-circuit conditions. If the fault current is high, manufacturers recommend that a circuit breaker receive a thorough inspection and replacement, if necessary. Records must be kept of maintenance and service history, along with fault interruption levels for each circuit breaker. After modern current-limiting fuses interrupt a fault, new factory-calibrated replacement fuses are installed. The original, superior short-circuit protection will be ensured for the motor circuit's life.
5. After a fault, the electrician generally has to walk to the storeroom to get replacement fuses, unless spare fuses are stored adjacent to the equipment. While this does require some additional downtime, it remains negligible. When fuses opened under fault conditions, there is a short somewhere in the circuit that must first be remedied before restoring power. The electrician will, in all probability, go back to the storeroom for circuit repair parts anyway. If properly selected current-limiting fuses are used in the original circuit, the starter will not sustain any significant damage or loss of overload calibration, and fewer repair parts will be required.

With circuit breakers protecting motor circuits, after a fault condition, it may be necessary to repair or replace the starter, so a trip to the storeroom may be necessary, regardless of the breakers "resettability." And if the starter is not significantly damaged, it may still need testing to ensure the circuit breaker's let-through energy has not caused the loss of starter overload calibration. In addition, the circuit breaker must be evaluated for suitability before being placed back into service. Qualified electricians must conduct the evaluation on site, which could take many hours to repair, test and/or possibly replace the breaker.

In summary, for motor branch circuit (short-circuit) protection, "resetting to save time" is not a significant benefit. Additionally, the circuit breaker's resettability in motor branch circuit applications may encourage an unsafe practice. The Motor branch circuit protection function is fault protection (short-circuits and ground faults). While faults do not occur on a regular basis, it is important to have the very best protection possible when they do. The best motor branch circuit protection can be best judged by:

- Reliability - its ability to retain its calibration and speed of operation over its lifetime
- Current-limiting protection -its ability to provide Type 2 "No Damage" protection to the motor starter
- Safety - its ability to meet a facility's safety needs.

After a high level fault on a motor branch circuit, fuses must be replaced, circuit breakers inspected, recalibrated and possibly replaced along with the motor starter.

7.14.10 Voltage unbalance and single phasing

Single-phasing occurs when one phase in a three-phase system opens, causing the other two phases to become unbalanced in voltage and current. This section examines the causes and how overcurrent protective devices function when single-phasing occurs.

Motor failures can be attributed to the following:

Cause	Percent of failures
Overloads	30
Contaminants	19
Single-phasing	14
Bearing failure	13
Old age	10
Rotor failure	5
Miscellaneous	9
Total	100

From the above data, 44% (30% overload + 14% single-phasing) of motor failures are related to HEAT.

Allowing a motor to reach and operate at a temperature 10°C above its maximum temperature rating will reduce the motor's expected life by 50%. Operating at another 10°C above this, the motor's life will be reduced again by 50%. This reduction in expected motor life continues for every additional 10°C above the maximum temperature rating and is sometimes referred to as the "half-life" rule.

Although there isn't an industry standard that defines electric motor life, it is generally considered to be 20 years under "normal" operating conditions.

A motor's "temperature rise" is the term used to express the equilibrium between the heat produced in the motor windings (copper losses), bearing friction, rotor and stator losses (core losses) and its heat dissipation. For example, a continuous duty, 40°C rise motor operating at full load current will stabilize its temperature at 40°C above ambient.

Standard motors are designed to not exceed their safe winding insulation temperature limit when the temperature rise produced within the motor, while delivering its rated horsepower, is added to the industry standard 40°C ambient temperature rating.

An electric motor's "service factor" (SF) is the percentage of overloading a motor can handle for short periods when operating normally within the correct voltage tolerances and rated frequency.

Example: A 10 Hp motor with a 1.0 SF can perform 10 Hp of work without exceeding its temperature rise requirements. A 10 Hp motor with a 1.15 SF can perform 11.5 Hp of work without exceeding its temperature rise requirements.

Overloads, if allowed to continue, will cause heat to build-up within the motor resulting in early failure of the motor's insulation. Insulation life is cut in half for every 10°C increase over the motor's rated temperature.

Voltage unbalance

For three-phase motors, when the voltage between all three phases is equal (balanced), current values in each phase winding will be the same.

The NEMA standard for electric motors and generators recommends limiting the maximum voltage unbalance to 1%.

When the voltages between the three phases (AB, BC, CA) are unequal (unbalanced), the current increases dramatically in the motor's windings. If allowed to continue, the motor will eventually be damaged.

To a limited extent, it's possible to operate a motor when the voltages between the phases is unbalanced. To do this, the motor's load must be reduced (commonly referred to as derating).

Phase voltage unbalance in percent (%)	Derate motor to these motor rating percentages (%)*
1	98
2	95
3	88
4	82
5	75

* This is a general rule. For specific motors consult the manufacturer.

Common unbalanced voltage conditions causes

- Unequal single-phase loads. Many panelboard specifications require loading be balanced to $\pm 10\%$ between all three phases
- Open Delta connections
- An open transformer connection causing a single-phase condition
- Improper transformer tap settings
- A "bank" or single phase transformer of unequal impedance (Z)
- Different size power factor correction capacitors, or "off the line."

Insulation life

Voltage unbalance impact on the insulation life of a typical T-frame motor having Class B insulation, running in a 40°C ambient and loaded to 100%, is shown in the table below.

Voltage unbalance percent (%)	Insulation life at service factor (SF)	
	1.0	1.15
0	1.00	2.27
1	0.90	2.10
2	0.64	1.58
3	—	0.98
4	—	0.51

Motors with a 1.0 service factor do not have as much heat-withstand capability as motors with a 1.15 service factor.

Older, larger U-frame motors with a greater ability to dissipate heat, could withstand overload conditions for longer periods than the newer, smaller T-frame motors.

Insulation classes

The following table shows the maximum operating temperatures for different insulation classes.

Insulation class	Max operating temperature °C
A	105
B	130
F	155
H	180



Calculating voltage unbalance and expected heat rise

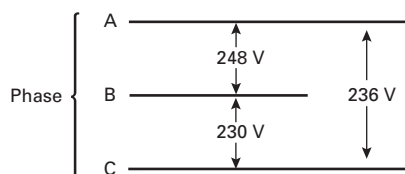


Figure 7.14.10.a

Step 1: From Figure 7.14.10.a, add together the three voltage readings.

$$248 \text{ V} + 236 \text{ V} + 230 \text{ V} = 714 \text{ V}$$

Step 2: Divide the voltage total by three to get the "average" voltage.

$$714 \text{ V} \div 3 = 238 \text{ V}$$

Step 3: Subtract the "average" voltage from the one voltage that result in the greatest voltage difference.

$$248 \text{ V} - 238 \text{ V} = 10 \text{ V}$$

Step 4: Next, determine the voltage unbalance percentage by using the formula $100 \times \text{greatest voltage difference} / \text{average voltage}$.

$$100 \times (10 \div 238) = 4.2 \text{ percent voltage unbalance}$$

Step 5: The expected temperature rise is found in the phase winding with the highest current using the formula: $2 \times (\text{percent voltage unbalance})^2$.

$$2 \times (4.2)^2 = 35.28 \text{ percent temperature rise.}$$

In this example, for a motor rated with a 60°C rise, the unbalanced voltage condition will result in a higher temperature rise in the phase winding with a corresponding shortening of life, if allowed to persist, the temperature will rise by $60^\circ\text{C} \times 135.28\% = 81.17^\circ\text{C}$

The National Electrical Code

The NEC Table 430.37 requires three overload protective devices (one in each phase) for protecting all three-phase motors.

Prior to the 1971 NEC, three-phase motors were considered protected from overload by just two overload protective devices. These devices could be properly sized time-delay, dual-element fuses, or overload heaters and relays (melting alloy type, bimetallic type, magnetic type, and solid-state type.)

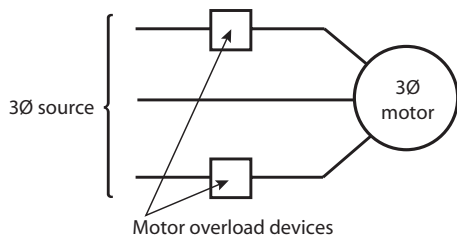


Figure 7.14.10.b Prior to 1971, the NEC accepted two overload devices for three-phase motors as depicted above.

Two motor overload protective devices provide adequate protection against balanced voltage overload conditions, where the voltage between phases is equal. When a balanced voltage overload persists, the protective devices usually simultaneously open. In some cases, one device opens and the other shortly after. In either case, three-phase motors are protected against overloads in a balanced voltage condition.

Three-phase motors protected by two overload protective devices are not assured protection against single-phasing. For example, when the electrical system is Wye/Delta or Delta/Wye connected, all three phases on the transformer bank's secondary side will continue to carry current when single-phasing, caused by an open phase on the transformer bank's primary side occurs. Single-phasing can be considered to be the worst case voltage unbalance condition possible.

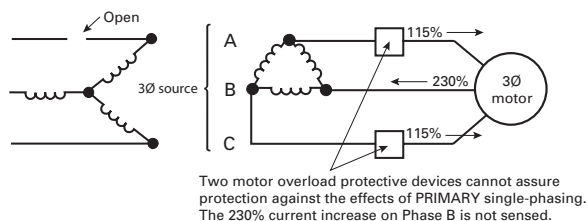


Figure 7.14.10.c This depicts a Wye/Delta transformation with one primary phase open. The motor is protected by two overload devices. One phase to the motor is carrying two times more current than the other two phases. Without an overload device in that phase, the motor will be damaged.

The NEC 430.36 requires that when fuses are used for motor overload protection, a fuse must be inserted in each phase. Where thermal overload devices (heaters, etc.) are used for motor overload protection, Table 430.37 requires one be inserted in each phase. With these requirements, motor burnouts caused by single-phasing have been greatly reduced, and are no longer a serious hazard to motor installations. Figure 7.14.10.d shows three overload protective devices protecting the three-phase motor.

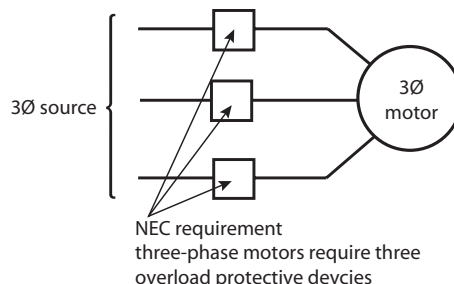


Figure 7.14.10.d Since 1971, the NEC has required three overload protective devices (one in each phase) for protecting three-phase motors.

Motor branch circuit short-circuit and ground fault protection

When sized according to NEC 430.52, a three-pole common trip circuit breaker or MCP can't protect against single-phasing damage.

While the causes of single-phasing can't ever be eliminated, motors can be protected from the single-phasing by using proper overcurrent protection.

In many applications FRN-R (250 V)/FRS-R (600 V) dual-element, time-delay fuses can be sized at or close to the motor's nameplate full-load amp rating without opening on normal motor start-up. This requires sizing the fuses at 100-125% of the motor's full-load current rating. Since all motors are not necessarily "fully loaded," it's recommended to use the motor's actual current draw and not the nameplate rating. This is possible for motor with a fixed load, but not recommended for motors with loads that vary. When sizing to the motor's actual running current is not practical, an economic analysis can determine if adding one of the electronic "black boxes" is financially justified. These electronic "black boxes" sense voltage and current unbalance, phase reversal and single-phasing, etc.

When Fusetron FRS-R and FRN-R dual-element, time-delay fuses are applied and single-phasing occurs, they can sense the overcurrent and quickly respond to take the motor off line.

For motor branch-circuit protection only, NEC 430.52 using the sizing guidelines shown below (see NEC 430.52 for specifics and exceptions).

Note: When sized according to Table 430.52, none of these overcurrent devices provides protection against single-phasing.

OCPD type	Normal	Maximum
Dual-element, time- delay fuses	175%	225%
Non-time-delay and all Class CC fuses	300%	400%
Inverse-time circuit breaker	250%	400% for motors 100 amps or less. 300% for motors more than 100 amps.
Instantaneous only trip† circuit breakers (sometimes referred to as MCPs. These are motor circuit protectors, not motor protectors.)	800%††	1300%†††

† Instantaneous only trip breakers are permitted to have time-delay. This could result in more damaging let-through current during short-circuits.

†† 1100% for design B energy efficient motors.

††† 1700% for design B motors.

Single-phasing

The term single-phasing, means one of the three phases is open. A secondary single-phasing condition subjects an electric motor to the worst possible unbalanced voltage.

If a three-phase motor is running when a “single-phase” condition occurs, it will attempt to continue delivering its full horsepower (enough to drive the load) until it burns out, or until the properly sized overload elements and/or properly sized dual-element, time-delay fuses take the motor off line.

For lightly loaded three-phase motors, running at 70% of normal full-load amps, the phase current will increase by the square root of three ($\sqrt{3}$ or 1.732) under secondary single-phase conditions. This will result in approximately 20% more current draw than the nameplate full load current. If the overloads are sized at 125% of the motor nameplate, circulating currents can still damage the motor. This is why it's recommended that motor overload protection be based upon the motor's actual running current under its given loading, rather than the nameplate current rating (assuming that running current is less than nameplate current).

Single-phasing causes are numerous

It should be acknowledged that nothing can prevent or eliminate all single-phasing events.

There are numerous causes for both primary and secondary single-phasing. Whenever a single-phasing condition occurs, the protective device must sense the resulting increase in current and respond quickly enough to prevent motor damage.

The term “single-phasing” is used when one phase of a three-phase system opens whether it occurs on the distribution transformer's primary or secondary side. When three-phase motors are not individually protected by three time-delay, dual-element fuses (sized per NEC 430.32), or three overload devices (one on each phase), they are subject to damaging overcurrents that result from primary or secondary single-phasing.

Typical causes for single-phasing on the transformer secondary

- A damaged motor starter contact opening one pole. The number of contact kits sold each year confirms that worn motor starter contacts are the most common single-phasing cause. Starter contact wear and tear from cycling can cause them to burn open, or develop very high contact resistance and result in single-phasing. This is most likely to occur on automatically started equipment such as air conditioners, compressors, fans, etc.
- A burned open overload relay (heater) caused by a line-to-ground fault on a 3 or 4 wire grounded system. This is more likely to occur on smaller size motor starters that are protected by non-current-limiting OCPDs.
- A damaged switch or circuit breaker on the main, feeder or motor branch circuit.
- An open fuse or open circuit breaker pole on main, feeder or motor branch circuit.
- An open cable or bus on the transformer's secondary terminals.
- An open cable caused by an overheated lug on secondary side connection to service.
- An open wire connection, such as caused by vibration in motor junction box or any pull box. Poor connections, particularly when aluminum conductors are not properly spliced to copper conductors, or when aluminum conductors are inserted into terminals and lugs specified for use with only copper or copper-clad conductors.
- An open motor winding.
- An open winding in a three-phase transformer.
- Any open circuit on any phase, anywhere between the transformer's secondary and the motor.

Hazards for secondary single-phasing on three-phase motors

When one secondary phase opens, the current to a motor in the two remaining phases theoretically increases to 1.73 (173%) times the motor's normal current draw. Due to power factor changes, the increase can be as much as 2 times (200%). When motors have a high inertia load, the current can approach locked-rotor values under single-phase conditions. Three properly sized time-delay, dual-element fuses (sized per NEC 430.32), and/or three properly sized overload devices will sense and quickly respond to this overcurrent.

Single-phasing on secondary, Delta-connected motor, FLA = 10 A

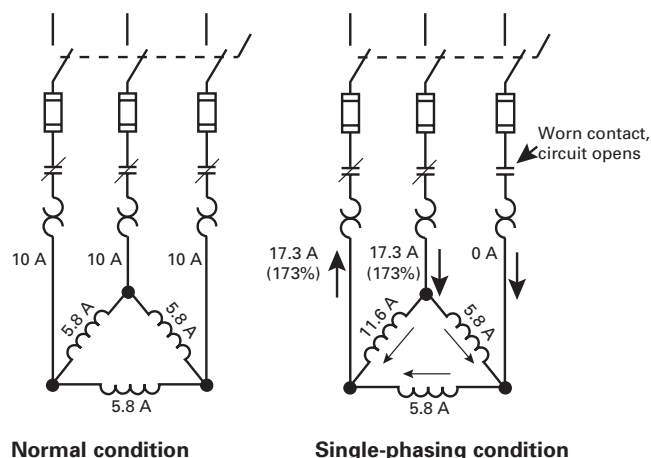


Figure 7.14.10.e This Delta-connected motor diagram shows the current increase in the two remaining phases after single-phasing occurs on the transformer's secondary.

Wye-connected motor, FLA = 10 A

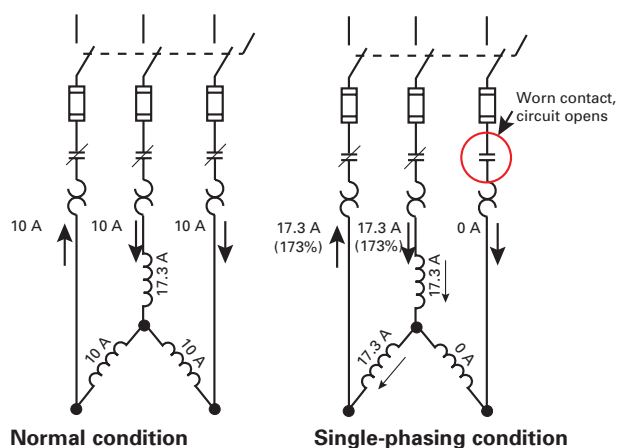


Figure 7.14.10.f This Wye-connected motor diagram shows the current increase in the two remaining phases after single-phasing occurs on the transformer's secondary.

Delta-connected motor: FLA = 10 A, Connected load = 6.5 A

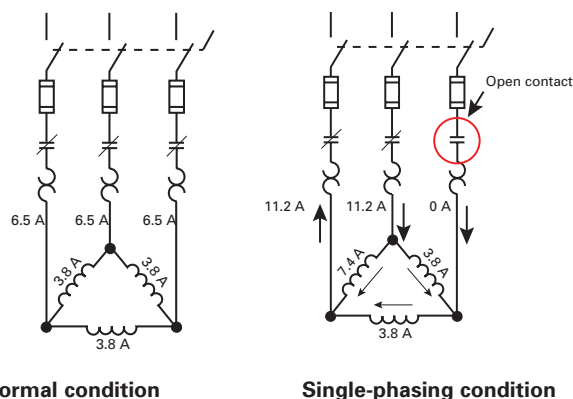


Figure 7.14.10.g This Delta-connected three-phase motor is loaded to only 65% of its rated horsepower with normal FLA = 10 A. For optimum protection, overload protection should be based upon the motor's actual current draw for its under-loaded operation. If the motor's load should vary, overload protection is difficult to achieve. Temperature sensors, phase failure relays and current differential relays should be installed.

When a motor is subject to single-phasing, the current in the remaining two phases increases to 173% of normal current. In most cases, overload relays will safely take the motor off line. However, should the overload relays or controller fail, properly sized Low-Peak or Fusetron time-delay, dual-element fuses can provide back-up overload protection and take the motor off line.

If the overload relays were sized at 12 A (based upon the motor nameplate FLA of 10 A), they would not "sense" or react to the single-phasing. If they were sized at 8 A ($6.5 \text{ A} \times 1.25 = 8.13 \text{ A}$), they would "sense" the single-phasing condition and take the motor off line.

Typical causes for single-phasing on the transformer primary

- Primary wire broken by:
 - Weather conditions (storm, wind, ice, sleet, hail)
 - Lightning
 - Vehicle or airplane striking pole or high-line
 - Falling trees or tree limbs
 - Construction mishaps
- Primary wire burned off from short-circuit created by birds or animals.
- Defective contacts on the primary's breaker or switch/failure to make up on all three poles.
- Failure of three-shot automatic recloser to make up on all three poles.
- Open pole on a three-phase automatic voltage tap changer.
- Open winding in one phase of transformer.
- Primary fuse open.

Single-phasing on primary: Delta-connected motor; FLA = 10 A

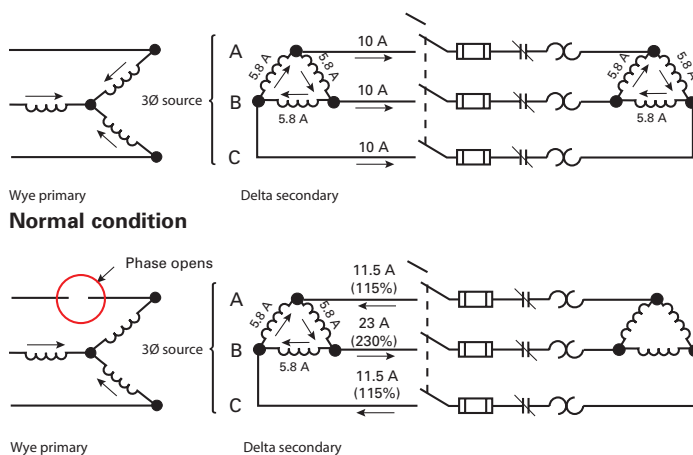
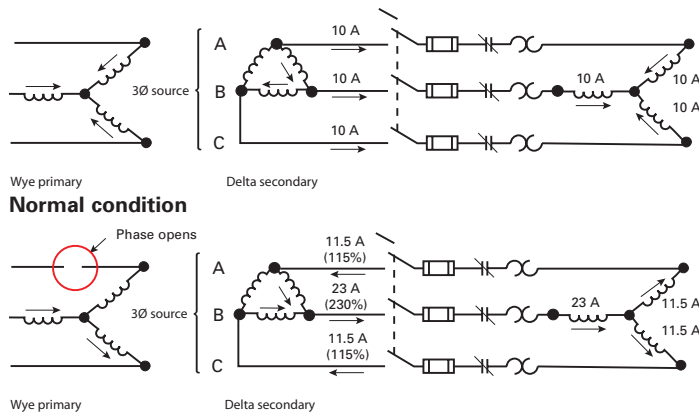


Figure 7.14.10.h

In Figure 7.14.10.h, the Delta-connected motor diagram shows how the phase currents to a three-phase motor increase when single-phasing occurs on the primary. For older installations where the motor is protected by only two overload devices, the phase winding subjected to the 230% current that does not have an overload device will burn up. However, properly sized overload relays or Low-Peak or Fusetron dual-element, time-delay fuses on each phase will take the motor safely off line.

Single-phasing on primary: Wye-connected motor; FLA = 10 A



Single-phasing condition

Figure 7.14.10.i

In Figure 7.14.10.i, the Wye-connected motor diagram shows how the phase currents to a three-phase motor increase when single-phasing occurs on the primary. For older installations where the motor is protected by only two overload devices, the phase winding subjected to the 230% current that does not have an overload device will burn up. However, properly sized overload relays or Low-Peak or Fusetron dual-element, time-delay fuses on each phase will take the motor safely off line.

Primary single-phasing hazards for three-phase motors

Probably the most damaging single-phasing condition is when one phase on a Wye/Delta or Delta/Wye transformer's primary side is open. Usually this is not within the electrical power user's control. When primary single-phasing occurs, unbalanced voltages appear on the motor circuit, causing excessive unbalanced currents.

When primary single-phasing occurs, the motor current in one secondary phase increases to 230% of normal current. Normally, the overload relays will protect the motor. However, if the overload relays or controller fail to function, Low-Peak or Fusetron time-delay, dual-element fuses properly sized and installed on each phase will provide backup overload protection to safely take the motor off line.

Single-phasing's impact on three-phase motors

Single-phasing's impact on three-phase motors varies with service conditions and motor thermal capacities. When single-phasing occurs, the motor temperature rise may not vary directly with the motor current, or it may increase at a rate greater than the increase in current. In some cases, protective devices that only sense current may not provide complete protection from single-phasing. Regardless, practical experience has proven that properly sized and maintained motor running overload devices can greatly reduce problems resulting from single-phasing for most motor installations. In some instances, additional protective means may be necessary when a higher degree of single-phasing protection is required. Generally, smaller horsepower rated motors have more thermal capacity than larger horsepower rated motors and are more likely to be protected by conventional motor running overload devices.

Case study

In January, 2005, a two-hour long primary single phasing event occurred at the Bussmann Division facility in St. Louis, Missouri. While the utility would not divulge its root cause, there were over 100 motors running in the facility. Since the motors were adequately protected with a motor overload protective device or element on each phase (such as a starter with three heater elements/ overload relay) and with three properly sized Fusetron or Low-Peak fuses providing backup motor overload protection, all motors were adequately protected from single-phasing incident. Not a single motor replacement or repair was needed, and the facility was quickly returned to service after replacing fuses and resetting overload relays.

Suggestions to protect three-phase motors against single-phasing

1. Per NEC 430.37, three-phase motors must have an overload protective device on each phase. Use motor overload protection such as overload relays/heater elements on each motor phase. Prior to 1971, only two overload protective devices were required and motors were much more susceptible to burnout.
2. For fully loaded motors, size the heater elements or set the overload protection properly per the motor nameplate FLA.
3. If the motor is oversized for the application or not fully loaded, measure the full load current and size the heaters or set the overload protection per the motor's actual running current.
4. Electronic motor overload protective devices typically have provisions to signal the controller to open if the phase currents/voltages are significantly unbalanced.
5. Install phase/voltage monitor devices that detect phase loss or significant imbalances and signal the controller to open.
6. Periodically test overload protective devices to ensure the overload heaters/overload relays are properly calibrated.

Following one or more of these suggestions, three-phase motors can be easily protected against overloads, including single-phasing. Then the motor circuit branch circuit short-circuit and ground fault protection required per NEC 430.52 can be achieved with many current-limiting fuses types, including LPJ-SP, LP-CC, TCF, LPN-R, LPS-R, FRN-R, FRS-R, JJS, JJN, SC and others. Many size these fuses for only short-circuit protection while some engineers and maintenance personnel want another protection level. For this, they utilize the fuse types and sizing in (7) below.

7. In addition to the motor overload protection, use three Fusetron dual-element, time-delay fuses (FRS-R/FRN-R) sized to provide backup motor overload protection. Low-Peak dual-element, time-delay fuses (LPS-RK/LPN-RK) can also be used, but in some cases they must be sized slightly greater than FRS-R and FRN-R fuses. When sized properly, these fuses serve two purposes: (1) motor branch circuit short-circuit and ground fault protection (NEC 430.52) and (2) motor running back-up overload protection.

7.15 Panelboards and other fusible equipment

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7.15.1 Overview

A panelboard is an electrical distribution system's component that divides the electrical power feed into branch circuits and/or feeder circuits, while providing an OCPD (fuse or circuit breaker) for each circuit in a common enclosure. In essence, panelboards are used to protect against electrical overloads and short-circuits while distributing electricity throughout a building or facility. The main panelboard components typically include:

- The enclosure
- Interior
- Overcurrent protection devices
- Labels
- Deadfront and trim
- Filler plates

The NEC defines a panelboard as "A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall, partition, or other support; and accessible only from the front." Panelboards are listed to UL 67 Standard for Panelboards.

Panelboards are often categorized by their general application, whether used for lighting, appliances or power.

Lighting and appliance panelboards contain overcurrent protection and a means to disconnect lighting, appliances, receptacles and other small load circuits. All other panelboards are used for power and may also feed other panels, motors and transformers in the building's or site's overall power distribution systems.

7.15.2 The enclosure

More commonly referred to as the "box" or "can," the enclosure provides the housing in which all the other panelboard components reside. The enclosure provides a degree of protection:

- To personnel against incidental contact with the energized equipment it contains
- To the enclosed equipment against specified environmental conditions

Enclosures are typically made from galvanized or painted steel with removable end panels that allow for simple conduit installation where installers can easily locate and cut holes as needed.

Cabinets, boxes and trims are listed to UL 50, "Enclosures for Electrical Equipment, Non-Environmental Considerations." This standard applies to enclosures for electrical equipment intended to be installed and used in non-hazardous locations in accordance with:

- Canadian Electrical Code, Part I, CSA C22.1,
- National Electrical Code, NFPA 70
- Mexico's Electrical Installations, NOM-001-SEDE

UL 50 covers enclosures for indoor locations (Types 1, 2, 5, 12, 12K, and 13) and enclosures for indoor/outdoor locations (Types 3, 3X, 3R, 3RX, 3S, 3SX, 4, 4X, 6 and 6P).

The enclosure must be in accordance with UL standards and include wiring gutters to provide proper wire bending space. Special cabinets can typically be provided at an additional charge from the manufacturer. Most standard panelboard boxes are supplied without knockouts (blank endwalls).

The National Electrical Manufacturers Association (NEMA) has established guidelines for electrical equipment enclosures. A NEMA Type 1 enclosure is the standard for indoor panelboard enclosures.

Panelboards can be installed using one of two common approaches:

- **Flush mounted** — the panelboard is placed in a recessed area between the wall studs
- **Surface mounted** — the panelboard projects out from the wall

Flush mounting saves space and is generally more aesthetically attractive, while surface mounting is ideal for buildings with concrete, block or steel walls, and columns. Generally, flush mounting is used for commercial, office, school and other public buildings, while surface mounting is used for industrial buildings, electrical closets and basements.



7.15.3 The interior

Inside the enclosure, overcurrent protection devices, busbars and other components are mounted on support rails. This interior assembly is commonly called a chassis. A busbar is a conductor used as a connection point for multiple circuits. Busbars are mounted to insulators on the interior rails, which are then mounted to studs inside the box. A neutral bar is also chassis- or gutter-mounted next to the interior, providing the termination point for the neutral wires from the incoming service and the load circuits.

7.15.4 Overcurrent protective devices (OCPDs)

OCPDs are connected to the busbars by various methods. The OCPD mounting method dictates what OCPDs can be used in each panelboard.

National Electrical Code Article 408 states a panelboard must be protected by an OCPD having a rating not greater than the panelboard's. The OCPD must be located within or at any point on the panelboard's supply side.

Exceptions to Article 408 selectively apply. Refer to the National Electrical Code Article 408 for specifics.

7.15.5 Labels

Panelboards should always be well labeled. Labels provide important information regarding the its voltage, amp and short-circuit current ratings, manufacturing date, panel vintage and renewal parts. This information is critical to ensuring the safety of people and equipment.

7.15.6 Deadfront and trim

The panelboard enclosure's front feature a its deadfront and trim. These components cover the panelboard's front surface and provides a hinged door for accessing to the panel's interior while preventing contact with energized components.

7.15.7 Filler plates

Filler plates cover any unused pole spaces (branch positions) not occupied by an OCPD. NEC 408.7, "Unused Openings" requires unused openings for circuit breakers and switches be covered using identified closures, or other approved means, that provide protection substantially equivalent to the enclosure's wall.

7.15.8 Ratings

7.15.8.1 Voltage rating

Voltage rating markings must be visible on a panelboard without disturbing wiring and other interior parts. Panelboard voltage markings will establish the specific applications and limitations of their applications. For example, a panelboard designed and intended for use only on a supply circuit involving two different potentials (for example, 120/240 volts, three-wire; or 208Y/120 volts, three-phase, four-wire) is so marked.

7.15.8.2 Current rating

The panelboard's current rating is the maximum continuous current that can be supplied through the main terminals. Each panelboard must be individually protected from within the Panelboard or on the supply side by an OCPD having a amp rating not greater than the panelboard's (408.36). E.g. a 400 A panelboard is protected by an internal 400 A fused main disconnect switch or a 400 A OCPD on the its supply side.

Exception No. 1: Individual protection is not required when the panelboard is used as service equipment in accordance with 230.71, where the panelboard is protected by three or more sets of fuses, those fuses must not supply a second bus structure within the panelboard assembly.

Exception No. 2: individual protection is not required when the panelboard is protected on it's supply side by two main sets of fuses which have a combined rating not greater than the panelboard. Panelboards wired under this exception must contain a maximum of 42 OCPDs.

Exception No. 3: For existing panelboards used as service equipment on individual residential occupancies, individual protection is not required.

Panelboards with snap switches rated at 30 A or less must be protected by fuses not larger than 200 A [408.36(A)]. Fusible panelboards are available with heavy duty toggle switches rated more than 30 A; these panelboards are not restricted by this 200 A requirement. If the panelboard is supplied through a transformer, the fuses protecting the panelboard must be located on the transformer secondary [408.36(B)] except where the fuse on the primary complies with 240.21(C)(1). [408.36(B) Exception]

Unless the assembly, including the OCPD(s), are marked for use at 100 percent of their current rating, OCPDs should not be continuously loaded to more than 80 percent of their rating if OCPD nuisance opening is to be avoided.

The Bussmann series Quik-Spec™ Coordination Panelboard is a fusible branch circuit lighting panel that offers the benefits inherent with fuse protection for building electrical systems. This innovative panel offers numerous advantages over other commercially available panelboards including simplified selective coordination with upstream fuses or circuit breakers when the published amp ratio tables are followed. For more information visit Eaton.com/bussmannseries.

7.15.9 Short-Circuit Current Rating (SCCR)

All panelboards have a short-circuit current rating. Some are explicitly marked, others are not and require delving into the interrupting ratings of the specific OCPDs they contain for which the documentation may reside in the installation manual or technical specification sheet that's not readily available. Those not marked with a specific SCCR may be marked with a maximum possible SCCR, but again, the SCCR remains dependent upon on the OCPD interrupting rating which, incidentally, does not take into account how well the OCPD has been maintained and whether or not it has retained its as-manufactured interrupting rating, making the panelboard SCCR dubious.

The panelboard SCCR ensures that the OCPDs it contains can open under fault conditions and the panelboard bus structure will withstand the magnetic forces generated by fault current passing through it. These markings are provided to ensure proper installation with respect to NEC 110.10.

Switches and circuit breakers under switching operations must be capable of closing in on a fault of the magnitude indicated on their marking. In addition, they must open satisfactorily on lesser faults of such magnitude that the opening of the overcurrent feature is delayed.

Typically, the panelboard's short-circuit current rating is determined by the lowest OCPD interrupting rating. The label must be read and care taken when replacing the OCPDs to ensure the panelboard's SCCR not compromised by a lower rated OCPD.

Certain exceptions to this rule exist where branch devices have been UL tested in combination with specific main devices having a higher interrupting rating. Where these defined main breaker and branch breaker combinations are used, the series short-circuit rating of the assembled panelboard will be the same as the series tested rating of the approved rated main breaker.

Series rating solutions apply to panels having main devices, or main lug only panelboards fed remotely by the device listed in the series ratings chart as the main, for which UL Listed tests were conducted. UL permits panelboards to be labeled with a short-circuit rating up to 200 kA symmetrical where UL Listed main and branch circuit combinations are used.

These combinations consist of main breakers or fusible devices connected ahead of, and in series with approved conventional devices. Two arrangements are acceptable and comply with UL standards for panelboards:

- The main OCPD may be installed in the panel as a main device
- The main OCPD may be mounted remote from the panel

In either case, the approved main and branch combinations must be followed. These arrangements are acceptable and are UL Listed having been tested in accordance with UL standards.

Industry standards and the NEC require protecting the entire electrical distribution system from damage due to short-circuit faults. NEC Article 230.205 states that service equipment must be suitable for the available short-circuit current at its supply terminals. The entire distribution system is required to meet this standard. Series rated systems have become an effective method for meeting these requirements. There are three protection systems used to protect low voltage power distribution equipment:

- Fully rated protection
- Fully rated, selectively coordinated protection
- Series rated protection

Fully rated protection — Where all OCPDs are rated for the full prospective short-circuit current at their lineside terminals throughout the system.

Selectively coordinated protection — A fully rated system where the closest upstream OCPD to the fault will open first, thus isolating the faulted circuit.

Series rated protection — A short-circuit interrupting rating assigned to a combination of two or more OCPDs that are connected in series, and in which the rating of the downstream device(s) in the combination is less than the series rating.

Series ratings are also known in the industry as integrated ratings, series combination ratings or series connected ratings.

In a series rated system, all OCPDs in series in the protective scheme must have been tested and listed by Underwriters Laboratories for series combination use in the system.

The UL Recognized Component Directory (the Yellow Book) contains breaker manufacturers' series connected listings. These are intended ONLY as a guideline for use by others who are responsible for their own testing, labeling and listing. Therefore, the UL Recognized Component Directory cannot be used to interpret series connected ratings in assembled equipment. The assembled equipment must also be UL tested for series ratings.

The fault current contribution of motors connected between series rated breakers must be considered. NEC Article 240.86 states that for series ratings, the motor full-load currents sum cannot exceed 1% of the lower rated circuit breaker's interrupting rating. The actual fault current contribution from induction motors is about four times their full-load current (impedance value of 25%). For example, if the downstream branch circuit breakers used in a series rated combination have an interrupting rating of 14,000 amps RMS Sym. for a 480 V system, the maximum allowable motor contribution to that panel from the branch circuit breakers is 140 A (1%). For typical induction motors, this is equivalent to 115 total horsepower at 480 V.

NEC requirements for series ratings may be met by equipment marked with ratings adequate for the available fault current at the installed point in the electrical system. Eaton panelboards and switchboards are marked consistent with NEC Article 240.83.

Additionally, Article 110.22 requires field marking on equipment where series ratings are used. This label is supplied standard with all Eaton panelboards and switchboards.

Note: The NEC requires the installer to properly apply and complete this label. Label(s) must be placed on all equipment where series ratings are used.

7.15.10 Service entrance rated

Service entrance equipment must meet specific characteristics per UL and NEC requirements. Service equipment is that equipment usually comprised of OCPDs (fuses/circuit breakers), switches and their accessories connected to the load end of service conductors to a building or other structure, and intended to constitute the supply's main control and cutoff.

A service entrance rated panelboard must meet basic requirements, including:

- Panels used as service entrance equipment must be located near the point where the supply conductors enter the building.
- A panelboard having main lugs only (MLO) must have a maximum of six service disconnects to de-energize the entire panelboard from the supply conductors. Where more than six disconnects are required, a main service disconnect must be provided. Removing a plug or cartridge fuse from its mounting, while serving to de-energize the circuit, does not provide service disconnection. Panelboard switches, pullout switches and some industrial control switches are suitable as service disconnects. Note that pullout switches, while they serve as a fuse puller, do have switchblades and contact jaws, and are tested as switches.
- A connector for bonding and grounding the neutral conductor must be included. There must be provision for connecting a grounded service conductor and a grounding-electrode conductor. If there is a neutral bus, a means to bond the panelboard enclosure or mounting pan to the neutral bus is required unless the bus is mounted in electrical contact with the enclosure or pan.
- A service-entrance-type UL label must be factory installed.
- Equipment ground fault protection must be provided for solidly grounded Wye electrical services of more than 150 V to ground, but not exceeding 600 V phase-to-phase for each service disconnecting means rated 1000 A or more.

7.15.11 Other fusible equipment



Safety switch

- 250 Vac and 600 Vac
- 30 to 1200 A
- Fuses: J, R, L, H
- SCCR: up to 200 kA
- Available with shunt trip and DC ratings



Bussmann Series CUBEFuse safety switch

- 600 Vac
- 30, 60 and 100 A
- Fuse: Class CF CUBEFuse
- SCCR: 200 kA
- Enclosures: NEMA Type 1, 3R, 12 and 4X



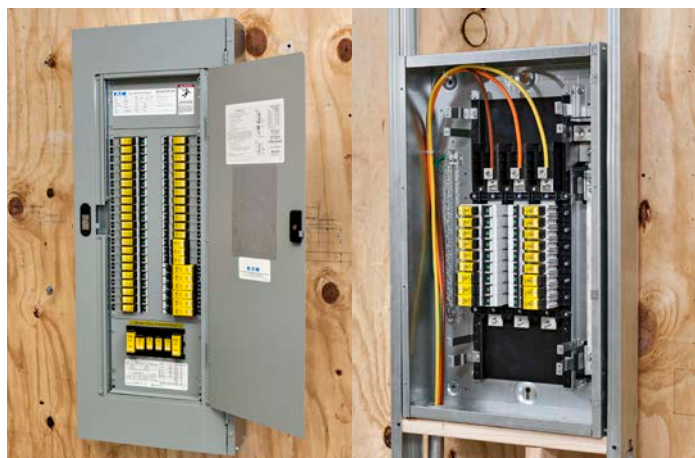
Eaton double door Line-Side Isolation Switch

- 240 Vac and 600 Vac
- 30 to 1200 A
- Fuse Class:
- Enclosures: NEMA Type 3R, 12 and 4/4X



Power distribution panelboard

- Available from various manufacturers
- Up to 600 Vac as well as DC voltage ratings
- Up to 1200 A
- Main lug only, fusible switch main, non-fused switch main
- Variety of fuse classes including CF, J, R, and L
- SCCR: 100 kA to 200 kA



Bussmann series QSCP panelboard

- 600 Vac and 125 Vdc (80 A and less branches)
- 30, 60, 100, 200 and 400 A
- Main lug only, fusible switch main, non-fused switch main
- Maximum branch: 100 A
- SCCR: 50 kA, 100 kA or 200 kA
- Branch fuses: Class CF CUBEFuse (time-delay or non-time delay)
- Enclosures: NEMA Type 1 and 3R



Fusible switchboards

- 600 Vac
- Up to 6000 A fusible main switches
- 100 to 2000 A feeders
- Fuses: Class CF, J, R, H, L
- SCCR: up to 200 kA
- Enclosures: NEMA Type 1, 12, 3R, 12

Fusible switchboards utilize Class L fuses in bolted pressure switches and other type switch with other class fuses up to 600 A, High fault capability and easy to achieve selective coordination with Low-Peak fuses.



Eaton Freedom Series fusible motor control center

- 600 Vac
- Up to 3200 A
- SCCR: 100 kA
- Fuse Class: J, R, L
- Enclosures: NEMA Type 1, 2, 3R, 12



Busmann series Power Module Switch

- 600 Vac
- 30 to 400 A, three-phase
- Fuses: Class J
- SCCR: 200 kA
- Enclosures: NEMA Type 1, 3R, 4 and 12



All-in-one UL 98 shunt trip elevator disconnect to meet any single elevator shutdown and disconnect requirement. Easy to achieve selective coordination with upstream Low-Peak fuses.



Busmann series Power Module Panel

- 600 Vac
- 400 or 800 A bus three-phase MLO or main fused switch
- 30 to 200 A feeder switches, 600 Vac
- Fuses: Class J
- SCCR: 200 kA
- Enclosures: NEMA Type 1, 3R

All-in-one UL 67 shunt trip multi-elevator panel disconnect to meet any elevator shutdown and disconnect requirement. Easy to achieve selective coordination with upstream Low-Peak fuses.

7.16 Solenoids (coils)

Solenoids are inductive devices. Like motors and transformers, they experience an inrush current when energized. Use the table below to size fuses so they will not have “nuisance” openings when operating.

Fuse type	Sizing	Fuse/volt recommendation
Branch circuit	Size at 125% or next size smaller	Up to 250 V: LPN-RK-SP, FRN-R (best) Up to 600 V: LPS-RK-SP, FRS-R, LPJ_SP, LP-CC, FNQ-R, TCF
Supplemental	Size at 125% or next size larger	Up to 32 V: MDL 9-30 A, FNM 20-30 A Up to 125 V: MDA 25-30 A, FNM 12-15 A Up to 250 V: MDL 1/16-8 A, MDA 2/10-20 A, FNM 1/10-10 A, MDQ 1/100-7 A Up to 500 V: FNQ 1/10-30 A

7.17 Switchboards

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7.17.1 Overview

For larger scale buildings or sites, a large single panel, frame or assembly of panels can be used for mounting the overcurrent switches and OCPDs, buses and other equipment. These freestanding, floor-mounted, solutions are switchboards.

Switchboards are most often mounted close to the wall and accessible from the front.

The NEC Article 100 defines a switchboard as: “A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. These assemblies are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets.”

Switchboards function the same as panelboards (and often simply feed other panelboards), but on a larger scale and at 600 Vac or less. They’re used to divide large blocks of electrical current into smaller blocks for use by electrical devices. This division is helpful for:

- Distributing power to loads
- Disconnecting loads for safer maintenance
- Protecting conductors and equipment against excess current from overloads, short-circuits and ground faults.

7.17.2 Primary switchboard components

7.17.2.1 The frame

The switchboard frame is a metal skeleton that houses all the other components. The bus is mounted within this frame and it distributes power from the incoming cables to the branch circuit devices. A horizontal bus distributes power to each switchboard section. The standard orientation for a horizontal bus is A-B-C, from top to bottom. In contrast, a vertical bus distributes power to the circuit protection devices and is normally oriented either left-to-right or front-to-back.

A switchboard enclosure houses one or more switchboard sections or switchboard interiors, or provides auxiliary wiring space for an adjacent switchboard section. A switchboard section is that switchboard portion that’s prevented by the structural framework from being physically separated into smaller units. Framework that’s welded or joined with steel rivets over 1/4 inch (6.4 mm) in diameter is considered to constitute a single section. Framework that’s joined with one-way

(tamper-proof) bolts is not considered to constitute a single section. An assembly consisting of an enclosure and terminal blocks or busbars is considered to be a switchboard section.

7.17.2.2 Bus

The standard switchboard bus is tin-plated aluminum. When requested, a copper, silver-plated copper or tin-plated copper bus are typically available from the manufacturer. Main bus and sub-main buses meet UL and NEMA standards for temperature rise on all Eaton Pow-R-Line switchboards. Special density rated buses are also available.

Unless marked otherwise, the supply, through and section busbars phase arrangement in a three-phase switchboard (but not including the connections to meter sockets) is A, B, C from front-to-back, top-to-bottom or left-to-right as viewed from the switchboard section’s front or interior.

7.17.2.3 Overcurrent protective devices

OCPDs are mounted to the vertical busbars from the unit’s front. Four common types are:

- Fusible switches
- Power circuit breakers
- Molded case circuit breakers
- Bolted pressure switches.

Other protective devices used in the switchboard interior may include meters, surge protective devices (SPDs), utility compartments, transfer switches, transformers and other equipment.

To properly select and size switchboard OCPDs, the allowable temperature rise must be taken into account as this impacts the devices’ tripping characteristics per UL 891.

Accordingly, the NEC requires OCPDs to be rated not less than 125% of the continuous load they’re protecting. To comply with this, an 80% derating factor must be used with all OCPDs (fusible switches/molded-case breakers), unless they are tested and listed for application at 100% of their rating. Fusible bolted pressure switches are 100% rated if listed and tested in the enclosure.

Pow-R-Line™ i switchboards are designed to accommodate fusible switches. Safety is provided by steel compartments that isolate each horizontally mounted switch from the vertical and main buses. For switchboards using circuit breakers, insulated copper runbacks carry power into the glass polyester barriered rear cable compartment.

Shunt-trip attachments for use with ground fault protective devices can be installed on 400-1200 A Type FDPW fusible switches. Both are UL Listed when the shunt-trip is factory installed.

Individually mounted OCPDs

Larger OCPDs may be individually mounted and in most cases this means the OCPD is vertically mounted in the switchboard, and connected via busbar. All insulated case circuit breakers, power air circuit breakers and fusible bolted pressure switches are individually mounted. Molded-case circuit breakers 600 A and above may be individually mounted when used as a main, or feeder device feeding other OCPDs within a section or adjacent sections.

Eaton’s solutions for individually mounted OCPDs include:

- Magnum SB insulated case circuit breakers, 800-5000 A, fixed or drawout
- Magnum DS power circuit breakers, 800-5000 A, fixed or drawout
- Series NRX™ insulated circuit breaker, 400-3000 A, fixed or drawout
- Molded case circuit breakers, 400-2500 A, fixed mounted
- Bolted pressure switches, 800-5000 A
- FDPW fusible switches, 400-1200 A

Compartmentalized feeder and branch OCPDs

Compartmentalized fusible switches and molded-case circuit breakers provide additional isolation. Individually mounted fusible switches and molded-case circuit breakers through 1200 A are available in a compartmentalized, rear-access, rear-connected switchboard.

Group mounted protective devices

Group-mounted circuit protective devices are an assembly of units mounted on a panelboard type chassis. Units may be molded-case breakers, fusible switches, customer metering and surge protective devices.

A main fusible switch or main molded-case circuit breaker (within the sizes listed for panelboard design) can be included in the panel-mounted assembly in lieu of a separate, individually mounted unit.

Eaton's solutions for group mounted OCPDs include:

- FDPW fusible switches, 30-1200 A
- Molded case circuit breakers, 15-1200 A

7.17.2.4 Instrumentation

The switchboard interior may also house specialized instrumentation. Meters can be used in the incoming section to measure current, voltage, power usage, peak demands and other important power characteristics. Instrumentation can be especially helpful in monitoring and managing power usage to ensure the highest possible efficiency.

7.17.2.5 Enclosures and exterior covers

Standard switchboard enclosures include NEMA Type 1 for indoor and Type 3R for outdoor uses. After equipment installation, the frame is enclosed with exterior cover panels. Like the panelboard's deadfront, these covers allow access to the protective devices while isolating the bus and wiring from accidental contact.

There are four main structure types common to all switchboards, although not all switchboards use all of them:

- The main structure contains the main disconnects or main lugs. It often contains surge protection, utility and/or customer metering equipment.
- The pull structure is a blank enclosure containing empty space through which cabling can be pulled. It's commonly used with service entrance switchboards where the utility feed comes through the floor. Service can be fed from the top without any exposed conductors.
- A distribution structure divides and sends power to branch circuit protection devices, then downstream to branch circuits to power loads. Power moves from the incoming structure to the distribution structure via cross bus.
- The Integrated Facility System (IFS) switchboard structure includes panelboards, dry-type transformers, transfer switches and blank back pans for field mounting other equipment.

The IFS is helpful when panelboards and dry-type transformers are used in the same room as switchboards because it can reduce the need for linear wall space and area required for equipment. A key IFS benefit is that it significantly reduces the installation and wiring time, and the number of pieces of equipment to be handled.

7.17.2.6 Listing and labeling

To obtain a UL label on a switchboard requires all its component devices (breakers, switches, etc.) to be UL Listed. In addition, the switchboard must comply with all applicable provisions of UL 891, "Switchboards." The UL 891 standard applies to switchboards nominally rated at 600 V or less, and intended for use in accordance with:

- Canadian Electrical Code, Part 1 (CE Code, Part 1)
- National Electrical Code (NEC), ANSI/NFPA 70
- Mexican Standard for Electrical Installations (Utility), NOM-001-SEDE.

These requirements cover switchboards for use on circuits with available RMS Sym. fault currents not exceeding 200 kA.

The UL Product Category Code for dead-front switchboards is under "Dead-Front Switchboards" (WEVZ). Reference the UL Product Spec at www.ul.com/productspec and the UL Online Certifications Directory at www.ul.com/database.

Today's modern electrical systems require that switchboards offer a wide electrical device selection, many of which don't fall within the scope of UL Listed devices. Therefore, the conditions under which a switchboard may be labeled are limited.

The guidelines below are important to consider when a UL label is specified:

- UL nameplates, where applicable, are supplied for each vertical structure rather than one common nameplate for the complete switchboard lineup. Where all the component devices in the switchboard are UL Listed and all applicable provisions of UL 891 are met, each switchboard section may be labeled.
- Individual switchboard vertical structures may be labeled where they comply with UL requirements, although other vertical structures in the same switchboard lineup may not meet the UL standards, and will not be labeled.

7.17.2.7 Switchboards vs. switchgear

Characteristic	Switchboard	Switchgear
Standards	CSA C22.2 No. 31 CSA C22.2 No. 244, harmonized with UL 891	CSA C22.2 No. 31 ANSI C37.20.1
Circuit protection	Fusible switches, molded-case circuit breaker or power circuit breakers (fixed or drawout)	Power circuit breakers (fixed or drawout)
Device mounting	Typically group mounted	Individually mounted
Breaker features	Breakers are factory sealed	Built for field maintenance, modification and inspection
	Internal accessories factory mounted	Accessory can be field mounted
	Breaker accessories can be field installed	Maximum selective coordination
Short-time rating	See breaker specifications	Short-time 30-cycle withstand ratings up to 85 kA (better selective coordination)
Production testing	Two production tests: dielectric voltage-withstand and ground fault protection	Seven production tests: dielectric, grounding of instrument transformer case, electrical operation and control wiring, control-wiring continuity, polarity verification, sequence and optional control-wiring dielectric
Service conditions	Service conditions are not addressed	Ambient air temperatures and altitude specified Derating factors are given for operating in varying altitudes
Temperature tests	Tests are not required for copper if bus density is 1000 A per square-inch, or for aluminum if bus density is 750 A per square-inch	Required for all bus ratings
Short-time withstand current test	Determined by testing at 600 V for three cycles at 60 Hz	Determined by testing at 635 V for four cycles at 60 Hz
Short-circuit bus testing	Phase to neutral only required under certain conditions and phase to ground not required	Requires phase to neutral and phase to ground
Barriers	Optional internal barriers	Optional barriers between breakers and bus and between breakers themselves
Enclosure structure	Requires indoor paint finish to pass 24-hour salt spray test Outdoor paint finish must pass 600-hour test	Requires indoor paint finish to pass 200-hour salt spray test Outdoor paint finish must pass 600-hour test
Access	Front or rear access	Front and rear access
Covers	Standard bolted front cover (feeders only)	Hinged front covers

7.17.3 Switchboard ratings

7.17.3.1 Voltage

A switchboard section or interior is rated for no more than 600 volts and may be marked with several alternate voltage ratings. A switchboard section or interior that's designed for use on supply circuits involving two different voltages is marked with a combination voltage rating, e.g., 208 Y/120 V, 480 Y/277 V.

If a switchboard section or interior contains a transformer with a secondary circuit that leaves the section or interior, the transformer secondary voltage rating is marked.

7.17.3.2 Current

Each switchboard section or interior is marked with the current rating of the supply bus and section bus (available up to 6000 A), and, in addition, with the rating of the through or splice bus supplying the next section or interior, if the through or splice bus current rating is less than the supply bus' current rating.

The adequacy of the supply, through, splice or section bus current rating with respect to the calculated load current (using the appropriate diversity factors in NEC Article 220) can only be determined at the installation time.

If the various phase busbars (including the neutral busbar) current ratings, are not identical, the current rating markings for each busbar and terminal are provided.

7.17.3.3 Short-circuit rating

Standard bus and connectors on all switchboards are rated for use on systems capable of producing up to 65 kA RMS Sym. short-circuit current at the incoming terminals.

Increased bus short-circuit ratings equal to that of connected switchboard devices, up to 200 kA RMS Sym., are available in most switchboards when approved main devices are installed. UL labeled switchboard sections are marked with their applicable short-circuit rating.

When air power circuit breakers are used as feeder devices, they may experience up to a 30-cycle (1/2 second) delay if the instantaneous setting is turned OFF. Eaton has qualified low voltage switchboards when air power circuit breakers are used as feeders (and mains) to 30 cycles. This rating is not recognized under the UL 891 standard. However, Eaton has witness tested the structure bussing with a qualified National Recognized Testing Laboratory (NRTL) at 30 cycles (1/2 second) up to 100 kAIC symmetrical.

7.17.4 Switchboards used as service equipment

Service equipment constitutes the main control and power cutoff means for the electric service (normally utility supply) brought into the building.

Where switchboards are used as service equipment, certain NEC and UL requirements apply that necessitate modifications not normally supplied in switchboards.

The following summarizes the requirements pertinent to applying a switchboard for service equipment:

- A. A switchboard with main lugs only (no main disconnect) must be designed so that all circuits in the switchboard can be disconnected from the supply source by the operation of no more than six operating handles (breaker or switch).
- B. Switchboard equipped with main disconnect devices are not subject to the above six disconnect limitation, as the entire board can be de-energized with the main disconnect device.
- C. Equipment ground fault protection must be provided for solidly grounded Wye electrical services of more than 150 V line-to-ground, but not exceeding 600 V line-to-line for each service disconnecting means rated 1000 A or more.
- D. For testing purposes, means are also required to disconnect

the switchboard neutral bus from the grounded service neutral conductor (single-phase, three-wire; and three-phase, four-wire systems). To comply with this requirement, a removable link (solid bar) is provided in the switchboard neutral bus. This link is generally located near the point where the main feeders enter the switchboard, or in the area of the main disconnect device where one is provided.

- E. To further comply with NEC and UL requirements, a separate bonding strap is connected from the neutral bus to the switchboard frame. This bonding connection is located on the removable neutral link's lineside, maintaining a service ground to the switchboard frame when the test link is removed.

In a switchboard section or interior marked as suitable for use as service equipment, any uninsulated, ungrounded busbar or terminal on the service disconnect's lineside is isolated by a barrier. So when every service disconnect is in the OFF position, no uninsulated live part is exposed to inadvertent contact while servicing any:

- Load terminal
- Neutral load terminal
- Branch circuit equipment grounding terminal
- Neutral disconnect link

The barrier may contain openings for ventilation.



7.18 Transfer switches

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7.18.1 Overview

The purpose of a transfer switch is to transfer load(s) to a different source of power. All transfer switches have to meet some basic requirements that are important to their performance in any power distribution system. A transfer switch can be a simple manual or a complex, automatic device.

These UL category codes exist for transfer switches:

- Transfer Switches (WPTZ)
- Automatic Transfer Switches for Use in Emergency Systems (WPWR)
- Automatic Transfer Switches for Use in Optional Standby Systems (WPXT)
- Meter-mounted Transfer Switches (WPXW)
- Automatic Transfer Switches Over 600 Volts (WPYC)
- Non-automatic Transfer Switches (WPYV)

Automatic transfer switch protection

Automatic transfer switches (ATS) are a vital part of many life safety-related systems and mission critical systems where power continuity is crucial. UL 1008 Transfer Switch Equipment has product standard requirements for 1000 V or less ATSs, including those listed for emergency use. NEC requires ATSs to be listed for emergency system use in the following:

- Article 700, Emergency Systems, 700.5
- Article 701, Legally Required Standby Systems, 701.5
- Article 517, Health Care Facilities, 517.26 for healthcare facility essential electrical systems
- Article 708, Critical Operation Power Systems (COPS), 708.24

When designing a power distribution system and specifying a transfer switch, two important overcurrent protection considerations must be addressed:

- The ATS short-circuit current rating (SCCR) must be greater than the available short-circuit current (110.10)
- How the overcurrent protective device selected to protect the ATS affects the system selective coordination

Note: The term Withstand and Closing (Close-On) Rating (WCR) which is commonly used with ATSs in the industry and UL 1008 is analogous to short-circuit current rating. These terms are used interchangeably in this section.

Both ATS SCCR and system selective coordination considerations are related to the proper OCPD selection. A misapplication of the relationship between a transfer switch and its OCPD can have a severe impact on the system integrity, and overall performance and project cost. The transfer switch's OCPD characteristics can impact whether selective coordination can be achieved for the full range of overcurrents.

This section focuses on ATS short-circuit current protection and addressing the details with regard to proper OCPD selection. Please see Section 4.2 on Selective Coordination for more information concerning system OCPD selective coordination.

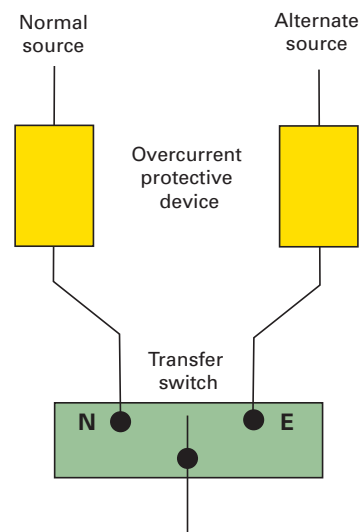


Figure 7.18.1.a

Automatic transfer switches must comply with UL 1008 Transfer Switch Equipment Withstand and Closing (Close-on) Ratings (WCR) Requirements.

Clearly understanding the relationship between a transfer switch's short-circuit current withstand and closing rating and its protective device is imperative to assure a well-designed installation (Figure 7.18.1.a). An ATS must be properly protected for short-circuit currents from either normal or alternate power source or, in the case of closed transition ATSs, the combined fault current from each source. If a transfer switch is subjected to a fault current above its short-circuit current withstand and closing rating, severe ATS damage (including a fire hazard and arc flash hazard), and severe injury or death may result.

UL 1008 SCCR nomenclature

The UL 1008 SCCR nomenclature used for marking ATS's that are suitable for emergency systems make use of "short-circuit withstand and closing rating," "short-time current rating" or other similar derivatives. Often, "short-circuit withstand and closing rating" is shortened to "withstand and closing rating" with WCR as its acronym.

The WCR is applicable when evaluating the ATSs overcurrent protection level when either considering a circuit breaker with an instantaneous trip or current-limiting fuses.

The short-time current ratings are applicable when an ATS is evaluated for protection by circuit breakers with a short-time delay (no instantaneous trip) and the interrupting time is intentionally delayed for a duration (such as 0.1, 0.3 or 0.5 second). In some applications, circuit breakers with short-time delays are utilized to achieve selective coordination with downstream circuit breakers. However, when a circuit breaker with intentional short-time delay and no instantaneous trip is protecting an ATS, the ATS must withstand the fault current for the duration of the short-time delay setting. Therefore, the ATS SCCR for "short-time current rating" is normally lower than when an ATS is protected by a circuit breaker with instantaneous trip.

7.18.2 NEC requirements

The following NEC sections pertain directly to the transfer switch's proper SCCR protection:

110.10 Circuit Impedance, Short-Circuit Current Ratings, and Other Characteristics: The transfer equipment (like many other electrical distribution components) must be able to hold together under the stressful forces of short-circuit current passing through it should a downstream short-circuit event occurs. This equipment must meet the requirements found in Chapter 1, 110.10 for short-circuit current ratings. The transfer switch's SCCR must be greater than the available fault current at that equipment.

700.5(E), 701.5(E), 702.5, 708.24(E): Introduced in the 2017 NEC, these sections require the transfer equipment's short-circuit current rating (based on the specific OCPD type and settings protecting the transfer equipment) be field marked on the transfer equipment's exterior.

702.4(A): Requires the optional standby system equipment be suitable for the maximum available short-circuit current at its terminals.

705.16 Interrupting Rating and Short-Circuit Current Rating: Consideration shall be given to the fault current contribution from all interconnected power sources for the OCPDs interrupting ratings and equipment short-circuit current ratings on interactive systems.

ATS SCCR

Transfer switches are tested, listed, and labeled for use with either fuses or circuit breakers; each offering different protection levels. UL 1008 Transfer Switch Equipment is the product standard for transfer switches. Within this standard there are two ATS short-circuit current withstand tests:

1. First, the transfer switch must withstand a short-circuit when the switch is in a closed position.
2. Second, during another withstand test, the ATS must transfer, close and withstand the short-circuit current until the current is cleared.

ATSs must pass both tests at the same available short-circuit current magnitude and survive within specified acceptable damage levels. The term commonly used in the industry for this ATS short-circuit current rating is WCR for Withstand and Closing (Close On) Rating.

A given ATS may have several SCCR levels marked on the equipment by the manufacturer, in accordance with UL 1008. These options provide the designer and installer flexibility depending on the desired OCPD and what the available short-circuit current is at the ATS's point of installation. An ATS product listing includes each SCCR level stated as a short-circuit current at maximum voltage when protected by an explicit OCPD, possibly including OCPD options and settings. Following are four common UL 1008 methods to determine ATS SCCR and OCPD combinations.

Figure 7.18.2.b illustrates an ATS equipment SCCR label with four OCPD categories and comments concerning their use. For each method, close attention must be paid to the type of OCPD and the requirements. The label is typically affixed on the enclosure outside or readily visible by opening a door or removing a cover. The label is useful during installation, inspection and post installation alterations. When interpreting an actual manufacturer's WCR tables and equipment labels, be sure to read all pertinent footnotes and referenced materials.



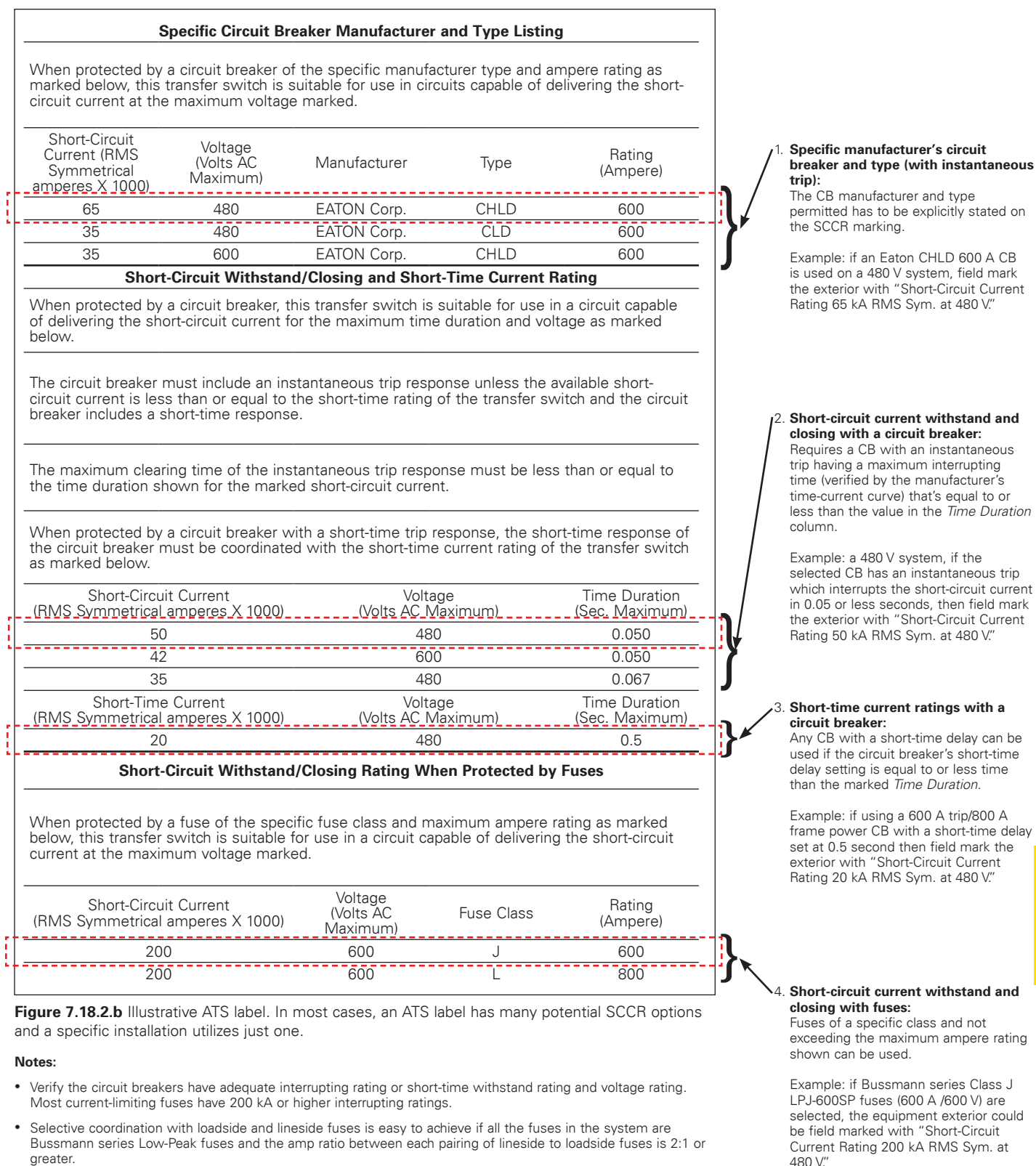


Figure 7.18.2.b Illustrative ATS label. In most cases, an ATS label has many potential SCCR options and a specific installation utilizes just one.

Notes:

- Verify the circuit breakers have adequate interrupting rating or short-time withstand rating and voltage rating. Most current-limiting fuses have 200 kA or higher interrupting ratings.
- Selective coordination with loadside and lineside fuses is easy to achieve if all the fuses in the system are Bussmann series Low-Peak fuses and the amp ratio between each pairing of lineside to loadside fuses is 2:1 or greater.

ATS UL 1008 Short-Circuit Current Ratings (withstand and closing ratings)

ATS rating (amps)	Current-limiting fuse			Specific circuit breaker*	Circuit breaker with instantaneous trip response		Circuit breaker with short-time delay response (no instantaneous)*** SCCR @ 480 V (kA RMS Sym.)		
	SCCR @ 480 V (kA RMS Sym.)	Max. fuse rating (amps)	UL fuse class	SCCR @ 480 V (kA RMS Sym.)	Max. Time** (mSec.)	SCCR @ 480 V (kA RMS Sym.)	0.2 mSec max. time	0.3 mSec max. time	0.5 mSec max. time
30	200	200	J	22	0.025	10	—	—	—
70, 100	200	200	J	25	0.025	10	—	—	—
150, 200, 260, 400	200	600	J	50	0.05	42	7.5	—	—
		800	L						
260, 400, 600	200	600	J	50	0.05	42	7.5	—	—
		800	L						
800, 1000, 1200	200	1600	L	65	0.05	50	36	36	—
1600, 2000	200	3000	L	100	0.05	100	42	42	36
	Relates to 4 below			Relates to 1 below	Related to 2 below		Relates to 3 below		

* Specific circuit breaker: with this option the ATS manufacturer will provide a list of specific circuit breakers by manufacturer and type.

** This option requires a circuit breaker with an instantaneous trip which interrupts the fault current within the maximum time specified in this column.

*** This option is for circuit breakers which have a short-time delay and not an instantaneous trip. The short-time delay setting must interrupt the fault current within the time duration selected.

Table 7.18.2.c This table and notes provide an example of the information ATS manufacturers provide as a starting point for specifying overcurrent protection for their automatic transfer switches. Fuses provide SCCR protection typically up to fault currents of 200 kA at 600 V. ATS SCCR based on circuit breakers, on the other hand, typically result in lower SCCR, vary by the system voltage, and may have exceptions for certain ATS options.

Table 7.18.2.c is an example of an SCCR (WCR) table for all amp ratings of one manufacturer's specific ATS series. This is useful information during the specification/procurement process. When interpreting an actual manufacturer's WCR tables and equipment labels, be sure to read all pertinent footnotes and referenced materials.

1. Specific manufacturer's circuit breaker and type: The circuit breaker manufacturer, type (model number) and amp rating has to be explicitly stated, e.g., Eaton, CLD, 600 A (see Figure 7.18.2.b for sample label).

ATS manufacturers typically provide many specific circuit breaker choices that have been tested and listed for a particular transfer switch. ATS manufacturers provide documentation for these acceptable "specific breakers." To view the specific tested and accepted breakers list, it's necessary to contact the ATS manufacturer.

Certain issues may arise when specific breaker combinations are used. Specific breaker ratings are usually a hindrance on bid day, because in most circumstances, the vendor providing the circuit breaker and the transfer switch are not the same. This places extra responsibility on the contractor and consulting engineer to make sure the ATS/circuit breaker pair is a tested and listed combination. During an inspection, specific breaker combinations are often highly scrutinized by the authority having jurisdiction (AHJ). Although a specific breaker may be properly short-circuit combination rated with the transfer switch for the initial installation, it is likely that over the systems life, the circuit breaker may need to be replaced. The person tasked with finding a replacement circuit breaker may not fully understand the importance of the relationship between the circuit breaker and the ATS it is protecting. If a new circuit breaker is installed that differs in type and/or rating, it may not be listed to protect the transfer switch, and could be a potential safety hazard.

2. Short-circuit current withstand and closing with a circuit breaker:

A circuit breaker can be used if it has an instantaneous trip with a maximum clearing time equal to or less than the ATS marked time duration. This includes a circuit breaker that has a short-time delay in addition to an instantaneous trip or instantaneous override.

An ATS that passes this test is able to withstand a fault of a given magnitude for a specified time duration such as 0.05 seconds (3 cycles) and not exceed certain damage criteria.

The purpose of the test is to allow a transfer switch to be used with any manufacturer's circuit breaker that incorporates an "instantaneous trip" when the transfer switch and circuit breaker are applied within their ratings. This allows an engineer more flexibility when specifying circuit breaker protection for a transfer switch.

This option does not have many of the procurement, installation, or replacement issues incurred when using the specific breaker option (1). Until recently this rating was referred to as the "any breaker" rating, the test was only for a 0.05 second duration and was considered the best practice solution when using circuit breakers for ATS protection. This however has changed recently with the advancement and growing understanding of selective coordination; see circuit breaker option (3), which follows.

3. Short-time current ratings with a circuit breaker: Any circuit breaker with a short-time delay (no instantaneous trip) can be used if the circuit breaker short-time delay setting is equal to or less than the ATS marked time duration. Be sure to adhere to the circuit breaker voltage and withstand rating limitations for short-time delay.

Designers desiring selective coordination with circuit breakers often use circuit breakers with short time delay tripping (CB without instantaneous trip) in vital systems. Circuit breakers with short-time delay and no instantaneous trip increase the time that an ATS must withstand a short-circuit current. The circuit breaker short-time delay must be set to trip within the time duration on the ATS label for this SCCR option.

The short time test subjects an ATS to a given fault current for up to 30 cycles, for which the ATS cannot sustain extensive damage and must be operable afterwards. The options available for transfer switches with short time ratings are limited and also usually carry a much higher price tag when compared to similar standard ATSs of the same amp size.

4. Short-circuit current withstand and closing with fuses: A fuse in a specific UL Class can be used when not exceeding the maximum amp rating shown in the marking. Be sure to adhere to the fuse voltage rating limitations. It's common that the fuse interrupting ratings will be equal to or greater than the marked ATS SCCR.

The current-limiting ability of fuses limits the let-through current and thereby reduces the damaging energy during a fault. This ensures the ATS will be protected even when exposed to very high fault levels. See Fuseology in Section 3 for a better understanding of how a fuse operates and is able to limit fault current. Along with providing far superior protection, fuses are simple to apply. The combination tested fuse class and maximum amp rating is given by ATS manufacturers along with the WCR protection level. ATS with fuse protection usually results in a 200 kA at 600 V WCR. In addition, selective coordination with lineside or loadside fuses is simple if the proper fuses are specified and applied in accordance with published selective coordination amp ratios.

7.18.3 Specifying proper ATS protection

It's fast and easy to specify fuse protection and achieve high ATS SCCR (WCR) for voltages of 600 V or less. In most cases, regardless of manufacturer, ATSs will have a 200 kA WCR with current-limiting fuses. This simplicity is far different than the process involved with choosing the right circuit breaker for protection. Compare Tables 1 and 2 which outline some ATS characteristics that must be evaluated to adequately specify fuse or circuit breaker protection for ATS WCR. When choosing circuit breaker protection, an ATS WCR varies considerably based on the circuit breaker type used and the ATSs characteristics; these considerations have an impact on the design as well as the installation. When using fuse protection, the specifier, installer or facility owner does not have to be concerned with the maximum available short-circuit current specifics during the design/install process, or whether the fault current may increase during the system life time, (because very few systems have available short-circuit currents above 200 kA).

What determines an ATS WCR when protected by fuses:

- Only the switch amp rating and the UL fuse class/max. amp rating
- For some systems, selective coordination is required and in most cases is easy to achieve with Bussmann series Low-Peak Fuses by simply maintaining a 2:1 amp ratio between lineside and loadside fuses.

What determines an ATS WCR when protected by a circuit breaker:

- ATS Manufacturer (ASCO, Russel, Zenith, Cummins, CAT/Eaton, Kohler, etc.)
- ATS Series (e.g., 300, 4000, 7000)
- Voltage (240, 480, 600)
- Frame size (amp rating)
- Bypass/non-bypass switch
- Number of poles (2, 3, 4)
- Neutral type (solid, switched, overlapping)
- Connection type (front/rear connect, mechanical/compression lugs)
- Circuit breaker type to be used: specific manufacturer, circuit breaker with instantaneous trip, or circuit breaker with a short-time delay (and for how long) without instantaneous trip
- Selective coordination for some systems

As seen in the ATS WCR list when protected by a circuit breaker, there are many factors that define the circuit breaker's protection level. Following the ATS manufacturer's WCR chart, (similar to Figure 7.18.2.c) a specifier or installer cannot be assured that in all applications a circuit breaker will provide adequate protection. Common configurations such as using a 4-pole overlapping neutral will result in a lower ATS WCR rating in certain cases. For one major ATS manufacturer, an ATS from 260 to 600 A has a 42 kA, 3-cycle WCR rating at 480 V, when protected by any circuit breaker. However, if a 260 to 600 A ATS with a 4-pole overlapping neutral is used, the rating would only be 35 kA for these switches when protected by any circuit breaker. These same ATSs protected by appropriate fuses have a WCR of 200 kA at 600 V.

Another commonly overlooked design concern is the connection type chosen for the ATS. Certain ATSs have optional front, rear or side connect versions to help accommodate sizing concerns, and aid in installation. For instance, an ATS when designed as a rear connect switch is rated for 65 kA WCR with a circuit breaker having an instantaneous trip that clears in 0.05 second, but may only have a 50 kA WCR if the front connect version is chosen with this style circuit breaker. Similarly when protected by a circuit breaker, the WCR for an ATS may vary with the specified cable connection type. While in most cases the standard connection type for ATS installation is mechanical screw type lugs, many projects request compression lugs. This will, in most cases, also adversely affect the WCR given to an ATS when protected by a circuit breaker. If these ATSs are protected by fuses, these ATS characteristics are a non-issue and the WCR is typically 200 kA.

7.18.4 Practical examples

Example 1, cost factor

Along with the superior current-limiting protection and simplicity provided by fuses, there is, in most cases, a substantial cost savings. The following pricing example has been taken from an actual transfer switch quote, and is a common occurrence across ATS manufacturers. The manufacturer name and part numbers have been omitted.

Requirement

A consulting engineer needs to specify the following for a hospital patient wing addition:

- Circuit breakers will be used upstream to protect the ATSs
- Five (5) automatic transfer bypass isolation switches, 600 A, 480 V, 4-pole switched neutral
- NEMA 1 enclosure

Initial ATS cost estimate

- From ATS manufacturer:
- The estimated cost per switch: \$15,000.00
- Cost for five (5) switches: \$75,000.00
- Footprint dimensions per switch: 34"W x 28"D (height not considered)

ATS cost modified due to fault current

When the fault current is calculated, it's determined there is 58 kA available short-circuit current at the ATS. The designer concludes that these transfer switches will require a WCR of 65 kA at 480 V. This assumes an instantaneous trip circuit breakers that interrupts fault current in 0.05 seconds or less will be used.

After reviewing the WCR chart provided by the ATS manufacturer, similar to Figure 7.18.2.c, the engineer discovers the transfer switch quoted above is only rated to withstand 42 kA for 0.05 seconds (3-cycles). In order to assure the ATS can withstand a fault current this high, it's necessary to move up to the next ATS frame size, and purchase an ATS with adequate WCR. The next frame size offered by this ATS manufacturer is their 800 to 1200 A ATS. The engineer must reference the WCR chart to determine that this size switch is only rated for 50 kA for 0.05 seconds. This will require the move up to an even larger ATS. The next ATS frame size manufactured is 1600-2000 A. After reviewing the WCR chart, the consulting engineer sees these switches can withstand faults of 100 kA, depending on the required ATS characteristics. Either way, this switch will be able to withstand the available 58 kA and meet the 65 kA 0.05 second requirement. The consulting engineer then refigures the price.

Requoting ATS cost estimate

From ATS manufacturer:

- The new cost per switch: \$35,000.00
- Cost for five (5) switches: \$175,000.00
- Footprint dimensions per switch: 38"W x 60"D

Additional cost =

\$20,000 per ATS multiply by 5 = \$100,000.00 to owner

- Additional floor space required = 20"W x 160"D in electrical room

This is a very common example and it may or may not be made clear during a bid or submittal review that these changes occurred, but the added costs are real. These additional costs are, in most cases, figured in by the ATS manufacturer during the initial bid and never questioned. There can be a substantial price premium incurred when using circuit breakers and the system has higher available short-circuit currents. The larger ATSs will also take up more floor space in an already crowded electrical room.

ATS cost with fuse protection

This situation could have been avoided by using fuses. If current-limiting fuses are specified upstream of the ATS, the energy let-through during a fault will be far below the ATS's withstand threshold, allowing the original 600 A (\$15,000) transfer switches to be protected from any fault up to 200 kA for 600 V or less. With fuse protection, the original ATS cost estimate would be applicable. This in turn would have saved the end user over \$100,000, and conserved floor space in the process.

Example 2, practical implications

The following demonstrates issues that may arise after initial design. A consulting engineer specifies an ATS protected by circuit breakers. The engineer calculates the available fault current as designed at the ATS to be 48 kA and labels the drawings accordingly. After reviewing the drawings, the contractor purchases an ATS with a 50 kA WCR. When installing the conduit and pulling the cables, the contractor finds a shorter path than originally planned to run the cabling to the ATS, and is able to save on conductor material and installation costs. The

ATS is manufactured, shipped and installed at the job site. When the "as installed" short-circuit and coordination study is conducted, it's determined the available fault current at the ATS is now 52 kA (ATS is only rated to withstand a 50 kA fault with circuit breaker protection).

An inspector will not approve an ATS that is not rated for use with the maximum available fault current. There are also liability concerns for all involved if an ATS is installed in this manner. If the contractor requests to return and purchase a properly rated ATS from the manufacturer, there will be a change order and extra costs involved. This example is common across the industry. The solution to this dilemma by some is to add cable length (run the cabling down a hallway and back again) to reduce the available fault current to what was originally expected. This is not a good practice when, in most cases, current-limiting fuses can provide a simple, no worry solution for transfer switches with available fault current up to 200 kA.

7.19 Transformers

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7.19.1 Transformers — 1000 V or less

The requirements of NEC 450.3 cover only transformer protection. In practice, other components must be considered in applying circuit overcurrent protection. For circuits with transformers, requirements for conductor protection per Articles 240 and 310, and for panelboards per Article 408, must be observed. Refer to 240.4(F), 240.21(B)(3), 240.21(C), 408.36(B).

Primary fuse protection only [450.3(B)]

If secondary fuse protection is not provided (as covered in 7.19.2) then the primary fuses must not be sized larger than as shown below (see Figure 7.19.a).

Individual transformer primary fuses are not necessary where the primary circuit fuse provides this protection.

Primary fuse only

Primary current	Primary fuse rating
9 amps or more	125% or next higher standard rating if 125% does not correspond to a standard fuse size.
2 amps to 9 amps	167% maximum
Less than 2 amps	300% maximum

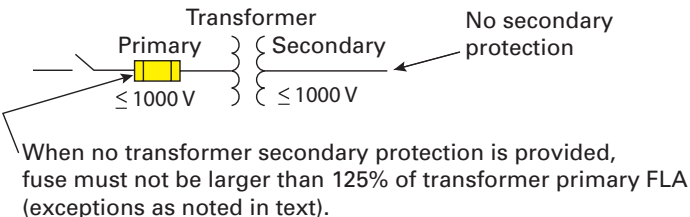


Figure 7.19.a

Note: Section 450.3 requirements pertain only to transformer protection. Additional circuit overcurrent protection for conductors or panelboards may be required per Articles 240, 310, 408, 430.72.

* Primary fuse (600 V or less) and secondary fuse (600 V or less). If secondary (600 V or less) fuses are sized not greater than 125% of transformer secondary current, individual transformer fuses are not required in the primary (600 V or less) provided the primary feeder fuses are not greater than 250% of the transformer rated primary current. (See Note 3 of Table 450.3(B) for overcurrent protection requirements of thermally protected transformers).

Primary and secondary fuses

Secondary current	Primary fuse rating	Secondary fuse rating
9 amps or more	250% max.	125% or next higher standard rating if 125% does not correspond to a standard fuse size
Less than 9 amps	250% max.	167% max.

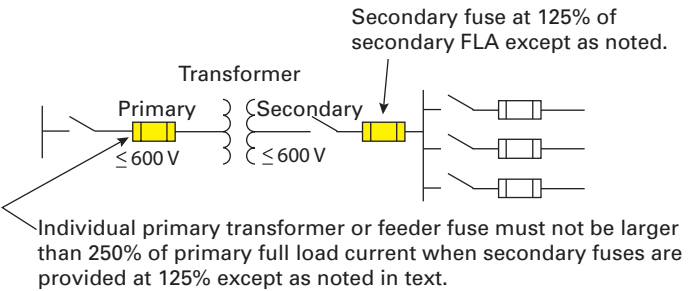


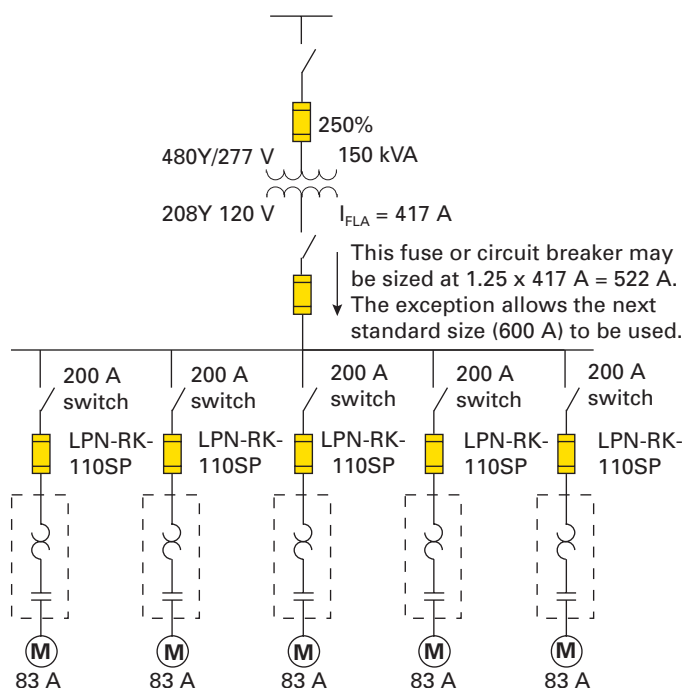
Figure 7.19.b

Note: Transformer overload protection will be sacrificed by using OCPDs sized much greater than the transformer full load amps (FLA). The 150%, 167%, 250% and 300% limits may not adequately protect transformers. It is suggested that for the optimum transformer overload protection, the fuse size should be within 125% of the transformer's FLA.

Normal magnetizing inrush currents for power transformers can range from 10 to 12 times the transformer full load current, for up to 6 cycles, and as high as 25 times transformer full load current at 0.01 seconds. Some transformers may have inrush magnitudes substantially greater. Severe inrush should be compared with fuse melting times to assure that unnecessary OCPD opening does not occur.

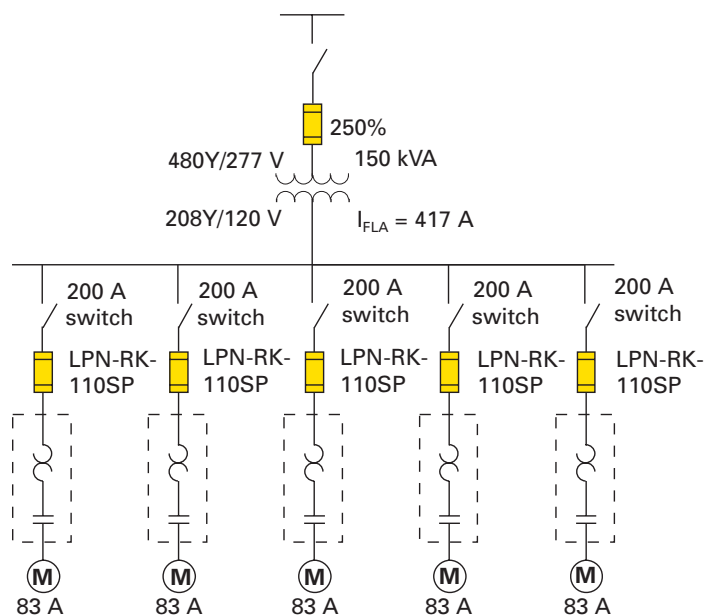
To properly protect transformers, there is a wide range of fuse amp ratings available. Fusetron Class RK5 and Low-Peak Class RK1 dual-element time-delay fuses can be sized on the transformer primary and/or secondary rated at 125% of the transformer FLA. These dual-element fuses have sufficient time-delay to withstand the transformers' high magnetizing inrush currents. These dual-element fuses also have wide amp rating range up to 15 A for protecting small control transformers.

The required secondary protection may be satisfied with multiple OCPDs that protect feeders fed from the transformer secondary. The total of these multiple OCPD amp ratings may not exceed the allowed value of a single secondary OCPD. If this method is chosen, dual-element, time-delay fuse protection offers much greater flexibility. Note design examples 1, 2, 3 and 4.



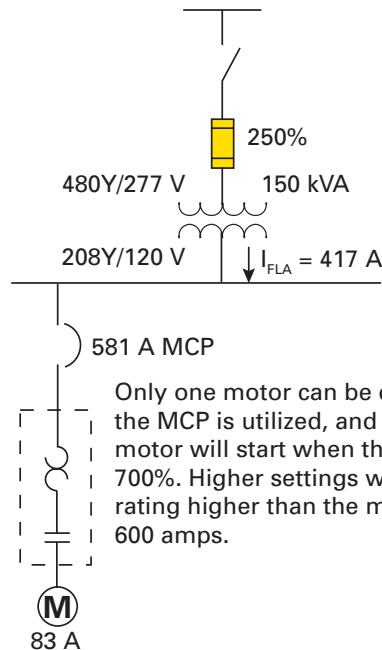
Design 1 Single secondary device

This design utilizes a single secondary OCPD. It provides the greatest degree of selective coordination, transformer protection, secondary cable protection and switchboard/panelboard/load center protection. The transformer cannot be overloaded to a significant degree if future loads are improperly added. With this arrangement the transformer's full capacity is available for use.



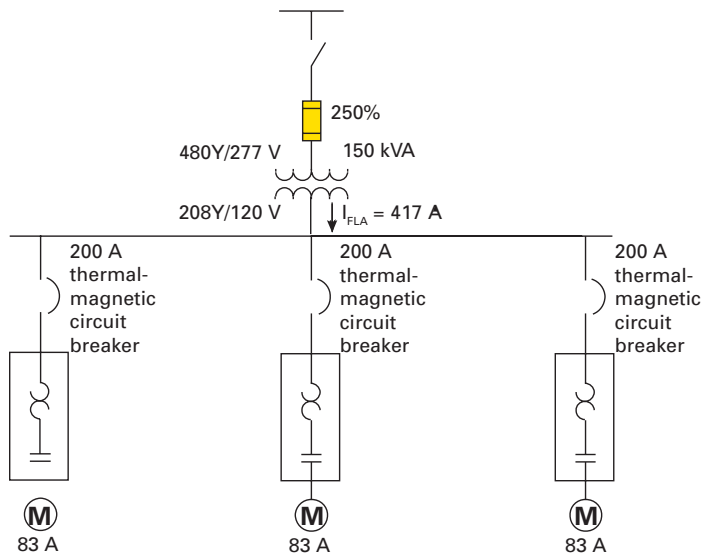
Design 2 No single secondary device

In this design, the single secondary OCPD is eliminated with much of the protection described in Design 1 reduced. If dual-element fuses are utilized as branch circuit protection, the transformer can continue to be loaded with the five 83 A motors because $5 \times 110 = 550$ A, (less than the maximum 600 A). If additional loads are improperly added, overload protection will be lost because the primary device can be sized at 250%.



Design 3 No single secondary device

For this design, the single secondary OCPD is eliminated and MCPs are utilized for branch circuit protection with the result that the transformer will be seriously under-utilized because only one motor can be connected. For one motor, $1 \times 700\%$ of 83 A = 581 A. For two motors, $2 \times 700\%$ of 83 A = 1162 A. Since the sum of the devices cannot exceed 600 A, only one motor can be connected when the motor circuit is protected by an MCP.



Design 4 No single secondary device

Here, using the same procedure, if the single secondary main OCPD is eliminated and thermal magnetic circuit breakers are utilized for branch circuit protection per 430.52, only three motors can be connected because the thermal magnetic breakers will have been sized at approximately 250% of the motor's FLA ($83 \text{ A} \times 250\% = 207.5 \text{ A}$.)

Note: If the thermal magnetic breakers are sized less than permitted by 430.52, nuisance tripping may result since the new energy efficient motors have higher inrush currents.

Using a 200 A circuit breaker would allow only three ($600 \div 200$) motors to be connected. Adding two motors of the same type as shown in Design 1 and Design 2 requires a larger transformer - one that would have a 1000 A or more secondary capability. A 300 kVA 208 V transformer has a 830 A secondary rating which is not sufficient. Therefore, the next standard size 3 Ø transformer is a 400 kVA with a 1110 A capacity to meet the rule.

7.19.2 Transformers — over 1000 V

Primary and secondary protection

In unsupervised locations (see Figure 7.19.c), with primary voltage over 1000 V, the primary fuse can be sized at a maximum of 300%. If the secondary is also over 1000 V, the secondary fuses can be sized at a maximum of 250% for transformers with impedances not greater than 6% or 225% for transformers with impedances greater than 6%, and not more than 10%. If the secondary is 1000 V or less, the secondary fuses can be sized at a maximum of 125%. Where these ratings do not correspond to a standard fuse size, the next higher standard size is permitted.

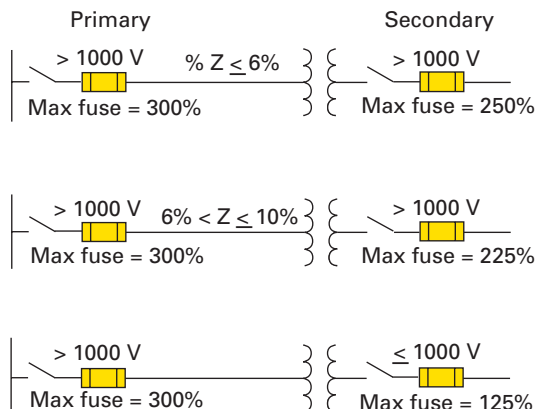


Figure 7.19.c Unsupervised locations.

In supervised locations (see Figure 7.19.d), the maximum ratings are as shown in the next diagram. These are the same maximum settings as the unsupervised locations except for 1000 V or less secondary voltages, where the secondary fuses can be sized at maximum of 250%.

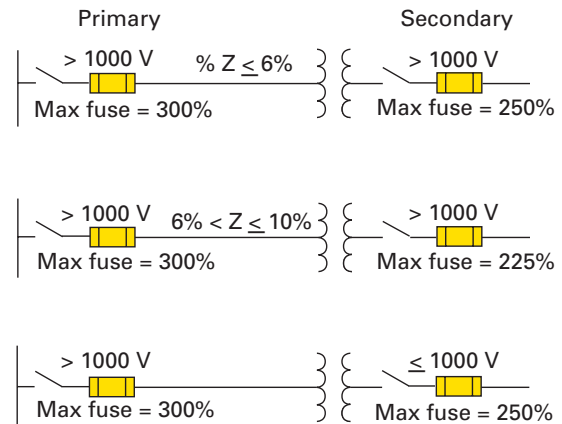


Figure 7.19.d Supervised locations

Primary protection only

In supervised locations, the primary fuses can be sized at a maximum of 250%, or the next larger standard size if 250% does not correspond to a standard fuse size.

Note: The use of “primary protection only” does not remove the requirements for compliance with Articles 240 and 408. See (FPN) in Section 450.3, which references 240.4, 240.21, 240.100 and 240.101 for proper secondary conductor protection.

7.19.3 E-Rated fuses for medium voltage potential and small power transformers

Low amperage, E-Rated medium voltage fuses are general purpose current-limiting fuses. A general purpose current-limiting fuse is capable of interrupting all current from the rated interrupting current down to the current that causes the fusible element to melt in 1 hour (ANSI C37.40). The “E” rating defines the fuse’s melting time-current characteristic and permits electrical interchangeability between fuses with the same E-Rating. For a general purpose fuse to have an E-Rating the following condition must be met:

The current responsive element must melt in 300 seconds at an RMS current within the range of 200% to 240% of the fuse’s continuous current rating, fuse refill or link (ANSI C37.46).

Bussmann series low amperage, E-Rated fuses are designed to provide primary protection for potential, small service and control transformers. These fuses offer a high level of fault current interruption in a self-contained, non-venting package which can be mounted indoors or in an enclosure.

Application

As for all current-limiting fuses, the basic application rules found in this publication’s Fuseology section should be observed. In addition, potential transformer fuses must have sufficient inrush capacity to successfully pass through the transformer’s magnetizing inrush current. If the fuse isn’t properly sized, it will open before the load is energized. The maximum magnetizing inrush current to the transformer at system voltage and its duration varies with the transformer’s design. Magnetizing inrush currents are usually denoted as a percentage of the transformer full load current, e.g., 10x, 12x, 15x, etc. The inrush current duration is usually given in seconds. Where this information is available, a check can easily be made on the appropriate Bussmann series minimum melting curve to verify proper fuse selection. In lieu of transformer inrush data, the rule of thumb is to select a fuse rated at 300% of the primary full load current and round up to the next larger standard rating.

Example:

The transformer manufacturer states that an 800 VA 2400 V, single-phase potential transformer has a 12x magnetizing inrush current lasting for 0.1 second.

$$A. I_{FL} = 800 \text{ VA} \div 2400 \text{ V} = 0.333 \text{ A}$$

$$\text{Inrush current} = 12 \times 0.333 = 4 \text{ A}$$

Since the voltage is 2400 V, we can use either a JCW-1E or JCD-1E.

B. Using the rule of thumb — 300% of 0.333 A is 0.999 A.

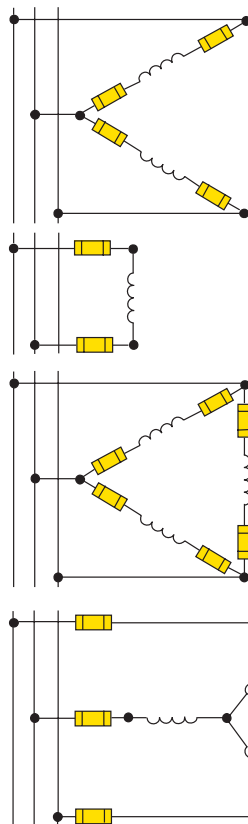
Therefore we would choose a JCW-1E or JCD-1E.

Typical potential transformer connections

The typical potential transformer connections encountered in industry can be grouped into two categories, as shown in Figure 7.19.e.

Category 1

Connections that require the fuse to pass only the magnetizing inrush of one potential transformer



Category 2

Connections that must pass the magnetizing inrush of more than one potential transformer

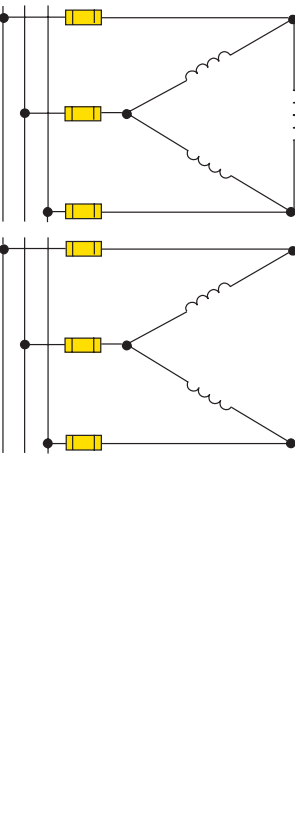


Figure 7.19.e E-Rated fuses for medium voltage transformers and feeders

Bussmann series E-Rated medium voltage fuses are general purpose current-limiting fuses. A general purpose current-limiting fuse is capable of interrupting all currents from the rated interrupted current down to the current that causes the fusible element to melt in 1 hour (ANSI C37.40). The fuses carry either an “E” or an “X” rating that defines the fuse’s melting time-current characteristic. The ratings are used to allow electrical interchangeability among fuses from different manufacturers.

For a general purpose fuse to have an “E” rating, the following conditions must be met:

1. 100E and below - the fuse element must melt in 300 seconds at 200% to 240% of its rating (ANSI C37.46).
2. Above 100E - the fuse element must melt in 600 seconds at 220% to 264% of its rating (ANSI C37.46).



Figure 7.19.f Bussmann series E-Rated medium voltage fuse.

A fuse with an “X” rating does not conform with the electrical interchangeability for an “E” rated fuse, but may offer the user other ratings that provide better protection for a particular application.

Application

The most popular application for E-Rated fuses is transformer protection. The fuse is applied to the transformer’s primary and used solely to prevent the transformer from rupturing due to short-circuits. It is important, therefore, to size the fuse so that it does not open on system inrush or permissible overload currents.

See section on transformers over 600 V for sizing recommendations. Magnetizing inrush must also be considered when sizing a fuse. In general, power transformers have a 12x magnetizing inrush current of the full load rating for a duration of 1/10 second.

Transformer kVA	System voltage		
	2.4 kV/fuse FLA	4.16 kV/fuse FLA	4.8 kV/fuse FLA
Three-phase transformers/transformer bank			
9	2.17 JCX-7E	1.25 JCY-5E	1.08 JCY-5E
15	3.6 JCX-10E	2.08 JCY-7E	1.8 JCY-7E
30	7.3 JCX-20E	4.2 JCY-15E	3.6 JCY-10E
45	10.8 JCX-25E	6.2 JCY-15E	5.4 JCY-15E
75	18.0 JCX-40E	10.4 JCY-25E	9.0 JCY-20E
112.5	27.0 JCX-65E	15.6 JCY-40E	13.5 JCY-30E
150	36.0 JCX-65E	20.8 JCY-40E	18.0 JCY-40E
225	54.0 JCX-100E	31.2 JCY-65E	27.0 JCY-65E
300	72.0 JCX-125E	41.6 JCY-80E	36.0 JCY-65E
500	120.0 JCX-200E	69.4 JCY-125E	60.0 JCY-100E
750	— —	104.0 JCY-150E	90.0 JCY-125E
1000	— —	139.0 JCY-200E	120.0 JCY-200E
Single-phase transformers			
3	1.25 JCX-5E	0.72 JCY-3E	0.63 JCY-3E
5	2.08 JCX-7E	1.20 JCY-5E	1.04 JCY-5E
10	4.17 JCX-15E	2.40 JCY-7E	2.08 JCY-7E
15	6.25 JCX-15E	3.61 JCY-10E	3.13 JCY-10E
25	10.4 JCX-25E	6.01 JCY-15E	5.21 JCY-15E
37.5	15.6 JCX-40E	9.01 JCY-20E	7.81 JCY-20E
50	20.8 JCX-40E	12.0 JCY-25E	10.4 JCY-25E
75	31.3 JCX-65E	18.0 JCY-40E	15.6 JCY-30E
100	41.7 JCX-80E	24.0 JCY-80E	20.8 JCY-40E
167	70.0 JCX-100E	40.0 JCY-100E	35.0 JCY-65E
250	104.0 JCX-150E	60.0 JCY-125E	52.0 JCY-100E
333	139.0 JCX-200E	80.0 JCY-125E	69.5 JCY-100E
500	— —	120.0 JCY-200E	104.0 JCY-150E
667	— —	— —	139.0 JCY-200E



7.19.4 Fuse sizing guides

Transformers 600 V nominal or less (NEC 450.3)

Protection type	Thermal overload protection	Transformer impedance	Rated current	Optimum protection*	NEC maximums	Fuse/volt recommendation
Primary only (Note: components on the secondary still need overcurrent protection)	—	—	Primary < 2 amps	125% or next size larger	300% or next size smaller (see NEC 430.72(C) for control circuit transformer maximum of 500%)	Up to 250 V: LPN-RK-SP, FRN-R Up to 600 V: KRP-C-SP, LPJ-SP, LPS-RK-SP, FNQ-R, FRS-R, TCF
			Primary ≥ 2 amps but < 9 amps	125% or next size larger	167% or next size smaller	
			Primary ≥ 9 amps	125% or next size larger	125% or next size larger**	
Primary and secondary	Without	—	Secondary < 9 amps (see A)	Primary and secondary fuses at 125% of primary and secondary FLA or next size larger	% of primary FLA (or next FLA size smaller) A = 250% B = 250% C = 600% D = 600% E = 400% F = 400%	
			Secondary ≥ 9 amps (see B)		% of secondary FLA A = 167% or next size smaller B = 125% or next size larger** C = 167% or next size smaller D = 125% or next size larger** E = 167% or next size smaller F = 125% or next size larger**	
	With	≤ 6%	Secondary < 9 amps (see C)			
			Secondary ≥ 9 amps (see D)			
		> 6% but < 10%	Secondary < 9 amps (see E)			
			Secondary ≥ 9 amps (see F)			

* When sizing the primary fuse for optimum protection, verify the inrush current with the transformer manufacturer and review fuse time-current characteristics.

**When 125% of FLA corresponds to a standard rating, the next larger size is not permitted.



Transformers over 600 V nominal (NEC 450.3)

Supervised installations

Protection for	Transformer impedance	Primary Sizing	Secondary volts	Secondary sizing	Fuse/volt recommendation
Primary only	N/A	Code maximum of 250% or next standard size if 250% does not correspond to a standard rating Note: Components on the secondary still need overcurrent protection	N/A	N/A	Up to 250 V: LPN-RK-SP, FRN-R Up to 600 V: LPS-RK-SP, LPJ-SP, KRP-C-SP, FRS-R, FNQ-R, TCF Up to 2.475 kV: 2NCLPT, 2CLPT Up to 2.75 kV: 2CLE, 2HLE
Primary and secondary	≤ 6%	At code maximum of 300%	> 600 V	At code maximum of 250%	Up to 2750/5500 V: JCW
			≤ 600 V	At code maximum of 250%	Up to 5.5 kV: 5HLE, 5CLE, 5HCL, 5BHCL, 5BHLE, 5AHLE, JCY, MV05, 5.5 ABWNA, 5.5 AMWNA, 5.5 FFN
	> 6% but < 10%	At code maximum of 300%	> 600 V	At code maximum of 225%	7 Up to 7.2 kV: 2 AMWNA, 7.2 TDLSJ, 7.2 TFLSJ
			≤ 600 V	At code maximum of 250%	Up to 8.3 kV: 8HLE, 8CLE, 8BHLE, 8AHLE, 8CLPT, 8NCLPT, 8HCL, 8.25 FFN Up to 15.5 kV: 15CLPT, 15NCLPT, 15CLE, 15HLE, 15BHLE, 15LHLE, 15HCL, 15BHCL, MV155, 15.5 CAVH Up to 17.5 kV: 17.5 CAV, 17.5 TDM Up to 24 kV: 24 TDM, 24 TFM, 24 FFM Up to 36 kV: 36 CAV, 36 TDQ, 36 TFQ Up to 38 kV: 38CLPT, 38 CAV

Unsupervised installations

Transformer impedance	Primary Sizing	Secondary volts	Secondary sizing	Fuse/volts recommendation
≤ 6%	At code maximum of 300% or next standard size if 300% does not correspond to a standard rating	> 600 V	At code maximum of 250% or next standard size if 250% does not correspond to a standard rating	Up to 250 V: LPN-RK-SP, FRN-R Up to 600 V: LPS-RK-SP, LPJ-SP, KRP-C-SP, FRS-R, FNQ-R, TCF
		≤ 600 V	At code maximum of 125% or next standard size if 125% does not correspond to a standard rating	Up to 2475 V: 2NCLPT, 2CLPT Up to 2.75 kV: 2CLE, 2HLE Up to 2750/5500 V: JCW
> 6% but < 10%	At code maximum of 300% or next standard size if 300% does not correspond to a standard rating	> 600 V	At code maximum of 225% or next standard size if 225% does not correspond to a standard rating	Up to 5.5 kV: 5HLE, 5CLE, 5HCL, 5BHCL, 5BHLE, 5AHLE, JCY, MV05, 5.5 ABWNA, 5.5 AMWNA, 5.5 FFN Up to 7.2 kV: 7.2 AMWNA, 7.2 TDLSJ, 7.2 TFLSJ
		≤ 600 V	At code maximum of 125% or next standard size if 125% does not correspond to a standard rating	Up to 8.3 kV: 8HLE, 8CLE, 8BHLE, 8AHLE, 8CLPT, 8NCLPT, 8HCL, 8.25 FFN Up to 15.5 kV: 15CLPT, 15NCLPT, 15CLE, 15HLE, 15BHLE, 15LHLE, 15HCL, 15BHCL, MV155, 15.5 CAVH Up to 17.5 kV: 17.5 CAV, 17.5 TDM Up to 24 kV: 24 TDM, 24 TFM, 24 FFM Up to 36 kV: 36 CAV, 36 TDQ, 36 TFQ Up to 38 kV: 38CLPT, 38 CAV

7.20 Uninterruptible Power Supply (UPS)

As an important design criterion of making power system reliable, the QSCP panelboard and fast-acting CUBEFuse are employed to protect the loadside of uninterruptable power supplies (UPS) commonly used in industries such as petrochemical or pharmaceutical, that have a need to maintain power to critical, sensitive loads.

These loads can include alarm and protection systems, sensors and monitors, distributed control systems (DCS) circuits and programmable logic controllers (PLC). These loads typically are fed via a UPS which presents unique design considerations with regard to overcurrent protection. These considerations include process load “holdup” times, UPS dropout, transfer switch operation and selective coordination.

Holdup time

Holdup times for DCS, PLC and critical instrumentation loads are typically 30 ms or less. These loads are also typically low amp circuits of 5 or less amps. See Figure 7.20.a.

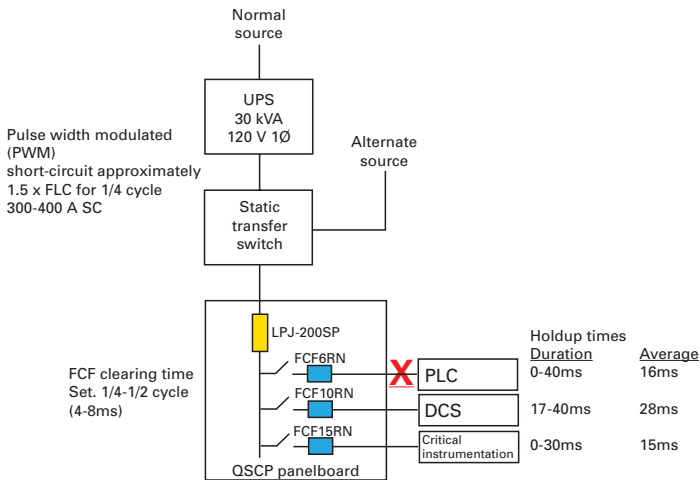


Figure 7.20.a

However, given the low fault current levels resulting from the UPS and/or a small conductor size, the overcurrent protective device (OCPD) operating time under fault conditions can exceed the critical load's holdup time.

Specifying OCPDs with fast fault clearing time characteristics and sizing them according to manufacturer's specifications is essential. The objective is to have the OCPD reliably clear fault conditions in times less than the critical loads' holdup time. In most cases, the non-time-delay (fast-acting) FCF CUBEFuse (blue label) can be sized small enough to ensure fault operating times within the critical devices' holdup time. The fast-acting CUBEFuses is available in the small amp ratings (1, 3, 6, 10 and 15 amps) that can provide this necessary protection.

UPS dropout and selective coordination

UPS dropout or damage occurs when a fault on one branch circuit powering critical loads is not cleared quickly enough so that it induces voltage drop on the UPS output. If the duration is long enough, the induced voltage dropout can result in damage to the UPS or, depending on the UPS type, cause some UPS systems to shut themselves down. When static transfer switches are used, the UPS dropout results in higher fault currents on critical branch circuits. If the branch circuit OCPDs do not selectively coordinate with panel feeder OCPDs, loss of all critical UPS loads can result. Figure 7.20.b shows a fuse panel that utilizes fuses that only require a minimum of 2:1 amp rating ratio to selectively coordinate.

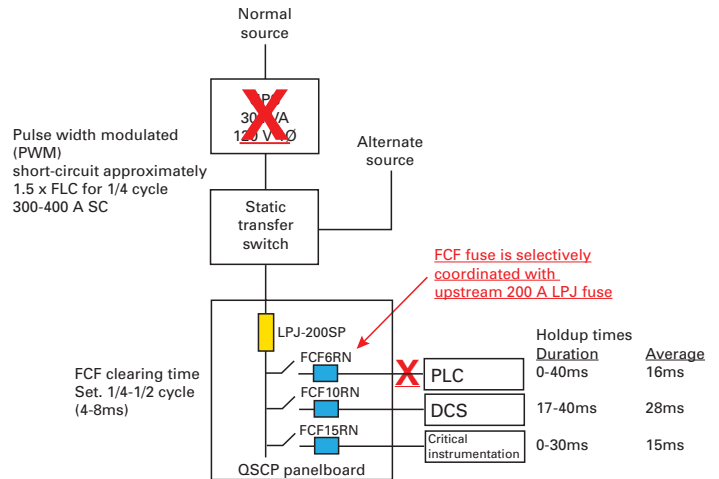


Figure 7.20.b



7.21 Variable frequency drive and power electronic device protection

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7.21.1 Overview

Variable frequency drives, soft starters, and other power electronic devices are increasingly more common in motor circuits. These devices are much more sensitive to the damaging effects of fault currents and therefore require a level of protection that may not be provided by circuit breakers or conventional fuses. Manufacturers of these devices have traditionally provided internal protection using high speed fuses, which are much more current-limiting than conventional branch circuit fuses. However, as drives and soft-starters have grown smaller and smaller, the internal fuses have been omitted by starter manufacturers in favor of short-circuit testing to UL standards with external protection.

Often, drives are shipped without fuses, and it's the installer's or owner's responsibility to provide this protection. During the design and installation stages, it's important to check the power electronic device's product data sheet, label or manual to understand the short-circuit protection options. With the proper fuse selection, a safer installation and better power electronic device protection may be realized. This can result in more productive operation and higher short-circuit current ratings.

7.21.2 Short-circuit testing

UL 508C, the standard to which drives and soft starters are listed, provides at least two levels of short-circuit protection. The Standard Fault Current test is mandatory to be listed, and there is an optional High Fault Current test which can be performed during the listing of the device.

UL also provides an "Outline of Investigation," UL 508E, which can be used to verify Type 2 (no damage) protection when protected by a specific current-limiting overcurrent protective device.

1. **The standard fault current test** evaluates the drive at rather low fault current levels and significant drive damage is permitted, i.e., the drive does not have function after the test. Fault current level examples 5000 A for 1.5 to 50 Hp drives and 10,000 A for 51 to 200 Hp drives.

The drive must be marked with the maximum short-circuit current rating (at which it was tested). It does not have to be marked with the type OCPD if it followed certain procedures. However, the manufacturer can list the drive with fuse protection only and then the label will be marked to identify that branch-circuit protection must be provided by fuses only (either high speed or branch circuit types).

2. **The high fault current test** can be at any level short-circuit current above the standard fault current test. Significant damage to the drive is permitted, i.e., the drive does not have function after the test.

The drive must be marked with the short-circuit current rating at which it was tested. In addition, it must be marked with the OCPD type(s) used for the test. If current-limiting branch circuit fuses (such as Class CC, CF, J, T, etc.) are used, then the test is conducted with special umbrella fuses. Umbrella fuses have energy let-through levels greater than the UL limits for various fuse classes and amp ratings, and energy let-through levels that are greater than commercially available fuses.

A drive can be listed and marked for either fuses or circuit breakers, or both. Typically, drives are marked for protection only by fuses since current-limitation is necessary to meet the requirements set forth in the product standard. If the unit is marked for fuse protection only, then only fuses of the proper type and size can be used. Some drives will be marked for protection by a specific amp and class fuse (for branch circuit fuses).

3. **Type 2 "No Damage" Protection** (no damage) is the best protection level. With Type 2 protection, the drive cannot be damaged and the unit is tested and marked with a high short-circuit current rating. It must be able to be put back into service after the fault has been repaired and the fuses replaced.

A clear understanding of semiconductor device types is needed when considering Type 2 protection (coordination) with variable speed drives. Only silicon controlled rectifier (SCR), gate turn-off thyristor (GTO) and diode-based devices can achieve Type 2 protection that's only possible with properly selected high speed fuses. Thyristor type devices can effectively share energy equally across the PN junction. They have short-circuit energy withstand levels that are lower than conventional branch circuit fuse let-throughs, but Type 2 protection can only be achieved with properly selected high-speed fuses.

Equipment that use insulated gate bipolar transistors (IGBTs), such as high frequency devices, cannot presently achieve Type 2 protection levels. IGBTs do not have enough surface area contact with the actual junction to help share energy evenly. While IGBTs share energy very well during long duration pulses, during short duration, high amplitude faults most of the energy is carried by an individual bonding wire or contact. For IGBT-based equipment, current fuse technology cannot effectively protect the bonding wires from overcurrent conditions making Type 2 No "Damage Protection" impossible to achieve. However, current high speed fuse technology can protect IGBTs from case rupture under short-circuit conditions.

7.21.3 Protecting drives and soft starters

There are two important considerations when selecting drive and soft starter protective devices:

1. The device must withstand the motor circuit's starting current and duty cycle without opening.
2. The device must clear a fault quickly enough to minimize damage.

The melting time-current characteristic curve can be used to verify a fuse's ability to withstand starting currents and duty cycle, while clearing I²t at the available fault current, and to verify the various protection levels described earlier. For more information on proper high speed fuse sizing, please see the High Speed Application Guide, publication no. 10507 available on Eaton.com/bussmannseries.

There are two fault types that can occur with drives and soft starters — internal and external. Internal faults are caused by component failures within the drive or soft starter, such as switching component failures (capacitors, SCRs, thyristors, IGBTs, etc.) External faults occur elsewhere in the circuit, such as a motor winding faulting to the grounded case.

Most soft starters utilize either silicon-controlled rectifiers (SCRs) or gate turn-off thyristors (GTOs) for power conversion. These devices depend on high speed fuses for protection from both internal and external faults. If high speed fuses are properly selected, Type 2 protection may be achieved.

Modern variable speed drives often utilize IGBTs as the main switching component. IGBTs have drastically lower energy withstands than SCRs and GTOs, and makes protecting these components very difficult. For external faults, drives using IGBTs incorporate electronic protection that shut the switching components off when fault currents are detected. However, over time, transient voltage surges can lead to the electronics' inability to shut the IGBT switching off which can lead to internal faults as the IGBTs fail and rupture. The IGBTs' violent rupture (expelling gases and shrapnel) can cause additional faults to adjacent components. High speed fuses may not be able to prevent an IGBT from failing, but properly selected high speed fuses can prevent its violent rupture, additional faults and posing a safety hazard.

Large variable speed drives often include internal high speed fusing to protect against components rupturing. However, small drives (below 200 Hp) do not often include internal fusing, so the user must supply the protection. With properly sized and applied high speed fuses, repair, replacement and lost productivity costs will be minimized.

7.21.4 Fuses for specific drives

Selection tables for various manufacturers' drives with Bussmann series fuse recommendations by specific drive model / catalog number are available on Eaton.com/bussmannseries.

7.21.5 Complying with the NEC

Traditional high speed fuses come in many different shapes and sizes, and can be recognized to UL and CSA standard 248-13 which does not contain requirements for overload performance or dimensions. Therefore, these fuses are not considered branch circuit protection per the NEC. However, Article 430, which covers motor circuits, does allow high speed fuses to be used in lieu of branch circuit protection when certain conditions are met.

Using high speed fuses (also referred to as semiconductor fuses) for protecting power electronic devices in lieu of normal branch circuit OCPDs is allowed per NEC 430.52(C)(5) (see Figure 7.21.5.a), which states that "Semiconductor fuses intended for the protection of electronic devices must be permitted in lieu of devices listed in Table 430.52 for power electronic devices, associated electromechanical devices (such as bypass contactors and isolation contactors), and conductors in a solid state motor controller system, provided that the marking for replacement fuses is provided adjacent to the fuses." Note this only allows using high speed fuses in lieu of branch circuit protection.

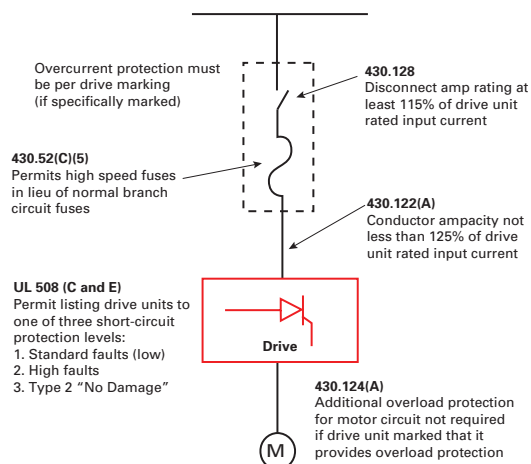


Figure 7.21.5.a Applicable UL and NEC sections.

Per NEC 430.124(A), if the variable speed drive is marked that it includes overload protection, additional overload protection is not required.

NEC 430.128 states that the disconnecting means for a variable speed drive system must have a rating not less than 115% of the rated input current on the drive. This means the disconnect required in front of each drive must be sized in accordance with the drive's rated input current, not the motor current. When connecting conductors between the disconnecting means and the drive, NEC 430.122(A) states that "Circuit conductors supplying power conversion equipment included as part of an adjustable speed drive system must have an ampacity not less than 125% of the rated input to the power conversion equipment." This means the conductors must be sized to the rated current on the conversion unit nameplate and not the motor rating.

7.21.6 Bussmann series DFJ (Class J) drive fuse

The Bussmann series DFJ drive fuse is a UL Listed, Class J, branch circuit fuse that provides high speed fuse performance for protecting semiconductor devices. Unlike traditional high speed fuses, the DFJ fuse is suitable for branch circuit protection (per the NEC) and fits in standard Class J fuseclips, holders and disconnects (see Figure 7.21.6.a).

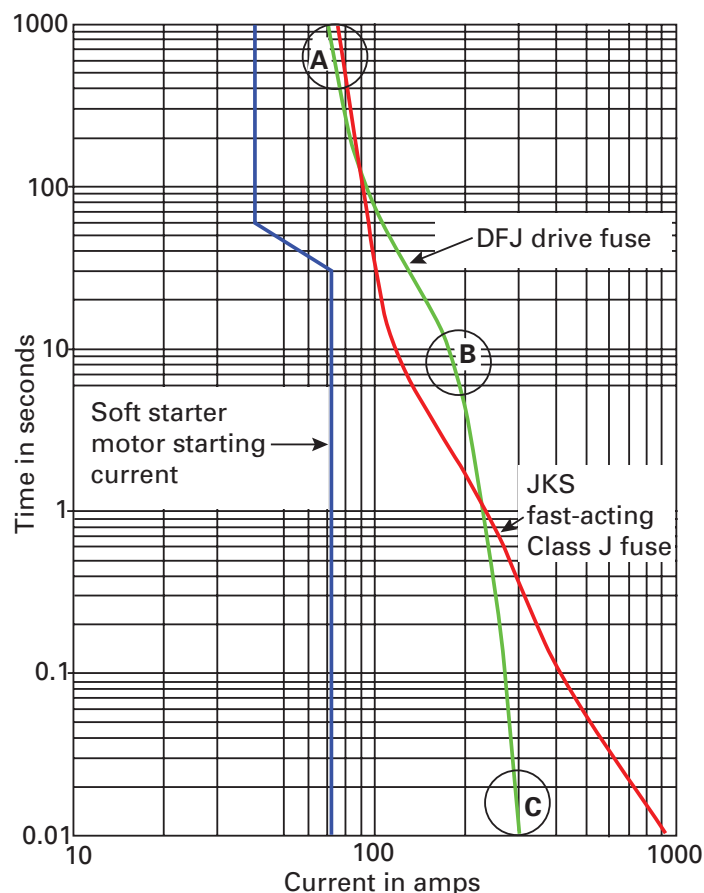


Figure 7.21.6.a Time-current characteristics comparisons show the DFJ's superior performance at three critical performance points.

Figure 7.21.6.a represents the typical AC drive's starting parameters as well as the melting characteristics of a traditional, non-time delay, Class J fuse and the DFJ fuse. There are three critical performance points shown:

A: Continuous region (amp rating) — The DFJ fuse's continuous current-carrying capacity is identical to the tradition Class J fuse. This meets UL branch circuit opening time requirements.

B: Overload region — Traditional, non-time delay Class J fuses have far less overload withstand than the DFJ fuse. This extended withstand allows for more reliable protection without nuisance openings.

C: Short-circuit region — The DFJ fuse has far lower required melting current and clearing I^2t than the traditional Class J fuse, allowing for greater current limitation and lower energy let-through (see Figure 7.21.6.b).

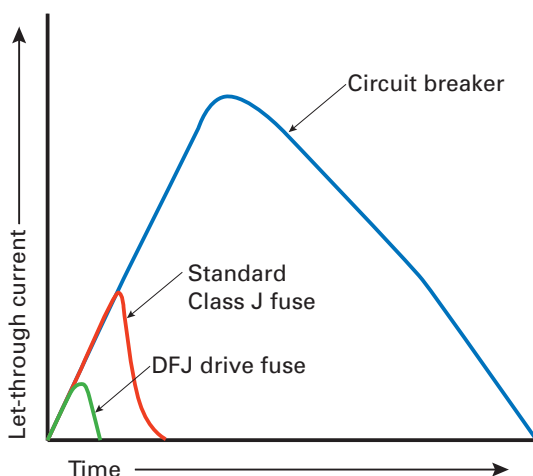


Figure 7.21.6.b The graph shown above represents the energy let-through of a circuit breaker, a standard, non-time delay Class J fuse, and the DFJ fuse during the same magnitude fault.

Under fault conditions, the DFJ fuse clears the fault much faster (and is much more current-limiting) than circuit breakers and standard Class J fuses. The DFJ fuse has high speed fuse performance under fault conditions to deliver high speed fuse protection for power electronic devices while being a UL Class J fuse that allows for its application using economical, standard Class J switches, blocks and holders.

7.21.7 2017 NEC change affecting variable (adjustable) speed drives

This change is contained in “Chapter 4 Equipment for General Use,” “Article 430 Motors, Motor Circuits, and Controllers, Part X. Adjustable-Speed Drive Systems,” “430.130 Branch Circuit Short-Circuit and Ground Fault Protection for Single Motor Circuits Containing Power Conversion Equipment,” “430.130(A) Circuits Containing Power Conversion Equipment.”

7.21.7.1 Significance of the change

This Code change is for listed adjustable speed drive short-circuit current ratings (SCCRs). The applicable UL product standards 508C Standard for Power Conversion Equipment and 61800-5-1 Standard for Adjustable Speed Electrical Power Drive Systems - Part 5-1: Safety Requirements - Electrical, Thermal and Energy already have this requirement. Protecting power electronics devices requires extra consideration discussion in 7.21.6.2, and Annex 3 provides greater insight into a significant transition occurring for adjustable speed drive SCCR protection.

- This Code change: Where the manufacturer’s instructions for their listed power electronic conversion equipment permits semiconductor fuses or instantaneous trip circuit breakers for use as the branch circuit short-circuit and ground fault protective device, they must be integrated in the same assembly.
- Semiconductor fuses are also commonly referred to as high speed fuses and instantaneous trip circuit breakers are commonly referred to as motor circuit protectors or MCPs.

- In addition, when semiconductor fuses or MCPs are used, UL 508C and UL 61800-5-1 require the drives to be marked with the specific fuse manufacturer and fuse model number, or MCP manufacturer and MCP model number. Plus the marking must state these protective devices must be integrated in the same assembly with the adjustable speed drive controller.
- These extra precautions are necessary since the MCPs and most semiconductor fuses are not branch circuit overcurrent protective devices as defined in Article 100. These application-limited devices are permitted in the NEC to be applied, with restrictions, for this application: see 430.52(C)(3), 430.52(C)(5), and 430.130(A)(4). They are recognized products which require the drive manufacturer to evaluate these specific devices for the specific application.
- Most adjustable speed drives are listed with specific OCPD types. For safety and compliance to 110.3(B), the adjustable speed drive manufacturer’s markings and instructions concerning the specific OCPD and corresponding SCCRs must be followed.

7.21.7.2 Protecting power electronic conversion equipment requires extra considerations

The adjustable speed drive product standard is transitioning from UL 508C to UL 61800-5-1 (see Table 7.21.7.d) and will result in more stringent short-circuit current testing for enhanced safety. The use of more current-limiting OCPDs and high speed fuses are expected to become more prevalent.

Adjustable speed drives present different short-circuit and ground fault protection challenges compared to the traditional electromechanical motor circuit devices. Typically, adjustable speed drives with Insulated Gate Bipolar Transistors (IGBTs) will shut down quickly for external faults on the adjustable speed drive output. However, drives listed to UL 508C may not have been evaluated for internal faults. The internal fault damage can be catastrophic and result in extensive damage to the drive and adjacent circuits and devices. In some cases, high speed fuses are the only type of OCPDs that provide the high degree of current-limitation necessary for drive internal fault protection. Superior current-limiting protection may minimize drive damage as well as collateral damage to adjacent circuits.

A specific adjustable speed drive model number may have multiple SCCRs conditional on the OCPD type and corresponding SCCR level achieved in the product standard testing evaluation, e.g., a drive may have two SCCRs: 5 kA for an OCPD complying with 430.52, and 100 kA when protected by a manufacturer’s specific high speed fuse model number. In some cases, an adjustable speed drive may be listed with only one permissible specific OCPD and corresponding SCCR. This information will be marked on the drive and/or noted in the installation instructions.

UL 508C is being phased out as the industry transitions to the new UL 61800-5-1 standard. These product standards pertain to open or enclosed power electronic conversion equipment that supply power to control a motor, or motors, operating at a frequency or voltage different than that of the input supply. One of the benefits is a significant improvement for adjustable speed drive short-circuit current protection.

7.21.8 Changing UL Standards

Effective February, 2016, any new adjustable speed drive design must be evaluated to UL 61800-5-1. Effective February, 2020, all adjustable speed drives are required to be evaluated to UL 61800-5-1, and UL 508C will be withdrawn. Table 7.21.8.a details three important differences affecting adjustable speed drive overcurrent protection as a result of this change.

Phasing out UL 508C	Effective February 2020 UL 61800-5-1
Motor output of the drive short-circuit tested.	All drive outputs short-circuit tested.
No specific requirements for the short-circuit testing of adjustable speed drive internal components (breakdown of components testing).	Internal adjustable speed drive components must be tested for both standard and high fault currents based on manufacturer's short-circuit current rating; unless analysis shows a different value is more severe.
Testing with cotton not required during short-circuit and breakdown of components testing with circuit breakers.	Cotton indicator is required for all short-circuit and breakdown of components tests when testing with circuit breakers.

Table 7.21.8.a Change in UL Standards.

Providing adjustable speed drives with adequate short-circuit protection can be a challenge. Adjustable speed drives listed to UL 61800-5-1 will include the additional (not required in 508C) short-circuit current testing and evaluation criteria for internal drive component failure (breakdown of components).

Without proper overcurrent protection, internal adjustable speed drive components, such as the power electronic devices and capacitors, can fail resulting in short-circuit current damage that may be catastrophic. Extensive damage could occur to the various drive elements and collateral damage could occur as well to adjacent devices and circuits.

UL 61800-5-1 requires testing to simulate internal drive component failures, therefore, the damage to other drive elements or collateral damage to other adjacent circuits will be greatly reduced or contained.

The drive manufacturers are transitioning to the new standard. To meet the requirements for short-circuit and breakdown of components testing, damage to internal drive components must be either contained (by physical means such as more rugged enclosure) or reduced through the use of current-limiting OCPDs. In many cases, traditional branch circuit breakers and some less current-limiting fuses may not be able to provide adequate protection. This may lead to the use of very current-limiting OCPDs with the semiconductor (high speed) fuses being the most current-limiting. The protection requirements can vary based on the horsepower range and typical adjustable speed drive designs in those ranges.

7.21.9 High speed fuse recommendations

Table 7.21.9.a contains Bussmann series high speed fuse recommendations for protecting solid state devices (diodes, SCRs, triacs, transistors).

Protection type	Sizing	Fuse/volts recommendation
Short-circuit only	F, S, K, and 170M fuse families sized up to several sizes larger than full load RMS or DC rating of device	Up to 130 V: FWA
		Up to 250 V: FWX
		Up to 500 V: FWH
		Up to 600 V: FWC, KAC, KBC
		Up to 700 V: FWP, 170M _L , SPP
		Up to 1000 V: FWJ, 170M _L , SPJ

Table 7.21.9.a

7.22 Welders

7.22.1 Arc welders

Arc welders must be protected by a fuse rated at not more than 200% of the rated primary current. The fuse protecting the supply conductor can serve as the welder protection as long as the fuse is rated at not more than 200% of I_{max} or the welder's rated primary current [630.12(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 200% of the conductor's rating [630.12(B)].

7.22.2 Resistance welders

Resistance welders must be protected by a fuse rated at not more than 300% of the welder's rated primary current. The fuse protecting the supply conductor can serve as the welder protection as long as the fuse is rated at not more than 200% of the welder's rated primary current [630.32(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 300% of the conductor's rating [630.32(B)].



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8.1 Data centers

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8.1.1 Overview

Data centers have become one of the most critical developments in the technology world. The explosion of communication, Smartphone applications, social media, cloud computing and the Internet of Things (IoT), allows individuals to weave the Internet into their daily routines. Also, businesses store and mine big data to become more productive in solving challenges long thought to be unsolvable.

The Internet allows everyone to work virtually, connect with each other globally, to exchange information and data in real time, and enables everyone to harvest and analyze large data to become much more productive. This, in turn, requires data managers to store more data in their data centers. So much so that the number of data centers has doubled approximately every five years and will continue to grow exponentially. It's estimated there will be a threefold increase in IP traffic growth moving forward from 2015 to 2020. Add in the growing IoT need for devices to always be connected and exchanging data at high volumes, managing data centers effectively is, and will always be, mission critical.

8.1.2 Energy efficiency

Design engineers, operators and owners face many challenges when designing, building and managing today's data centers. The electrical distribution system is a key consideration when designing within the whitespace. To ensure maximum uptime, a very complex electrical distribution system is required to support the data center from incoming power down to the server racks, with each system portion presenting its own challenges.

Total cost of ownership is one of the first challenges that the designer is confronted with. It's estimated that the electricity needed to power the entire system represents 50% of the annual operating cost. With electrical power consumption this large, there are many ways to measure how efficiently it's being used. Power Usage Effectiveness (PUE) is a popular metric to quantify this. PUE is a scale for how efficiently a data center uses power for its IT equipment versus the total power consumed, expressed as:

$$PUE = \frac{\text{Total power consumption}}{\text{IT equipment power consumption}}$$

The goal is to get the PUE value as close as possible to 1.0. In recent studies and surveys with data center owners and operators, it's been noted the average PUE is around 2.0, meaning that roughly half the data center's power consumption isn't powering the IT equipment. To lower this ratio, many designers tend to focus on the energy used for cooling and auxiliary power as that's non-value added power consumption. However, one must not lose sight of using the "effective" power more efficiently as it can indirectly affect the amount of non-value added power consumed within the whitespace and result in a more positive affect on total power consumed. Increasing the system voltage is a way to achieve this. By removing transformers that step power down to 208 V, or lower, can result in 2% or more efficiency gains.

While today's servers are smaller, they still require the same amount of power. With more servers installed per rack, each rack is now consuming more total power. In turn, higher system voltages provide efficiency gains down to the rack level that can result in reduced space for the same computing capacity, or greater computing capacity in the same space. The table below shows the power delivered to the server rack based on the volts and amps supplied from the busway or Remote Power Panel (RPP) to the rack Power Distribution Unit (PDU).

Circuit capacity (amps)	De-rated value (amps)	208 Vac 3-phase (kW)	415 Vac 3-phase (kW)	480 Vac 3-phase (kW)
20	16	5.8	11.5	13.3
30	24	8.6	17.3	19.9
50	40	14.4	28.8	33.2
60	48	17.3	35.6	39.9

Table 8.1.2.a

Table 8.1.2.a shows that higher voltages can greatly improve the power density at the rack level. By integrating this concept into the designs for medium to large data centers, designers and engineers can lower the up-front capital costs for the electrical distribution system. This also includes reducing the overall whitespace square footage, the number of installed transformers and conductor sizes, etc. All the advantages of higher voltages can decrease the total ownership cost by reducing the initial capital to build a data center and the yearly operating expenses.

There can be a caveat by moving to electrical systems with higher density and efficient power distribution, and that is the available fault current experienced throughout the whitespace. Since more power is delivered with lower impedance, fault currents can be much higher than in lower voltage designs. Per the NEC and to ensure safety, designers must calculate available fault current levels at multiple points in the system. Circuit protection must then be incorporated into many points in the system to protect its components and, more importantly, the people servicing it. Determining adequate circuit protection is an issue faced by many designers when creating higher power density systems.



Figure 8.1.2.b Typical data center busway, busway drop units and rack PDU with high fault current levels.

8.1.3 Design flexibility

Another challenge faced by data center engineers is to ensure their electrical system design is flexible and scalable. During a data center's life cycle, IT refreshes are typically required to keep up with increasing demands. Also, multi-tenant data centers are rapidly increasing with an expected 15% compound annual growth rate that outpaces the overall data center growth rate. As companies lease server space within a data center, the data center owner must accommodate changing power needs all the way down to the rack level. Ensuring that power distribution is scalable throughout the system requires the accompanying circuit protection is also scalable.

For fixed, non-removable busway drops and RPPs with circuit breakers, having a scalable solution requires the owner to shut down the upstream overcurrent protective device (OCPD) in order to service or replace downstream devices, or replace the busway drop altogether. This causes downtime that's more widespread than necessary (which can be costly) or require extensive planning to execute. The issue faced by designers is how to future-proof their electrical system's design so that it's scalable to meet the inevitable increasing power demands. Products that allow designers to accommodate such changes are increasingly in demand.

8.1.4 Fusible design benefits

Modern fuse solutions continue to evolve with better designs, materials, physical size and service features to provide critical protection for the demanding requirements of variable speed drives, UPSs, photovoltaic systems, electrical vehicle power and control systems, building emergency systems and critical operations power systems. They also have many features that benefit designers, maintainers and owners of today's and tomorrow's data centers.

These advantages are more pronounced when considering the challenges posed by data center trends to higher energy efficiency and greater power density. As a consequence, OCPDs in the PDUs, RPPs, busway plug-in units and rack PDUs must have higher interrupting ratings. The electrical equipment, such as PDUs/RPPs and busway plug-in units, must typically have higher short-circuit current ratings. Additionally, for data centers with higher fault currents, ensuring selective coordination becomes more critical for avoiding unnecessary system outages. Similarly, higher voltages and fault currents generally demand higher performance OCPDs and greater attention paid to electrical safe work practices. For instance, when using non-current limiting OCPDs, higher fault currents result in higher arc flash incident energy, posing a greater safety risk. However, this is not necessarily the case with current-limiting fuses that can reliably mitigate arc flash incident energy, even for high fault currents.

In this section, the fuse benefits are divided into four general topics:

- Electrical installation safety requirements
- Reliability
- Safe work practices
- Flexibility

Taken in total, current-limiting fuses for data centers are a simple and easy means to ensure proper electrical ratings, selective coordination and safe work practices. This helps assure reliable protection upon the initial installation as well as when upgrades or changes occur during a data center's life cycle. In most cases, fusible solutions perform as well (or better) in systems with high fault currents. When changing equipment layouts, fusible solutions offer unique flexibility benefits.

8.1.5 Electrical installation safety requirements

There are mandatory NEC and OSHA safety requirements for electrical equipment that must be met upon the initial installation and throughout the system's life cycle. Most people recognize that electrical equipment voltage ratings must be equal to or greater than the system voltage. However, two other critical ratings include:

- Interrupting Rating (IR)
- Equipment Short-Circuit Current Rating (SCCR)

8.1.5.1 Interrupting rating

Interrupting Rating (IR) is the maximum fault current at a specified voltage that a circuit breaker or fuse can safely interrupt under standard test conditions.

All OCPDs must have IRs equal to or greater than the available fault current at their lineside terminals per NEC 110.9 and OSHA 1910.303(b) (4). It is a serious safety hazard to have an OCPD installed where the available fault current exceeds the OCPD's IR. If a circuit breaker or fuse attempts to interrupt a fault current exceeding its IR, the device can catastrophically fail in a violent explosion. Scan the QR codes in Figure 8.1.5.1.a to view the slow motion videos of fuses and a circuit breaker being misapplied.



Figure 8.1.5.1.a

Along with fault current levels trending up in new data centers, existing data centers can be expanded, increasing fault current levels beyond the existing OCPDs' IRs. Current-limiting fuses typically have IRs of 100 kA, 200 kA or 300 kA for 600 Vac or less. With higher voltage distribution to the cabinet (i.e., 415 Vac or greater), it's not uncommon to have 20 kA to 50 kA or more available fault current on a RPP or busway plug-in unit. Even the rack PDUs can have high fault currents, as shown in Figure 8.1.2.b.

Therefore, the 5 kA IR or 10 kA IR circuit breakers, often used in rack PDUs, may be inadequate for many installations.

Circuit breaker solutions for higher available fault currents are either:

- Fully rated circuit breakers (each circuit breaker has an individual IR equal or greater than the available fault current at its lineside terminals)
- Series combination rated circuit breakers (a circuit breaker is permitted to have an IR less than the available fault current at its lineside terminals if installed in a panelboard that is tested, listed and marked with a specific lineside circuit breaker or fuse)

Fully rated circuit breakers with higher IRs cost more and may have a larger footprint. In either case, with fully rated or series rated circuit breaker systems, achieving selective coordination is usually more difficult than when using standard molded case circuit breakers, and this is more pronounced as the fault currents and voltages increase.

Modern current-limiting fuses inherently provide high, fully rated IRs for systems with fault currents up to 100 kA or 200 kA without any price premium or footprint increase. All high IR current-limiting fuses are simple to selectively coordinate and easily provide excellent circuit component protection. In addition, each current-limiting fuse class has unique physical dimensions so that replacement fuses will always be of the same fuse class and will maintain the safety of high Interrupting Ratings.

8.1.5.2 Equipment Short-Circuit Current Rating (SCCR)

A principal advantage to fusing data center circuits is the current-limiting fuse's ability to greatly reduce the let-through energy during faults. Per UL 248 fuse product standard, current-limiting fuses are not permitted to exceed maximum allowable energy let-through values under fault conditions. This provides excellent component protection and is a safety benefit. The most current-limiting Bussmann series fuses provide superior fault current protection. All equipment and components in the data center's electrical system are required per NEC 110.10 and OSHA 1910.303(b)(5) to have an SCCR equal to or greater than the available fault current. This includes transfer switches, UPSs, PDUs, RPPs, busways, bus plug-in units, computer room air conditioner (CRAC) units and row coolers, etc.

Most fusible panelboards, busway systems and enclosed disconnects can be tested, listed and marked with a 200 kA SCCR. E.g., when not protected by current-limiting fuses, a common 250 A data center busway system has a standard SCCR of 22 kA. This same busway, when protected upstream by 400 A or less Bussmann series LPJ fuses, has been tested and listed with a 200 kA SCCR at 600 V or less.

As a result of higher efficiencies and higher power density designs electrical systems are capable of delivering higher fault current levels. A key current-limiting device benefit when a fault occurs is to quickly drive the fault current down to zero and keep the let-through energy below levels that damage equipment.

Scan the QR codes in Figure 8.1.5.2.a to view normal speed videos that illustrate the quick cutoff action a 200 A current-limiting (clears in less than 1/2 cycle) fuse delivers versus a non-current-limiting OCPD that takes approximately one cycle to open.

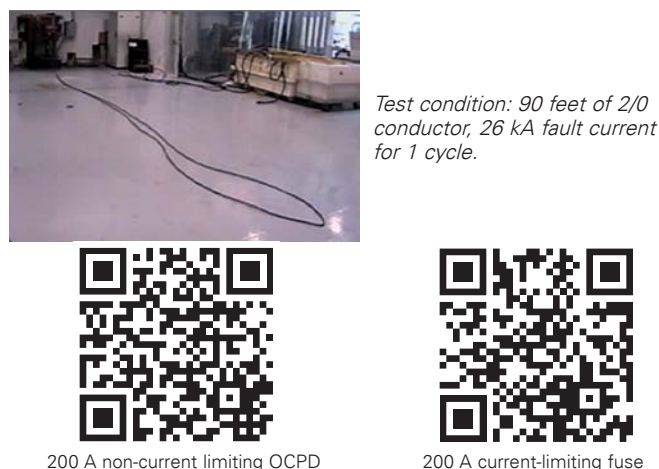


Figure 8.1.5.2.a

8.1.6 Reliability

8.1.6.1 Selective coordination

Long before it was an NEC requirement, preventing an unnecessary power outage has been a design consideration in data centers and mission critical facilities. Mission critical system designers understand the added reliability that selectively coordinated OCPDs provide. 2014 NEC 645.27 requires the OCPDs in critical operations data systems to be selectively coordinated.

Using properly selected and applied fuses in data centers alleviates the design hassle of trying to achieve selectively coordinated OCPDs at the cabinet and busway (or PDU) levels as well as further upstream. To achieve selective coordination, fuses simply need to maintain a 2:1* amp rating ratio for upstream and downstream Bussmann series Low-Peak fuses. This eliminates the possibility of cascading multiple OCPD levels under fault conditions.

When OCPDs are not selectively coordinated, multiple, upstream OCPD levels can cascade open on a fault condition. For example: a fault in a power supply or rack PDUs results not only in one of the rack PDU OCPDs opening (as it should), but the OCPDs in RPP or busway plug-in units unnecessarily open, resulting in the unnecessary power outage to the entire rack PDU. Even worse results would be if the much larger amp rated feeder OCPD (200 to 400 A) supplying the busway or PDU/RPP should open for a fault in the rack PDU, there would be an unnecessary power outage to an entire PDU/RPP or busway run.

8.1.6.2 Inherent fuse reliability

Fuse operation is based on a simple thermal principle; the fuse element will rapidly melt or vaporize and open at a very specific energy level. Users can be assured the fuse element's precise thermal attributes will always operate when called upon to remove a fault and protect valuable equipment. The internal parts of modern current-limiting fuses do not require maintenance so that the ongoing maintenance cost of a fusible system is typically less. However, it remains important to periodically inspect electrical equipment for signs of overheating, poor connection or insufficient conductor ampacity.

8.1.7 Safe work practices

The safe work practices for electrical systems are important for worker safety and power system reliability. OSHA has regulations that must be followed, and NFPA 70E Standard for Electrical Safety in the Workplace is the leading consensus standard on how to comply with the OSHA safe work practice regulations.

8.1.7.1 Servicing fuses

Modern fuse solutions, like the Bussmann series CCPB/CUBEFuse — UL 98 Listed branch circuit fusible disconnect switch, make servicing fuses much simpler than typical safety switches or older, fusible panelboards.

As shown in Figure 8.1.7.1.a, the CUBEFuse can be serviced without removing the PDU/RPP deadfront or accessing the busway plug-in enclosure interior. The CCPB/CUBEFuse combination is IP20 finger-safe when installed in a panelboard/RPP with deadfront construction as shown in Figure 8.1.8.2.b (see CUBEFuse and the CCPB disconnect switch for details) or when installed in a busway plug-in unit as shown in Figure 8.1.8.3.a. Should a fuse open, simply open the panelboard's door to view the CCPB/CUBEFuse or merely look at the busway plug-in exterior to view the CCP/CUBEFuse. The open fuse(s) will be identified by either the open fuse indicating light on the CCPB or the optional permanent indicator on the time-delay CUBEFuse. Both the CCPB and CCP disconnect switches are interlocked with the CUBEFuse. When extracting or inserting a CUBEFuse, the disconnect switch handle must be in the "OFF" position.



Figure 8.1.7.1.b The low profile CCP is the smallest UL 98 Listed fused disconnect measuring 2-1/2 x 2-1/8 x 3/4 inches (63 x 54 x 19 mm).



Figure 8.1.7.1.c 2-pole CCPLP disconnect with SC-20 fuses. When the switch handle is in the OFF position, the fuse access door interlock allows access to the fuse compartment for extracting or inserting fuses.

8.1.7.2 Renewability

OSHA 1910.334(b)(2) is the law concerning an OCPD that opens due to an overcurrent. If an overload caused the opening, then fuses can be replaced or circuit breakers reset after the cause has been identified and remedied. However, if a faulted circuit caused the opening, then fuses cannot be replaced nor circuit breakers reset "...until it has been determined that the equipment and circuit can be safely energized." To avoid possible catastrophic damage to equipment or unsafe working conditions, it is important to identify the source of the fault and repair the faulted circuit before restoring power. Additionally, the conductors and electrical components on the faulted circuit path should be verified suitable to be placed back into service. When a fuse opens an overcurrent, it is replaced with a new, factory-calibrated fuse, ensuring the same protection level, which is an advantage of using fuses.

Per NFPA 70E 225.3, if a circuit breaker opens a fault approaching its interrupting rating, the circuit breaker must be inspected and tested in accordance with manufacturer's instructions and determined to be operating within specifications before it can be placed back into service.

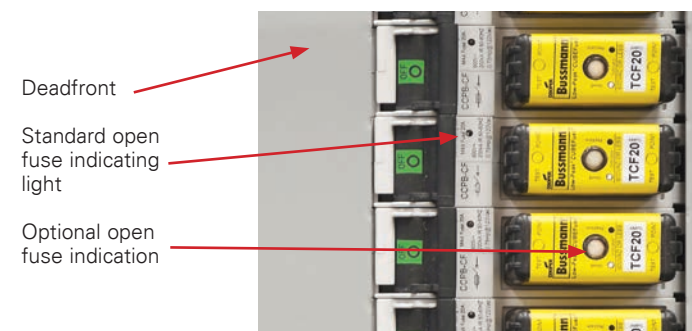


Figure 8.1.7.1.a Servicing equipment with the finger-safe CCPB/CUBEFuse is easy.

8.1.7.3 Arc flash reduction

Arc flash is a frequent concern in today's data centers. With minimizing downtime a priority, it is important wherever possible to have current-limiting OCPDs to mitigate arc flash hazards. By limiting energy let-through and quickly bringing current down to zero, fuses can reduce the arc flash incident energy experienced during most arc flash events. This especially pertains to the fuse types and amp ratings used in rack PDUs (typically 20 A current-limiting fuses) and busway plug-in units (typically 100 A or less current-limiting fuses). This also pertains to the busway when protected by fuses in the end-feeds.

In addition, mitigating arc flash hazard depends on the OCPD's "design and condition of maintenance" per 2018 NFPA 70E 130.5(3). If OCPDs requiring maintenance are not maintained, an arc flash event can be more severe than that predicted by an arc flash risk assessment. 2018 NFPA 70E 205.4 requires OCPDs to be maintained and the "maintenance, tests, and inspections to be documented." Fuses are inherently reliable for fault conditions as there is no need to maintain the fuses' internal parts. All that is necessary is to maintain the external connections and proper environmental conditions.

8.1.7.4 Current-limiting fuse safety system

By design, a given UL class current-limiting fuse cannot be inserted into mountings designed for another fuse class. For instance, a Class CF CUBEFuse is the only fuse type that can be installed in mountings for a CUBEFuse. As a result, fuses with lower voltage and interrupting ratings, (or lower current limitation performance) can't be accidentally put into service. This is a significant safety benefit when utilizing current-limiting fusible equipment.

Rejection features for fuse amp ratings can vary based on the fuse class and the type selected made by the designer and installer. For instance, an SC-20 fuse (commonly used in rack PDUs) has a unique dimension - only SC-20 fuses can be inserted in a 20 A Class G fuse mounting.

Each approach provides different benefits, depending on the UL fuse classes used in the system design.

8.1.8 Data center products for flexibility

There are data center operation flexibility and inventory benefits for some applications utilizing the CUBEFuse/ CCP disconnect switch combination. Each flexibility attribute is described in the following.

Current-limiting fuses provide excellent overcurrent protection for the challenging needs of modern data centers. The following section will discuss the solutions current-limiting fuses provide for broad PDU and busway architectures.

8.1.8.1 Compact Circuit Protector and CUBEFuse

For data center applications, the Compact Circuit Protector Base (CCPB, bolt-on version) and CCP (DIN-Rail version) that use the CUBEFuse are some of the smallest UL 98 fused disconnects that offer great advantages for PDU and busway architectures. The innovative finger-safe CUBEFuse with a 300 kA IR is available in ratings from 1 to 100 A have been on the market for nearly two decades and offer many advantages including the smallest footprint of any UL class fuse above 30 A with more than 100 kA IR. The CUBEFuse is available in two versions: 600 Vac/300 Vdc time-delay (TCF) and 600 Vac/dc fast-acting (FCF). See Figure 8.1.8.1.a. Both CUBEFuse versions are very current-limiting to provide excellent equipment short-circuit current protection and arc flash incident energy mitigation.

The time-delay TCF is available in both indicating and non-indicating versions, while the non-time delay (fast-acting) FCF is available only as a non-indicating fuse.



Figure 8.1.8.1.a Time-delay (TCF) and fast-acting (FCF) CUBEFuse.



Figure 8.1.8.1.b Bolt-on Compact Circuit Protector Base (CCPB) with non-indicating CUBEFuse, and DIN-Rail mount Compact Circuit Protector (CCP) with indicating CUBEFuse.



Figure 8.1.8.1.c DIN-Rail CCP (shown) and bolt-on CCPB are available in 1-, 2- and 3-pole versions.

The Compact Circuit Protector (CCPB or CCP) is available in ratings up to 100 A. The UL 98 Listed Compact Circuit Protector disconnect and CUBEFuse combination provides an excellent overcurrent protection/disconnect solution for many applications. The Quik-Spec Coordination Panelboard (QSCP) chassis utilizes the bolt-on CCPB and CUBEFuse to provide the means for fusible PDUs/RPPs. The QSCP chassis (without enclosure) is sold to manufacturers for integration into their PDUs/RPPs with additional features such as monitoring.

For the data center busway architecture, the CCP with CUBEFuse is incorporated into busway plug-in units. The available CCP versions offer excellent switch/fuse combinations for data center applications.

There are two Compact Circuit Protector versions using the CUBEFuse (see Figure 6):

- 1. CCP: DIN-Rail mount version, which allows small fusible switch applications such as the plug-in busway unit up to 100 A.
- 2. CCPB: bolt-on version used in the QSCP panelboard, which allows fusible panelboards having up to 100 A rated branch circuits with same width and depth footprint as traditional circuit breaker panelboards.

All CCPs or CCPBs have a disconnect amp rating and horsepower rating. A CCP or CCPB of a specific amp rating can accept any CUBEFuse amp rating equal or less than the CCP or CCPB amp rating.

There is a notable difference in the bolt-on CCPB and the DIN-Rail mount CCP. The DIN-Rail mount CCP is available in 30 A, 60 A and 100 A ratings and accepts the CUBEFuse as shown in Table 8.1.8.1.d.

CCP amp rating	CUBEFuse amp range
30	1 to 30
60	1 to 60
100	1 to 100

Table 8.1.8.1.d

The bolt-on CCPB is available in the NEC standard 15, 20, 30, 40, 50, 60, 70, 90 and 100 A branch circuit ratings. Each CCPB will accept any CUBEFuse amp rating equal or less than its amp rating.

This fuse amp rating “rejection” feature provides some important options and flexibility for data center management. For instance, if a busway plug-in unit uses a CCP 60 A and the cable whip is rated 60 A, then any CUBEFuse from 1 to 60 A can be installed.

This allows for greater system flexibility for upgrading if the initial installation has a 60 A CCP with a 30 A CUBEFuse. Then should modifications be required to increase the available current in the cabinet, all that’s needed is installing the desired amp rated fuse up to 60 A. The ability to increase the circuit amps by simply swapping out fuses can save time and reduce inventory of busway plug-in units since the entire busway plug-in unit does not have to be removed and replaced with a higher amp rated unit.

8.1.8.2 QSCP and PDU/RPP



Figure 8.1.8.2.a RPP utilizing QSCP chassis with CUBEFuse feeding Eaton ePDUs utilizing CCPLPs with SC fuses.

The UL Listed QSCP is rated 600 Vac and easily applied to either 208 Vac or 415 Vac data center applications (or up to 600 Vac), and is available with 18, 30 or 42 factory configured branch positions. The images in Figure 9 show the QSCP as a complete NEMA 1 panelboard (left) and as a chassis (right) that manufacturers integrate into their PDU/ RPP equipment, and adding additional features such as monitoring.

Examples of the QSCP chassis in other RPPs are shown in Figures 8.1.8.2.a, 8.1.8.2.b and 8.1.8.2.c.

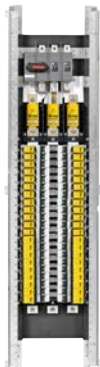
The QSCP panelboard, in ratings up to 400 A and SCCRs up to 200 kA, can easily achieve selective coordination in an all-fused system or with upstream tested circuit breakers. It provides excellent arc flash hazard mitigation and is an excellent panelboard for electrical distribution systems supplying non-IT equipment loads in a data center such as the computer room air conditioners/air handlers (CRAC/CRAH).

Complete QSCP panelboard in NEMA 1 enclosure

QSCP chassis available to manufacturers for integration into other designs.



Complete QSCP panelboard in NEMA 1 enclosure



QSCP chassis available to manufacturers for integration into other designs.

8.1.8.2.b Quik-Spec Coordination Panelboard (QSCP).



Figure 8.1.8.2.c Eaton RPP with QSCP chassis.

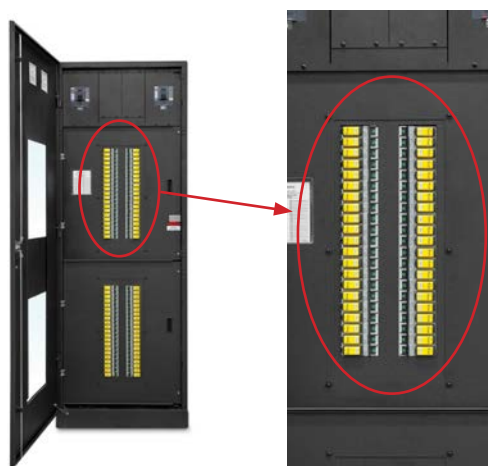


Figure 8.1.8.2.d RPP with QSCP chassis. Courtesy Cyberex, Thomas & Betts Power Solutions.



Figure 8.1.8.2.e RPP with QSCP chassis and spare CUBEFuse holder. Courtesy Liebert FDC— power distribution cabinet from Emerson Network Power™.

Two methods for specifying CCPBs into PDUs/RPPs are:

1. The CCPB amp rating can be specified for any of the available 15, 20, 30, 40, 50, 60, 70, 90 or 100 A branch circuit amp ratings. Each CCPB will accept any CUBEFuse amp rating equal to or less than its amp rating.
2. The CCPB amp rating can be specified, limiting the maximum amp rating to 30, 60 or 100 A, or a mixture of these amp ratings. This narrowing the number of specified CCPB amp ratings provides the benefit of more flexibility and less CCPB inventory needed when changes are made to circuits or PDUs/RPPs. For instance, if all the CCPB disconnects in an RPP are 60 A, then it will accept all CUBEFuse amp ratings from 1 to 60 A. By installing 60 A CCPBs, if the branch circuit conductors are changed to a different ampacity, the CCPBs do not need replacing; only the CUBEFuse will need changing to the appropriate amp rating. Similarly, if the RPP is moved, only the CUBEFuse will need to be changed so it meets the circuit protection needs at its new location.

With the QSCP, all branch circuit CUBEFuse are accessible without removing covers or exposing any live parts. The QSCP also has a spare fuse holder so replacements can always be at hand. Due to CUBEFuse current limitation, the energy during many fault conditions is greatly reduced which, in turn, can reduce the amount of damage during a fault, allowing for faster repairs. Together, these features can reduce Mean-Time-To-Repair (MTTR).

8.1.8.3 Busway plug-in fusible disconnect

A busway plug-in utilizing the DIN-Rail mount CCP is suitable for any voltage up to 600 Vac. The cable whip connects the busway unit to the rack PDU. See Figure 8.1.8.3.a.

Like the QSCP, the CCP used in a busway plug-in unit also allows access to the CUBEFuse without removing covers or exposing any live parts, as shown in Figures 8.1.8.3.b and 8.1.8.3.c. Again CUBEFuse current limitation greatly reduces the energy let-through during many fault conditions which can reduce the damage during a fault, allowing for faster repairs. Selective coordination with rack PDU fusing is easily achieved (see next page for details). Together, these features can reduce MTTR.



Figure 8.1.8.3.a StarLine Track Busway fusible disconnects utilizing CCP with CUBEFuse feeding ServerTech rack PDU utilizing the CCPLP with SC fuses.



Figure 8.1.8.3.b StarLine Track Busway fusible disconnects using the DIN-Rail mount CCP with CUBEFuse. Courtesy of Universal Electric Corporation (UEC).



Figure 8.1.8.3.c Eaton Busway fusible disconnects use the DIN-Rail mount CCP with CUBEFuse.

8.1.8.4 Low Profile Compact Circuit Protector (CCPLP) and SC fuses

Eaton's Bussmann series Low Profile Compact Circuit Protector (CCPLP) is a unique addition to the CCP product line. This fused disconnect adapts the same CCP technology and is the smallest UL 98 disconnect switch in the electrical industry. This small footprint makes the CCPLP's Class G version (with SC-20 fuses) ideal for rack PDUs. Available in 1-, 2- and 3-pole versions, the Class G CCPLP has a 100 kA SCCR at 600 V so it can be installed in virtually any data center without worrying about the available fault current.

By using the Class G CCPLP disconnect in the rack PDU, the rack PDU, IT equipment and circuits can be properly protected in systems with higher voltages, like 415/240 V, and higher available fault currents, up to 100 kA. As with the entire CCP product line, the disconnect's switch is interlocked with the fuse access door. To extract or insert an SC-20 fuse, the CCPLP switch must first be in the "OFF" position before the fuse access door can be opened.

In addition, the Class G CCPLP can isolate a rack PDU's faulted subsection to keep the power fed to the remaining sub-sections (when rack PDU fuses are selectively coordinated with upstream RPP fuses or busway plug-in fuses; see Note on Selective Coordination for rack PDU below). See Figure 8.1.8.3.a. If a fault or overload were to occur on rack PDU Branch 1, the Branch 1 fuse would open and remove the overcurrent from the circuit. The rest of the rack PDU would remain in operation. Rack PDU manufacturers provide options for local and remote notification of fuse openings. Remote notification includes both Simple Network Management Protocol traps (SNMP traps) and email alerts.

In addition to the Class G CCPLP, there are also Class CC and UL Midget / IEC 10x38 versions. All versions are in Table 8.1.8.4.a.

Catalog symbol	Fuse class	Volts AC	Amps	SCCR (kA)	Poles
CCPLP_-G	G	600	20	100	1, 2, 3
CCPLP_-CC*	CC	600	30	200	1, 2, 3
CCPLP_-M	UL Midget	240	30	10	1, 2, 3
CCPLP_-M	IEC 10x38	400	32	120	1, 2, 3

* Horsepower rated, see data sheet no. 10372.

Table 8.1.8.4.a

Available Bussmann series fuses include:

Fuse class	Time-delay	Fast-acting
G	SC-20	—
CC	LP-CC, FNQ-R	KTk-R
UL Midget	FNm, FNQ	BAF, KLM, KTK
IEC 10x38	C10G C10M	—

8.1.9 Rack PDU fuse selective coordination with upstream fuses



Figure 8.1.9.a Partial views of fused rack PDU utilizing CCPLP with SC fuses. This rack PDU uses SC fuses to protect the receptacles and circuit to the power supplies. Courtesy of Server Technology, Inc.

The easiest way to achieve selective coordination with fuses is to use the published Fuse Selectivity Ratio Guide (see the section Selective Coordination in this handbook).

20 A SC fuses are commonly used with the CUBEFuse, either time-delay (TCF) or non-time delay/fast-acting (FCF). The published selectivity amp ratio for an upstream CUBEFuse supplying a downstream SC fuse is 4:1. To ensure selective coordination, a rack PDU using a 20 A SC-20 fuse would need, at a minimum, an 80 A CUBEFuse upstream.

Additionally, testing at specific system voltages have demonstrated that SC-20 fuses will selectively coordinate with 30 and 40 A TCF fuses (up to the available fault current in kA) shown in Table 8.1.9.a.

	System voltage	Lineside	
		TCF30	TCF40 or greater
Loadside SC-20	208/120	33.8 kA	100 kA
	415/240	14.5 kA*	100 kA

* Available fault current measured at the point where the rack PDU (with a minimum 5 foot cable whip) is connected to the source.

Table 8.1.9.b

As mentioned before, other fuse classes could be used in rack PDUs. For the amp ratios, please consult the published Fuse Selectivity Ratio Guide in this handbook.

8.1.10 Addressing data center owner needs

Need	Solution
Reliability	Modern fuses are simple thermal devices with no moving parts. If a fuse opens, it's replaced with a new, factory-calibrated fuse of the same class and electrical performance.
Low maintenance	Fuses do not require maintenance. Periodic inspection of all electrical equipment should be made for signs of overheating, poor connections or insufficient conductor ampacities.
High power density	Fuses make it easy to use higher voltages like 415/240 V and/or higher amp ratings without worrying about high fault currents or difficulty in achieving selective coordination.
High energy efficiency	Fusible solutions can handle high fault currents. There is no need to use higher impedance transformers or reactors to reduce fault current levels. These high impedance devices can add cost/space and lower the overall data center efficiency.
Increased uptime	Fuses allow for easy selective coordination up to 100 kA or 200 kA at voltages up to 600 V.
Equipment protection and arc flash mitigation	Current limitation can significantly reduce a fault's magnitude and duration. The lower energy let-through can reduce arc flash incident energy and helps limit damage to the equipment.
Flexibility	Easier circuit changes by installing CCP disconnects to accommodate future growth and increasing fuse size to meet amp rating needs. If changes to the electrical system cause the available fault current to increase, it will not affect selective coordination and is unlikely to exceed the fuse interrupting rating.
Low MTTR	CUBEFuse and SC-20 fuses used in Compact Circuit Protectors are easy and fast to replace without exposing workers to energized parts.
Easy compliance with NEC requirements	No worry solution with high IR to handle fault currents up to 200 kA or more, and easily achieve selective coordination.

8.1.11 Other Bussmann series products used in data centers



Low voltage fuses (600 V or less) for protecting feeders and busway end feeds

- LPJ Class J
- JJS Class T



High speed fuses for protecting UPSs and static transfer switches

- Square body
- Cylindrical bolt-on



High SCCR Surge Protective Devices for protection against overvoltage surges

- Type 1 UL Listed
- Type 2 UL Recognized DIN-Rail



High SCCR power distribution blocks for achieving high equipment SCCRs in PDUs and RPPs

- Open versions or finger-safe versions for added safety

8.2 HVAC

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8.2.1 Overview

Air conditioning and refrigeration equipment requirements are covered in Article 440 of the National Electrical Code and UL 1995. Hermetic motor-compressors are not rated in "full load amps" as are standard motors. Instead, different terms are used, such as rated load current, branch circuit selection current, maximum continuous current, minimum circuit ampacity, and maximum overcurrent protection. This equipment has overcurrent protection requirements that differ from that for ordinary motors covered in Article 430.

8.2.2 Branch circuit protection

Individual Motor-Compressor(s) and HVAC Equipment Having Motor-Compressor(s) and Other Loads (Such as fan motors, electric heaters, coils, etc.).

Fuses sized for branch circuit protection only must not exceed 175% of the hermetic motor-compressor rated load current or branch circuit selection current (whichever is larger). If this size fuse cannot withstand the motor starting current, a higher amp rating is permitted, but in no case can the fuse size exceed 225% [440.22(A)].

Low-Peak™ and Fusetron™ dual-element fuses are recommended for branch circuit protection of air conditioning and refrigeration hermetic motor-compressors because these fuses have an adequate time-delay for motor starting surges.

Refer to the nameplate on the equipment. The sizing (amp rating) for the overcurrent protection has been determined by the manufacturer of the equipment. It is not necessary to apply any further multipliers to arrive at the proper size. This has already been done by the manufacturer. The marked protective device rating is the maximum protective device rating for which the equipment has been investigated and found acceptable by nationally recognized testing laboratories.

See "Listed or Labeled Equipment" for requirement when nameplate states Maximum Size Fuse. This is a critical requirement, and must be followed without exception to be in compliance with 110.3(B) of the Code. NEC 110.3(B) requires that listed or labeled equipment must be installed in accordance with any instructions included in the listing or labeling.

8.2.3 Individual hermetic motor compressor

The amp rating of the disconnect must be at least 115% of the compressors rated load current or branch circuit selection current, whichever is greater [440.12(A)(1)]. 440.12(A)(1) Exception permits a non-fused disconnect rated less than 115% of the specified current if this disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(A)(2).

The equivalent horsepower rating to comply with 430.109 can be obtained by taking the larger horsepower value from: (1) NEC Tables 430.248, 430.249 or 430.250 using the greater of either the rated load current or the branch circuit selection current to select the corresponding horsepower rating, or (2) horsepower rating from Tables 430.251(A) and 430.251(B) corresponding to the locked-rotor current. For both preceding (1) and (2), if the value falls between two horsepower ratings in a table, the equivalent horsepower rating to use is the larger of the two; i.e., round up to the larger Hp. [440.12(A)(2)].

8.2.4 Hermetic motor-compressor and other loads

The amp rating of the disconnecting means must be at least 115% of the sum of all of the individual loads within the equipment at rated load conditions [440.12(B)(2)]. 440.12(B)(2) Exception permits a non-fused disconnect rated less than 115% of the sum of all the individual loads if the disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(B)(1).

The horsepower rating of the disconnecting means must be at least equal to the equivalent horsepower determined per 440.12(B)(1) which accounts for all the individual loads with the equipment at rated load conditions.

8.2.5 Controller

The controller for a hermetic motor-compressor must have a continuous duty full load current rating not less than the nameplate rated current or branch circuit selection current (whichever is larger) [440.41] and the controller must also have a locked rotor current rating equal to or greater than the locked rotor current of the compressor [440.41(A)]. Where the controller serves a hermetic motor-compressor(s) plus other loads, the controller rating is determined according to 440.12(B), in much the same manner as determining the disconnecting means rating. It may be necessary to refer to Tables 430.251(A) and (B) to convert locked rotor current values to horsepower.

The branch circuit protective device rating must not exceed the maximum protective device rating shown on a manufacturer's heater table for use with a given motor controller [440.22(C)]. Where the equipment is marked Maximum Size Fuse amp rating rather than stating Maximum Overcurrent Device amp rating, only fuses can be used for the branch circuit protection.

8.2.6 Short-Circuit Current Rating (SCCR)

The 2017 NEC introduced SCCR requirements for HVAC equipment. Section 440.10, "Short-Circuit Current Rating," is separated into two first level sub-divisions. The first, (A) "installation," reminds the NEC user of the already existing requirement found in 110.10 that motor controllers of multi-motor and combination-load equipment must not be installed where the available short-circuit current exceeds its short-circuit current rating. The new requirement found in the second first level sub-division (B) titled "Documentation," is a marking requirement for this equipment. This section requires the following:

"(B) Documentation. When motor controllers or industrial control panels of multi-motor and combination load equipment are required to be marked with a short-circuit current rating, the available short circuit current and the date the short circuit current calculation was performed shall be documented and made available to those authorized to inspect the installation."

440.4(B) Requires the nameplate of this equipment to be marked with its short-circuit current rating. There are exceptions for which this requirement does not apply:

- One and two family dwellings
- Cord and attachment-plug connected equipment

So for most commercial and industrial applications, air conditioning and refrigeration equipment with multi-motor and combination loads must have the short-circuit current rating marked on the nameplate.

The enforcement process for SCCR includes three key steps:

1. **Ratings:** Each power distribution system component and assembly that carries current, other than an overcurrent protective device, will have an SCCR. Those solutions that are listed will more often than not include a requirement as part of the listing marking requirements to be marked with the SCCR rating.
2. **Fault current:** The available short-circuit current at the electrical equipment in question must be known.
3. **Compare:** An evaluation must be conducted to ensure that the SCCR is greater than or equal to the available fault current at the equipment.

The requirements added as part of the 2017 version of the NEC provide the necessary information and guidance for the proper application of this equipment. A potential hazard exists where the available fault current exceeds the short-circuit current rating.

8.2.7 Room air conditioners

Room air conditioners (hermetic refrigerant motor-compressor) installed in the conditioned room are considered as single-motor units when the conditions of 440.62 are met. This condition also applies to conditioners containing a heating unit. Branch circuit requirements are determined by nameplate rating (440.62).

Because of all the fires caused by mistreated cords, single-phase cord-and-plug connected room air conditioners are now required to have either an AFCI (arc-fault circuit interrupter) or a LCDI (leakage current detection and interruption) attached to the plug.

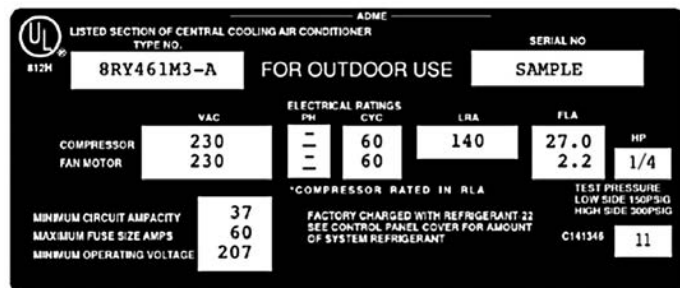


Figure 8.2.7.a

8.2.8 Electric heat

Electric space heating equipment employing resistance type heating elements, rated more than 48 A, must have heating elements subdivided. Each subdivided load must not exceed 48 A, and the fuse for each load should not exceed 60 A (Reference 422.22.(B)). If a subdivided load is less than 48 A, the fuse rating should be 125% of that load.

Exception: Boilers employing resistance type immersion electric heating elements in an ASME rated and stamped vessel may be subdivided into circuits not exceeding 120 A, and protected by a fuse at not more than 150 A (Ref. 424.22(B) and 424.72(A)). If a subdivided load is less than 120 A, the fuse rating should be 125% of that load.

Fusetron™ dual-element fuses in the sizes required above provide protection for electric heat applications (their lower internal resistance offers cooler operation than ordinary fuses.)

Non-time delay (fast-acting) Limitron™ fuses (JJN and JJS) in the sizes required above provide protection for electric heat applications and offer small physical size to reduce space material cost.

8.2.9 2017 NEC SCCR requirements

The 2017 NEC dealing with HVAC equipment and SCCR is found in Chapter 4 Equipment for General Use, Article 440 Air-Conditioning and Refrigeration Equipment, Part I. General.

There was a revision to 440.4 Marking on Hermetic Refrigerant Motor-Compressors and Equipment, 440.4(B) Multi-motor and Combination-Load Equipment.

The significance of this code change concerns multi-motor and combination-load hermetic refrigeration equipment rated 60 amps or less.

- Previous editions of the NEC exempted this equipment's nameplate from being marked with its short-circuit current rating (SCCR). This exception has been removed.
- Now, this type of equipment must have its short-circuit current rating marked on its nameplate, the same as all other HVAC equipment in 440.4(B).

Marking the nameplate with the short-circuit current rating as required by 440.4(B) ties in with 440.10(A) and 440.10(B).

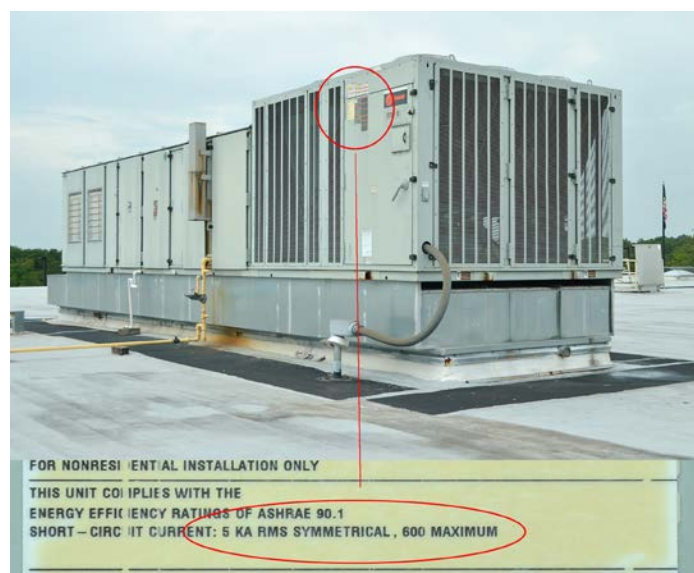


Figure 8.2.9.a HVAC units cannot be installed where the available short-circuit current is greater than the equipment SCCR. The unit above would be a Code violation if installed at "HVAC Rooftop — North" as summarized in the report shown in Figure 8.2.9.b.

The 2017 NEC contains a new requirement found in 440.10 Short-Circuit Current Rating, 440.10(A) Installation and 440.10(B) Documentation.

The significance of this addition covers calculating and documenting short-circuit current and prohibiting equipment installation if its SCCR is less than the available fault current at point of installation.

With a few exceptions, 440.4(B) already requires that air conditioning and refrigeration, multi-motor and combination-load equipment be marked with their SCCR.

If the equipment is required to be marked with an SCCR, now:

- **New 440.10(B)** — the available short-circuit current must be calculated, documented and made available to the inspector along with the date the calculation was made.
- **New 440.10(A)** — the equipment must not be installed if its SCCR is not equal to or greater than the available short-circuit current (see the example summary in Figure 8.2.9.b).

The specifications provided to the HVAC original equipment manufacturer need to include the minimum required SCCR.

If consulting engineers are involved, coordination between the electrical and mechanical engineering departments should be made so that the specified minimum acceptable equipment SCCR is greater than the available short-circuit current.

Summary of Short-Circuit Current Study for Ernest Operations, Inc., January, 23, 2017

By Fred Byrd

The calculations are on the pages following this summary table

Equipment Designation	Available Short-Circuit Current amps rms sym.
Service Equipment	45,340
Motor Control Center 1	30,600
Motor Control Center 2	26,780
Distribution Panel - North	15,345
Distribution Panel - South	36,070
Industrial Control Panel 1	16,290
HVAC Rooftop — North	13,700
HVAC Rooftop — South	9,980
Panelboard 1	17,460
Panelboard 2	8,440
Panelboard 3	15,050
Panelboard 4	36,745

Figure 8.2.9.b This example summary table report documents the available short-circuit current for HVAC — North. The SCCR must be equal to or greater than the available short-circuit current.

What to look for:

- All hermetic refrigerant motor-compressors and equipment subject to 440.4(B) is manufacturer nameplate marked with their SCCR, including equipment rated less than 60 amps.
- Available short-circuit current and documentation is provided to inspector.
- Do not install nor approve equipment installation if the SCCR is less than the available short-circuit current.

8.3 Photovoltaic systems

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8.3.1 Overview

Photovoltaic (PV) systems convert the energy from the sun to usable electrical power. In most cases, system components include the following:

- **Solar cells:** The solar cell is the basic PV system component that generates electricity when exposed to light.
- **Modules:** These are complete, environmentally protected units that consist of solar cells, optics and other components designed to generate DC power when they are exposed to light. Modules do not consist of trackers.
- **Panels:** A PV panel is a collection of modules that are mechanically fastened and wired together, and designed to provide a field installable unit.
- **Inverters:** The inverter converts DC voltage generated by the PV modules to usable AC voltage.
- **Balance of system (BoS):** Combiner boxes, conductors, overcurrent protection devices, disconnect switches, mounting brackets, and various accessories that connect from the DC source to AC system or DC source to DC utilization system.

Larger PV systems may also contain transformers to change the AC voltage levels to the desired levels.

There are five basic types of solar photovoltaic systems:

- Interactive system
- AC module system
- DC coupled multi-mode system
- AC coupled multi-mode system
- Stand-alone system

Stand-alone systems supply power independent of any other electrical power source. Interactive systems operate in parallel with another electrical power source such as being connected to an electrical utility system. An interactive system may also supply electric power to the production or distribution network. Hybrid systems include other power sources, such as wind and hydroelectric generation.

There are various overcurrent protection needs and requirements for different parts of the PV system. This section is an introductory discussion of the various PV systems with many of the overcurrent protection requirement considerations.

See Figure 8.3.a. The basic power-generating component of a solar photovoltaic system is the solar cell. In order to generate useful levels of power, groups of cells are combined to form modules. Modules are then grouped into panels, and several panels form a solar array. A photovoltaic power source can consist of one or more arrays.



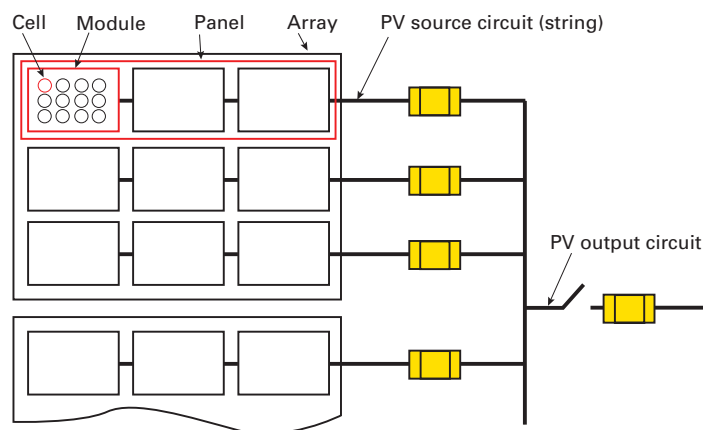


Figure 8.3.a

8.3.2 Unique PV considerations

8.3.2.1 Direct Current (DC) vs. Alternating Current (AC)

For the OCPD and any other type of device that must stop the flow of current, DC systems present challenges that AC systems do not. DC currents are more difficult to interrupt. For disconnects and overcurrent protective devices, arcs that are generated from opening DC currents are generally more difficult to extinguish than the arcs generated from disconnecting AC currents. This is because DC systems have no zero crossings in the waveform. Fuses and circuit breakers and other disconnecting devices leverage the zero crossing when interrupting AC currents. Special care must be taken to ensure products are listed for the installation in the system in which they are applied.

8.3.2.2 Product standards

Photovoltaic system solutions must be listed to standards put together specifically for this unique application. The following is a list of key standards in this space.

- UL 1741 Inverters, Converters, Controllers, and Interconnection System for Use with Distributed Energy Resources
- UL 2579 Low-Voltage Fuses — Fuses for Photovoltaic Systems: DC rated fuses which have performance criteria suitable for the high temperature extremes under cyclic load conditions experienced in the DC PV source circuits (such as combiner boxes) and in the DC PV output circuits (such as recombiner boxes or at the inverter).

Listed UL 2579 fuses will be evidenced by a listing mark on the fuse. These fuses will be marked with one of the following:

- Letters "PV"
- Letters "gPV"
- Text "Photovoltaic Fuse" Disconnects



Figure 8.3.2.a

- UL 248 Class fuses: Fuses with general industry DC ratings for use in other portions of DC PV system not subject to the harsh environment that the source and output circuits must endure.
- UL 98B Enclosed and Dead-Front Switches for use in Photovoltaic Systems, for fusible and non-fusible switches for DC PV applications.

8.3.2.3 Fault conditions

The maximum fault current generated by a PV source (I_{sc} , short-circuit current), is generally 110% to 115% of its max power current ratings. Refer to individual PV module specifications for the exact value of I_{sc} .

This is quite different from the conventional AC system supplied by utility or on-site generators. However, parts of photovoltaic systems may have to withstand higher short-circuit currents as many systems have storage battery banks which can deliver substantial short-circuit current. Also, if the system is connected to a conventional electrical distribution system fed by a utility, short-circuit current can be substantial.

8.3.2.4 Environmental conditions

There can be harsh temperatures, extreme temperature cycling, wind, and humidity considerations with PV systems.

Operating temperature variations are typically specified from -40°C to 85°C. As ambient temperature decreases (assuming the same sunlight intensity), the maximum power delivery of the PV modules increases. This is evidenced by the negative temperature coefficient of the maximum power of the modules typically at -0.5%/°C.

8.3.2.5 System voltages

The typical PV system DC voltage ratings are 600 V or less, 1000 V and 1500 V. The overcurrent protective device PV DC voltage ratings for these systems are 600 Vdc, 1000 Vdc, and 1500 Vdc. The trend in the PV industry is towards higher DC and AC voltages as transmission of power becomes more efficient at these higher voltages.

8.3.2.6 System grounding

PV systems can be negative ground, positive ground, center ground, or ungrounded. From a circuit protection stand-point, there are no differences between negative or positive grounding. In a grounded system, the ungrounded conductor legs are fused. Ungrounded systems utilize an isolated array where neither of the array poles are grounded. In an ungrounded system, both positive and negative legs are fused. See NEC 690.35 for more information.

8.3.3 Maximum system voltages

Proper OCPD selection must include consideration given to maximum voltage of the system. The voltage of any given PV system will be determined by the connection of PV modules. The maximum voltage of a PV system is determined by the highest voltage between any two circuit conductors or any conductor and ground. The maximum voltage is used to determine the voltage rating of conductors, cables, disconnects, overcurrent devices, and other equipment in the PV system.

The NEC establishes maximum voltages allowed for a few different types of installations.

- On or in one- and two- family dwellings: 600 V or less.
- On or in other than dwellings: 1000 V or less
- PV systems not located on or in buildings: 1500 V or less and are not required to comply with parts II and III of Article 490.

8.3.3.1 PV Source and output circuits

There are three methods that can be used to determine the maximum PV source and output circuit voltage. The designer must take into consideration ambient temperatures in which the PV system is installed as they play an important role in the system's maximum voltage — when ambient temperatures get colder the panel's voltage will increase. The NEC offers a source for lowest-expected ambient as part of an Informational Note to 690.7(A). The ASHRAE Handbook — Fundamentals, 2013 has a chapter titled "Extreme Annual Mean Minimum Design Dry Bulb Temperature" that can be referenced when determining maximum system voltages. There are other references that can be used when approved by the authority having jurisdiction (AHJ).

- a. Module instructions — Voltage in the system is determined by the voltage of each PV module connected in series. For a given string of PV modules connected in series, add each PV module-rated open-circuit voltage for the maximum voltage. The instructions from each module manufacturer will include instruction for correcting the voltage based upon the lowest expected ambient temperature. Open-circuit voltage temperature coefficients should be used in accordance with the instructions included in the listing or labeling of the module.
- b. Crystalline and multi-crystalline modules — The maximum voltage is determined by adding each PV module's rated open-circuit voltage of series-connected modules. The open-circuit voltage of each module must be corrected for the lowest expected ambient temperature through leveraging correction factors provided in NEC Table 690.7(A). This table offers correction factors for ambient temperatures below 25°C (77°F). They are used by multiplying the rated open-circuit voltage by the correction factor that corresponds to the ambient temperature. The multiplying factors range from 1.02x for temperatures from 20°C to 25°C (68°F to 76°F) to 1.25x for temperatures from -36°C to -40°C (-32°F to -40°F). The maximum voltage is increased as temperature decreases up to a maximum of 1.25 times the rated open-circuit voltage of the modules.
- c. PV systems of 100 kW or larger — The maximum voltage can be determined by a licensed engineer who has documented plans that have been stamped with a PE license. Recognized industry standards are permitted to be used. A recognized industry standard method for calculating maximum voltage of a PV system is published by Sandia National Laboratories; reference SAND 2004-3535, Photovoltaic Array Performance Model. (<http://prod.sandia.gov/techlib/access-control.cgi/2004/043535.pdf>.)

8.3.3.2 DC-to-DC converter source and output circuits

DC-to-DC converters are used in a variety of applications ranging from computer power supplies to DC motor drives. In this case, a DC-to-DC converter is a device installed in the PV source circuit or PV output circuit that can provide an output DC voltage and current at a higher or lower value than the input DC voltage and current. These devices take in unregulated DC voltages and produce as an output regulated DC voltages. They maximize the energy harvest for photovoltaic systems and for wind turbines, and are often called power optimizers. For obvious reasons for PV, these devices are gaining popularity. The value they provide include but are not limited to the following:

- Each PV panel works at its maximum power point
- Different PV panels can be connected at the same DC link voltage
- Using isolated DC-DC converters allows independent grounding of each PV panel
- Possibility of PV panel disconnection in case of fire

When these devices are utilized in PV systems in the source and output circuit, the maximum voltage is calculated based on one of the following:

- a. Single DC-to-DC converter — The maximum voltage is the maximum rated voltage output of the DC-to-DC converter
- b. Two or more series connected DC-to-DC converters — The maximum voltage is determined in accordance with manufacturer instructions. Typically the maximum voltage is determined by adding the rated output voltages of each DC-to-DC converter connected in series.

8.3.3.3 Bipolar source and output circuits

Bipolar PV arrays are those that have two outputs, each having opposite polarity to a common reference point or center tap. These types of installations are not commonly used today but were popular prior to 2002.

The maximum voltage for these systems is the highest voltage between the 2 wire circuit conductors where one conductor of the 2 wire circuit is connected to the functional ground reference (center tap). Special precautions are required to be taken to prevent overvoltage in the event of a ground-fault or arc-fault.

8.3.4 Maximum circuit currents

The current produced by PV modules is unique. Current in these systems is limited and directly affected by the intensity of sunlight. PV modules are listed with short-circuit current (I_{sc}) and maximum power current (I_{mp}). The short-circuit current values are used for conductor sizing.

The NEC addresses maximum current calculations based upon the location in the circuit separating the focus into six different locations including the following:

1. PV Source circuit
2. PV Output circuit
3. Inverter output circuit
4. Stand-alone inverter output circuit
5. DC-to-DC converter source circuit
6. DC-to-DC output circuit

One must understand the location in the PV system in order to determine which section of the NEC to use to calculate the maximum circuit currents. Each of these areas are discussed here.

8.3.4.1 PV Source circuits

PV source circuits are those circuits between modules and from modules to the common connection points of the DC system. These circuits will be the beginning point for circuit current calculations.

PV systems with generating capacity < 100 kW — Add together the parallel connected PV module rated short-circuit currents and multiply by 1.25. This 1.25 multiplier accounts for the increased irradiance and the PV module's ability to produce more than its rated current. A single string of modules that has an I_{sc} value of 9.2 A each would have a maximum current calculated as $1.25 \times 9.2 \text{ A} = 18.4 \text{ A}$.

PV systems with generating capacity = 100 kW — The amount of current produced by PV source circuits can be determined for PV systems with a generating capacity of 100 kW or greater as part of a documented and PE stamped PV system design that uses an industry standard method. The calculated maximum current value as part of this study must be based on the highest 3-hour current average resulting from simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method is not permitted to be less than 70 percent of the sum of parallel connected PV module rated short-circuit currents multiplied by 1.25. The NEC offers one recognized industry standard method for calculating maximum current of a PV system, Sandia National Laboratories; reference SAND2004-3535, Photovoltaic Array Performance Model.

8.3.4.2 PV output circuits

PV output circuits are the result of combining various strings of PV modules. There are no additional multiplying factors necessary as the maximum current is calculated by adding all of the parallel source circuit maximum currents.

8.3.4.3 Inverter output circuits

The technology of the inverter makes it such that the maximum current is the inverter continuous output current rating which is obtained from the inverter nameplate.

8.3.4.4 Stand-alone inverter input circuit

The maximum current is the stand-alone continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.

8.3.4.5 DC-to-DC converter source circuit

The DC-to-DC source circuit conductors could either be those between DC-to-DC converters or those from the DC-to-DC converter to the common connection point of the DC system. The technology of the DC-to-DC converter makes it such that the maximum current is the DC-to-DC converter continuous output current rating.

8.3.4.6 DC-to-DC converter output circuit

The DC-to-DC output circuit are the circuit conductors between the DC-to-DC converter and the inverter or DC utilization equipment. The maximum current is the sum of parallel connected DC-to-DC converter source circuit currents as calculated in 690.8(A)(5).

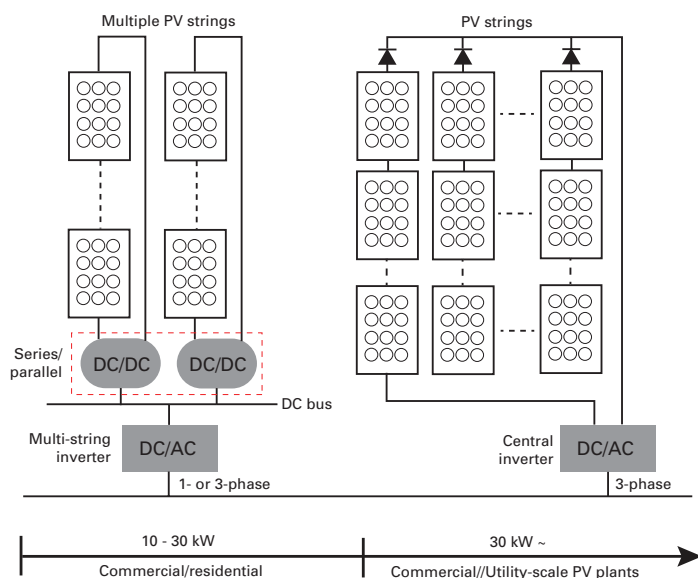
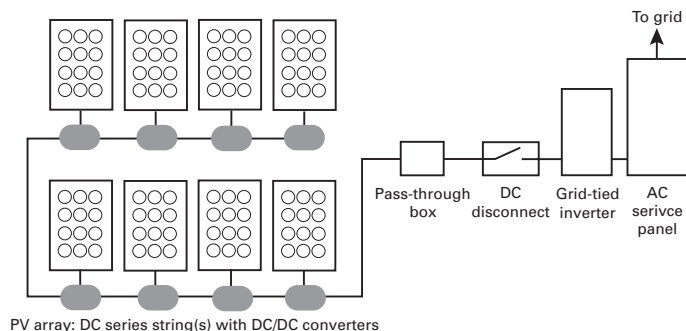


Figure 8.3.6.a

8.3.5 PV Conductors

8.3.5.1 Selection

PV systems are covered by Article 690 but must still comply with the requirements of chapters 1 to 4 as these chapters apply generally to all electrical installations. Temperature rating as well as dry and wet location ratings for conductors are important ratings for those conductors used in PV installations due to their location.

Since PV modules operate at elevated temperatures and are exposed to a variety of environmental conditions, the insulation of the module interconnection conductors is required to be sunlight resistant and rated for wet locations at a 90°C temperature rating or above. PV applications leverage USE-2 wire and conductors designed specifically for PV applications. The UL Standards used for investigating USE-2 wire (TYLZ) and PV wire (ZKLA) are UL 854 Service-Entrance Cables and UL Subject 4703 Outline for Photovoltaic Wire, respectively.

The use of USE-2 wire is limited in its application for PV systems but has been a popular choice for PV module interconnections. PV wire was introduced as part of the 2008 version of the NEC. The construction and performance requirements for USE-2 and PV wire are similar except for some key attributes that make PV wire more appropriate for these installations.

- PV wire has a 90°C wet rating and up to 150°C dry rating and is typically used for interconnecting PV modules.
- USE-2 wire is designated as underground service entrance cable typically for connecting to the terminals of service equipment. It is limited to installations in maximum 90°C wet and dry conditions.
- USE-2 wire is rated 600 V
- PV wire can be rated 1000 V and 2000 V to accommodate photovoltaic modules intended for use in systems with a system voltage greater than 600 V
- USE-2 wire is suitable for use in grounded PV arrays only but PV wire can be used within both grounded and ungrounded PV arrays
- USE-2 minimum conductor size is 14 AWG
- PV wire minimum conductor size is 18 AWG
- PV and USE-2 wire uses thermoset insulation and jacket typically made of XLPE or EPCV
- PV wire uses an additional 15 mils of 90°C wet and dry rated integral PVC insulation and jacket

In general, PV wire comes with a thicker insulation or jacket which provides additional mechanical protection against the physical abuse that PV installations present. PV wire also employs stranded copper conductors to make it flexible enough for the intended application.

8.3.5.2 Conductor ampacity

PV system currents are considered continuous. The minimum conductor size must be at least the larger conductor size as determined by the two following methods:

1. **Before application of adjustment and correction factors** — The minimum conductor size must have an ampacity that is 125% of the maximum circuit current as calculated in section 9.3.3 of this handbook before adjustment or correction factors. The conductor selected would be based on the following
 - a. Circuit amps of 1.25 x the maximum circuit current
 - b. Table 310.15(B)(16)
 - c. Section 110.14

The temperature correction factors of 310.15(B)(2) and the adjustment factors of 310.15(B)(3) should not be considered.

As an example, if the maximum circuit current is calculated to be 60 A, the following is used to determine the minimum size conductor:

- a. Circuit amps = 1.25 x 60 A = 75 A
- b. Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) is a 6 AWG copper conductor.
- c. If it is assumed that the equipment termination is 90°C, the value determined as part of (b) of 6 AWG above is accurate. If the equipment is 75°C rated, the proper size conductor would have to be increased to a 4 AWG copper conductor per 110.14.

2. **After applying adjustment and correction factors** — The minimum conductor size must have an ampacity sufficient to accommodate the maximum current calculated as part of 7.7.8 in this handbook after the application of adjustment and correction factors. This method does not apply 125% to the calculated value of maximum circuit current.

As an example, if the maximum circuit current is calculated to be 60 A and the conductors are in a raceway with 6 current carrying conductors and the conductors are in an ambient temperature of 120°F, the following would be used to determine the minimum size conductor for this application:

a. Circuit amps = maximum circuit amps = 60 A

b. Adjustment factor: From Table 310.15(B)(3)(a), the adjustment factor for 6 current carrying conductors in a raceway is 80%. The adjustment circuit amps is calculated as follows:

$$\text{Circuit amps} = 60 \text{ A} \div 0.8 = 75 \text{ A}$$

c. Correction factor: The ambient temperature of this installation is beyond the 90°C rating of the conductor. The 0.82 correction factor is obtained from 310.15(B)(2)(a) based on an ambient of 120°F and a conductor insulation rating of 90°C. The new circuit amps is calculated as follows: (note the adjustment is made in addition to the correction factor applied in (b) above.)

$$\text{Circuit amps} = 75 \text{ A} \div 0.82 = 91.46 \text{ A}$$

d. Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) to carry 91.46 A is a 4 AWG copper conductor.

e. If the equipment is rated 90°C, the value determined as part of (d), 4 AWG above is accurate. If the equipment is rated 75°C, the proper size conductor would have to be increased to a 3 AWG copper conductor.

For the examples presented here, the conductor size for this specific application would be the largest determined by the above two methods which is a 3 AWG copper conductor.

In some applications, the source circuit conductor sizing may be more dependent upon voltage drop considerations. Source conductor ampacity selected at the minimum permitted by 690.8(B) for long length source circuits may result in unacceptable voltage drops. For long length source circuits, the source conductor may be sized to minimize voltage loss and as a result the chosen conductor ampacity is greater than the minimum conductor ampacity per 690.8(B).

8.3.6 Overcurrent protective device selection

Once the conductor is selected as per section 8.3.5 of this document, the overcurrent protective device can be selected to protect the conductor at its ampacity. PV systems are unique in that there are instances when overcurrent protective devices are not required. When the circuits have enough ampacity for the highest available current, overcurrent protection is not required. If no OCPD is provided, there must not be any external sources such as parallel-connected source circuits, batteries or backfeed from inverters. The short-circuit currents from all sources must not exceed the ampacity of the conductors and the maximum overcurrent protective device size rating specified for PV modules or DC-to-DC converters.

8.3.6.1 OCPD rating selection

The minimum size for an OCPD can either be 100% or 125% of the maximum calculated currents. If the OCPD is 100% of the maximum currents calculated in 8.3.4, the OCPD and the equipment within which it resides must be 100% rated. The use of adjustable electronic overcurrent protective devices that are rated or set in accordance with 240.6 of the NEC are also permitted. Care should be exercised when applying electronic circuit breakers as their use may be limited in that they cannot safely handle backfeed current.

The maximum size of an OCPD is dependent upon the ampacity of the conductor selected or equipment within which it is located. It is the requirement of 690.9 of the NEC that PV system DC circuit and inverter output conductors and equipment must be protected against overcurrents.

8.3.6.2 Listing requirements

All overcurrent protective devices used in PV systems must be listed for use in PV systems. Reference 8.3.2.2 for details on proper OCPD listings.

8.3.6.3 Backfeed current

Care must be taken when applying OCPDs and switches to ensure they are applied within their rating when it comes to safety interrupting / breaking current flowing in either direction through the device. Some switches and circuit breakers may not be permitted to be applied in an application where they could be called upon to interrupt or break current flowing in more than one direction. If these devices are labeled "Line" and "Load," they're not permitted to be applied in applications where they could experience backfeed current. (Reference 690.13(F)(2))

8.3.7 PV Disconnecting means

The ampacity of DC fusible PV switches must be equal to or greater than the fuse ampacity. The ampacity of DC non-fused PV switches must be equal to or greater than 1.25 times the maximum circuit current. In all cases, switches must have an interrupting rating suitable for the nominal DC circuit voltage and fault current available at the switch line terminals.

If a fuse is energized from both directions, a means to disconnect (isolate) the fuse from all sources of supply is required (690.16 (A)). While the phrase "disconnecting means" is used, the second paragraph of 690.16(B) makes it clear that it is actually isolation that is required. Isolation can be accomplished by either a load-break disconnecting means, or by a non-loadbreak fuse holder such as the CHPV1 PV modular DIN-Rail fuse holder. Non-load-break disconnecting (isolating) means must be marked "Do not open under load."

Fuses in source circuits must be able to be isolated independently of fuses in other source circuits.

Fuses on PV output circuits must also have disconnecting means (isolation) so that they can be isolated from all energized sources (690.16(B)). A disconnecting (isolation) means must be within sight of the fuses, readily accessible, externally operable, not allow the operator to be exposed to live parts, clearly show whether it is in the open or closed position, and have an interrupting rating sufficient for the application. If the disconnecting or isolating means is more than 6 feet from the fuses, a directory is to be posted at the fuses showing the location of the disconnecting (isolating) means.

8.3.8 Overvoltage protection

The unique nature of PV installations makes these electrical systems vulnerable to overvoltages and surges from lightning strikes and static discharges. These surges need to be intercepted before they take down the entire PV system by damaging the PV components such as the arrays, charge controller, inverter, or combiner boxes.

These voltage protective devices are called Surge Protective Devices (SPDs) and are normally placed in every PV electrical enclosure such as combiner boxes, re-combiner boxes, inverters, and chargers.

8.3.9 Connecting to other sources

Most PV systems will ultimately interconnect with an infrastructure's power distribution system. NEC Article 705 "Interconnected Electric Power Production Sources" is the reference when installing one or more electric power production sources operating in parallel with a primary source of electricity. When connecting to premise wiring, the PV system is operating in parallel with the utility.

The point of connection is permitted to either be on the supply side of the service disconnecting means or the load side of the service disconnecting means.

8.3.9.1 Supply side connection

When an interconnected power production source, such as a PV system or a wind system, is connected to the supply side of the service disconnect, the conductors connecting this system must have overcurrent protection within 10 feet of their connection to the service conductors/bus. Normally, an AC disconnect with overcurrent protection can be installed within the 10 foot limit. If however this disconnect with overcurrent protection is not installed within 10 feet of the connection point, then it is permitted to use cable limiters (or a current-limiting circuit breaker) to connect the Interconnected Electric Power Production source (normally a PV system or wind system) ahead of the service disconnect/overcurrent protection. The cable limiters provide short-circuit protection for these conductors. Installing cable limiters on the supply side of the service disconnect is permitted in 230.82.

8.3.8.2 Loadside connection

When the interconnected power product source is on the loadside of the service disconnecting means, specific requirements must be in place per NEC 705.12(B). When the distribution equipment is fed simultaneously by a primary source of electricity and one or more other power sources, and when this equipment will supply multiple branch circuits or feeders, special requirements must be addressed. These include the following:

- **Dedicated overcurrent and disconnect.** Each source interconnection must be made at a dedicated circuit breaker or fusible switch.
- **Bus or conductor amp rating.** There are special considerations that must be addressed for feeders, taps and busbars as per 705.12(B)(2).
- **Marking requirements.** Each of the overcurrent devices used for the interconnection point must be marked to indicate the presence of all sources.
- **Backfeed considerations.** Circuit breakers, if backfed, must be listed for the application. If marked line and load they cannot be backfed.
- **Fastening requirements.** Section 408.36(D) requires that plug-in type OCPDs that are backfed must be secured in place by an additional fastener that requires other than a pull to release the device from the mounting means on the panel. Section 705.12(B)(5) permits listed plug-in-type circuit breakers that are listed and identified as interactive to omit the additional fastener.

8.3.10 Example PV source and output circuit calculations

Module description:

- Cell type: polycrystalline silicon
- Cell size: 125 mm (5")
- No. of cells and connection: 72 in Series
- Maximum system voltage: 1000 Vdc

Electrical data:

- Maximum power voltage (V_{pm}): 34.6 V
- Open circuit voltage (V_{oc}): 43.1 V
- Maximum power current (I_{pm}): 5.31 A
- Short-circuit current (I_{sc}): 5.90 A

Reference Figure 8.3.10.a for system configuration/location information.

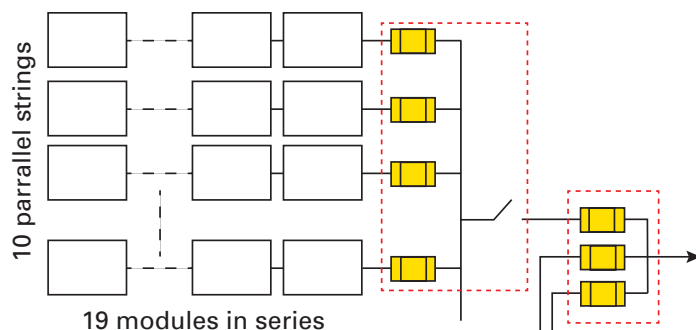


Figure 8.3.10.a

System configuration / location information

- 19 modules per string (in series)
- 10 parallel strings
- -4°F is installation location lowest expected ambient temperature
- 110°F is the installation location maximum expected ambient temperature

8.3.10.1 Maximum system voltage

Maximum voltage is determined by the open circuit voltage of each module multiplied by the number of modules in series and then adjusted based on ambient temperature.

The first step in this process is to determine the maximum voltage based only on the open circuit voltage ratings of the modules as follows:

$$V_{max} = 43.1 \text{ V} \times 19 = 818.9 \text{ V}$$

Next, Table 690.7 must be consulted for the voltage correction factors for the lowest temperature stated which is -4°F. Per this table, the correction factor is 1.18. The maximum PV system voltage is adjusted as necessary as follows:

$$V_{max} = 818.9 \text{ V} \times 1.18 = 966.3 \text{ V}$$

Based on this information, a UL 2579 listed fuse with maximum of 1000 Vdc rating must be used.

8.3.10.2 Source circuit conductor

The source circuit conductors and overcurrent protective device amp rating selection must proceed as per 8.3.5 and 8.3.6.

Calculate maximum source circuit conductor current

The source circuit conductors must be selected based upon the maximum amps of the source circuit and then either the conditions of use or 125% of that value.

The first step is to calculate the maximum circuit ampacity as follows:

$$\text{Max circuit amps} = 1.25 \times I_{sc}$$

Based on the information for this example, the maximum source circuit amps is calculated as follows:

$$\text{Max circuit amps} = 1.25 \times 5.9 \text{ A} = 7.38 \text{ A}$$

PV Conductor selection and ampacity

The conductor can then be selected for this application. The larger of the two must be used:

- Before application of adjustment and correction factors — The conductor selected for each of the 10 strings of PV modules would be based on the following:
 - Circuit amps = $1.25 \times 73.8 \text{ A} = 9.23 \text{ A}$
 - Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) is a 18 AWG copper conductor. This conductor though must be protected by an OCPD that does not exceed 7 A based on 240.4(D)(1). Thus a 16 AWG copper wire would have to be used as this wire is permitted to be protected with an OCPD no greater than 10 A which exceeds the calculated 9.23 A of maximum circuit amps.
 - Since the equipment is rated 90°C, the value determined as part of (b) of 16 AWG above is accurate.
- After applying adjustment and correction factors, the conductor selected for each of the 10 strings of PV modules would be based on:
 - Circuit amps = maximum circuit amps = 73.8 A
 - Adjustment factor: There are no adjustment factors necessary based on the description of this application.
 - Correction factor: The ambient temperature of this installation is beyond the 90°C rating of the conductor. The correction factor of 0.87 is obtained from 310.15(B)(2)(a) based on an ambient of 110°F and a conductor insulation rating of 90°C. The new circuit amps is calculated as follows: (note the adjustment is made in addition to the correction factor applied in (b) above.)

$$\text{Circuit amps} = 73.8 \text{ A} \div 0.87 = 8.48 \text{ A}$$
 - Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) to carry 8.48 A is a 18 AWG copper conductor. This conductor though must be protected by an OCPD that does not exceed 7 A based on 240.4(D)(1). Thus a 16 AWG copper wire would have to be used as this wire is permitted to be protected with an OCPD no greater than 10 A which exceeds the calculated 9.23 A of maximum circuit amps.
 - Since the equipment is rated 90°C, the value determined as part of (d) of 16 AWG above can be used.

For the examples presented here, the conductor size for this specific application would be the largest determined by the above two methods which is a 16 AWG copper conductor.

OCPD Selection

The minimum size for this OCPD is 125% of the 73.8 A maximum current or 9.23 A. The next size OCPD is permitted to be chosen which is 10 A.

The maximum size of the OCPD is dependent upon the selected conductor's ampacity, which in this case is a 16 AWG conductor. The maximum size OCPD for a 16 AWG conductor protection based on 240.4(D)(2) is 10 A.

The fuse for this application would be a 10 A PV fuse rated for a maximum voltage of 1000 V.

8.3.10.3 Output circuit maximum amps

The output circuit conductors and overcurrent protective device amp rating selection must proceed as per 8.3.5 and 8.3.6.

Calculate maximum output circuit conductor current

The output circuit maximum amps is the total source circuit amps calculated based on the number of strings in this system. Each string as per 8.3.4 has a maximum circuit current of 73.8 A. This installation has 10 parallel strings so the maximum output circuit current is calculated as:

$$\text{Max output circuit current} = 73.8 \text{ A} \times 10 = 73.8 \text{ A}$$

PV Conductor selection and ampacity

The conductor can then be selected for this application. The larger of the two must be used:

- Before application of adjustment and correction factors — The conductor selected for the output circuit that is comprised of a total of 10 strings of PV modules would be based on the following:
 - Circuit amps = $1.25 \times 73.8 \text{ A} = 92.25 \text{ A}$
 - Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) is a 4 AWG copper conductor.
 - Since the equipment is rated 90°C, the value determined as part of (b) of 4 AWG above is accurate.
- After application of adjustment and correction factors — The conductor selected for each of the 10 strings of PV modules would be based on the following:
 - Circuit amps = maximum circuit amps = 73.8 A
 - Adjustment factor: There are no adjustment factors necessary based on the description of this application.
 - Correction factor: The ambient temperature of this installation is beyond the 90°C rating of the conductor. The correction factor of 0.87 is obtained from 310.15(B)(2)(a) based on an ambient of 110°F and a conductor insulation rating of 90°C. The new circuit amps is calculated as follows: (note the adjustment is made in addition to the correction factor applied in (b) above.)

$$\text{Circuit amps} = 73.8 \text{ A} \div 0.87 = 84.83 \text{ A}$$
 - Based on 90°C insulation, the minimum size conductor from Table 310.15(B)(16) to carry 84.83 A is a 4 AWG copper conductor.
 - Since the equipment is rated 90°C, the value determined as part of (d) of 4 AWG above can be used.

For the examples presented here, the conductor size for this specific application would be the largest determined by the above two methods which is a 4 AWG copper conductor.

OCPD Selection

The minimum size for this OCPD is 125% of the 73.8 A maximum current or 92.25 A. The next size OCPD is permitted per 240.4(B) to be chosen which is 100 A.

The maximum size of the OCPD is dependent upon the ampacity of the conductor selected which is in this case is a 4 AWG conductor. The maximum size OCPD for a 4 AWG conductor is 100 A. If a larger size conductor is used for voltage drop considerations a larger OCPD is permitted to be used the maximum size dependent upon the size of the conductor selected.

The fuse for this application would be a 100 A PV fuse rated for a maximum voltage of 1000 V.



8.3.11 PV solutions

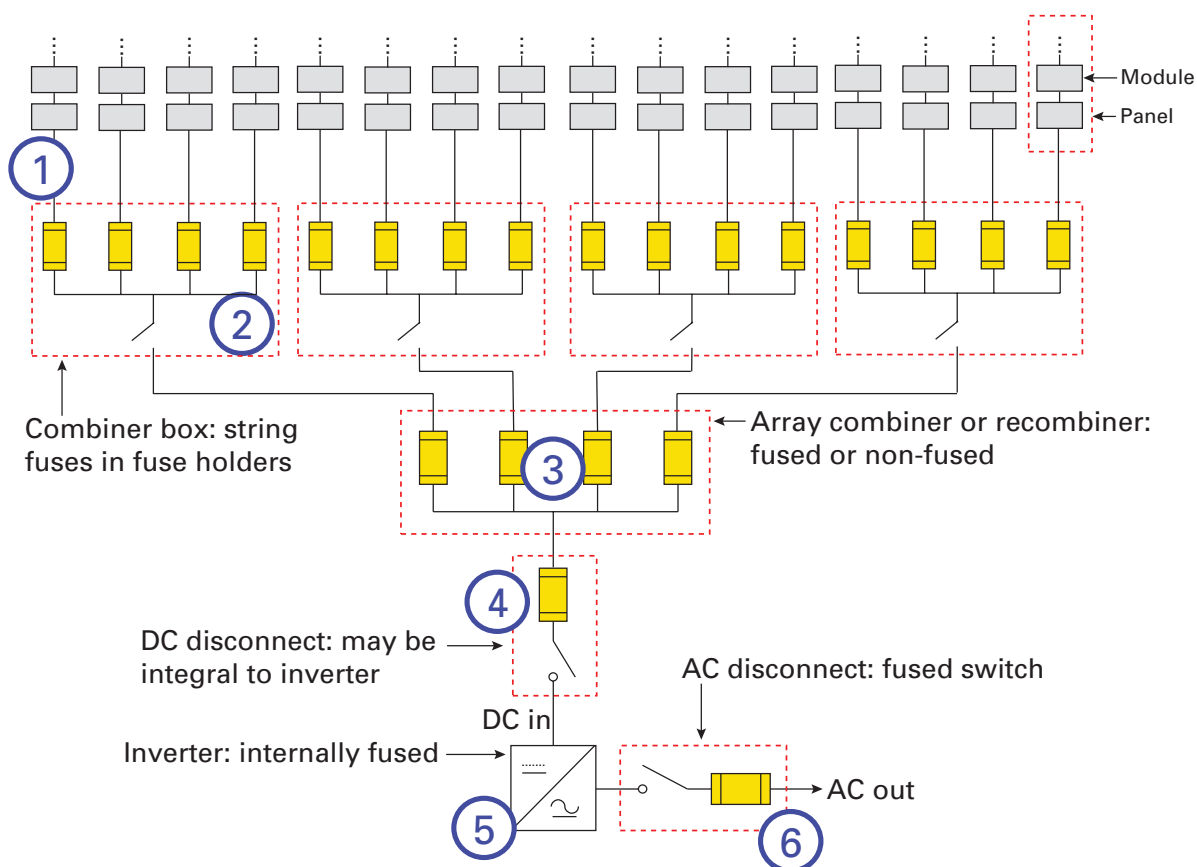


Figure 8.3.11.a Generalized PV system one-line diagram.

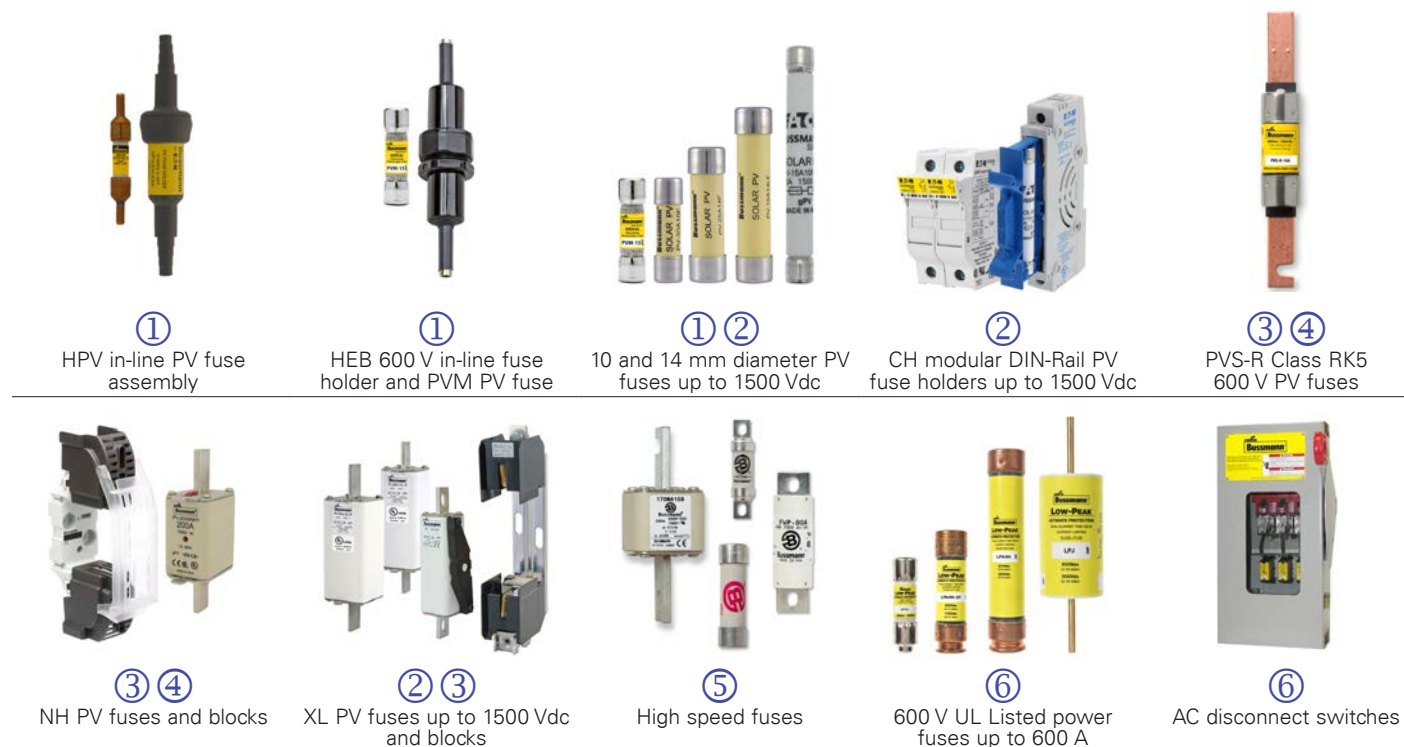


Figure 8.3.11.b Bussmann series products for protecting PV systems.

8.4 Fuse application in hazardous locations

Based upon the NEC

The various atmospheric characteristics of hazardous gases, vapors and dusts depend on the specific hazardous material involved. Therefore, it's necessary that equipment be identified not only for the location class, but also for the specific gas, vapor or dust that will be present (500.5).

Class I Division 1

Fuses located in Class I Division 1 locations are required to be provided with enclosures that are identified as a complete assembly for use in Class I locations [501.115(A)].

Class I Division 2

Fuses located in Class I Division 2 locations should be selected based upon the application and enclosure type. Only certain fuse types are permitted to be used in general purpose enclosures. 501.105(B)(5), 501.115(B)(3) and 501.115(B)(4) address the fuse use in Class I Division 2 locations. (See Figure 8.4.c).

- Any plug or cartridge type fuse, as allowed by NEC Chapters 1 through 4, is suitable for protecting motors, appliances and lamps, provided the fuse is installed in an enclosure identified for the location.
- Fuses for the protecting motors, appliances and lamps installed in general purpose enclosures must also meet one of the following:
 - They are non-indicating, filled and a current-limiting type. Many Bussmann series fuses meet this criteria (See Figure 8.4.a and Table 8.4.b)
 - They are the type in which the element is immersed in oil or other approved liquid. Bussmann series fuses are not available in this product type.
 - The element is hermetically sealed against gases and vapors. Bussmann series fuses are not available in this product type.
- Fuses protecting meters, instruments and relays can be any plug or cartridge type if they meet these installation criteria:
 - In a circuit not subject to overloading
 - On the switch loadside and complying with 501.105(B)(1)
- Fuses installed in a luminaire and used as supplemental protection can be any listed cartridge type.

There are so many variables governing proper fuse selection for use in general purpose enclosures, the quickest and most appropriate choice is a current-limiting, non-indicating, filled fuse. This fuse type is suitable for all applications mentioned above so the chance for misapplication is minimized. In addition, a rejection style fuse will help ensure only the proper fuse type is installed in the future. For 30 A and less power or control applications, the Bussmann series Class CC fuses meet the criteria. (See Figure 8.4.a.)

Class II and Class III

Class II, Division 1: Fuses must be provided with enclosures identified for the location [502.115(A)].

Class II, Division 2: Fuses must be provided with enclosures that are dust-tight or otherwise identified for the location [502.115(B) and 502.135(B)(3)].

Class III: Fuses must be provided with dust-tight enclosures [503.115].



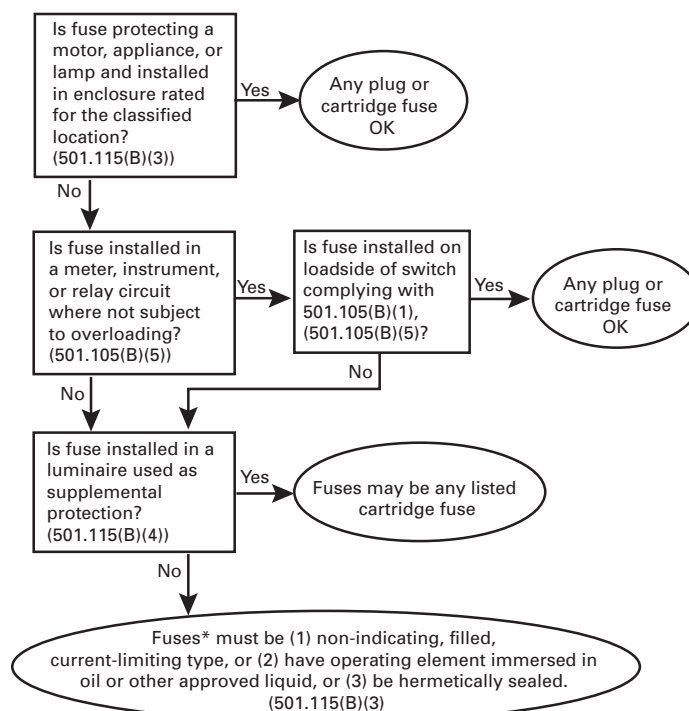
Figure 8.4.a Bussmann series non-indicating, filled, current-limiting fuses.

UL fuse class	Catalog symbols/amps
CC	LP-CC, KTK-R, FNQ-R* up to 30 A
CF	TCF, FCF up to 100 A
T	JJN up to 1200 A, JJS up to 800 A
J	LPJ, JKS up to 600 A
G	SC up to 60 A
RK1	KTN-R, KTS-R 1 - 600 A, LPN-RK-SP* 3-1/2 to 6-1/4 and 70-600 A, LPS-RK-SP* 65-600 A
RK5	FRN-R 3-1/2 to 7-1/2 and 225-600 A, FRS-R** 65-600 A
L	KRP-C-SP, KTU 601-6000 A, KLU 601-4000 A

* Fuses from July 1996 or date code C28 to present only.

**Fuses from October 1997 or date code D40 to present only

Table 8.4.b How to verify a fuse as current-limiting. 600 V or less current-limiting fuses are listed, and marked "current-limiting."



* For the protection of motors, appliances and lamps installed in general purpose enclosures

Figure 8.4.c NEC Article 501, fuses for use in Class I Division 2 locations.

9 Appendix

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9.1 Electrical formulas

To find	Single-phase	Two-phase	Three-phase	Direct current
Amps when kVA is known	$\frac{kVA \times 1000}{E}$	$\frac{kVA \times 1000}{E \times 2}$	$\frac{kVA \times 1000}{E \times 1.73}$	Not applicable
Amps when horsepower is known	$\frac{Hp \times 746}{E \times \% \text{ eff.} \times pf}$	$\frac{Hp \times 746}{E \times 2 \times \% \text{ eff.} \times pf}$	$\frac{Hp \times 746}{E \times 1.73 \times \% \text{ eff.} \times pf}$	$\frac{Hp \times 746}{E \times \% \text{ eff.}}$
Amps when kilowatts are known	$\frac{kW \times 1000}{E \times pf}$	$\frac{kW \times 1000}{E \times 2 \times pf}$	$\frac{kW \times 1000}{E \times 1.73 \times pf}$	$\frac{kW \times 1000}{E}$
Kilowatts	$\frac{I \times E \times pf}{1000}$	$\frac{I \times E \times 2 \times pf}{1000}$	$\frac{I \times E \times 1.73 \times pf}{1000}$	$\frac{I \times E}{1000}$
Kilovolt-amperes	$\frac{I \times E}{1000}$	$\frac{I \times E \times 2}{1000}$	$\frac{I \times E \times 1.73}{1000}$	Not applicable
Horsepower	$\frac{I \times E \times \% \text{ eff.} \times pf}{746}$	$\frac{I \times E \times 2 \times \% \text{ eff.} \times pf}{746}$	$\frac{I \times E \times 1.73 \times \% \text{ eff.} \times pf}{746}$	$\frac{I \times E \times \% \text{ eff.}}{746}$
Watts	$E \times I \times pf$	$I \times E \times 2 \times pf$	$I \times E \times 1.73 \times pf$	$E \times I$
Energy efficiency		$\frac{\text{Load horsepower} \times 746}{\text{Load input kVA} \times 1000}$		
Power factor (pf)	$\frac{\text{Power consumed}}{\text{Apparent power}}$	$= \frac{W}{VA}$	or $\frac{kW}{kVA}$	$= \cos \theta$

Where:

I = Amps

E = Volts

Hp = Horsepower

kVA = Kilovolt-amperes

kW = Kilowatts

pf = Power factor

% eff. = Percent efficiency

9.2 Glossary of common electrical terms

Ampere (amp) — The measurement of intensity of rate of flow of electrons in an electrical circuit. An amp is the amount of current that will flow through a resistance of one ohm under a pressure of one volt.

Amp rating — The current-carrying capacity of a fuse. When a fuse is subjected to a current above its amp rating, it will open the circuit after a predetermined period of time.

Amp squared seconds, I^2t — The measure of heat energy developed within a circuit during the fuse's clearing. It can be expressed as "Melting I^2t ", "Arcing I^2t " or the sum of them as "Clearing I^2t ". "I" stands for effective let-through current (RMS), which is squared, and "t" stands for time of opening, in seconds.

Arcing time — The amount of time from the instant the fuse link has melted until the overcurrent is interrupted, or cleared.

Breaking capacity — (See Interrupting rating)

Cartridge fuse — A fuse consisting of a current responsive element inside a fuse tube with terminals on both ends.

Class CC fuse — 600 V, 200 kA amp interrupting rating, branch circuit fuses with overall dimensions of 13/32" x 1-1/2". Their design incorporates a rejection feature that allows them to be inserted into rejection fuse holders and fuse blocks that reject all lower voltage, lower interrupting rating 13/32" x 1-1/2" fuses. They are available from 1/10 through 30 amps.

Class CF fuse — A finger-safe UL Listed branch circuit rated fuse. Available in time-delay or fast-acting versions, the Class CF fuse has Class J electrical performance and is available in ratings from 1 to 100 A in 30, 60 and 100 A case sizes.

Class G fuse — A size rejecting branch circuit fuse in ratings from 1/2 through 20 amps (600 Vac) and 25 through 60 amps (480 Vac) with a 100 kA interrupting rating. The size rejecting feature helps to eliminate overfusing. The fuse diameter is 13/32" while the length varies from 1-5/16" to 2-1/4".

Class H fuse — 250 V and 600 V, 10 kA interrupting rating branch circuit fuses that may be renewable or non-renewable. These are available in ratings from 70 through 600 amps.

Class J fuse — These rejection style fuses are rated to interrupt a minimum of 200 kA AC. They are labeled as "current-limiting", are rated for 600 Vac and are not interchangeable with other classes. They are available from 1 through 600 amps.

Class K fuses — These are fuses listed as K-1, K-5, or K-9 fuses. Each subclass has designated I^2t and I_m maximums. These are dimensionally the same as Class H fuses, and they can have interrupting ratings of 50 kA, 100 kA, or 200 kA. While these fuses are current-limiting, they are not marked "current-limiting" on their label since they do not have a rejection feature.

Class L fuse — These fuses are rated for 601 through 6000 amps, and are rated to interrupt a minimum of 200 kA AC. They are labeled "current-limiting" and are rated for 600 Vac. They are intended to be bolted into their mountings and are not normally used in clips. Some Class L fuses have designed-in time-delay features for all purpose use.

Class R fuse — These are high performance fuses rated 1/10 through 600 amps in 250 V and 600 V ratings. All are marked "current-limiting" on their label and all have a minimum of 200 kA interrupting rating. They have identical outline dimensions with the Class H fuses but have a rejection feature that prevents the user from mounting a fuse of lesser capabilities (lower interrupting capacity) when used with special Class R Clips. Class R fuses will fit into either rejection or non-rejection clips.

Class T fuse — An industry class of 300 V and 600 V fuses in ratings from 1 through 1200 amps (300 V) and 1 through 800 amps (600 V). They are physically very small and can be applied where space is at a premium. They are fast-acting fuses, with an interrupting rating of 200 kA RMS.

Classes of fuses — The industry has developed basic physical specifications and electrical performance requirements for fuses with voltage ratings of 600 V or less. These are known as standards. If a type of fuse meets the requirements of a standard, it can fall into that class. Typical UL branch circuit fuse classes are CC, CF, G, H, J, K, L, RK1, RK5 and T.

Clearing time — The total time between the beginning of the overcurrent and the final opening of the circuit at rated voltage by an overcurrent protective device. Clearing time is the total of the melting time and the arcing time.

Current limitation — A fuse operation relating to short-circuits only. When a fuse operates in its current-limiting range, it will clear a short-circuit in less than 1/2 cycle. Also, it will limit the instantaneous peak let-through current to a value substantially less than that obtainable in the same circuit if that fuse were replaced with a solid conductor of equal impedance.

Dual-element fuse — A fuse with a special design that utilizes two individual-elements in series inside the fuse tube. One element, the spring actuated trigger assembly, operates on overloads up to 5 - 6 times the fuse current rating. The other element, the short-circuit section, operates on short-circuits up to its interrupting rating.

Electrical load — The part of the electrical system that actually uses the energy or does the work required.

Fast-acting fuse — A fuse that opens on overload and short-circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads, when sized near the full load current of the circuit.

Fault current — Fault currents can be short-circuit currents, ground fault currents or arcing fault currents.

Fuse — An overcurrent protective device with a fusible link that operates and opens the circuit on an overcurrent condition.

High speed fuse — A fuse with no intentional time-delay in the overload range and designed to open as quickly as possible in the short-circuit range. These fuses are often used to protect solid-state devices.

Inductive load — An electrical load which pulls a large amount of current — an inrush current — when first energized. After a few cycles or seconds, the current "settles down" to the full-load running current.

Interrupting rating — The rating which defines a fuse's ability to safely interrupt and clear short-circuits. This rating is much greater than the amp rating of a fuse. The NEC defines interrupting rating as "The highest current at rated voltage that an overcurrent protective device is intended to interrupt under standard test conditions."

Melting time — The amount of time required to melt the fuse link during a specified overcurrent. (See arcing time and clearing time.)

“NEC” Dimensions — These are dimensions once referenced in the NEC. They are common to Class H and K fuses and provide interchangeability between manufacturers for fuses and fusible equipment of given amp and voltage ratings.

Ohm — The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one amp to flow under a pressure of one volt.

Ohm’s Law — The relationship between voltage, current, and resistance, expressed by the equation $E = IR$, where E is the voltage in volts, I is the current in amps, and R is the resistance in ohms.

One time fuse — Generic term used to describe a Class H non-renewable cartridge fuse, with a single-element.

Overcurrent — Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short-circuit or ground fault. (Ref. NEC Article 100.)

Overload — Operation of equipment in excess of normal, full load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short-circuit or ground fault, is not an overload. (Ref. NEC Article 100.)

Peak let-through current, I_p — The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Renewable fuse (600 V and below) — A fuse in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards.

Resistive load — An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS current — The RMS (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating affect in the resistance as the periodic current does.

Semiconductor fuse — Fuses used to protect solid-state devices. See “high speed fuse.”

Short-circuit — Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit – it takes a “short cut” around the load and back to the source.

Short-circuit current rating (SCCR) — This term applies to components (single devices) and assemblies (equipment). For the component, it is the maximum fault current it can sustain without the occurrence of excessive damage. For equipment, it is the assembly’s rating, generally limited by the lowest component SCCR in the circuit as determined by an approved method such as UL 508A, Supplement SB.

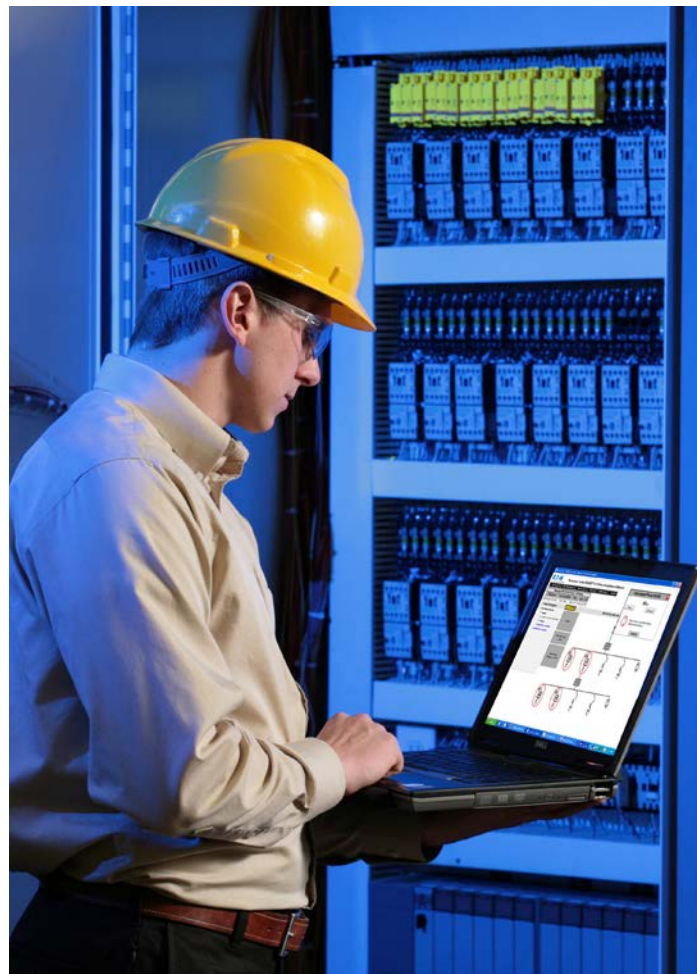
Short-circuit withstand — The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage. Typically applies to devices or components that do not have a marked short-circuit current rating, such as conductors, transfer switches or semiconductor devices.

Single-phasing — The condition that occurs when one phase of a three-phase system opens, either in a low voltage (secondary) or high voltage (primary) distribution system. Primary or secondary single-phasing can be caused by any number of events. This condition results in unbalanced currents in polyphase motors and unless protective measures are taken, may cause overheating and failure.

Threshold current — The symmetrical RMS (root mean square) available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off a peak let-through chart where the fuse curve intersects the A—B line. A threshold ratio is the relationship of the threshold current to the fuse’s continuous current rating.

Time-delay fuse — A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Voltage rating — The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an overcurrent. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.



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9.3 SELECTIVE COORDINATION INSPECTION FORM

This form provides documentation to ensure compliance with the following 2017 NFPA 70, National Electrical Code® requirements for selective coordination found in Articles **100, 620, 645, 695, 700, 701 and 708**.

JOB #: _____ NAME: _____

LOCATION: _____ FIRM: _____

COMPLIANCE CHECKLIST**1. Selective Coordination Definition — Article 100**

“Coordination (Selective). The localization of an overcurrent condition to **restrict outages** to the circuit or equipment affected, **accomplished by the selection and installation** of overcurrent protective devices and their ratings or settings for the **full range of available overcurrents**, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents.”

2. Verify Selective Coordination Requirements**Article 620 — Elevators, Dumbwaiters, Escalators, Moving Walkways, Wheelchair Lifts and Stairway Chair Lifts**

620.62 Selective Coordination. Requires the overcurrent devices in each disconnecting means to be selectively coordinated with any other supply sided overcurrent protective devices where more than one driving machine disconnecting means is supplied by a single feeder.

YES NO N/A
☐ ☐ ☐

Article 645 — Information Technology Equipment

645.27 Selective Coordination. Requires critical operations data system(s) overcurrent devices to be selectively coordinated with all supply-side overcurrent protective devices.

YES NO N/A
☐ ☐ ☐

Article 695 — Fire Pumps

695.3(C) Multibuilding Campus-Style Complexes.

(3) Selective Coordination. Requires the overcurrent protective device(s) in each disconnecting means to be selectively coordinated with any other supply-side overcurrent protective device(s).

YES NO N/A
☐ ☐ ☐

Article 700 — Emergency Systems

700.32 Selective Coordination. Requires emergency systems overcurrent devices to be selectively coordinated with all supply-side overcurrent protective devices.

YES NO N/A
☐ ☐ ☐

Article 701 — Legally Required Standby Systems

701.27 Selective Coordination. Requires legally required standby system(s) overcurrent devices to be selectively coordinated with all supply-side overcurrent protective devices.

YES NO N/A
☐ ☐ ☐

Article 708 — Critical Operations Power Systems (COPS)

708.54 Selective Coordination. Requires critical operations power system(s) overcurrent devices to be selectively coordinated with all supply-side overcurrent protective devices.

YES NO N/A
☐ ☐ ☐

3. Verify Selective Coordination Documentation**Per 620.62, 700.32, 701.27 and 708.54**

Selective coordination is required to be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection must be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

YES NO N/A
☐ ☐ ☐

Note: Documentation can include short-circuit study, time-current curves, manufacturer selective coordination tables and required types, ratings and settings of overcurrent protection devices to achieve selective coordination.

Signature: _____

Date: _____

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9.4 INTERRUPTING RATING AND SHORT-CIRCUIT CURRENT RATING INSPECTION FORM

Page 1 of 3

This form provides documentation to ensure compliance with the following 2017 NFPA 70, National Electrical Code® requirements for interrupting ratings, short-circuit current ratings and the marking requirements for available fault current found in Articles **100, 110, 230, 409, 430, 440, 620, 670, 700, 701, 702, 705 and 708**.

JOB #: _____ NAME: _____

LOCATION: _____ FIRM: _____

COMPLIANCE CHECKLIST

Several sections in the Code require proper interrupting rating of overcurrent protective devices and short-circuit current ratings of equipment. In addition to the requirements listed below, other equipment, such as panelboards, switchboards, busway, motor control centers, disconnects, automatic transfer switches and fire pump controllers should be verified for proper short-circuit current ratings in accordance with NEC 110.3(B) and 110.10 as shown below.

1. Interrupting Rating and Short-Circuit Current Rating Definition — Article 100

Interrupting Rating. The highest current at rated voltage that an overcurrent protective device is intended to interrupt.

Short-Circuit Current Rating. The maximum fault current that equipment or components can sustain without the occurrence extensive damage.

2. Verify Proper Interrupting Ratings, Short-Circuit Current Ratings and Available Fault Current Marking

Article 110 — Requirements for electrical installation

110.3(B) Installation and Use. Requires listed or labeled equipment to be installed and used in accordance with any instructions included in the listing or labeling	YES ☐	NO ☐	N/A ☐

110.9 Interrupting Rating. Requires equipment intended to interrupt current at fault levels to have an interrupting rating at nominal voltage sufficient for current available at the line terminals of the equipment.	YES ☐	NO ☐	N/A ☐

Note: See NEC 240.86(B) for permitted use of series rated combinations in new installations, provided motor contribution limits per 240.86 are not exceeded and equipment is field marked in accordance with 110.22(C).

110.10 Circuit Impedance, Short-Circuit Current Ratings, and Other Characteristics. Requires equipment to have a short-circuit current rating equal to or greater than the available fault current so that the selected overcurrent protective device can clear a fault without extensive damage to the electrical equipment in the circuit.	YES ☐	NO ☐	N/A ☐

110.24 Available Fault Current.

(A) Field Marking. Requires service equipment in other than dwelling units to be legibly marked in the field with the maximum available fault current and the date of calculation. The calculation must be documented and made available to those authorized to design, install, inspect, maintain or operate the system

YES ☐	NO ☐	N/A ☐

(B) Modifications. Requires the maximum available fault current to be verified or recalculated as necessary to ensure the service equipment ratings are sufficient for the maximum available fault current at the line terminals of the equipment when modifications to the electrical installation occur that affect the maximum available fault current at the service. The required field marking(s) in 110.24(A) must be adjusted to reflect the new level of maximum available fault current.

YES ☐	NO ☐	N/A ☐

Article 230 — Services

230.82(3). Requires meter disconnect switches to have a short-circuit current rating sufficient for the available short-circuit current.	YES ☐	NO ☐	N/A ☐

Article 409 — Industrial control panels

409.110(4). Requires the marking of the short-circuit current rating of the industrial control panel based on one of the following:

a. Short-circuit current rating of a listed and labeled assembly

YES ☐	NO ☐	N/A ☐

b. Short-circuit current rating established utilizing an approved method

YES ☐	NO ☐	N/A ☐

Exception to (4): Marking of the short-circuit current rating is not required for industrial control panels containing only control circuit components.

409.22 Short-Circuit Current Rating.

(A) Installation. Prohibits an industrial control panel from being installed where the available fault current exceeds its marked short-circuit current rating.

YES ☐	NO ☐	N/A ☐

(B) Documentation. Requires the available short-circuit current at the industrial control panel and the date the calculation was performed be documented and made available to those authorized to inspect the installation.

YES ☐	NO ☐	N/A ☐

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9.4 INTERRUPTING RATING AND SHORT-CIRCUIT CURRENT RATING INSPECTION FORM

Page 2 of 3

Article 430 — Motors, Motor Circuits and Controllers			
430.8 Motor Controllers. Requires a motor controller to be marked with the voltage, the current or horsepower rating and the short-circuit current rating.	YES ☐	NO ☐	N/A ☐
430.98(A) Motor Control Centers. Requires the motor control center to be marked with the short-circuit current rating and be plainly visible after installation.	YES ☐	NO ☐	N/A ☐
430.99 Available Fault Current. Requires the available short-circuit current at the motor control center and the date the calculation was performed be documented and made available to those authorized to inspect the installation.	YES ☐	NO ☐	N/A ☐
Article 440 — Air Conditioning and Refrigeration Equipment			
440.4(B) Multimotor and Combination-Load Equipment. Requires multimotor and combination-load equipment to be provided with a visible nameplate marked with the maximum rating of the branch-circuit device, and the short-circuit current rating of the motor controllers or industrial control panel.	YES ☐	NO ☐	N/A ☐
Exception: Marking of the short-circuit current rating is not required for multimotor and combination-load equipment used in one- and two-family dwellings, cord-and attachment-plug-connected equipment.			
440.10 Short-Circuit Current Rating.	YES	NO	N/A
(A) Installation. Prohibits motor controllers of multimotor and combination-load equipment from being installed where the available fault current exceeds its marked short-circuit current rating.	☐	☐	☐
(B) Documentation. Requires the available short-circuit current at the motor controller or industrial control panel of multimotor and combination load equipment and the date the calculation was performed be documented and made available to those authorized to inspect the installation.	YES ☐	NO ☐	N/A ☐
Article 620 — Elevators			
620.16 Short-Circuit Current Rating.			
(A) Marking. Requires the marking of the short-circuit current rating of the elevator control panel based on one of the following:	YES	NO	N/A
a. Short-circuit current rating of a listed and labeled assembly	☐	☐	☐
b. Short-circuit current rating established utilizing an approved method			
(B) Installation. Prohibits an elevator control panel from being installed where the available fault current exceeds its marked short-circuit current rating.	YES ☐	NO ☐	N/A ☐
620.51(D)(2) Available Short-Circuit Current Field Marking. Requires the elevator control panel to be legibly marked in the field with the maximum available fault current at the line terminals and the date of calculation. When electrical system modifications occur that affect the maximum available short-circuit current, the marked value must be verified or recalculated as necessary and labeling adjusted to reflect the new value.	YES ☐	NO ☐	N/A ☐
Article 670 — Industrial Machinery			
670.3(A)(4). Requires the marking of the short-circuit current rating of the machine industrial control panel based on one of the following:	YES	NO	N/A
a. Short-circuit current rating of a listed and labeled assembly	☐	☐	☐
b. Short-circuit current rating established utilizing an approved method			
670.5 Short-Circuit Current Rating.	YES	NO	N/A
(1) Prohibits industrial machinery from being installed where the available short-circuit current exceeds its marked short-circuit current rating.	☐	☐	☐
(2) Requires the industrial machinery to be legibly marked in the field with the maximum available fault current and the date of calculation.	YES ☐	NO ☐	N/A ☐

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9.4 INTERRUPTING RATING AND SHORT-CIRCUIT CURRENT RATING INSPECTION FORM

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Article 700 — Emergency Systems			
700.5(E) Documentation. Requires the short-circuit current rating of the transfer equipment be field marked on the exterior based on the specific overcurrent protective device type and settings protecting the transfer equipment.	YES ☐	NO ☐	N/A ☐
Article 701 — Legally Required Standby Systems			
701.5(D) Documentation. Requires the short-circuit current rating of the transfer equipment be field marked on the exterior based on the specific overcurrent protective device type and settings protecting the transfer equipment.	YES ☐	NO ☐	N/A ☐
Article 702 — Optional Standby Systems			
702.5 Transfer Equipment. Requires the short-circuit current rating of the transfer equipment be field marked on the exterior based on the specific overcurrent protective device type and settings protecting the transfer equipment.	YES ☐	NO ☐	N/A ☐
Article 705 — Interconnected Electric Power Production Sources			
705.16 Interrupting and Short-Circuit Current Rating. Requires consideration of the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.	YES ☐	NO ☐	N/A ☐
Article 708 — Critical Operations Power Systems (COPS)			
708.24(E) Documentation. Requires the short-circuit current rating of the transfer equipment be field marked on the exterior based on the specific overcurrent protective device type and settings protecting the transfer equipment.	YES ☐	NO ☐	N/A ☐

Signature

Date

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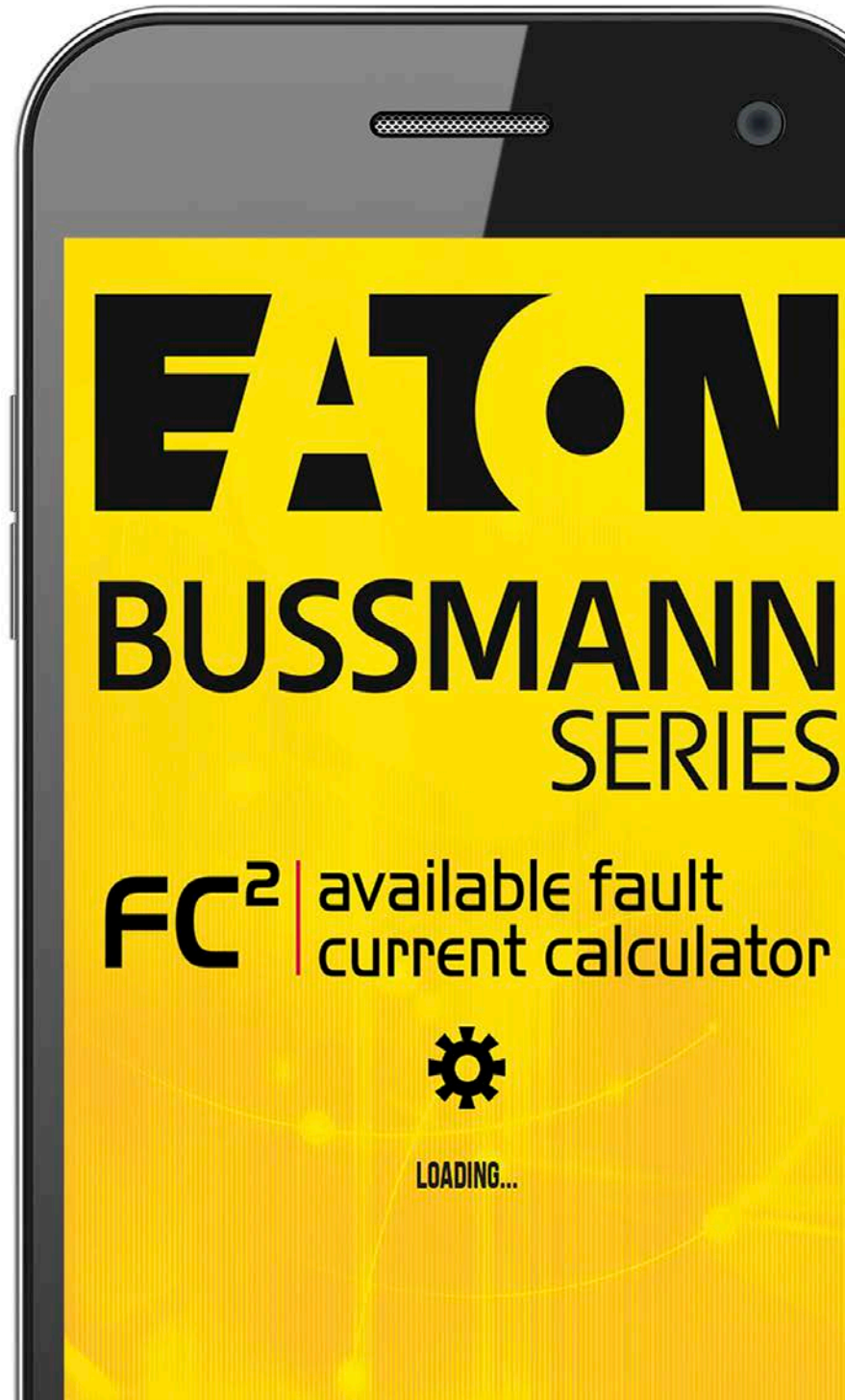
Calculate available fault current anytime, anywhere

Eaton's most popular app, the [Bussmann™ series FC² Available Fault Current Calculator](#), puts available fault current calculations in the palm of your hand.

FC² calculates single- and three-phase system fault current levels and makes point-to-point calculations easy. It also generates NEC® 110.24 compliant labels, one-line diagrams, and documents the calculations. Plus, it features fuse sizing guide for main, feeder and branch circuits.

FC² is free and available for all Apple iPhones, iPads, and Android™ mobile devices. It has English, Spanish and French modes to address local language and equipment marking requirements.

Visit Eaton.com/bussmannseries to learn more or use the web-based version.



Don't miss an opportunity to upgrade your fuse protection

Three tiers offer distinct levels of circuit protection

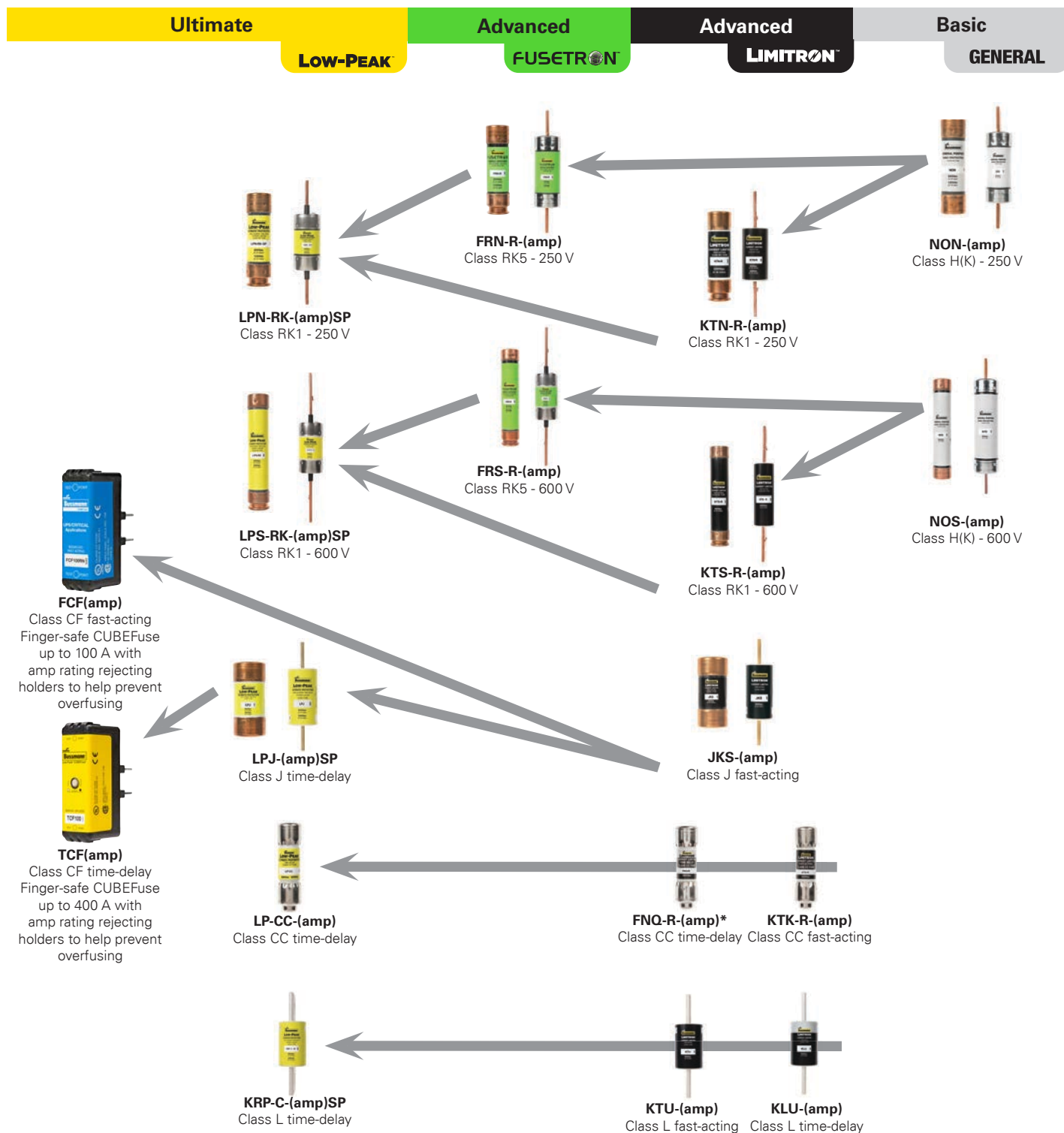
- 1. Ultimate** — Unique element designs deliver a powerful combination of operating characteristics in one fuse — fast short-circuit protection, current limitation, and time-delay with up to 300 kA interrupting ratings.
- 2. Advanced** — Choose between fast-acting, short-circuit, current limiting protection or time-delay energy efficient, current limiting protection based on the application with 200 kA interrupting ratings.
- 3. Basic** — Basic single-element protection for service, feeder and branch circuit applications with up to 100 kA interrupting ratings.

The arrows below show you the way



CUBEFuse™ protection

For finger-safe protection in a small footprint up to 600, upgrade to the time-delay (up to 400 A) or fast-acting (up to 100 A) CUBEFuse. Amp rating rejection feature helps prevent overfusing in the CUBEFuse holder or CCP2-CF UL 98 disconnect switch.



* FNQ-R fuses are suggested on primary of control transformers - do NOT upgrade to LP-CC.

Low-Peak™ Upgrade program and fuse inventory consolidation

The Low-Peak Upgrade program offers superior performance while reducing the number of SKUs that need to be in stock. Bussmann series Low-Peak fuses feature a high degree of current limitation to help provide the superior component protection and help mitigate arc flash hazard.

Listed below are upgrades by branch circuit class. The left column contains catalog symbols for Bussmann series and competitor products. The right column contains the Low-Peak upgrade for consolidating and simplifying inventory.

To find out more about the advantages offered by the Low-Peak Upgrade program, visit Eaton.com/bussmannseries.

This is only a consolidated cross reference of the most common fuses. For a more extensive cross reference for fuses, please visit Eaton.com/bussmannseries/FuseFinder.

250 Volt Class R/H(K)

Fuse symbol	Low-Peak upgrade
A2D	LPN-RK-SP
A2D-R	
A2K	
A2K-R	
A2Y (Type 1)	
AT-DE	
CHG	
CRN-R (Type 3)	
CTN-R	
DEN	
DLN	
DLN-R†	
ECN	
ECN-R	
ERN	
FLN	
FLN-R	
FRN	
FRN-R	
FTN-R	
GDN	
HAC-R	
HB	
KLN-R	
KON	
KTN-R	
LENRK	
LKN	
LLN-RK	
LON-RK	
NCLR	
NLN	
NON	
NRN	
OTN	
REN††	
RFN	
RHN	
RLN	
TR	
655	
660	
10KOTN	
50KOTN	LPN-RK-SP

† Obsolete, must be replaced with a another electrically equivalent fuse.
†† 70 to 600 amp versions obsolete. Must be replaced with a another electrically equivalent fuse.

600 Volt Class R/H(K)

Fuse symbol	Low-Peak upgrade
A6D	LPS-RK-SP
A6K-R	
A6X (Type 1)	
ATS-DE	
CHR	
CTS-R	
DES	
DES-R	
DLS	
DLS-R†	
ECS-R	
ERS	
FLS	
FLS-R	
FRS	
FRS-R	
FTS-R	
GDS	
HA	
KLS-R	
KOS	
KTS-R	
LES	
LES-R	
LES-RK	
LKS	
LLS-RK	
LOS-RK	
NLS	
NOS	
NRS	
OTS	
RES††	
RFS	
RHS	
RLS	
SCLR	
TRS	
TRS-R	
656	
10KOTS	
50KOTS	LPS-RK-SP

† Obsolete, must be replaced with a another electrically equivalent fuse.
†† 70 to 600 amp versions obsolete. Must be replaced with a another electrically equivalent fuse.

Class CC and Midget

Fuse symbol	Low-Peak upgrade
A6Y (Type 2B)	LP-CC
ABU	
AGU	
ATDR	
ATM	
ATMR	
ATQ	
BAF	
BAN	
BLF	
BLN	
CCMR	
CM	
CMF	
CNM	
CNQ	
CTK	
CTK-R	
FLM	
FLQ	
FNM	
FNQ	
GGU	
HCLR	
KLK	
KLK-R	
KTK	
KTK-R	
MCL	
MEN	
MEQ	
MOF	
MOL	
OTM	
TRM	
6JX	LP-CC
*FNQ-R suggested on primary of control transformers.	
ATQR	
FNQ-R	FNQ-R
KLDR	

Class J

Fuse symbol	Low-Peak upgrade
A4J	LPJ-SP
AJT	
CJ	
CJS	
GF8B	
HRCXXJ	
J	
JA	
JCL	
JDL	
JFL	
JHC	
JKS	
JLS	
JTD	LPJ-SP

Class L

Fuse symbol	Low-Peak upgrade
A4BQ	KRP-C-SP
A4BT	
A4BY	
A4BY (Type 55)	
CLF	
CLL	
CLU	
HRC-L	
KLLU	
KLPC	
KLU	
KTU	
L	
LCL	
LCU	KRP-C-SP

The competitive fuse catalog symbols shown were derived from published information for various manufacturers. Because competitive products may differ from Bussmann series products, it is recommended that each selected product be checked for required electrical and mechanical characteristics before substitutions are made. Eaton is not responsible for misapplications of our products.

Overcurrent protection is application dependent. Consult the latest catalogs and application literature, or contact our Application Engineers toll free, 7:00 a.m. to 5:00 p.m. Central time, Monday-Friday at 855-287-7626 (855-BUSSMANN).

Customer satisfaction team:

Available to answer questions regarding Bussmann series products and services Monday-Friday, 7:00 a.m. — 6:00 p.m. Central Time.

- Toll-free phone: 855-287-7626 (855-BUSSMANN)
- Toll-free fax: 800-544-2570
- Email: BussCustSat@Eaton.com

Emergency and after-hours orders:

Next flight out or will call shipment for time-critical needs. Customers pay only standard product price, rush freight charges, and modest emergency service fee. Place these orders through the customer satisfaction team during regular business hours.

- After hours: 314-995-1342

My.Eaton.com:

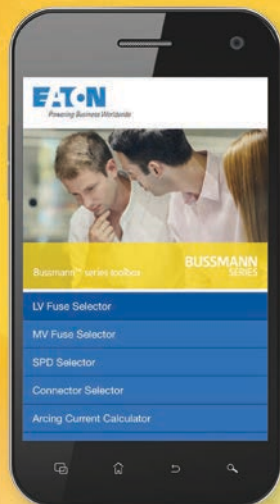
Provides real time product availability, net pricing, order status and shipment tracking. Log onto My.Eaton.com or call:

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Application engineering:

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- Toll-free phone: 855-287-7626 (855-BUSSMANN)
- Email: FuseTech@Eaton.com



Bussmann series toolbox

All the tools you need, in the palm of your hand.

- > FC² Available Fault Current Calculator
- > Arcing Current Calculator
- > Low Voltage Fuse Selector
- > Medium Voltage Fuse Selector
- > Motor Protection Selector
- > Surge Protective Device Selector
- > Connector Selector
- > Competitor Cross Reference
- > Distributor Locator
- > SCCR Protection Suite
- > OSCAR™ 2.1 Online Compliance Software
- > Selective Coordination Designer v1.0
- > RoHS Compliance Product Search

<http://toolbox.bussmann.com>

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