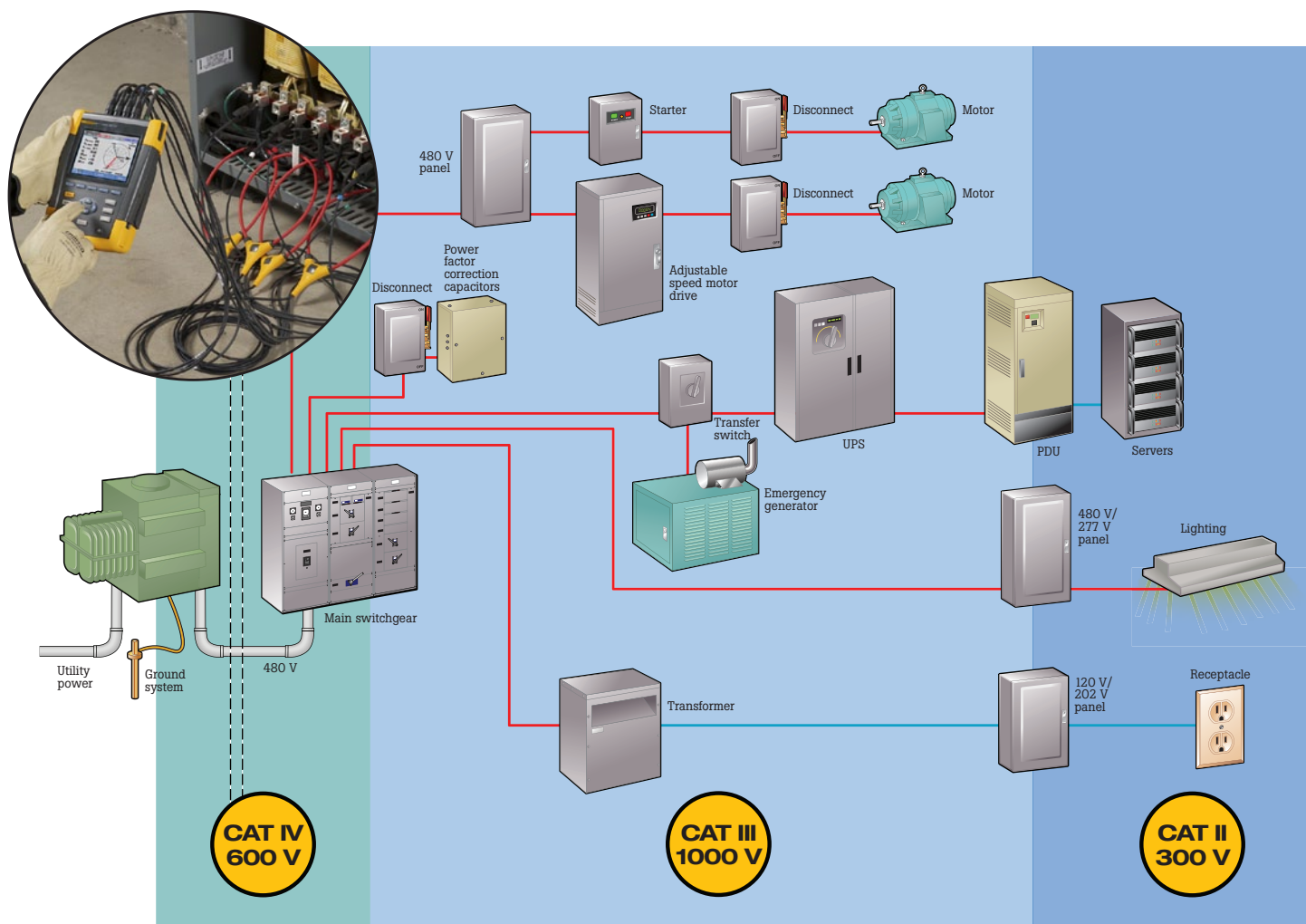


The costs of poor power quality

Application Note

Productivity is the key to survival in today's globally competitive environment. When you think about the basic inputs to production—time, labor, and materials—you can see there isn't much room for optimization. You have 24 hours per day, labor is costly, and you don't have much choice in materials. Thus, every company must use automation to gain more output from the same inputs, or perish.

So, we rely on automation, which in turn relies on clean power. Power quality problems can cause processes and equipment to malfunction or shut down. And the consequences can range from excessive energy costs to complete work stoppage. Obviously, power quality is critical.





The interdependence of various systems adds layers of complexity to power quality issues. Your computers are fine, but the network is down so nobody can book a flight or file an expense report. The process is operating correctly, but the HVAC has shut down and production must stop. Mission-critical systems exist throughout the facility and throughout the enterprise—power quality problems can bring any one of these to a grinding halt at any time. And that will usually be the worst possible time.

Where do power quality problems come from? Most originate **inside the facility**. They may be due to problems with:

- Installation—improper grounding, improper routing, or undersized distribution.
- Operation—equipment operated outside of design parameters.
- Mitigation—improper shielding or lack of power factor correction.
- Maintenance—deteriorated cable insulation or grounding connections.

Even perfectly installed and maintained equipment in a perfectly designed facility can introduce power quality problems as it ages.

The direct measurement of wastes due to poor power quality can be achieved with the Fluke 430 Series II instruments, which directly measure waste due to harmonics and unbalance, and quantify the cost of that waste based on the unit cost of power from the utility.

Power quality problems can also originate from outside the facility. We live with the threat of unpredictable outages, voltage sags, and power surges. Obviously, there's a cost here. How do you quantify it?

Measuring power quality costs

Power quality problems make their effects felt in three general areas: downtime, equipment problems, and energy costs.

Let's walk through an example. Your factory makes 1,000 widgets per hour, and each widget produces \$9 of revenue. Thus, your revenue per hour is \$9,000. If your costs of production are \$3,000 per hour, your operating income is \$6,000 per hour when production is running. When production is down, you lose \$6,000 per hour of income and you still have to pay your fixed costs (e.g., overhead and wages). That's what it costs to be down. But, downtime has other costs associated with it:

- **Scrap.** How much raw material or work in process do you have to throw away if a process goes down?
- **Restart.** How much does it cost to clean up and restart after an unplanned shutdown?
- **Additional labor.** Do you need to pay overtime or outsource work to respond to a downtime incident?

Downtime

To quantify system downtime costs, you need to know two things:

1. The revenue per hour your system produces.
2. The costs of production.

Also, consider the business process. Is it a continuous, fully utilized process (e.g., a refinery)? Must your product be consumed when produced (e.g., a power plant)? Can customers instantly switch to an alternative if the product is not available (e.g., a credit card)? If the answer to any of these questions is yes, then lost revenue is difficult or impossible to recover.

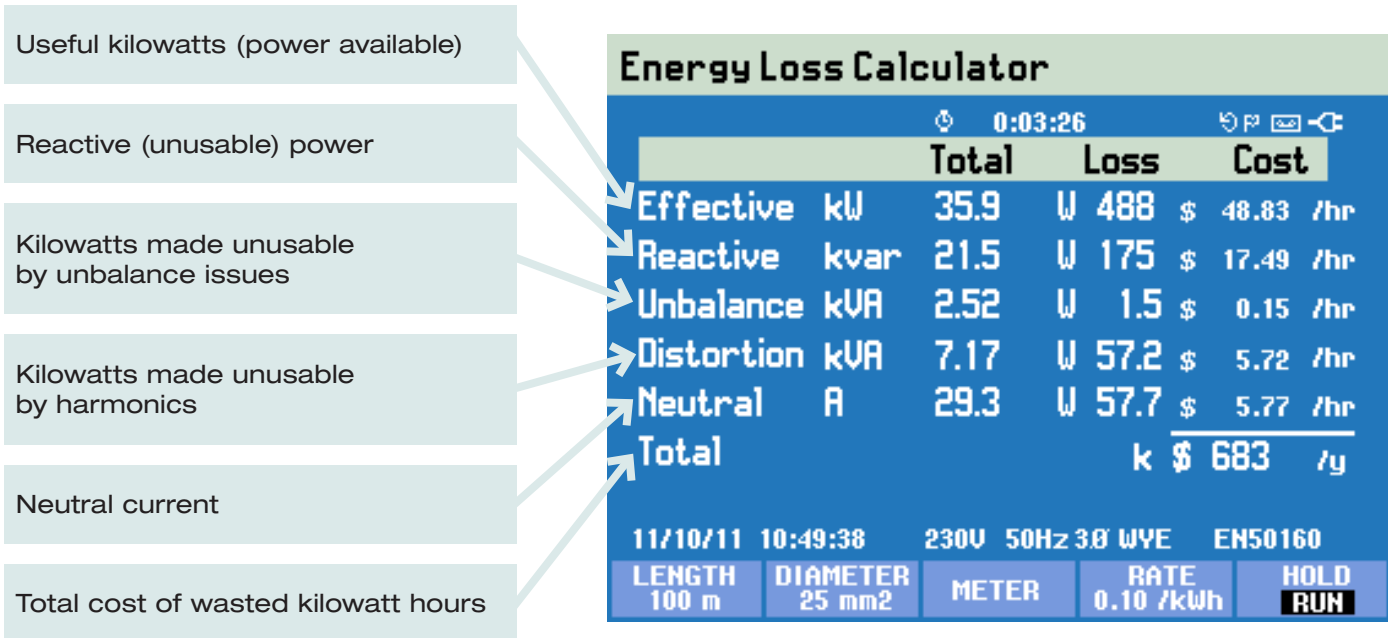
Are you an OEM producer? If you can't make timely deliveries, your customer may switch to a source that can.

Equipment problems

Exact costs are hard to quantify, because you are dealing with many variables. Did that motor really fail from excess harmonics, or was there some other cause? Is Line Three producing scrap because variations in the power supply are causing variations in machine performance? To get the correct answers, you need to do two things:

1. Troubleshoot to the root cause.
2. Determine the actual costs.

Here's an example. Your factory is making plastic webbing that must be of uniform thickness. Operators consistently report high scrap rates in the late afternoon. You can directly trace machine speed variances to low voltage caused by heavy HVAC loads. The operations manager calculates the net scrap costs are \$3,000 per day. That's the revenue cost of your low voltage. But, don't forget other costs, such as those we identified for downtime.



Useful kilowatts (power available)

Reactive (unusable) power

Kilowatts made unusable by unbalance issues

Kilowatts made unusable by harmonics

Neutral current

Total cost of wasted kilowatt hours

Energy costs

To reduce your power bill, you need to record consumption patterns and adjust the system and load timing to reduce one or more of the following.

1. Actual power (kWh) usage
2. Power factor penalties
3. A peak demand charge structure

Until now, capturing the cost of energy waste caused by power quality issues was a task for the most expert engineers. The cost of waste could only be calculated by serious number crunching, a direct measurement of the waste and monetization was not possible. With the patented algorithms used in the Fluke 430 Series II products, waste caused by common power quality issues such as harmonics and unbalance can be measured directly. By inputting the cost of energy in to the instrument the cost is directly calculated.

You can reduce power usage by eliminating inefficiencies in your distribution system. Inefficiency sources include:

- High neutral currents due to unbalanced loads and triplen harmonics.
- Heavily loaded transformers, especially those serving non-linear loads.

- Old motors, old drives, and other motor-related issues.
- Highly distorted power, which may cause excessive heating in the power system.

You can avoid power factor penalties by correcting for power factor. Generally this involves installing correction capacitors. But, first correct for distortion on the system—capacitors can present low impedance to harmonics and installing inappropriate PF correction can result in resonance or burned out capacitors. Consult a power quality engineer before correcting PF if harmonics are present.

You can reduce peak demand charges by managing peak-loading. Unfortunately, many people overlook a major component of this cost—the effect of poor power quality on peak power usage—and thus

underestimate their overpayments. To determine the real costs of peak-loading, you need to know three things:

1. “Normal” power usage
 2. “Clean power” power usage
 3. Peak-loading charge structure
- By eliminating the power quality problems, you reduce the size of the peak demands **and the base from which they start.**

By using load management, you control when specific equipment operates and thus how the loads “stack on top of each other.”

Now your building averages 515 kWh and your peak-load drops to 650 kWh. But, you add load management to move some loads around and now fewer loads stack on top of each other at once—your new peak-load rarely goes beyond 595 kWh.

Let’s walk through an example. Your factory/office complex averages 570 kWh of consumption during the workday, but hits peaks of 710 kWh most days. Your utility charges you for each 10 kWh over 600 kWh for the whole month, any time you exceed 600 kWh during a 15-minute peak measurement window. If you were to correct for power factor, mitigate harmonics, correct for sags, and install a load management system, you would see a different power usage picture—one you can calculate.



Saving money with PQ

You've tallied up the costs of poor power quality. Now, you need to know how to eliminate those costs. The following steps will get you there.

- **Examine design.** Determine how your system can best support your processes and what infrastructure you need to prevent failure. Verify circuit capacity before installing new equipment. Re-check critical equipment after configuration changes.
- **Comply with standards.** For example, examine your grounding system for compliance with IEEE-142. Examine your power distribution system for compliance with IEEE-141.
- **Examine power protection.** This includes lightning protection, TVSS, and surge suppression. Are these properly specified and installed?
- **Get baseline test data on all loads.** This is the key to predictive maintenance, and it allows you to spot emerging problems.
- **Question mitigation.** Mitigating power quality problems includes correction (e.g., grounding repair) and coping (e.g., K-rated transformers). Consider power conditioning and backup power.
- **Review maintenance practices.** Are you testing, then following up with corrective actions? Conduct periodic surveys at critical points—for example, check neutral to ground voltage and ground current on feeders and critical branch circuits. Conduct infrared surveys of distribution equipment. Determine root causes of failures, so you know how to prevent recurrences.
- **Use monitoring.** Can you see voltage distortions before they overheat motors? Can you track transients? If you don't have power monitoring installed, you probably won't see a problem coming—but you will see the downtime it causes.

At this point, you need to determine the costs of prevention and remediation—and then compare those to the costs of poor power quality. This comparison will allow you to justify the investment needed to fix the power quality problems. Because this should be an ongoing effort, use the right tools so you can do your own power quality testing and monitoring rather than outsourcing it. Today, it's surprisingly affordable—and it will always cost less than downtime.

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