SCHEME :K

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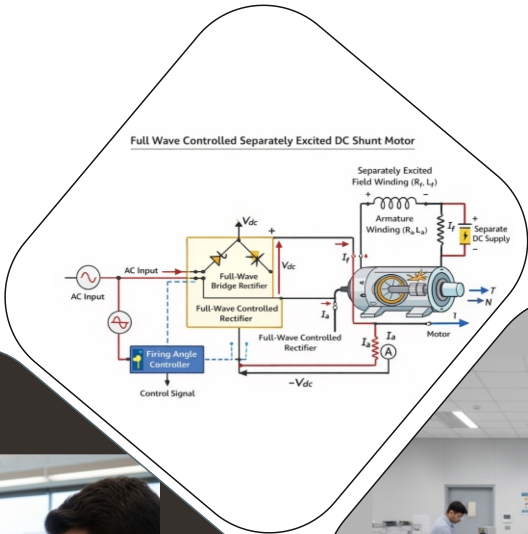
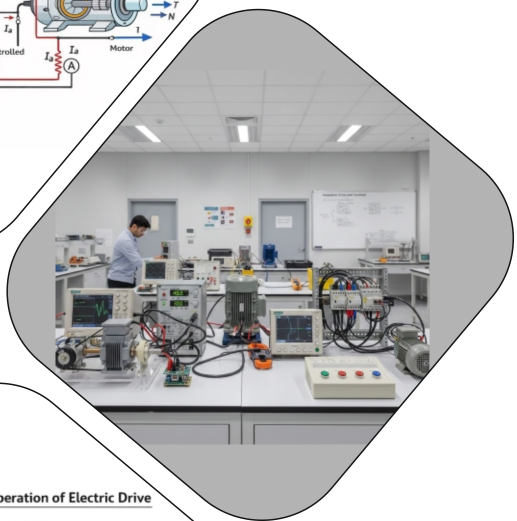
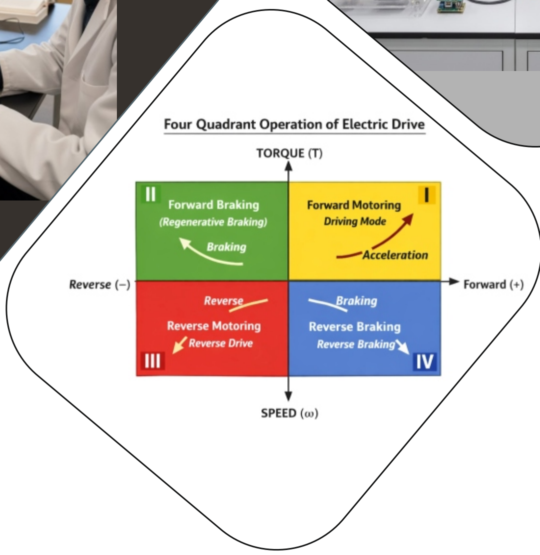
Roll No.:__________ Year : 20 ___ 20 __
Exam Seat No. :______________________

LABORATORY MANUAL FOR

INDUSTRIAL DRIVES AND CONTROL (316330)







ELECTRICAL ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

CORE VALUES

MSBTE believes in the following:

- Education industry produces live products.
- Market requirements do not wait for curriculum changes.
- Question paper is the reflector of academic standards of educational organization.
- Well designed curriculum needs effective implementation too.
- Competency based curriculum is the backbone of need based program.
- Technical skills do need support of life skills.
- Best teachers are the national assets.
- Effective teaching learning process is impossible without learning resources.

A Laboratory Manual For

INDUSTRIAL DRIVES AND CONTROLS

(316330)

Semester –VI

(EE/EP)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education, Mumbai

(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)

4th Floor, Government Polytechnic Building, 49, Kherwadi, Bandra (East), Mumbai- 400051.

MAHARASHTRA STATE

BOARD OF TECHNICAL EDUCATION

Certificate

This is to certify that Mr. /Ms.……………………………………………

Roll No. ……………………………of fourth Semester of Diploma in …..……………………..……………………………of Institute ……..……………………………………………………………… (Code : ………) has completed the term work satisfactorily in course **Industrial Drives And Controls (316330)** for the academic year 20…….to 20…….. as prescribed in the curriculum.

Place: …………….. **Enrollment No: ……………….**

Date: ………………. **Exam Seat No: …………………**

Subject Teacher Head of department Principal

Seal of Institute

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'I' Scheme curricula for engineering diploma programmes with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through "chalk and duster" activity in the classroom situation. Accordingly, the "I scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age old practice of conducting practical to 'verify the theory" (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The basic aim of this course is that, the student must learn the basic concepts, rules and laws of electric and magnetic circuits and practical thereof. The basic concepts of electrical engineering in this course will be very useful for understanding electrical circuits.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

<u>**Program Outcomes (POs)**</u>

- **PO 1. Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, sciences and engineering fundamentals and engineering specialization to solve the engineering problems.
- **PO 2. Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.
- **PO 3. Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of system components or processes to meet specified needs.
- **PO 4. Engineering tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.
- **PO 5. Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.
- **PO 6. Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.
- **PO 7. Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

Program Specific Outcomes (PSOs):

- **PSO 1.** Maintain various types of static and rotating electrical equipment and power system with **its** control.
- **PSO 2.** Install and maintain all types of illumination and utilization system in residential, commercial and industrial sector considering conservation of electrical energy.

List of Industry Relevant Skills

The following industry relevant skills of the competency in 'Industrial Drives and Control' used in industrial zone are expected to be developed in you by undertaking the practical of this laboratory manual.

1. Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.
2. Ability to make connections.
3. Ability to test / plot / Verify and Investigate characteristics.
4. Ability to select proper ranges of meters.

Practical-Course outcome matrix

COURSE LEVEL LEARNING OUTCOMES (COS)

1. CO1 – Apply the basics of electric drive for precise motor control operation.
2. CO2 - Use appropriate braking method for different AC and DC motors.
3. CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.
4. CO4 – Control precisely the speed of a given Induction Motor using appropriate AC Drive technique.Use three phase transformer for different applications.
5. CO5 - Control precisely the speed of a given motor using advanced techniques

Sr.No.	Title of the Practical	CO1	CO2	CO3	CO4	CO5
1	*Identification of various parts of DC drive.	✓	-	-	-	-
2	Identification of various parts of AC drive.	✓	-	-	-	-
3	*Speed control of DC shunt motor using single phase half wave-controlled converter.	-	-	✓	-	-
4	*Speed control of DC shunt motor using single phase full wave converter.	-	-	✓	-	-
5	Speed control of DC shunt motor using single phase semi converter.	-	-	✓	-	-
6	Speed control of DC Shunt motor by armature voltage control method using stepdown chopper.	-	-	✓	-	-
7	Speed control of DC series motor by armature voltage control method using stepdown chopper.	-	-	✓	-	-
8	Speed control of three phase squirrel cage induction motor using stator voltage control.(Thyristor circuit)	-	-	-	✓	-
9	*Speed control of three phase squirrel cage induction motor using VFD.	-	-	-	✓	-
10	*Speed control of three phase slip ring induction motor using rotor resistance control method.	-	-	-	✓	-
11	*Soft start and control the speed of single/three phase induction motor by varying supply frequency using VSI and maintaining constant v/f ratio.	-	-	-	✓	-
12	Connection of different parts of BLDC drive after identifying its different parts.	-	-	-	-	✓
13	Speed control of DC shunt motor using microcontroller drive.	-	-	-	-	✓
14	*Speed control of DC motor using PLC.	-	-	-	-	✓
15	* Perform Plugging operation on given induction motor	-	✓	-	-	-

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each experiment
3. Involve students in performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in. the students after the completion of the practical exercise.
5. Teachers should give opportunity to students for hands on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected the students by the industry.
8. Finally give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions.

Instructions for Students

1. Listen carefully the lecture given by teacher about subject, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make record all programs.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual
6. Student shall refer technical magazines.
7. Student should develop habit to submit the practical's on date and time.
8. Student should well prepare while submitting write-up of exercise.
9. Attach/paste separate papers wherever necessary.

Content Page

List of Practical's and Progressive Assessment Sheet

13	Speed control of DC shunt motor using microcontroller drive.	103					
14	*Speed control of DC motor using PLC.	109					
15	* Perform Plugging operation on given induction motor	116					
Total							

Note:
Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No. 1: Identification of various parts of DC drive

I Practical Significance:

DC drives are extensively used in industrial applications where precise speed control, high starting torque and smooth acceleration are required. Understanding the construction and function of different parts of a DC drive helps students to operate, troubleshoot and maintain industrial drive systems effectively. This practical gives hands-on exposure to real industrial drive hardware.

II Industry / Employer Expected Outcome(s):

- Identify major hardware components of a DC drive.
- Understand the role of power electronics in motor control.
- Relate drive components with industrial applications.

III Course Level Learning Outcome(s):

CO1 - Apply the basics of electric drive for precise motor control operation

IV Laboratory Learning Outcome(s):

- Identify and explain the function of various parts of a DC drive system.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment the student will be able to:

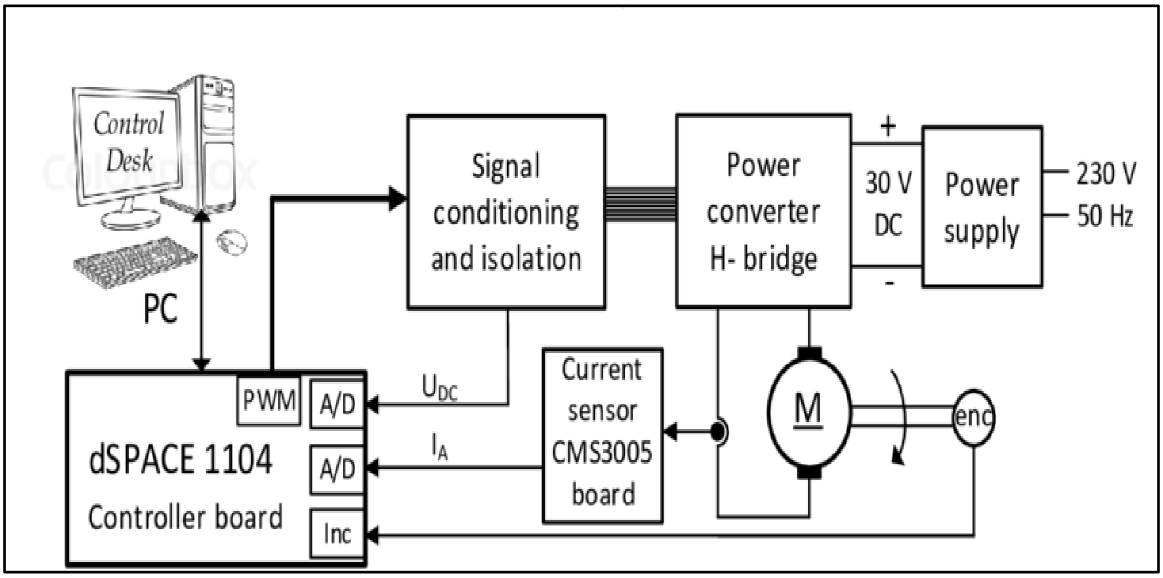
- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Develop confidence in identifying industrial drive systems.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC Drive is a power electronic system used to control the speed torque and direction of a DC motor. It converts AC supply into a controlled DC output using rectifier and semiconductor devices such as SCRs or IGBTs. A DC drive system consists of several important components each performing a specific function to ensure smooth and efficient operation of the DC motor. The AC supply provides the necessary electrical input power to the drive. This supply is fed to the drive through the input terminals which act as the connection point between the power source and the drive system. The rectifier unit is a crucial part that converts the incoming AC supply into DC supply required for the operation of the DC motor. After rectification, the DC output contains ripples; hence a DC link capacitor is used to smoothen the DC voltage and provide a stable output.

The processed DC power is then controlled by power semiconductor devices such as SCRs or IGBTs, which regulate the voltage and current supplied to the motor, thereby controlling its speed and torque. The operation of these power devices is governed by the control circuit board, which generates appropriate firing or control pulses based on the reference speed and feedback signals. For manual speed adjustment, a speed control potentiometer is provided, which allows the operator to vary the speed of the DC motor smoothly. During operation, power devices generate heat; therefore, a heat sink is used to dissipate excess heat and protect the components from thermal damage. Additionally, a cooling fan is provided to maintain a safe operating temperature inside the drive enclosure. Finally, the controlled DC output is supplied to the DC motor through armature terminals, where electrical energy is converted into mechanical energy to drive the load efficiently.

VII Actual Circuit Diagram used in laboratory with related equipment rating:



VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Drive Trainer kit	Industrial / Lab model	1
2	DC motor	Rated as per lab	1
3	AC Supply	230 V / 415 V, 50 Hz	1
4	Connecting wires	Standard	1
5	Safety gloves	Insulated	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Do not touch live terminals.
3. Check proper earthing.
4. Do not overload the DC drive.
5. Keep hands away from rotating parts.

X Procedure:

1. Ensure the main supply is switched off.
2. Observe the DC drive panel carefully.
3. Identify input terminals and rectifier unit.
4. Locate DC link capacitor and power devices.
5. Identify control circuit board and potentiometer.
6. Observe cooling fan and heat sink arrangement.
7. Identify DC motor armature terminals.
8. Note down the function of each part.
9. Switch OFF the supply after observations.

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Name of Part	Location	Functions
1	AC Input Terminals	Front panel	
2	Rectifier Unit	Inside drive	
3	DC Link Capacitor	After rectifier	
4	Power Devices	Heat sink mounted	
5	Control Circuit	PCB section	

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. State the role of SCR/IGBT
2. List applications of DC drives
3. How speed is controlled in DC drive.

XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 2: Identification of various parts of AC drive

I Practical Significance:

AC drives are widely used in industries for speed control of AC motors, especially three-phase induction motors. This practical helps diploma students to understand the basic construction, components and working principle of an AC drive system used in industrial applications.

II Industry / Employer Expected Outcome(s):

- Identify major hardware components of a AC drive
- Understand the role of power electronics in motor control.
- Relate drive components with industrial applications

III Course Level Learning Outcome(s):

CO1 - Apply the basics of electric drive for precise motor control operation

IV Laboratory Learning Outcome(s):

- Identify and explain the function of various parts of AC drive (VFD) system.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Develop confidence in identifying industrial AC drive systems.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

An AC Drive also known as a Variable Frequency Drive (VFD) is used to control the speed of an AC motor by varying the frequency and voltage of the supply. The AC supply is first converted into DC using a rectifier. This DC is smoothened using a DC link capacitor. Then an inverter converts DC back into AC of variable frequency. By changing frequency, the speed of the AC motor is controlled.

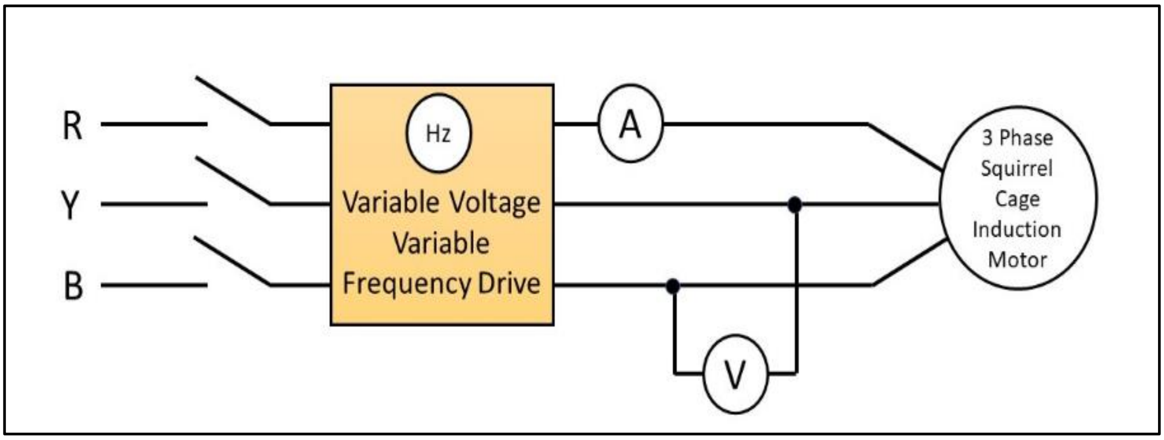

Fig2.1.Basic Block diagram of AC drive

VII Actual Circuit Diagram used in laboratory with related equipment rating:

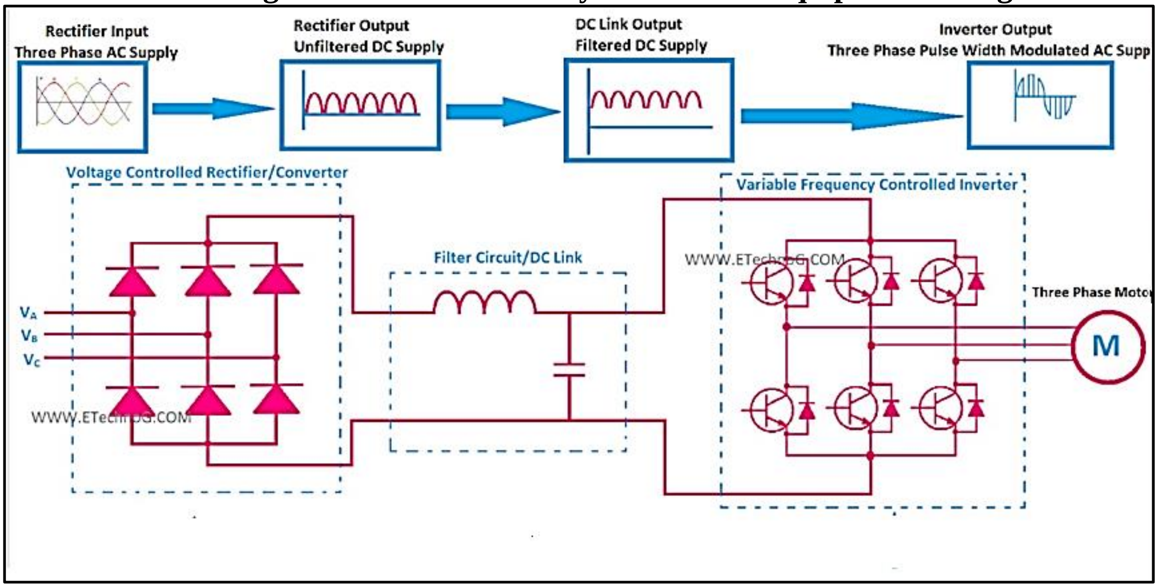

Fig2.2.Actual circuit diagram of AC drive

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	AC Drive Trainer kit	Industrial / Lab model	1
2	3-Phase Induction Motor	Rated as per lab	1
3	AC Supply	230 V / 415 V, 50 Hz	1
4	Connecting wires	Standard	1
5	Safety gloves	Insulated	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Do not touch live terminals.
3. Check proper earthing.
4. Do not overload the AC drive.
5. Keep hands away from rotating parts.

X Procedure:

1. Ensure the main supply is switched off.
2. Observe the AC drive panel carefully.
3. Identify input terminals and rectifier unit.
4. Locate DC link capacitor and power devices.
5. Identify control circuit board and potentiometer.
6. Observe cooling fan and heat sink arrangement.
7. Note down the function of each part.
8. Switch OFF the supply after observations.

XI Resources used:

Sr. No.	Resource	Specification
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2		
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Name of Part	Location	Functions
1	AC Input Terminals	Front panel	
2	Rectifier Unit	Inside drive	
3	DC Link Capacitor	After rectifier	
4	Inverter (IGBT)	Heat sink mounted	
5	Control Circuit	PCB section	

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. Why DC link capacitor is used.
2. List applications of AC drives.
3. How speed is controlled in AC drive.

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 3: Speed control of DC shunt motor using single phase half wave-controlled converter.

I Practical Significance

DC shunt motors are widely used in industries where constant speed and good speed regulation are required. Using a single-phase half controlled converter the armature voltage can be varied smoothly which results in speed control of DC motor.

II Industry / Employer Expected Outcome(s):

- Understand DC motor speed control using power electronics
- Operate controlled rectifier circuits safely
- Analyze relationship between armature voltage and speed

III Course Level Learning Outcome(s):

CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.

IV Laboratory Learning Outcome(s):

- Control speed of DC shunt motor using single phase half wave-controlled converter.
- Plot torque speed characteristics of the DC shunt motor.
- Plot torque- current characteristics of the DC shunt motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC shunt motor is widely used in industrial applications due to its nearly constant speed characteristics and good speed regulation. The speed of a DC shunt motor can be controlled by varying the armature voltage or the field flux. In this method, speed control is achieved by armature voltage control using a single-phase half-wave controlled converter. A single-phase half-wave controlled converter consists of one thyristor (SCR) and a freewheeling diode connected to a single-phase AC supply. The converter converts fixed AC voltage into a variable DC output voltage by controlling the firing angle (α) of the SCR. This variable DC voltage is applied to the armature of the DC shunt motor, while the field winding is supplied with a constant DC voltage. When the AC supply is applied, the SCR conducts only when it is forward biased and triggered at a firing angle α during the positive half cycle of the AC supply. By delaying the firing angle, the conduction period of the SCR is reduced, resulting in a lower average output voltage. The freewheeling diode provides a path for the armature current when the SCR is off, ensuring continuous and smooth current flow.

The average output voltage of a single-phase half-wave controlled converter is given by:

$$V_o = \frac{V_m}{2\pi}(1 + \cos\alpha)$$

$$E_b = k\phi\omega$$

$$\omega = \frac{E_b}{k\phi}$$

$$E_b = (V - I_a R_a)$$

$$\omega = \frac{V - I_a R_a}{k\phi}$$

The speed of DC shunt motor can be given by

$$N = \frac{V}{k\phi} - \frac{I_a R_a}{k\phi}$$

The Torque produced by DC shunt motor can be given by

$$T = kI_a$$

The below waveforms represent the operation of a DC shunt motor fed by a single-phase half-wave controlled converter with a freewheeling diode. The first waveform shows the AC supply voltage V_s which is sinusoidal. The second waveform shows the armature terminal voltage V_t which appears only from the firing angle α to π in each positive half cycle when the SCR is triggered during the negative half cycle and before firing the voltage is zero due to the SCR being OFF and the freewheeling diode conducting. The third waveform represents the armature current i_a which is assumed to be nearly constant at I_a because of the motor's inductance. The fourth waveform shows the source current i_s(equal to thyristor current i_T) which flows only during the conduction interval of the SCR from α to π.The last waveform represents the freewheeling diode current i_{fd} which flows when the SCR is OFF, providing a continuous path for the armature current and maintaining smooth motor operation. Overall, these waveforms explain how varying the firing angle α controls the average armature voltage and hence the speed of the DC shunt motor in one-quadrant operation.

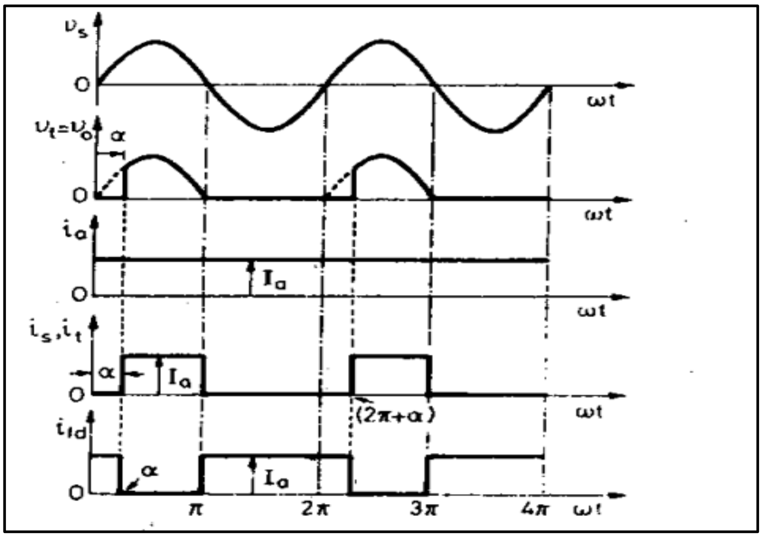

Fig3.1.Single Phase half converter drive waveform

VII Actual Circuit Diagram used in laboratory with related equipment rating:

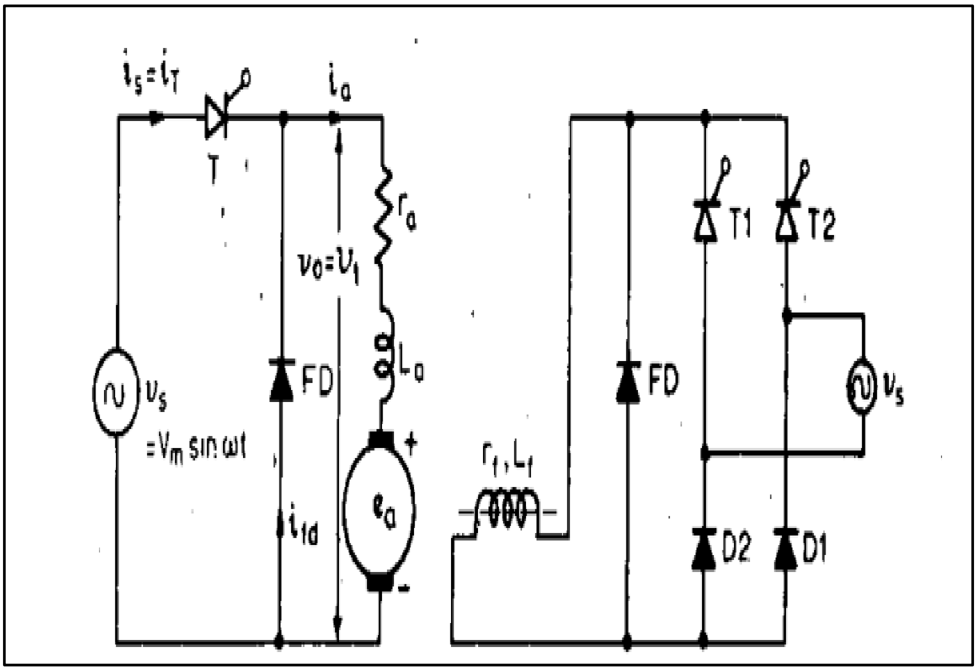

Fig3.2.Single Phase half converter drive circuit diagram

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Shunt Motor	Industrial / Lab model	1
2	Single Phase Half Controlled Converter	Trainer kit	1
3	AC Supply	230 V / 415 V, 50 Hz	1
4	Voltmeter (DC)	0–300 V	1
5	Ammeter (DC)	0–10 A	1
6	Tachometer	0–3000 RPM	1
7	Connecting Wires	Standard	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Field supply must be given before armature supply
3. Do not exceed rated armature current
4. Increase firing angle gradually
5. Keep hands away from rotating parts.

X Procedure:

1. Connect the circuit as per circuit diagram
2. Keep firing angle control at maximum position
3. Switch ON AC supply
4. Switch ON field supply of DC motor
5. Gradually vary firing angle of SCRs
6. Note armature voltage, current, and speed
7. Repeat readings for different firing angles
8. Calculate torque produced by shunt motor.
9. Switch OFF supply after completion

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table and Calculation:

Sr. No.	Triggering angle	Output voltage	Output current	Speed	Torque	Output voltage (Theoretically)
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. Why field current is kept constant in DC shunt motor.
2. What is half controlled converter?
3. How firing angle affects output voltage.
4. State advantages of half controlled converter

XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 4: Speed control of DC shunt motor using single phase full wave-controlled converter

I Practical Significance

DC shunt motors are widely used in industries where constant speed and good speed regulation are required. A single-phase full wave controlled converter provides better output voltage control, higher power handling, and smoother DC output as compared to half controlled converters.

II Industry / Employer Expected Outcome(s):

- Control DC motor speed using phase-controlled converters
- Operate full wave controlled rectifier circuits safely
- Analyze relationship between firing angle ,armature voltage and speed

III Course Level Learning Outcome(s):

CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.

IV Laboratory Learning Outcome(s):

- Control speed of DC shunt motor using single phase full wave-controlled converter.
- Plot torque speed characteristics of the DC shunt motor.
- Plot torque- current characteristics of the DC shunt motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC shunt motor is widely used in industrial applications because it offers nearly constant speed and good speed regulation. The speed of a DC shunt motor can be effectively controlled by varying the armature voltage, while keeping the field current (and hence flux ϕ) constant. In this method, a single-phase full-wave controlled converter is employed to obtain a variable DC voltage from a fixed single-phase AC supply. A single-phase full-wave controlled converter consists of four thyristor (SCRs) connected in a bridge configuration. By controlling the firing angle α of the SCRs, the average DC output voltage applied to the motor armature can be varied smoothly. During each half cycle of the AC supply, a pair of SCRs conducts, allowing power flow to the motor armature.

When the SCRs are triggered at a delay angle α the converter output voltage appears from α to π in each half cycle. The armature current remains nearly continuous due to the inductive nature of the motor. By increasing the firing angle, the average armature voltage decreases, resulting in a reduction in motor speed; conversely, decreasing the firing angle increases the armature voltage and hence the speed.

The **average output voltage** of a single-phase full-wave controlled converter is given by:

$$V_{avg} = \frac{2V_m}{\pi}\cos\alpha$$

$$E_b = k\phi\omega$$

$$\omega = \frac{E_b}{k\phi}$$

$$E_b = (V - I_a R_a)$$

$$\omega = \frac{V - I_a R_a}{k\phi}$$

The speed of DC shunt motor can be given by

$$N = \frac{V}{k\phi} - \frac{I_a R_a}{k\phi}$$

The Torque produced by DC shunt motor can be given by

$$T = kI_a$$

The below waveform show the operation of a DC shunt motor fed by a single-phase full-wave controlled converter. The AC supply voltage v_s is sinusoidal while the converter output voltage v_{ab} appears after the firing angle α in both half cycles. The armature current i_a remains nearly constant due to motor inductance. The source current i_s is flows during the conduction of SCR pairs and reverses in alternate half cycles. Each thyristor conducts for π radians, carrying the armature current. By changing the firing angle α, the average armature voltage and hence the speed of the DC shunt motor are controlled smoothly in one-quadrant operation.

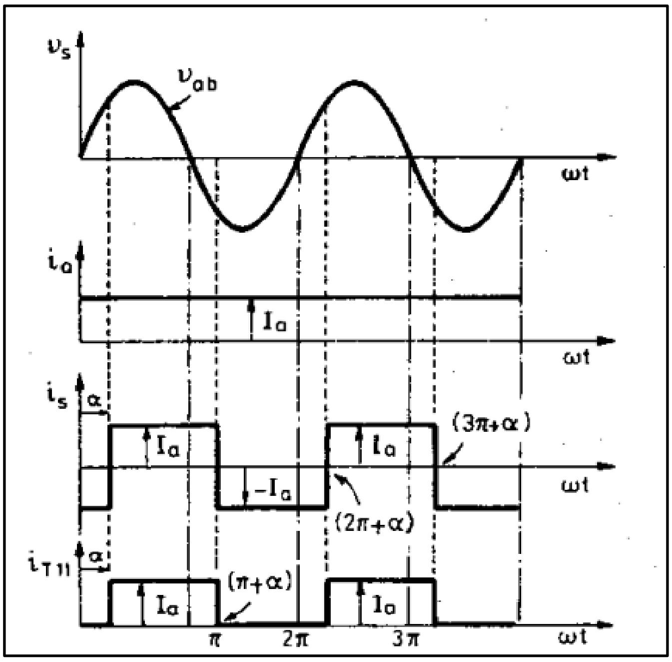

Fig4.1.Single Phase full converter drive waveform

VII Actual Circuit Diagram used in laboratory with related equipment rating:

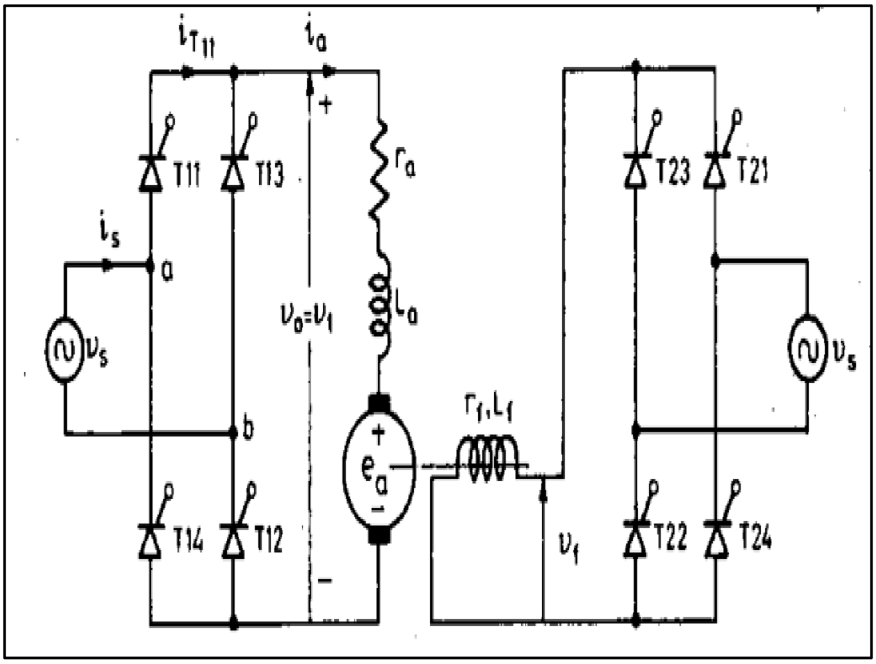

Fig4.2.Single Phase full converter drive circuit

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Shunt Motor	Industrial / Lab model	1
2	Single Phase full Controlled Converter	Trainer kit	1
3	AC Supply	230 V / 415 V, 50 Hz	1
4	Voltmeter (DC)	0–300 V	1
5	Ammeter (DC)	0–10 A	1
6	Tachometer	0–3000 RPM	1
7	Connecting Wires	Standard	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Field supply must be given before armature supply
3. Do not exceed rated armature current
4. Increase firing angle gradually
5. Keep hands away from rotating parts.

X Procedure:

1. Connect the circuit as per circuit diagram
2. Keep firing angle control at maximum position
3. Switch ON AC supply
4. Switch ON field supply of DC motor
5. Gradually vary firing angle of SCRs
6. Note armature voltage, current, and speed
7. Repeat readings for different firing angles.
8. Calculate torque produced by shunt motor.
9. Switch OFF supply after completion

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table and calculation

Sr. No.	Triggering angle	Output voltage	Output current	Speed	Torque	Output voltage (Theoretically)
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. What is full wave controlled converter?
2. State applications of full controlled converter
3. State advantages of full controlled converter

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 5: Speed control of DC shunt motor using single phase semi converter

I Practical Significance

Speed control of a DC shunt motor using a single-phase semi-converter is practically significant because it provides smooth and economical armature voltage control for low-power DC drives. The semi-converter allows continuous control of motor speed by varying the firing angle, while maintaining unidirectional current which ensures stable and safe motor operation.

II Industry / Employer Expected Outcome(s):

- Control DC motor speed using phase-controlled converters.
- Operate full wave controlled rectifier circuits safely.
- Analyze relationship between firing angle, armature voltage and speed.

III Course Level Learning Outcome(s):

CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.

IV Laboratory Learning Outcome(s):

- Control speed of DC shunt motor using single phase semi controlled converter.
- Plot torque speed characteristics of the DC shunt motor.
- Plot torque- current characteristics of the DC shunt motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC shunt motor is preferred in many applications because it offers nearly constant speed and good regulation. The speed of a DC shunt motor can be controlled effectively by varying the armature voltage while keeping the field current (and hence flux ϕ) constant. In this method a single-phase semi-converter is used to obtain a variable DC voltage from a fixed AC supply. A single-phase semi-converter consists of two thyristor (SCRs) and two diodes arranged in a bridge configuration. By controlling the firing angle α of the SCRs, the average output DC voltage applied to the motor armature can be varied. Compared to a fully controlled converter, the semi-converter allows power flow in one direction only, making it suitable for one-quadrant operation (forward motoring).When the AC supply is applied, and the SCRs are triggered at a delay angle α in each half cycle. During the conduction period, the converter supplies voltage to the motor armature. When the SCRs are OFF, the freewheeling action of the diodes maintains the continuity of armature current. This results in reduced current ripple, smoother torque and improved motor performance.

The average output voltage of a single-phase semi-converter depends on the firing angle and is given by:

$$V_{avg} = \frac{V_m}{\pi}(1 + \cos\alpha)$$

$$E_b = k\phi\omega$$

$$\omega = \frac{E_b}{k\phi}$$

$$E_b = (V - I_a R_a)$$

$$\omega = \frac{V - I_a R_a}{k\phi}$$

The speed of DC shunt motor can be given by

$$N = \frac{V}{k\phi} - \frac{I_a R_a}{k\phi}$$

The Torque produced by DC shunt motor can be given by

$$T = kI_a$$

The given waveform represent the operation of a DC shunt motor fed by a single-phase semi-converter under continuous armature current condition. The top waveform shows the AC supply voltage V_s which is sinusoidal in nature. Due to controlled switching of the SCRs the converter output voltage V_o appears in segments of each half cycle, starting after the firing angle α. The armature current i_a remains nearly constant at I_a because of the high inductance of the motor armature indicating continuous conduction. The source current i_s flows only during the conduction intervals of the thyristors and follows the direction of the applied supply voltage while remaining zero during freewheeling periods. The thyristor current i_T equals the armature current during its conduction interval and becomes zero when the SCR is turned off. During the non-conduction period of the SCRs, the freewheeling diode current i_{fd} flows, providing an alternate path for the armature current and maintaining smooth torque. Overall, these waveform explain that by varying the firing angle α the average DC output voltage of the semi-converter and hence the speed of the DC shunt motor can be smoothly controlled in one-quadrant operation, with improved power factor and reduced current ripple compared to a half-wave controlled converter.

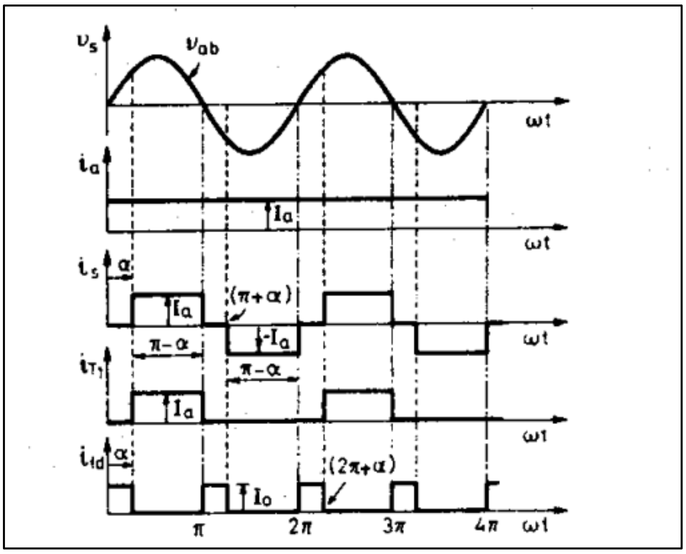

Fig5.1.Single Phase semi converter drive waveform

VII Actual Circuit Diagram used in laboratory with related equipment rating:

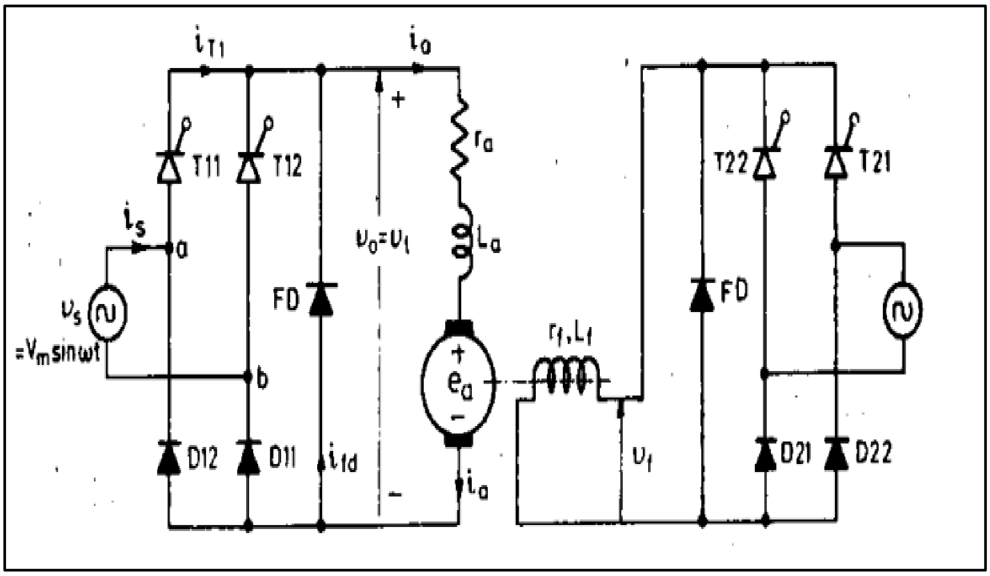

Fig5.2.Single Phase semi converter drive circuit diagram

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Shunt Motor	Industrial / Lab model	1
2	Single Phase Semi Controlled Converter	Trainer kit	1
3	AC Supply	230 V / 415 V, 50 Hz	1
4	Voltmeter (DC)	0–300 V	1
5	Ammeter (DC)	0–10 A	1
6	Tachometer	0–3000 RPM	1
7	Connecting Wires	Standard	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Field supply must be given before armature supply
3. Do not exceed rated armature current
4. Increase firing angle gradually
5. Keep hands away from rotating parts.

X Procedure:

1. Connect the circuit as per circuit diagram
2. Keep firing angle control at maximum position.
3. Switch ON AC supply
4. Switch ON field supply of DC motor
5. Gradually vary firing angle of SCRs
6. Note armature voltage, current, and speed
7. Repeat readings for different firing angles
8. Calculate torque produced by shunt motor.
9. Switch OFF supply after completion

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table and calculation

Sr. No.	Triggering angle	Output voltage	Output current	Speed	Torque	Output voltage (Theoretically)
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. What is the function of a single-phase semi-converter in DC motor speed control?
2. Why is a freewheeling diode required in the converter circuit?
3. State any two advantages of using a single-phase semi-converter.
4. What are the applications of DC shunt motor speed control using semi-converter?

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 6: Speed control of DC shunt motor by armature voltage control method by using step down chopper.

I Practical Significance

This practical helps in understanding efficient and smooth speed control of a DC shunt motor using armature voltage control with a step-down chopper, which is widely used in industrial DC drive applications.

II Industry / Employer Expected Outcome(s):

- Ability to control the speed of DC shunt motor.
- Understanding of armature voltage control method.
- Knowledge of relationship between duty cycle, voltage and speed.

III Course Level Learning Outcome(s):

CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.

IV Laboratory Learning Outcome(s):

- Control the speed of DC shunt motor by armature voltage control method using step down chopper.
- Plot torque- current characteristics of the DC shunt motor
- Plot torque- Speed characteristics of the DC shunt motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC shunt motor has its field winding connected in parallel with the armature due to which the field current remains nearly constant. The speed of a DC shunt motor is mainly dependent on the armature voltage when the field flux is constant. According to the speed equation of a DC motor speed is directly proportional to armature voltage and inversely proportional to field flux. In the armature voltage control method the field current is kept constant and the armature voltage is varied to control the speed. A step-down (buck) chopper is a DC–DC power electronic converter that converts a fixed DC input voltage into a variable DC output voltage by rapidly switching the semiconductor device ON and OFF. The average output voltage of the chopper depends on the duty cycle which is the ratio of ON time to total switching time. By increasing the duty cycle, the average armature voltage increases and hence the motor speed increases. Similarly, decreasing the duty cycle reduces the armature voltage and motor speed. This method provides smooth, efficient, and fast speed control, and is widely used in modern DC motor drive and industrial control systems.

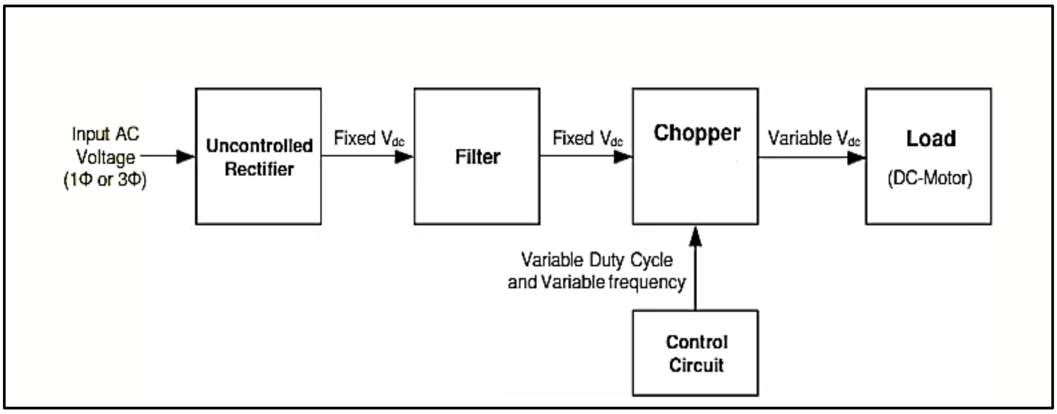

Fig.6.1.Block diagram of chopper fed DC shunt motor

The output voltage of step down chopper can be given by

$$V_o = D \times V_s$$

Where:

- V_o = Output voltage
- V_s= Supply voltage
- D = Duty cycle

$$E_b = k\phi\omega$$

$$\omega = \frac{E_b}{k\phi}$$

$$E_b = (V_o - I_a R_a)$$

$$\omega = \frac{V_o - I_a R_a}{k\phi}$$

The speed of DC shunt motor can be given by

$$N = \frac{V}{k\phi} - \frac{I_a R_a}{k\phi}$$

The Torque produced by DC shunt motor can be given by

$$T = kI_a$$

VII Actual Circuit Diagram used in laboratory with related equipment rating:

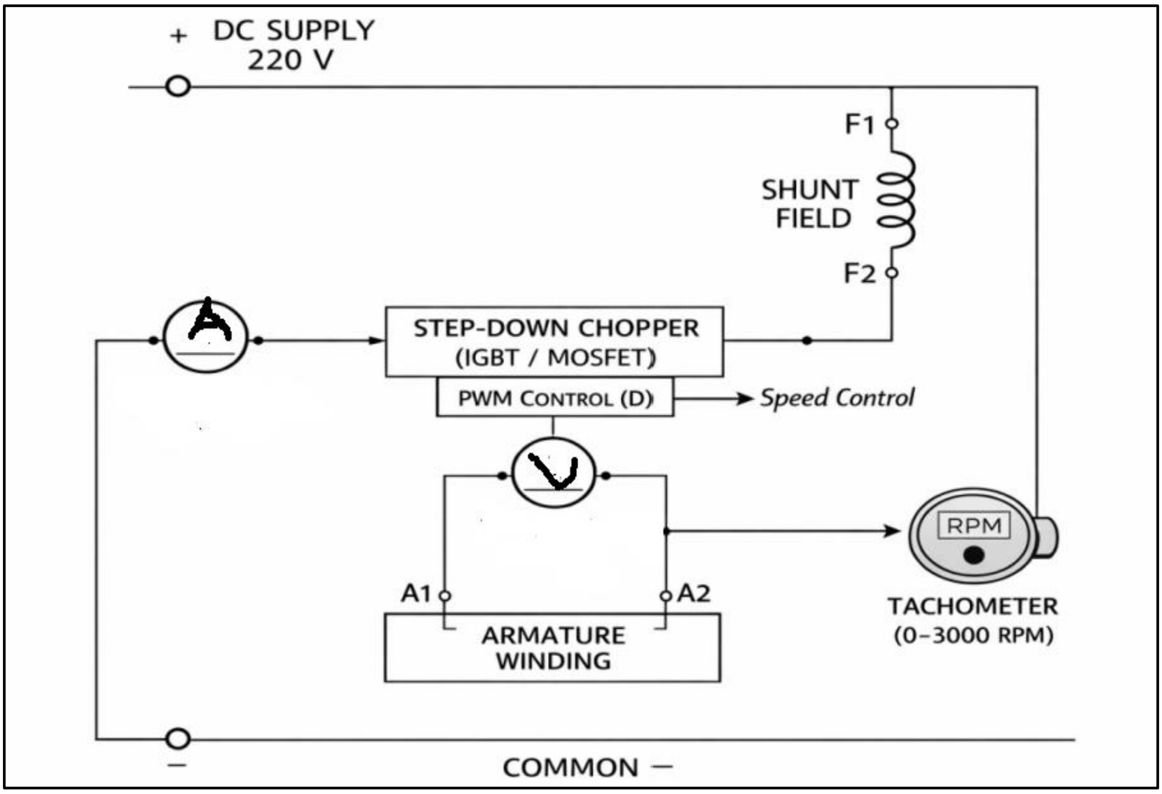

Fig.6.2.Actual circuit diagram of chopper fed DC shunt motor

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Shunt Motor	Industrial / Lab model	1
2	Step down chopper	IGBT / MOSFET Trainer kit	1
3	DC Supply	220 V	1
4	Voltmeter (DC)	0–300 V	1
5	Ammeter (DC)	0–10 A	1
6	Tachometer	0–3000 RPM	1
7	Connecting Wires	Standard	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Field supply must be given before armature supply
3. Do not exceed rated armature current
4. Keep hands away from rotating parts.

X Procedure:

1. Ensure DC supply is OFF.
2. Connect the circuit as per the circuit diagram.
3. Set duty cycle control knob to minimum position.
4. Switch ON DC supply.
5. Switch ON field supply and adjust field rheostat to rated value.
6. Gradually increase the duty cycle of the chopper.
7. Observe and note Armature voltage, Armature current and motor speed
8. Take readings for different duty cycle values.
9. After completing observations, reduce duty cycle to minimum.
10. Switch OFF DC supply.

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table and calculation:

Sr. No.	Duty Cycle	Output voltage	Output current	Speed	Torque	Output voltage (Theoretically)
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XIV Results:

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. What is a step-down (buck) chopper?
2. How does duty cycle affect the armature voltage and speed of a DC shunt motor?
3. State two advantages of chopper control over conventional speed control methods.

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 7: Speed control of DC series motor by armature voltage control method by using step down chopper.

I Practical Significance

DC series motors are widely used in applications requiring high starting torque such as electric traction, cranes and hoists. Speed control using armature voltage control with a step-down chopper provides smooth control, high efficiency and quick response. This practical helps students understand modern chopper-based DC motor drives used in industries.

II Industry / Employer Expected Outcome(s):

- Control the speed of a DC motor using chopper technique.
- Understand armature voltage control method.
- Analyze relationship between firing angle armature voltage and speed.

III Course Level Learning Outcome(s):

CO3 - Control precisely the speed of a given DC motor using appropriate phase-controlled converter and chopper.

IV Laboratory Learning Outcome(s):

- Control speed of DC series motor by armature voltage control method using step down chopper.
- Plot torque speed characteristics of the DC series motor.
- Plot torque- current characteristics of the DC series motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices.
- Handle electrical equipment responsibly.
- Work cooperatively in a laboratory environment.

VI Relevant Theoretical Background:

A DC series motor has its field winding connected in series with the armature. Therefore, the field current and armature current are the same. The speed of a DC series motor depends on armature voltage, armature current, and flux.

In the armature voltage control method, the applied armature voltage is varied while keeping the supply constant. A step-down (buck) chopper is a DC–DC converter that converts fixed DC input voltage into variable DC output voltage by controlling the duty cycle (D) of the switching device.

The average output voltage of the chopper is given by:

$V_o = D \times V_s$

$$E_b = k\phi\omega$$

$$\omega = \frac{E_b}{k\phi}$$
$$E_b = (V_o - I_aR_a)$$
$$\omega = \frac{V_o - I_aR_a}{k\phi}$$

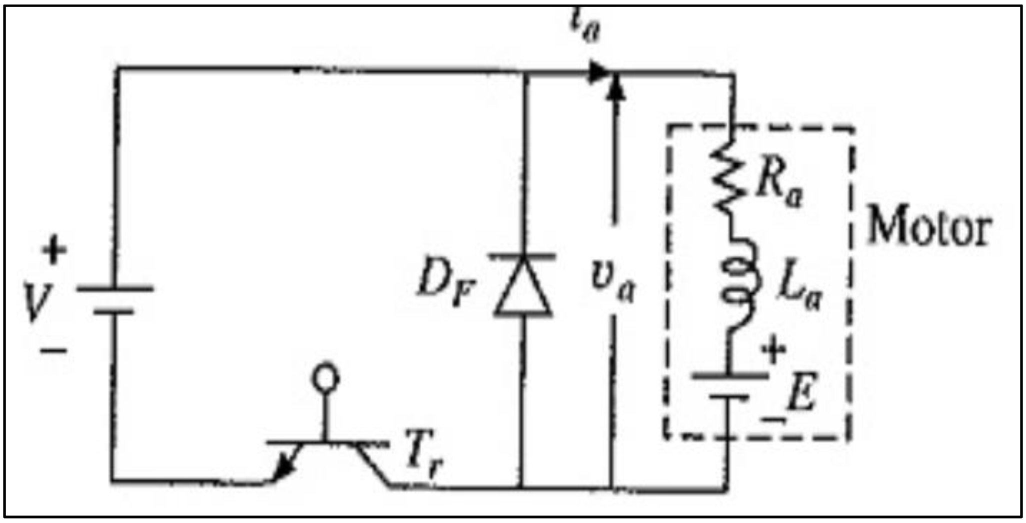
The speed of DC shunt motor can be given by

$$N = \frac{V}{k\phi} - \frac{I_aR_a}{k\phi}$$

The Torque produced by DC series motor can be given by

$$T = k\phi I_a$$
$$\phi \propto I_a$$

VII Actual Circuit Diagram used in laboratory with related equipment rating:



VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	DC Shunt Motor	Industrial / Lab model	1
2	Step down chopper	IGBT / MOSFET Trainer kit	1
3	DC Supply	200 V	1
4	Voltmeter (DC)	0–300 V	1
5	Ammeter (DC)	0–10 A	1
6	Tachometer	0–3000 RPM	1
7	Connecting Wires	Standard	1

IX Precautions to Be Followed:

1. Ensure supply is off before connections.
2. Field supply must be given before armature supply
3. Do not exceed rated armature current
4. Keep hands away from rotating parts.

X Procedure:

1. Ensure DC supply is OFF.
2. Connect the circuit as per the circuit diagram.
3. Set duty cycle control knob to minimum position.
4. Switch ON DC supply.
5. Gradually increase the duty cycle of the chopper.
6. Observe and note Armature voltage, Armature current and motor speed
7. Take readings for different duty cycle values.
8. After completing observations, reduce duty cycle to minimum.
9. Switch OFF DC supply.

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Duty Cycle	Output voltage	Output current	Speed	Torque	Output voltage (Theoretically)
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2						
3						
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. Why is the flux directly proportional to armature current in a DC series motor?
2. What happens to the speed of a DC series motor when the armature current increases?
3. Why should a DC series motor not be operated at no load?
4. How does armature voltage control using a step-down chopper affect the flux and speed of a DC series motor?

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 8: Speed control of three phase squirrel cage induction motor using stator voltage control. (Thyristor circuit)

I Practical Significance:

Three-phase squirrel cage induction motors are widely used in industries due to their rugged construction, low cost, and minimal maintenance. In many industrial applications such as fans, blowers, and pumps, it is necessary to control the motor speed according to load requirements. This experiment demonstrates a simple and economical method of speed control by varying the stator voltage using a thyristor-based AC voltage controller. Understanding this method helps students gain practical knowledge of power electronic control of AC motors and its real-time industrial applications.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO4 - Control precisely the speed of a given Induction Motor using appropriate AC Drive technique.

IV Laboratory Learning Outcome(s):

- Control the speed of three phase squirrel cage induction motor by varying stator voltage using thyristor circuit.
- Plot torque speed characteristics of three phase squirrel cage induction motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Develop interest in power electronics–based motor control systems
- Demonstrate safe handling of electrical machines and power electronic circuits
- Appreciate the importance of controlled motor operation in industrial environments
- Show responsibility while working with high-voltage and rotating equipment

VI Relevant Theoretical Background:

The speed of a three-phase induction motor is given by:

$$N = N_s(1 - s)$$

where,

- N= rotor speed (rpm)
- N_s= synchronous speed (rpm)

- s= slip

The synchronous speed depends on supply frequency and number of poles. Since the frequency remains constant, speed control is achieved by varying the slip. In stator voltage control, the supply voltage to the stator is varied using a thyristor-based AC voltage controller. When the stator voltage is reduced, the electromagnetic torque decreases because torque is proportional to the square of the applied voltage. As torque decreases, the slip increases, resulting in a reduction in motor speed. This method is suitable for applications requiring speed control below rated speed and where load torque decreases with speed.

VII a. Circuit Diagram:

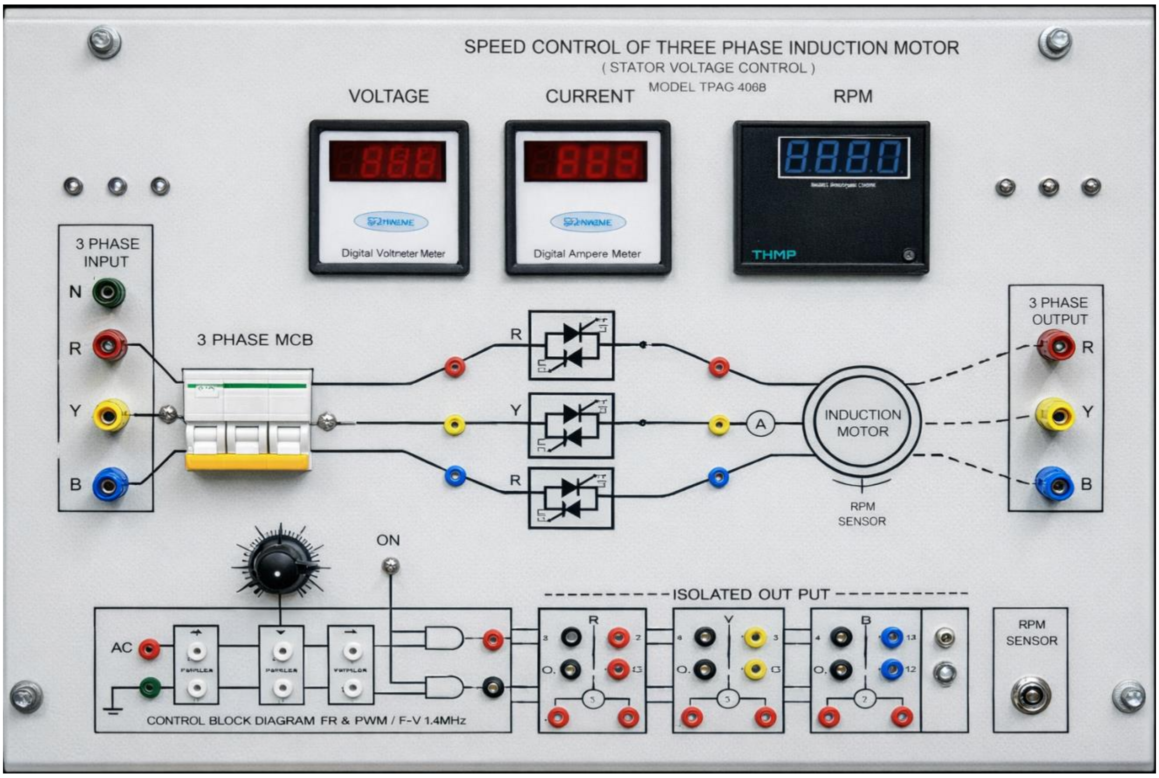

Figure 8.1: three phase squirrel cage induction motor Trainer Kit

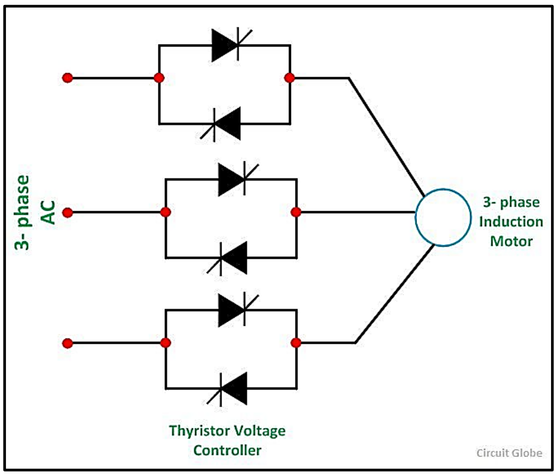

Figure 8.2: Stator voltage control of induction motor

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	Three-phase squirrel cage Induction Motor	415 V, 50 Hz, 3-phase	1
2	Thyristor Based AC Voltage Controller	3-phase, firing angle control	1
3	AC Voltmeter	(0–500) V AC or suitable	1
4	AC Ammeter	(0–10) A AC or suitable	1
5	Tachometer	0-3000 RPM Digital / Analog	1
6	Power Supply	3-phase, 415 V, 50 Hz	1

IX Precautions to Be Followed:

1. Ensure all connections are tight and correct before switching ON the supply
2. Keep the firing angle control knob at minimum position initially
3. Do not exceed the rated voltage and current of the motor
4. Avoid touching live terminals during operation
5. Switch OFF the supply immediately in case of abnormal noise or vibration
6. Ensure proper earthing of all equipment

X Procedure:

1. Connect the three-phase induction motor to the thyristor-based AC voltage controller as per the circuit diagram.
2. Connect voltmeter and ammeter in appropriate positions to measure stator voltage and current.
3. Ensure the firing angle control is set to minimum output voltage.
4. Switch ON the three-phase power supply.
5. Gradually increase the firing angle using the controller to vary the stator voltage.
6. Measure and note down the corresponding stator voltage, current, and motor speed using a tachometer.
7. Repeat the above steps for different voltage levels.
8. After completing the observations, reduce the voltage to minimum and switch OFF the supply.

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Stator Voltage (V)	Line Current (A)	Speed (rpm)
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. Why is stator voltage control suitable only for light load applications?
2. How does torque vary with stator voltage in an induction motor?
3. What is the role of thyristors in speed control?
4. Why is this method not suitable for constant torque loads?

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Graph:

1. Draw a graph taking Voltage in Volts on X – axis and speed in rpm on Y-axis

Scale

X-Axis: 1cm=………………………..… Y- Axis: 1cm=……………………………

XVIII References / Suggestions for Further Reading:

1. Bimbhra, P. S., Power Electronics, Khanna Publishers
2. Dubey, G. K., Fundamentals of Electrical Drives, Narosa Publishing House
3. Nagrath, I. J., and Kothari, D. P., Electric Machines, Tata McGraw-Hill
4. Rashid, M. H., Power Electronics – Circuits, Devices and Applications, Pearson

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Handling of hardware setup and instruments	10%
2	Identification of circuit components / modules	20%
3	Measurement of electrical and mechanical parameters	20%
4	Working in teams (collaboration & role clarity)	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values	10%
6	Interpretation of experimental results	05%
7	Conclusion (clarity and correctness)	05%
8	Practical related questions (concepts, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 9: Speed control of three phase squirrel cage induction motor using VFD.

I Practical Significance:

Speed control of induction motors is essential in modern industries to improve energy efficiency, process control, and equipment life. Using a Variable Frequency Drive (VFD), the speed of a three-phase squirrel cage induction motor can be smoothly controlled by varying the supply frequency and voltage. This experiment helps students understand industrial motor control techniques widely used in conveyors, pumps, elevators, HVAC systems, and machine tools.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO4 - Control precisely the speed of a given Induction Motor using appropriate AC Drive technique.

IV Laboratory Learning Outcome(s):

- Speed control of three phase squirrel cage induction motor using Variable frequency Drive (VFD).
- Plot torque speed characteristics of three phase squirrel cage induction motor

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Appreciate the importance of VFDs in industrial motor control
- Develop a safety-conscious attitude while working with electrical drives
- Demonstrate confidence in handling modern industrial control equipment
- Show responsibility and discipline while following standard operating procedures

VI Relevant Theoretical Background:

A three-phase squirrel cage induction motor runs at a speed slightly less than synchronous speed, which is given by:

$$N_s = \frac{120f}{P}$$

Where:

- N_s= Synchronous speed (rpm)
- f= Supply frequency (Hz)
- P= Number of poles

A Variable Frequency Drive (VFD) controls the speed of the induction motor by varying the frequency of the supply voltage while maintaining a constant **V/f ratio**. This ensures constant flux in the motor and prevents magnetic saturation. Main functions of a VFD:

- Converts fixed AC supply to DC (Rectifier)
- Smoothens DC using DC link capacitors
- Converts DC back to variable AC (Inverter)

VII a. Variable Frequency Drive (VFD):

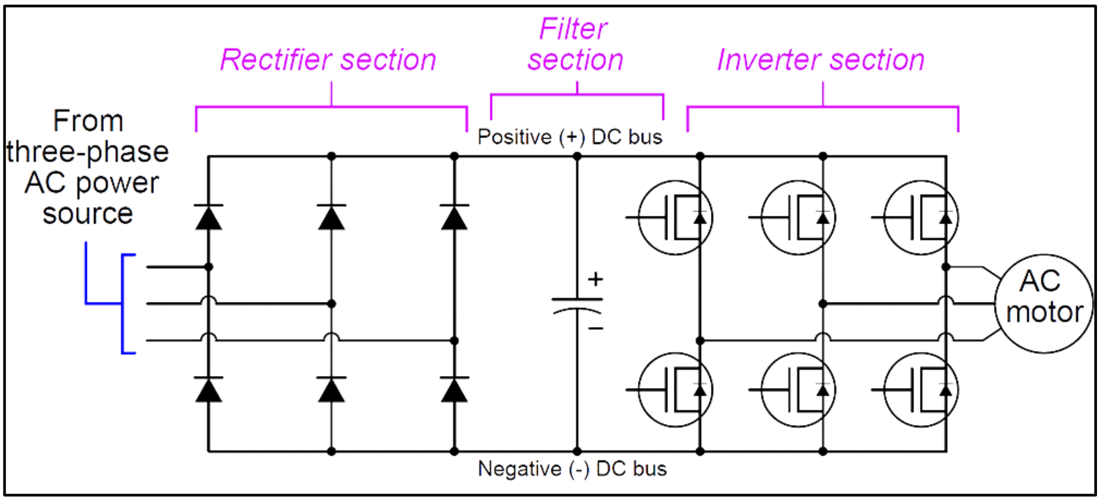

Figure 9.1: Variable Frequency Drive

b. Actual Circuit Diagram Used in Laboratory with Equipment Specifications:

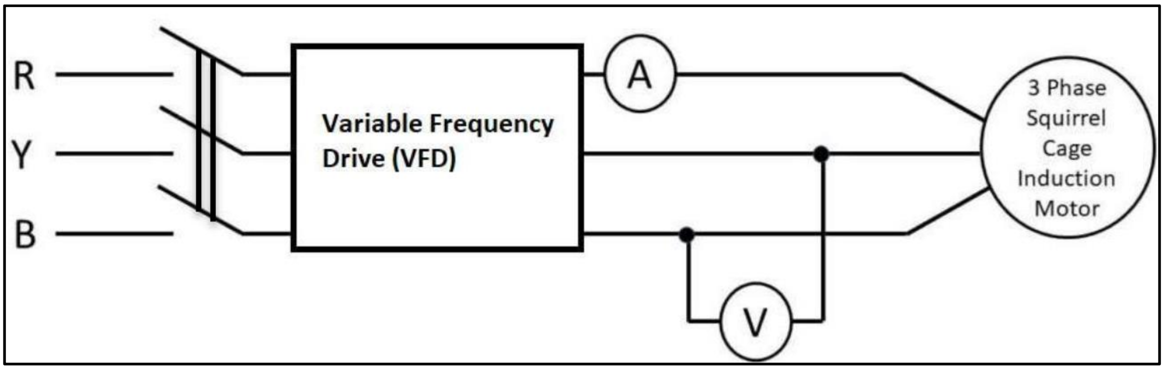

Figure 9.2: speed control of three phase induction motor by using VFD

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	Three-phase squirrel cage Induction Motor	Squirrel cage, 415 V, 50 Hz, 1 HP	1
2	Variable Frequency Drive (VFD)	415 V AC input, V/f control	1
3	Three-phase AC Supply	415 V, 50 Hz	1
4	AC Voltmeter	(0–500) V AC or suitable	1
5	AC Ammeter	(0–10) A AC or suitable	1
6	Tachometer	0-3000 RPM Digital / Analog	1

IX Precautions to Be Followed:

1. Ensure proper earthing of the motor and VFD.
2. Do not change motor connections while supply is ON.
3. Set VFD parameters as per motor nameplate ratings.
4. Increase frequency gradually to avoid sudden mechanical stress.
5. Avoid touching live terminals during operation.
6. Ensure cooling ventilation of the VFD is not blocked.

X Procedure:

1. Connect the three-phase supply to the input terminals of the VFD.
2. Connect the output terminals of the VFD to the induction motor.
3. Set motor rated voltage, current, frequency, and speed in the VFD parameters.
4. Switch ON the main supply.
5. Set initial frequency to a low value (e.g., 10 Hz).
6. Start the motor using the VFD control panel.
7. Gradually increase the frequency and note down the motor speed at each step.
8. Observe voltage, current, and speed for different frequencies.
9. After completion, reduce frequency to zero and switch OFF the supply.

XI Resources used:

Sr. No.	Resource/Software	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Frequency (Hz)	Line Voltage (V)	Line Current (A)	Motor Speed (rpm)
1	Minimum F:			
2	Maximum F:			

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. Why is V/f control used in induction motor drives?
2. What happens if frequency is increased without increasing voltage?
3. List advantages of using a VFD over conventional speed control methods.
4. Why squirrel cage induction motors are preferred in industries?
5. What are the main parts of a VFD?
6. What is slip in an induction motor?

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XVIII References / Suggestions for Further Reading:

1. Bimal N. Bose, *Modern Power Electronics and AC Drives*, Pearson Education
2. G.K. Dubey, *Power Semiconductor Controlled Drives*, PHI
3. R. Krishnan, *Electric Motor Drives – Modeling, Analysis and Control*, Pearson
4. Manufacturer manuals of VFD (ABB / Siemens / Schneider Electric)
5. NPTEL Lectures on Electrical Drives

Graph:

1. Draw a graph taking Line voltage in Volts on X – axis and speed in rpm on Y-axis

2. Draw a graph taking Frequency in Hertz on X – axis and speed in rpm on Y-axis

Scale

1. X-Axis:1cm= Y-Axis: 1cm=

2. X-Axis:1cm= Y-Axis: 1cm=

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Safe handling of VFD, induction motor, and measuring instruments	10%
2	Identification of VFD terminals, motor connections, and control parameters	20%
3	Measurement of electrical (voltage, current, frequency) and mechanical (speed) parameters at different VFD settings	20%
4	Working in teams (coordination, role clarity, adherence to safety practices)	10%
Product Related: 10 Marks		**40%**
5	Calculation of synchronous speed and slip at different frequencies	10%
6	Interpretation of speed-frequency characteristics of the induction motor using VFD	05%
7	Conclusion based on observations (clarity, correctness, industrial relevance)	05%
8	Practical related questions (VFD principle, V/f control, advantages, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 10: Speed control of three phase slip ring induction motor using rotor resistance control method.

I Practical Significance:

This experiment demonstrates speed control of a slip ring induction motor, which is widely used in industries requiring high starting torque. It helps students understand how external rotor resistance affects speed, torque, and current. The method is useful in cranes, hoists, elevators, rolling mills, and conveyors. Students gain hands-on experience in motor control, measurement, and safe operation of industrial drives.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO4 - Control precisely the speed of a given Induction Motor using appropriate AC Drive technique.

IV Laboratory Learning Outcome(s):

- Control the speed of three phase slip ring induction motor using rotor resistance control method.
- Plot torque speed characteristics of three phase Slip ring induction motor.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe laboratory practices while working with rotating machines.
- Demonstrate discipline, responsibility, and teamwork during practical work.
- Develop confidence in handling electrical machines and control circuits.
- Appreciate the importance of energy control and efficiency in industrial drives.

VI Relevant Theoretical Background:

A three-phase slip ring induction motor has a wound rotor with slip rings connected to external resistances.

Principle of Rotor Resistance Control:

- At start, external resistance is added in the rotor circuit.
- Increasing rotor resistance:
    - ➢ Increases starting torque

- ➢ Reduces starting current
- ➢ Increases slip
- ➢ Reduces speed

- As resistance is gradually cut out, the motor accelerates and reaches near rated speed.

Speed Equation:

$$N = N_s(1 - s)$$

Where:

- N= Rotor speed
- N_s= Synchronous speed
- s= Slip

VII Actual Circuit Diagram used in laboratory with related equipment rating:

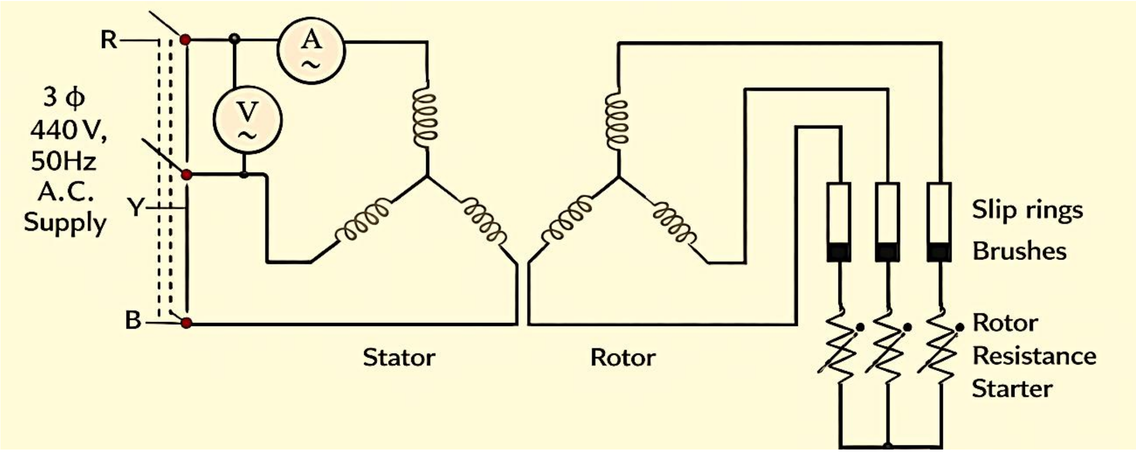

Figure 6.1: Speed Control of Slip Ring Induction Motor Using Rotor Resistance Starter

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	Three phase Slip Ring Induction Motor	3-Phase, 415 V, 50 Hz, 5 HP (or lab rated)	1
2	Rotor Resistance Starter	3-phase, step type	1
3	Three Phase AC Supply	415 V, 50 Hz	1
4	Voltmeter	(0–500) V AC or suitable	1
5	Ammeter	(0–10) A AC or suitable	1
6	Tachometer	0-3000 RPM, Digital / Analog	1

IX Precautions to Be Followed:

1. Ensure proper earthing of motor and control panel.
2. Do not touch live terminals.
3. Start motor with maximum rotor resistance.
4. Increase or decrease resistance gradually.
5. Do not exceed rated current of the motor.

X Procedure:

1. Connect the circuit as per the circuit diagram.
2. Keep the rotor resistance at maximum position.
3. Switch ON the three-phase supply.
4. Observe smooth starting of the motor.
5. Measure and note:
   - Line voltage
   - Line current
   - Speed using tachometer
6. Gradually reduce rotor resistance in steps.
7. Record corresponding speed and current for each step.
8. Continue until minimum resistance is reached.
9. Switch OFF the supply after observations.

XI Resources used:

Sr. No.	Resource	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Approximate % of external resistance in rotor circuit	Line Voltage (V)	Line Current (A)	Speed (RPM)
1	Maximum 100% (full)			
2	Step-1 Reduced 75%			
3	Step-2 Reduced 50%			
4	Step-3 Reduced 25%			
5	Minimum 0%			

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

(Note: - Teacher should provide various questions related to practical- sample given)

1. Why rotor resistance is added during starting?
2. What happens to torque when rotor resistance increases?
3. Why this method is not suitable for continuous speed control?
4. What are applications of slip ring induction motor?
5. Compare rotor resistance control with V/f control.
6. Why squirrel cage motors do not allow rotor resistance control?
7. What is slip and how does it affect speed?

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja – Electrical Machines
2. P. S. Bimbhra – Electrical Machinery
3. Nagrath & Kothari – Electric Machines

Graph: Draw a graph taking rotor resistance in % on X – axis and speed in rpm on Y-axis

Scale

X- Axis: 1cm=…………………………… Y- Axis: 1cm=……………………………

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60%**
1	Handling of slip ring induction motor, rotor resistance starter, and measuring instruments	10%
2	Identification of stator, rotor terminals, external rotor resistance, and control circuit components	20%
3	Measurement of electrical (voltage, current) and mechanical (speed, torque variation) parameters	20%
4	Working in teams (coordination during resistance variation and safety practices)	10%
	Product Related: 10 Marks	**40%**
5	Calculation of slip and speed for different rotor resistance values	10%
6	Interpretation of speed-torque characteristics obtained using rotor resistance control	05%
7	Conclusion based on experimental observations (clarity and correctness)	05%
8	Practical related questions (principle, advantages, limitations, applications)	15%
9	Timely submission of practical manual with neat observations and documentation	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 11: Soft start and control the speed of single/three phase induction motor by varying supply frequency using VSI and maintaining constant v/f ratio.

I Practical Significance:

This experiment demonstrates a modern and energy-efficient method of controlling the speed of an induction motor using a Voltage Source Inverter (VSI). By maintaining a constant V/f (Voltage to Frequency) ratio, smooth starting (soft start) and effective speed control of the motor can be achieved. This method reduces starting current, mechanical stress, and power losses, making it highly suitable for industrial applications such as conveyors, pumps, elevators, fans, and compressors.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO4 - Control precisely the speed of a given Induction Motor using appropriate AC Drive technique.

IV Laboratory Learning Outcome(s):

- Test the performance of v/f control-based induction motor drive

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Appreciate the importance of energy-efficient motor control techniques
- Show confidence and responsibility in handling inverter-fed motor systems
- Demonstrate teamwork and discipline during laboratory work
- Understand the industrial relevance of VSI-based motor control

VI Relevant Theoretical Background:

An induction motor's speed depends on the supply frequency, given by:

$$N_s = \frac{120f}{P}$$

Where:

- N_s= synchronous speed (rpm)
- f= supply frequency (Hz)

- *P*= number of poles

To maintain constant motor flux and torque, the V/f ratio must remain constant.

If frequency is reduced without reducing voltage, the motor may saturate.

If voltage is reduced too much, torque will decrease. A Voltage Source Inverter (VSI) converts fixed DC voltage into variable AC voltage and frequency. By gradually increasing frequency and voltage while keeping V/f constant, soft starting is achieved. This avoids high inrush current and sudden mechanical jerks.

VII a. Sample Circuit Diagram:

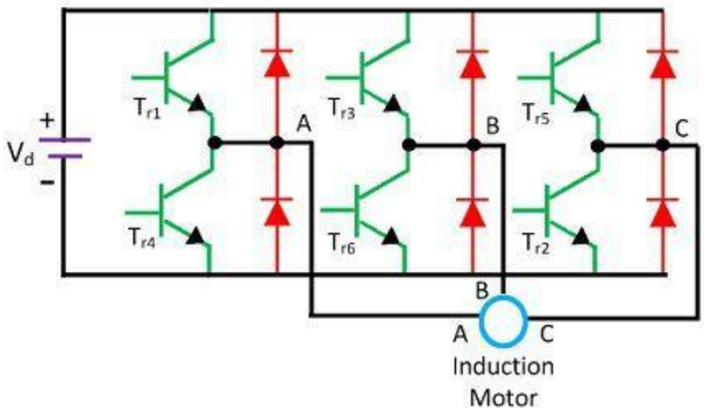

Figure 11.1: voltage source inverter fed three phase induction motor

Figure 11.2: Speed Control of Induction Motor Using Voltage Source Inverter Trainer kit

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	Voltage Source Inverter (VSI) kit / VFD	1-phase / 3-phase, 230 V / 415 V, 0–50 Hz	1
2	Induction Motor	Single/Three phase, 0.5 HP / 1 HP or suitable	1
3	AC Power Supply	230 V / 415 V, 50 Hz	1
4	Digital Voltmeter	0–500 V AC	1
5	Digital Ammeter	0–10 A AC	1
6	Tachometer	0–3000 rpm	1

IX Precautions to Be Followed:

1. Ensure all connections are tight and correct before switching ON supply
2. Set initial frequency and voltage to zero before starting the VSI
3. Do not exceed the rated voltage and current of the motor
4. Avoid touching live terminals during operation
5. Increase frequency gradually to ensure soft starting
6. Switch OFF supply immediately in case of abnormal noise or overheating

X Procedure:

1. Connect the induction motor to the output terminals of the VSI as per diagram
2. Connect the VSI input to the AC supply
3. Keep the frequency set to minimum (0–5 Hz)
4. Switch ON the supply and start the VSI
5. Gradually increase the frequency while maintaining constant V/f ratio
6. Note the corresponding motor speed, voltage, and current
7. Repeat readings for different frequency values
8. Observe smooth acceleration of the motor (soft start)
9. After completion, reduce frequency to zero and switch OFF the supply

XI Resources used:

Sr. No.	Resource/Software	Specification
1		
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Frequency (Hz)	Line Voltage (V)	Speed (rpm)
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4			
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XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. What is meant by V/f control?
2. Why is constant V/f ratio required for induction motor control?
3. What are the advantages of soft starting?
4. What is the function of a Voltage Source Inverter (VSI)?
5. How does frequency affect motor speed?
6. Compare DOL starting and V/f control method
7. List industrial applications of VFD-controlled induction motors

Graph:

1. Draw a graph taking Line voltage in Volts on X – axis and speed in rpm on Y-axis

2. Draw a graph taking Frequency in Hertz on X – axis and speed in rpm on Y-axis

Scale

1. X-Axis: 1cm=………………………..… Y- Axis: 1cm=……………………………

2. X- Axis: 1cm=………………………… Y- Axis: 1cm=……………………………

XVIII References / Suggestions for Further Reading:

1. Bimbra, P. S., Power Electronics, Khanna Publishers
2. Dubey, G. K., Power Semiconductor Controlled Drives, PHI Learning
3. Bose, B. K., Modern Power Electronics and AC Drives, Pearson
4. NPTEL Course: Electrical Machines & Drives
5. Manufacturer Manuals of VFD (ABB / Siemens / Schneider Electric)

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of VSI, induction motor, and measuring instruments during soft start operation	10%
2	Identification of circuit components/modules (VSI, DC link, inverter switches, control panel)	20%
3	Measurement of electrical (V, I, f) and mechanical (speed, torque trend) parameters at different frequencies	20%
4	Working in teams (coordination during start-up, parameter setting, safety practices)	10%
Product Related: 10 Marks		**40%**
5	Calculation of V/f ratio and expected synchronous speed at different frequencies	10%
6	Interpretation of results (effect of frequency variation on speed and current)	05%
7	Conclusion based on soft start and V/f control characteristics	05%
8	Practical related questions (VSI operation, V/f control principle, soft start advantages)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 12: Connection of different parts of BLDC drive after identifying its different parts.

I Practical Significance:

Brushless DC (BLDC) motors are widely used in modern industrial and domestic applications such as electric vehicles, CNC machines, robotics, HVAC systems, and household appliances due to their high efficiency, low maintenance, and precise speed control. This experiment helps students understand the construction, identification, and correct interconnection of various components of a BLDC drive system. It builds practical knowledge required for installation, commissioning, and troubleshooting of industrial drive systems.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO5 - Control precisely the speed of a given motor using advanced techniques.

VI Laboratory Learning Outcome(s):

- Identify parts of BLDC motor drive.
- Connect the parts of BLDC motor drive.

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Develop safety awareness while handling electrical drive systems
- Demonstrate responsible behavior while connecting power electronic equipment
- Appreciate the importance of correct wiring and component identification
- Show confidence in handling industrial motor drive setups
- Follow standard laboratory practices and teamwork discipline

VI Relevant Theoretical Background:

A BLDC drive system consists of a BLDC motor, a power electronic inverter, a controller, position sensors, and a DC power supply. Unlike conventional DC motors, BLDC motors do not use brushes and commutators. Instead, electronic commutation is achieved using semiconductor switches controlled by a controller based on rotor position feedback. The controller receives rotor position information from Hall effect sensors and accordingly switches the inverter transistors

(MOSFETs/IGBTs) to energize the stator windings in proper sequence. This results in smooth rotation of the rotor.

VII a. Sample of Circuit Diagram:

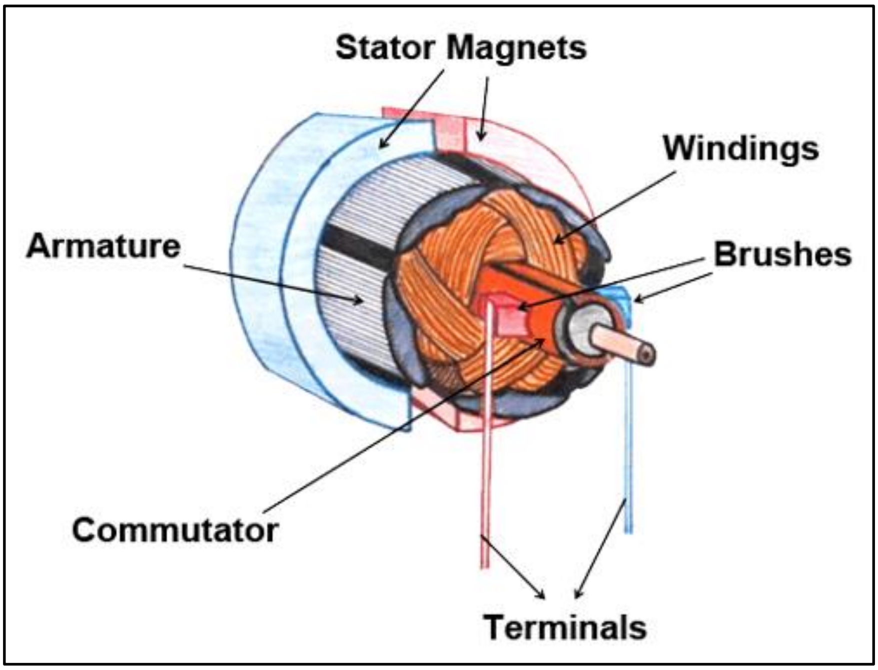

Figure 12.1: Brushed DC motors use brushes and a commutator

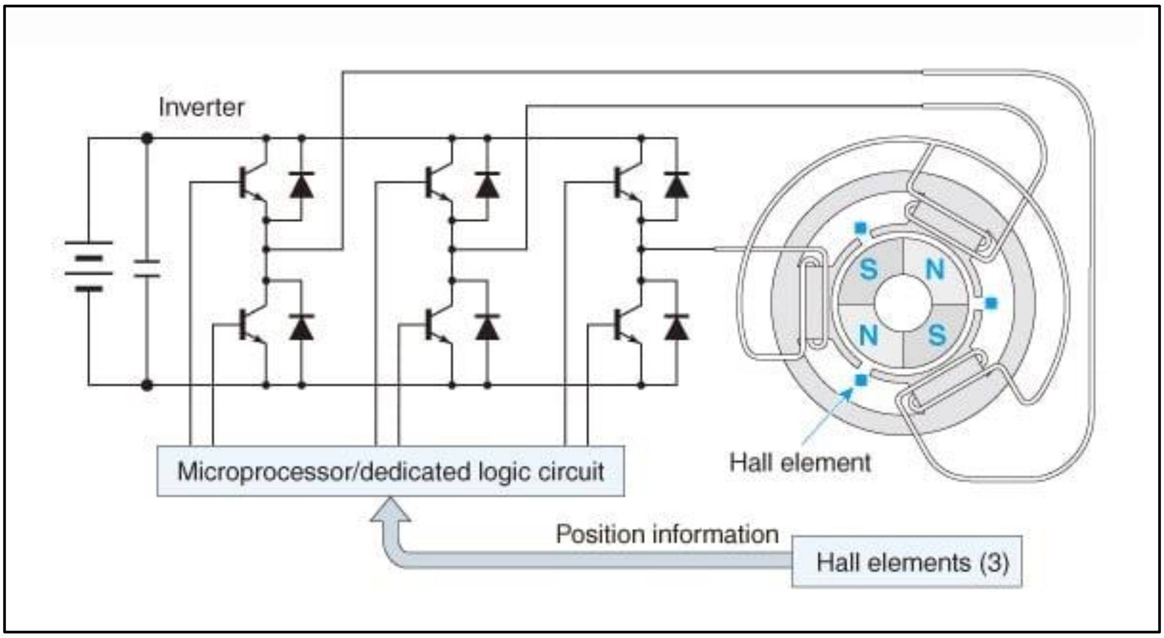

Figure 12.2: BLDC motor using Hall-effect sensors.

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	BLDC Motor	Rated voltage: 24V / 48V DC, 3-phase	1
2	BLDC Drive / Controller	Compatible with motor rating	1
3	DC Power Supply	0–48V DC, suitable current rating	1
4	Hall Sensor Cable	5/6 pin connector	1
5	Power Cables	Insulated copper wires	As required
6	Multimeter	Digital, AC/DC measurement	1
7	Connecting Leads	Banana / socket type	As required

IX Precautions to Be Followed:

- Ensure the power supply is OFF before making any connections.
- Verify the voltage rating of the BLDC motor and controller.
- Do not interchange Hall sensor connections randomly.
- Use properly insulated wires to avoid short circuits.
- Avoid loose connections at power and control terminals.
- Do not touch rotating parts while the motor is running.
- Switch OFF the supply immediately in case of abnormal noise or heating.

X Procedure:

A. Identification of BLDC Motor Drive Components:

BLDC motor drive system consists of the following parts:

1. DC Power Supply
   - Provides DC input voltage to the inverter circuit.
   - Acts as the main energy source for the BLDC motor drive.
2. Inverter (Three-Phase Bridge)
   - Consists of six power electronic switches with freewheeling diodes.
   - Converts DC power into controlled three-phase AC supply.
   - Supplies power to the stator windings of the BLDC motor.
3. Microprocessor / Dedicated Logic Circuit
   - Controls switching of inverter devices.

- Receives rotor position information from Hall sensors.
- Generates proper gate pulses for electronic commutation.

4. BLDC Motor Stator Windings

- Three stator windings are shown connected to the inverter output.
- These windings produce a rotating magnetic field.
- Interact with rotor magnets to produce torque.

5. BLDC Motor Rotor

- Located inside the stator.
- Contains permanent magnets marked as N and S poles.
- Rotates according to the stator magnetic field.

6. Hall Elements (Three Hall Sensors)

- Mounted inside the motor near the rotor.
- Sense rotor magnetic pole position.
- Provide feedback signals for commutation control.

7. Position Information Path

- Shown as a signal line from Hall elements to the controller.
- Carries rotor position data required for switching sequence.

B. Connection of BLDC Motor Drive Components:

The interconnection of BLDC motor drive components is explained below:

1. DC Supply to Inverter Connection

- DC power supply terminals are connected to the DC input of the inverter.
- Correct polarity must be maintained.
- This supplies DC voltage to the inverter bridge.

2. Inverter to Stator Windings Connection

- Three inverter output terminals are connected to the three stator windings of the BLDC motor.
- These connections provide electronically controlled three-phase supply.
- Proper switching produces rotating magnetic field.

3. Hall Elements to Controller Connection

- Outputs of the three Hall sensors are connected to the microprocessor / logic circuit.
- These signals indicate rotor position.
- Essential for correct electronic commutation.

4. Controller to Inverter Gate Connection

- Control signals from the microprocessor are connected to inverter switches.
- Based on Hall sensor inputs, the controller turns ON/OFF inverter switches.
- Ensures correct sequence of phase energization.

5. Feedback-Based Closed-Loop Operation

- Rotor position feedback continuously updates the controller.
- Controller adjusts inverter switching accordingly.
- Enables smooth and efficient BLDC motor operation.

XI Resources used:

Sr. No.	Resource used	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Parameter	Observation
1	DC supply voltage	______ V
2	DC supply current	______ A
3	Phase connections (U-V-W)	Correct / Incorrect
4	Hall sensor connection	Proper / Improper
5	Motor starting	Smooth / Not smooth
6	Direction of rotation	Clockwise/ Anticlockwise

XVI Result(s):

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XVII Interpretation of Results:

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XVIII Conclusions and Recommendations:

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XIX Practical Related Questions:

1. What is a BLDC motor?
2. Why electronic commutation is used in BLDC motors?
3. What is the role of Hall effect sensors in BLDC drives?
4. List the advantages of BLDC motors over DC motors.
5. What will happen if Hall sensor connections are incorrect?
6. Name any two applications of BLDC drives in industry.

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XX References / Suggestions for Further Reading:

1. B. L. Theraja and A. K. Theraja, Electrical Technology, S. Chand Publications
2. R. Krishnan, Electric Motor Drives – Modeling, Analysis and Control, Pearson Education
3. Dubey G. K., Fundamentals of Electrical Drives, Narosa Publishing House
4. BLDC Motor Drive Manuals and Manufacturer Datasheets
5. NPTEL Video Lectures on Electric Drives

XXI Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of BLDC drive hardware setup and measuring instruments	10%
2	Identification of different parts of BLDC drive (motor, controller, Hall sensors, power supply, driver module)	20%
3	Correct connection of BLDC motor, controller, sensors, and supply as per diagram	20%
4	Working in teams (coordination, role clarity, safety awareness)	10%
Product Related: 10 Marks		**40%**
5	Understanding of function of each BLDC drive component	10%
6	Interpretation of BLDC drive operation after successful connections	05%
7	Conclusion (clarity and correctness)	05%
8	Practical related questions (BLDC working principle, advantages, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 13: Speed control of DC shunt motor using microcontroller drive

I Practical Significance:

Speed control of DC motors is widely required in industrial applications such as conveyor belts, elevators, rolling mills, CNC machines, and electric traction systems. Using a microcontroller for speed control provides precise, flexible, and efficient control compared to conventional methods. This experiment helps students understand modern digital motor control techniques used in automation and industrial drives.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO5 - Control precisely the speed of a given motor using advanced techniques.

IV Laboratory Learning Outcome(s):

- Control the speed of DC shunt motor using microcontroller.
- Plot torque speed characteristics of DC shunt motor
- Plot torque current characteristics of DC shunt motor

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Develop a positive attitude towards safe handling of electrical machines and electronic circuits
- Appreciate the role of microcontrollers in modern industrial drive systems
- Demonstrate responsibility while operating motor control equipment
- Work effectively in a team during experimental setup and testing

VI Relevant Theoretical Background:

A DC shunt motor has its field winding connected in parallel (shunt) with the armature. The speed of a DC shunt motor is given by:

$$N \propto \frac{V - I_a R_a}{\Phi}$$

Where:

- N= speed of motor
- V= applied voltage

- I_a= armature current
- R_a= armature resistance
- Φ= flux

In this experiment, speed control is achieved by varying the armature voltage using a PWM (Pulse Width Modulation) technique generated by a microcontroller (such as Arduino). By changing the duty cycle of the PWM signal, the average voltage applied to the motor changes, resulting in speed variation. A motor driver circuit is used between the microcontroller and motor to handle higher current requirements.

VII Sample of Circuit Diagram:

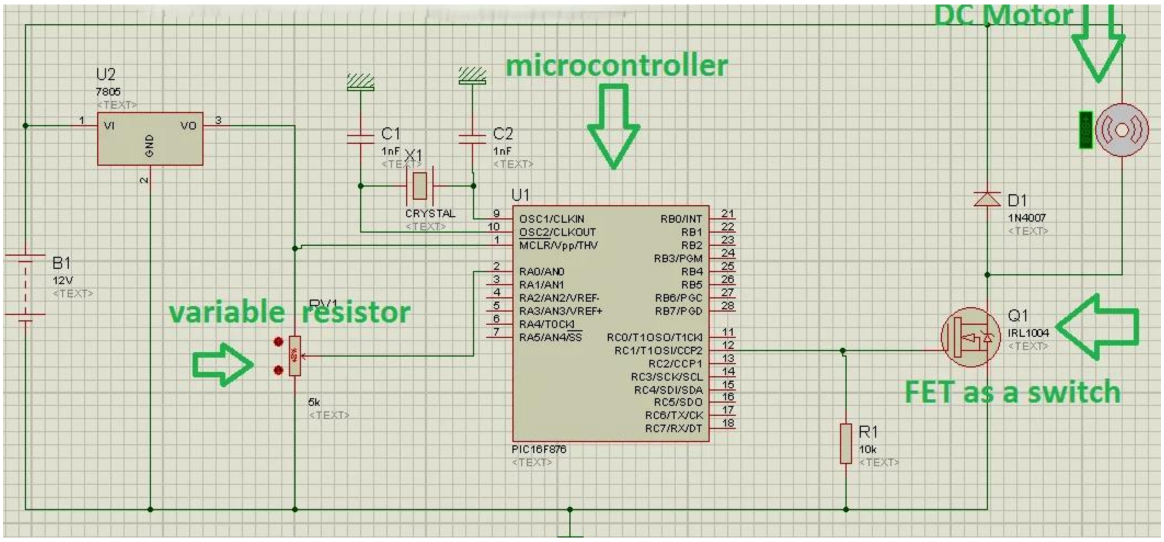

Figure:13.1: Microcontroller-Based Speed Control of DC Shunt Motor

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	PIC Microcontroller	PIC16F876	1
2	DC Shunt Motor	12 V DC	1
3	MOSFET	IRF540	1
4	Voltage Regulator	7805 (5 V)	1
5	Diode	1N4007	1
6	Potentiometer	5 kΩ	1

7	Resistor	10 kΩ	1
8	Crystal Oscillator	4 MHz	1
9	Capacitor	1 nF	2
10	DC Power Supply / Battery	12 V	1
11	Connecting Wires	Patch wires	As required
12	Ground Terminal	Common ground	As required

IX Precautions to Be Followed:

1. Ensure all circuit connections are made correctly as per the diagram before switching ON the supply.
2. Do not exceed the rated voltage and current of the DC shunt motor.
3. Use a proper free-wheeling diode across the motor to protect the MOSFET from back EMF.
4. Ensure the 7805-regulator output is exactly 5 V before connecting it to the microcontroller.
5. Provide a proper heat sink to the MOSFET to avoid overheating.
6. Ensure all grounds (power supply, microcontroller, MOSFET) are connected to a common ground.
7. Load the correct HEX program into the microcontroller before running the simulation.
8. Set the correct oscillator frequency in Proteus as per the crystal used.
9. Start the experiment with the potentiometer at minimum position.
10. Avoid loose connections to prevent short circuits and damage to components.

X Procedure:

1. Open Proteus ISIS and create a new project by selecting a blank schematic. Give an appropriate project name related to DC shunt motor speed control using a PIC microcontroller.
2. Click on Pick Devices and select the required components: PIC16F876 microcontroller, DC motor, IRF540 MOSFET, 7805 voltage regulator, 1N4007 diode, 5 kΩ potentiometer, 10 kΩ resistor, 12 V DC source or battery, crystal oscillator (4 MHz), two 1 nF capacitors, and ground terminals.
3. Place the PIC16F876 at the center of the schematic. Connect the VDD pin of the PIC to the output of the 7805 voltage regulator and the VSS pin to ground. Connect the input of the 7805 to the 12 V supply and its ground pin to the common ground.

4. Connect the crystal oscillator between the OSC1 and OSC2 pins of the PIC microcontroller. Connect one 1 nF capacitor from each oscillator pin to ground to provide stable clock operation.
5. Place the potentiometer on the left side of the circuit. Connect one end of the potentiometer to +5 V and the other end to ground. Connect the wiper terminal of the potentiometer to RA0/AN0 pin of the PIC to provide a variable analog voltage input for speed control.
6. Connect the RC2/CCP2 pin of the PIC microcontroller to the gate of the IRF540 MOSFET. Connect a 10 kΩ resistor between the MOSFET gate and ground to ensure proper switching and avoid floating gate conditions.
7. Connect the drain terminal of the MOSFET to the negative terminal of the DC motor. Connect the positive terminal of the DC motor to the +12 V supply. Connect the source terminal of the MOSFET to ground.
8. Place a 1N4007 diode across the motor terminals with the cathode connected to the positive terminal of the motor and the anode connected to the MOSFET drain to protect the circuit from back EMF generated by the motor.
9. Ensure all ground points in the circuit, including the PIC, MOSFET source, voltage regulator ground, and power supply negative, are connected to a common ground.
10. Double-click on the PIC microcontroller and load the compiled HEX file generated from the given program code. Set the clock frequency in the PIC properties to match the crystal frequency used in the circuit.
11. Run the simulation. Initially keep the potentiometer at minimum position so that the ADC reads a low value and the PWM duty cycle is small, resulting in low motor speed. Gradually rotate the potentiometer; the ADC value increases and the program updates the PWM duty cycle, increasing the average voltage applied to the motor and thereby increasing the motor speed smoothly.
12. Observe that rotating the potentiometer in the opposite direction reduces the PWM duty cycle and decreases the motor speed. This confirms successful speed control of the DC shunt motor using PWM generated by the PIC microcontroller.

Code for Speed control of DC Motor

```
long ADCValue=0;
long ADCValueOld=1;
```

```
#byte portA = 0X05
#byte portB = 0X06
#byte portC = 0X07

void main()
{
set_tris_A(0b00101011);
set_tris_B(0b00000001);
set_tris_C(0b00000000);

portA=0X00;
portB=0X00;
portC=0X00;

setup_adc_ports(ALL_ANALOG);
setup_adc(ADC_CLOCK_INTERNAL);
setup_spi(FALSE);
setup_counters(RTCC_INTERNAL,WDT_288MS);
setup_timer_1(T1_INTERNAL|T1_DIV_BY_1);
setup_timer_2(T2_DIV_BY_1,255,1);
setup_ccp1(CCP_OFF);
setup_ccp2(CCP_PWM);
enable_interrupts(global);

set_adc_channel(0);
delay_us(10);

while(1)
{
ADCValue = Read_ADC();
delay_ms(100); // monitor 10 times a second

if ( ADCValue != ADCValueOld )
```

```
{
set_pwm2_duty(ADCValue);
ADCValueOld = ADCValue;
}
}
}
```

XI Resources used:

Sr. No.	Resource/Software	Specification
1		
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	PWM Duty Cycle (%)	Speed (RPM)
1	20	
2	40	
3	60	
4	80	
5	100	

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. What is a DC shunt motor?
2. Why is PWM used for speed control?
3. What is the role of a motor driver circuit?
4. How does duty cycle affect motor speed?
5. What are the advantages of microcontroller-based motor control?
6. Why direct connection of a motor to a microcontroller is not possible?

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XVIII References / Suggestions for Further Reading:

1. B. L. Theraja & A. K. Theraja, Electrical Technology, S. Chand
2. P. S. Bimbhra, Electrical Machinery, Khanna Publishers
3. Muhammad Ali Mazidi, The 8051 Microcontroller and Embedded Systems

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of microcontroller-based drive, DC shunt motor, and measuring instruments	10%
2	Identification of circuit components / modules (microcontroller, driver, power supply, DC motor)	20%
3	Measurement of electrical parameters	20%
4	Working in teams (coordination, role clarity, safety awareness)	10%
Product Related: 10 Marks		**40%**
5	Calculation of theoretical speed values and control parameters	10%
6	Interpretation of speed variation results with respect to control input	05%
7	Conclusion (clarity and correctness)	05%
8	Practical related questions (concept of DC shunt motor speed control, microcontroller role, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 14: Speed control of DC motor using PLC.

I Practical Significance:

Speed control of DC motors is widely used in industries such as conveyors, elevators, rolling mills, robotic systems, and machine tools. Using a Programmable Logic Controller (PLC) for speed control improves accuracy, reliability, automation, and safety. This experiment helps students understand how PLCs interface with electrical drives and how industrial motor control systems are implemented in real-time applications.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO5 - Control precisely the speed of a given motor using advanced techniques.

IV Laboratory Learning Outcome(s):

- Control the speed of DC motor using Programmable Logic Controller (PLC).

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Develop a positive attitude towards industrial automation systems
- Follow safety rules while working with electrical machines and PLCs
- Work responsibly in a team during wiring, programming, and testing
- Appreciate the importance of PLC-based control in modern industries

VI Relevant Theoretical Background:

A DC motor converts electrical energy into mechanical energy. The speed of a DC motor mainly depends on:

- Applied armature voltage
- Field current (flux)

In industrial applications, speed control is commonly achieved by varying the armature voltage. A PLC is an industrial digital controller used to automate processes. In this experiment, the PLC controls the speed of a DC motor by:

- Generating control signals

- Switching the motor ON/OFF
- Controlling speed using preset values, analog output, or PWM through a drive/interface

The PLC program is written using ladder logic, which simulates relay-based control circuits.

VII Sample of Circuit Diagram:

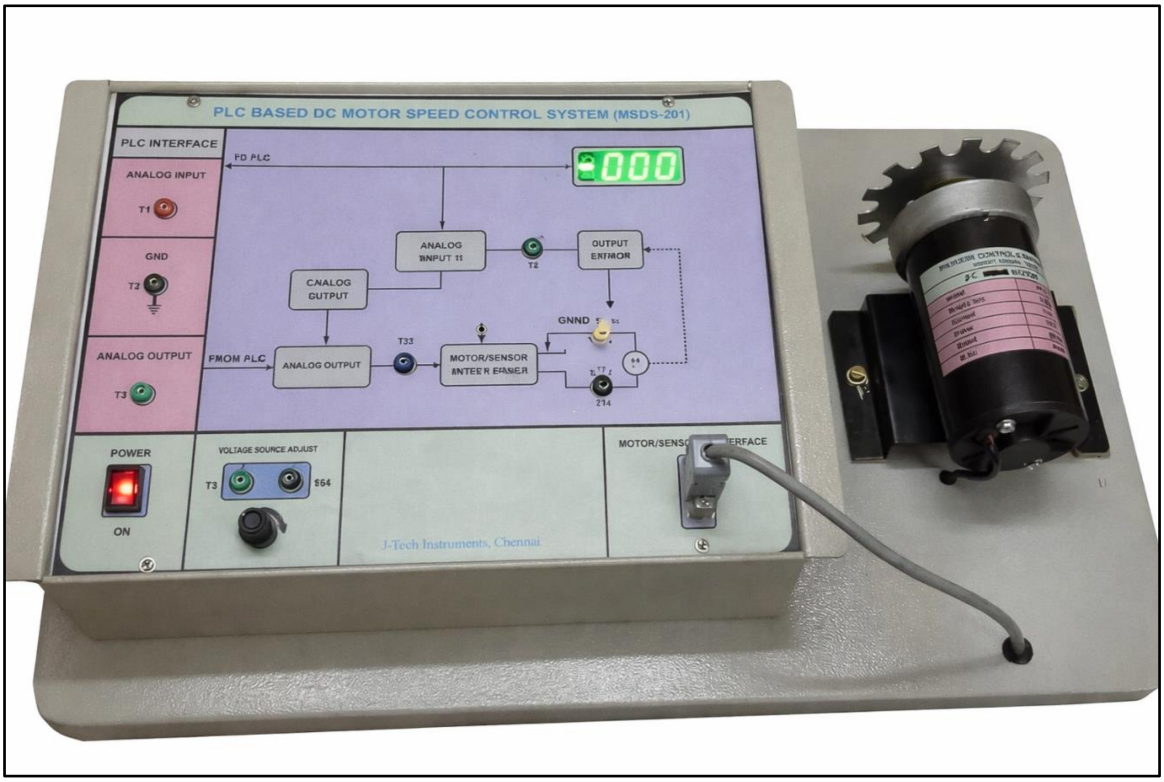

Figure 14.1: Speed control of DC motor using PLC trainer kit

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Apparatus / Equipment	Specification / Details
1	PLC-based DC Motor Speed Control Trainer Kit	Model: MSDS-201
2	Programmable Logic Controller (PLC)	Analog input and analog output supported
3	DC Motor	Low voltage DC motor with speed control
4	Speed Sensor / Encoder	Mounted with motor for speed feedback
5	Analog Output Module	0–10 V DC
6	Power Supply	Inbuilt regulated DC power supply

7	Motor / Sensor Interface	Inbuilt on trainer kit
8	Patch Cords / Connecting Wires	Suitable for trainer terminals
9	PC / Laptop (if required)	PLC programming software installed

IX Precautions to Be Followed:

1. Ensure all connections are proper before switching ON the power supply.
2. Do not change wiring while the power supply is ON.
3. Set the PLC analog output to minimum value before starting the motor.
4. Avoid touching rotating parts of the DC motor during operation.
5. Operate the trainer kit within the specified voltage and current limits.
6. Switch OFF the power supply after completing the experiment.

X Procedure:

1. Connect the DC motor to the motor drive as per the circuit diagram.
2. Connect PLC input terminals to start/stop push buttons.
3. Connect PLC output terminals to the motor drive control terminals.
4. Switch ON the power supply to the PLC and motor drive.
5. Write the ladder logic program for speed control in PLC software.
6. Download the program into the PLC.
7. Switch PLC to RUN mode.
8. Press the START push button to run the motor.
9. Change speed settings using PLC logic (preset/analog/PWM).
10. Observe and record the motor speed for different control values.
11. Press STOP button to stop the motor.

XI Resources used:

Sr. No.	Resource/Software	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	PLC Analog Output (V)	Motor Speed (RPM)	Remarks
1			Low speed
2			Moderate speed
3			Medium speed
4			High speed
5			Maximum speed

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. What is the function of a PLC in motor control?
2. How is the speed of a DC motor controlled?
3. Why PLC is preferred over conventional control circuits?
4. What is ladder logic?

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XVIII References / Suggestions for Further Reading:

1. B.L. Theraja & A.K. Theraja – Electrical Machines
2. Raghuwanshi – Industrial Automation and PLC
3. Siemens PLC Programming Manual
4. NPTEL – Industrial Drives and Control Video Lectures

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of PLC hardware, DC motor setup, and measuring instruments	10%
2	Identification of PLC I/O, power supply, DC motor, and control modules	20%
3	Measurement of electrical parameters (armature voltage/current) and speed	20%
4	Working in teams (PLC programming, wiring coordination, safety practices)	10%
Product Related: 10 Marks		**40%**
5	Development of PLC logic / program for speed control	10%
6	Interpretation of speed variation results with respect to PLC control	05%
7	Conclusion (clarity and correctness)	05%
8	Practical related questions (concepts, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 15: Perform Plugging operation on given induction motor

I Practical Significance:

Plugging is an important electrical braking method used in industrial drive systems to quickly stop an induction motor. This experiment helps students understand how rapid braking is achieved by reversing the phase sequence while the motor is running. Plugging is commonly used in applications such as cranes, elevators, rolling mills, and machine tools, where fast stopping is essential for safety and process control.

II Industry / Employer Expected Outcome(s):

The aim of this course is to help the student to attain the following industry-identified competency through various teaching-learning experiences; Control precisely the speed, torque and power of different motors to ensure optimal performance of industrial drive system.

III Course Level Learning Outcome(s):

CO2 - Use appropriate braking method for different AC and DC motors.

IV Laboratory Learning Outcome(s):

- Perform Plugging operation on given induction motor

V Relevant Affective Domain Related Outcome(s):

After performing this experiment, the student will be able to:

- Follow safe working practices while handling electrical machines
- Develop responsibility and discipline during motor operation
- Show alertness and caution during braking operations
- Appreciate the importance of controlled stopping in industrial drives

VI Relevant Theoretical Background:

Plugging, also known as reverse current braking, is a method of electrical braking in an induction motor. In this method, the phase sequence of the supply is reversed while the motor is running, which causes the motor to produce a torque opposite to the direction of rotation. As a result:

- The motor speed rapidly decreases
- A large braking current flows through the stator
- The kinetic energy of the motor is dissipated as heat

The supply must be disconnected exactly at zero speed; otherwise, the motor will start rotating in the opposite direction.

VII a. Sample of Circuit Diagram:

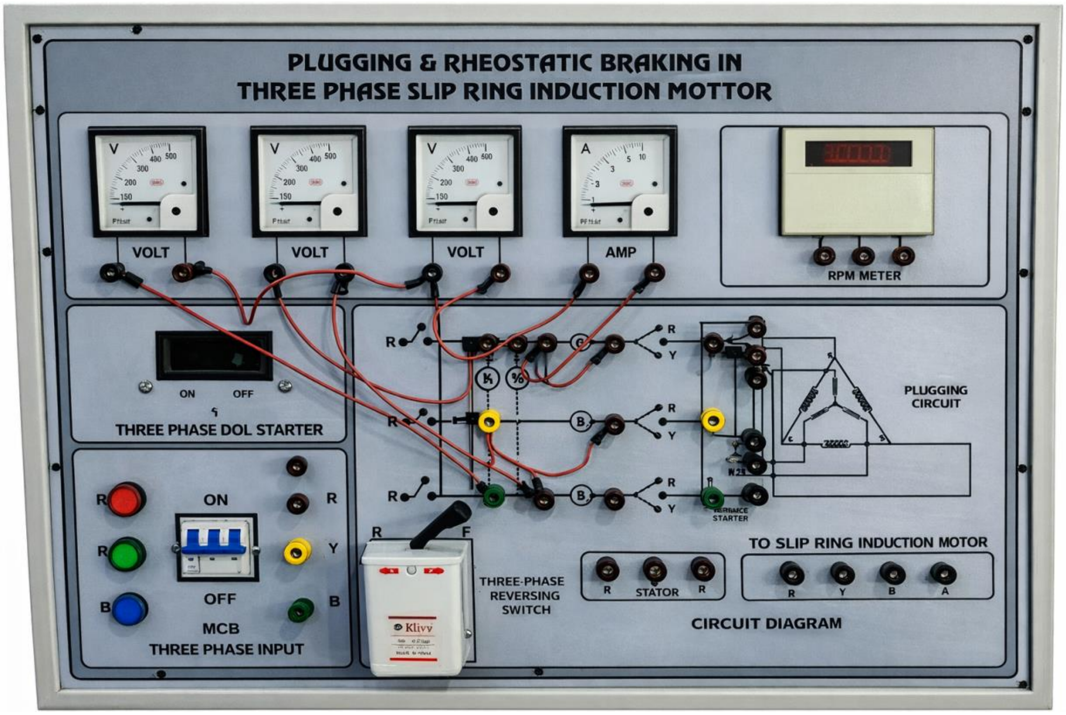

Figure 15.1: Trainer kit for Plugging Braking in Three Phase Induction Motor

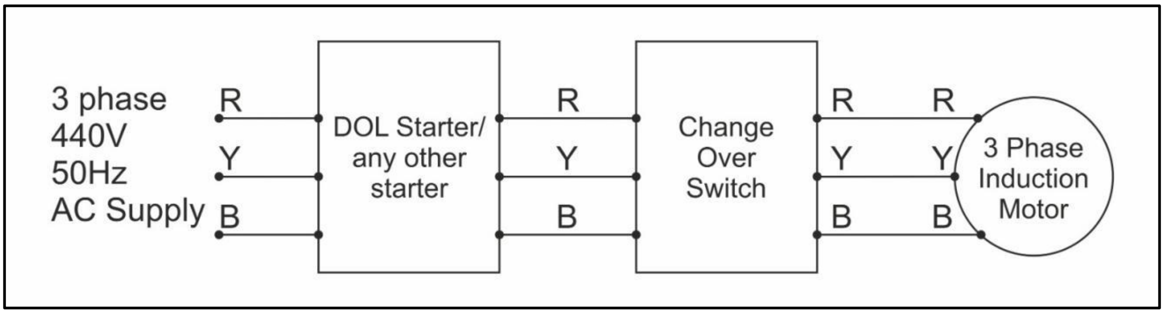

Figure 15.2: Circuit diagram during normal operation

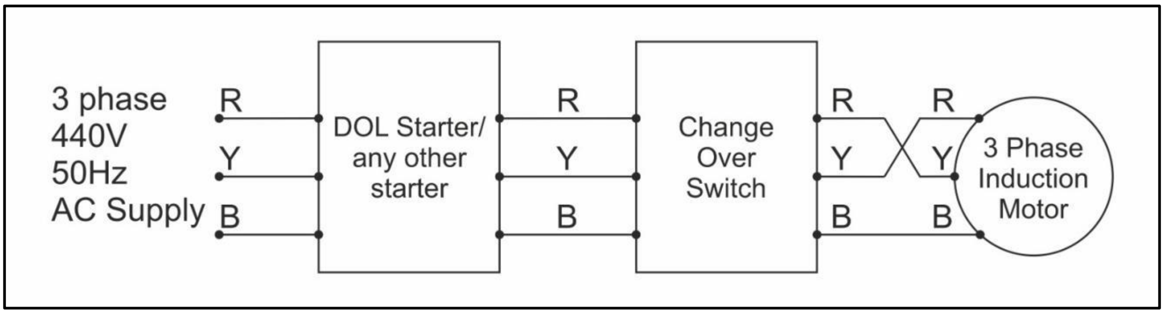

Figure 15.3: Circuit diagram during plugging operation

VIII Required Resources/Apparatus/Equipment with Specifications:

Sr. No.	Name of Resource	Specification	Quantity
1	Three-phase Induction Motor	415 V, 50 Hz	1
2	Three-phase AC Supply	415 V, 50 Hz	1
3	Plugging Switch / Reversing Switch	TPDT or equivalent	1
4	AC Voltmeter	(0–500) V AC or suitable	1
5	AC Ammeter	(0–10) A AC or suitable	1
6	Tachometer	0-3000 RPM Digital	1
7	Stopwatch	Digital	1

IX Precautions to Be Followed:

1. Ensure all connections are tight and correct before switching ON the supply
2. Do not apply plugging for a long duration to avoid overheating
3. Use current-limiting devices if provided
4. Switch OFF the supply exactly when motor speed reaches zero
5. Never touch live terminals
6. Wear proper lab uniform and follow lab safety rules

X Procedure:

1. Connect the induction motor as per the circuit diagram
2. Check the phase sequence
3. Switch ON the three-phase supply and allow the motor to reach rated speed
4. Now Switch off the supply and note down stop time using stopwatch
5. When motor stops again start the motor and allow the motor to reach rated speed
6. Operate the plugging switch to reverse the phase sequence
7. Observe the sudden reduction in motor speed
8. Note the braking stopping time using stopwatch
9. Switch OFF the supply immediately when speed reaches zero

XI Resources used:

Sr. No.	Resource/Software	Specification
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XII Actual Procedure

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XIII Observation Table:

Sr. No.	Time required to stop motor without plugging (sec)	Time required to stop motor with plugging (sec)
1		

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

1. What is plugging in an induction motor?
2. Why is high current drawn during plugging?
3. What will happen if supply is not disconnected at zero speed?
4. Compare plugging with regenerative braking
5. Why is plugging not used continuously?
6. List industrial applications of plugging

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1. B. L. Theraja & A. K. Theraja – Electrical Technology, Vol. II
2. P. S. Bimbhra – Electrical Machinery
3. M. G. Say – Alternating Current Machines
4. https://www.youtube.com/watch?v=8XTw9AWJA0U

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of hardware setup and measuring instruments during plugging operation	10%
2	Identification of circuit components / modules used in plugging of induction motor	20%
3	Measurement of electrical (voltage, current) and mechanical (speed, stopping time) parameters	20%
4	Working in teams (collaboration & role clarity)	10%
Product Related: 10 Marks		**40%**
5	Calculation of theoretical values related to plugging operation	10%
6	Interpretation of experimental results and braking behavior	05%
7	Conclusion based on observations (clarity and correctness)	05%
8	Practical related questions (concepts, applications)	15%
9	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	