

Revised Syllabus

For

ITI

Electrician



**LAL BAHADUR SHASTRI PARAMEDICAL SKILL
AND TRAINING COUNCIL, INDIA**

**लाल बहादुर शास्त्री पैरामेडिकल कौशल और प्रशिक्षण
परिषद, भारत**

मुख्य कार्यालय : 4वीं मंजिल, प्राइम प्लाजा, इंदरा नगर, लखनऊ

प्रशासनिक कार्यालय : द्वितीय तल, सुनील कम्पलेक्स, वेस्टर्न कचेरी रोड, मेरठ

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(To be implemented from 2026-27 session)



Syllabus Of ITI “Electrician

FIRST YEAR (1ST)

S.NO	Subject	Distribution Of Mark			
		TH	PR	Viva -Voce	Total
ER-1	Trade Practical – I	-	200	100	300
ER-2	Trade Theory – I	100	-	-	100
ER-3	Workshop Calculation & Science	50	-	-	50
ER-4	Engineering Drawing	50	-	-	50
ER-5	Employability Skills	50	-	-	50
	Total	250	200	100	550

SECOND YEAR(2ND YEAR)

S.NO	Subject	Distribution Of Mark			
		TH	PR	Viva-Voce	Total
ER-1	Trade Practical	-	200	100	300
ER-2	Trade Theory	100	-	-	100
ER-3	Workshop Calculation & Science	50	-	-	50
ER-4	Engineering Drawing	50	-	-	50
ER-5	Employability Skills	50	-	-	50
ER-6	Internal Assessment / Formative Assessment	200	-	-	200
	Total	450	200	100	750

FIRST YEAR (1ST) ITI, Electrician

Workshop Safety & First Aid

Workshop Safety & First Aid is one of the most important subjects in the **ITI Electrician Trade**. An electrician works with electrical circuits, high voltage, electrical machines, hand tools, power tools, ladders, and various electrical equipment. Electrical work involves risks such as electric shock, burns, fire, explosions, and mechanical injuries. Therefore, every electrician must understand and follow proper safety rules and be able to provide immediate first aid in case of an accident.

Workshop safety refers to the set of rules, procedures, and precautions followed to prevent accidents and create a safe working environment. First Aid is the immediate and temporary care given to an injured or ill person before professional medical treatment becomes available. Knowledge of workshop safety and first aid helps reduce injuries, protect lives, and maintain efficient industrial operations.

Objectives of Workshop Safety

The main objectives of workshop safety are:

- To prevent accidents and injuries.
- To protect workers from electrical hazards.
- To ensure safe handling of electrical tools and equipment.
- To reduce fire and explosion risks.
- To maintain a clean and organized workplace.
- To increase productivity through safe working practices.
- To comply with national safety laws and industrial regulations.

Basic Electricity

Basic Electricity is the foundation of the **ITI Electrician Trade**. It deals with the study of electric charge, voltage, current, resistance, power, energy, electrical circuits, and their practical applications. Electricity is one of the most important forms of energy used in homes, industries, transportation, communication, healthcare, agriculture, and almost every modern technological system.

An electrician must understand the fundamental principles of electricity before working with electrical installations, machines, transformers, motors, generators, and control systems. Knowledge of basic electricity enables an electrician to install, operate, maintain, troubleshoot, and repair electrical equipment safely and efficiently.

What is Electricity?

Electricity is the movement or flow of **electrons** through a conductor due to a potential difference (voltage). Electrons are tiny negatively charged particles present in every atom. When electrons move from one point to another through a conducting material, an electric current is produced.

Electricity is an invisible form of energy that can be converted into light, heat, motion, sound, and chemical energy.

Structure of an Atom

Every substance is made up of atoms. An atom consists of three fundamental particles:

- **Protons** – Positively charged particles located in the nucleus.
- **Neutrons** – Neutral particles located in the nucleus.
- **Electrons** – Negatively charged particles revolving around the nucleus.

Electrical Quantities & Units

Electrical Quantities & Units are the basic measurements used to describe electrical circuits and electrical equipment. Every electrician must understand these quantities because they are used in designing, installing, testing, operating, and maintaining electrical systems. Electrical quantities help in measuring the behavior and performance of electrical circuits, while electrical units provide a standard method of expressing these measurements.

The **International System of Units (SI Units)** is used worldwide for electrical measurements. Knowledge of electrical quantities and units enables electricians to select appropriate electrical components, calculate circuit values, troubleshoot faults, and ensure safe operation of electrical installations.

Objectives of Electrical Quantities & Units

The main objectives are:

- To understand the basic electrical quantities.
- To learn SI units used in electrical engineering.
- To measure electrical parameters accurately.
- To perform electrical calculations correctly.
- To ensure safe and efficient operation of electrical systems.
- To develop troubleshooting skills using electrical measurements.

Ohm's Law

Ohm's Law is one of the most fundamental laws in electrical engineering. It was discovered by the German physicist **Georg Simon Ohm** in **1827**. This law explains the relationship between **Voltage (V)**, **Current (I)**, and **Resistance (R)** in an electrical circuit.

Ohm's Law is the foundation of the **ITI Electrician Trade** because almost every electrical calculation involving circuits, electrical installations, motors, transformers, batteries, and electronic devices is based on this principle. By applying Ohm's Law, electricians can determine the required voltage, current, or resistance in a circuit, making it essential for designing, testing, troubleshooting, and maintaining electrical systems.

Definition of Ohm's Law

Ohm's Law states:

"At constant temperature, the current flowing through a conductor is directly proportional to the applied voltage and inversely proportional to the resistance of the conductor."

This means:

- If the **voltage increases**, the **current increases**.
- If the **resistance increases**, the **current decreases**.
- If the **voltage decreases**, the **current decreases**.

Series & Parallel Circuits

Series and Parallel Circuits are the two basic methods of connecting electrical components in an electrical circuit. Every electrician must understand these types of circuits because they are widely used in **domestic wiring, industrial installations, electronic devices, power distribution systems, control panels, and electrical machines**.

The behavior of **current, voltage, resistance, and power** differs in series and parallel circuits. Understanding these differences helps electricians design circuits correctly, troubleshoot electrical faults, and ensure safe and efficient operation of electrical equipment.

Objectives of Series & Parallel Circuits

The main objectives are:

- To understand the construction of series and parallel circuits.
- To study the flow of current and voltage.
- To calculate equivalent resistance.
- To compare the characteristics of both circuits.
- To apply these circuits in practical electrical installations.
- To troubleshoot electrical circuits effectively.

Cells & Batteries

Cells and Batteries are the primary sources of **Direct Current (DC)** electrical energy. They convert **chemical energy into electrical energy** through electrochemical reactions. Cells and batteries are widely used in portable electronic devices, automobiles, emergency lighting systems, UPS systems, solar power systems, communication equipment, medical instruments, and industrial applications.

In the **ITI Electrician Trade**, understanding cells and batteries is essential because electricians frequently install, test, maintain, charge, and replace batteries in various electrical and electronic systems. Proper knowledge of battery construction, working principles, charging methods, maintenance, and safety precautions ensures reliable power supply and long service life.

Objectives of Cells & Batteries

The main objectives are:

- To understand the construction and working of cells and batteries.
- To study different types of cells and batteries.
- To understand battery ratings and characteristics.
- To learn charging and maintenance procedures.
- To identify applications of different batteries.
- To ensure safe handling and disposal of batteries.

Magnetism & Electromagnetism

Magnetism and Electromagnetism are fundamental concepts in electrical engineering and form the basis of many electrical machines and devices. Every **ITI Electrician** must understand these topics because electrical equipment such as **motors, generators, transformers, relays, contactors, electric bells, loudspeakers, measuring instruments, and circuit breakers** operate on the principles of magnetism and electromagnetism.

Magnetism is the property by which certain materials attract iron, nickel, cobalt, and other magnetic materials. **Electromagnetism** is the branch of science that studies the relationship between electricity and magnetism. When electric current flows through a conductor, it produces a magnetic field around it. This principle is widely used in electrical engineering.

Objectives of Magnetism & Electromagnetism

The main objectives are:

- To understand the principles of magnetism.
- To study magnetic materials and magnetic fields.
- To understand the properties of magnets.
- To learn the principles of electromagnetism.
- To study electromagnetic induction.
- To understand the applications of magnetism in electrical engineering.

DC Generator

A **Direct Current (DC) Generator** is an electrical machine that converts **mechanical energy into direct current (DC) electrical energy** based on the principle of **Faraday's Law of Electromagnetic Induction**. It is one of the most important machines studied in the **ITI Electrician Trade** because it forms the foundation for understanding electrical energy generation and the working principles of many electrical machines.

A DC generator is widely used in **battery charging systems, laboratories, electroplating, welding, DC motor supply, emergency power systems, and industrial applications** where a direct current supply is required.

Objectives of DC Generator

The main objectives are:

- To understand the construction and working of a DC generator.
- To study the principle of electromagnetic induction.
- To identify the main parts of a DC generator.
- To understand different types of DC generators.
- To study the applications and characteristics of DC generators.
- To learn maintenance and safety procedures.

DC Motor

A **Direct Current (DC) Motor** is an electrical machine that converts **Direct Current (DC) electrical energy into mechanical energy**. It operates on the principle that **when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force**. DC motors are widely used in industries where **high starting torque, precise speed control, and smooth operation** are required.

In the **ITI Electrician Trade**, the study of DC motors is essential because they are commonly used in **electric vehicles, cranes, hoists, rolling mills, machine tools, conveyors, elevators, battery-operated equipment, and industrial automation systems**.

Objectives of DC Motor

The main objectives are:

- To understand the construction and working of a DC motor.
- To study the operating principle of a DC motor.
- To identify the main parts and their functions.
- To classify different types of DC motors.
- To understand speed control and applications.
- To learn maintenance and safety procedures.

Transformers

A **Transformer** is a **static electrical device** that transfers **electrical energy from one circuit to another through electromagnetic induction** without changing the frequency of the supply. It is one of the most important electrical machines used in **power generation, transmission, distribution, industries, homes, hospitals, communication systems, and renewable energy systems**.

A transformer is used to **increase (step-up)** or **decrease (step-down)** the voltage level of alternating current (AC). Since transformers work only with **Alternating Current (AC)**, they are essential components of every electrical power system.

For an **ITI Electrician**, understanding the construction, working, types, testing, maintenance, and applications of transformers is essential for installation, operation, maintenance, and troubleshooting of electrical systems.

Objectives of Transformers

The main objectives are:

- To understand the principle of transformer operation.
- To study the construction of transformers.
- To understand the working of transformers.
- To identify different types of transformers.
- To understand transformer losses and efficiency.
- To learn transformer maintenance and safety practices.

Electrical Measuring Instruments

Electrical Measuring Instruments are devices used to **measure electrical quantities** such as **voltage, current, resistance, power, energy, frequency, capacitance, inductance, insulation resistance, and power factor**. These instruments are essential in electrical engineering for testing, installation, maintenance, fault diagnosis, and quality control.

In the **ITI Electrician Trade**, measuring instruments are indispensable because electricians use them to ensure that electrical systems are operating safely, efficiently, and according to specifications. Accurate measurement helps prevent equipment damage, reduces electrical accidents, and improves the reliability of electrical installations.

Objectives of Electrical Measuring Instruments

The main objectives are:

- To understand the purpose of electrical measuring instruments.
- To study different types of measuring instruments.
- To learn the construction and working of common instruments.
- To perform accurate electrical measurements.
- To troubleshoot electrical faults using measuring instruments.
- To ensure safe operation during testing.

Wiring Materials & Tools

Wiring Materials and Tools are the basic requirements for installing, maintaining, repairing, and testing electrical wiring systems. Every **ITI Electrician** must have thorough knowledge of the different wiring materials and tools used in domestic, commercial, and industrial electrical installations.

Electrical wiring materials include **conductors, cables, switches, sockets, distribution boards, protective devices, conduits, accessories, and insulation materials**. Similarly, electrical tools are used for cutting, stripping, bending, drilling, fastening, testing, and repairing electrical systems.

The correct selection and proper use of wiring materials and tools ensure **safe, efficient, reliable, and long-lasting electrical installations**.

Objectives of Wiring Materials & Tools

The main objectives are:

- To understand different wiring materials.
- To identify electrical hand tools.
- To learn the functions of wiring accessories.
- To select suitable materials for electrical installations.
- To perform wiring safely and efficiently.
- To maintain tools properly.

Domestic Wiring

Domestic Wiring is the process of installing electrical wiring and accessories in residential buildings such as **houses, apartments, flats, bungalows, and residential complexes** to distribute electrical power safely and efficiently. A domestic wiring system supplies electricity from the **distribution board (DB)** to various electrical appliances such as **lights, fans, sockets, refrigerators, air conditioners, televisions, water heaters, washing machines, and kitchen appliances**.

In the **ITI Electrician Trade**, domestic wiring is one of the most important practical subjects. A qualified electrician must know how to **design, install, test, maintain, and troubleshoot domestic electrical installations** while following the **National Electrical Code (NEC) of India, IS 732 standards, and Central Electricity Authority (CEA) Safety Regulations**.

Objectives of Domestic Wiring

The main objectives are:

- To understand the principles of domestic electrical wiring.
- To identify wiring materials and accessories.
- To learn different wiring systems.
- To understand house wiring circuits.
- To perform safe installation and maintenance.
- To follow electrical safety standards.

Earthing

Earthing (Grounding) is one of the most important safety measures in electrical engineering. It is the process of connecting the **non-current-carrying metallic parts** of electrical equipment to the **general mass of the earth** through a low-resistance conductor. Earthing provides a safe path for fault current to flow into the ground, protecting people and electrical equipment from electric shock, fire hazards, and damage caused by insulation failure or lightning.

In the **ITI Electrician Trade**, earthing is a fundamental topic because every electrical installation—whether domestic, commercial, or industrial—must have a proper earthing system to ensure safe and reliable operation.

Objectives of Earthing

The main objectives are:

- To understand the concept and importance of earthing.
- To study the different types of earthing.
- To identify earthing materials and accessories.
- To understand the methods of earthing installation.
- To learn testing and maintenance of earthing systems.
- To ensure electrical safety by proper earthing.

Soldering

Soldering is the process of joining two or more metal parts by using a **filler metal called solder**, which melts at a lower temperature than the base metals. During soldering, the base metals do not melt; only the solder melts and flows into the joint by **capillary action**, creating a strong electrical and mechanical connection.

Soldering is widely used in **electrical wiring, electronic circuit assembly, PCB manufacturing, communication equipment, electrical repairs, and instrument maintenance**. For an **ITI Electrician**, soldering is an essential skill for making reliable electrical connections and repairing electrical equipment.

Objectives of Soldering

The main objectives are:

- To understand the principle of soldering.
- To identify soldering tools and materials.
- To learn the soldering process.
- To prepare strong and reliable electrical joints.
- To understand different types of soldering.
- To follow safety precautions during soldering.

Electrical Drawings

Electrical Drawings are graphical representations of electrical systems, circuits, wiring layouts, and electrical equipment using **standard symbols, lines, and notations**. These drawings help electricians, engineers, technicians, and contractors understand how electrical installations should be carried out, operated, maintained, and repaired.

Electrical drawings are an essential part of the **ITI Electrician Trade** because every electrical installation, from a small house to a large industrial plant, is planned and executed using electrical drawings. They provide clear instructions regarding the location of equipment, wiring routes, circuit connections, and safety devices.

Objectives of Electrical Drawings

The main objectives are:

- To understand the importance of electrical drawings.
- To identify different types of electrical drawings.
- To interpret electrical symbols and notations.
- To read wiring diagrams accurately.
- To prepare simple electrical drawings.
- To perform electrical installations according to drawings.

Workshop Calculations

Workshop Calculations are the mathematical calculations used in electrical workshops to perform accurate measurements, estimate materials, calculate electrical quantities, and solve practical engineering problems. Every **ITI Electrician** must have a sound knowledge of workshop calculations because they are essential for **electrical installation, maintenance, testing, troubleshooting, and estimating work**.

Workshop calculations include **basic arithmetic, fractions, decimals, percentages, ratios, geometry, mensuration, unit conversions, and electrical calculations**. These calculations help electricians perform their work accurately, reduce material wastage, improve efficiency, and ensure safety.

Objectives of Workshop Calculations

The main objectives are:

- To understand the importance of workshop mathematics.
- To perform basic mathematical calculations.
- To calculate electrical quantities accurately.
- To estimate materials required for electrical installations.
- To apply geometry and mensuration in workshop practice.
- To improve accuracy and efficiency in electrical work.

SECOND YEAR(2ND YEAR) ITI, Electrician

Module 1 – DC Generator

Construction of DC Generator

A **Direct Current (DC) Generator** is an electrical machine that converts **mechanical energy into direct current (DC) electrical energy**. It works on the principle of **Faraday's Law of Electromagnetic Induction**, which states that **whenever a conductor cuts magnetic lines of force, an electromotive force (EMF) is induced in the conductor**.

The construction of a DC generator is designed to produce a continuous DC output efficiently and reliably. It consists of two main parts:

- **Stator (Stationary Part)**
- **Rotor (Rotating Part)**

Each component performs a specific function in the generation of electricity.

Objectives of Construction of DC Generator

The main objectives are:

- To understand the construction of a DC generator.
- To identify the main parts of a DC generator.
- To explain the function of each component.
- To understand the role of the magnetic circuit and electrical circuit.
- To learn the importance of proper maintenance of generator components.

Principle and Working

A **Direct Current (DC) Generator** is an electrical machine that converts **mechanical energy into direct current (DC) electrical energy**. It is widely used in industries, battery charging systems, electroplating plants, welding equipment, and as an exciter in power stations.

The operation of a DC generator is based on the **Principle of Electromagnetic Induction**, discovered by **Michael Faraday**. When a conductor moves in a magnetic field and cuts magnetic lines of force, an electromotive force (EMF) is induced in the conductor. The generated electrical energy is collected through the **commutator and brushes** as a direct current.

Objectives

The main objectives are:

- To understand the principle of a DC generator.
- To study the working of a DC generator.
- To explain the process of electromagnetic induction.
- To understand the function of the commutator and brushes.
- To learn the energy conversion process in a DC generator.

EMF Equation

The **Electromotive Force (EMF)** generated in a **DC Generator** is the voltage produced when the armature conductors rotate and cut the magnetic field. The amount of EMF generated depends on factors such as the **magnetic flux per pole, number of poles, speed of rotation, total number of armature conductors, and the type of armature winding**.

The **EMF Equation** is an important mathematical expression used to calculate the voltage generated by a DC generator. It helps engineers and electricians design, analyze, and test DC generators for different applications.

Objectives

The main objectives are:

- To understand the EMF equation of a DC generator.
- To identify the factors affecting generated EMF.
- To derive the EMF equation.
- To calculate the generated voltage using the EMF equation.
- To understand the effect of speed, flux, and winding type on EMF.

Types of DC Generators

A **DC generator** converts **mechanical energy into direct-current electrical energy**. All DC generators operate on the principle of **electromagnetic induction**, but they are classified according to the method used to produce the magnetic field.

The field system of a DC generator may receive current from:

- A separate external DC source, or
- The generator's own armature output.

Based on the method of excitation, DC generators are mainly divided into:

1. **Separately Excited DC Generator**
2. **Self-Excited DC Generator**

Self-excited generators are further classified as:

- Shunt Generator
- Series Generator
- Compound Generator

Characteristics

The **characteristics of a DC generator** show the relationship between different electrical quantities such as:

- Generated EMF
- Terminal voltage
- Field current
- Armature current
- Load current

These characteristics help us understand how the generator behaves under **no-load and load conditions**. They are useful for selecting a suitable DC generator for lighting, battery charging, welding, electroplating, and industrial applications.

Objectives

After studying this topic, the trainee will be able to:

- Understand the meaning of DC generator characteristics.
- Explain open-circuit, internal, and external characteristics.
- Describe the characteristics of separately excited, shunt, series, and compound generators.
- Understand the effect of load on terminal voltage.
- Select a suitable generator for a particular application.

Applications

A **DC Generator** converts **mechanical energy into direct current (DC) electrical energy**. Before the widespread use of semiconductor rectifiers, DC generators were the primary source of DC power. Even today, they are used in many industrial, laboratory, and special-purpose applications where a reliable DC supply is required.

The applications of a DC generator depend on its **voltage regulation, current capacity, and type of field excitation** (Shunt, Series, Compound, or Separately Excited).

Objectives

After studying this topic, the trainee will be able to:

- Explain the applications of DC generators.
- Identify the suitable type of DC generator for different purposes.
- Understand industrial uses of DC generators.
- Select the correct generator according to load requirements.

Testing

Testing of a DC generator means checking the generator to determine whether it is mechanically sound, electrically safe, and capable of producing the required voltage and current.

Testing is carried out:

- Before installation
- After repair or rewinding
- During regular maintenance

- When the generator gives low voltage
- When excessive sparking or heating occurs
- Before putting the machine into service

The main purpose of testing is to check the generator's **insulation, winding condition, voltage build-up, load performance, efficiency, voltage regulation, temperature rise, commutation, and safety.**

Objectives

After studying this topic, the trainee will be able to:

- Explain the need for testing a DC generator.
- Perform visual and mechanical inspection.
- Test armature and field windings.
- Measure insulation resistance.
- Check voltage build-up.
- Perform no-load and load tests.
- Determine voltage regulation and efficiency.
- Identify common faults.
- Follow safety precautions during testing.

Maintenance

Maintenance of a DC generator means regular inspection, cleaning, adjustment, lubrication, testing, and repair of the machine to keep it in safe and efficient working condition.

A DC generator contains both electrical and mechanical parts. Its brushes, commutator, bearings, windings, terminals, cooling system, and protective devices require regular attention.

Proper maintenance helps to:

- Prevent sudden breakdown
- Reduce sparking and overheating
- Improve efficiency
- Maintain correct terminal voltage
- Increase generator life
- Reduce repair costs
- Ensure safe operation

Objectives

After studying this topic, the trainee will be able to:

- Explain the need for DC generator maintenance.
- Identify daily, weekly, monthly, and annual maintenance activities.

- Maintain brushes and commutator.
- Inspect armature and field windings.
- Maintain bearings and cooling systems.
- Detect common faults during maintenance.
- Follow electrical and mechanical safety precautions.

Fault Finding

Fault finding in a DC generator means systematically locating the cause of a problem and taking the correct corrective action.

A DC generator may fail because of electrical, mechanical, magnetic, or operational faults. Common symptoms include:

- Generator does not produce voltage
- Low output voltage
- Excessive terminal voltage
- Voltage fluctuation
- Heavy sparking at brushes
- Overheating
- Abnormal noise
- Excessive vibration
- Poor voltage regulation
- Generator fails under load

Module 2 – DC Motor

Construction

The **construction of a DC generator** refers to the arrangement and assembly of all the mechanical and electrical parts that work together to convert **mechanical energy into direct current (DC) electrical energy**.

A DC generator mainly consists of **two major parts**:

1. **Stator (Stationary Part)** – Produces the magnetic field.
2. **Rotor or Armature (Rotating Part)** – Rotates inside the magnetic field and generates electricity.

The construction of a DC generator is designed to ensure:

- Efficient magnetic flux distribution
- Smooth rotation of the armature
- Efficient current collection
- Reliable operation with minimum losses

Objectives

After studying this topic, the trainee will be able to:

- Explain the construction of a DC generator.
- Identify the main parts of a DC generator.
- Describe the function of each part.
- Understand the materials used in different parts.
- Explain the importance of each component in power generation.

Working Principle

A **DC generator** is an electrical machine that converts **mechanical energy into direct-current electrical energy**.

It works on the principle of **electromagnetic induction**. When a conductor moves in a magnetic field and cuts magnetic flux, an electromotive force is induced in the conductor.

The mechanical energy required to rotate the armature may be supplied by:

- Diesel engine
- Steam turbine
- Water turbine
- Electric motor
- Petrol engine
- Wind turbine

Definition

A DC generator is a rotating electrical machine that converts mechanical energy into electrical energy in the form of direct current.

Back EMF

Back EMF is an important phenomenon in a DC motor. When the armature of a DC motor rotates inside a magnetic field, an EMF is induced in the armature conductors.

According to **Lenz's Law**, this induced EMF acts in a direction opposite to the applied supply voltage. Therefore, it is called:

- Back EMF
- Counter EMF
- Counter Electromotive Force

It is generally represented by:

EbE_bEb

Back EMF automatically controls the armature current and protects the motor during normal operation.

Back EMF is mainly associated with a **DC motor**. In a DC generator, the corresponding voltage is called generated EMF.

Torque

Torque is the turning or rotational force produced by a DC motor. When current-carrying armature conductors are placed in the magnetic field produced by the field poles, each conductor experiences a mechanical force. The combined effect of these forces produces a turning moment on the armature.

This turning moment rotates the motor shaft and is called **motor torque** or **electromagnetic torque**.

Torque is generally represented by:

T or τ

Its SI unit is:

Newton-metre (N·m)

Objectives

After studying this topic, the trainee will be able to:

- Define torque.
- Explain how torque is produced in a DC motor.
- State Fleming's Left-Hand Rule.
- Derive the torque equation of a DC motor.
- Explain the relationship between torque, flux, and armature current.
- Differentiate between armature torque and shaft torque.
- Calculate motor torque from power and speed.
- Compare torque characteristics of shunt, series, and compound motors.
- Identify common causes of low or excessive torque.

Types of DC Motors

A **DC motor** is an electrical machine that converts **direct-current electrical energy into mechanical energy**. It works on the principle that a current-carrying conductor placed in a magnetic field experiences a mechanical force.

DC motors are classified according to the method used to produce their magnetic field and the manner in which the field winding is connected to the armature circuit. Different types of DC motors have different characteristics related to:

- Starting torque
- Speed regulation
- Load-handling capacity
- Efficiency
- Control of speed
- Industrial applications

The main types of DC motors are:

1. Separately excited DC motor
2. Self-excited DC motor
 - DC shunt motor
 - DC series motor
 - DC compound motor
3. Permanent magnet DC motor

The selection of a DC motor depends on the type of load, required starting torque, operating speed, and speed-regulation requirements.

Objectives

After studying this topic, the trainee will be able to:

- Define a DC motor.
- Explain the basis of classification of DC motors.
- Identify the different types of DC motors.
- Distinguish between separately excited and self-excited motors.
- Name the shunt, series, and compound types of DC motors.
- Understand the importance of field-winding connections.
- Select a suitable type of DC motor for different applications.
- Recognize the basic operating characteristics of different DC motors.

Speed Control

Speed control of a DC motor is the process of increasing, decreasing, or maintaining the speed of the motor according to the requirements of a particular application. The speed of a DC motor is one of its most important characteristics because many industrial machines require different operating speeds for efficient and safe operation.

The speed of a DC motor depends mainly on three factors:

- Applied armature voltage
- Magnetic flux produced by the field winding
- Armature circuit resistance

By controlling any one of these factors, the speed of the motor can be varied over a wide range. DC motors are widely used in applications where accurate and smooth speed control is

required, such as electric traction, cranes, elevators, rolling mills, conveyors, machine tools, paper mills, and printing presses.

Different methods of speed control are used depending on the type of DC motor, the required speed range, efficiency, load characteristics, and operating conditions. Proper speed control improves machine performance, increases productivity, reduces power consumption, enhances safety, and extends the service life of the motor.

Objectives

After studying this topic, the trainee will be able to:

- Define speed control of a DC motor.
- Explain the need for speed control in industrial applications.
- State the factors affecting the speed of a DC motor.
- Identify the different methods of speed control.
- Distinguish between field control and armature control methods.
- Understand the importance of speed regulation in DC motors.
- Select a suitable speed control method for different applications.
- Explain the advantages of proper speed control.
- Recognize the industrial uses of controlled-speed DC motors.
- Prepare for the detailed study of various DC motor speed control methods.

Characteristics

The **characteristics of a DC motor** describe the relationship between important operating parameters such as **speed, torque, armature current, and output power** under different load conditions. These characteristics help us understand how a DC motor behaves during starting, running, and when the load changes.

The performance of a DC motor depends on its type, such as **shunt motor, series motor, or compound motor**. Each type has different speed and torque characteristics, making it suitable for specific industrial applications. By studying these characteristics, engineers and technicians can select the most appropriate motor for a particular job, ensure efficient operation, and prevent overloading or improper use.

The three principal characteristics of a DC motor are:

1. **Torque–Armature Current (T–I_a) Characteristic**
2. **Speed–Armature Current (N–I_a) Characteristic**
3. **Speed–Torque (N–T) Characteristic**

These characteristics provide valuable information about the motor's starting torque, speed regulation, load-carrying capacity, and overall performance.

Objectives

After studying this topic, the trainee will be able to:

- Define the characteristics of a DC motor.
- Explain the importance of motor characteristics in electrical engineering.
- Identify the three main characteristics of a DC motor.
- Understand the relationship between speed, torque, and armature current.
- Distinguish the characteristics of shunt, series, and compound DC motors.
- Interpret characteristic curves under different load conditions.
- Select a suitable DC motor based on its operating characteristics.
- Analyze the performance of a DC motor for various industrial applications

Applications

A **DC motor** is an electrical machine that converts **direct-current (DC) electrical energy into mechanical energy**. Due to its excellent speed control, high starting torque, quick response to load changes, and smooth operation, the DC motor is widely used in domestic, commercial, and industrial applications.

Different types of DC motors are designed to meet different operating requirements. For example, **DC shunt motors** are suitable for applications requiring nearly constant speed, **DC series motors** are preferred where very high starting torque is required, and **DC compound motors** are used where both good starting torque and fairly constant speed are essential.

The selection of a DC motor depends on several factors, such as load characteristics, speed requirements, starting torque, duty cycle, efficiency, and operating conditions. DC motors are commonly used in cranes, hoists, elevators, conveyors, electric traction systems, rolling mills, machine tools, printing presses, battery-operated vehicles, robotics, and many other industrial and commercial machines.

Studying the applications of DC motors helps trainees understand the suitability of each type of motor for different practical purposes and enables them to select the correct motor for a specific application.

Objectives

After studying this topic, the trainee will be able to:

- Define the applications of DC motors.
- Explain the importance of DC motors in industrial and commercial fields.
- Identify the different applications of DC shunt, series, and compound motors.
- Select a suitable type of DC motor for various operating conditions.
- Understand the relationship between motor characteristics and their applications.
- Recognize the factors affecting the selection of a DC motor.
- Describe the use of DC motors in modern electrical and industrial systems.
- Appreciate the advantages of DC motors in applications requiring speed control and high starting torque.
- Differentiate the applications of different types of DC motors.
- Prepare for the detailed study of individual DC motor applications in various industries.

Maintenance

Maintenance of a DC motor is the process of inspecting, cleaning, lubricating, testing, adjusting, and repairing the motor at regular intervals to ensure safe, reliable, and efficient operation. Proper maintenance helps the motor perform at its rated efficiency, reduces unexpected breakdowns, and increases its service life.

A DC motor consists of several important components such as the **armature, field winding, commutator, brushes, bearings, shaft, and cooling system**. These parts are subjected to electrical, mechanical, and thermal stresses during operation. If regular maintenance is neglected, problems such as excessive sparking, overheating, bearing failure, insulation damage, poor speed regulation, and reduced efficiency may occur.

Maintenance may be carried out as **routine, preventive, predictive, or corrective maintenance**, depending on the operating conditions and maintenance schedule. Regular inspection and timely replacement of worn or damaged parts improve motor reliability, reduce maintenance costs, minimize downtime, and ensure safe operation in industrial and commercial applications.

Objectives

After studying this topic, the trainee will be able to:

- Define the maintenance of a DC motor.
- Explain the importance of regular motor maintenance.
- Identify the main components requiring periodic inspection and maintenance.
- Distinguish between routine, preventive, predictive, and corrective maintenance.
- Understand the procedures for cleaning, lubrication, inspection, and testing of a DC motor.
- Recognize common maintenance problems and their causes.
- Improve the efficiency, reliability, and service life of a DC motor through proper maintenance.
- Follow safe maintenance practices while working on DC motors.
- Maintain maintenance records and inspection schedules.

Module 3 – AC Three Phase Motor

Three Phase Induction Motor

A **Three-Phase Induction Motor** is an **AC electric motor** that converts **three-phase electrical energy into mechanical energy** through the principle of **electromagnetic induction**. It is one of the most widely used electrical machines in industries because of its simple construction, rugged design, high efficiency, reliable performance, and low maintenance requirements.

Unlike a DC motor, a three-phase induction motor does not require brushes, a commutator, or an external electrical connection to the rotor. When a three-phase AC supply is applied to the stator winding, a **rotating magnetic field (RMF)** is produced. This rotating magnetic field

induces an electromotive force (EMF) and current in the rotor conductors. The interaction between the rotating magnetic field and the induced rotor current produces **electromagnetic torque**, causing the rotor to rotate in the same direction as the rotating magnetic field.

Three-phase induction motors are classified mainly into **Squirrel Cage Induction Motors** and **Slip Ring (Wound Rotor) Induction Motors**. These motors are extensively used in industries to drive pumps, fans, compressors, conveyors, machine tools, blowers, crushers, rolling mills, textile machinery, and many other mechanical loads requiring continuous and reliable operation.

Because of their durability, high starting reliability, good speed characteristics, and economical operation, three-phase induction motors are considered the backbone of modern industrial power systems.

Objectives

After studying this topic, the trainee will be able to:

- Define a three-phase induction motor.
- Explain the basic principle of operation of a three-phase induction motor.
- Understand the importance of electromagnetic induction in motor operation.
- Identify the major parts of a three-phase induction motor.
- Classify the different types of three-phase induction motors.
- Recognize the advantages of three-phase induction motors over other types of motors.
- Understand the industrial importance and applications of three-phase induction motors.
- Explain the concept of the rotating magnetic field (RMF).
- Appreciate the need for three-phase induction motors in modern industrial systems.
- Prepare for the detailed study of construction, working principle, characteristics, speed control, applications, and maintenance of three-phase induction motors.

Construction

The **construction of a three-phase induction motor** refers to the design, arrangement, and assembly of its various mechanical and electrical components that work together to convert **three-phase electrical energy into mechanical energy**. A well-designed construction ensures efficient operation, reliable performance, long service life, and minimum maintenance.

A three-phase induction motor is mainly divided into **two major parts**:

1. **Stator** – The stationary part of the motor that carries the three-phase winding and produces the rotating magnetic field (RMF).
2. **Rotor** – The rotating part placed inside the stator, where current is induced by electromagnetic induction to produce torque.

The stator and rotor are separated by a small **air gap**, which allows the rotor to rotate freely while maintaining effective magnetic coupling. Other important components such as the

frame, shaft, bearings, end shields, cooling fan, and terminal box provide mechanical support, smooth rotation, cooling, and safe electrical connections.

Based on rotor construction, three-phase induction motors are classified into:

- **Squirrel Cage Induction Motor**
- **Slip Ring (Wound Rotor) Induction Motor**

The simple, rugged, and brushless construction of the three-phase induction motor makes it highly reliable and suitable for continuous operation in various industrial applications.

Objectives

After studying this topic, the trainee will be able to:

- Define the construction of a three-phase induction motor.
- Identify the major parts of a three-phase induction motor.
- Differentiate between the stator and rotor.
- Explain the function of each constructional component.
- Distinguish between squirrel cage and slip ring rotor constructions.
- Understand the purpose of the air gap, shaft, bearings, cooling fan, and terminal box.
- Recognize the materials used in different parts of the motor.
- Appreciate the importance of proper motor construction for efficient and reliable operation.
- Understand the mechanical and electrical arrangement of the motor.
- Prepare for the detailed study of each constructional part of a three-phase induction motor.

Rotating Magnetic Field

A **Rotating Magnetic Field (RMF)** is the magnetic field produced when a **balanced three-phase AC supply** is applied to the three-phase stator winding of an induction motor. The three stator windings are placed **120° electrical apart**, and the alternating currents flowing through them create magnetic fluxes that continuously change in magnitude and direction. The combined effect of these three alternating fluxes produces a **single magnetic field that rotates continuously** around the inner circumference of the stator.

The rotating magnetic field is the **fundamental principle** behind the operation of a three-phase induction motor. This rotating field cuts the stationary rotor conductors, inducing an electromotive force (EMF) and current in the rotor by **electromagnetic induction**. The interaction between the rotating magnetic field and the induced rotor current produces electromagnetic torque, causing the rotor to rotate in the same direction as the rotating magnetic field.

The speed of the rotating magnetic field is called **synchronous speed**, which depends on the supply frequency and the number of poles of the motor. The concept of the rotating magnetic field is also used in synchronous motors and other AC electrical machines.

Understanding the rotating magnetic field is essential for studying the working principle, speed, torque, slip, and performance characteristics of three-phase induction motors.

Objectives

After studying this topic, the trainee will be able to:

- Define a rotating magnetic field (RMF).
- Explain how a rotating magnetic field is produced in a three-phase induction motor.
- Understand the role of a balanced three-phase AC supply in producing the RMF.
- Explain the importance of the 120° phase displacement between stator windings.
- Understand the relationship between the rotating magnetic field and electromagnetic induction.
- Explain the significance of the rotating magnetic field in torque production.
- Define synchronous speed and understand its relationship with the rotating magnetic field.
- Recognize the importance of the rotating magnetic field in the operation of three-phase induction motors.

Slip

Slip is one of the most important concepts in the study of a **three-phase induction motor**. It is defined as the **difference between the synchronous speed of the rotating magnetic field and the actual speed of the rotor**, expressed either as a percentage or as a decimal (fraction).

In a three-phase induction motor, the stator winding produces a **rotating magnetic field (RMF)** that rotates at **synchronous speed (N_s)**. The rotor attempts to follow this rotating magnetic field, but it **can never reach the synchronous speed**. If the rotor were to rotate at the same speed as the rotating magnetic field, there would be no relative motion between them, no electromagnetic induction would take place, no rotor current would be induced, and consequently **no torque would be produced**.

Therefore, the rotor always rotates at a speed slightly lower than the synchronous speed. This difference in speed is known as **slip**. Slip is essential for the operation of an induction motor because it enables the induction of rotor current and the development of electromagnetic torque.

The value of slip varies with the load on the motor. At **no load**, the slip is very small, whereas at **full load**, the slip increases. Knowledge of slip is important for understanding the speed, torque, efficiency, and performance characteristics of three-phase induction motors.

Objectives

After studying this topic, the trainee will be able to:

- Define slip in a three-phase induction motor.
- Explain the concept of synchronous speed and rotor speed.
- Understand why slip is necessary for the operation of an induction motor.
- State the relationship between slip, synchronous speed, and rotor speed.
- Explain the effect of load on the slip of an induction motor.

- Understand the importance of slip in the production of rotor current and electromagnetic torque.
- Distinguish between synchronous speed and actual rotor speed.

Torque

Torque is the **turning force** or **rotating moment** developed by a three-phase induction motor that causes the rotor to rotate and drive the connected mechanical load. It is one of the most important performance parameters of an induction motor because it determines the motor's ability to start, accelerate, and operate various types of loads.

In a three-phase induction motor, when a **three-phase AC supply** is applied to the stator winding, a **rotating magnetic field (RMF)** is produced. This rotating magnetic field induces an electromotive force (EMF) and current in the rotor conductors through **electromagnetic induction**. The interaction between the rotating magnetic field and the induced rotor current produces an **electromagnetic force**, which creates a **turning moment known as torque**.

The amount of torque developed depends on several factors, including the **rotor current, magnetic flux, slip, rotor resistance, and supply voltage**. During operation, the torque of an induction motor changes with the load and varies from **starting torque** to **maximum (breakdown) torque** and finally to the **full-load torque**. Understanding the torque characteristics of an induction motor is essential for selecting the correct motor for different industrial applications such as pumps, fans, compressors, conveyors, cranes, hoists, and machine tools.

The SI unit of torque is the **Newton-metre (N·m)**.

Objectives

After studying this topic, the trainee will be able to:

- Define torque in a three-phase induction motor.
- Explain how torque is produced in an induction motor.
- Understand the role of the rotating magnetic field and electromagnetic induction in torque production.
- State the factors affecting the torque of an induction motor.
- Recognize the importance of slip in torque development.
- Identify the different types of torque, such as starting torque, maximum torque, and full-load torque.
- Understand the relationship between torque and motor performance.
- Appreciate the importance of torque in starting and driving different mechanical loads.
- Select a suitable induction motor based on torque requirements.

Starting Methods

The **starting methods of a three-phase induction motor** are the techniques used to start the motor safely and efficiently while limiting the **high starting current** and ensuring adequate **starting torque**. When a three-phase induction motor is connected directly to the power supply, it draws a very high current, typically **5 to 8 times the full-load current**, which may cause voltage drop in the supply system, overheating of the motor, and mechanical stress on the motor and driven equipment.

To overcome these problems, different starting methods are employed depending on the motor rating, supply conditions, and load requirements. These methods reduce the starting current and provide suitable starting torque for smooth and reliable operation.

The most commonly used starting methods are:

- **Direct-On-Line (DOL) Starter**
- **Star-Delta Starter**
- **Auto Transformer Starter**
- **Rotor Resistance Starter (Slip Ring Motor)**
- **Soft Starter**
- **Variable Frequency Drive (VFD)**

The selection of a suitable starting method depends on factors such as **motor power, type of load, starting torque requirement, frequency of starting, and electrical supply capacity**. Proper starting methods improve motor life, reduce electrical and mechanical stresses, and ensure safe and efficient operation in industrial applications.

Objectives

After studying this topic, the trainee will be able to:

- Define the starting methods of a three-phase induction motor.
- Explain why starting methods are necessary for induction motors.
- Understand the problems caused by high starting current.
- Identify the different methods used to start three-phase induction motors.
- Differentiate between DOL, Star-Delta, Auto Transformer, Rotor Resistance, Soft Starter, and VFD starting methods.

Star-Delta Starter

A **Star-Delta Starter** is a **reduced-voltage starting method** used to start **three-phase squirrel cage induction motors**. It is designed to **reduce the high starting current** drawn by the motor during starting while providing a smooth and safe acceleration to its normal operating speed.

In this method, the motor stator windings are initially connected in the **Star (Y)** configuration during starting. In the star connection, each phase winding receives only **58% of the line voltage**, which significantly reduces the starting current and starting torque. Once the motor reaches about **80–90% of its rated speed**, the starter automatically changes the winding

connection from **Star (Y)** to **Delta (Δ)** using a timer and contactors. In the delta connection, the motor receives the full line voltage and operates at its rated power, speed, and torque.

A Star-Delta Starter is commonly used for **medium and large-capacity induction motors** where high starting current could cause voltage drops in the electrical supply system or mechanical stress on the driven equipment. It is widely used for **pumps, fans, compressors, blowers, conveyors, machine tools, and other industrial machines** that do not require high starting torque.

The Star-Delta Starter is economical, reliable, easy to maintain, and one of the most widely used motor starters in industrial electrical installations.

Objectives

After studying this topic, the trainee will be able to:

- Define a Star-Delta Starter.
- Explain the need for using a Star-Delta Starter.
- Understand the principle of reduced-voltage starting.
- Describe the operation of Star and Delta connections during motor starting.
- Explain how a Star-Delta Starter reduces the starting current.
- Identify the main components of a Star-Delta Starter, such as contactors, timer, overload relay, and push buttons.
- Understand the sequence of operation from Star to Delta connection.
-

DOL Starter

A **Direct-On-Line (DOL) Starter** is the **simplest and most commonly used motor starter** for starting **three-phase induction motors**. In this method, the motor is connected **directly to the full line voltage** of the three-phase power supply through a starter consisting of a **contactor, overload relay, and start/stop push buttons**. Since the motor receives the full supply voltage at the time of starting, it develops **maximum starting torque** but also draws a **high starting current**, which is typically **5 to 8 times the full-load current**.

The DOL Starter is mainly used for **small and medium-sized induction motors** where the power supply system can withstand the high inrush current without causing excessive voltage drop. It provides reliable motor starting, overload protection, no-voltage protection, and easy operation, making it one of the most economical and widely used motor starters in domestic, commercial, and industrial applications.

A DOL Starter is suitable for driving loads such as **water pumps, air compressors, fans, blowers, conveyors, machine tools, and small industrial machines** where high starting torque is required. Due to its simple construction, low cost, ease of installation, and minimum maintenance, it is extensively used in electrical installations.

Objectives

After studying this topic, the trainee will be able to:

- Define a Direct-On-Line (DOL) Starter.
- Explain the need for a DOL Starter in three-phase induction motors.
- Understand the principle of direct full-voltage motor starting.
- Identify the main components of a DOL Starter, such as the contactor, overload relay, start push button, stop push button, and no-volt coil.
- Explain the working sequence of a DOL Starter.

Reversing Starter

A **Reversing Starter** is a motor starter used to **change the direction of rotation** of a **three-phase induction motor**. It enables the motor to run in both **forward and reverse directions** by interchanging any **two phases of the three-phase power supply**. Changing the phase sequence reverses the direction of the rotating magnetic field, causing the motor rotor to rotate in the opposite direction.

A Reversing Starter consists of **two contactors** (Forward Contactor and Reverse Contactor), an **overload relay**, **Start/Stop push buttons**, and an **electrical and mechanical interlocking system**. The interlocking arrangement ensures that both contactors cannot operate simultaneously, preventing short circuits and protecting the motor and electrical system.

Reversing Starters are widely used in applications where machines need to move in both directions, such as **hoists, cranes, elevators, conveyors, rolling mills, machine tools, drilling machines, lathes, and lifting equipment**. They provide safe, reliable, and convenient control of motor direction while offering overload and no-voltage protection.

Due to their simple operation, effective safety features, and versatility, Reversing Starters are extensively used in industrial automation and motor control systems.

Objectives

After studying this topic, the trainee will be able to:

- Define a Reversing Starter.
- Explain the need for reversing the direction of a three-phase induction motor.
- Understand the principle of reversing motor rotation by changing the phase sequence.
- Identify the main components of a Reversing Starter.
- Explain the functions of forward and reverse contactors.
- Understand the purpose of electrical and mechanical interlocking.
- Recognize the importance of overload and no-voltage protection.
- Identify industrial applications of Reversing Starters.

Module 4 – AC Single Phase Motor

Construction

The **construction of a Reversing Starter** refers to the arrangement of its **electrical and mechanical components** that enable a **three-phase induction motor** to operate safely in both **forward and reverse directions**. The starter is designed to reverse the direction of motor rotation by interchanging any **two phases** of the three-phase supply while providing protection against overloads, short circuits, and accidental simultaneous operation.

A Reversing Starter consists of **two magnetic contactors**, namely the **Forward Contactor (F)** and the **Reverse Contactor (R)**. These contactors are connected with a **mechanical interlock** and an **electrical interlock** to ensure that only one contactor can operate at a time. The starter also includes an **overload relay**, **Start and Stop push buttons**, **control circuit wiring**, **power circuit**, **auxiliary contacts**, and a **protective enclosure**.

When the Forward contactor is energized, the motor rotates in the forward direction. When the Reverse contactor is energized, two supply phases are interchanged, causing the rotating magnetic field to reverse and the motor to rotate in the opposite direction. The interlocking arrangement prevents both contactors from closing simultaneously, thereby avoiding phase-to-phase short circuits and ensuring safe operation.

The robust construction of the Reversing Starter provides reliable motor control and is widely used in industrial applications where bidirectional motor operation is required.

Objectives

After studying this topic, the trainee will be able to:

- Define the construction of a Reversing Starter.
- Identify the main components of a Reversing Starter.
- Explain the function of the Forward and Reverse contactors.
- Understand the purpose of the overload relay and auxiliary contacts.
- Explain the importance of electrical and mechanical interlocking.
- Identify the power circuit and control circuit of a Reversing Starter.

Working Principle

The **working principle of a Reversing Starter** is based on **changing the phase sequence** of the three-phase power supply to reverse the direction of rotation of a **three-phase induction motor**. In a three-phase induction motor, the direction of the **rotating magnetic field (RMF)** depends on the sequence of the three supply phases. By interchanging any **two phases** of the supply, the direction of the rotating magnetic field is reversed, causing the motor to rotate in the opposite direction.

A Reversing Starter uses **two magnetic contactors**—the **Forward Contactor** and the **Reverse Contactor**. When the Forward contactor is energized, the motor receives the normal phase sequence and rotates in the forward direction. When the Reverse contactor is energized, two supply phases are interchanged, reversing the phase sequence and causing the motor to rotate in the reverse direction.

To ensure safe operation, the Reversing Starter is provided with **electrical interlocking** and **mechanical interlocking**, which prevent both contactors from operating simultaneously. If both contactors were energized at the same time, a phase-to-phase short circuit could occur, resulting in severe damage to the motor and starter. The starter also includes an **overload relay** that disconnects the motor from the supply in case of excessive current, protecting the motor from overheating and damage.

The Reversing Starter provides safe, reliable, and efficient control of motor direction and is widely used in industrial machines that require forward and reverse motion.

Objectives

After studying this topic, the trainee will be able to:

- Explain the working principle of a Reversing Starter.
- Understand how changing the phase sequence reverses the direction of motor rotation.
- Describe the operation of the Forward and Reverse contactors.
- Explain the role of the rotating magnetic field (RMF) in motor direction.
- Understand the importance of electrical and mechanical interlocking.
- Explain the function of the overload relay during motor operation.
- Describe the sequence of forward and reverse motor operation.
- Recognize the safety features incorporated in a Reversing Starter.
- Understand the practical applications of a Reversing Starter in industrial motor control.

Split Phase Motor

A **Split Phase Motor** is a **single-phase AC induction motor** designed to produce the **starting torque** required to start the motor. Since a single-phase AC supply alone cannot create a rotating magnetic field, the Split Phase Motor uses **two stator windings**—the **main (running) winding** and the **auxiliary (starting) winding**. These windings are placed **90° electrical apart**, and due to their different electrical characteristics, a phase difference is created between the currents flowing through them. This phase difference produces a **rotating magnetic field**, which develops the starting torque required to rotate the rotor.

Once the motor reaches approximately **70–80% of its rated speed**, the starting winding is automatically disconnected by a **centrifugal switch** or an electronic starting device. The motor then continues to operate using only the main winding.

Split Phase Motors are simple in construction, economical, and reliable. They provide **moderate starting torque** and are commonly used in applications where heavy starting torque is not required. Typical applications include **fans, blowers, washing machines**,

centrifugal pumps, office equipment, small machine tools, grinders, and household appliances.

Due to their easy operation, low cost, and dependable performance, Split Phase Motors are widely used in domestic, commercial, and light industrial applications.

Objectives

After studying this topic, the trainee will be able to:

- Define a Split Phase Motor.
- Explain the need for a starting winding in a single-phase induction motor.
- Understand the basic principle of operation of a Split Phase Motor.
- Identify the main winding and auxiliary (starting) winding.
- Explain the function of the centrifugal switch in motor operation.
- Understand how the rotating magnetic field is produced during starting.
- Recognize the characteristics of a Split Phase Motor.
- Identify the advantages and limitations of Split Phase Motors.
- Recognize the common applications of Split Phase Motors.

Capacitor Start Motor

A **Capacitor Start Motor** is a **single-phase AC induction motor** that uses a **starting capacitor** connected in series with the **auxiliary (starting) winding** to produce a **high starting torque**. Since a single-phase AC supply cannot produce a rotating magnetic field by itself, the capacitor creates a large phase difference between the currents in the main winding and the starting winding. This phase difference generates a **strong rotating magnetic field**, enabling the motor to start smoothly and efficiently.

The motor consists of two stator windings: the **main (running) winding** and the **auxiliary (starting) winding**. During starting, the capacitor and starting winding remain connected in the circuit. When the motor reaches approximately **70–80% of its rated speed**, a **centrifugal switch** or an electronic relay automatically disconnects the starting winding and the capacitor from the circuit. The motor then continues to operate using only the main winding.

Capacitor Start Motors develop **high starting torque**, making them suitable for applications where heavy loads must be started. They are widely used in **air compressors, refrigeration units, water pumps, reciprocating pumps, conveyors, machine tools, agricultural equipment, and other machines requiring high starting torque**.

Because of their excellent starting performance, reliable operation, and simple construction, Capacitor Start Motors are among the most commonly used single-phase motors in domestic, commercial, and industrial applications.

Objectives

After studying this topic, the trainee will be able to:

- Define a Capacitor Start Motor.
- Explain the need for a capacitor in a single-phase induction motor.
- Understand the basic principle of operation of a Capacitor Start Motor.
- Identify the main winding, auxiliary winding, capacitor, and centrifugal switch.
- Explain how the capacitor produces the required phase difference for starting.
- Understand how a rotating magnetic field is produced during starting.
- Recognize the high starting torque characteristics of a Capacitor Start Motor.
- Identify the advantages and limitations of Capacitor Start Motors.

Capacitor Run Motor

A **Capacitor Run Motor**, also known as a **Permanent Split Capacitor (PSC) Motor**, is a **single-phase AC induction motor** in which a **run capacitor** is permanently connected in series with the **auxiliary (starting) winding** throughout both the starting and running conditions. Unlike a Capacitor Start Motor, the capacitor in a Capacitor Run Motor remains in the circuit continuously, eliminating the need for a centrifugal switch.

The permanent capacitor creates a phase difference between the currents in the **main winding** and the **auxiliary winding**, producing a **rotating magnetic field**. This enables the motor to start and continue running smoothly with improved power factor, higher efficiency, quieter operation, and reduced vibration. Although the starting torque of a Capacitor Run Motor is **moderate**, it provides excellent running performance and is well suited for loads that do not require high starting torque.

Capacitor Run Motors are widely used in applications such as **ceiling fans, exhaust fans, blowers, air coolers, air conditioners, room heaters, office equipment, and small pumps**, where smooth, quiet, and continuous operation is essential.

Because of their simple construction, reliable performance, low maintenance, and efficient operation, Capacitor Run Motors are among the most commonly used single-phase motors in domestic and commercial electrical appliances.

Objectives

After studying this topic, the trainee will be able to:

- Define a Capacitor Run Motor.
- Explain the basic principle of operation of a Capacitor Run Motor.
- Understand the function of the permanently connected run capacitor.
- Identify the main winding, auxiliary winding, and run capacitor.
- Explain how the rotating magnetic field is produced during both starting and running.
- Understand why a Capacitor Run Motor does not require a centrifugal switch.
- Recognize the characteristics of a Capacitor Run Motor.
- Identify the advantages and limitations of Capacitor Run Motors.
- Recognize the common domestic and commercial applications of C

Universal Motor

A **Universal Motor** is a **single-phase series motor** that is specially designed to operate on **both alternating current (AC) and direct current (DC) supplies**. Because it can run on either type of electrical supply, it is called a **Universal Motor**. The motor operates on the principle of the **series motor**, in which the field winding and armature winding are connected in series. When current flows through both windings, a strong magnetic field is produced, generating high starting torque and causing the armature to rotate.

The construction of a Universal Motor is similar to that of a **DC series motor**, but it is modified to operate efficiently on AC supply. It uses **laminated iron cores** to reduce eddy current losses and compensating features to improve performance on alternating current. Universal Motors are capable of operating at **very high speeds**, often ranging from **3,000 to 20,000 revolutions per minute (RPM)** or even higher, depending on the design and application.

These motors provide **high starting torque**, compact size, light weight, and excellent speed control. Due to these characteristics, Universal Motors are widely used in **portable electric drills, mixers, grinders, vacuum cleaners, hair dryers, sewing machines, food processors, and other household and portable power tools**.

Because of their versatility, high-speed operation, and ability to run on both AC and DC supplies, Universal Motors are among the most widely used motors in domestic appliances and portable electrical equipment.

Objectives

After studying this topic, the trainee will be able to:

- Define a Universal Motor.
- Explain why it is called a Universal Motor.
- Understand the basic principle of operation of a Universal Motor.
- Identify the main constructional parts of a Universal Motor.
- Explain how the motor operates on both AC and DC supplies.
- Recognize the characteristics of high starting torque and high-speed operation.
- Understand the advantages and limitations of Universal Motors.

Shaded Pole Motor

A **Shaded Pole Motor** is a **single-phase AC induction motor** that uses a **shading coil (copper ring)** to produce the starting torque required for motor operation. It is one of the **simplest, smallest, and least expensive** types of single-phase induction motors. Unlike other single-phase motors, a Shaded Pole Motor does **not require a starting winding, capacitor, or centrifugal switch**. Its simple construction makes it highly reliable and easy to maintain.

The stator of a Shaded Pole Motor has **salient poles**, and each pole is partially surrounded by a **copper shading ring** called the **shading coil**. When an alternating current flows through

the stator winding, the shading coil delays the magnetic flux in the shaded portion of the pole. This creates a weak **rotating magnetic field**, which produces the starting torque and causes the rotor to rotate from the unshaded part toward the shaded part of the pole.

Shaded Pole Motors develop **low starting torque**, have **low efficiency**, and are generally used for **light-duty applications** where only a small amount of starting torque is required. They are commonly used in **table fans, exhaust fans, refrigerator evaporator fans, electric clocks, hair dryers, small blowers, record players, toys, and other small household appliances**.

Because of their simple design, low manufacturing cost, quiet operation, and dependable performance, Shaded Pole Motors remain widely used in low-power domestic and commercial electrical equipment.

Objectives

After studying this topic, the trainee will be able to:

- Define a Shaded Pole Motor.
- Explain the basic principle of operation of a Shaded Pole Motor.
- Understand the function of the shading coil (copper ring).
- Explain how the shading coil produces the starting torque.
- Identify the main constructional parts of a Shaded Pole Motor.
- Understand why the motor does not require a capacitor or centrifugal switch.
- Recognize the characteristics of a Shaded Pole Motor.
- Identify the advantages and limitations of Shaded Pole Motors.

Applications

The **applications of a Shaded Pole Motor** are mainly found in **low-power, light-duty electrical appliances** where **low starting torque, simple construction**, and **quiet operation** are sufficient. Due to its low manufacturing cost, compact size, and reliable performance, the Shaded Pole Motor is widely used in domestic, commercial, and small industrial equipment that operates on a **single-phase AC supply**.

Since this motor produces **low starting torque** and operates at relatively low efficiency, it is not suitable for heavy-load applications. Instead, it is preferred for devices that require continuous operation with light mechanical loads. The absence of a capacitor, centrifugal switch, and starting winding makes the motor highly dependable and reduces maintenance requirements.

Shaded Pole Motors are commonly used in **table fans, exhaust fans, refrigerator evaporator fans, air coolers, small blowers, hair dryers, electric clocks, record players, vending machines, display equipment, toys, and other small household appliances**. They are also used in cooling and ventilation systems where quiet and continuous operation is important.

Because of their simplicity, durability, and economical operation, Shaded Pole Motors remain one of the most widely used motors for small-capacity electrical appliances.

Objectives

After studying this topic, the trainee will be able to:

- Define the applications of a Shaded Pole Motor.
- Identify the domestic, commercial, and industrial applications of Shaded Pole Motors.
- Understand why Shaded Pole Motors are suitable for light-duty applications.
- Recognize the relationship between motor characteristics and its applications.
- Select suitable applications based on the motor's low starting torque and power rating.
- Understand the advantages of using Shaded Pole Motors in small electrical appliances.
- Differentiate between applications of Shaded Pole Motors and other single-phase motors.

Module 5 – Alternator

Construction

The **construction of a Shaded Pole Motor** is simple, compact, and economical. It mainly consists of a **stator with salient poles**, a **main winding**, a **copper shading coil (shading ring)**, and a **squirrel cage rotor**. The shading coil is fitted around a portion of each stator pole to create the starting torque. Since the motor does not require a **starting winding, capacitor, or centrifugal switch**, its construction is simple, reliable, and requires very little maintenance.

Objectives

After studying this topic, the trainee will be able to:

- Define the construction of a Shaded Pole Motor.
- Identify the main parts of the motor.
- Explain the function of the shading coil.
- Understand the purpose of the stator and squirrel cage rotor.
- Appreciate the simple and economical construction of the motor

Working Principle

The **working principle of a Shaded Pole Motor** is based on the **production of a weak rotating magnetic field** by a **shading coil (copper ring)** fitted on a part of each stator pole. The delayed magnetic flux in the shaded portion creates the starting torque, causing the **squirrel cage rotor** to rotate from the **unshaded side toward the shaded side**. After starting, the motor continues to run on a single-phase AC supply.

Objectives

After studying this topic, the trainee will be able to:

- Explain the working principle of a Shaded Pole Motor.
- Understand the function of the shading coil.
- Describe how the rotating magnetic field is produced.
- Explain the direction of rotor rotation.
- Understand the basic operation of the motor after starting.

EMF Equation

The **EMF (Electromotive Force) Equation** is the mathematical expression used to calculate the **induced voltage** generated in an electrical machine due to **electromagnetic induction**. It shows the relationship between the induced EMF and factors such as **magnetic flux, frequency, and the number of turns of the winding**. The EMF equation is important for understanding the performance and design of electrical machines such as **transformers, generators, and AC motors**.

Objectives

After studying this topic, the trainee will be able to:

- Define the EMF equation.
- Understand the importance of the EMF equation in electrical machines.
- Identify the factors affecting the induced EMF.
- Explain the relationship between flux, frequency, and the number of turns.
- Prepare for the detailed study and calculation of the EMF equation

Synchronization

Synchronization is the process of **matching the voltage, frequency, phase sequence, and phase angle** of an incoming alternator (or generator) with the existing power system before connecting it to the electrical grid or busbars. Proper synchronization ensures smooth operation, prevents electrical disturbances, and protects the generator and connected equipment from damage.

Objectives

After studying this topic, the trainee will be able to:

- Define synchronization.
- Understand the need for synchronization before connecting an alternator to the supply system.
- Identify the conditions required for proper synchronization.
- Explain the importance of voltage, frequency, phase sequence, and phase angle matching.
- Prepare for the detailed study of synchronization methods and procedures.

Voltage Regulation

Voltage Regulation is the ability of an electrical machine, especially an **alternator**, to maintain a constant output voltage as the load changes. It is defined as the **change in terminal voltage from no-load to full-load conditions**, while keeping the speed and excitation constant. Good voltage regulation ensures a stable power supply and efficient operation of electrical equipment.

Objectives

After studying this topic, the trainee will be able to:

- Define voltage regulation.
- Understand the importance of voltage regulation in an alternator.
- Explain the effect of load on terminal voltage.
- Recognize the factors affecting voltage regulation.
- Prepare for the detailed study of voltage regulation calculation and methods of determination.

Characteristics

The **characteristics of an alternator** describe the relationship between its **output voltage, load current, and field excitation** under different operating conditions. These characteristics help in understanding the performance, efficiency, and voltage regulation of the alternator. The main characteristics studied are **Open Circuit Characteristic (OCC)**, **Short Circuit Characteristic (SCC)**, and **Load Characteristic**.

Objectives

After studying this topic, the trainee will be able to:

- Define the characteristics of an alternator.
- Identify the different types of alternator characteristics.
- Understand the importance of OCC, SCC, and Load Characteristics.
- Explain how alternator performance changes under different operating conditions.
- Prepare for the detailed study and analysis of alternator characteristics.

Applications

The **applications of an alternator** include the generation of **alternating current (AC) electrical power** for domestic, commercial, industrial, and transportation purposes. Alternators are the primary source of electricity in **power stations**, where they convert **mechanical energy** from turbines or engines into electrical energy. They are also widely used in automobiles, diesel generator sets, wind turbines, hydroelectric plants, and backup power systems because of their high efficiency, reliability, and continuous power generation capability.

Objectives

After studying this topic, the trainee will be able to:

- Define the applications of an alternator.
- Identify the major fields where alternators are used.
- Understand the importance of alternators in power generation.
- Recognize the use of alternators in industrial, domestic, and automotive applications.
- Prepare for the detailed study of various practical applications of alternators.

Maintenance

Maintenance of an alternator is the process of **inspecting, cleaning, testing, lubricating, and servicing** its electrical and mechanical components to ensure safe, reliable, and efficient operation. Regular maintenance helps prevent breakdowns, improves performance, extends the service life of the alternator, and ensures a continuous supply of electrical power.

Objectives

After studying this topic, the trainee will be able to:

- Define alternator maintenance.
- Understand the importance of regular maintenance.
- Identify the major components requiring maintenance.
- Recognize routine inspection and servicing procedures.

Module 6 – Synchronous Motor & MG Set

Construction

The **construction of an alternator** refers to the arrangement of its **main electrical and mechanical parts** that work together to generate **alternating current (AC)**. The major parts of an alternator are the **stator, rotor, shaft, bearings, frame, slip rings**, and **brushes** (in brush-type alternators). A strong and efficient construction ensures reliable performance, high efficiency, and long service life.

Objectives

After studying this topic, the trainee will be able to:

- Define the construction of an alternator.
- Identify the main parts of an alternator.
- Understand the function of the stator and rotor.
- Recognize the purpose of the mechanical and electrical components.
- Prepare for the detailed study of the construction and operation of an alternator.

Working

The **working of an alternator** is based on **Faraday's Law of Electromagnetic Induction**. When the **rotor** rotates inside the stationary **stator winding**, the rotating magnetic field cuts the stator conductors and induces an **alternating electromotive force (EMF)**. This induced EMF produces **alternating current (AC)**, which is supplied to the external electrical circuit. The alternator converts **mechanical energy into electrical energy** efficiently and is widely used in power generation.

Objectives

After studying this topic, the trainee will be able to:

- Explain the working principle of an alternator.
- Understand the role of electromagnetic induction in power generation.
- Identify the functions of the rotor and stator during operation.
- Understand the conversion of mechanical energy into electrical energy.
- Prepare for the detailed study of the working process and operation of an alternator.

Starting Methods

The **starting methods of an alternator** refer to the procedures used to bring the **prime mover** (such as a diesel engine, steam turbine, or water turbine) to its rated speed before the alternator begins generating electricity. After reaching the required speed, the field winding is excited, and the alternator starts producing AC power. Proper starting ensures safe, reliable, and efficient operation of the alternator.

Objectives

After studying this topic, the trainee will be able to:

- Define the starting methods of an alternator.
- Understand the need for proper starting before power generation.
- Identify the role of the prime mover and excitation system.
- Recognize the basic steps involved in starting an alternator.
- Prepare for the detailed study of alternator starting procedures and safety precautions.

Hunting

Hunting is the **oscillation or fluctuation of the rotor** of a synchronous machine (alternator) about its normal synchronous position due to sudden changes in load or system disturbances. It causes the rotor speed and power angle to vary temporarily before the machine returns to

stable operation. Excessive hunting may lead to vibration, noise, reduced efficiency, and loss of synchronism.

Objectives

After studying this topic, the trainee will be able to:

- Define hunting in an alternator.
- Understand the causes of hunting.
- Recognize the effects of hunting on alternator performance.
- Identify the importance of controlling hunting for stable operation.
- Prepare for the detailed study of hunting, damping methods, and preventive measures.

Power Factor Improvement

Power Factor Improvement is the process of increasing the **power factor** of an electrical system to make it operate more efficiently. A low power factor results in higher current, increased power losses, poor voltage regulation, and reduced system efficiency. By improving the power factor, electrical power is utilized more effectively, reducing energy losses and improving the overall performance of electrical equipment. Common methods include the use of **capacitor banks**, **synchronous condensers**, and **phase advancers**.

Objectives

After studying this topic, the trainee will be able to:

- Define power factor improvement.
- Understand the importance of improving the power factor.
- Identify the disadvantages of a low power factor.
- Recognize the common methods used for power factor improvement.
- Prepare for the detailed study of power factor correction methods and their practical applications.

Motor Generator Set (MG Set)

A **Motor Generator Set (MG Set)** is a combination of an electric motor and a generator mechanically connected through a common shaft. The motor converts electrical energy into mechanical energy, while the generator converts it back into electrical energy of the required voltage, frequency, or type.

Objectives

After studying this topic, the trainee will be able to:

- Define a Motor Generator Set.

- Identify the main parts of an MG Set.
- Understand its basic working principle.
- Explain the conversion of electrical and mechanical energy.
- Recognize the common applications of an MG Set.

Applications

A **Motor Generator Set (MG Set)** is widely used where a **stable, isolated, or specially controlled electrical power supply** is required. It is used for voltage conversion, frequency conversion, electrical isolation, and supplying power to sensitive equipment in industries, hospitals, laboratories, and power stations.

Objectives

After studying this topic, the trainee will be able to:

- Identify the applications of a Motor Generator Set.
- Understand the importance of MG Sets in electrical systems.
- Recognize the use of MG Sets for voltage and frequency conversion.
- Explain the role of MG Sets in providing electrical isolation.
- Prepare for the detailed study of MG Set applications in industrial and commercial installations.

Module 7 – Electronic Practice

Diodes

A **diode** is a **two-terminal semiconductor device** that allows electric current to flow in **one direction** and blocks it in the opposite direction. It is one of the most important electronic components and is widely used in **rectifiers, power supplies, switching circuits, and protection circuits**.

Objectives

After studying this topic, the trainee will be able to:

- Define a diode.
- Identify the basic construction and terminals of a diode.
- Understand the one-way conduction property of a diode.
- Recognize the common applications of diodes in electronic circuits.
- Prepare for the detailed study of diode characteristics and operation.

Rectifiers

A **rectifier** is an electronic device or circuit that **converts alternating current (AC) into direct current (DC)**. It mainly uses **diodes** to allow current to flow in one direction. Rectifiers are widely used in **power supplies, battery chargers, electronic equipment, and industrial applications**.

Objectives

After studying this topic, the trainee will be able to:

- Define a rectifier.
- Understand the purpose of AC to DC conversion.
- Identify the role of diodes in rectifier circuits.
- Recognize the common types and applications of rectifiers.

Zener Diode

A **Zener diode** is a **special type of semiconductor diode** designed to operate in the **reverse breakdown region** without damage. It maintains a nearly constant output voltage and is widely used for **voltage regulation, voltage reference, and circuit protection** in electronic devices.

Objectives

After studying this topic, the trainee will be able to:

- Define a Zener diode.
- Understand the working principle of a Zener diode.
- Identify the voltage regulation property of a Zener diode.
- Recognize the common applications of Zener diodes in electronic circuits.
- Prepare for the detailed study of Zener diode characteristics and operation.

Transistors

A **transistor** is a **three-terminal semiconductor device** used to **amplify or switch electronic signals**. It is one of the most important components in modern electronics and is widely used in **amplifiers, switching circuits, digital devices, power supplies, and control systems**. The two main types of transistors are **BJT (Bipolar Junction Transistor)** and **FET (Field Effect Transistor)**.

Objectives

After studying this topic, the trainee will be able to:

- Define a transistor.
- Identify the basic terminals and types of transistors.
- Understand the functions of amplification and switching.
- Recognize the common applications of transistors in electronic circuits.
- Prepare for the detailed study of transistor characteristics and operation.

SCR

A **Silicon Controlled Rectifier (SCR)** is a **four-layer, three-terminal semiconductor device** used to control high voltage and high current in electrical and electronic circuits. It acts as a **controlled switch**, allowing current to flow only when a trigger signal is applied to its **gate** terminal. SCRs are widely used in **power control, motor speed control, battery chargers, and rectifier circuits**.

Objectives

After studying this topic, the trainee will be able to:

- Define a Silicon Controlled Rectifier (SCR).
- Identify the terminals and basic construction of an SCR.
- Understand the switching operation of an SCR.
- Recognize the common applications of SCRs in power control circuits.
- Prepare for the detailed study of SCR characteristics and operation.

TRIAC

A **TRIAC** is a **three-terminal semiconductor switching device** that can conduct current in **both directions** when triggered. It is widely used to control **AC power** in electrical and electronic circuits. TRIACs are commonly used in **light dimmers, fan speed controllers, heater controls, and AC motor control applications**.

Objectives

After studying this topic, the trainee will be able to:

- Define a TRIAC.
- Identify the terminals and basic construction of a TRIAC.
- Understand the bidirectional switching operation of a TRIAC.
- Recognize the common applications of TRIACs in AC power control circuits.
- Prepare for the detailed study of TRIAC characteristics and operation.

DIAC

A **DIAC** is a **two-terminal bidirectional semiconductor switching device** that conducts current only after its **breakover voltage** is reached, regardless of the direction of current flow. It is mainly used to **trigger TRIACs** in AC power control circuits, ensuring smooth and reliable switching. DIACs are commonly used in **light dimmers, fan regulators, and motor speed control circuits**.

Objectives

After studying this topic, the trainee will be able to:

- Define a DIAC.
- Identify the terminals and basic construction of a DIAC.
- Understand the bidirectional switching operation of a DIAC.
- Recognize the role of a DIAC in triggering a TRIAC.
- Prepare for the detailed study of DIAC characteristics and applications.

UJT

A **Unijunction Transistor (UJT)** is a **three-terminal semiconductor device** mainly used for **switching, timing, triggering, and pulse generation** applications. Unlike a BJT, it has only **one PN junction** and is widely used to trigger **SCRs and TRIACs** in power control circuits due to its simple construction and reliable operation.

Objectives

After studying this topic, the trainee will be able to:

- Define a Unijunction Transistor (UJT).
- Identify the terminals and basic construction of a UJT.
- Understand the working principle of a UJT.
- Recognize the applications of UJT in triggering and timing circuits.
- Prepare for the detailed study of UJT characteristics and operation.

Logic Gates

Logic gates are the **basic building blocks of digital electronic circuits**. They perform logical operations on one or more binary inputs (**0** and **1**) to produce a single binary output. Common logic gates include **AND, OR, NOT, NAND, NOR, XOR, and XNOR**, which are widely used in computers, digital systems, automation, and control circuits.

Objectives

After studying this topic, the trainee will be able to:

- Define logic gates.
- Identify the different types of logic gates.
- Understand the basic operation of logic gates using binary

Relays

A **relay** is an **electrically operated switching device** used to control one electrical circuit by another. It works by using an **electromagnet** to open or close electrical contacts, allowing low-power control of high-power circuits. Relays are widely used in **motor control, protection systems, automation, and industrial control circuits**.

Objectives

After studying this topic, the trainee will be able to:

- Define a relay.
- Identify the main parts of a relay.
- Understand the basic working principle of a relay.
- Recognize the common applications of relays in electrical circuits.
- Prepare for the detailed study of relay types and operation.

Electronic Components

Electronic components are the basic elements used to build **electronic circuits and devices**. They control, regulate, amplify, store, or transfer electrical signals. Electronic components are classified as **passive components** (such as resistors, capacitors, and inductors) and **active components** (such as diodes, transistors, and integrated circuits). They are widely used in electrical, electronic, communication, and automation systems.

Objectives

After studying this topic, the trainee will be able to:

- Define electronic components.
- Classify electronic components into active and passive types.
- Identify the basic functions of common electronic components.
- Recognize the applications of electronic components in electronic circuits.
- Prepare for the detailed study of various electronic components and their operation.

PCB Soldering & Testing

PCB (Printed Circuit Board) Soldering and Testing is the process of **mounting electronic components on a PCB, soldering them securely, and checking the completed circuit for proper operation**. Good soldering ensures reliable electrical connections, while testing helps identify faults such as open circuits, short circuits, and incorrect component placement before the circuit is put into service.

Objectives

After studying this topic, the trainee will be able to:

- Define PCB soldering and testing.
- Understand the importance of proper soldering techniques.
- Identify the basic tools and materials used for PCB soldering.
- Recognize the methods used to test PCB circuits for faults.
- Prepare for the detailed study of PCB assembly, soldering, and testing procedures.

Module 8 – Control Panel Wiring

Control Panel Components

Control panel components are the electrical and electronic devices installed inside a **control panel** to control, protect, monitor, and distribute electrical power. Common components include **MCBs, MCCBs, contactors, relays, timers, push buttons, selector switches, indicator lamps, overload relays, fuses, terminals, and meters**. These components ensure the safe and efficient operation of electrical systems and machinery.

Objectives

After studying this topic, the trainee will be able to:

- Define control panel components.
- Identify the common components used in control panels.
- Understand the basic functions of each component.
- Recognize the importance of control panel components in electrical systems.
- Prepare for the detailed study of control panel assembly, wiring, and maintenance.

Push Buttons

Push buttons are **manual control switches** used to start, stop, or control the operation of electrical and electronic circuits. They are commonly available in **Normally Open (NO)** and **Normally Closed (NC)** types and are widely used in **control panels, motor starters, industrial machines, and automation systems**.

Objectives

After studying this topic, the trainee will be able to:

- Define a push button.
- Identify the different types of push buttons.
- Understand the basic working of NO and NC push buttons.
- Recognize the applications of push buttons in control circuits.
- Prepare for the detailed study of push button wiring and operation.

Contactors

A **contactor** is an **electromagnetic switching device** used to control high-power electrical circuits with a low-power control signal. It is widely used for **starting and stopping motors, controlling lighting systems, heating equipment, and industrial machinery**. Contactors provide safe, reliable, and frequent switching in electrical installations.

Objectives

After studying this topic, the trainee will be able to:

- Define a contactor.
- Identify the main parts of a contactor.
- Understand the basic working principle of a contactor.
- Recognize the applications of contactors in electrical control circuits.
- Prepare for the detailed study of contactor types, wiring, and operation.

Overload Relay

An **overload relay** is a **protective device** used to protect electric motors from **overload conditions and overheating**. It works by sensing excessive current over a period of time and disconnecting the motor control circuit to prevent damage. Overload relays are commonly used with **contactors and motor starters** in industrial and commercial electrical systems.

Objectives

After studying this topic, the trainee will be able to:

- Define an overload relay.
- Understand the purpose of motor overload protection.
- Identify the basic working principle of an overload relay.
- Recognize the applications of overload relays in motor control circuits.

- Prepare for the detailed study of overload relay types, settings, and operation.

Timer

A **timer** is a **control device** used to operate electrical circuits after a **preset time delay**. It is commonly used for **automatic starting, stopping, sequencing, and protection** of electrical equipment. Timers are widely used in **motor control circuits, industrial automation, lighting systems, and process control applications**.

Objectives

After studying this topic, the trainee will be able to:

- Define a timer.
- Understand the purpose of time-delay control in electrical circuits.
- Identify the basic types of timers.
- Recognize the applications of timers in control and automation systems.
- Prepare for the detailed study of timer operation and wiring.

Indicator Lamps

Indicator lamps are **visual signaling devices** used to indicate the **operating status or condition** of an electrical circuit or equipment. They provide instant information such as **power ON, power OFF, fault, running, or trip condition**. Indicator lamps are widely used in **control panels, switchboards, industrial machines, and automation systems**.

Objectives

After studying this topic, the trainee will be able to:

- Define an indicator lamp.
- Understand the purpose of visual indication in electrical systems.
- Identify the common types and colors of indicator lamps.
- Recognize the applications of indicator lamps in control panels and electrical circuits.
- Prepare for the detailed study of indicator lamp operation and wiring.

Control Circuit Wiring

Indicator lamps are **visual signaling devices** used to indicate the **operating status or condition** of an electrical circuit or equipment. They provide instant information such as **power ON, power OFF, fault, running, or trip condition**. Indicator lamps are widely used in **control panels, switchboards, industrial machines, and automation systems**.

Objectives

After studying this topic, the trainee will be able to:

- Define an indicator lamp.
- Understand the purpose of visual indication in electrical systems.
- Identify the common types and colors of indicator lamps.
- Recognize the applications of indicator lamps in control panels and electrical circuits.
- Prepare for the detailed study of indicator lamp operation and wiring.

Power Circuit Wiring

Power circuit wiring is the process of connecting **electrical power components** such as **MCBs, MCCBs, contactors, overload relays, motors, and power cables** to supply electrical power to loads safely and efficiently. It forms the **main current-carrying path** in electrical installations and control panels, ensuring reliable power distribution and equipment operation.

Objectives

After studying this topic, the trainee will be able to:

- Define power circuit wiring.
- Identify the main components used in a power circuit.
- Understand the purpose of power circuit wiring.
- Recognize the importance of safe and correct wiring practices.
- Prepare for the detailed study of power circuit design, wiring, and testing.

Motor Starter Wiring

Motor starter wiring is the process of connecting the **power circuit and control circuit** of a motor starter to ensure the safe starting, stopping, and protection of an electric motor. It involves components such as **contactors, overload relays, push buttons, MCBs, and timers**. Proper wiring ensures reliable motor operation and protects the motor from electrical faults.

Objectives

After studying this topic, the trainee will be able to:

- Define motor starter wiring.
- Identify the components used in a motor starter circuit.
- Understand the purpose of power and control wiring.
- Recognize the importance of correct motor starter wiring.
- Prepare for the detailed study of motor starter wiring diagrams and testing.

Panel Assembly

Panel assembly is the process of **installing, mounting, wiring, and arranging electrical components** inside a control panel according to the circuit diagram and safety standards. It includes components such as **MCBs, contactors, relays, timers, terminals, indicator lamps, and wiring accessories**. Proper panel assembly ensures safe, reliable, and efficient operation of electrical systems.

Objectives

After studying this topic, the trainee will be able to:

- Define panel assembly.
- Identify the components used in an electrical control panel.
- Understand the basic steps involved in panel assembly.
- Recognize the importance of proper layout, wiring, and safety.
- Prepare for the detailed study of panel assembly, wiring, and testing.