Field Technician
Wireman Control Panel

(Job Role)

Qualification Pack: Ref. Id. ELE/Q7302

Sector: Electronics

Textbook for Class XII

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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Foreword

The National Curriculum Framework (NCF)–2005 recommends bringing work and education into the domain of the curricula, infusing it in all areas of learning while giving it an identity of its own at relevant stages. It explains that work transforms knowledge into experience and generates important personal and social values, such as self-reliance, creativity and cooperation. Through work, one learns to find one's place in society. It is an educational activity with an inherent potential for inclusion. Therefore, an experience of involvement in productive work in an educational setting will make one appreciate the worth of social life and what is valued and appreciated in the society. Work involves interaction with material or people (mostly both), thus, creating a deeper comprehension and increased practical knowledge of natural substances and social relationships. Through work and education, school knowledge can be easily linked to learners' life outside the school. This also makes a departure from the legacy of bookish learning and bridges the gap between the school, home, community and workplace. The NCF–2005 also emphasises Vocational Education and Training (VET) for all those children, who wish to acquire additional skills and seek livelihood through vocational education after either discontinuing or completing school education. VET is expected to provide a 'preferred and dignified' choice rather than a terminal or last resort option.

As a follow-up of this, NCERT has attempted to infuse work across subject areas and contributed in the development of the National Skill Qualification Framework (NSQF) for the country, which was notified on 27 December 2013. It is a quality assurance framework that organises all qualifications according to the level of knowledge, skills and attitude. These levels, graded from one to ten, are defined in terms of learning outcomes, which the learners must possess regardless of whether they are obtained through formal, non-formal or informal learning. The NSQF sets common principles and guidelines for a nationally recognised qualification system, covering schools, vocational education and training institutions, technical education institutions, colleges, and universities.

It is under this backdrop that Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal, a constituent of NCERT, has developed learning outcomes based modular curricula for vocational subjects from Classes IX to XII. This has been developed under the Centrally Sponsored Scheme of Vocationalisation of Secondary and Higher Secondary Education of the Ministry of Education, erstwhile Ministry of Human Resource Development.

This textbook has been developed as per the learning outcomes based curriculum, keeping in view the National Occupational Standards (NOSs) for the job role and to promote experiential learning related to the vocation. This will enable the students to acquire necessary skills, knowledge and attitude.

I acknowledge the contribution of the development team, reviewers and all institutions and organisations, which have supported in the development of this textbook. NCERT welcomes suggestions from students, teachers and parents, which would help us to further improve the quality of the material in subsequent editions.

Hrushikesh Senapaty
Director
National Council of Educational
Research and Training

New Delhi
September 2020

About the Textbook

The electronic industry, which is growing exponentially in India, plays a crucial role in the evolution of communication and computer hardware. Electronics act like a backbone to growing sectors like space technology, IT industry, communication technology, etc. In our daily life, we deal with a number of electronic gadgets and products that make our life much easier.

The electronic industry employs a large number of engineers and technicians to design, develop, test, manufacture, install and repair electrical and electronic equipment.

A Field Technician—Wireman Control Panel reads the wiring diagram, and routes, and wires various components within the panel in accordance with the diagram. The individual at work is responsible for wiring all the components present within the panel as per the specifications provided by the design engineering team. The individual must have the ability to work in a high decibel noise environment and in a standing position for long hours.

The textbook for the job role of 'Field Technician—Wireman Control Panel' has been developed to impart knowledge and skills through hands-on learning experience, which forms a part of experiential learning. Experiential learning focusses on the learning process of an individual. Therefore, the learning activities are student-centered rather than teacher-centered. The textbook has been developed with the contribution of expertise from subject and industry experts and academicians, making it a useful and inspiring teaching–learning resource material for students. Care has been taken to align the content of the textbook with the National Occupational Standards (NOSs) for the job role so that the students acquire necessary knowledge and skills as per the performance criteria mentioned in the respective NOSs of the Qualification Pack (QP).

The textbook has been reviewed by experts so as to make sure that the content is not only aligned with the NOSs, but is also of high quality.

The NOSs for the job role of Field Technician – Wireman Control Panel covered through this textbook are as follows:

1. ELE/N7302: Wiring control panel
2. ELE/N9962: Interacting with co-workers
3. ELE/N9963: Maintaining safe work surroundings

Chapter 1 discusses the concept of electricity, basics of electrical products, electrical generation, transmission and distribution of power for residential, commercial and industrial application. Chapter 2 explains the busway, its construction, type and application. Chapter 3 deals with the different types of circuit breakers and their operation. Chapter 4 talks about the residential control panel along with its components and installation. Chapter 5 discusses the distribution of power in a commercial or industrial area and the panel board system and its parts. Chapter 6 highlights the design and construction of a switchboard and their types. Chapter 7 deals with electrical drives, such as AC drives, and soft starters. Chapter 8 talks about the motor, generator and starter. Chapter 9 discusses the programmable logic controller, and its operations. Chapter 10 will help you learn about the various testing methods and meter and Chapter 11 talks about workplace safety system.

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The Council also acknowledges the contribution of the Review Committee members V. P. Srivastava, *Professor* (Retd), NCERT, New Delhi and V. B. Bhatia, *Professor* (Retd), Delhi University for carefully evaluating and giving suggestions for the improvement of this book.

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The Council is grateful to Saroj Yadav, *Professor* and *Dean* (A), NCERT, and Ranjana Arora, *Professor* and *Head*, Department of Curriculum Studies, for their sincere efforts in coordinating the review workshops for the finalisation of this textbook. The Council acknowledges the copyediting and valuable contribution of Shilpa Mohan, *Assistant Editor* (Contractual), Chanchal Chauhan, *Proofreader* (Contractual) in shaping this book. The efforts of Pawan Kumar Barriar, *DTP Operator* and Neha Nayal, *DTP Operator* (Contractual), Publication Division, NCERT, for flawless layout design are also acknowledged.

Contents

Do You Know?

According to the 86th Constitutional Amendment Act, 2002, free and compulsory education for all children in 6-14 year age group is now a Fundamental Right under Article 21-A of the Constitution.

EDUCATION IS NEITHER A PRIVILEGE NOR FAVOUR BUT A BASIC HUMAN RIGHT TO WHICH ALL GIRLS AND WOMEN ARE ENTITLED

Give Girls Their Chance !

Chapter 1

Electrical Power

Introduction

Electricity is the presence and flow of electric charge. It is one of the most widely used forms of energy. People use electricity to do many jobs every day – from lighting, heating and cooling homes to powering electrical appliances. Therefore, it is important to understand the concept of electricity for installation and troubleshooting of electrical appliances.

In this chapter, we will focus on the basics of electrical products, electrical generation, transmission and distribution of power for residential, commercial and industrial application.

Electric Power

Electric power is the heart of an electrical network. As per the law of conservation of energy, we can change one form of energy into another, for example, hydel, thermal, and solar energy can be changed into electrical energy.

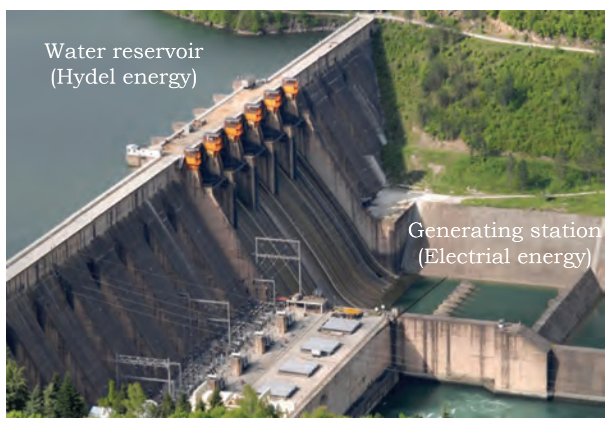


Fig. 1.1: Hydel power plant for generation of electric power

Power from a power generating plant is distributed to residential, commercial and industrial areas using transmission lines and substations as shown in Figs 1.1, 1.2 and 1.3.

Fig. 1.2: Transmission tower for transmission of electric power

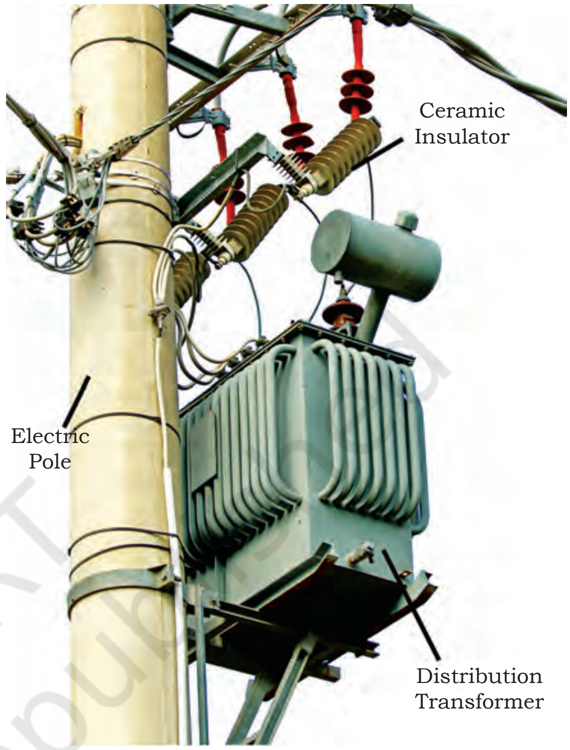


Fig. 1.3: Distribution of electric power for residential use

Table 1.1 shows the share of electric power consumption in various areas.

Table 1.1: Electric power consumption in various areas

Generated electric power consumption (2017-18)	Consumption (in percentage)
Industrial consumption	41.48%
Residential consumption	24.20%
Commercial consumption	5.51%
Agricultural consumption	18.08%
Traction consumption	1.27 %
Transmission and distribution loss	9.46%

Power Sources

India's electricity sector is dominated by fossil fuel. For example, in 2017-18, coal produced about three fourth (¾th) of the electricity as shown in Fig. 1.4. There are several other sources used to produce power. For example, coal, oil and uranium fuels are used to convert water into steam to drive a turbine. The output shaft of the turbine is connected to an alternating current (AC) generator as shown in Fig. 1.5. The AC generator is rotated by the turbine, which converts mechanical energy into electrical energy.

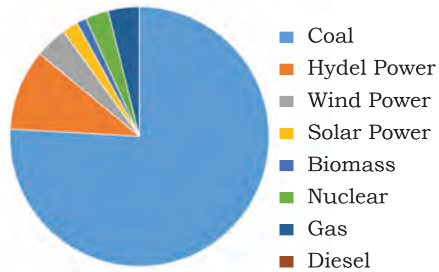


Fig. 1.4: Energy consumption in electric power generation

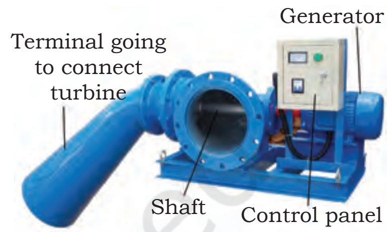


Fig.1.5: Micro-hydro power utilities

> **Assignment 1**
>
> Coal is widely used in thermal power stations to produce electricity. Since we use a number of electrical appliances, the demand for electricity is increasing everyday. Through research and review, find out how we can reduce the consumption of coal in the generation of electricity.

Power Station

We hardly think about the power stations generating electric power while using the electrical appliances and machines. Power stations are an industrial facility for the generation of electric power (Fig. 1.6). These power stations are far from residential areas. A power station contains one or more electric generators.

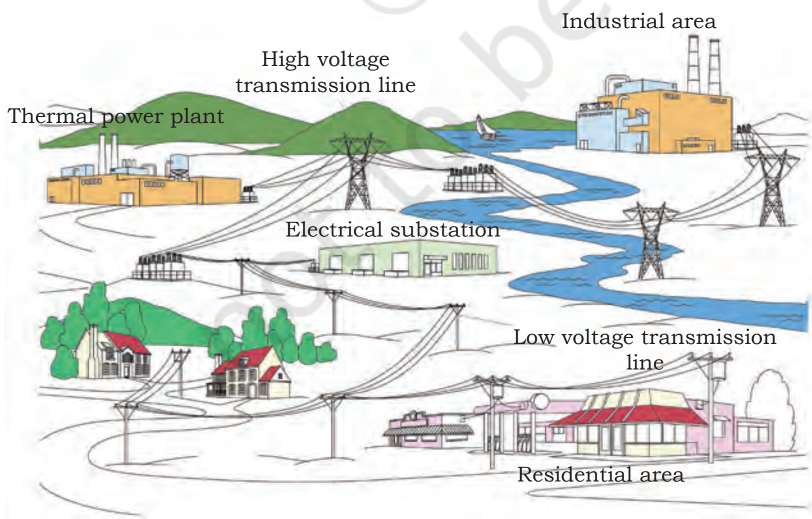


Fig.1.6: Transmission of electric power from the generating power plant to different distribution locations using a transmission line

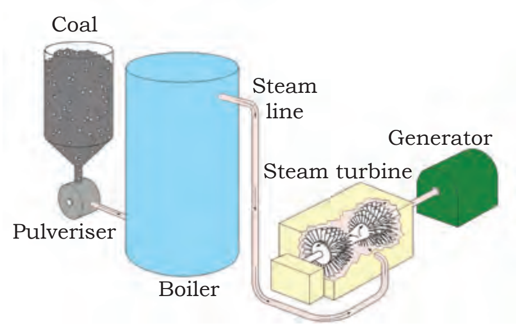


Fig.1.7: Conceptual view of a thermal power plant

A generator converts mechanical power into electrical power. Most power stations in the world burn fossil fuels, such as coal, oil and natural gas to generate electricity (Fig. 1.7). These days, there is rising use of cleaner renewable fuel sources, such as solar, wind, wave and hydroelectric. For example, a hydroelectric power station is used for the generation of electric power.

Hydroelectric power plants convert hydel energy to mechanical energy as shown in Figs 1.8 and 1.9.

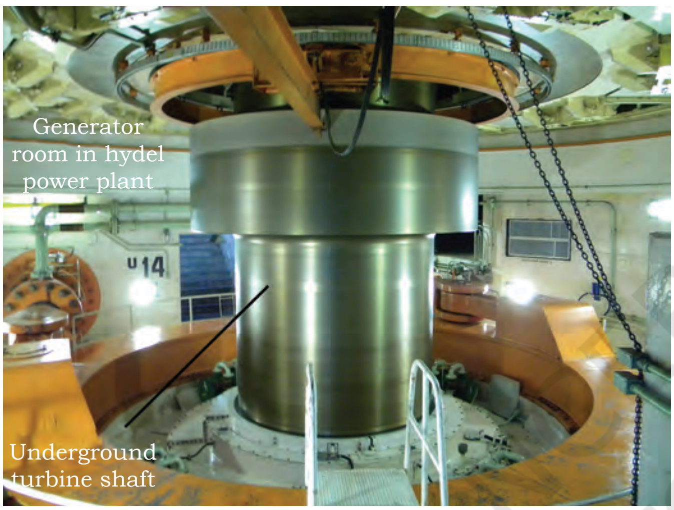


Fig. 1.8: An underground turbine shaft in a hydel power plant

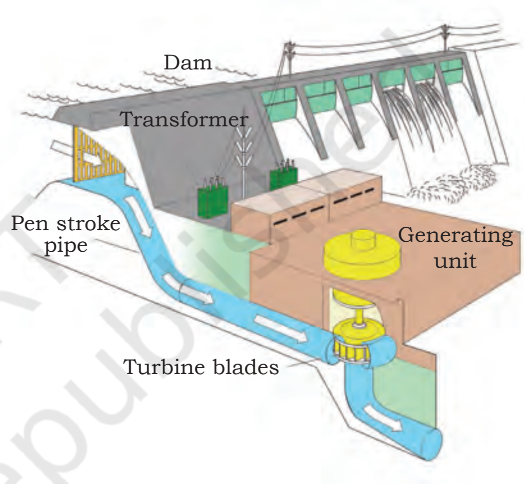


Fig.1.9: A hydel power plant which converts hydel energy into mechanical energy

Assignment 2

Visit a nearby thermal power plant or hydel power plant. Observe the working of the power plant, overview of the control system and how a boiler, generator, turbine and control panel works. Prepare a report mentioning the major things observed by you.

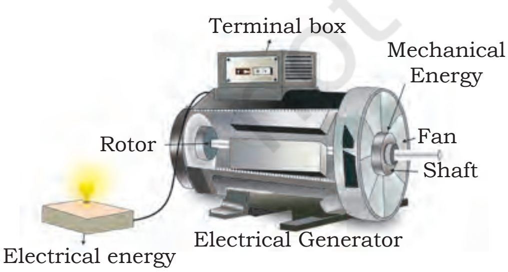


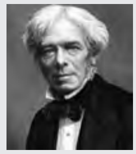
Fig.1.10: An electrical generator converts mechanical energy into electrical energy

Generator

Electric power can be generated in various types of power plants, that is, thermal, hydel or nuclear. The different power plants use different raw material or resource material to generate electric power. For example, coal is used as raw material or resource material in a thermal power plant. However, a generator is a common machine used in every power plant to generate electric power. A generator transforms mechanical energy into electrical energy as shown in Fig. 1.10.

Inventor's Dairy

British scientist *Michael Faraday* discovered the fundamental principles of electricity generation in the 1820s and early 1830s.



Mechanical force is applied on a shaft or axle to rotate the turbine. This mechanical force, which could be falling water, steam, or wind is used to rotate the shaft or axle on which the armature or rotor is formed. For example, Figs 1.11 and 1.12 show a turbine (water wheel) using falling water to rotate the shaft of an electric generator.

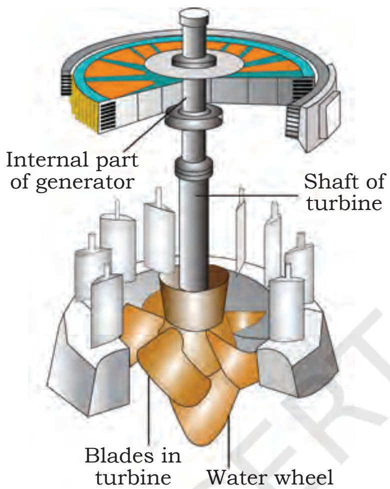


Fig.1.11: Connection of the turbine to the generator using a shaft

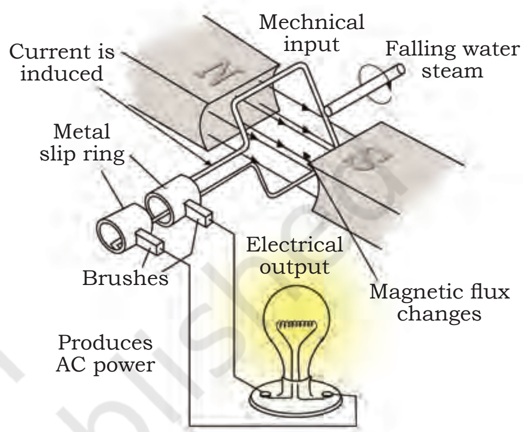


Fig.1.12: The basic principle of an AC generator

Practical Activity 1

Construct a model of an electric generator that can light a small bulb.

Material required

A piece of cardboard, glue gun, one neodymium magnet smaller than the constructed cardboard housing, 00 feet of 30 gauge enamel coated copper wire, one 1.5 volt light bulb, light bulb holder (optional), alligator clips (optional), ruler, pencil, awl or other device to puncture the cardboard.

Procedure

1. Prepare a box out of cardboard as shown in Fig. a. Mark the folds as per the figure.

NOTES

2. Now, fold the cardboard along the marks.
3. Use glue to stick the sides to make the box.
4. Make a hole in the centre of the long side of the box on both sides.
5. Now, slide the nail through the hole.
6. Using the hot glue gun, attach the magnet to the nail as shown in Fig. b. Make sure there is enough room for the magnet to rotate freely.

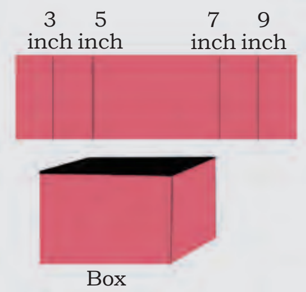


Fig. a: Box construction

7. Next, wrap the wire around the outer portion of the box.
8. Now, attach the bulb in the holder and secure the wire to the holder using the alligator clips.
9. Now, when you rotate the nail, the bulb will glow. This illustrates the process of generating electric power.

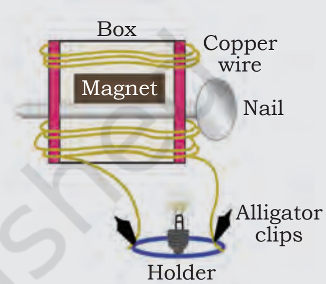


Fig. b: Full setup for the generator

ENERGY TRANSFORMATION

The role of a generator is to convert mechanical energy into electrical energy. This generated energy is transmitted to consumers via transmission lines as shown in Fig. 1.13. The most efficient way to transmit energy is by increasing the voltage and reducing the current. This task is performed by the transformer.

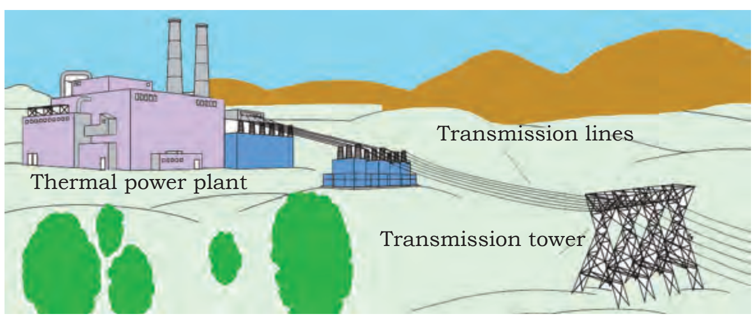


Fig.1.13: Transfer of energy from the generating station to the distribution station via transmission lines

It is necessary to minimise energy loss in the form of heat in transmission lines. These losses are equal to the product of square of the current and resistance of the power lines and are represented as I^2R. Once the electrical energy reaches the end user, it steps down to the voltage level required by the user.

Transformer

A transformer, a static unit as shown in Fig. 1.14, requires an AC power supply to operate. It works on the principle of *mutual induction*. It is used to step up the voltage at the generating end and step down the voltage at the user end. A transformer transfers energy from a primary coil to a secondary coil by mutual induction. The AC generator provides electrical power to the primary coil. The magnetic field produced by the primary coil induces voltage into the secondary coil, which supplies power to the connected load. The load in this case would be the entire electrical distribution network including all residential, commercial and industrial consumers. A step-up transformer is used to increase and a step-down is used to decrease the voltage from one level to another.

Fig.1.14: Transformer in the electrical substation

Parts of a Transformer

A transformer has various parts as explained below.

Transformer Tank

It holds the transformer winding. Oil is filled in the tank for cooling. A transformer tank must be air-tight to stop external contaminants.

High Voltage Bushings

They are the terminals where the primary winding of the transformer terminates. Bushing serves as an insulator.

Low Voltage Bushings

They are the terminals where the secondary winding of the transformer terminates. Bushing serves as an insulator.

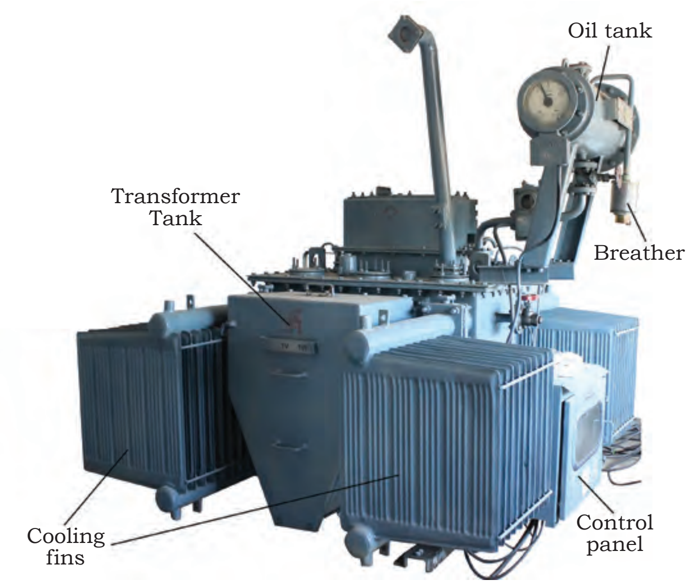


Fig. 1.15: Parts of a transformer

Low voltage bushing can be easily distinguished from high voltage bushing. Low voltage bushings are usually smaller in size compared to the high voltage bushing.

Cooling Fins or Radiators

They help to dissipate the heat of a transformer, which is absorbed by oil insulation. They are placed on the outer body of a transformer.

Cooling Fans

They can be usually found attached to the cooling fins. Cooling fans help to raise the transformer capacity when the load increases to a larger value.

Conservator Tank

It is an oil preservation system in which the oil in the main tank is isolated from the atmosphere.

Drain Valve

It is usually found at the bottom of the transformer tank, depending on the manufacturer. It is used whenever oil replacement is necessary.

Dehydrating breathers

They are used to prevent the transformer from being adversely affected by the moisture present in the air. It helps to maintain the insulation capability of the oil.

Oil Temperature or Pressure Gauges

They are used to monitor the internal characteristics of the transformer. These gauges help to check the level of temperature of winding and the pressure of oil inside the transformer.

Control Panel

It is the monitoring device of the transformer. It can be used to monitor pressure gauge, oil temperature and auto cooling fans.

For example, a 1:2 step-up transformer is used to step up 220 volts to 440 volts. Likewise, a 2:1 step down transformer is used to step-down 440 volts to 220 volts as shown in Fig. 1.16.

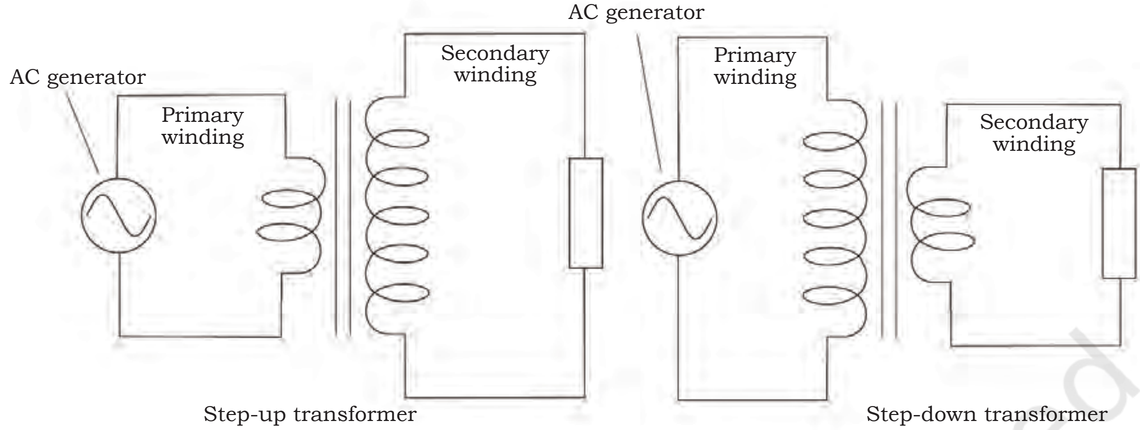


Fig. 1.16: Step-up and step-down transformer

Assignment 3

Visit a distribution transformer in an electrical substation. Observe the difference between a step-up and a step-down transformer. Identify the difference in their construction. Make a report about the parts of a transformer, different ratings of a transformer, name of the oil filled in a transformer, difference between a step-up and a step-down transformer.

Three Phase System

A generator produces three voltages in a three-phase system. Each voltage phase rises and falls at the same frequency (50 Hz in India). However, the phases are offset from each other by 120° as shown in Fig. 1.17.

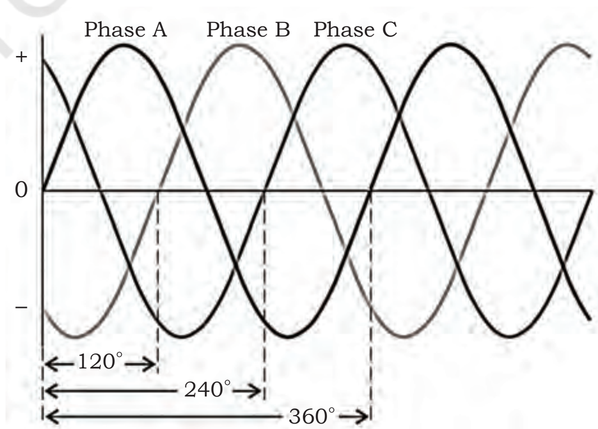


Fig. 1.17: Graphical representation of a three-phase system

Three Phase Transformer

In addition to single-phase connections, transformers can also be used to supply power to three or more phase connections. Transformers that can supply voltage to three or more phases are known as poly phase transformers. These transformers can be used to generate or

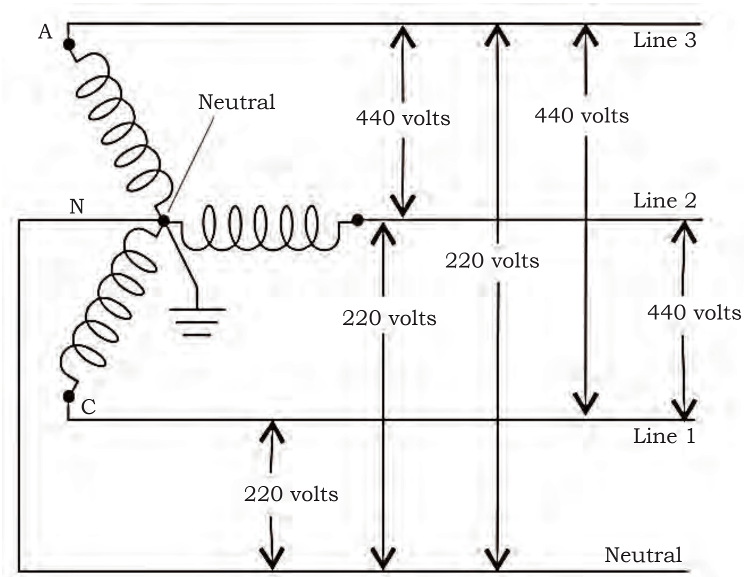


Fig. 1.18: Primary or secondary coils connected in a star configuration

supply power on a large scale, such as for industrial or commercial use. Compared to single phase transformer, a three phase transformer has many advantages. It provides a more economical approach by using less material. The three phases carry equal current and voltage. However, these three phases are 120 degree apart from each other as shown in Fig. 1.17.

Three phase transformers require a total of six coils. Three coils are used in the primary side of the transformer, while the remaining three are used in the secondary side. All the six coils can be connected in either a star or a delta configuration. Fig. 1.18 shows primary or secondary coils connected in a star configuration. Fig. 1.19 shows primary or secondary coils connected in a delta configuration.

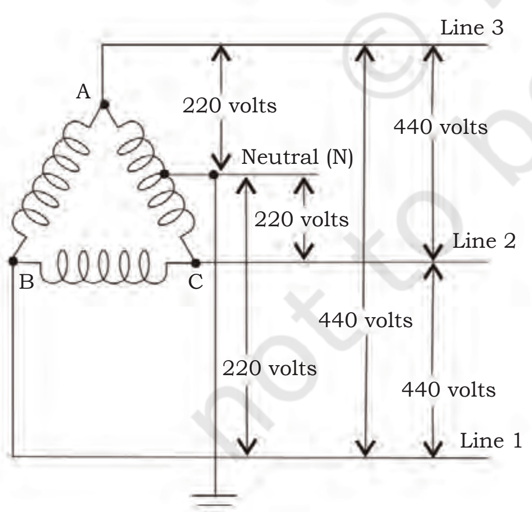


Fig. 1.19: Primary or secondary coils connected in a delta configuration

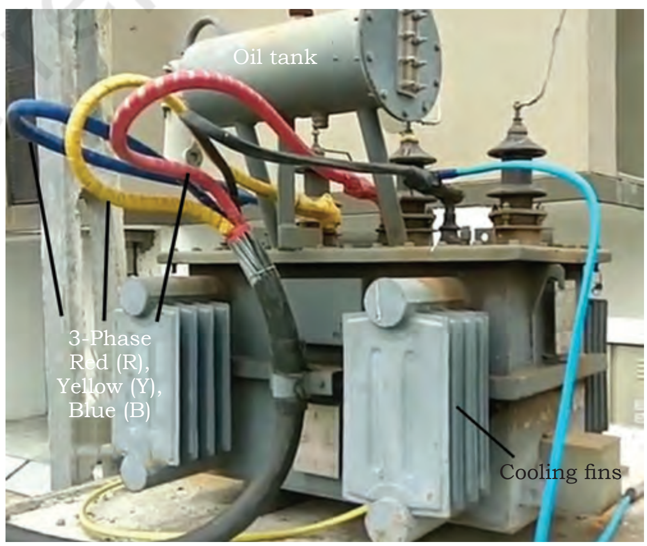


Fig. 1.20: Transformer showing a three phase output (red-yellow-blue)

Practical Exercise

Visit a transformer manufacturing site and illustrate how three-phase transformer is manufactured.

Material required

Writing material

Procedure

Observe the following steps in a transformer manufacturing site.

Step 1. Observe the cutting of core as shown in Fig. a. Note that a three-phase transformer is used in a generating station, transmitting station, and distributing station of an electrical system.

Fig. a: Cutting of core

Fig. b: Assembling the number cores that are being cut

Step 2. Observe the manufacturing of primary and secondary winding as shown in Figs c and d.

Step 3. Observe the formation of a conservator as shown in

Fig. c: Making a three-phase transformer's primary winding using a winding machine in the form of a bundle

Fig. d: Making a three-phase transformer's secondary winding using a winding machine

Fig. e: Making the main tank and the oil tank

Notes

Notes

Step 4. Observe the assembling of coils into the core as shown in Figs f, g, h, and i.

Fig. f: Insertion of insulation paper in the core of a three-phase transformer

Fig. g: Insertion of a secondary coil in the core

Fig. h: Insertion of bundles of primary coil in the core

Fig. i: Insertion of I section in the core

Step 5. Observe the coil connection in a star or delta configuration as shown in Figs j and k.

Fig. j: Making a series of connections of all the bundles of the primary coil. The terminals of the coils are connected in such a way that it forms a delta configuration.

Fig. k: Making of coil terminals connection for the secondary winding. The coil terminal is connected in such a way that it forms a star configuration.

Step 6. Observe the fitting of high voltage and low voltage bushing on the main tank of the transformer as shown in Fig. l and m.

Fig. l: Fitting high voltage bushing on the transformer

Fig. m: Fitting low voltage bushing on the transformer

Step 7. Observe the placing of the core assembly into the main tank of a three-phase transformer as shown in Fig. n.

Fig. n: Assembly in the transformer tank

Step 8. Observe the testing of transformer as shown in Fig. o.

Fig. o: Testing the transformer

Motor

An electric motor converts electrical energy into mechanical energy as shown in Fig. 1.21. This conversion is usually obtained through the generation of a magnetic field by means of current flowing into one or more coils.

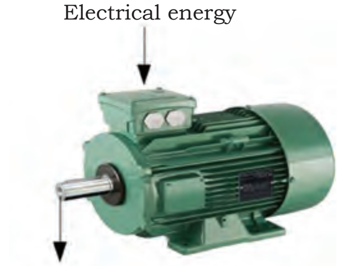


Fig. 1.21: A motor converts electrical energy into mechanical energy

Electric Power Distribution

Electrical power distribution can be classified as:

1. Residential application
2. Commercial application
3. Industrial application

Residential Application

Power generated in a power plant is stepped up to high voltage. Using transmission lines, this high voltage is then transmitted to the local electrical substation, where it is stepped down to a lower voltage for distribution.

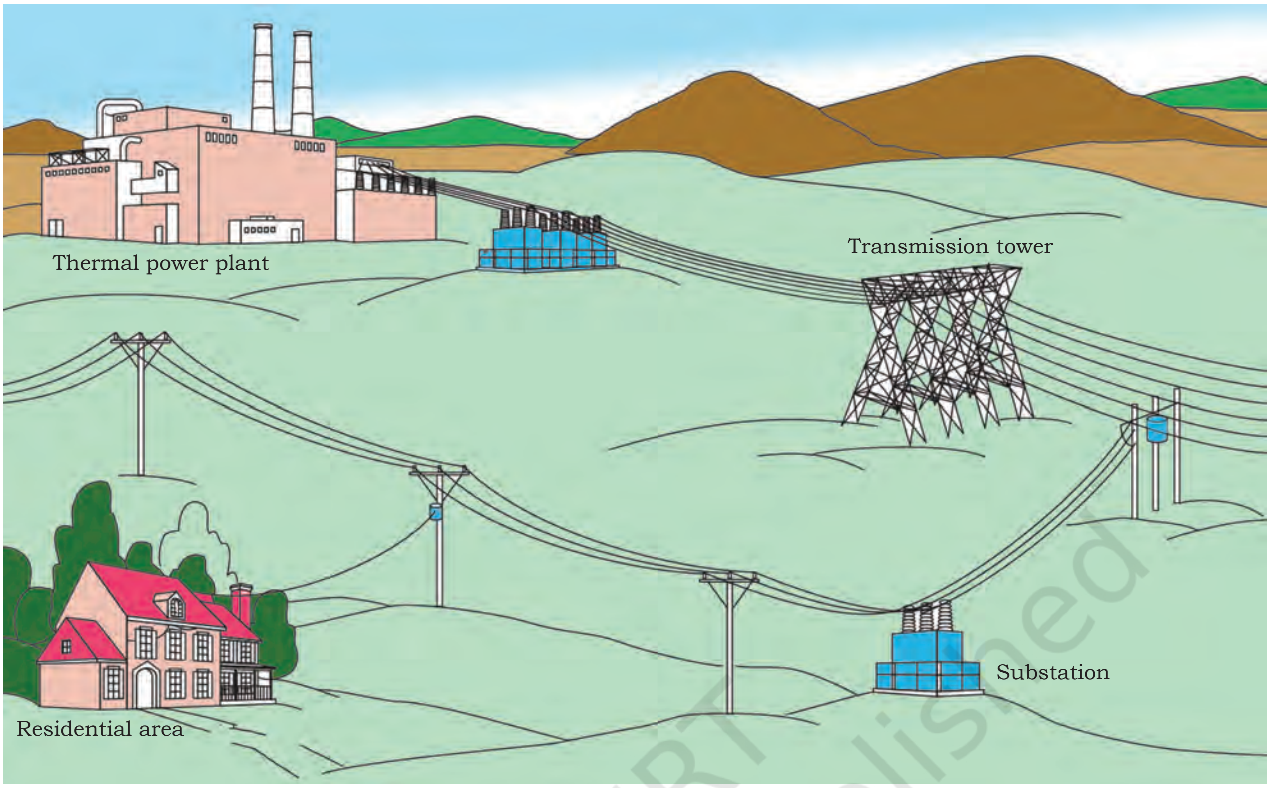


Fig. 1.22: Distribution of electric power using a transmission line for residential application

Fig. 1.22 shows how power generated from a generating station reaches its final destination, a residential area. It is stepped down to 240 volts using a step down transformer. Only single-phase power is used in a typical residential application.

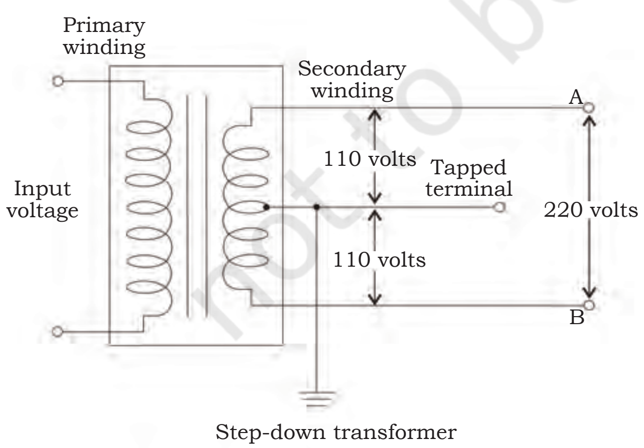


Fig. 1.23: Single-phase and three-wire supply system

Power Supply

In residential application, the most common supply system is used. It is a single-phase and three-wire supply system as shown in Fig. 1.23. In this system, there is 220 volt between live wires and neutral, and 440 volts between two live wires. The 220 volt supply is used for general purpose home appliances and lighting. The 440 volt supply is used for heating, cooling, cooking, and other high-demand loads.

Service Entrance

Power distributed by the state electricity board, enters the house through a metering device and connects to a load centre. This is known as service entrance as shown in Fig. 1.24. Residential service can come from an overhead utility step down transformer, which is a distribution transformer in a small area.

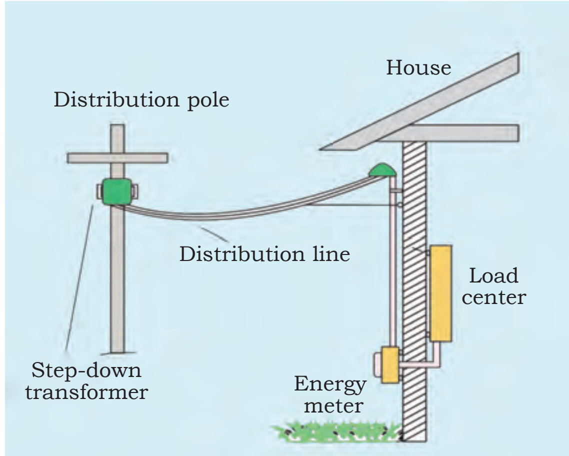


Fig. 1.24: The service line entering through an energy meter and load centre

Energy Meter

An energy meter is used to measure the amount of energy consumed by an electrical appliance in a house. A familiar term for it is watt-hour meter located outside our houses. The watt-hour meter is used by the state electricity board for billing purposes, to determine how much electricity has been consumed. A single phase energy meter is shown in Fig. 1.25. A three-phase energy meter line diagram is shown in Fig. 1.26.

Fig. 1.25: Single-phase energy meter

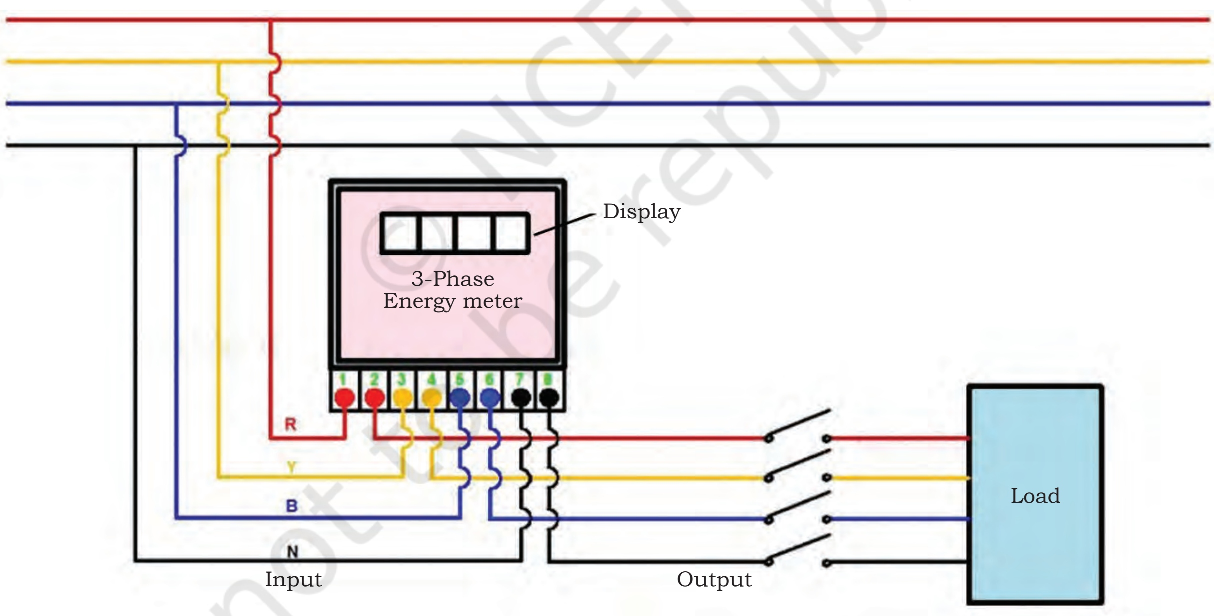


Fig. 1.26: Three-phase energy meter wire diagram

Main Control Panel

The main control panel, as shown in Fig. 1.27, is an enclosure in which the energy meter, circuit breaker, and busbar are built to form a panel. This panel

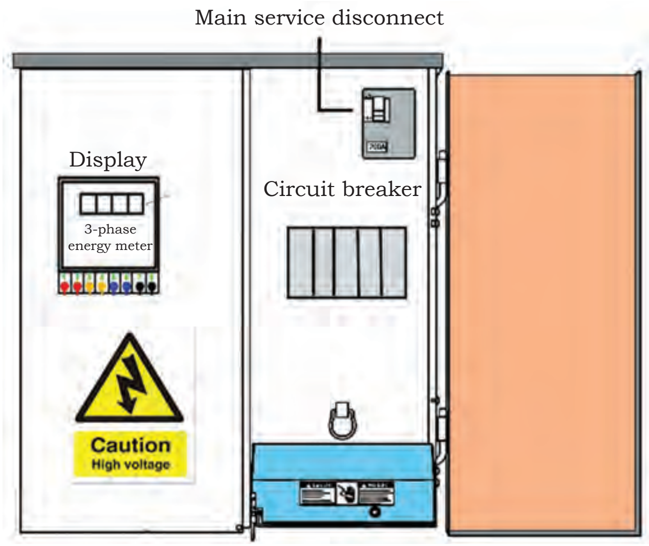


Fig. 1.27: Main control panel

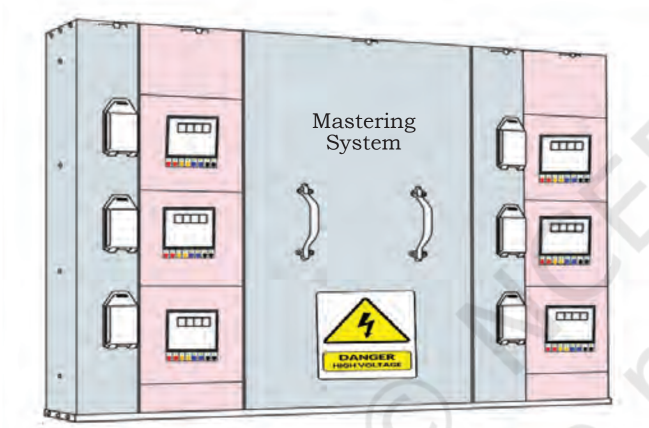


Fig. 1.28: Modular and metering system

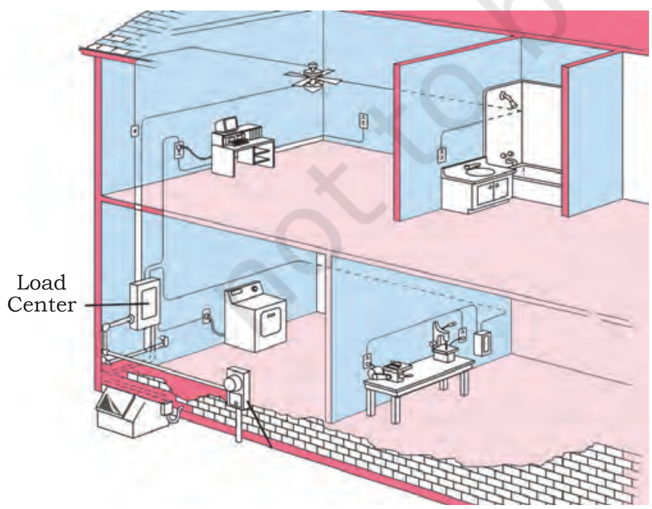


Fig. 1.29: Distribution of electrical power in a household

controls the electrical distribution in a residence.

Modular Meter Centres and Metering Systems

Modular meter centres are used for multi-family such as duplexes or apartment buildings. These are used in combination with load centres. They are available with two to six meter compartments as shown in Fig. 1.28.

Metering systems are another option for multi-family. These are self-contained systems with two to six meter compartments. Individual branch circuit breakers for tenants are located in a separate compartment adjacent to the meter socket.

Distribution of Power in a Household

Power distributed by the electricity board, enters the house through a metering device and connects to a load centre. The incoming power then goes to a load centre which provides circuit control and overcurrent protection. Then the power is distributed from the load centre to various branch circuits for lighting, appliances, and electrical outlets as shown in Fig. 1.29.

Load Centres

Panel boards are the power control unit in industry. Load centres used for residential application are typically rated at 225 amps or less and 240 volts maximum. A load centre consists of an enclosure, interior, and trim. Circuit breakers are mounted in the interior to provide circuit protection and control for light, heat, and power circuits. Fig. 1.30 shows the internal parts of a load centre.

Circuit Breakers

Circuit breakers provide manual means of energising and de-energising a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit. Residential circuit breakers are available with current ratings from 15-125 amps and a voltage rating of 220/440 volts. In residential applications, single-pole breakers protect 220 volt circuits; two-pole breakers protect 440 volt circuits. Fig. 1.31 shows a single pole and double pole miniature circuit breaker (MCB).

Enclosed Circuit Breaker and Disconnects

In this type of circuit breaker, an enclosure is used to enclose the circuit breakers as shown in Fig. 1.32. Disconnects provide a safe and simple means of disconnecting power.

Surge Arrester

Surge is a sudden fluctuation in the power supply. To protect the load from these sudden fluctuations, a surge arrester is used. It is a type of circuit breaker used in the load centre. A surge arrester mounts in a load centre in the same way as a conventional circuit breaker (Fig. 1.33). It protects electronic equipment, such

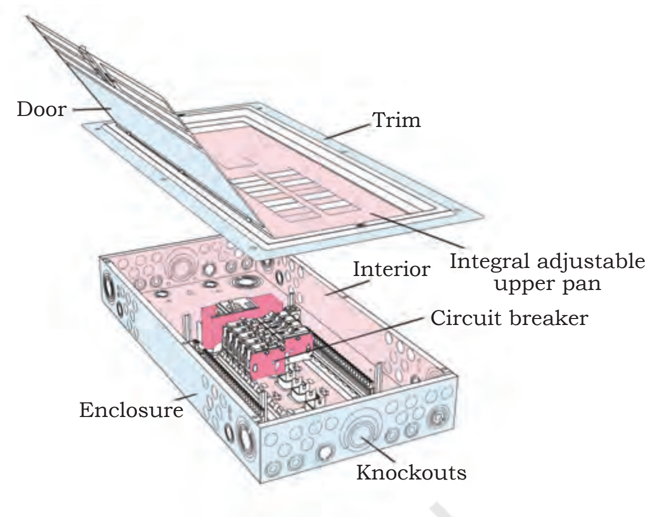


Fig. 1.30: Internal parts of load centre

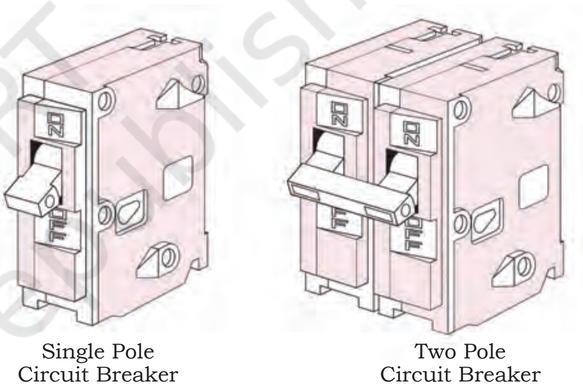


Fig. 1.31: Single pole and double pole miniature circuit breaker

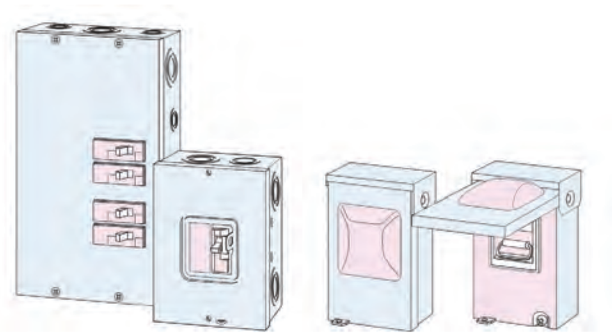


Fig. 1.32: Enclosed circuit breaker and disconnect

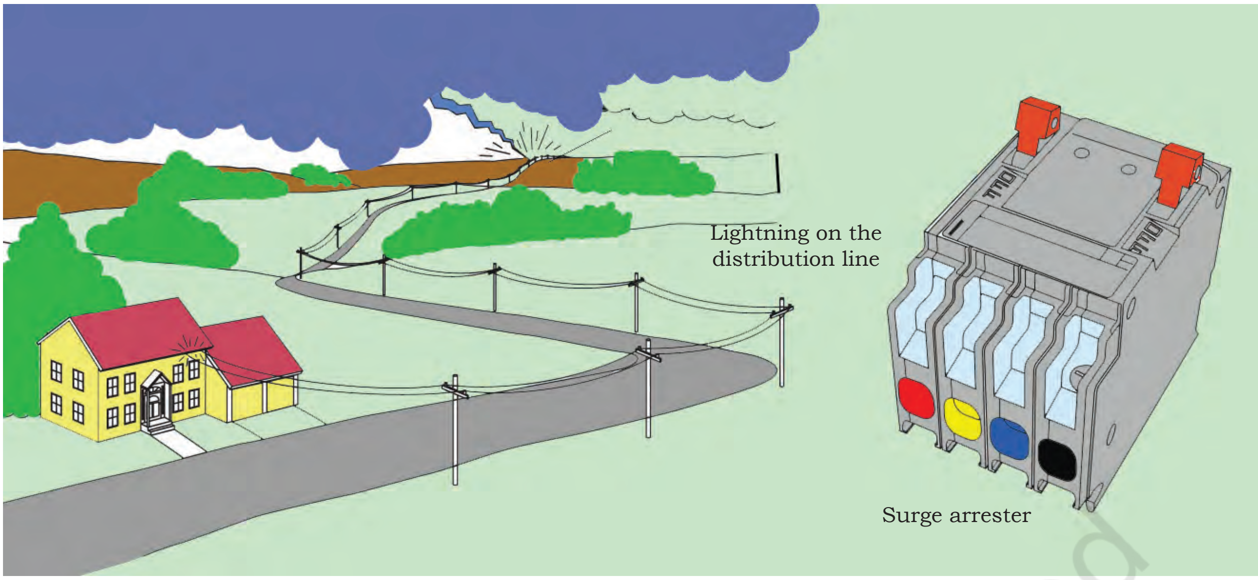


Fig. 1.33: Role of a circuit breaker during a surge or lightning

as televisions or computers, from electrical surges in the electrical system.

Ground Fault Circuit Interrupter (GFCI)

A ground fault circuit interrupter (GFCI) is a device used in electrical wiring. It is used to disconnect a circuit when current imbalance is detected (Fig. 1.34). Such an imbalance is sometimes caused by current passing through a person, if that person is in contact with a ground and an energised part of the circuit. This could result in electric shock. GFCI is designed to protect a person against electric shock. A normal circuit breaker is designed to protect against overload, but, GFCI protects from short circuits and ground faults. GFCI is required in certain residential electric sockets, such as the bathroom, kitchen sink, etc.

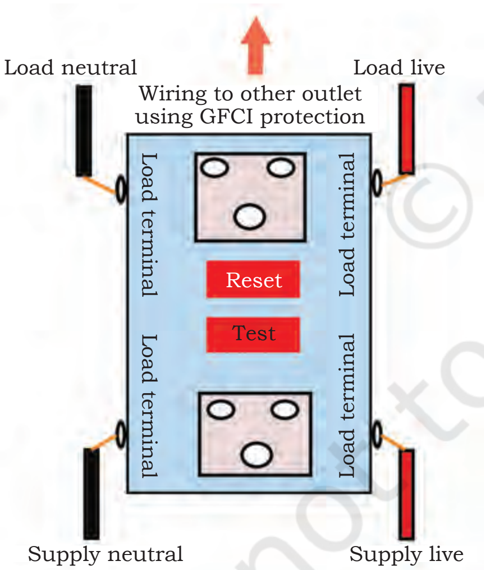


Fig. 1.34: Connection diagram of ground fault circuit interrupter

The circuit breaker will interrupt the power supply when there is a current overload caused by a short circuit or by the load itself drawing more current than the rating of a circuit breaker. For example, if the circuit breaker is rated for 15 amps, it will break the circuit as soon as the circuit load draws more than 15 amps.

GFCI will turn the circuit off when there is a current leak. GFCI monitors the current going to the load and compares it to the current coming from the load. If there is any difference between the two, GFCI will 'interrupt' or turn the circuit off. Fig. 1.35 shows an electric iron drawing 2A current from a socket via GFCI, but due to ground fault, 0.05A is being wasted through the ground path. GFCI will compare the current coming back from the electric iron, which is 1.95A. If both the incoming and outgoing current is not the same, it will turn off the supply to the electric iron and save the person from electric shock.

Arc Fault Circuit Interrupter (AFCI)

GFCI devices are designed to protect a person from getting a shock when touching an ungrounded appliance. Arc Fault Circuit Interrupters (AFCI), in comparison, protect against fire from an unintended arc (Figs 1.36 and 1.37).

Commercial Applications

Electricity is commercially used in a number of places such as small offices, stores, large complexes such as hotels, restaurants, office buildings, and shopping malls (Fig. 1.38). Typically, commercial applications have higher demand for electrical power than residential applications. In commercial applications, electricity is used for heating, cooling, and lighting on a much

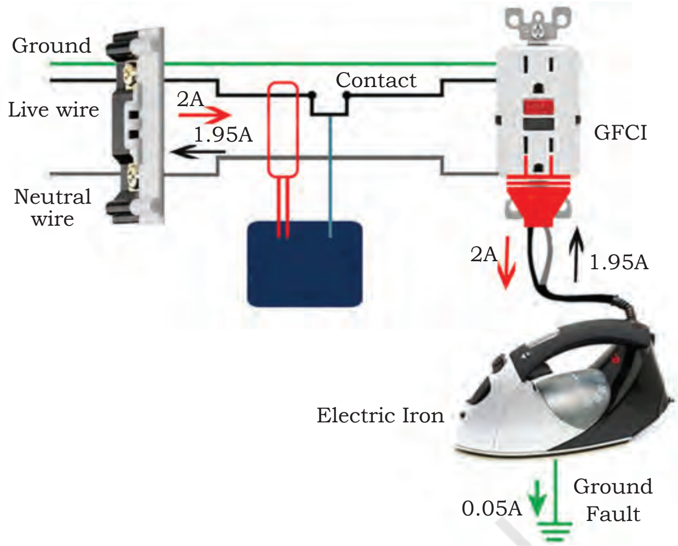


Fig. 1.35: Application of GFCI in an electrical circuit

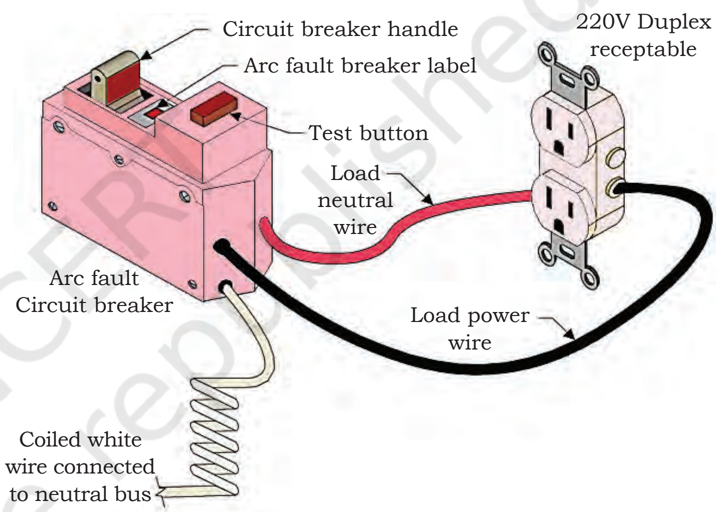


Fig. 1.36: Arc fault circuit interrupter

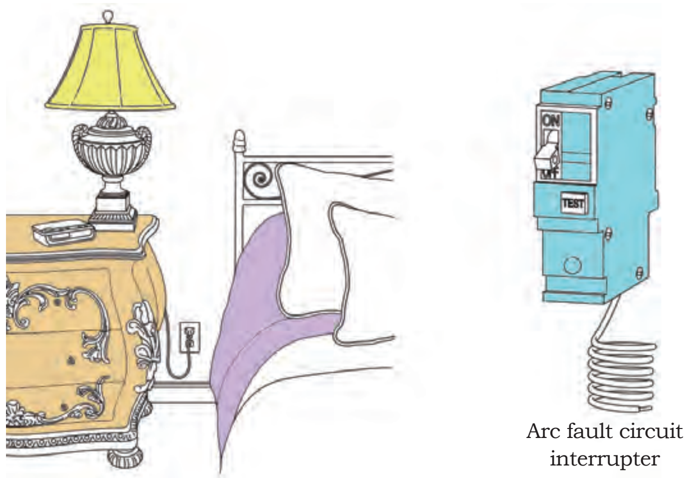


Fig. 1.37: Application of arc fault circuit interrupter

larger scale. Some commercial applications may also operate machinery, such as elevators and small conveyors.

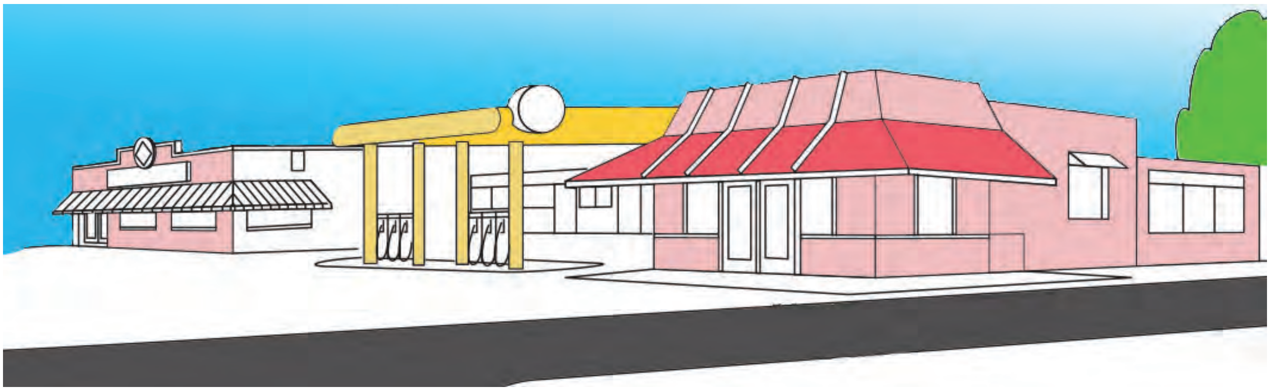


Fig. 1.38: Commercial building

Busway

Busway is the path or route through which power will be transferred from one section to another. Busway is the medium through which electrical signals can travel from one machine to another. There are two methods to route power into a building or distribute power throughout a building, through a conduit or a busway, as shown in Fig. 1.39.

The distribution system in a building consists of a combination of busway and conduit. Busway is a pre-fabricated electrical distri-bution. Busway consists of uncovered copper conductors supported on insulators. This system consists of busbars in a protective enclosure. Busbars are the electrical conductors that carry power. The bars are individually insulated and enclosed in houses.

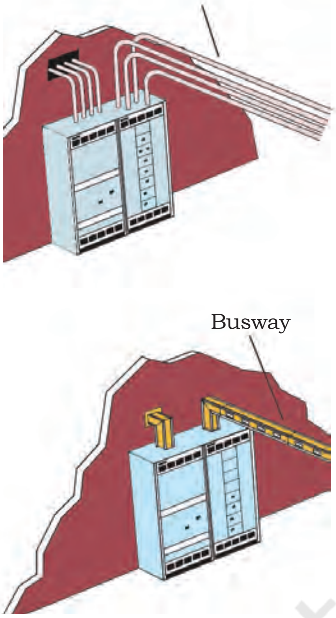


Fig. 1.39: Cable and conduit used in panel distribution

Service Entrance

The service entrance is the point from where electric power enters a residential area. The service entrance in a residence is commonly thought of as a breaker or fuse box. In large commercial or industrial area electrical systems, the service entrance may be a main disconnect panel and thereby called the main panel. For industrial or commercial purpose, outdoor feeder busway is used. This involves routing the electrical power inside the premises of a commercial building or industry. This can be done using a transformer outside the premises of the industry or commercial building. For distribution of electrical power inside the building or campus, indoor feeder or plug-in busways are used as shown in Fig. 1.40.

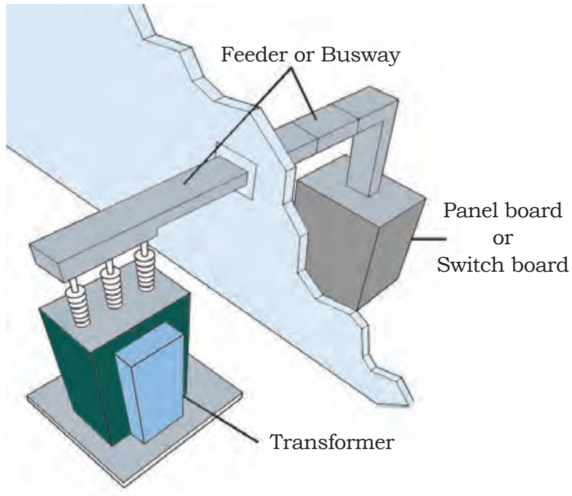


Fig. 1.40: Service entrance

Busway in a Distribution System

In our daily life, we use a variety of electrical or electronic gadgets and equipment. To run these gadgets and equipment, we need a proper and safe distribution of electrical power. Busway can be a way to transfer this electrical power. Since we know that busway is in pre-fabricated form, it can be easily connected to other busways. For distribution purpose, electrical power can be easily supplied to any part of the house, building or campus. It requires very little time for installation. A vertical busway can be used for distribution of electrical power in a multistorey building, as shown in Fig. 1.41. These are the major advantages of using a busway in the distribution system.

Fig. 1.41: Busway used in the distribution system

Power Distribution in Commercial Applications

In commercial areas, such as malls, shopping complexes, and electronic complexes, there is requirement of a large amount of power to run small and heavy machinery like motors of high horse power (HP) to run elevators, escalators, etc. To distribute this large amount of power safely, highly insulated cables and busways are used. To direct and control the routing of high electrical power, high rated service entrance equipment is used in commercial application. Panel boards and switchboards can be used in commercial application to distribute the power safely to the machinery. Load centres, panel boards, and switchboards are similar in function and appearance, but they are different products and designed to meet different needs.

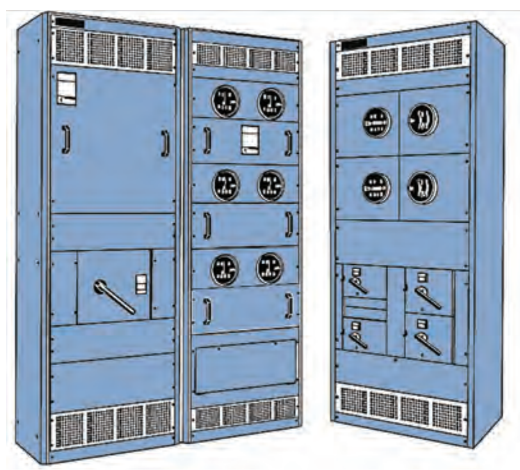


Fig. 1.42: Commercial metering switch board

Commercial Metering

In residential areas, electrical power consumed by the load can be measured by using one or two energy meters. In case of commercial areas like shopping malls and complexes, multiple energy meters are required to measure electrical power used by different shops, showroom, outlets, etc. This multiple metering to measure the power consumed by the shops, and outlets, is known as commercial metering. Switchboards are designed for multi-metering as shown in Fig. 1.42.

Industrial Applications

In commercial areas, there is a requirement of a high amount of electrical power. This power is used in a variety of loads, such as motors, high wattage bulbs, halogens, air conditioners and refrigerators. In industry, the power requirement is even more for industrial loads of heavy machinery, such as electric cranes, milling machines and grinding machines. Heavy electrical power is the primary requirement for the operation of these loads. Voltage is received and distributed at much higher levels than residential and commercial applications. In industry, high power is received from high transmission lines as shown in Fig. 1.43. The equipment designed for industrial applications must be designed for high voltage rating and to receive high transmission voltage.

Voltage Classes

We know that electrical and electronic devices require electrical power for their operation. Electric power,

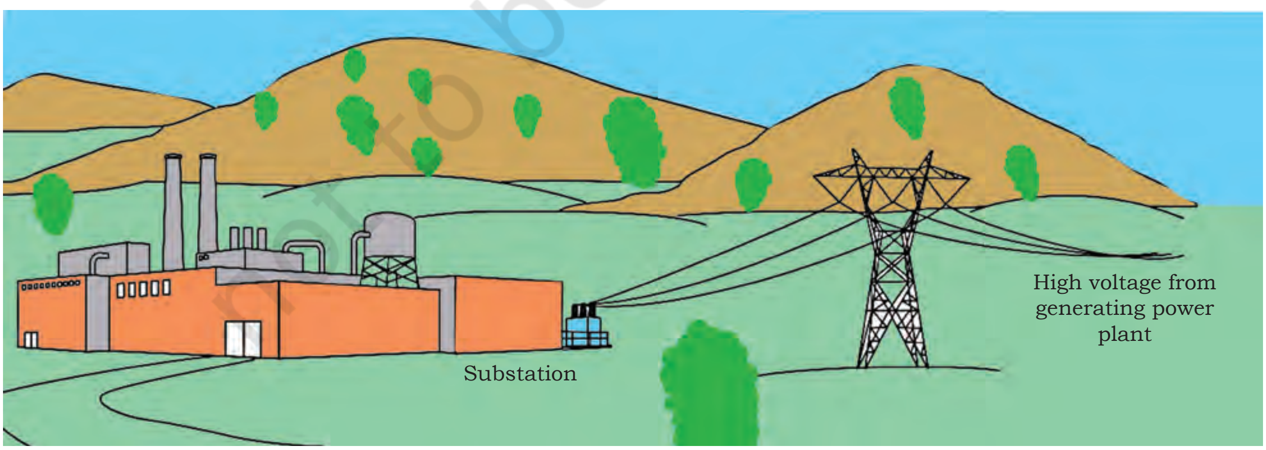


Fig. 1.43: High voltage transmitted to the distribution electric power station

which is delivered by electrical substations, has different voltage levels, which may vary according to the requirement. In accordance with the power distributed by a utility company, a range of voltage levels can be divided into a number of classes. The Institute of Electrical and Electronics Engineers (IEEE), divides voltage systems into the following classes:

Low voltage system	**Medium voltage system**	**High voltage system**	**Extra high voltage system**
1000 volt or less	1000 to 1,00,000	1,00,000 volts to 2,30,000	2,40,000 volts to 8,00,000

Switchgear

An electrical network includes generation, transmission and distribution of electric power. While dealing with electrical circuit, equipment and load, it is important to monitor the control over the operation of the electrical system and its safety. In an electrical system, the unit which operates the routing of power cables, controls the equipment and safety of individuals, is known as a switchgear as shown in Fig. 1.44. Switchgear includes switches, which can be disconnected, fuses or circuit breakers. The basic function of a switchgear is to protect from faulty current, overload, surge and short circuit. Switchgears are responsible for the safety, reliability, and flexibility of an electrical system. For example, in a house, the domestic electric panel boards at the entrance of the service line act as switchgear, which has a fuse or miniature circuit breaker.

Fig. 1.44: Switchgear in the substation

Assignment 4

Visit the nearest electrical substation and observe the switchgear and identify its various elements. Prepare a report on it.

Notes

Check Your Progress

A. Multiple choice questions

1. The most efficient way to transmit electrical energy using a transmission line is _______________.
   (a) increase voltage and current
   (b) increase voltage and reduce current
   (c) decrease voltage and increase current
   (d) decrease voltage and current
2. Which of the following meter is used to measure the amount of power consumed in residence?
   (a) Voltmeter (b) Ammeter
   (c) Barometer (d) Energymeter
3. A protecting device used in an electric circuit to protect against electric shock is _______________.
   (a) TPS (b) PROFIBUS
   (c) GFCI (d) GMI
4. The voltage rating for medium voltage equipment is _______________.
   (a) 480 volts
   (b) 1000 volts or less
   (c) greater than 1000 to 100,000 volts
   (d) greater than 100,000 to 230,000 volts
5. The voltage rating for high voltage equipment is ________.
   (a) 480 volts
   (b) 1000 volts or less
   (c) greater than 1000 to 100,000 volts
   (d) greater than 100,000 to 230,000 volts
6. The voltage rating for low voltage equipment is ________.
   (a) 480 volts
   (b) 1000 volts or less
   (c) greater than 1000 to 100,000 volts
   (d) greater than 100,000 to 230,000 volts
7. The voltage rating for extra high voltage equipment is _______________.
   (a) 2,40,000 volts to 8,00,000 volts
   (b) greater than 1000 to 100,000 volts
   (c) greater than 100,000 to 230,000 volts
   (d) for 1000 volts or less
8. Which of the following units is used for the safety, reliability, flexibility of an electrical system?
   (a) Busway (b) Transformer
   (c) Load centre (d) Switchgear
9. Which of the following units acts as a medium for transmitting electrical signals from one machine to another?

(a) Transformer (b) Load centre
(c) Busway (d) Circuit breaker

10. The electrical device that converts electrical energy to mechanical energy is called ____________.
(a) Generator (b) Motor
(c) Switch (d) Switchgear

B. Fill in the blanks

1. GFCI protects us from __________ and __________.
2. To protect the load from these sudden fluctuations __________ is used.
3. Load centre consists of an enclosure, interior, and __________.
4. Three phase transformers are used in __________ station, transmitting station, and __________ station of an electrical system.
5. A transformer is a __________ unit.
6. Sudden fluctuation in electric power is called _________.
7. Coal, oil, and uranium are fuels used to convert water into steam, which in turn drives a __________.
8. GFCI stands for ground __________ circuit __________.
9. AFCI stands for _______________ circuit ________.
10. In an electrical system, the unit which performs the operation of routing of power cables, controlling the equipment and safety of individuals is known as __________.

C. State whether the following statements are True or False

1. Armature is the rotating part of a motor or generator.
2. A brush is a stationary or fixed part of a generator.
3. According to Faraday's law of electromagnetic induction, whenever a conductor moves in a magnetic field, EMF gets induced across the conductor.
4. An AC generator is also known as alternator.
5. Circuit breakers provide over current protection of a circuit.
6. A generator converts mechanical energy into electrical energy.
7. Switchgear is used in substation.
8. GFCI is designed for protection of a person against electric arc.
9. AFCI is designed for protection of a person against electric shock.
10. Load centre is a term used for the panel board in industry.

NOTES

NOTES

D. Short answer questions

1. Write down the classification of a distribution system.
2. Write down the manufacturing steps of a three-phase transformer.
3. Discuss the concept of a three-phase transformer. How it is different from a one-phase transformer?
4. Discuss the scenario of power source available in India.
5. What is the role of a generator in the electric power station?
6. List out the different parts of a transformer.
7. Write short notes on:
   (a) Load centre
   (b) Switchgear
   (c) Service entrance
   (d) Busway
   (e) Circuit breaker

Chapter 2

Busway in Control Panel Design

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Introduction

In Chapter 1, we discussed power generation, transmission and distribution in detail. We learnt that a transformer is used to step up the voltage and step down the current to minimise loss during the transmission of electric power. This step up electric power is transmitted through transmission lines. These transmission lines terminate in an electrical substation, where it is again step down to the operating voltage level. At this lower voltage, power is distributed to the loads safely and precisely. To perform this task a platform is used to direct, assist and route the cable. This platform over which, cables, conduits and heavy conductors are used to transmit electrical power to the load is known as a busway. This chapter will discuss the busway, its construction, type and application.

Busway

An electrical substation plays a major role in the distribution of electric power. This power in is further transmitted by distribution lines. These lines distribute electrical power for residential, commercial and industrial purpose. Residential, commercial and industrial distribution uses several methods to transport electrical energy. These methods of distribution use heavy conductors that run on a tray or conduit. Once these conductors and power cables are installed, it is difficult to change the set-up. Power can also be distributed using busbars in an enclosure. This is called a busway, as shown in Fig. 2.1.

Fig. 2.1: Electrical busway

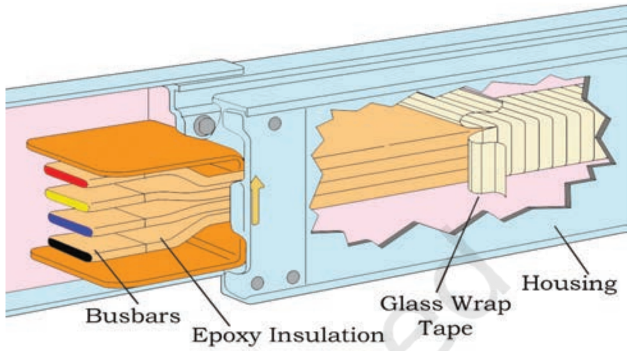


Fig. 2.2: Internal components of a busway

Purpose of a Busway

The modern electrical power system is complexly spread over a large geographical area. A busbar is essential in the electrical power system. A busbar is a conductor that serves as a common connection for two or more circuits. It is represented by a straight line with a number of connections attached to it. Standard busbars in a busway are made of aluminium or copper. How to manually assemble a busbar is shown in Fig. 2.3. Fig. 2.4 shows the line diagram of a busbar.

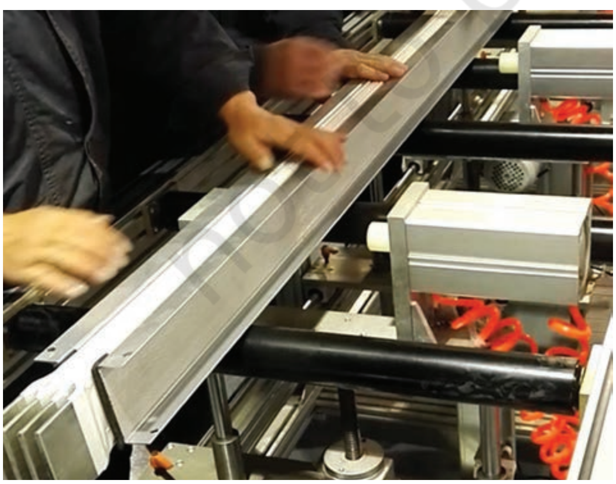


Fig. 2.3: Manual assembly line of a busbar

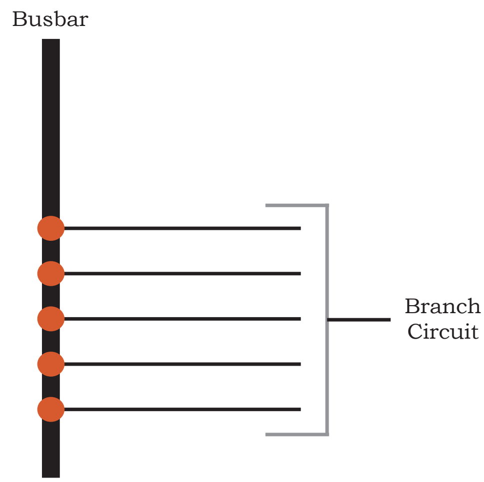


Fig. 2.4: Line diagram of a busbar

A busway is a prefabricated electrical distribution system. The purpose of a busway is to carry the busbars kept in a protective enclosure as shown in Fig. 2.5. A busway includes busbars, an insulating material and housing.

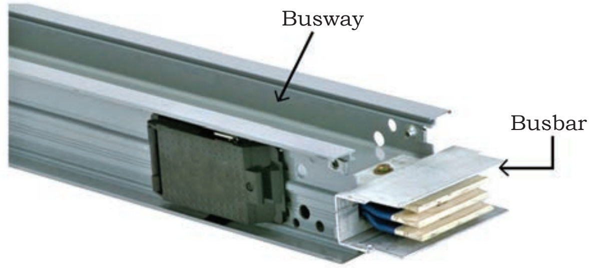


Fig. 2.5: A busway showing busbar housing

Busway in a Distribution System

In a distribution system, electrical power is distributed using power cables and wires. Since the electrical power system is vast and complex it requires a number of wires and cables for distribution. So to protect and safely transmit the electrical power cables and wires, a busway is used in the distribution system as shown in Fig. 2.6. The major advantage of a busway is that it can easily connect to other busway sections. By connecting a number of busways, electrical power can be supplied to any area of a building. It takes less time and manpower for the installation of a busway.

Fig. 2.6: A busway in a power distribution system

The distribution system consists of a combination of busway, cable, conduit, distribution transformer, panel board and switchboard as shown in Fig. 2.7. For example, the power coming from a substation or transformer is first received by the energy meter. It then enters the plant through a distribution switchboard. A switchboard acts as the main disconnecting point. In case of any fault or short circuit, the input supply coming to the plant can be turned off manually or automatically. Simply put, it isolates or stops the power supply coming inside a plant.

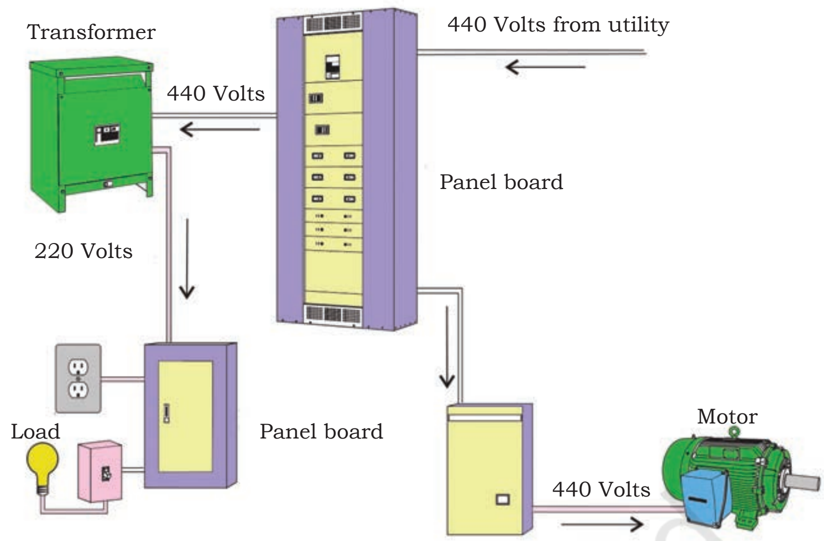


Fig. 2.7: A power distribution system

Fig. 2.8 shows that the power coming to the plant is divided into three sections. There are three feeding points – left feeder, middle feeder and right feeder.

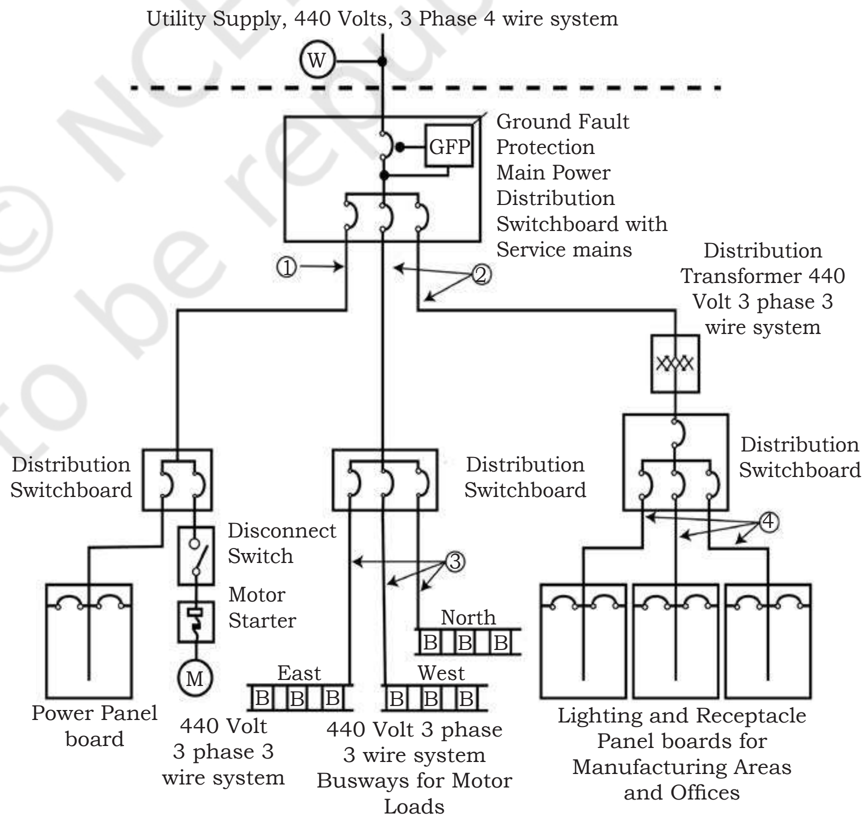


Fig. 2.8: Diagram to show the distribution system

The feeder on the left feeds power to the switchboard, which in turn feeds it to the panel board and motor. The middle feeder feeds another switchboard. This switchboard divides the power into three wires, where each wire has three phases, which is distributed in different directions. The feeder on the right is first fed into the step down transformer. The output of the transformer is then fed to the distribution switchboard, through which it is distributed to the lighting and panel board.

Types of Busways

Busways are of two types— feeder busway, and plug-in busway.

Feeder Busway

Feeder busways are used to distribute power to loads that are either fixed in place or are concentrated in one physical area. These loads may be a large machine, motor control centre, panel board, or switchboard. In industries there are a number of loads that require a continuous supply from the source for a very long time. In these cases feeder busways are used.

Feeder busways are used at a service entrance as shown in Fig. 2.9. The service entrance is the point from where supply conductors enter a building or other structure. Feeder busways are used to bring power from a utility transformer to the main switchboard inside a building.

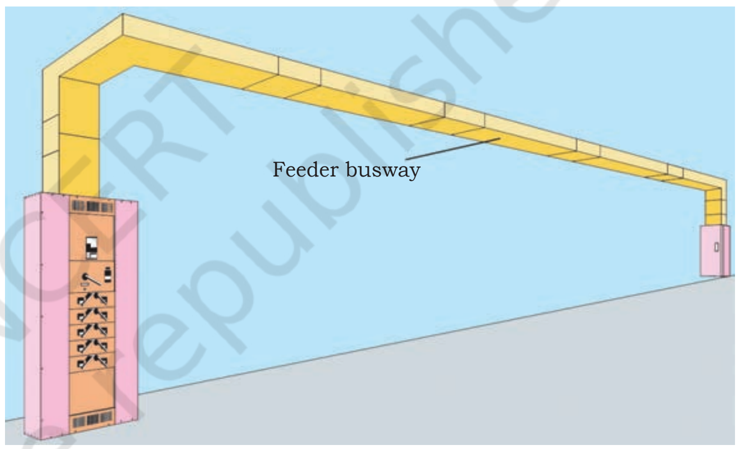


Fig. 2.9: Feeder busway

Plug-in Busway

By using plug-in busway units, load connections can be added

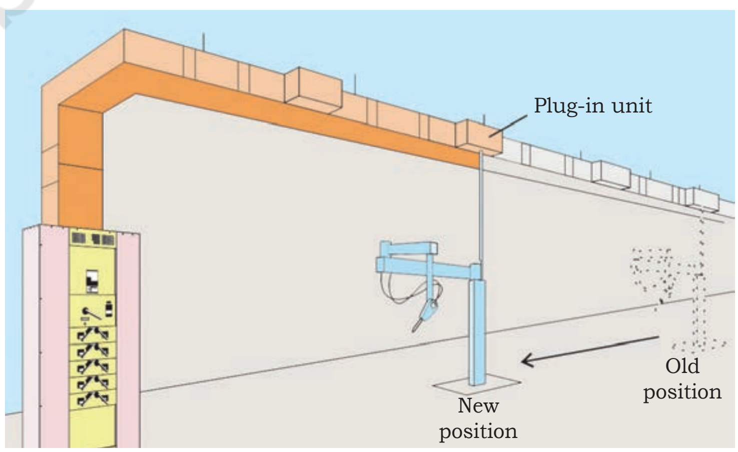


Fig. 2.10: Plug-in busway

or relocated easily as shown in Fig. 2.10. A plug-in busway is used in applications where power requirements are distributed over a large area. A plug-in busway is for indoor use only.

Fig. 2.11: Industrial application of a busway

Application

A busway is used in various industrial applications, and residential installations of the power distribution system. A busway used in an industrial location can supply power to heavy equipment, lighting, and air conditioning as shown in Fig. 2.11. Busway risers or vertical busways can be installed in a high-rise building.

Busway Construction

To understand a busway better, we have to understand the construction of a busway. A busway consists of busbars, enclosure, phase arrangement, busway length, etc.

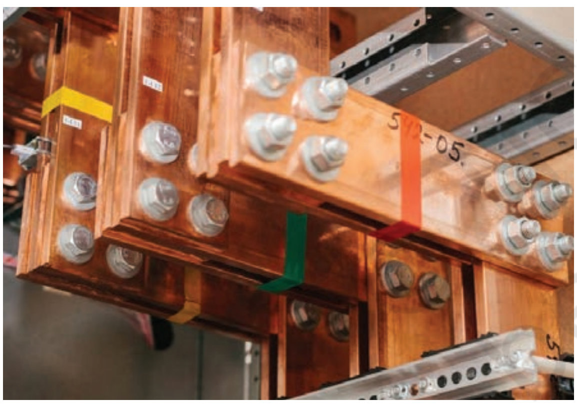


Fig. 2.12: A busbar for power distribution

Busbar

As mentioned earlier, busbars are conductors that carry electric power to the loads. A typical busway has three or four busbars, which are made up of aluminium or copper as shown in Fig. 2.12. These busbars function as electrical conductors. Aluminium busbars can carry current up to 4000 amperes (A) and copper busbars can carry current up to 5000 amperes (A). Busbars manufactured for use in feeder busways differ from those manufactured for use in plug-in busways. Each busbar is called a phase. Busbars are separated electrically with proper insulation.

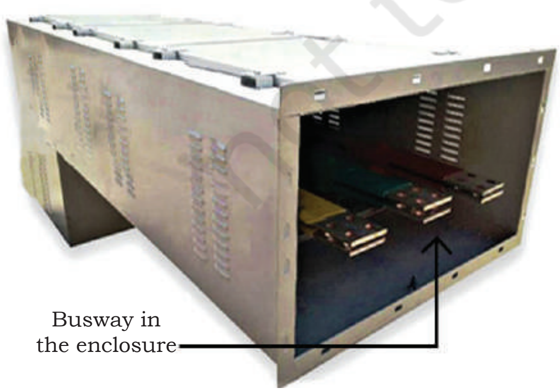


Fig. 2.13: Enclosure on a busbar

Enclosure

Glass wrap tape is wrapped around busbars, as shown in Fig. 2.13, to provide additional protection and to hold the bars together. Busbars are then installed in an enclosure. The enclosure provides protection from damage and support to the busbar.

Phase Arrangement

Busbars are required to have phases in sequence, so that an installer can have the same fixed phase arrangement in each termination point. This has been established by the National Electrical Manufacturers Association. Fig. 2.14 illustrates accepted NEMA phase arrangements both vertically and horizontally.

Fig. 2.15 illustrates the proper phase arrangement of busbars in a busway.

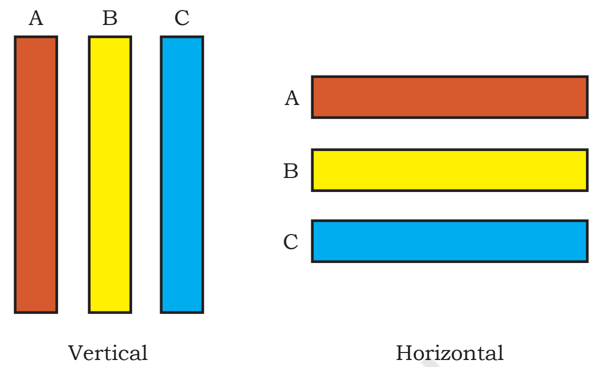


Fig. 2.14: Phase arrangement in a busway

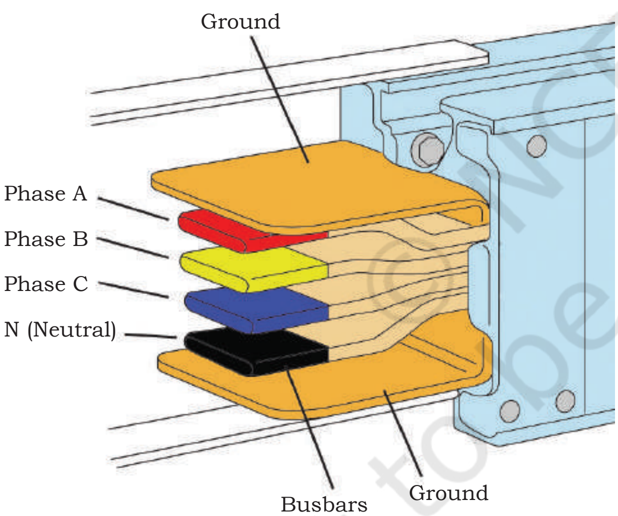


Fig. 2.15: Busbar representing phases in a busway

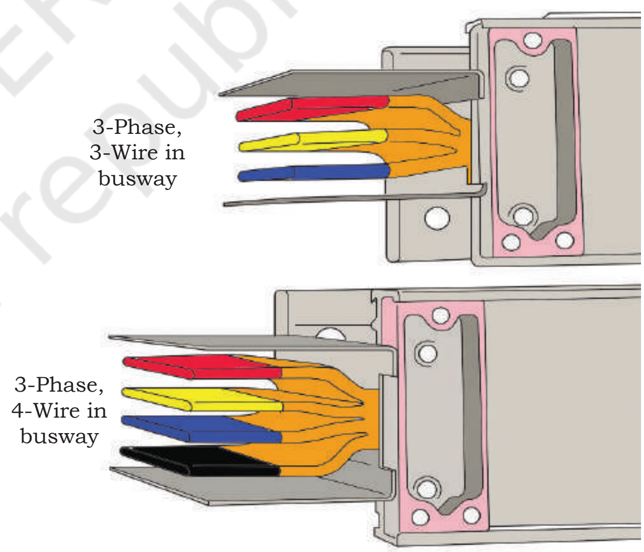


Fig. 2.16: Number of busbars

Number of Busbars

The number of bars depends on the number of phases in the power supply and whether or not a neutral or ground is used as shown in Fig. 2.16.

Busway Lengths

The standard length of a plug-in busway and feeder busway is 10 feet, as shown in Fig. 2.17. A busway is also available in 4 feet, 6 feet and 8 feet lengths.

Plug-in Outlets

A plug-in outlet has the features of a molded guard. This guard prevents accidental finger contact with live conductors as shown in Fig. 2.18. A feeder busway does not have any plug-in outlets.

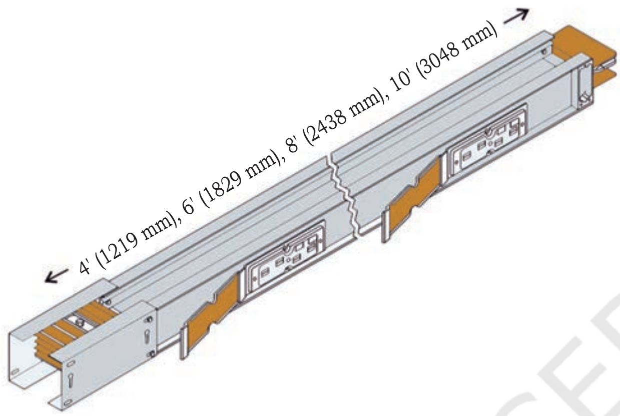


Fig. 2.17: Busway lengths

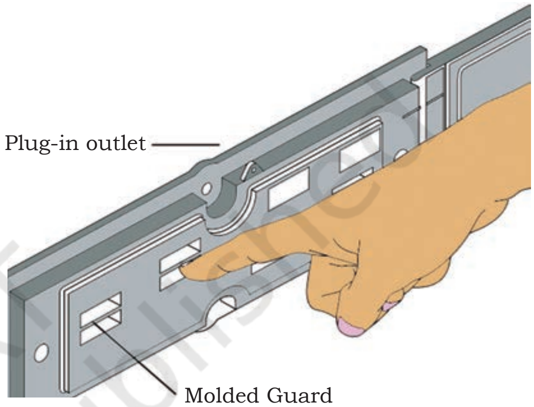


Fig. 2.18: Plug-in outlets

Practical Exercise

Bending or turning the cable in a control panel using a busbar.

Material required

Cable, busbar

Procedure

Fig. a

In a high voltage control panel, thick cables are used to distribute electric power to the loads. As shown in Fig. a, these cables are hard and thick, and will not bend even if required.

The bus bend bar is a device, that is used to bend the cable without damaging the same. Bended busbars are shown in Figs b and c.

Fig. b

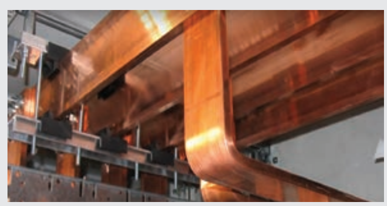


Fig. c

Busway System Component

There are a number of components that form a busway system. Some of them have been listed in this section. Certain components available in one type of busway system may not be available in another type.

Although the components used in various busway systems perform the same or similar functions, they cannot be interchanged from one system to another. Systems are tested and rated as a complete unit and when the components are interchanged, the ratings and system integrity cannot be guaranteed. Fig. 2.19 shows how busbars clamped together with a joint stack or busbars can be bolted.

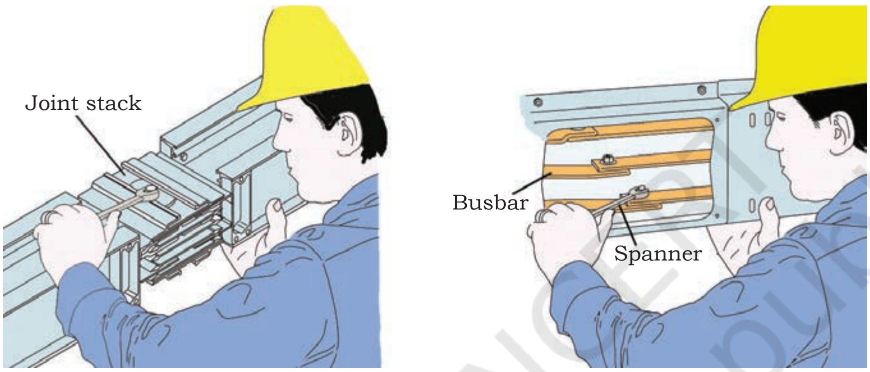


Fig. 2.19: Busbar are clamped together with a joint stack

Joint Stack

A busway system uses a single-bolt joint stack to connect busway sections. The busbars from two

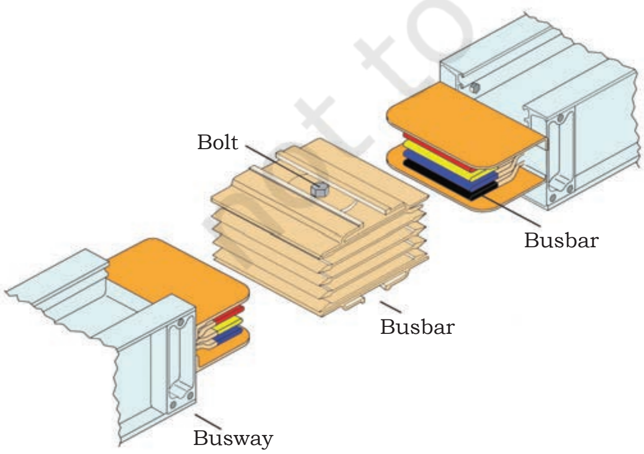


Fig. 2.20: Joint stack connection

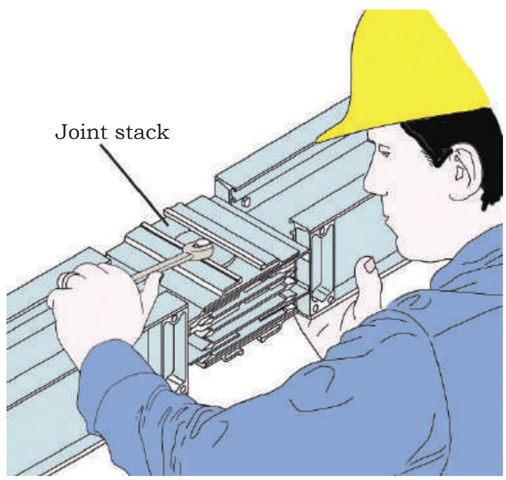


Fig. 2.21: Joint stack connecting the busbar

busway sections are slid into a joint stack as shown in Fig. 2.20. The assembly is clamped tightly together with the single bolt located on the joint stack as shown in Fig. 2.21.

While distributing the electric power using a busway, it is not necessary to always keep the path of the busway straight. As per the requirement it can turn left or right, up or down, ensuring distribution of electric power in all directions. In such a situation, we need components to give the required turn or direction to the busway.

Elbows

Elbows allow for turns and height changes in a busway system. An elbow can turn the busway system right or left, up or down as shown in Fig. 2.22. Elbows are supplied with a joint stack and covers.

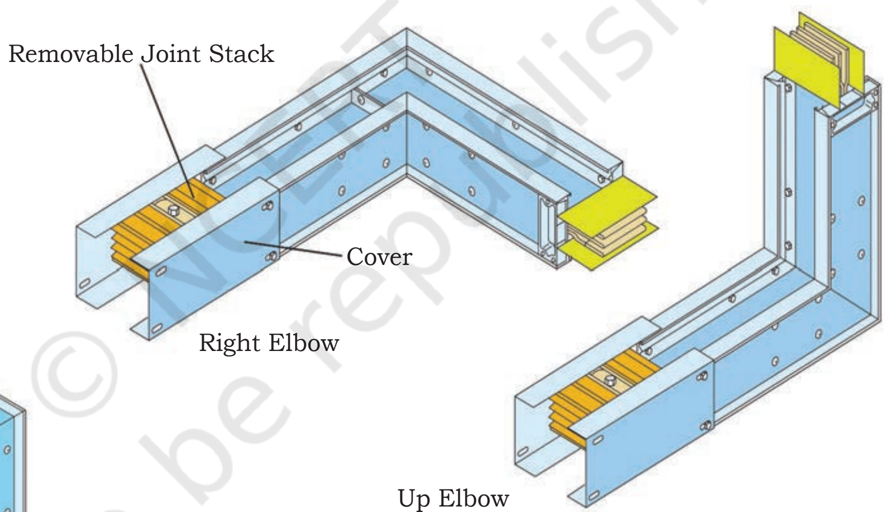


Fig. 2.22: Connecting elbow in a busway

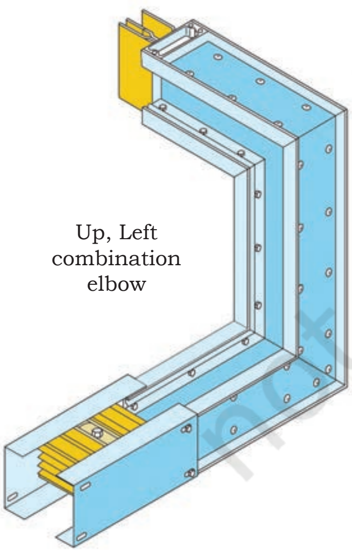


Fig. 2.23: Combination elbow in a busway (up left combination elbow)

Combination Elbows

Combination elbows can also turn the busway system up or down, and right or left as shown in Fig. 2.23.

Tees

A tee is T-shaped busway. It has three directions. In one section, a new connect can be established, while the other two directions have a joint stack. These joint stacks are used to connect to other busways as shown in Fig. 2.24. Tees can start a new section to the right, left, up, or down. Tees are supplied with two joint stacks.

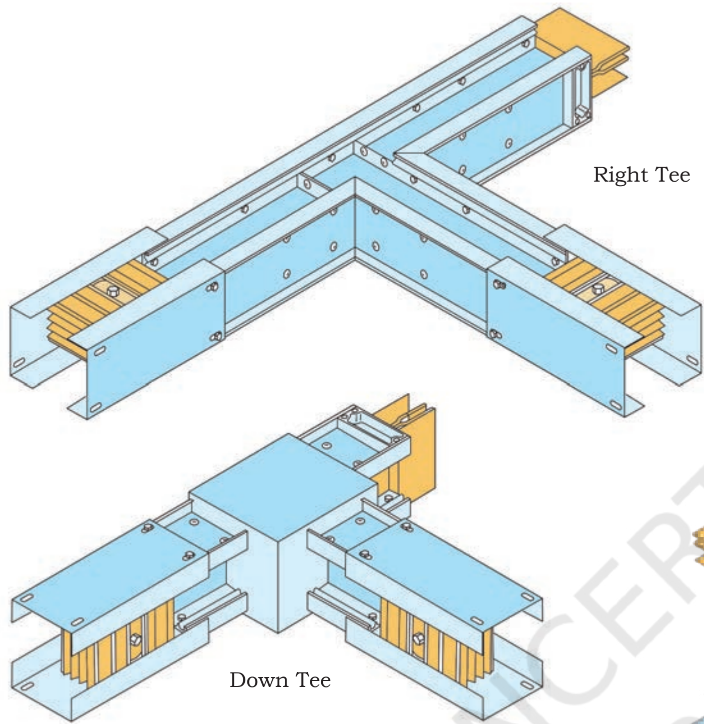


Fig. 2.24: Tee connecting a busway

Crosses

A cross allows a busway run to expand in four directions as shown in Fig. 2.25.

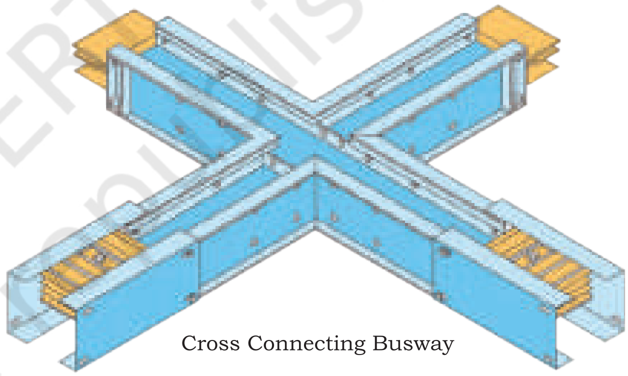


Fig. 2.25: Cross connecting a busway

Offsets

Offsets allow the busway system to continue in the same direction. Offsets can move the busway system to the right, left, up, or down. They are supplied with a joint stack as shown in Fig. 2.26. A combination elbow and offset look the same, the difference being that offsets continue in the same direction. An elbow changes the direction of a busway.

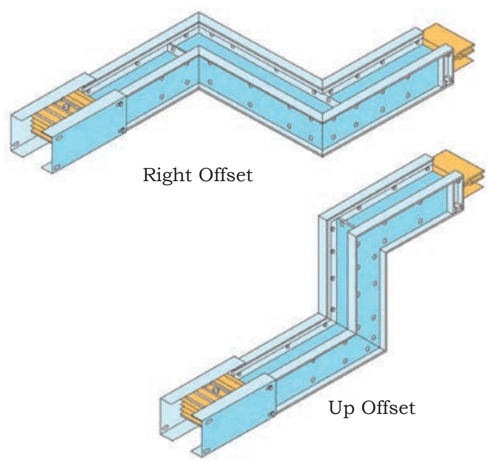


Fig. 2.26: Offset in a busway

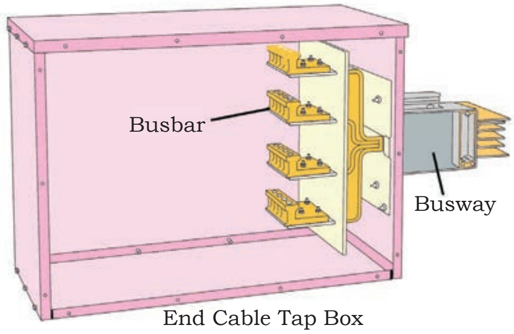


Fig. 2.27: End cable tap box

Cable Tap Boxes

In most cases, a busbar is carried by a busway. In the event that a busway is carrying electrical power cables for power distribution, then you need a component, that can connect the cable and busbar. This action can be performed using tap boxes. A tap box is used to connect electrical cables to the busway distribution system. End cable tap boxes can be installed at either end of the busway system as shown in Fig. 2.27.

Centre or plug-in cable tap boxes can be installed along the length of a busway system as shown in Fig. 2.28. Plug-in cable tap boxes can be used in a plug-in busway.

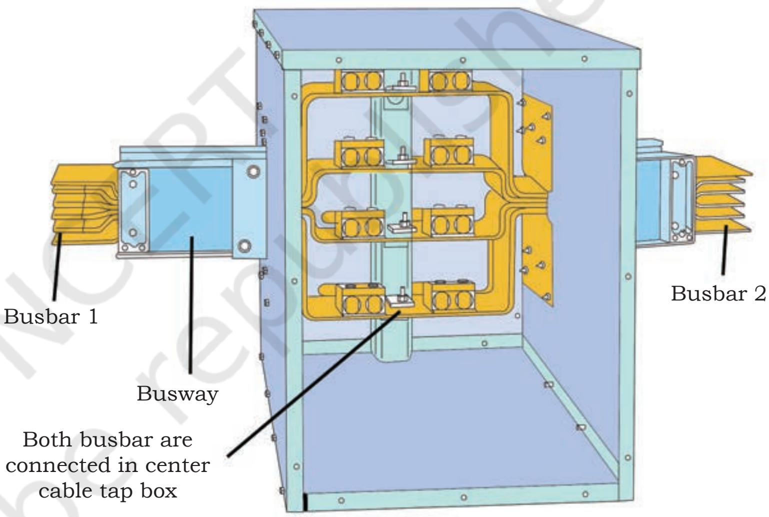


Fig. 2.28: Installation of a centre tap box along the length of a busway

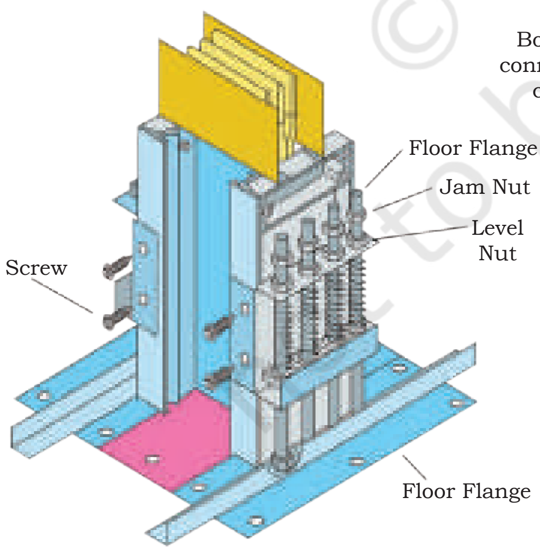


Fig. 2.29: Hanger

Hangers

A busway is supported by various hangers. When a vertical run of a busway passes through a floor, a floor support is required. Spring hangers provide a secure mounting to a busway in riser applications as shown in Fig. 2.29.

Several types of hangers are available to suspend the busway from a ceiling, a structural steel support, or mounted to a wall as shown in Fig. 2.30.

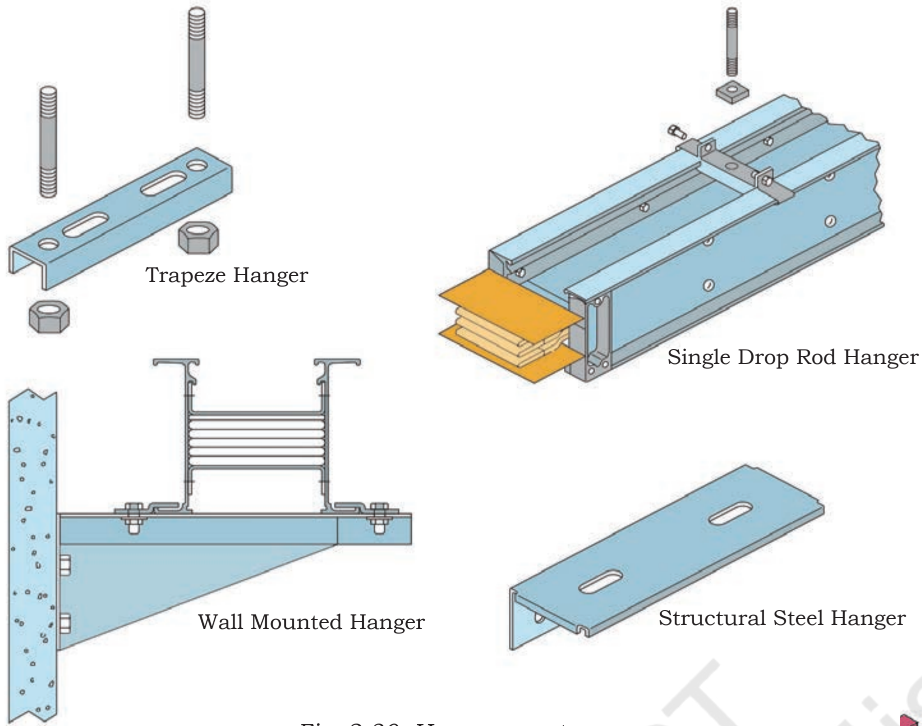


Fig. 2.30: Hangers parts

Flanges

Wall, ceiling, and floor flanges are designed to close off the area around a busway as it passes through a wall, ceiling, or floor. The flange provides an air tight seal around the busway as shown in Fig. 2.31.

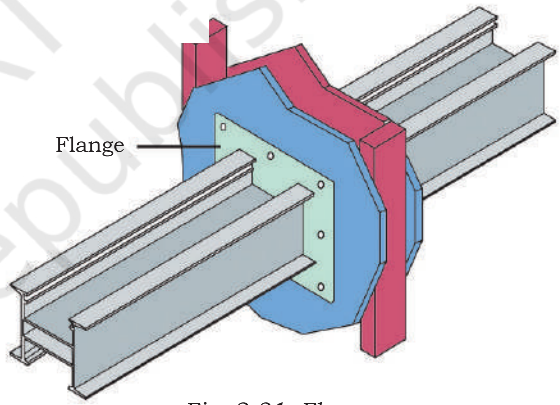


Fig. 2.31: Flange

Assignment 1

1. List the components used in a busway system.
2. List the material that can be used to manufacture a busway.

Practical Exercise

Installation of a busbar in a wiring system

Material required

Busbar, lugs, spanner, screwdriver, combination plier, drill machine

Procedure

There are a number of loads in a commercial area and all of them require a high amount of current for their operation. If we use a wire for the supply to these loads, the wire may get burnt, as the current flowing through them is much higher as shown in Fig. a. If such a distribution is used, it will damage the electrical system.

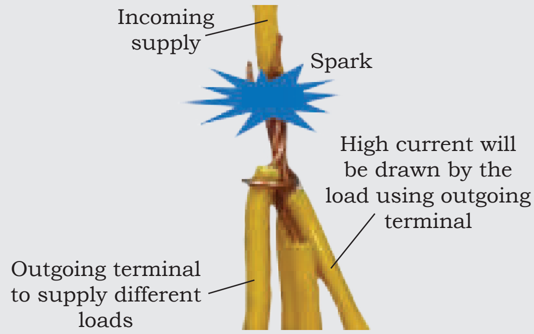


Fig. a

To overcome this situation you can use a busbar. Follow the following steps to install a busbar for both low and high voltage panel.

1. Take a copper busbar of the required length as shown in Fig. b.

Fig. b Copper busbar

2. Make a hole on the busbar at the required place using a drill machine as shown in Fig. c.

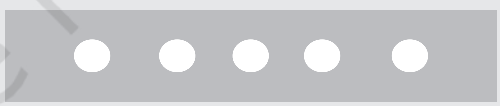


Fig. c Drilled busbar

3. Use a cable instead of wire as shown in Fig. d.

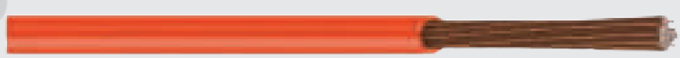


Fig. d

4. Use the lugs of appropriate sizes to connect to the cable as shown in Fig. e.

Fig. e

5. Now, the cable is ready to connect to the busbar as shown in Fig. f.

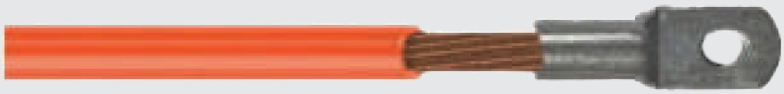


Fig. f

6. Align the cable with the busbar as shown in Fig. g.

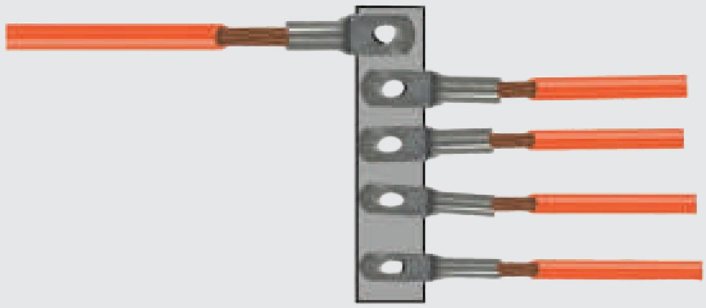


Fig. g

7. Screw and tighten them using a screwdriver and spanner for a tight connection as shown in Fig. h.

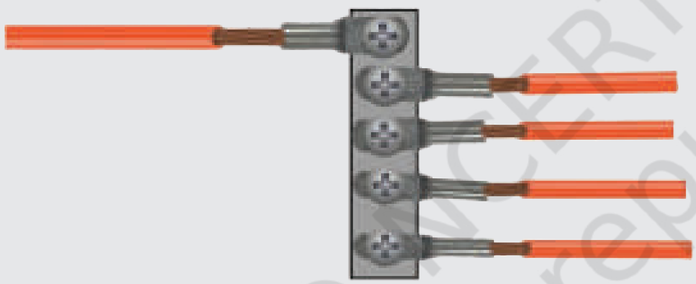


Fig. h

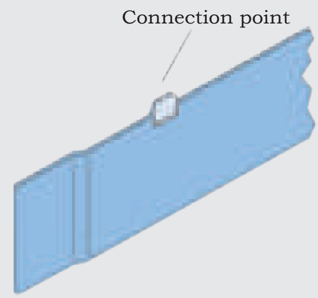
Check Your Progress

A. Multiple choice questions

1. The two types of busways are ___________ .
   (a) feeder and service entrance
   (b) feeder and plug-in
   (c) plug-in and service enter
   (d) indoor and outdoor
2. How many phases are used for heavy voltage supply in the busway?
   (a) Two
   (b) Four
   (c) Three
   (d) Five

3. The maximum current rating of a busway with aluminium busbars is ___________ amperes.
   (a) 2,000
   (b) 3,000
   (c) 4,000
   (d) 5,000

4. The busbar shown in the figure is used for which busway?



   (a) feeder
   (b) plug-in
   (c) service entrance
   (d) outdoor

5. Which of the following is used to provide airtight connection to a busway?
   (a) Reducers
   (b) Service heads
   (c) Flanges
   (d) Expansion fittings

6. Which of the following is used to hang the busway?
   (a) End closers
   (b) Service heads
   (c) Hanger
   (d) Flanged ends

7. What is the current carrying capacity of a copper busbar?
   (a) 5000 amperes
   (b) 1000 amperes
   (c) 2000 amperes
   (d) 3000 amperes

8. Combination elbows can turn a busway system and ___________.
   (a) up and right
   (b) left and down
   (c) right and left
   (d) up or down and right or left

B. Fill in the blanks

1. A ___________ distributes electrical power throughout a building.
2. Electrical power in a commercial area can be distributed using ___________ .
3. Busways have ___________ inside their enclosure.

4. A standard busbar is made up of ____________ or ____________.
5. In enclosure, ___________ tape is used to wrap a busbar.
6. To provide air tight sealing, ___________ is used in a busway system.
7. To continue the busway in the same direction ___________ is used.
8. The two types of busways are ___________ and ___________
9. To expand the busway in four directions, _____________ is used.
10. In high power distribution ___________ phases and ___________ neutrals are used in a busway.

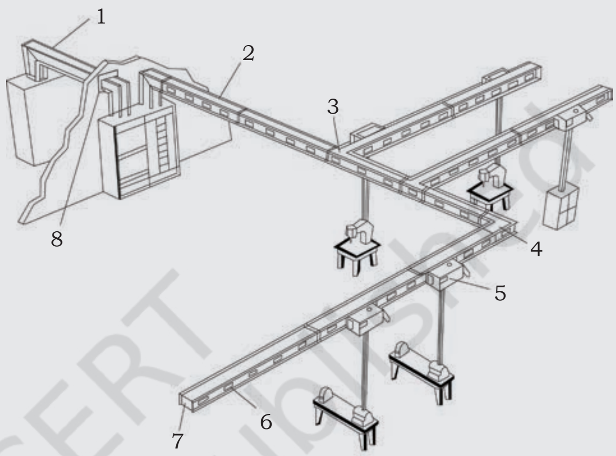
C. State whether the following statements are True or False

1. Hangers are used to support a busway. These hangers counter the weight of a busway.
2. The flange provides an air tight seal around a busway.
3. Hanger is used to turn the busbar in right or left direction.
4. Combination elbows can turn a busway system up or down, and right or left.
5. In a distribution system, electrical power is distributed using a power cable and wires.
6. NEMA stands for National Electrical Manufacturers Association.
7. A plug-in busway is dynamic in nature.
8. A feeder busway is static in nature.
9. A joint stack is used to terminate a busbar.
10. A centre tape box is used to hang the bars.

D. Short answer questions

1. What is a busway?
2. What are the types of a busway?
3. Differentiate between a feeder busway and a plug-in busway.
4. What is the role of flanges in the busway?
5. List out the names of various busway system components.

6. Identify the components in the following illustration:
   (a) Tee
   (b) Elbow
   (c) Feeder Busway
   (d) Wall Flange
   (e) Plug-in Unit
   (f) Plug-in Busway
   (g) End Closer
   (h) Plug-in Outlet



Chapter 3

Circuit Breaker

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Introduction

One day, a little boy Ram turned on the television to watch *Swayam Prabha,* NCERT's education channel, he saw fumes and smoke emitting from the television as shown in Figs 3.1 and 3.2. A terrified Ram immediately switched off the power button and informed his father about the situation. His father asked him what could be the solution for such a problem.

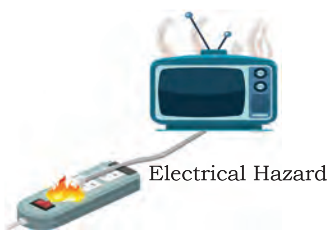

Fig. 3.1: Effect of excessive current

Fig. 3.2: Wire burning due to excessive current

Ram studied different resources to find a solution and wondered whether a circuit breaker could solve the issue. In this chapter you will understand the different types of circuit breakers and their operation.

Need of Circuit Breaker

Current flow in a conductor generates heat and excessive heat can damage the electrical components.

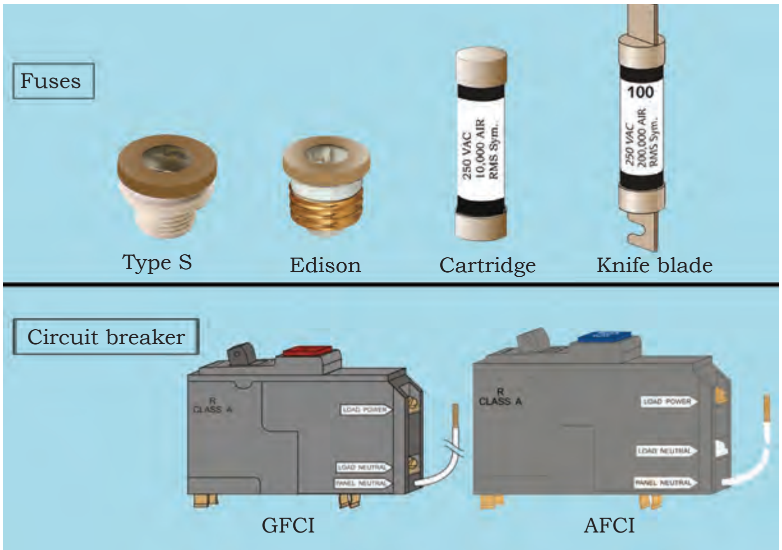

Fig. 3.3: Different type of the circuit breakers and overcurrent protection device

So, conductors are rated for current carrying capacity. Circuit breakers are used to protect conductors from excessive current flow as shown in Fig. 3.3.

Excessive current is referred to as overcurrent. Overcurrent is defined as, any current in excess of the rated current of an equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. Protection against temperature is termed as 'overcurrent protection'. Overcurrent is caused by overload, short circuit, and ground fault.

Overload

An overload occurs when too many devices are operated on a single circuit as shown in Fig. 3.4, or a piece of electrical equipment is made to work harder than it is designed for.

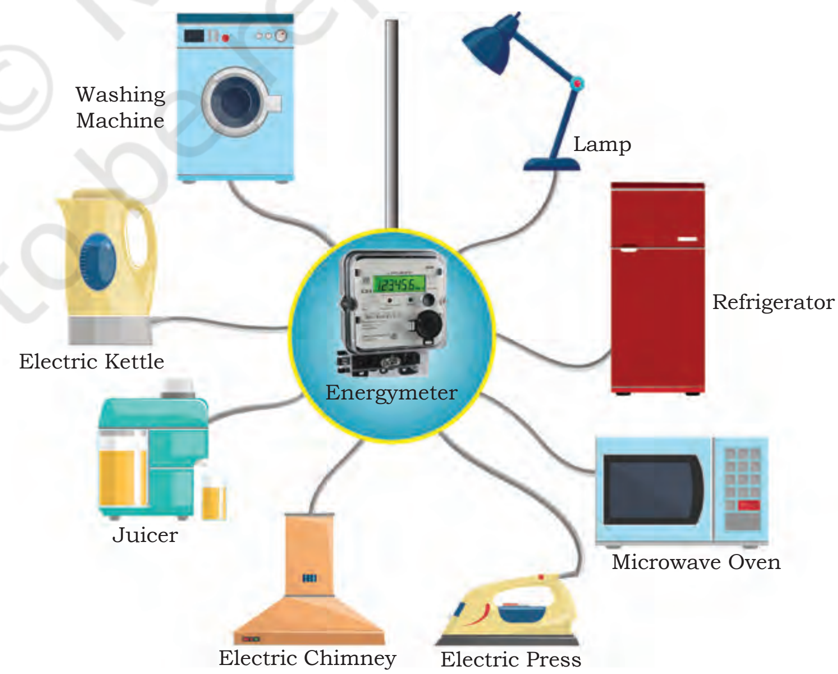

Fig. 3.4: Overload in the house

A motor rated for 10 ampere may draw 20, 30 or more amperes in an overload condition. For example, when the motor of a conveyor is not working freely, it will draw more current from the supply, causing the motor to work harder and draw more current. Due to this the motor starts heating up. This can damage the motor and its parts. Using an overcurrent protector, such a situation can be avoided.

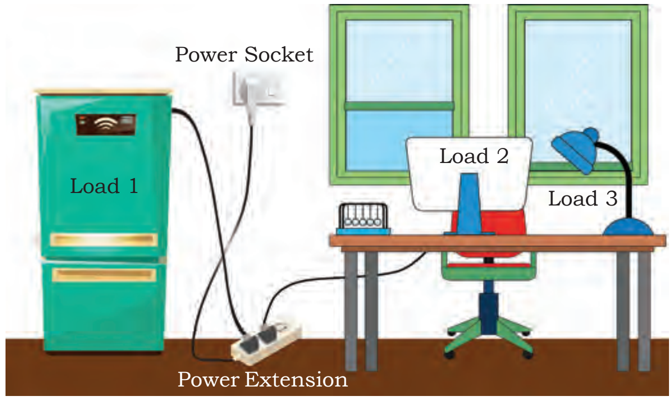

Fig. 3.5: Overloading at the socket

Short Circuit

A short circuit occurs when there is a direct but unintended connection between line-to-line or line-to-neutral conductors. Short circuits can generate very high current and lead to rise in temperatures thousands of degrees above the defined ratings. Figs 3.6, 3.7 and 3.8 show a bulb connected by two wires. Due to a cut or damage in the wire, unintentional removal of insulation may occur. This may cause the uninsulated portion of wires to touch each other, resulting in negligible resistance or short circuit. Negligible resistance during a short circuit causes a large amount of current flow, which could lead to excessive heat and damage the wires.

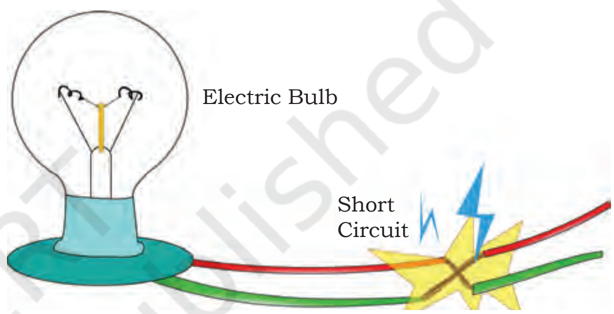

Fig. 3.6: Sparking due to short circuit

Note: In case of short circuit, the bulb will not get any current.

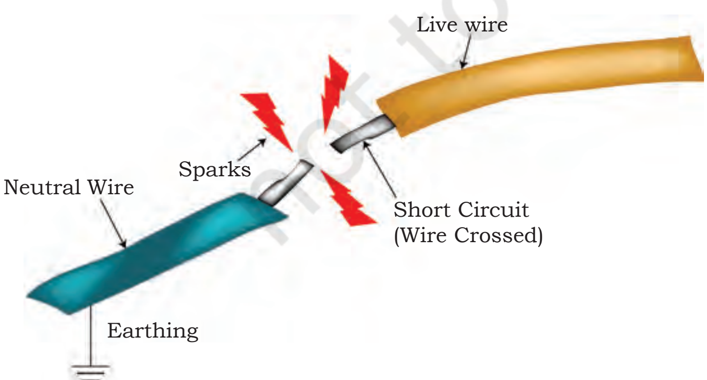

Fig. 3.7: Sparking due to the conductors coming in contact with each other

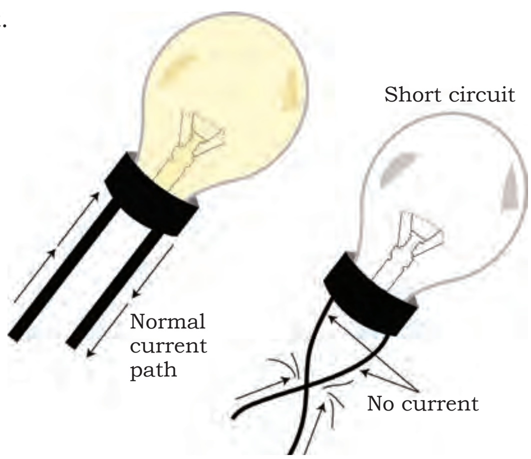

Fig. 3.8: Normal current path and short circuit path

Fig. 3.9: Ground fault may result in an electric shock

Ground Fault

A ground fault occurs when electrical current flows from a conductor to uninsulated metal that is not designed to conduct electricity. Fig 3.9 shows ground fault in a drilling machine.

Assignment 1

1. Calculate load at your home by adding up the wattage of all electrical and electronic appliances.
2. List out the devices in your home, which are grounded. What is the need of a ground?
3. If a short circuit occurs between a live wire and neutral wire, what will happen to the MCB you have used for protection in the circuit? Will it trip?

Types of Overcurrent Protective Devices

Circuit protection is not required, if overloads or short circuits can be eliminated. Unfortunately overloads and short circuits do occur. To protect a circuit against these, different types of overcurrent protection devices are used.

Fuse

A fuse is an electromechanical device, installed to protect the circuit against overload, overcurrent, or a short circuit. A fuse is a one-time device. The electric fuse was invented by Thomas Alva Edison in 1890. The heat produced by overcurrent causes the current carrying element of a fuse to melt, thereby disconnecting the load from the voltage source. It is available in many types depending on the construction as shown in Figs. 3.10 (a-d).

Fig. 3.10: Different types of fuse: (a) Mini fuse (b) SMD fuse (c) Cartridge fuse (d) Axial fuse

Construction and Working of a Fuse

Construction

A general fuse consists of a low resistance metallic wire enclosed in a non-combustible material.

The fuse consists of a fuse carrier, base body and fuse element as shown in Fig. 3.11. The base body and fuse carrier are made of ceramic, glass, plastic or moulded mica laminates. They are used to connect and install in series, with a circuit and device, which needs to be protected from a short circuit and over supply of current. Otherwise, the electrical appliance can get damaged.

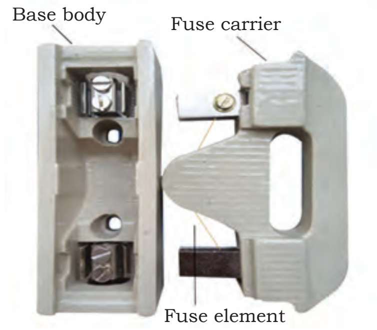

Fig. 3.11: The different parts of a fuse

Working principle of a fuse

The working principle of a fuse is based on the *heating effect of current*. Whenever a short circuit or overcurrent or mismatched load connection occurs, the thin wire inside the fuse melts from the heat generated by the heavy current flowing through it. Therefore, it disconnects the power supply and electric circuit. Generally, a fuse wire is a very low resistance component and does not affect the normal operation of the system connected to the power supply. The melting point of some metals is given in Table 3.1.

Table 3.1: Melting point of metals

Metal	Melting point in ˚C
Silver	980
Tin	240
Zinc	419
Lead	328
Copper	1090
Aluminium	665

Practical Exercise

Identify the parts and connection of a kitkat fuse in a simple electric circuit

Material required

Kitkat fuse, fuse element, combination plier, line tester

Procedure

1. Open the fuse carrier of the kitkat fuse and observe its parts.
2. Identify the parts of the fuse and label them as fuse carrier, fuse element, fuse base, heat resistant padding as shown in Fig. a.

3. Now, connect the kitkat fuse in the circuit as per the circuit diagram shown in Figs b and c.

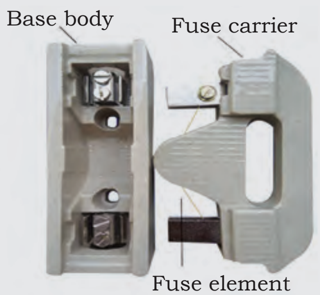

Fig. a

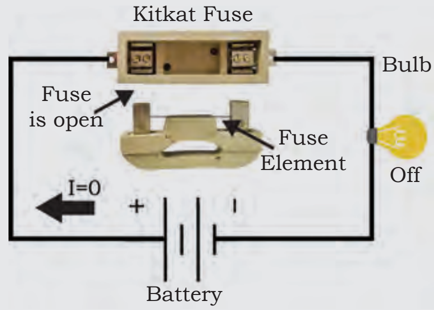

Fig. b

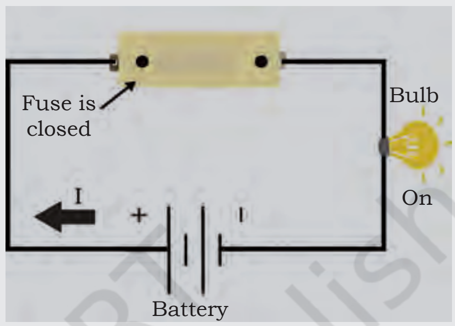

Fig. c

4. Understand the role of a kitkat fuse in an electric circuit.

Types of Fuses

Various types of fuses are available, classified on the basis of their parameters. Largely they are classified as DC and AC fuse on the basis of input supply voltages. In a control panel mainly AC fuses are used, hence you will understand the various types of AC fuses in this section.

DC fuse

DC fuse operates on DC power supply. The amplitude of DC remains constant. The only difficulty with a DC fuse is that the arc produced by the direct current is difficult to compensate, as the DC voltage remains constant. This constant voltage produces a high arc between the electrodes of the fuse. To reduce the DC fuse arcing, the electrodes are placed further apart, due to which the size of a DC fuse is bigger as compared to an AC fuse.

AC fuse

An AC fuse operates on AC power supply. The amplitude of AC supply varies instantaneously. In India, the rate of change of AC supply is 50 cycles per second. It means that an AC signal will have 50 positive half and 50 negative half in one second. This rate of change is called frequency of AC signal. Thus, the arc produced in an AC fuse can be easily compensated as compared to the arc in a DC circuit. An AC fuse is classified further into low voltage fuse and high voltage fuse as shown in Fig 3.12.

Low Voltage Fuse

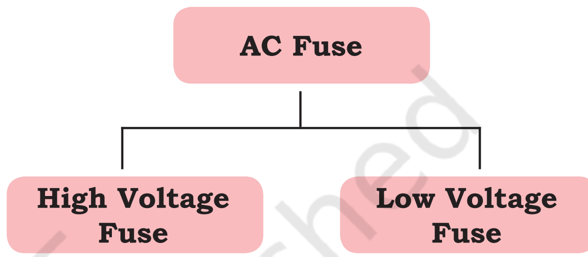

Fig. 3.12: Classification of AC fuses

Low voltage fuse can be further divided into four classes: rewirable fuse, cartridge fuse, dropout fuse and striker fuse as shown in Fig 3.12.

Rewirable fuse is a commonly used fuse in *house wiring*. The fuse wire can be changed if the wire is blown off due to excess heating or current flow. It is also known as a kitkat fuse (shown in Fig. 3.11 earlier). The base of the fuse is made of porcelain or ceramic. It holds wires made of either copper or aluminum.

In a **cartridge type or totally enclosed fuse**, the fuse element is fit into an enclosed container. It has metal contacts on both sides. A cartridge fuse is further classified into a D-type cartridge fuse and a link type cartridge fuse.

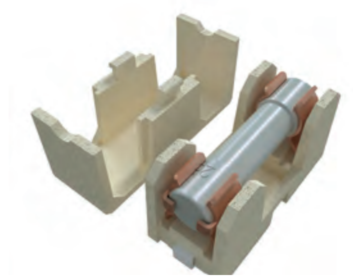

Fig. 3.13: D-type cartridge fuse

- The main parts of a **D-type cartridge fuse** are the base, adapter ring, cartridge and a fuse cap as shown in Fig. 3.13. The cartridge is kept in the fuse cap, and the fuse cap is fixed to the fuse base.
- In a **link type cartridge or high rupturing capacity (HRC)** fuse, the fuse element carries fault current for a longer duration. If the fault is not clear, then the fuse element will melt and open the circuit. HRC fuse has high-speed operation and does not require maintenance, but, the fuse element needs to be rplaced after each operation.

The enclosure of the HRC fuse is filled with powdered pure quartz, which acts as a heat absorbing material. Silver and copper wire is used to make the fuse wire. Fig. 3.14 (a) and (b) show a cartridge fuse with a blade and a hole cartridge fuse with a blade.

Fig. 3.14 (a): Cartridge fuse with a blade

Fig. 3.14 (b): Hole cartridge fuse with a blade

- In a **dropout fuse** the melting of the fuse causes the fuse element to drop in the lower portion of the fuse. This type of fuse is used for the protection of outdoor transformers as shown in Fig. 3.15 (a) and (b).

Fig. 3.15 (a): Dropout fuse

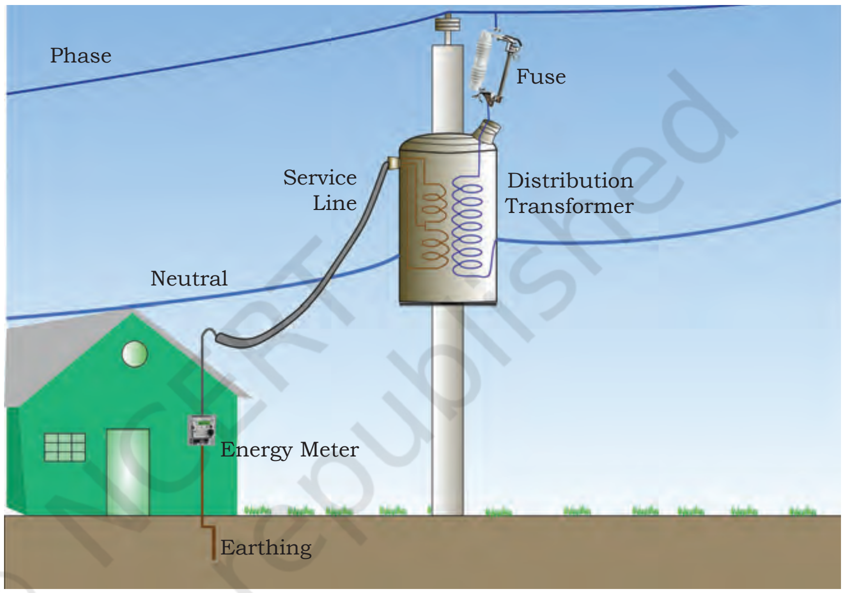

Fig. 3.15 (b): Dropout fuse mounted on an electric pole

Fig. 3.16: Blown fuse, 1 - Fuse body, 2 - Striker pin ejected from the fuse, indicating that the fuse is blown

Striker fuse is also known as a pin fuse. When the fuse blows, a pin ejects from one end in such a way that the fuse cannot be reinstalled as shown in Fig. 3.16. This ejected pin indicates that the fuse has blown. It is a mechanical device with enough force and displacement to trip circuits.

High Voltage HRC Fuse

This type of fuse deals with high voltage. While operating with high voltage, the corona effect may occur. Therefore, high voltage fuses are specially designed to overcome the corona effect. HRC fuses are mainly classified into three types – cartridge type high voltage HRC fuses, expulsion type high voltage fuses and liquid type HRC fuses.

In a cartridge type high voltage HRC fuse the fuse element is wound in the shape of a helix, which avoids the corona effect at higher voltages. It has two fused elements placed parallel to each other, one of low resistance and the other of high resistance as shown in Fig. 3.17. The low resistance wire carries normal current, which is blown out, thereby reducing the short circuit current during a fault condition. Corona effect in an electrical system means “the glow around a conductor at high potential” or a cloud of charge around a high voltage transmission wire. The corona effect is shown in Fig. 3.18.

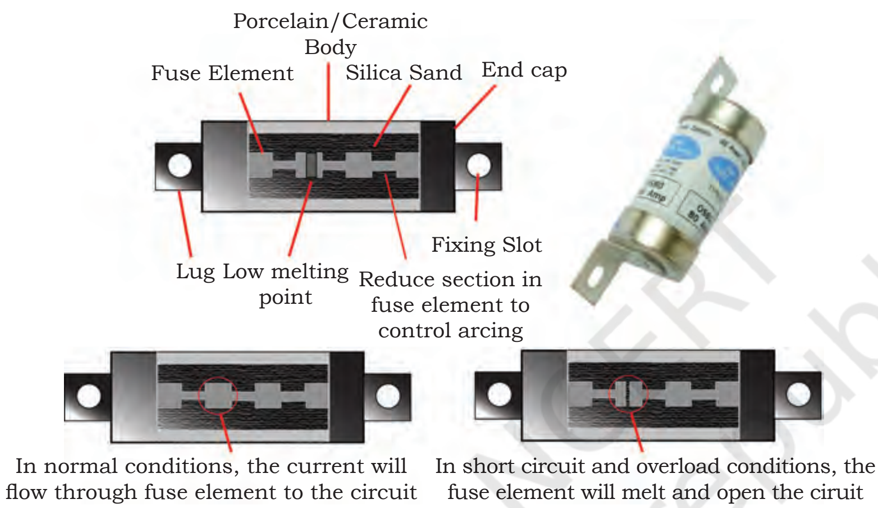

Fig. 3.17: High rupturing capacity (HRC) fuse

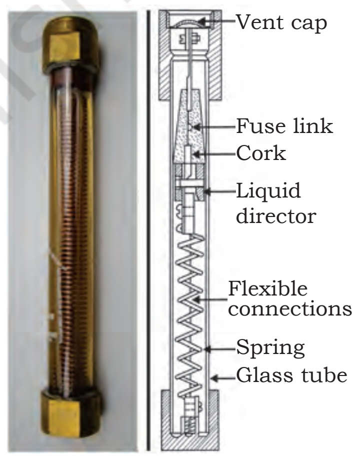

Fig. 3.19: Liquid type high voltage HRC fuse

Liquid type high voltage HRC fuse is filled with carbon tetra-chloride and sealed at both ends. When a fault occurs the current exceeds beyond the permissible limit and blows out the fuse element. The liquid of the fuse acts as an arc extinguishing medium for the HRC fuse as shown in Fig. 3.19. They can be used for transformer protection and as a backup protection to the circuit breaker.

Expulsion type high voltage fuse is a vented fuse in which the expulsion effect of the gases produced by internal arcing, either alone or aided by other mechanisms, results in current interruption. Expulsion type fuses are widely used for the protection of feeders and transformers because of their low cost as shown in Fig. 3.20.

Fig. 3.20: Expulsion type high voltage fuse

Applications of a Fuse

Fuses are used in motors and transformers, home distribution boards, general electrical appliances and devices, laptops, cell phones, gaming systems, printers, digital cameras, DVD players, portable electronics, LCD monitors, scanners, battery packs, hard disk drives and power converters.

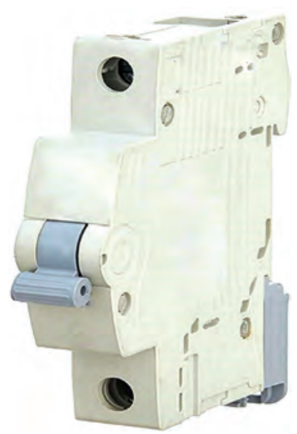

Fig. 3.21: Miniature circuit breaker

Miniature Circuit Breaker (MCB)

The word 'miniature' means 'very small', and 'circuit breaker' means a protection device designed to open and close a circuit. Therefore, we can define it as a small device, which is used for circuit protection. It is another type of circuit breaker. It automatically turns off electric circuit in case of overcurrent or any fault in the electrical supply, as shown in Fig. 3.21. The manufacturer prescribes the value of current beyond which the circuit will turn off.

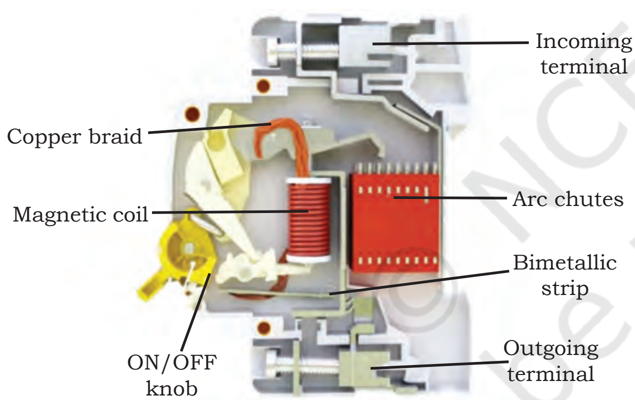

Fig. 3.22: Internal parts of an MCB

Miniature Circuit Breaker Parts

Fig 3.22 shows the internal parts of a miniature circuit breaker design. They are incoming terminal, copper braid, arc chute, magnetic coil, ON/OFF switch, bimetallic strip and outgoing terminal.

At the **incoming terminal** the incoming phase is connected. **Copper braid** connects the moving element with the static element.

Arc chute is a set of insulating barriers on a circuit breaker arranged to confine the arc and prevent it from causing damage. Arc chute extinguishes the arc, which is produced due to heavy current. **Magnetic coil** is part of the thermal tripping arrangement. In case of heavy short circuit current, a magnetic field is formed.

ON/OFF switch can be manually used by the user. **Bimetallic strip,** (bi means two) means a metallic plate. Two metal plates are used, steel and brass, as shown in Fig 3.23. Each metal has a different thermal expansion capability, which can be beneficial for mechanical change. If we heat up the bimetallic strip it will bend upwards or downwards depending upon the two metal strips and the way these have been joined.

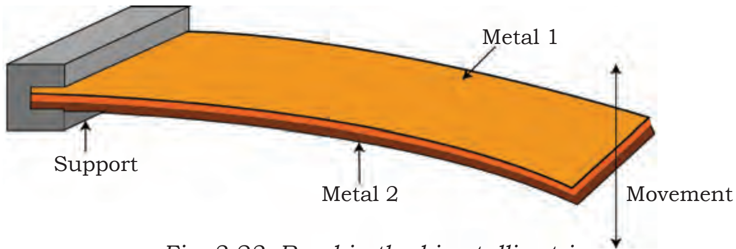

Fig. 3.23: Bend in the bimetallic strip

Outgoing terminal is from where the phase that entered through the incoming terminal leaves the MCB.

Practical Exercises

Activity 1

Identify the parts and connection of a MCB in a simple electric circuit.

Material required

MCB, screwdriver, line tester

Procedure

1. Observe the MCB and identify its parts.
2. Open the MCB using a screwdriver. Identify and name the internal parts as shown in Fig. a.

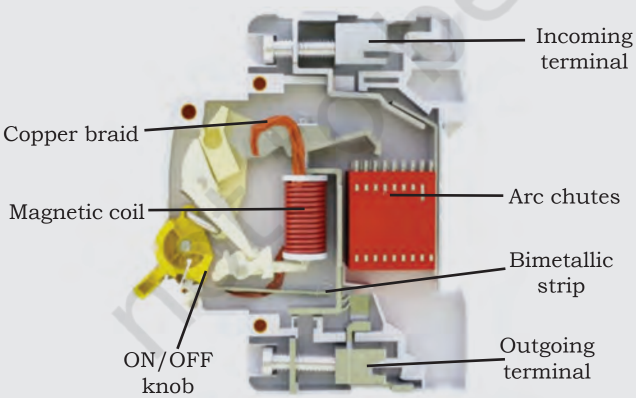

Fig. a: Internal parts of an MCB

3. Now, connect the MCB in an electric circuit as per the circuit diagram as shown in Fig. b.

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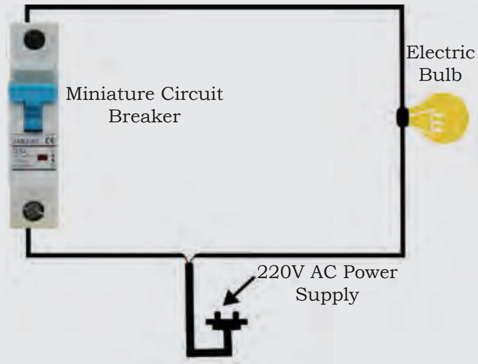


Fig. b

4. Trip the MCB and observe the load. Understand the role of MCB in the electric circuit.

Activity 2

Bend a bimetallic strip

Material required

Two bimetallic strips, ice-cube, burner

Procedure

Follow the following procedure to bend the bimetallic strip.

1. Take a bimetallic strip made of steel and brass as shown in Fig. a. Material 'A' is made of steel and material 'B' is made of brass. Steel and brass are two different materials. Each of them have different rate of thermal expansion.

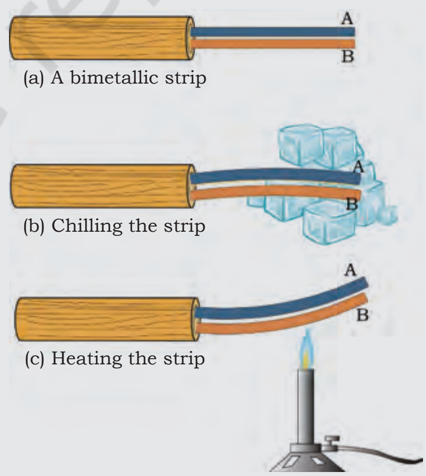


Fig. a: Steps to show how to bend the strip

2. A material with a higher coefficient of thermal expansion will respond more to temperature changes than a material with a lower coefficient of thermal expansion.

3. As shown in Fig. (b) observe that material ‘A’ shrinks less when cooled and expands less when heated than material ‘B’ as shown in Fig. (c).
4. Brass has more coefficient of thermal expansion than steel.
5. Perform these steps to understand the nature of a bimetallic strip in MCB.

Activity 3

Understand the tripping mechanism of an MCB

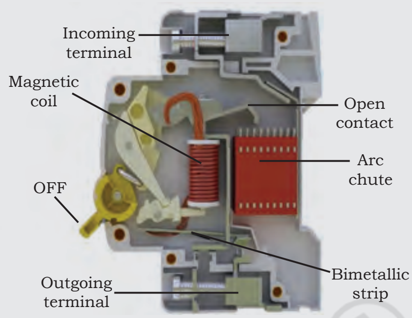
Material required

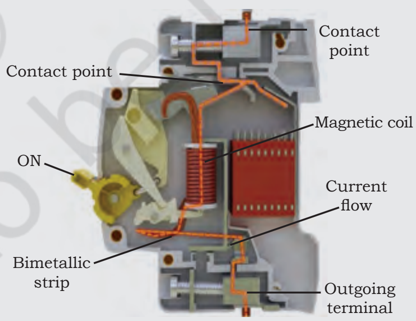
MCB

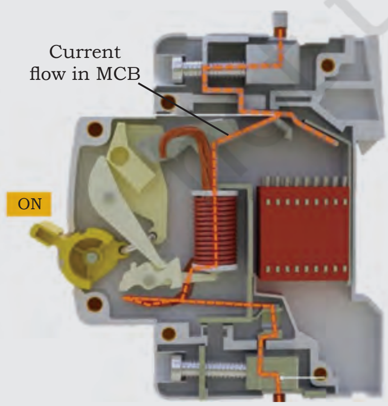
Procedure

Figs a and b illustrate the tripping mechanism of a MCB.

1. The circuit breaker contacts (open or closed) and the position of the knob can easily be seen in both, OFF and ON, state as shown in Figs a and b.
2. In the ON state, the moveable contact touches the fixed contact as shown in Fig. b.







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Assignment 2

1. Search on the Internet, the rating of commonly use MCBs for single-phase supply used in house wiring.
2. Visit an electrical shop and collect specifications of different MCBs.
3. Name different MCBs that are used for commercial purposes.

Check Your Progress

A. Multiple choice questions

1. How many metals are used to form a bimetallic strip?
   (a) One metal
   (b) Two metal
   (c) Three metal
   (d) Four metal
2. Which of the following is not part of a MCB?
   (a) Processor
   (b) Copper Braid
   (c) Arc chute
   (d) Magnetic coil
3. Which of the following is not a type of fuse?
   (a) Cartridge type high voltage HRC fuse
   (b) Liquid types high voltage HRC fuse
   (c) Expulsion type high voltage fuse
   (d) Stroke Fuse
4. Which of the following is not a type of low voltage fuse?
   (a) Rewirable fuse
   (b) Cartridge fuse
   (c) Dropout fuse
   (d) Cartridge type high voltage HRC fuse
5. Which of the following is not a high voltage fuse?
   (a) Cartridge type high voltage HRC fuse
   (b) Expulsion type high voltage fuse
   (c) Liquid type high voltage fuse
   (d) Solid type high voltage fuse
6. The most commonly used fuse in house wiring is ________________.
   (a) rewirable fuse
   (b) D-type cartridge fuse
   (c) dropout fuse
   (d) link type cartridge
7. Which of the following principle is used in the operation of a fuse?
   (a) Heating effect of current
   (b) Electromagnetic induction

(c) Faraday's law
(d) Magnetic field

8. Which of the following material is used to make the casing of a fuse?
(a) Ceramic
(b) Glass
(c) Plastic
(d) All of the above

9. Which of the following is/are reason(s) for overcurrent in a system?
(a) Overload
(b) Short circuit
(c) Ground fault
(d) All of the above

10. Which of the following is the basic classification of a fuse?
(a) AC
(b) DC
(c) AC and DC
(d) None of the above

B. Fill in the blanks

1. A bimetallic strip is made up of __________ and __________.
2. In a rewirable fuse the base is made up of __________.
3. A fuse is also called __________ device.
4. A general fuse consists of a __________ metallic wire enclosed in a non-combustible material.
5. A __________ fault occurs when electrical current flows from a conductor to uninsulated metal that is not designed to conduct electricity.
6. A short circuit occurs when there is a direct but unintended connection between __________ or __________ conductors.
7. The melting point of copper is __________ degree Celsius.
8. In India, the rate of change of AC supply is __________ cycles per second.
9. The standard unit of frequency is __________.
10. The enclosure of the HRC fuse is filled with powdered pure quartz, which acts as __________ material.

C. State whether the following statements are True or False

1. Melting point of silver is 980 ˚C.
2. Corona in electrical system means "the glow around a conductor at high potential".

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3. Arc chute extinguishes the arc produced due to heavy current.
4. The ON/OFF switch can be manually used by the user.
5. A bimetallic strip uses two similar metals bonded together.
6. In MCB the live/phase wire is screwed at the input terminal.
7. The current from the coil goes to the bimetallic strip by means of another thick wire.
8. In cartridge type high voltage HRC fuse the fuse element is wound in the shape of a helix, which avoids the corona effect at higher voltages.
9. In high rupturing capacity fuse, the fuse element carries the fault current for a longer duration.
10. In dropout fuse the melting of fuse causes the fuse element to drop in the lower support of fuse.

D. Short answer questions

1. What is the role of a circuit breaker in the electrical system?
2. Write down the working principle of a fuse.
3. What are the types of fuse?
4. List the names of low voltage fuse.
5. List the names of high voltage fuse.
6. List the material used to make the case of a fuse.
7. Write short notes on:
   (a) AC fuse
   (b) DC fuse
   (c) Link type cartridge or high rupturing capacity
   (d) Cartridge type high voltage HRC fuse
   (e) Liquid type high voltage HRC fuse

Chapter 4

Installation of Residential Control Panel

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Introduction

Ram was watching the television with his family when suddenly, rain and a thunderstorm cut off the power supply. Ram's father checked the energy meter and turned on the circuit breakers from there. Ram curiously asked his father about this box, and his father explained about the residential control panel and the controlling features of the panel. Likewise, we find a metallic or wooden box in our homes too, which is placed outside the house. This metallic or wooden box is used for the distribution of electric power in the house. It acts as a junction, through which electric power is distributed to different rooms. In this chapter, students will learn about the residential control panel along with its components and installation.

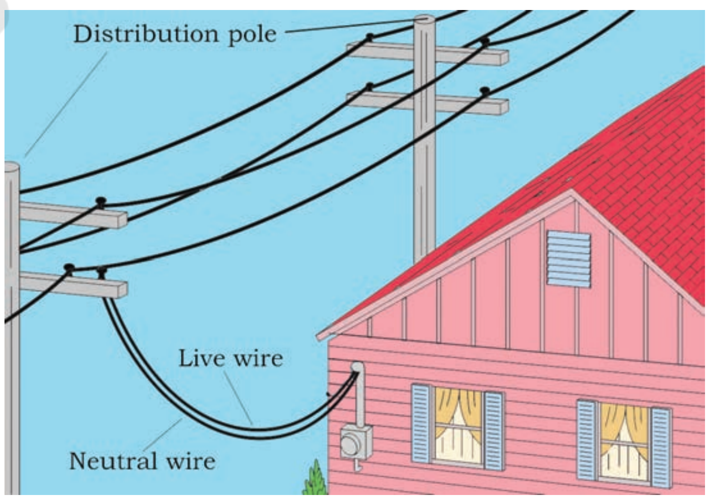

Fig. 4.1: Distribution of electric power in a residential area

Electric Power Distribution Systems

A power distribution system is used in every residential, commercial and industrial building.

Residential Distribution

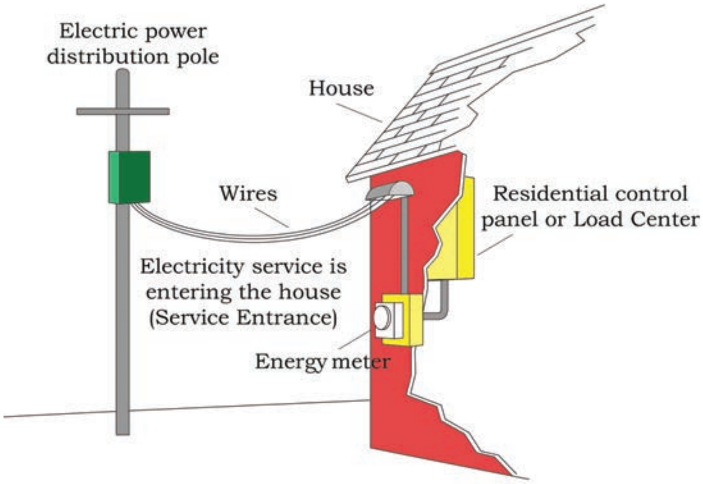

Fig. 4.2: Electricity service entering an individual house

In residential power distribution system, power is distributed to the house through a service entrance. Service in reference to electricity is the facility of electric power provided by the utility company for commercial and domestic purpose. Entrance is the entry point from where electric power enters the house. Therefore, a service entrance is the first section through which electric power enters the house as shown in Fig. 4.2. The incoming power supply is connected to this equipment, which provides a means to control and cut off the supply in an emergency.

Role of Load Centre in Residential Distribution

In an electrical system, 'load' means 'appliance, machinery, equipment, which consume electric power' and centre means 'the point from where an activity or process is directed'. Therefore, load centre is the point from where an activity or process of electrical appliance can be controlled. Load centre is the control unit as shown in Fig. 4.3.

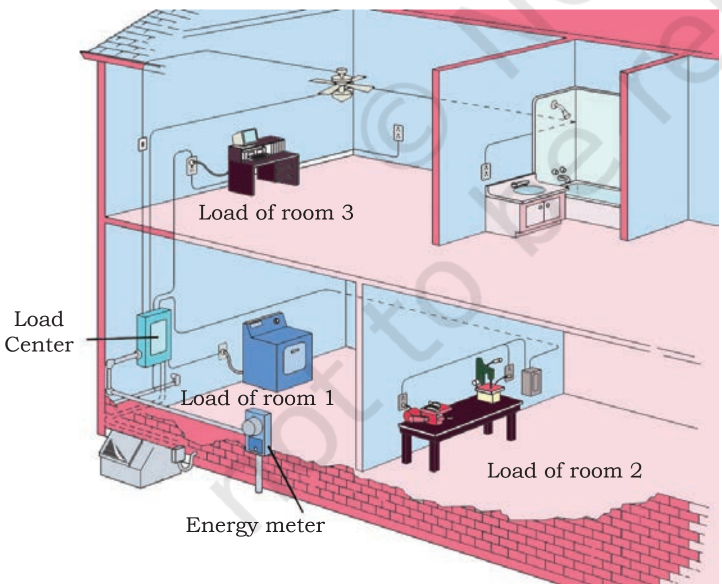

Fig. 4.3: A load centre is connected to different loads

The electric power distribution network, installed in our houses, is an example of residential power distribution system. Electric power from a substation enters the house through a metering device called energy meter. The incoming power then goes to a residential control panel or load centre. This load centre provides circuit control and overcurrent protection. From there, power is distributed to various rooms of the house through branch circuits. These branch circuits include lighting circuit, electrical and electronic appliances as shown in Fig. 4.4.

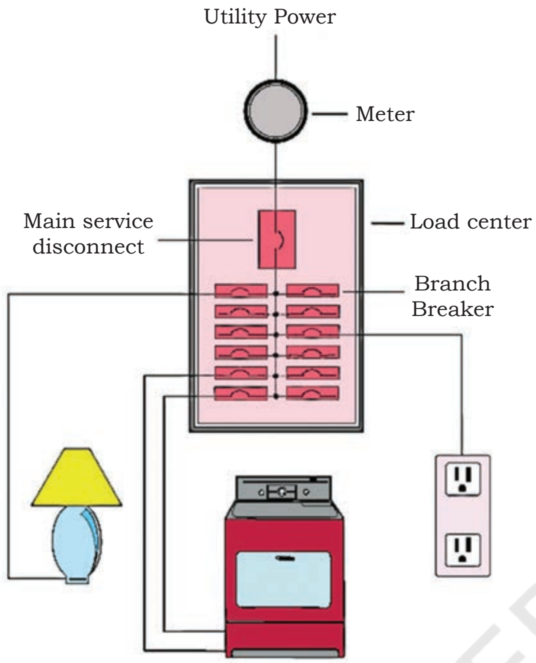

Fig. 4.4: Electric power distribution to various appliances (load) in different rooms

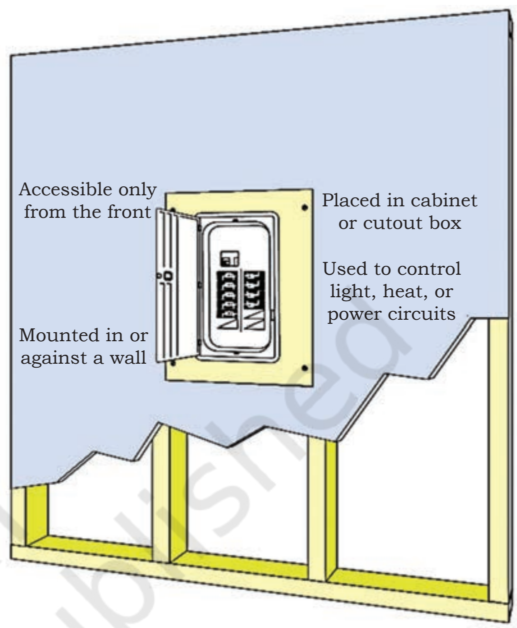

Fig. 4.5: Load centre mounted on a wall

Components in Load Centre

A load centre can be a single panel or a group of panels that can be assembled to form a single panel. A load centre includes a busbar, circuit protection devices, equipped switches for the control of light, fan, machinery, power circuit, etc. A load centre as single unit in a cabinet or enclosure can be mounted on the wall and can be accessible only from the front, as shown in Fig. 4.5.

Some of the major components of a load centre are enclosure, interior and trim.

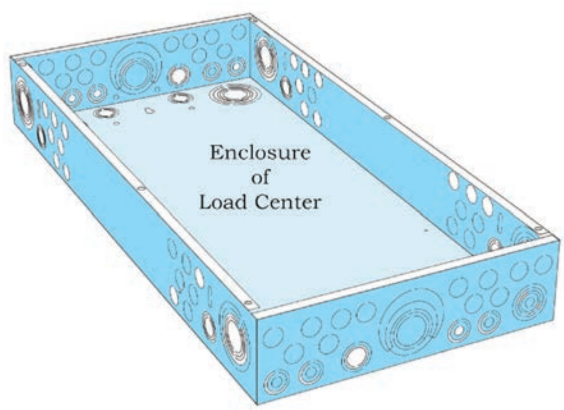

Fig. 4.6: Enclosure

An **enclosure** is an outer box, constructed of galvanised steel as shown in Fig. 4.6. It houses the other components and is designed to provide component and

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personnel protection. The box has hole for cable and conduit connection. These holes are called knockouts.

Practical Exercise

Removing the knockout from the enclosure.

Material required

Enclosure, screwdriver, hammer, combination plier

Procedure

Follow the following steps to remove the knockout from the enclosure.

1. Identify the knockouts on the enclosure. Mark the ones to be removed as per the need of the load centre. Knockouts are shown in Fig. a.

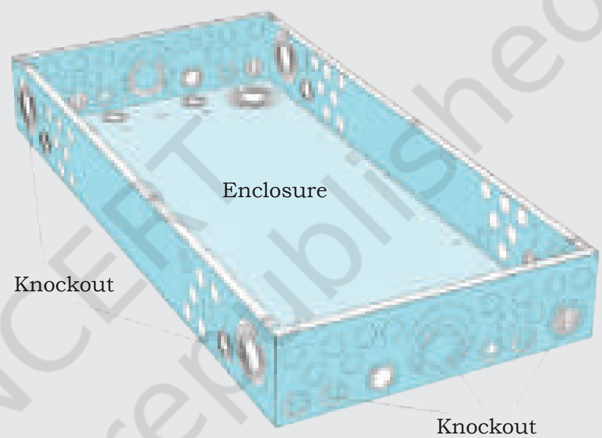

Fig. a: Knockouts

2. Use a screwdriver and hit gently using a hammer as shown in Fig. b.

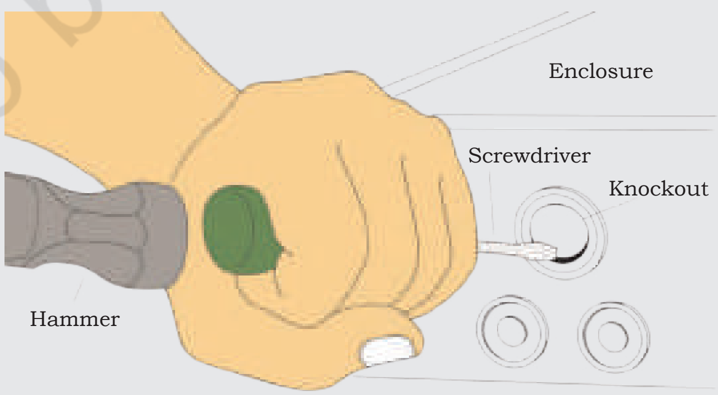

Fig. b: Removing knockouts

3. Use a combination plier to plug out the enclosure material as shown in Fig. c.

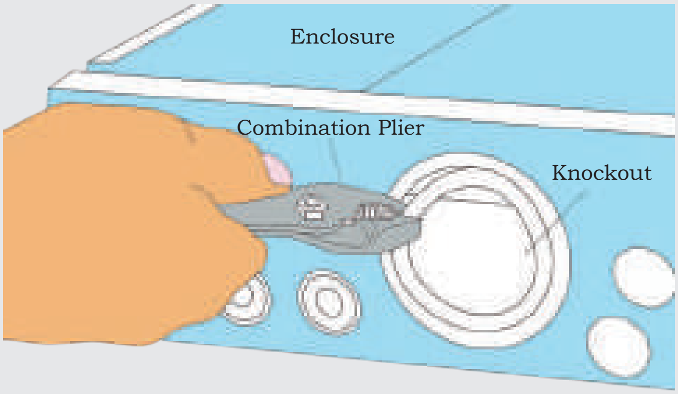

Fig. c: Plugging out enclosure material

The **interior** consists of several components, including busbars, neutral bars and circuit breakers as shown in Fig. 4.7.

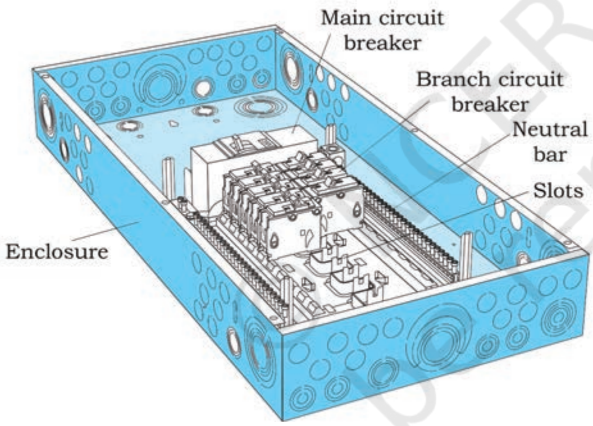

Fig. 4.7: Internal components of a load centre

The **busbar** serves as a common connection for two or more circuits as shown in Fig. 4.8. Load centre busbars are made with tin plated aluminium or copper.

Fig. 4.8: Copper busbar

Power leaves the load centre through a phase or live wire(s) of a circuit. Then it operates electrical devices, such as light bulb, fan, etc. The electrical current returns to the load centre through the neutral circuit wire, usually black in colour, which is connected to the **neutral busbar**. The bar is connected to the load centre and returns the current back to the electric utility grid as shown in Fig. 4.9.

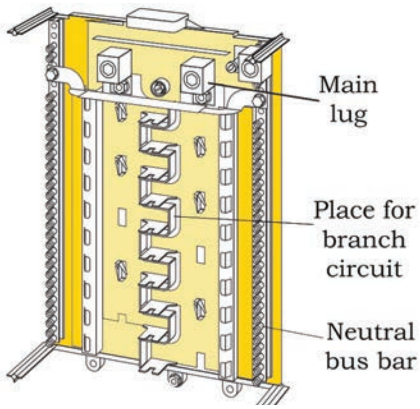

Fig. 4.9: Neutral busbar

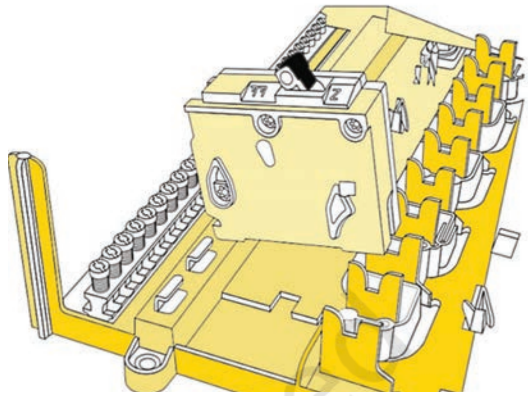

Fig. 4.10: Circuit Breaker

Circuit breakers can be a weak link because at the time of over current it breaks the path and hence protects the circuit from damage. Circuit breaker is shown in Fig. 4.10.

Label identifies the load centre's catalogue number, enclosure type, voltage rating and ampere rating. The additional information on the label are: circuit breaker types that can be used with the load centre, short circuit ratings and wiring diagrams as shown in Fig. 4.11.

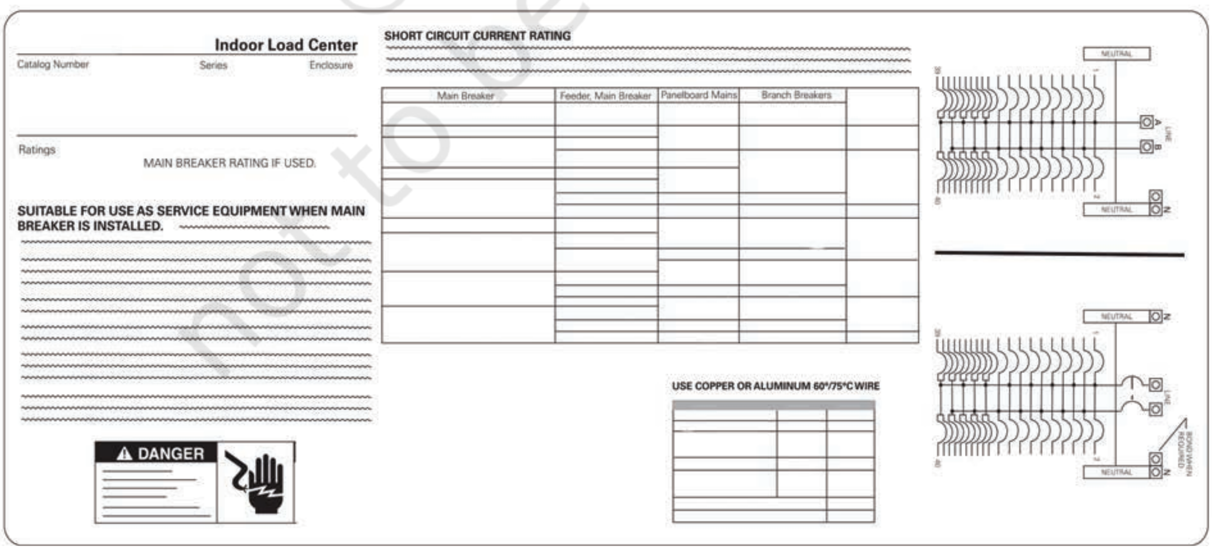

Fig. 4.11: Label on the load centre

The **trim assembly** is the front portion of the load centre that covers the interior. The trim includes a door and an adjustable upper pan.

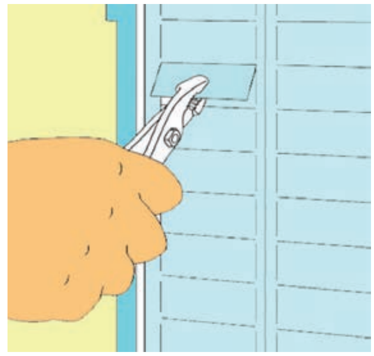

Fig. 4.12: Trim assembly

Types of Load Centres

If you look at a load centre from top to bottom, you will find that the electrical panel is full of circuit breakers. To make the installation easy, breakers are usually numbered and mapped. This will be discussed in a later section. Load centres are divided into two, main breaker load centre and main lug load centre, on the basis of circuit breaker use in the load centre

Main breaker load centre

Load centres have a number of circuit breakers, but, a large circuit breaker is placed at the top. Shown in Fig. 4.13, is known as the main breaker. This main breaker can disconnect the power of the entire house, if the overall load rises too high or if there is another serious problem in the electrical system. Usually, these problems involve momentary power fluctuations, such as due to lightning or thunder in the rainy season.

Note: The main circuit breaker is large in size, voltage and current rating. This high current rating is called amperage of a circuit breaker. In a house, the amperage value of the main circuit breaker is around 20 ampere.

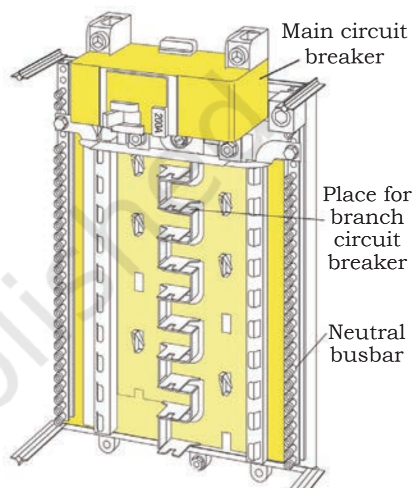

Fig. 4.13: Main breaker load centre

Practical Activity 1

Calculate the amperage value for a circuit breaker.

Material required

Writing material

Procedure

1. Consider a room with 4 tube lights, 4 ceiling fans and 2 LED bulbs. The power consumed by a tube light is 40 watt, ceiling fan is 60 watt, and LED bulb is 20 watt.
2. To calculate the total current consumed by the tube lights, ceiling fans, and LED bulbs, use the formula P = V × I, as power is equal to the multiplication of voltage and current.
   Power of 4 tube lights = 4 × 40= 160 watt.
   Power of 4 ceiling fans = 4 × 60 = 240 watt.
   Power of 2 LED bulb will be = 2 × 20 = 40 watt.
   Total power consumption in the hall = Power of 4 tube lights + Power of 4 ceiling fans + Power of 2 LED bulb

Total power being consumed in the hall = 160 + 240 + 40 = 440 watt

A single phase supply provides 220 volts in a house.

By using the formula:

Power = Voltage × Current

440 = 220 × I

I = 2 A

Thus, the circuit breaker should at least have an amperage value of 2 ampere or more.

Main lug load centre

While the main breaker load centre uses a main circuit breaker, the main lug load centre does not have a main circuit breaker. The incoming supply cables are connected directly to the main lugs and busbars, as shown in Fig. 4.14.

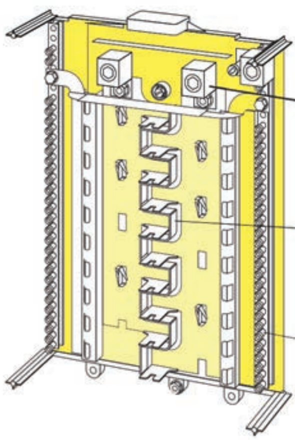

Fig. 4.14: Main lug load centre

This type of load centre has no primary overload protection. So, it is not used in houses or industries as a first entering load centre. It is used as a distribution load centre. Therefore, it is a secondary load centre that is used in further distribution of electricity within the house or the industry. Fig. 4.15 shows the use of a main lug load centre.

Main lug load centres are sometimes referred to as add-on, secondary or downstream panels. These panels are added when all circuit slots in the main breaker load centre are full or when a remote panel is required. For example, a main breaker load centre might supply power to a main lug load centre located in an area of the house used as a workshop. Main lug load centres are also fed from metering equipment when used in apartment installations.

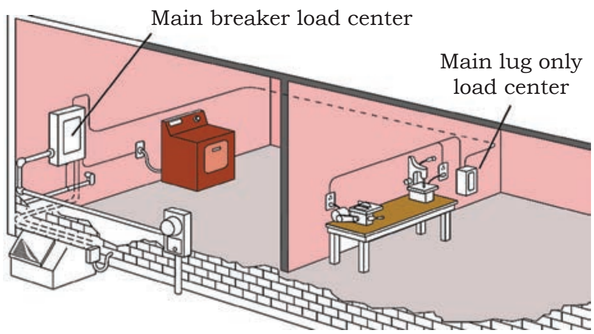

Fig. 4.15: Installation of a main breaker load centre and main lug only load centre

A circuit breaker breaks the circuit, when overload occurs. This overload draws more current through the source. This results in generation of heat in the conductor.

Practical Activity 2

Illustrate the heating effect of current.

Material required

Thermocol sheet, two nails, nichrome wire, wire, battery, switch

Procedure

1. Make a circuit as shown in Fig. a.

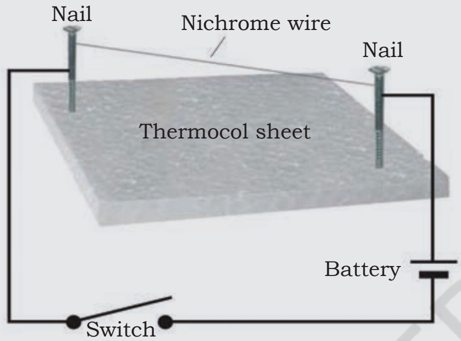

Fig. a

2. Take about a 10 cm long piece of nichrome wire and tie it between the nails. Nichrome wire can be obtained from an electric repair shop or use a piece of discarded coil from an electric heater.
3. Touch the wire. Now switch ON the circuit.
4. After a few minutes, when electric current passes through it, the wire will get heated. This is the heating effect of the electric current. Do not hold it for a long time. Switch off the current. Do not touch the wire immediately as it will be hot. Touch the wire after a few minutes and you will still be able to feel a little heat.

Assignment 1

Make a list of electric appliances that use the heating effect of electric current.

Load Centre Ratings

When selecting load centres and overcurrent protection devices, it is extremely important to know both the maximum continuous amperes and available fault current. There are two ways to meet this requirement, by full rating, and series rating.

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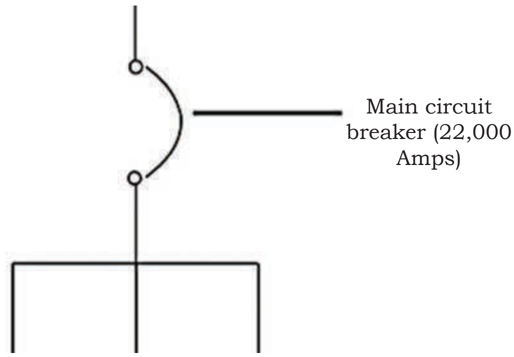

Fig. 4.16: Same rating of main circuit breaker and branch breaker

Full rating

In this method, all the circuit breakers including the main and branch circuit breakers must have a rating equal to or greater than the available fault current. For example, in case of a building using the full rating method, it will have every circuit protection device rating at, at least, 22,000 amperes. Fig. 4.16 shows that the main circuit breaker and each branch breaker is rated 22,000 amperes.

Series rating

In this method, the main circuit protection device must have a rating equal to or greater than the fault current of the system. The subsequent circuit protection devices connected in the series can be rated at lower values. For example, the main circuit protection device must have a rating of 22,000 amperes, which is equal to or greater than the fault current of the system, but the subsequent circuit protection device must have 10,000 amperes, which is at a lower value, as shown in Fig. 4.17.

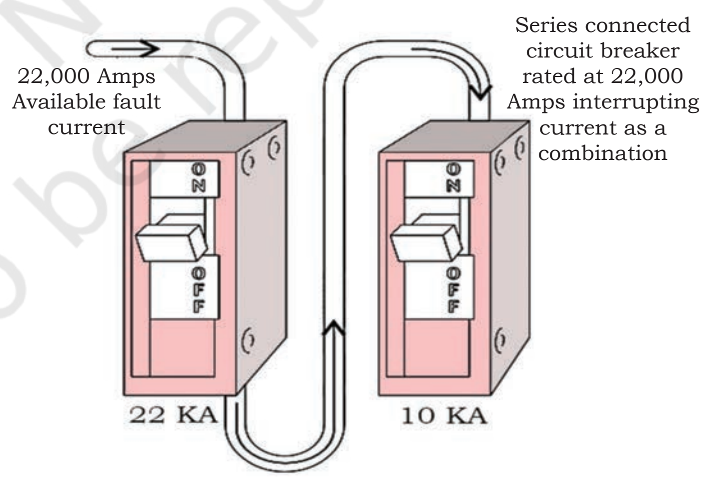

Fig. 4.17: Series rating

Earthing and Grounding

The terms grounding and earthing have been used interchangeably, though they are not the same. There is a micro difference between the two.

Ground or earth in a mains electrical wiring system is a conductor that provides a low resistance path to the earth to prevent hazardous voltages appearing on the equipment or distribution network.

Table 4.1: Difference between earthing and grounding

Earthing	Grounding
Earthing is more commonly used in Britain, European and most of the Commonwealth countries' standards (IEC, IS).	Grounding is the word used in North American standards (NEC, IEEE, ANSI, and UL).
Earthing means connecting the metallic part of a machine that does not carry current under normal conditions to the earth.	Grounding means connecting the live part, means the part which carries current under normal conditions to the earth. Grounding refers to the current carrying part of the system, such as neutral of the transformer or generator.
It is done for the protection of electrical equipment and to provide a least resistive path from the equipment to the earth.	It is done for the protection of power system equipment and to provide an effective return path from the machine to the power source.
For example, electrical equipment frames, enclosures, supports, etc.	For example, grounding of neutral point of a star connected transformer.
It is done at the domestic level.	It is done at the power distribution level.
Earthing is to ensure safety or protection of electrical equipment and humans by discharging electrical energy to the earth.	Because of lighting, line surges or unintentional contact with other high voltage lines, dangerously high voltages can develop in the electrical distribution system wires. Grounding provides a safe, alternate path around the electrical system of your house, thus, minimising damage from such occurrences.

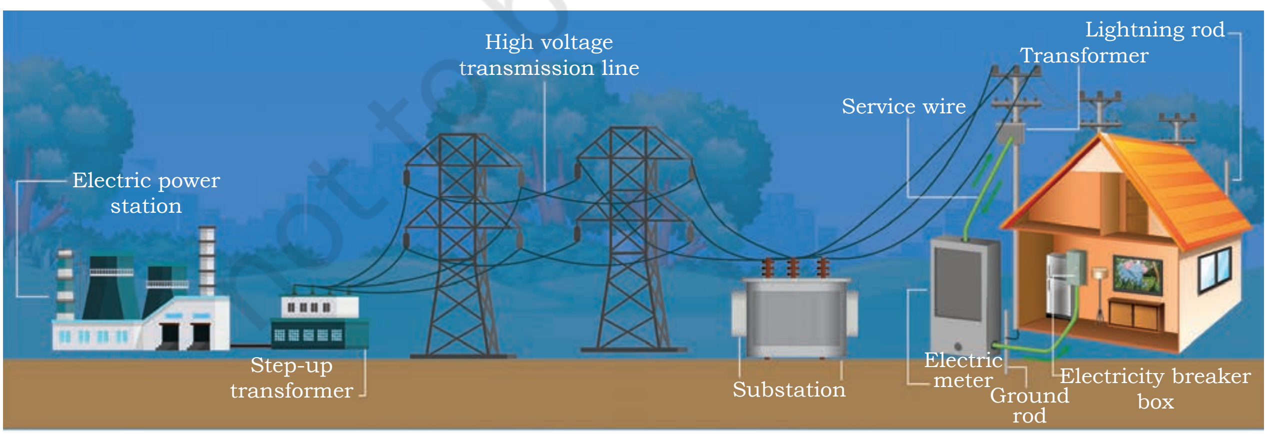

Fig. 4.18: Grounding at the distribution level

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Practical Activity 3

Install plate type earthing

Material required

Tools for digging, metallic plate, galvanised iron (GI) pipe, wire, coal, salt, water, water container

Procedure

1. Dig land in an area of 1.5 × 1.5m to a depth of approximately 3m as shown in Fig. a.

Fig. a: Excavation to form a pit for earthing

2. To enhance the conductivity of soil, fill the pit with a mixture of coal and salt as shown in Fig. b.

Fig. b: Filling the pit with coal and salt

3. Place a 500×500×10mm copper plate in the pit. Attach this plate with a wire as shown in Fig. c.

Fig. c: Placing a copper plate in the pit

4. Pass the metallic wire attached to the copper plate, through a hollow part of GI pipe as shown in Fig. d.

Fig. d: Wire from copper plate passing through GI pipe

5. Fill the rest of the pit with a mixture of coal, sand and salt. Cover the top of the pipe with a T-section to prevent mud and dust from entering the pipe. In summer, the pit should be watered to keep it from drying.

Service Entrance Grounding

The neutral is grounded only at the service entrance, never at any downstream equipment. In Fig. 4.19, the neutral is grounded by connecting neutral to a grounding electrode. The enclosure is also connected to the ground through the grounding electrode connector.

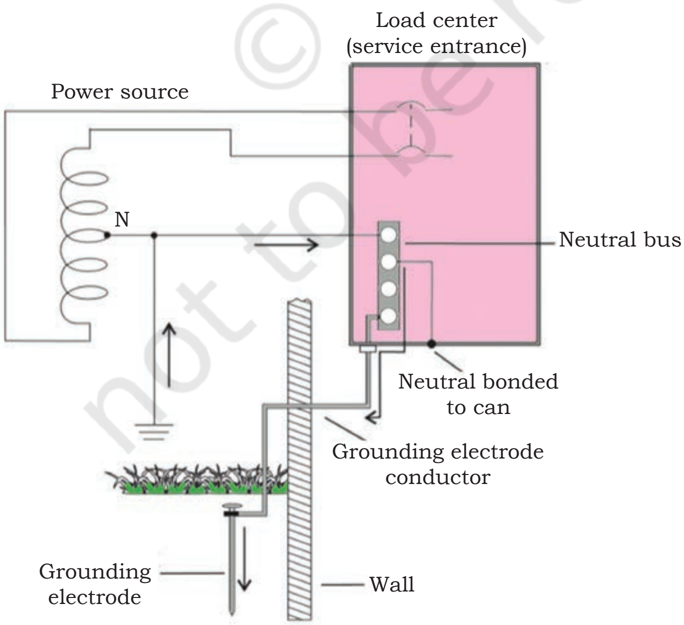

Fig. 4.19: Service entrance grounding

Notes

Check Your Progress

A. Multiple choice questions

1. A label does not contain which of the following information?
   (a) Load centre's catalog number
   (b) Current rating
   (c) Voltage rating
   (d) Number of circuit breakers
2. Which of the following meters is used to measure the amount of power consumed by the loads in a house?
   (e) Energy meter
   (a) Ammeter
   (b) Voltmeter
   (c) Multimeter
3. Neutral can be grounded at ________________.
   (d) service entrance
   (a) downstream equipment
   (b) upstream equipment
   (c) anywhere in the premises
4. Which of the following components is not involved in the interior of a load centre?
   (a) Busbars
   (b) Neutral bars
   (c) Circuit breakers
   (d) Light arrester
5. A load centre is also called ________________ unit.
   (a) control
   (b) processing
   (c) logical
   (d) panel
6. Which of the following is the reason for heating effect in a wire?
   (a) Due to high voltage
   (b) Due to high power
   (c) Due to thick conductor
   (d) Due to high current
7. Which of the following are load centre rating methods?
   (a) Full rating
   (b) Series rating
   (c) Full and series rating
   (d) Parallel rating
8. Which of the following material is used to manufacture enclosure of load centre?
   (a) Iron
   (b) Copper
   (c) Wood
   (d) Galvanised steel

9. Which of the following methods are not used for distribution of electric power?
   (a) Residential distribution
   (b) Commercial distribution
   (c) Industrial distribution
   (d) Household distribution
10. Which of the following places can be earthed?
   (a) Domestic level
   (b) Power distribution level
   (c) Substation
   (d) High tension line

B. Fill in the blanks

1. A _______________ system distributes electrical power throughout a building.
2. Load centres are covered by _______________.
3. The two types of load centres are main _____________ and main _______________ only.
4. Main lug only load centres are sometimes referred to as _______________ or _______________ panels.
5. The _______________ rating method is to select circuit protection devices with individual ratings equal to or greater than the available fault current.
6. The enclosure of the outer box is made up of _______________.
7. Holes on an enclosure are known as _______________.
8. In earthing, coal and salt increases the _______________ of soil.
9. The interior of an enclosure is covered by _______________ assembly.
10. High current rating of a circuit breaker is known as _______________.

C. State whether the following statements are True or False

1. Load centre as a single unit placed in a cabinet or enclosure can be mounted on the wall.
2. Current flow in a conductor always generates heat.
3. The trim assembly is the back portion of the load centre that covers the interior.
4. When overload occurs circuit breaker breaks the circuit.
5. Excessive current in a circuit is prevented by the use of overcurrent safety devices.
6. Earthing protects us from getting electric shock.
7. In overload conditions, circuits draw less current.

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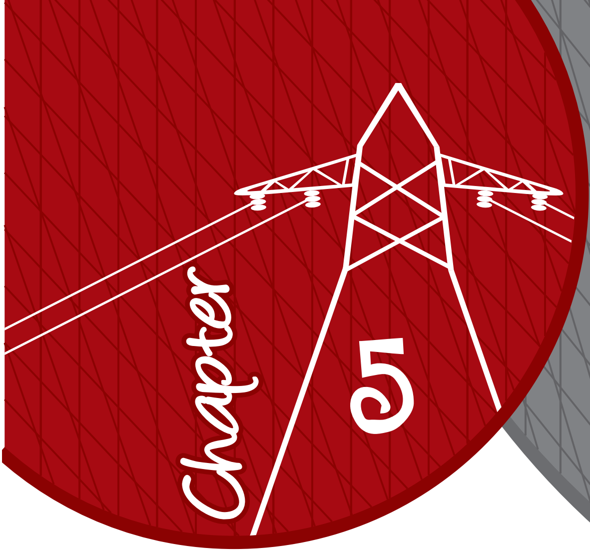
8. Neutral buses are present in a main busbar.
9. Enclosures protect the box from external damage.

D. Short answer questions

1. What is a load centre?
2. What are the types of load centre?
3. Explain the construction of a load centre.
4. How does the rating of a load centre affect the electrical distribution?
5. Explain the concept of service entrance grounding.
6. Write down the difference between earthing and grounding.



Installation of Industrial Control Panel

171202CH05

Introduction

On her way to Delhi with her father to visit the international science exhibition, Riya saw many medium and large-scale industries. Riya also saw a dedicated high power transmission line going towards the industrial area, which was the power distribution system. In commercial or industrial area, the point from where electric power is controlled and transmitted is known as the panel board. In this chapter, you will understand the distribution of power in a commercial or industrial area and the panel board system and its parts.

Commercial and Industrial Power Distribution

While the load controlling point in a residential building is called a load centre, the power distribution controlling point in a commercial, industrial area is called a panel board. This type of distribution is more complex as the number of electrical appliances and users increase. A distribution system consists of metering devices to measure power consumption. It has main and branch protective devices, conductors, transformers and switching devices to start-stop electric power flow. Electric power may be distributed through various switchboards, transformers and panel boards as shown in Fig. 5.1.

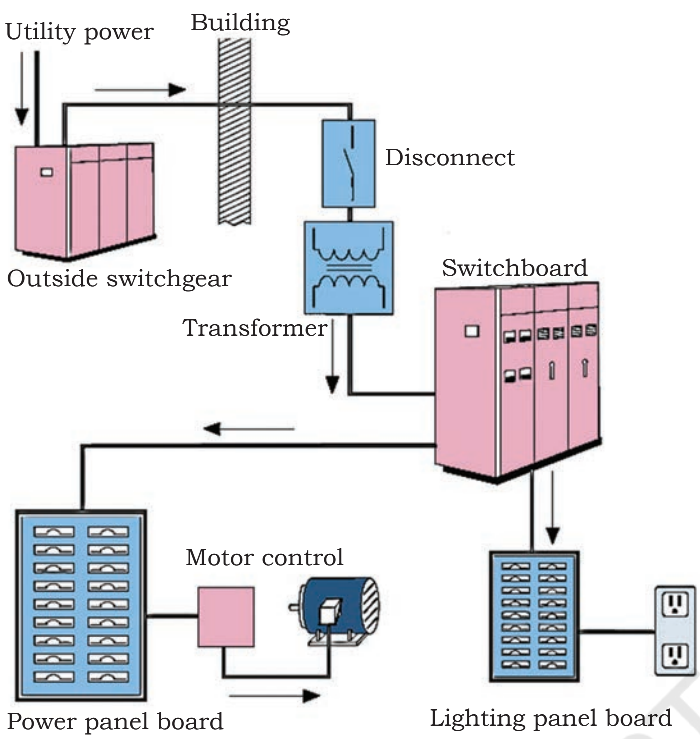


Fig. 5.1: Commercial and industrial distribution of power

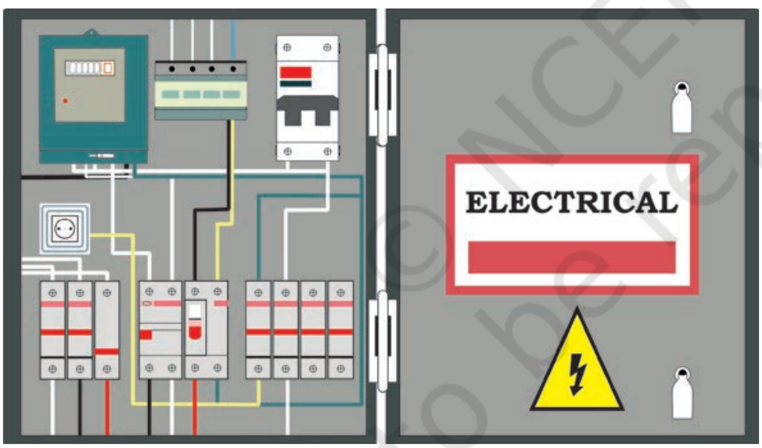


Fig. 5.2: Panel board

Panel Boards

Electrical distribution systems, whether simple or complex, typically include panel boards. In the earlier Unit, we studied about the load centre, which is also a control unit. Load centre and panel boards are almost the same terms with a few differences. As a panel board is designed for industrial purposes, it must have a high rated overload protecting device, a more complex controlling circuit, which control all the heavy equipment, provide circuit control and overcurrent protection as shown in Fig. 5.2.

A panel board is a single panel or a group of panels. A panel board includes buses, automatic overcurrent devices, equipped with or without switches, and power circuits. A panel board is generally designed to be placed in a cabinet. A panel board mounted on a wall or partition as shown in Fig. 5.4 is accessible only from the front.

Panel boards basically fall into two categories, lighting and appliance panel boards, and power panel boards.

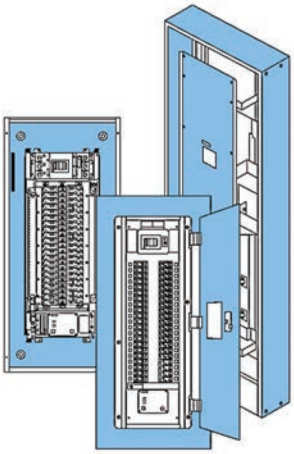


Fig. 5.3: Panel board in different sizes

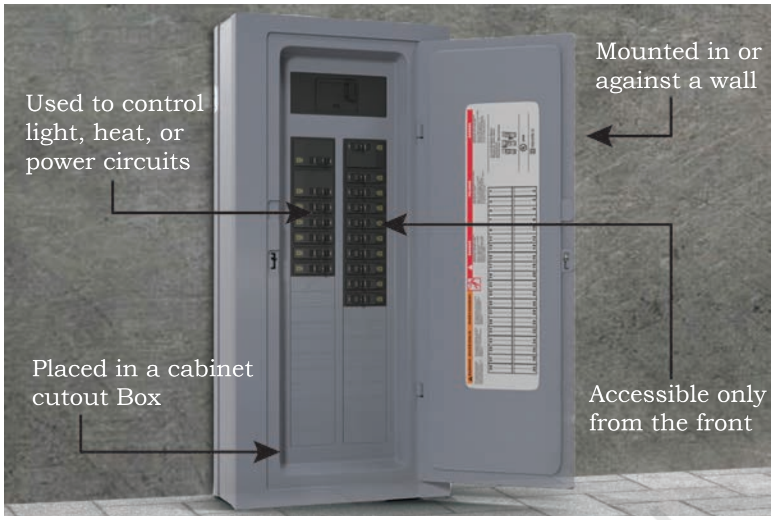


Fig. 5.4: Panel board mounted on the wall

Lighting and appliance panel board is a component of an electric power supply system. It divides electric power into sub-circuits with a separate fuse or circuit breaker provided for each circuit, in a common enclosure.

Power panel board represents products of high-level engineering from different industrial manufacturers. The panel board is flexible and strengthens the industrial distribution system. These panel boards are easy to install. These newer designs also simplify wiring and reduce material requirements, saving additional installation time.

Fig. 5.5: Power panel board

Panel Board Construction

Panel boards are available in different sizes with variation in construction. They contain a can, interior, circuit protection devices, label and trim.

The can is constructed using galvanised steel, and houses other components. It is also referred to as the box or an enclosure. It is designed to provide component and personnel protection. Removable end panels allow the user to cut whatever conduit holes are necessary, as shown in Fig. 5.6. Mounting studs are used to support the interior or group mounted devices.

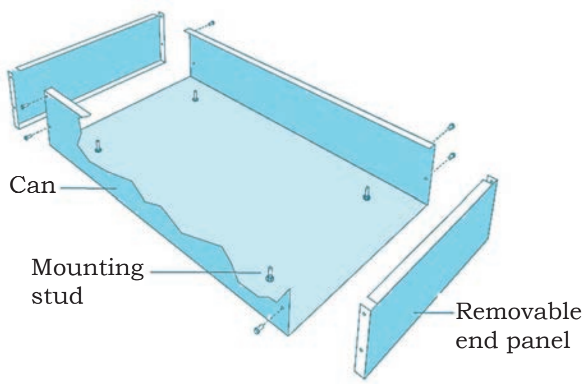


Fig. 5.6: Can

The interior consists of several components, including overcurrent protection devices, busbars and insulated neutral busbars. The interior is mounted using four mounting studs in the can.

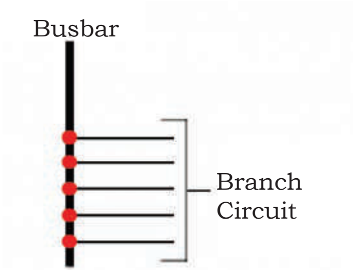


Fig. 5.7: A schematic diagram of a busbar

Busbars

A busbar is a conductor that serves as a common connection for two or more circuits. It is represented schematically by a straight line with a number of connections made to it as shown in Fig. 5.7. Busbars must be located in a place that is free from physical damage and should be held firmly in place. Standard busbars in panel boards are made up of aluminium, but copper busbars can also be used.

Electrical Manufacturers Association Rule

Busbars are required to have phases in sequence, so that an installer can have the same fixed phase arrangement in each termination point in any panel board or switchboard. This is established by the Electrical Manufacturers Association. A phase sequence, which is not as per the Electrical Manufacturers Association must be marked on the panel board. It is assumed that busbars are arranged according to the Electrical Manufacturers Association rules. Fig. 5.8 illustrates the accepted phase arrangements of the Electrical Manufacturers Association.

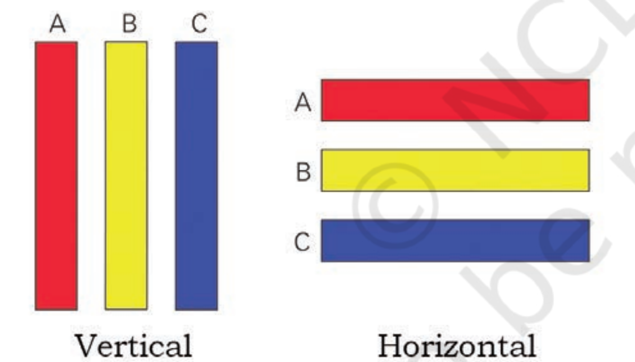


Fig. 5.8: Vertical and horizontal alignment of a busbar

A high leg busbar or conductor is permanently marked with a finish that should be colour-coded as shown in Fig. 5.9. In a control panel board various power supplies are used. Some power supply systems use a transformer with a three-phase, four-wire (3Ø4W), delta-connected secondary. In these systems, the voltage of one phase is higher than the other two phases. This is called the high leg.

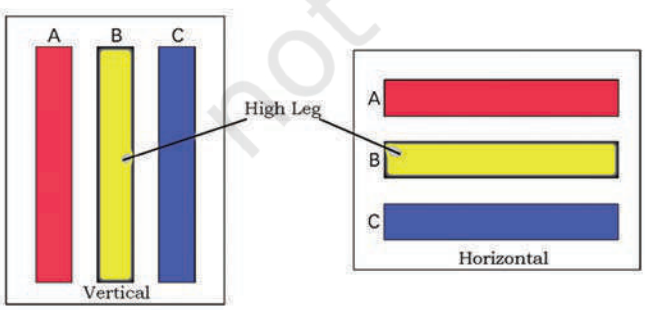


Fig. 5.9: High leg in a busbar

Split neutral, an insulated neutral busbar means an equal number of neutral connections are available on both sides of the panel board. Split neutrals are connected together through a busbar. Insulation separates the neutral busbar from the power supply busbars.

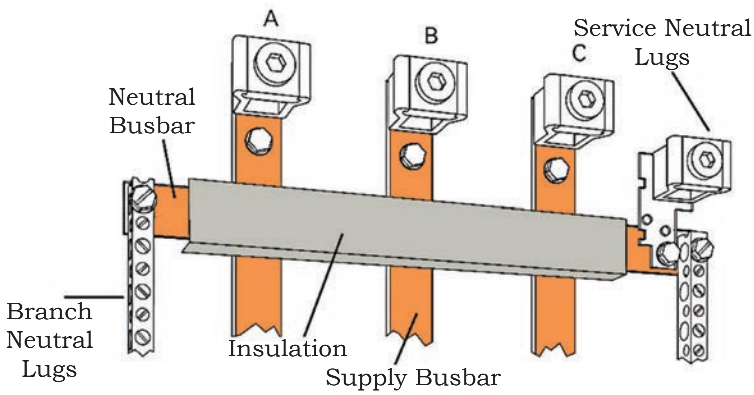


Fig. 5.10: Splitting of neutral busbar

Fusible disconnect switch is a device used on panel boards to provide overcurrent protection. Properly sized fuses located in the switch open when an overcurrent condition exists. The switch and its outer handle are shown in Figs 5.12 and 5.13.

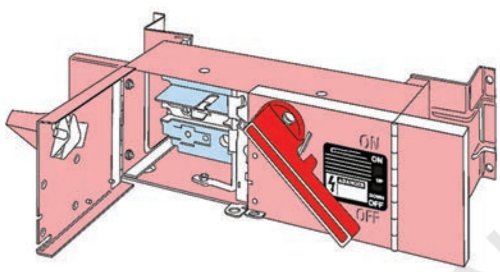


Fig. 5.11: Fusible disconnect switch


Fig. 5.12: Handle of fusible switch

Fig. 5.13: Outer covering of fusible switch

Circuit protection devices mount directly to the busbars. Fig. 5.14 illustrates how a circuit breaker is mounted on the panel board bus.

Dead front and trim are the front surfaces of a panel board that cover the interior. The trim includes an access door as shown in Fig. 5.15.

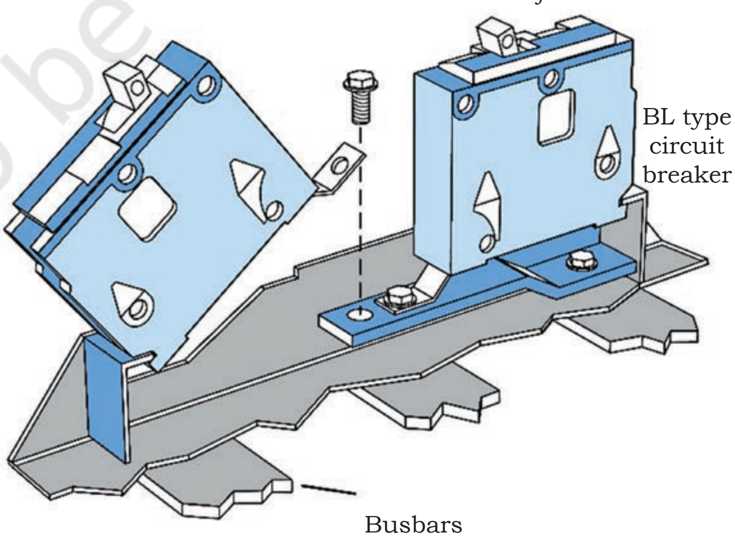


Fig. 5.14: Assembling a circuit protection device

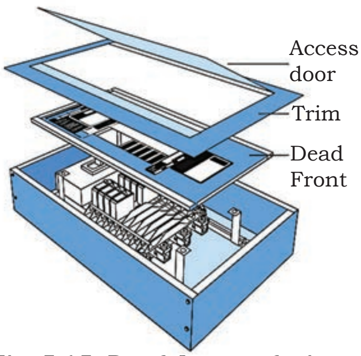


Fig. 5.15: Dead front and trim in the panel board

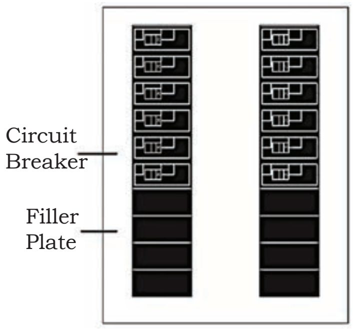


Fig. 5.16: Filler plates in a panel board

These components provide access to the overcurrent devices while sealing off the busbars and internal wiring from direct contact.

Filler plates are used to cover any unused pole spaces not filled by a circuit breaker as shown in Fig. 5.16.

Practical Excercise

Activity 1

Installation of panel board

Material required

Can or enclosure, screwdriver, circuit breakers, combination plier

Procedure

Follow the following steps to install the panel board.

Step 1. Take a can or enclosure as shown in Fig. a.

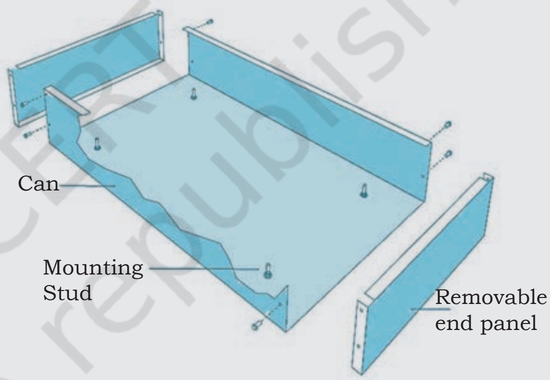


Fig. a

Step 2. Remove the knockout using a screwdriver as shown in Fig. b.

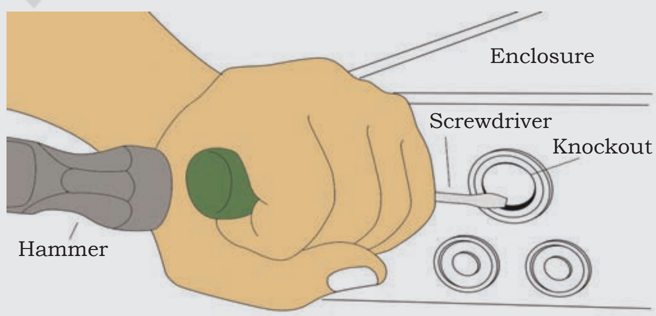


Fig. b

Step 3. Mount the main circuit breaker and branch circuit breaker in the enclosure as shown in Fig. c.

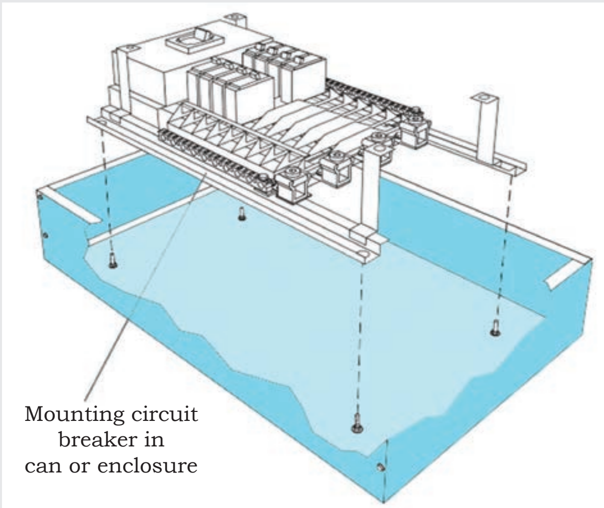


Fig. c

Step 4. Connect the cable, using lugs, on to a different circuit breaker including the main and branch circuit breaker as shown in Fig. d.

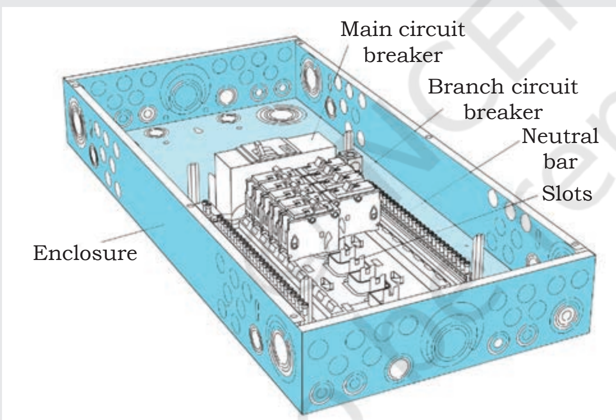


Fig. d

Enclosures

The Electrical Manufacturers Association has established guidelines for electrical equipment enclosures. These enclosures are explained in Practical Activity 2. Fig. 5.17 shows a general enclosure of a panel board.

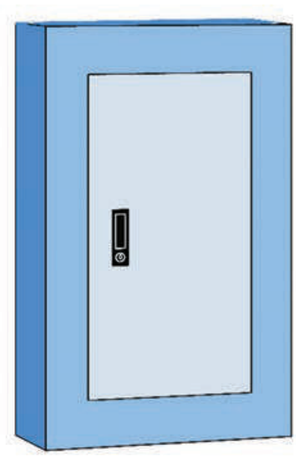


Fig. 5.17: Enclosure of a panel board

NOTES

Activity 2

Identify the specifications of different enclosures

Material required

Different types of panel enclosures

Procedure

Step 1. Identify and name the type of enclosure given in Fig. a, and list its characteristics.

Step 2. Identify and name the type of enclosure given in Fig. b and list its characteristics.

Fig. a

Fig. b

Step 3. Identify and name the type of enclosure given in

Fig. c and list its characteristics.

Fig. c

Step 4. Identify and name the type of enclosure given in Fig. d and list its characteristics.

Fig. d

Types of Panel Boards

There are two types of panel boards, the main breaker panel board, and the main lug only panel board.

In the main breaker panel board, the incoming supply cables are connected to the line side of the main breaker as shown in Fig. 5.18. These cables feed power to the panel board and its branch circuits. The main breaker can disconnect power to the panel board. This way, it protects the system from short circuits, and overloads. Ground faults can be addressed if it is equipped with ground fault protection. Main breakers are

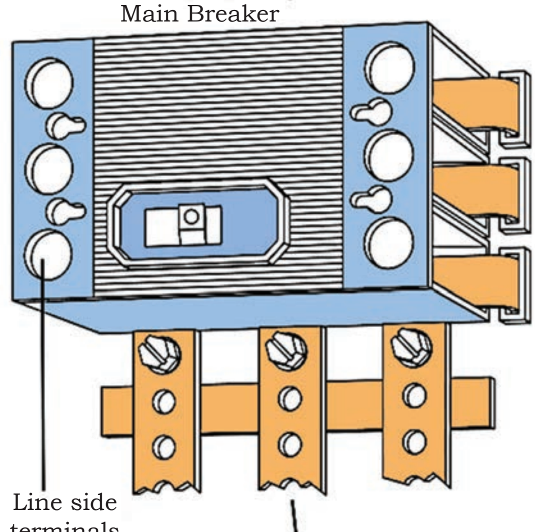


Fig. 5.18: Main breaker in the panel board

connected to the main busbars using the branch bus as shown in Fig. 5.19. This means there is no cable connection required from the main circuit breaker to the main busbars. Connecting the bus provides a higher degree of circuit integrity because there is less chance for loose connection, which leads to overheating.

Depending on the panel board, the main breaker can either be mounted horizontally or vertically as shown in Fig. 5.20.

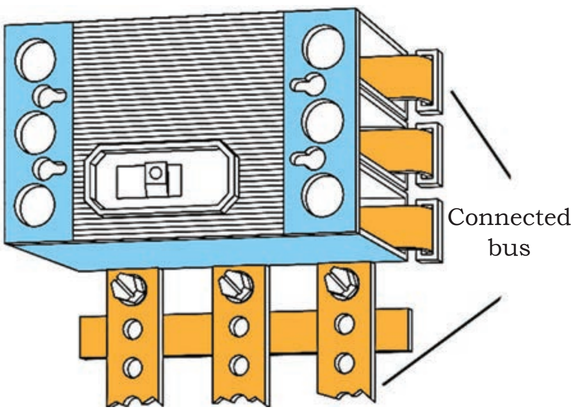


Fig. 5.19: Connection of bus in the panel board

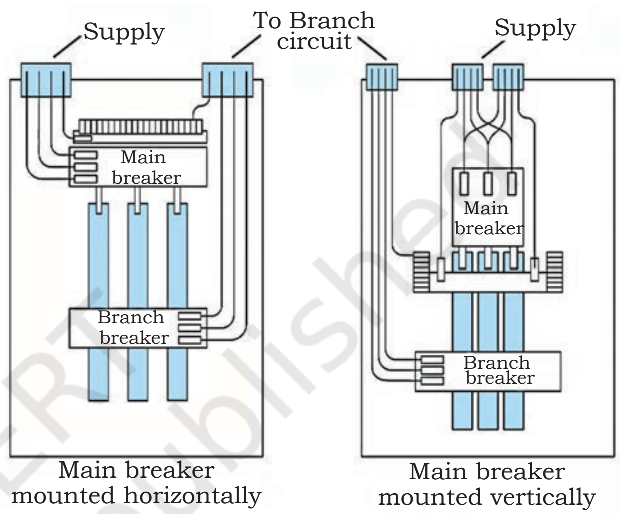


Fig. 5.20: Horizontal and vertical mounting of the main breaker

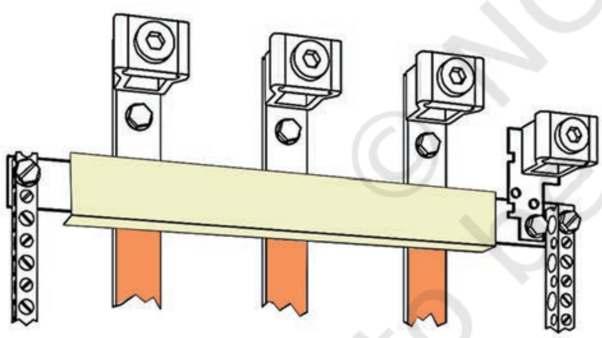


Fig. 5.21: Main lug only breaker

A main lug only panel board does not have a main circuit breaker. The incoming supply cables are connected directly to the busbars as shown in Fig. 5.21. In this type of panel board, overload protection is not provided.

Check Your Progress

A. Multiple choice questions

1. Which of the following components are used in the interior of the panel board?
   (a) Overcurrent protection devices
   (b) Busbars
   (c) Insulated neutral busbars
   (d) All of the above

2. Busbar is a conductor that serves as a common connection for ____________ circuit(s).
   (a) one (b) two
   (c) three (d) two or more
3. Which of the following statements is true in the context of mounting a main breaker in the panel board?
   (a) Main breaker is mounted horizontally
   (b) Main breaker is mounted vertically
   (c) Main breaker can be mounted horizontally or vertically
   (d) Main breaker is mounted separately
4. Which of the following is the front part of the panel board?
   (a) Access door (b) Trim
   (c) Dead front (d) All of these
5. Which of the following is not a type of enclosure?
   (a) Type 1 (b) Type 3R/12
   (c) Type 3 (d) Type 5R/12
6. Which of the following is a type of panel board?
   (a) Main breaker
   (b) Main lug only
   (c) Main breaker and main lug only
   (d) None of the above
7. Which of the following is a type of enclosure?
   (a) Type 1 (b) Type 3R/12
   (c) Type 3 (d) All of these

B. Fill in the blanks

1. A panel board is designed for the ____________ purpose.
2. Standard busbars in panel boards are made of ___________, but ___________ busbars can also be used.
3. A ____________ is a type of device used on panel boards to provide overcurrent protection.
4. A distribution system consists of metering devices to measure ____________ consumption.
5. Panel boards basically fall into two categories, which are ____________ and ____________.

C. State whether the following statements are True or False

1. The interior of a panel board consists of several components, including overcurrent protection devices, busbars and insulated neutral busbars.
2. A busbar is a conductor that serves as a common connection for two or more circuits.
3. Circuit protection devices mount indirectly to the busbars.

NOTES

NOTES

4. In a panel board an insulated neutral bus is provided.
5. Load centre and panel boards are almost the same terms with few difference.

D. Short answer questions

1. What is a service panel board?
2. What are the types of service panel board?
3. What are the types of enclosures?
4. Write down the constructional details of the panel board.
5. What is the use of fusible disconnect switch?
6. Write down the classification of a panel board.

Chapter 6

Installation of a Switchboard

171202CH06

Introduction

In the previous chapters, you learned about the different control elements that are used to operate the electrical system. These are panels, load centres and switchgears. They are used to execute smooth distribution of power. A group of panels, load centres, etc., called a switchboard are used in substations, buildings, organisations, institutes, etc. In this chapter, you will understand the design and construction of a switchboard and their types.

Switchboard

A switchboard is a large single panel, frame, or assembly of panels. Overcurrent device, switches, protective devices and buses are mounted on a switchboard. They are usually mounted on the front or back, or both. Switchboards are generally accessible from the rear as well as from the front.

Fig. 6.1 illustrates a switchboard made of two sections. Several overcurrent protective devices (such as circuit breakers, fuse and control levers) are mounted on the switchboard.

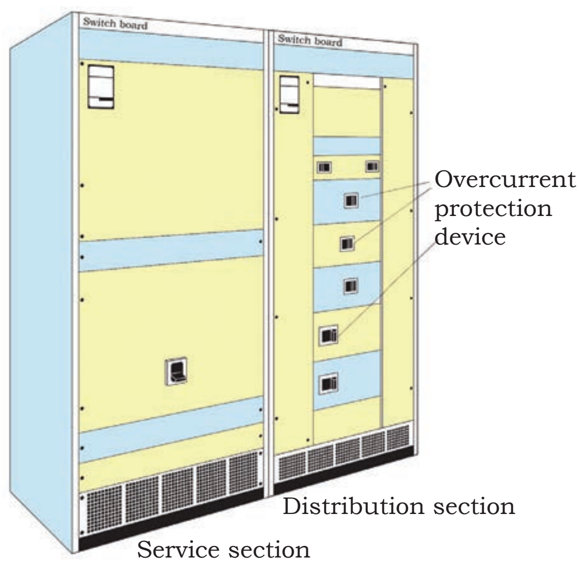


Fig. 6.1: Switchboard

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Buses are mounted inside the switchboard as shown in Fig. 6.2.

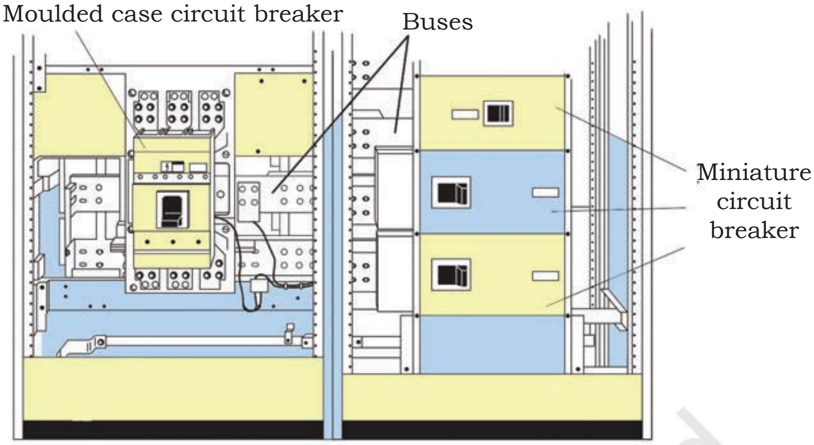


Fig. 6.2: Buses are mounted inside a switchboard

Depending on the design, switchboards may be installed next to a wall or away from the wall to permit accessibility to the rear end of the switchboard.

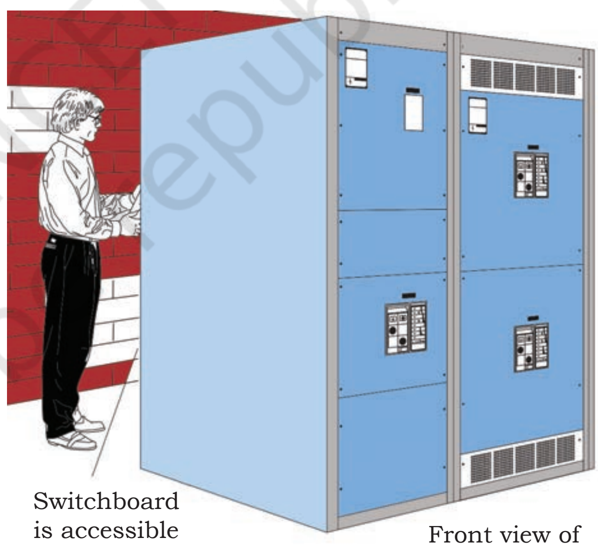


Fig. 6.3: Accessibility of a switchboard

Switchboard Construction

There are several components that make up a switchboard. They consist of a frame, overcurrent protective devices, buses, instrumentation and outer covers.

Frame

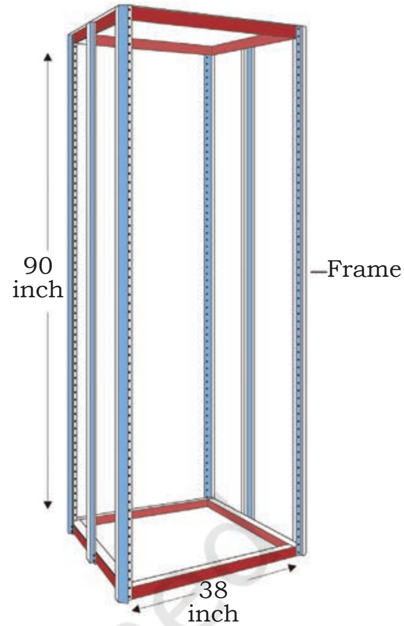


Fig. 6.4: Frame of a switchboard

The frame of a switchboard houses and supports the other components. A typical switchboard frame is 90 inches high and 38 inches wide. Optional heights of 70 inches and width of 32 inches and 46 inches are also available.

Bus

A bus is a conductor that serves as a common connection between two or more circuits. Buses are mounted within the frame. Horizontal buses are used to distribute power to each switchboard section. Vertical buses are used to distribute power via overcurrent devices to the load devices. Vertical and horizontal busbars are shown in Fig. 6.5. Standard busbars on switchboards are made of aluminium, but copper busbars are available as an option.

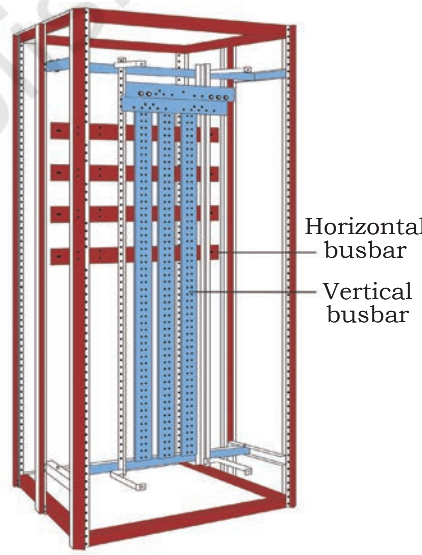
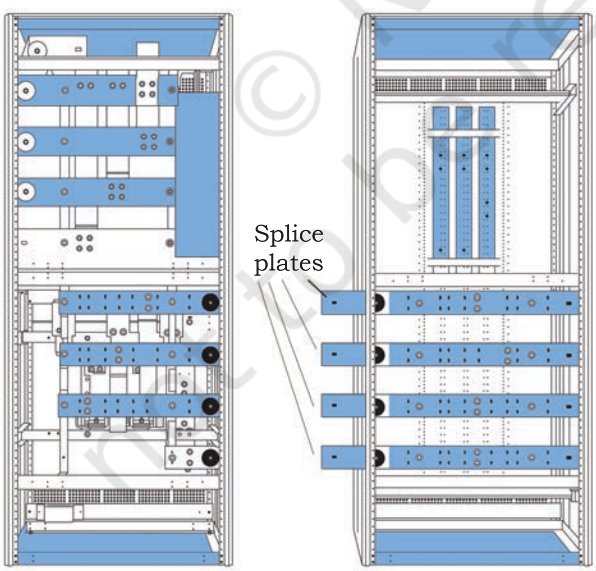


Fig. 6.5: Bus in a frame

Splice Plates

Splice plates are used to join the horizontal busbars and adjoining switchboard sections. The horizontal busbar is pre-drilled to accept the splice plates, as illustrated in Fig. 6.6.



Rear view of switchboard

Fig. 6.6: Rear view of a switchboard showing splice plates in the frame

Protective Devices

Operator components are mounted on the front side of the switchboard. This includes protective devices, such as circuit breaker, disconnect switches, meters and fuses, which can be covered by a trim panel as shown in Fig. 6.7.

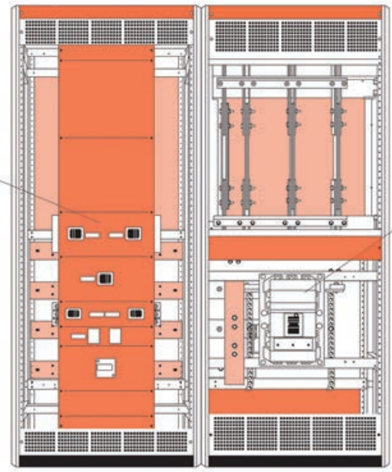


Fig. 6.7: Front view of a switchboard showing protective device mounted in a switchboard

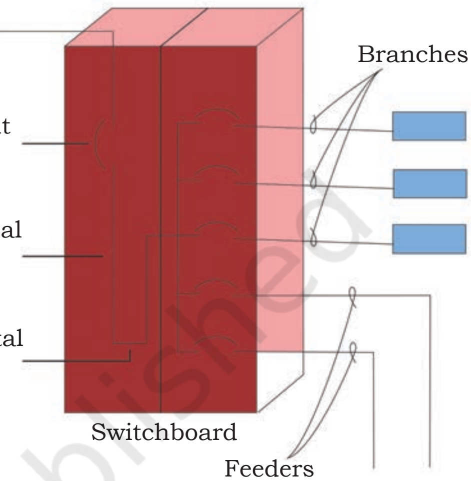


Fig. 6.8: One-line diagram showing switchboard connections

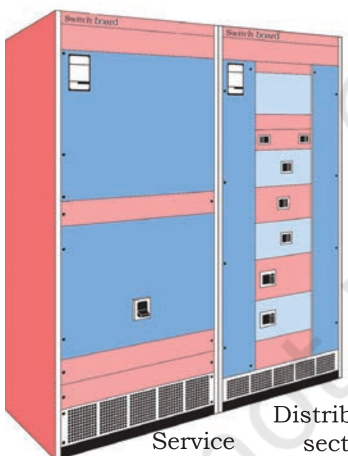


Fig. 6.9: Service section in a switchboard

Switchboards are explained by using block diagrams and/or one-line diagrams, which show the connectivity of the wires. Fig. 6.8 illustrates a two section switchboard.

Service Section

A typical switchboard consists of a service section as shown in Fig. 6.9, also referred to as the main section, and one or more distribution sections. The service section can be fed directly from the utility transformer. In addition to the main disconnect, the service section usually contains utility or customer metering provisions.

Service Entrance Methods

There are several options to bring power to the switchboard service section. Cable can be brought to the switchboard from the top or the bottom. It can also be brought to the top of the switchboard through a conduit as shown in Fig. 6.10 (a). If the cable has a large diameter and requires more room, extra space of 10” to 30” height can be added as shown in Fig. 6.10 (b). A bus duct entrance can be used when a metal bus is used instead of cables as shown in Fig. 6.10 (c).

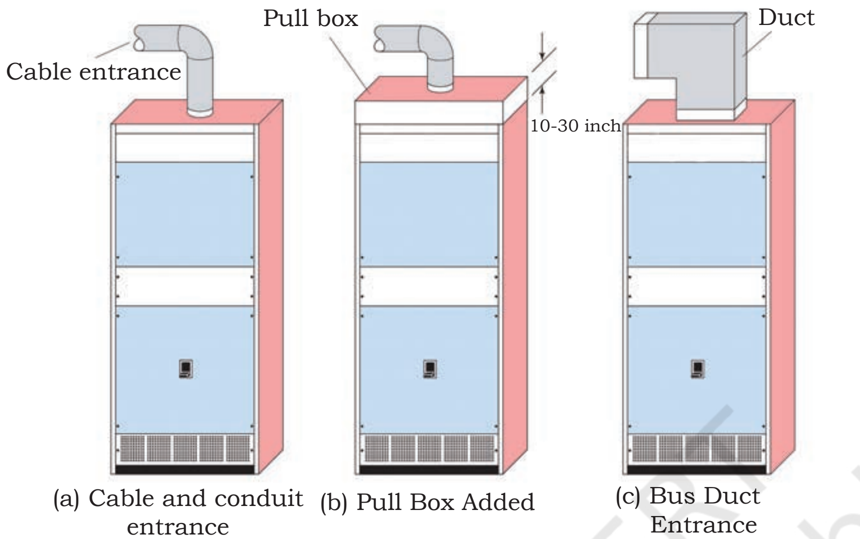


Fig. 6.10: Service entrance method

Practical Activity 1

Illustrate the different cable feeding methods in a switchboard.

Material required

Switchboard cables

Procedure

1. Locate the conduit in a switchboard.
2. Insert the cable into the switchboard through a conduit.
3. Connect the cables coming from the conduit to the circuit protection device, such as MCB, MCCB, and fuse.
4. Fig. a shows that in the first switchboard, cables are connected at the bottom of the switchboard.
5. In the second switchboard, cables are connected to the switchboard through a pull section.
6. In the third switchboard, cables are connected to the switchboard through a pull section using a cross busbar. A cross busbar eliminates the need to bend the cables.
7. Thus, Fig. a shows how the cables are fed into the switchboard in three different ways.

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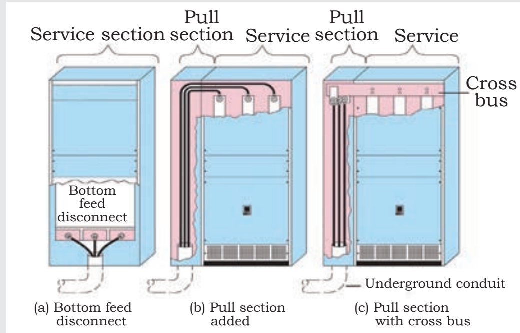

Fig. (a:) Different feeding methods in a switchboard

Fusible Switch

A fusible switch is another disconnect device used in the service section as shown in Fig. 6.11. The external interfacing of a fusible switch is shown in Fig. 6.12.

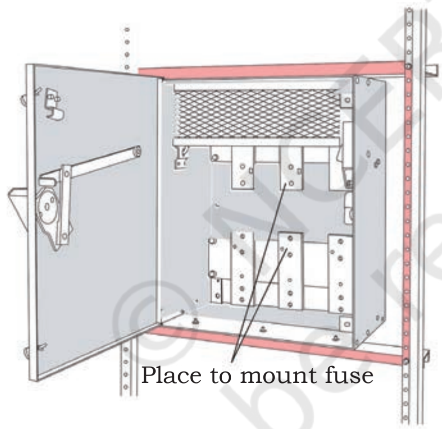

Fig. 6.11: Fusible switch in the board

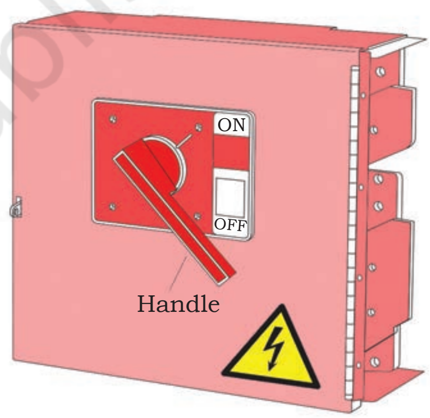

Fig. 6.12: Interfacing of a fusible switch

Handle Extension

Some of the handles are difficult to operate on the larger circuit breakers. A handle extension that allows more energy to be applied to the circuit breaker handle is also available. This makes it easier to open and close the circuit breaker.

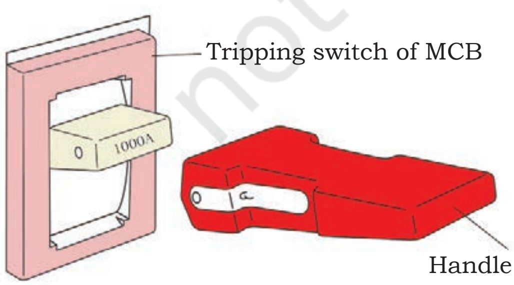

Fig. 6.13: Handle extension

Distribution Section

The distribution section receives power from the service section and distributes it to various downstream loads as shown in Fig. 6.14.

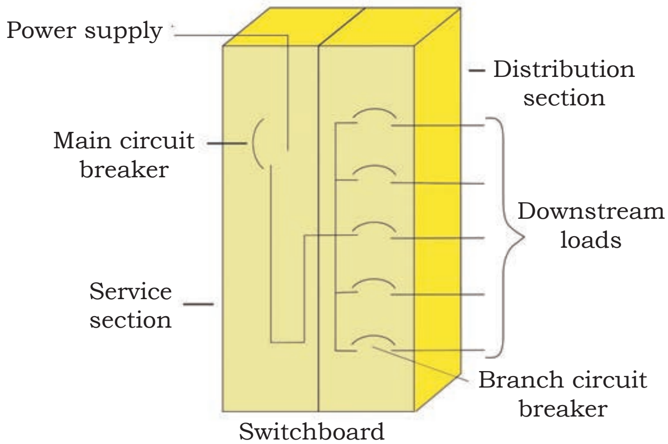

Fig. 6.14: A diagram of a distribution section

SB1, SB2 and SB3 Switchboards

There is a variety of switchboards and the selection is determined by factors, such as space, load and environment. SB1, SB2 and SB3 switchboards can be found in industrial plants, hospitals and commercial buildings.

(a) **SB1 switchboards** are designed to be used in an application where space is a consideration. SB1 switchboards are rear aligned and are accessible from the front. The service section can be deeper than the distribution section as shown in Fig. 6.15. By aligning the rear, the switchboard can be installed against a wall.

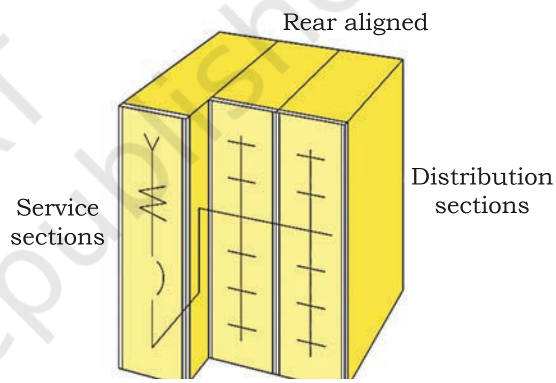

Fig. 6.15: SB1 switchboard

(b) **SB2 switchboards** have standard rear alignment. Both front and rear alignment options are available. SB2 switchboards are front accessible and front connected. Fig. 6.16 illustrates an SB2 switchboard that is front and rear aligned. In this example, a pull

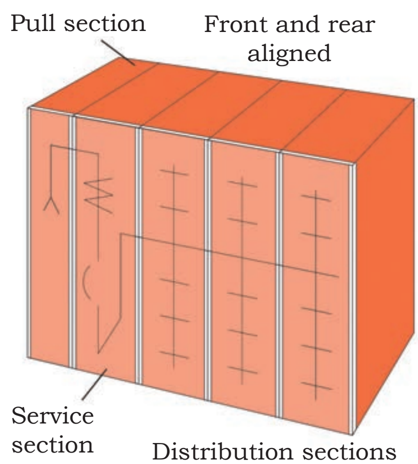

Fig. 6.16: SB2 switchboard

Notes

section has been added to allow room to pull cable up from the bottom to connections in the top of the service section. SB2 switchboards can be mounted against a wall.

(c) **SB3 switchboards** are front and rear aligned. SB3 switchboards are designed for special configurations, such as incoming and outgoing busway connections. The switchboard is designed as a service entrance switchboard. When the main service disconnects, the distribution devices are contained in a single unit as shown in Fig. 6.17.

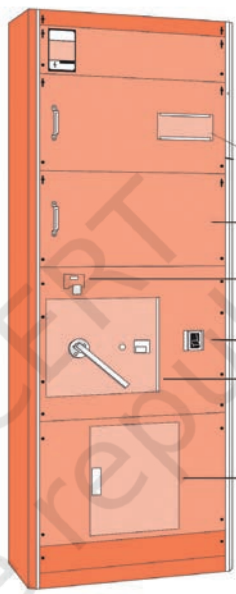

Fig. 6.17: SB3 switchboard

Check Your Progress

A. Multiple choice questions

1. Which of the following is not a type of switchboard?
   (d) SB1
   (e) SB2
   (f) SB3
   (g) SB4
2. Which of the following is a type of switchboard?
   (a) SB1
   (b) SB2
   (c) SB3
   (d) All of the above

3. In which switchboard is a service section is deeper than the distribution section?
   (a) SB1
   (b) SB2
   (c) SB3
   (d) SB2 and SB3
4. Which of the following components are used in switchboards?
   (a) Frame
   (b) Overcurrent protective devices
   (c) Buses
   (d) All of the above
5. The most commonly used switchboard size is __________.
   (a) 90 inches high and 38 inches wide
   (b) 100 inches high and 40 inches wide
   (c) 150 inches high and 50 inches wide
   (d) 60 inches high and 45 inches wide
6. Handle extension is used with __________.
   (a) busbar
   (b) busway
   (c) MCB trip
   (d) switchgear
7. Which of the following switchboard is front and rear aligned?
   (a) SB1
   (b) SB2
   (c) SB2
   (d) All of the above

B. Fill in the blanks

1. Switchboards are generally accessible from the __________________ as well as the ________________.
2. A typical switchboard frame is ________________ high and ________________ wide.
3. Horizontal buses are used to distribute power to each ________________ section.
4. Vertical buses are used to distribute power via overcurrent devices to the ________________.
5. A bus duct entrance can be used when ________________ is used instead of cables.

C. State whether the following statements are True or False

1. A handle extension allows more leverage to be applied to the circuit breaker handle.
2. SB1 switchboards are designed to be used in an application where space is a consideration.

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3. SB2 switchboards may be mounted against a wall.
4. SB3 switchboards are front and rear aligned.
5. A switchboard is a large single panel, frame, or assembly of panels.
6. Splice plates are used to join the horizontal busbars and switchboard sections.

D. Short answer questions

1. What is a switchboard?
2. How is a switchboard different from a panel board and load centre?
3. Explain in brief the construction of a switchboard.
4. What is the specification that has to be kept in mind while feeding the cable into the switchboard?
5. Define SB1, SB2 and SB3 type of switchboard.

Chapter 7

AC Drives and Soft Starters

171202CH07

Introduction

Electrical drives are an integral part of industrial and automation processes, particularly where precise control in speed of motor is the prime requirement. In addition, all modern electric trains or locomotive systems have been powered by electrical drives. Robotics is another major area where adjustable speed drives offer precise speed and position control. In this chapter, you will learn about electrical drives, such as AC drives, and soft starters.

AC Drives

In an electrical network, 'AC' stands for 'alternating current' and drives represent the 'controlling' of the circuit or system. Therefore, AC drives are used to control the operating speed of an electrical system specially AC or DC motors. By using AC drives, one can change the rotating speed of the motor torque, or the direction of rotation.

AC Drive in Our Daily Life

An AC drive has a special place in modern electrical and electronic equipment. They have a better interfacing menu, which helps a person in operating the AC drive easily.

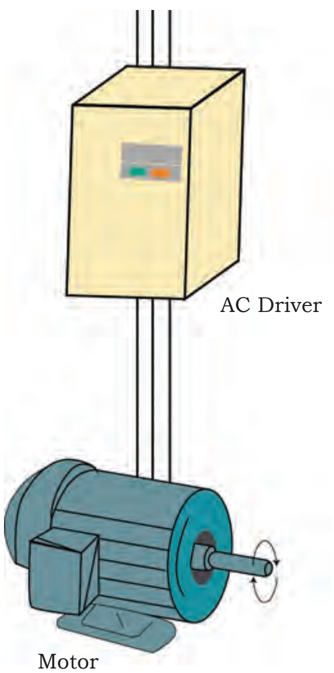

Fig. 7.1: AC motor control by AC driver

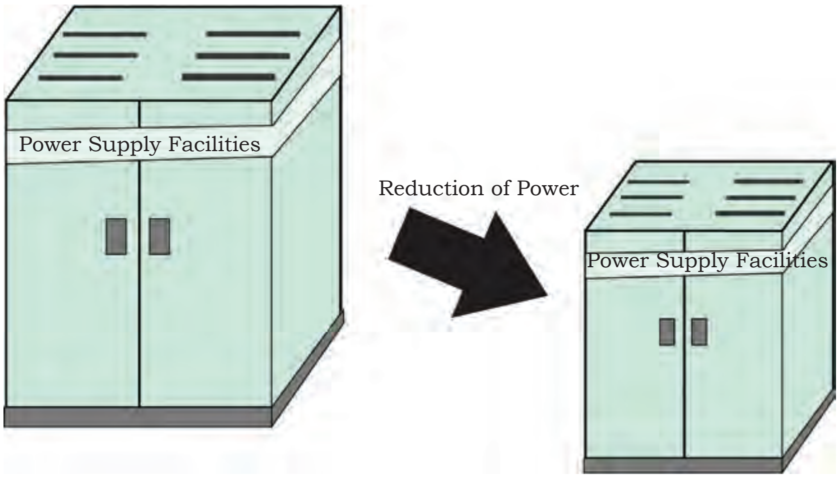

Fig. 7.2: Analogy for minimisation of power

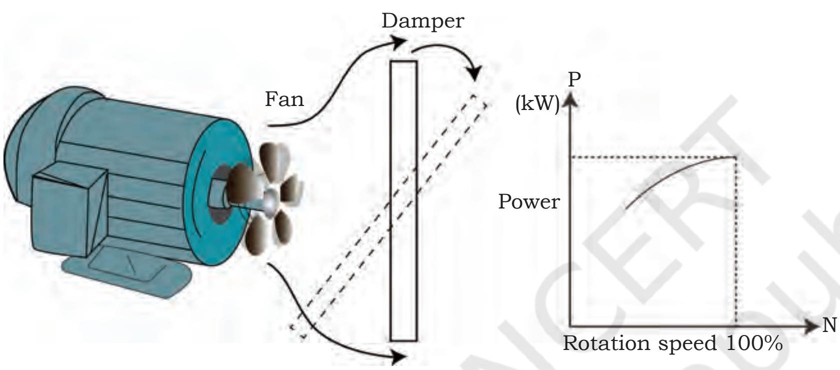

Fig. 7.3: Motor without AC drive

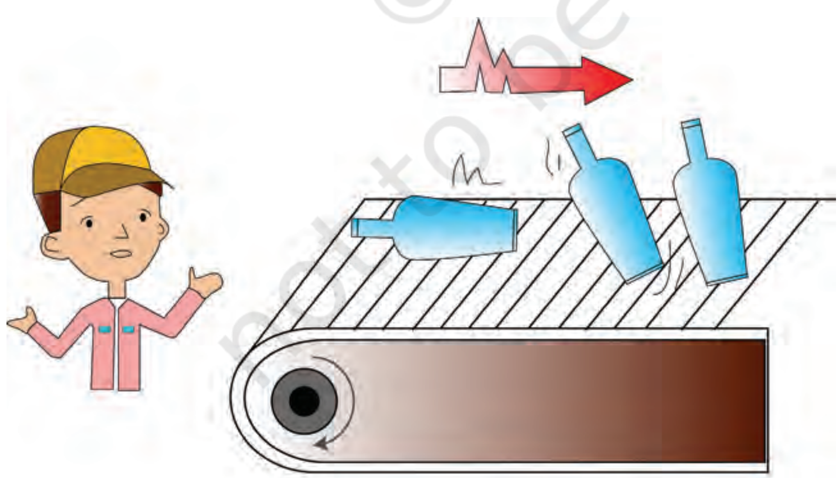

Fig. 7.4: Conveyor without motor drive

AC drives can minimise power supply requirement, as the input power to the AC motor is properly utilised to generate maximum power through it.

The following comparison can illustrate the role of an AC drive in the manufacturing system.

Manufacturing Unit without AC Drive

In some places, there is a requirement to maintain airflow to cool heavy machines. The speed of an electric motor cannot vary without any drive. By using a damper (on-off valve), airflow can be regulated (Fig. 7.3). Airflow can be reduced by using a damper but electricity consumption will remain the same.

Fig. 7.4 shows that the bottles fall from the conveyor if the speed of the conveyor is not maintained.

Manufacturing Unit with AC Drive

By using a motor drive, motor speed can vary easily. An AC drive acts as an electrical and electronic control unit between the power supply and motor as shown in Fig. 7.5. By using AC drives, electric energy can be saved.

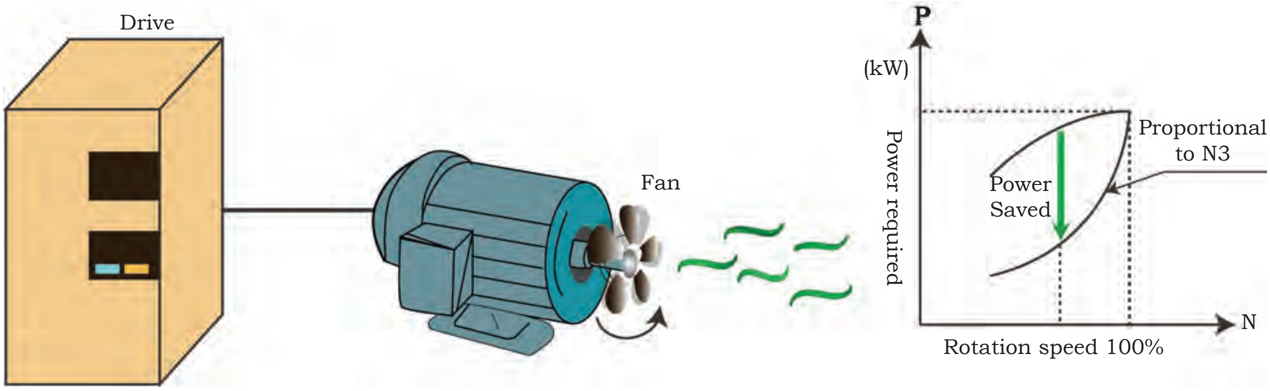

Fig. 7.5: Motor with AC drive

Fig. 7.6 shows that an AC drive can assist in a manufacturing unit. It helps to maintain the speed of a conveyor.

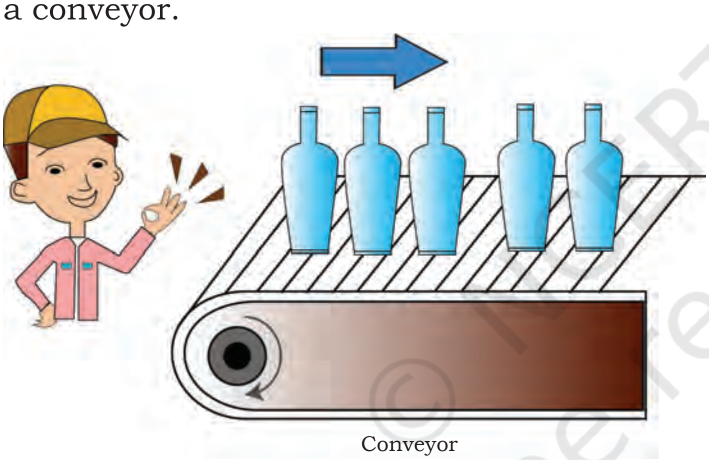

Fig. 7.6: Conveyor with a motor drive

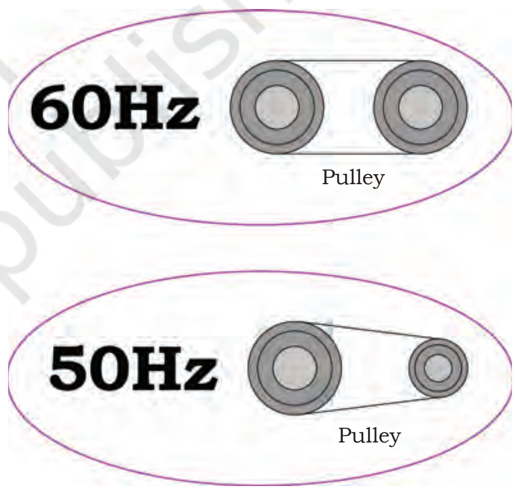

Fig. 7.7: Pulleys adjust speed if there is no motor drive

Without AC Drives

If AC drives are not used, it will be hard to adjust the frequency or speed of motor. To adjust the speed of the motor or frequency, bulky pulleys need to be installed as shown in Fig. 7.7.

With AC Drives

Fig. 7.8 shows that an AC drive can be used to control the

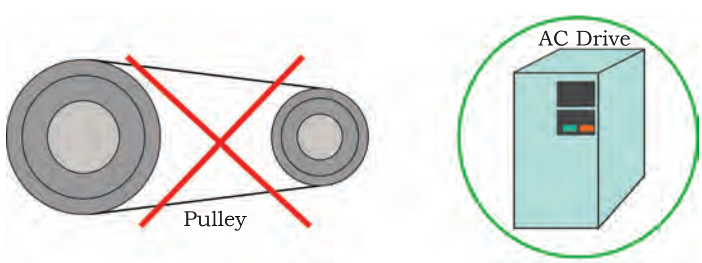

Fig. 7.8: AC drives can be used to adjust frequency

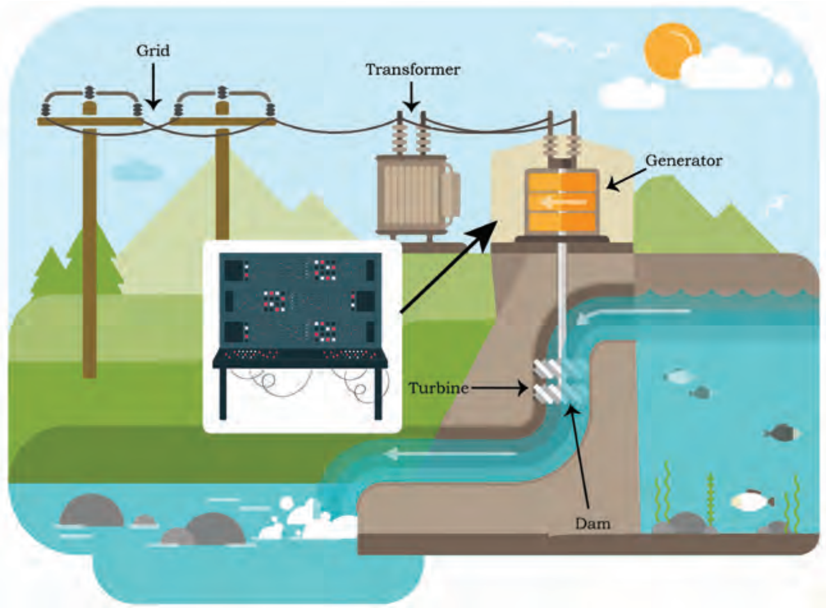

Fig. 7.9: At hydel power plants, drives are used to control the speed of turbine and generators

speed of the motor and the frequency over which it is operating.

Why Electrical Drives are Needed?

Adjustable speed drives are necessary for precise and continuous control of speed, position, or torque due to different loads. There are many other reasons too to use adjustable speed drives. Some of these are:

- To achieve high efficiency in the electrical system.
- To increase accuracy for stopping or reversing the operations of the motor.
- To control the starting current.
- To provide protection.
- To establish advanced control with variation of parameters like temperature and pressure.

Fig. 7.9 illustrates how the AC drives can be used in a power station.

The block diagram of an electric drive is shown in Fig. 7.10.

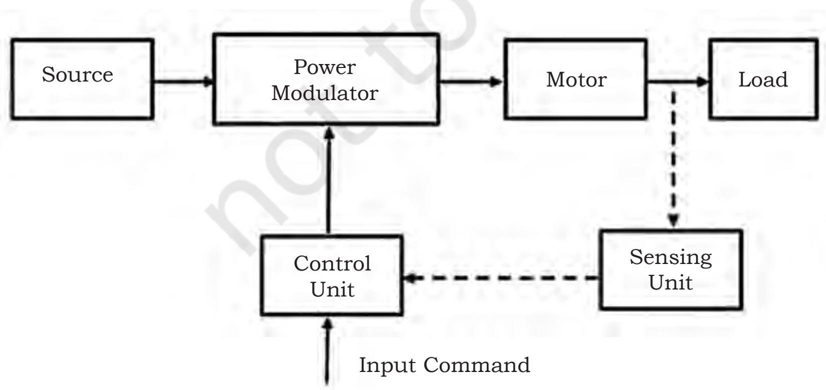

Fig. 7.10: Block diagram of AC electric drive

Parts of Electrical Drive

The main parts of an electrical drive are power modulator, motor, controlling unit and sensing units. These parts are explained below in detail.

Power modulator regulates the output power of the source.

It controls the power from the source to the motor. The power modulator converts energy according to the requirement of the motor. For example, if the source is DC and an induction motor is used then power modulator converts DC into AC.

Control unit controls the power modulator, which operates at small voltage and power levels. The control unit also operates the power modulator as desired. It also generates the commands for the protection of the power modulator and motor.

Sensing unit senses certain drive parameters like the motor current and speed. It is mainly required either for protection or for closed loop operation.

Application of Electric Drive

It is used in a large number of industrial and domestic applications like transportation systems, rolling mills, paper machines, textile mills, machine tools, fans, pumps, robots and washing machine.

A variable speed drive used to control DC motors are known as DC drives and a variable speed drive used to control AC motors are called AC drives.

Classification of AC Drives

AC drives are used to drive the AC motor especially three phase induction motors because these are predominant over other motors in most of the industries. In industrial terms, an AC drive is also called variable frequency drive (VFD), variable speed drive (VSD) or adjustable speed drive (ASD).

Principle of Variable Frequency Drives (VFD)

Though there are different types of VFDs (or AC drives), all of them work on same principle, which is converting fixed incoming voltage and frequency into variable voltage

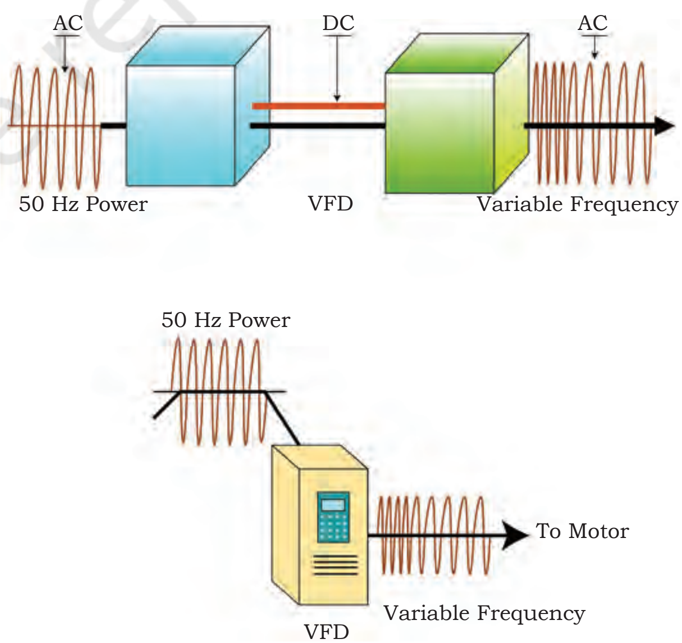

Fig. 7.11: Variable frequency drives

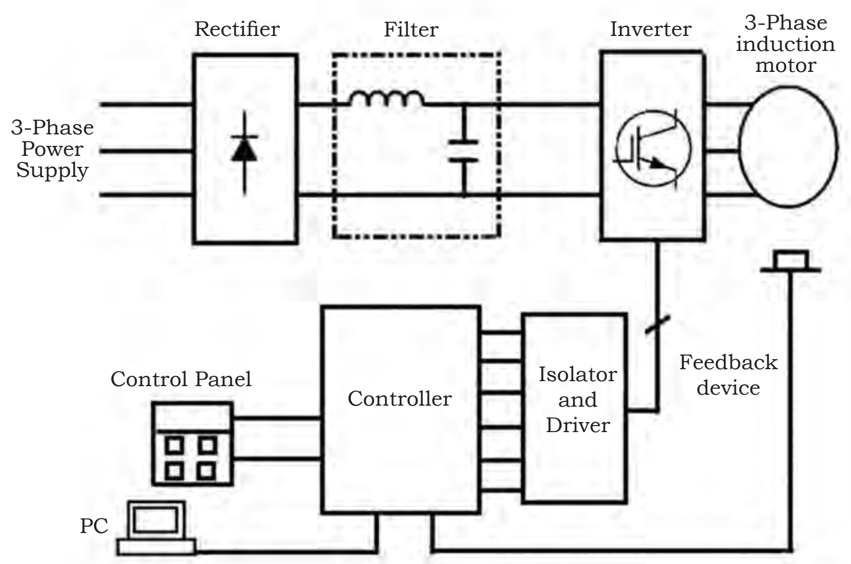

Fig. 7.12: Block diagram of variable frequency drives

and frequency output as shown in Fig. 7.11. The frequency of the drive determines how fast the motor can run. The combination of voltage and frequency decides the amount of torque that the motor can generate.

A VFD is made of power electronic converters, filter, a central control unit, a microprocessor or microcontroller and other sensing devices. The block diagram of a typical VFD is shown in Fig. 7.12. The different stages of a VFD, such as drive outputs, motor and output are shown in Fig. 7.13.

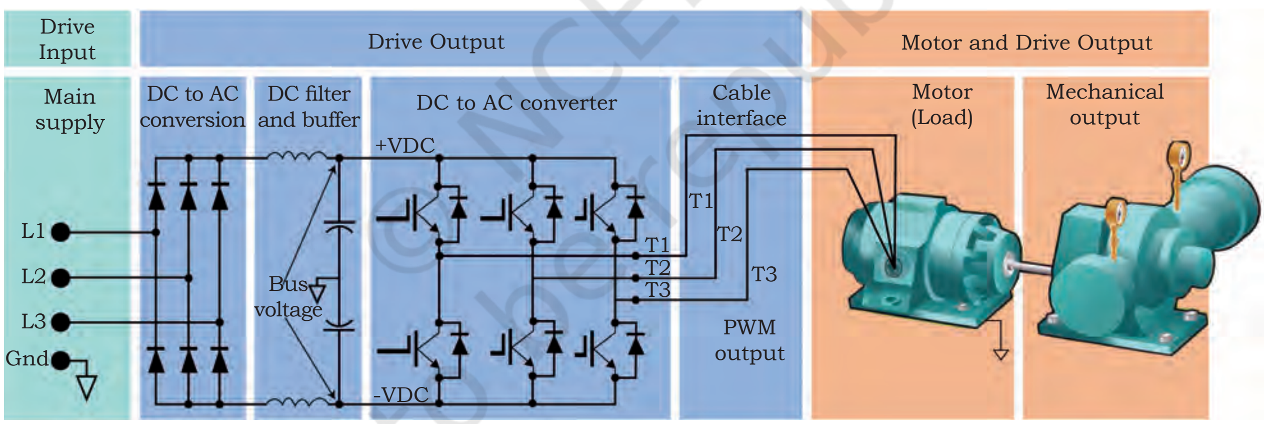

Fig. 7.13: Stages of variable frequency drives

Rectifier converts AC power into DC power with negligible ripples.

Full Wave Centre Tapped Rectifier

The process of converting AC power into DC power is called rectification. It can be achieved by using a single diode or a group of diodes.

Definition of Full Wave Rectifier

A full wave rectifier converts both half cycles of the AC signal into a pulsating DC signal.

As shown in Fig. 7.14, the full wave rectifier converts both positive and negative half cycles of the input AC signal into output pulsating DC signal.

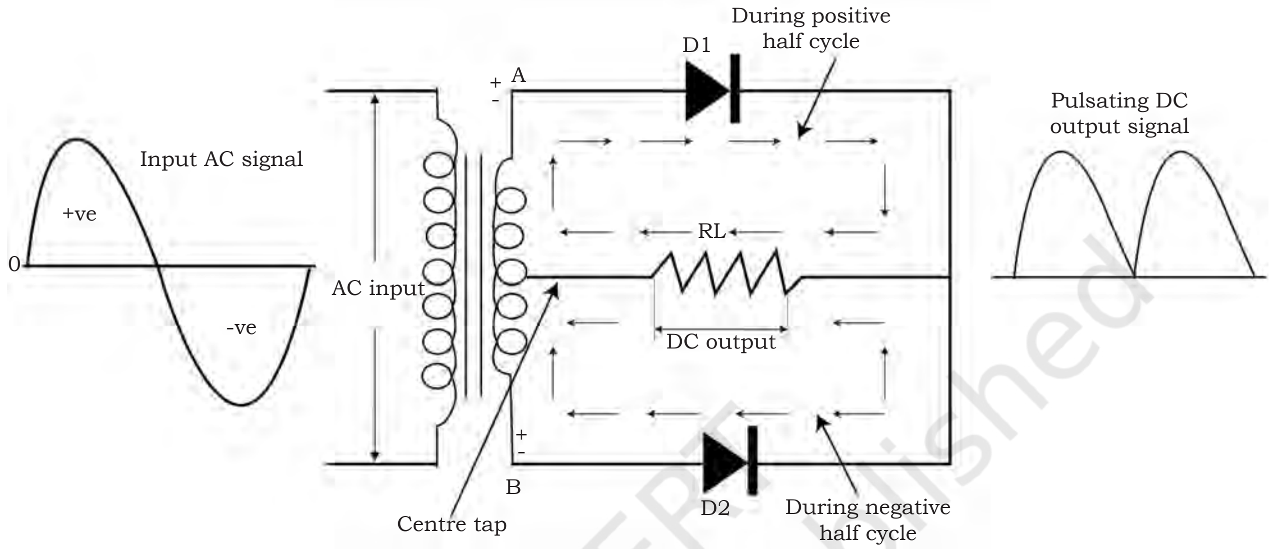

Fig. 7.14: Centre-tapped full wave rectifier

Centre Tapped Transformer

When an additional wire is connected across the middle of the secondary winding of a transformer, it is known as a centre tapped transformer.

A centre tapped transformer has another important feature. The secondary winding of the centre tapped transformer divides the input AC power or AC signal (VP) into two parts.

Voltages V1 and V2 are equal in magnitude but opposite in direction. That is, the voltages (V1 and V2) produced by the upper and lower part of the secondary winding are 180 degrees out of phase with each other.

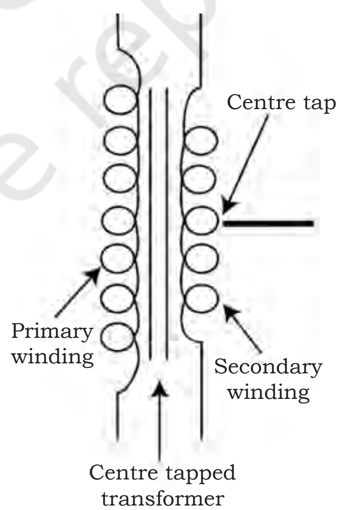

Fig. 7.15: Diagram of Centre Tapped Transformer

Fig. 7.16: Centre Tapped Transformer

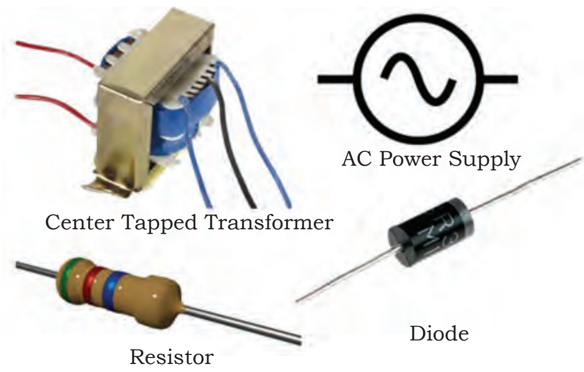

Fig. 7.17: Components of a full wave rectifier

Components of a Centre Tapped Rectifier

The centre tapped full wave rectifier is made of an AC source, a centre tapped transformer, two diodes and a load resistor as shown in Fig. 7.17.

The AC source is connected to the primary winding of the centre tapped transformer. A centre tap (additional wire) connected in the middle of the secondary winding divides the input voltage into two parts as shown in Fig. 7.18.

How a Centre Tapped Full Wave Rectifier Works

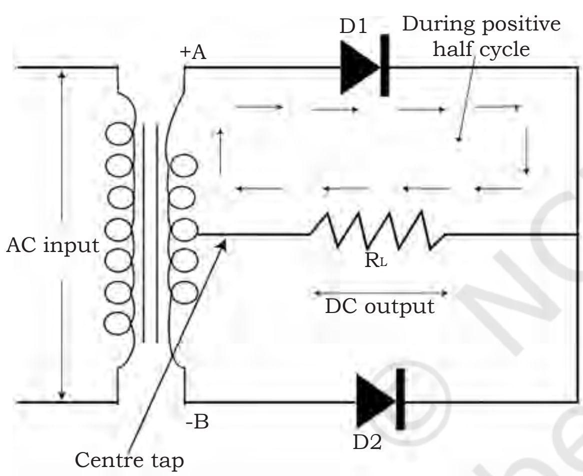

Fig. 7.18: Operation during positive half cycle

When input AC voltage is applied to the primary winding, it is then step down by the secondary winding of the centre tapped transformer. This secondary voltage is divided into two parts: positive and negative.

During the positive half cycle of the input AC signal, terminal A becomes positive, terminal B becomes negative and centre tap is grounded (zero volts). Positive terminal A is connected to the p-side of diode D1 and negative terminal B is connected to the n-side of diode D1 as shown in Fig. 7.18. Therefore, diode D1 is forward biased during the positive half cycle and allows electric current through it.

On the other hand, negative terminal B is connected to the p-side of diode D2 and positive terminal A is connected to the n-side of diode D2 as shown in Fig. 7.18. Therefore, diode D2 is reverse biased during the positive half cycle.

During the negative half cycle of the input AC signal, terminal A becomes negative, terminal B becomes positive and centre tap is grounded (zero volts). Negative terminal A is connected to the p-side of diode

D1 and positive terminal B is connected to the n-side of diode D1 as shown in Fig. 7.19. Therefore, diode D1 is reverse biased during the negative half cycle and does not allow electric current through it.

On the other hand, positive terminal B is connected to the P-side of diode D2 and negative terminal A is connected to the N-side of diode D2 as shown in Fig. 7.19. Therefore, diode D2 is forward biased during the negative half cycle and allows electric current through it.

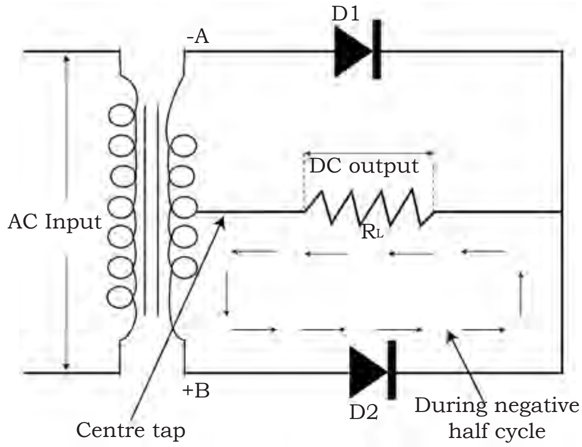

Fig. 7.19: Operation during negative half cycle

Thus, diode D1 allows electric current during the positive half cycle and diode D2 allows electric current during the negative half cycle of the input AC signal. As a result, both half cycles (positive and negative) of the input AC signal are allowed. Therefore, the output DC voltage is almost equal to the input AC voltage as shown in Fig. 7.20.

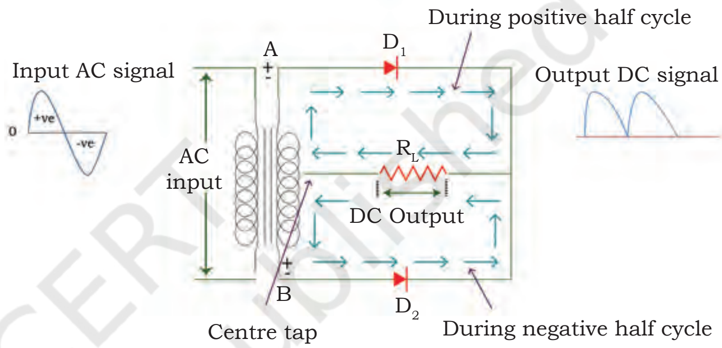

Fig. 7.20: Input and output waveform of full wave rectifier

Filter section then removes ripples and produces the fixed DC from pulsating DC.

Capacitor Filter

The output of a centre tapped full wave rectifier is pulsating DC as shown in Fig. 7.20. Pulsating means that the output is not constant or smooth. To smoothen the pulsating output, use filters as shown in Fig. 7.21.

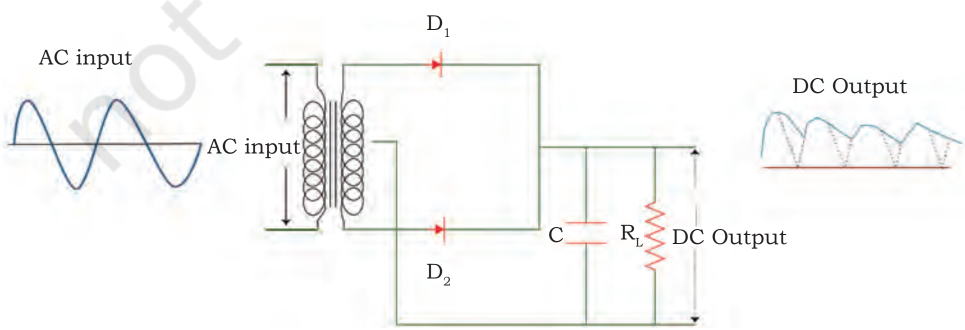

Fig. 7.21: Full wave rectifier with capacitor filter

Filter is made of capacitor and resistor as shown in Fig. 7.22. This filter is known as resistor capacitor (RC) filter.

The charging and discharging time of the capacitor is different. The charging time of the capacitor is less compared to the discharging time of the capacitor. The output of the rectifier is pulsating DC voltage. The rising edge of the pulsating DC output will charge the capacitor. In addition, the falling edge of the pulsating DC will discharge the capacitor. Due to the low charging time and the high discharging time of the capacitor, the output voltage will be smooth. Fig. 7.23 shows the charging and discharging part in the DC output waveform. The output waveform shape is shown in Fig. 7.24.

Central controller is like the brain of the VFD. It controls and monitors the operation of the VFD. Inside the central controller, a microcontroller or microprocessor is used for controlling the operation.

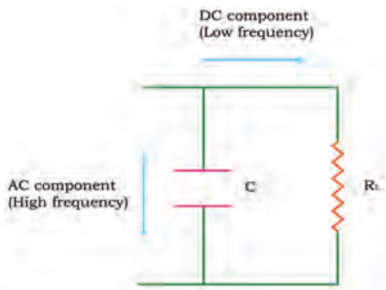

Fig. 7.22: Capacitor filter

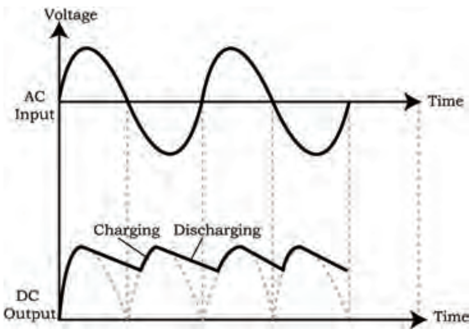

Fig. 7.23: Smooth output waveform of the rectifier using filter

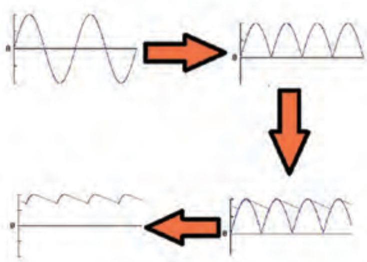
Fig. 7.24: AC signal voltage being converted into pulsating DC and then filtered


Fig. 7.25: Microcontroller

LED Panel of VFD

The indicator and operation of an LED panel are described below to set parameters and monitor the VFD, as shown in Fig. 7.26.

Control Schemes of VFD

There are different speed control techniques implemented for variable frequency drives. The major classification of control techniques used in modern VFDs is given below.

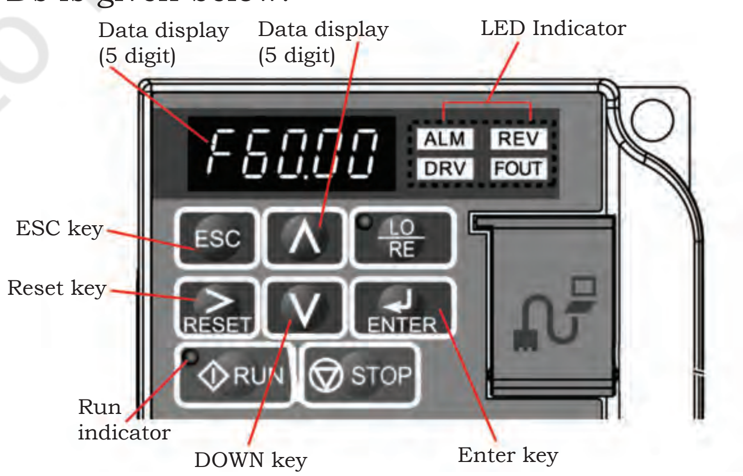

Fig. 7.26: LED panel display of VFD

- Scalar Control
- Vector Control
- Direct Torque Control

The speed of a conveyor can be controlled by using AC drives, for instance, a machine, which operates at different speeds using an AC drive. For example, a conveyor may have bottles bunched close together for filling and then spread out for labelling. For this, two motors and two drives would be required. One motor to run the filling section at a given speed and a second motor to run the labelling section slightly faster, spreading the bottles out. This action can be precisely executed by an AC drive.

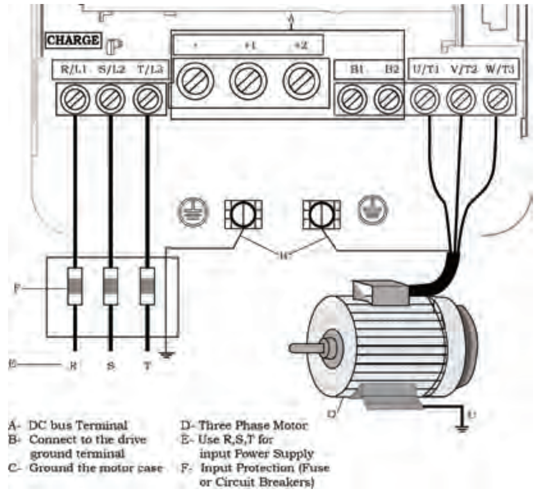

Fig. 7.27: Terminal connectivity of VFD

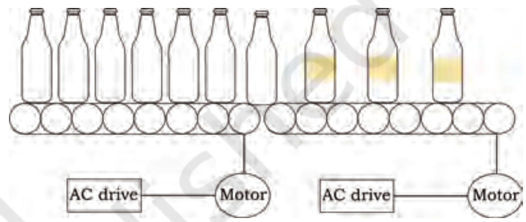

Fig. 7.28: Bottle conveyor machine

Soft Starter

In technical terms, a soft starter is any device that reduces the torque applied to an electric motor. It generally consists of solid state devices like thyristors to control the application of supply voltage to the motor. The starter works on the premise that the torque is proportional to the square of the starting current, which in turn is proportional to the applied voltage. Thus, the torque and current can be adjusted by reducing the voltage at the time of starting the motor. Fig. 7.29 shows a soft starter.

Fig. 7.29: Soft starter used for smooth start of a motor

Point to Remember
Failure to follow these instructions can result in malfunction or damage to the soft starter.
Failure to follow these instructions can result in serious injury to the user and serious damage to the soft starter.

Panel Description

Fig. 7.30 describes the functionality of a panel.

Point to Remember
Make sure all safety measures are taken before starting the motor to avoid personal injury.
Never operate the soft starter with the front cover removed.
Make sure all safety measures are taken before switching on the power supply.

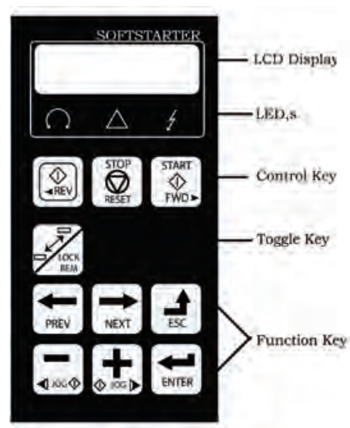

Fig. 7.30: Panel description of VFD

Fig. 7.31: Silicon control rectifier

Power SCR

SCR or silicon controlled rectifier is a three-pin device, with three basic terminals – anode, cathode and gate. SCR has four layers. The gate terminal is the control terminal when external voltage is applied across the anode-cathode voltage. Fig. 7.31 shows a silicon control rectifier.

Fig. 7.32 shows that an equivalent circuit of SCR can be formed by dividing the SCR as PNP and NPN transistor. The transistor types have been discussed in the Class XI textbook.

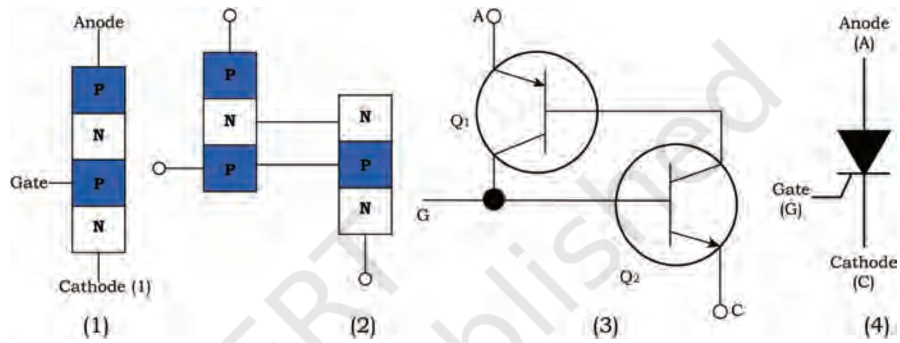

Fig. 7.32: (1) Structure of SCR, (2) Symbol of SCR, (3) Equivalent circuit of SCR and (4) Equivalent circuit of SCR

SCR Firing

In the case of SCR, the word 'firing' defines the sudden discharge of electrons.

This discharge can be controlled by applying voltage at the gate terminal.

As SCR is used as a switch, applying appropriate voltage at the gate terminal will turn 'ON' the SCR.

Note: SCR are electronic devices used in power electronics.

LCD Display Description

Fig. 7.33 describes the functionalities of LCD display.

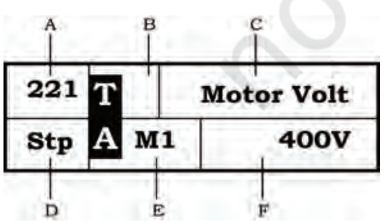

Fig. 7.33: LCD display of VFD

Table 1: Description of LCD display

Area A	Shows menu number
Area B	Shows whether menu is in toggle mode (T) or in local mode (L)
Area C	Shows the abbreviated name of the active menu
Area D	Shows the status of the soft starter.

	The following status indications are possible: Acc: Motor starting Dec: Motor stopping I2t: Active I2t motor protection Run: Motor runs at full speed Jog: Motor runs at jog (average or gentle) speed Trip: Tripped Stp: Motor has stopped
Area E	Shows active parameter set: A, B, C, or D; and if it is a motor parameter: M1, M2, M3, or M4
Area F	Shows the setting or selection in the active menu. Shows warnings and alarm messages.

LED Indicators Description

The three light emitting diodes in Fig. 7.34 indicate the status of the soft starter and motor/machine. Depending on the operating mode, the TRIP and RUN indicators will also flash to alert the user about a coming event or action.

Fig. 7.34: Symbolic representation of LED light

Table 2: LED indication

LED symbol	**Status**			
	ON	NORMAL FLASHING (2 Hz)*	SLOW FLASHING (1Hz)*	OFF
Power (green)	Main supply power ON			Power off
Trip (red)	Soft starter tripped	Warning	Awaiting auto reset	No trip
Run (green)	Running at full load	Start and stop ramp		Soft starter not active
*Frequency: 1Hz = 1 flash per second, 2Hz = 2 flash per second				

Control Key Description

	START REVERSE RUN	Start the motor with reversed (left) rotation. It requires reversing contactor.
	STOP/RESET	Stop motor. Reset soft starter after trip.

	START FORWARD RUN	Start the motor with forward (right) rotation.

Function Keys

	ENTER	Step to lower menu level. Confirm a changed setting.
	ESCAPE	Step to higher menu level. Ignore a changed setting
	PREVIOUS	Step to previous menu within the same level. Move cursor one position to the left.
	NEXT	Step to next menu within the same level. Move cursor one position to the right.
	(-) MINUS or JOG REV	Decrease a value. Change a selection. Or Start reverse jog function.
	(+) PLUS or JOG FWD	Increase a value. Change a selection. Or Start forward jog function.

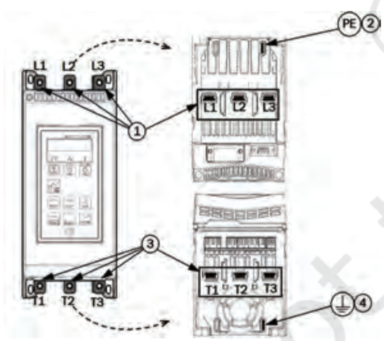

Fig. 7.35: Supply and motor connection

Mains and Motor Connections

1. Three-phase mains supply connection, L1, L2, L3.
2. Protective earth (PE) connection for mains supply.
3. Motor power supply connection T1, T2, T3.
4. Motor earth, connection (Fig. 7.35).

Check Your Progress

A. Multiple choice questions

1. Which of these is not the role of an electric drive in an electrical system?
   (a) control speed, position, or torque of different loads
   (b) control position
   (c) control torque of different loads
   (d) circuit breaking

2. Which of the following is not the control key on the VFD panel?
   (a) Start reverse run
   (b) Stop/Reset
   (c) Start forward run
   (d) Forward-reverse run
3. Which of the following is not a function key on the VFD panel?
   (a) Enter
   (b) Escape
   (c) Previous
   (d) Numlock
4. In bridge rectifier the output will be in the form of ___________.
   (a) AC
   (b) DC
   (c) Pulsating DC
   (d) Square waveform
5. VFD stands for _____________.
   (a) Variety frequency drive
   (b) Variation fault detection
   (c) Variation frequency detection
   (d) Variable frequency drive
6. Which of the following components is not in the VFD?
   (a) Power electronic converters
   (b) Filter
   (c) Central control unit
   (d) RAM
7. Bridge full wave rectifier contains _____________.
   (a) one diode
   (b) two diodes
   (c) three diodes
   (d) four diodes
8. The role of a capacitor filter in the rectifier is to ________.
   (a) convert AC to DC
   (b) remove the noise
   (c) remove the DC components in the signal
   (d) smoothen the pulsating DC into pure DC
9. Which of the following is not the control scheme of the VFD?
   (a) Scalar control
   (b) Vector control
   (c) Direct torque control
   (d) Indirect torque control
10. Which of the following is not the symbolic representation of LED light?
   (a) Trip
   (b) Power
   (c) Run
   (d) Stop

NOTES

Notes

B. Fill in the blanks

1. When an additional wire is connected across the middle of the secondary winding of a transformer, it is known as a _____________.
2. The output of a centre tapped full wave rectifier is _____________.
3. Filter is made up of _____________ and _____________.
4. In VFD central controller, _____________ are used to control the operation.
5. The schemes of VFD control are __________, __________ and ___________.

C. State whether the following statements are True or False

1. By using AC drives, one can change the rotating speed of the motor.
2. Power modulator converts energy according to the requirement of the motor.
3. Centre tapped transformer is used in full wave rectifier.
4. Rectifier converts AC power into DC power with negligible ripples.
5. In filter, charging time of the capacitor is less compared to the discharging time of the capacitor.

D. Short answer questions

1. What is an AC drive?
2. List out the areas where AC drives are used.
3. What is silicon control rectifier?
4. What is the role of a soft starter in the electrical system?
5. What are the advantages of using AC drives in the electrical system?
6. How is variable frequency control used to adjust the frequency of the voltage supply?
7. What is rectification? Explain the centre tapped full wave rectifier.
8. What do you understand by the term centre tapped?
9. List out the keys that are used in a VFD panel.
10. What are the control schemes of the VFD?

Chapter 8

Electrical Machines

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Introduction

Electrical distribution system is a large network that is generated, transmitted and distributed to different residential, commercial and industrial areas. The majority of these systems rely upon generators, transmission towers, starters and protecting devices. These systems are the backbone of an electrical system. In this chapter, you will learn about the motor, generator and starter.

Generator

As shown in Fig. 8.1, a generator transforms mechanical energy into electrical energy. Mechanical force is applied on the axle of generator. This mechanical force generated by falling of water, steam or wind, is used to rotate the shaft or axle on which the armature or rotor is formed. For example, a turbine (water wheel) that uses falling water to rotate the shaft of an electric generator.

Fig. 8.1: Electrical generator

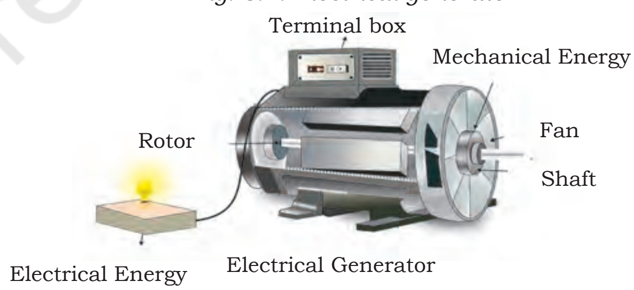

Fig. 8.2: Electrical generator converting mechanical energy into electrical energy

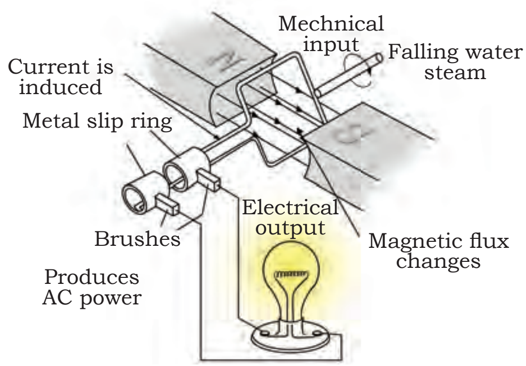

Fig. 8.3: Setup of a generator

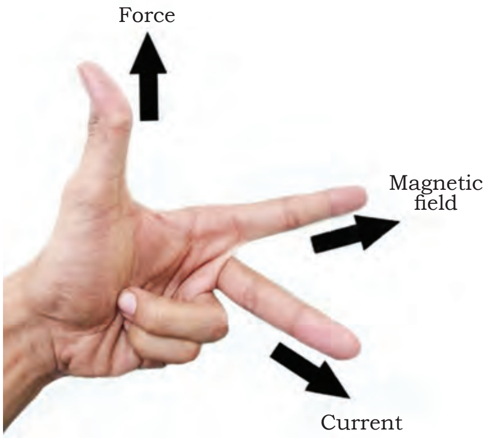

Fig. 8.4: Fleming's left hand rule used in the operation of a motor

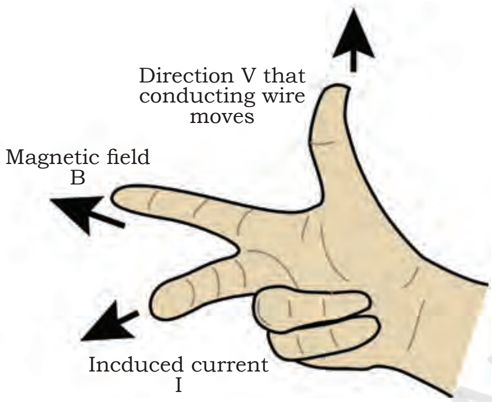

Fig. 8.5: Fleming's right hand rule used in the operation of a generator

Fleming's Left Hand Rule

When we stretch our left hand as shown in Fig. 8.4, then the forefinger, middle finger and thumb are perpendicular to each other. The forefinger represents the magnetic field, the middle finger represents the direction of current and the thumb represents the direction of force. It applies on the electric motor.

Fleming's Right Hand Rule

When we stretch our right hand as shown in Fig. 8.5, then, like the left hand, the forefinger, middle finger and thumb are perpendicular to each other. Here the forefinger represents the magnetic field, the middle finger represents the direction of current and the thumb represents the direction of force. It applies on the electric generator.

An electromagnet is an artificial magnet. When electrical material like a wire is wound around the magnetic material, and current passes through the wire, it produces a magnetic field along the magnetic material. This phenomenon is due to the magnetic effect of current. Field windings are used to produce magnetic field in a generator or motor. Magnetic field can be provided by magnets or by electromagnets. Mostly, electromagnets generate the magnetic field in AC generators. Electromagnets are supplied with an external current to keep the magnetic field at its desired magnetic strength.

Types of Generator

Generators are of two types—AC generator and DC generator.

AC Generator

AC generator is also known as an alternator. It is an electrical machine that generates AC voltage. It can be further classified as a single-phase AC generator, and a three-phase AC generator.

Working of an Alternator or AC Generator

According to the Faraday's Law of Electromagnetic Induction, whenever a conductor moves in a magnetic field, an electromotive force is induced across the conductor. If a closed path is provided to the conductor, induced electromotive force causes current to flow in the circuit, as shown in Fig. 8.6.

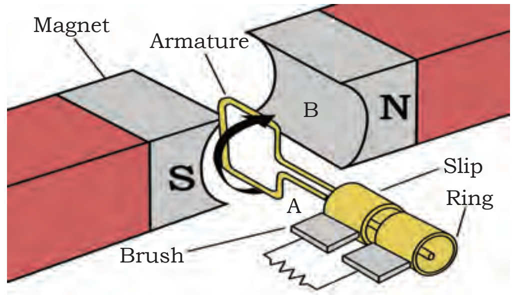

Fig. 8.6: Setup of an AC generator

Place the conductor coil, ABCD, in a magnetic field, as shown in Fig. 8.7. The direction of the magnetic flux will be from N pole to S pole. The coil is connected to slip rings, and the load is connected through brushes resting on the slip rings.

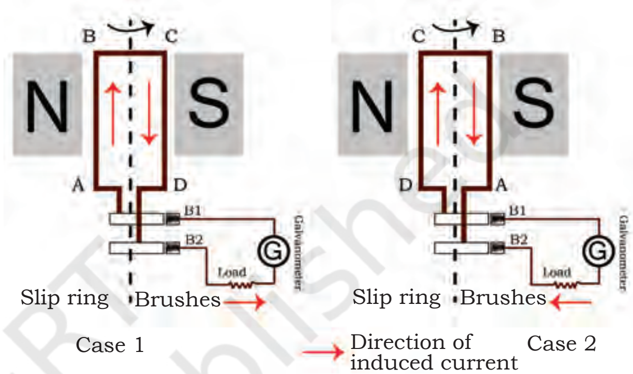

Fig. 8.7: The two cases that show the operation of an AC generator

In Case 1 (Fig. 8.7), the coil is rotating clockwise. In this case, the direction of induced current can be given by Fleming's right hand rule, and it will be along A-B-C-D. As the coil is rotating clockwise, after half time, the position of the coil will become as shown in Case 2 in Fig. 8.7. In Case 2, the direction of the induced current will be DCBA according to Fleming's right hand rule. It shows that, the direction of the current changes after half-time, which means we get an alternating current.

DC Generator

DC generator is an electrical machine that generates DC voltage. According to Faraday’s Law of Electromagnetic Induction, whenever a conductor is placed in a varying magnetic field or a conductor is moved in a magnetic field, an emf gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of a DC generator. If the conductor is provided with a closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. Fleming’s right-hand rule gives the direction of induced current. Fig. 8.8 shows pulsating DC on commutator output.

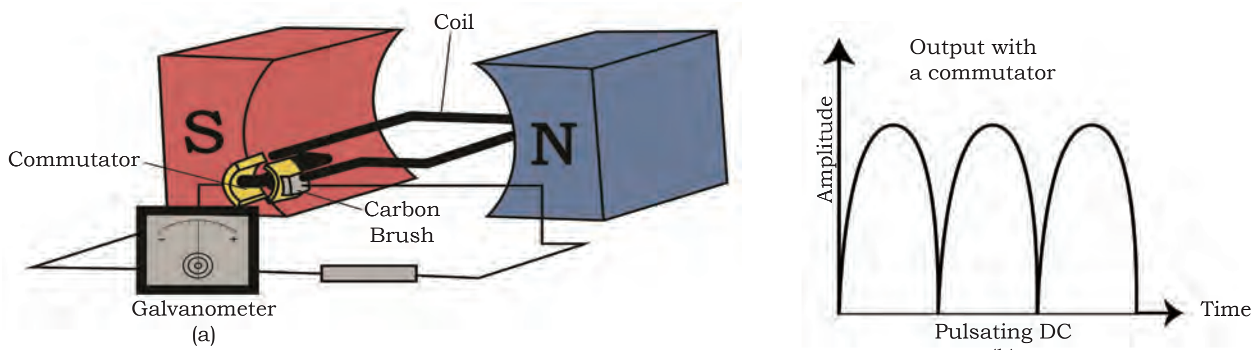

Fig. 8.8: (a) Set up of DC Generator (b) Pulsating DC

In an AC generator, current is collected by using a slip ring. While in a DC generator, current is collected by a split ring.

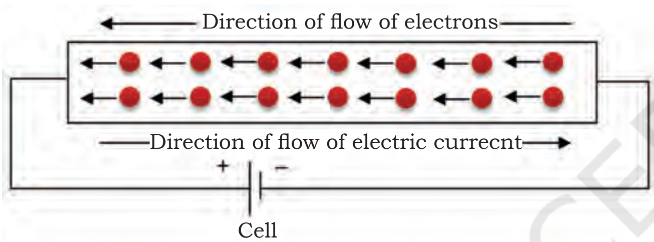

Fig. 8.9: Electromotive force exerted by external voltage

Electromotive force is an electrical force that is exerted on the electrons. This force is responsible for the movement of electrons (Fig. 8.9).

Armature is the rotating part of a motor or generator. Conductors are wound into the armature slots. The axle on which the armature is formed is known as a shaft. An armature (coil) is the movable coil of wire that rotates through a magnetic field. An armature (coil) may consist of many coils similar to the armature in a DC generator.

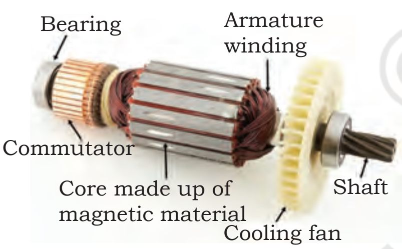

Fig. 8.10: Motor armature

A brush is a stationary or fixed part of a generator used for collecting current, which is produced due to induced electromagnetic force. Brushes in an AC generator are the sliding contacts that ride against slip rings and are used to connect the armature to the external AC circuit.

Key Concepts

Slip ring (associated with AC machines) is like a finger ring that maintains contact with carbon brushes. A slip ring can be compared with a vehicle tyre, and how it maintains contact with the road while moving. A slip ring too maintains contact with carbon brushes in the same way. The purpose of a slip ring is to collect power from an AC generator or to give power to an AC motor.

Split ring (associated with DC machines) is a half ring like the brake shoes of drum brakes. The purpose of a split ring is to convert AC to DC and provide DC supply to a DC generator and to convert DC to AC and provide AC supply to a DC motor.

Note: DC cannot be generated using Faraday's Law of Electromagnetic Induction and Lenz's law. It can only be transformed from AC to DC.

In case of a DC generator, AC is generated, and split rings/commutator helps transform generated AC to DC, and collect DC power.

In case of a DC motor, DC is supplied, and split rings/commutator helps transform supplied DC to AC. This AC further produces torque.

The differences between a DC and an AC generator are:

1. In an AC generator armature, the ends of the coil(s) are attached to slip rings.
2. In a DC generator armature, the ends of the coil(s) are attached to a commutator (split ring).

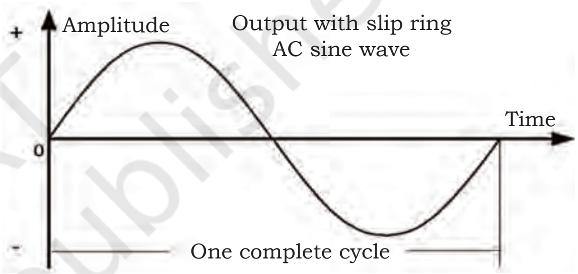

Fig. 8.11: One cycle of AC signal

Slip and split ring are metallic rings connected to the ends of armature coils(s) and are used to connect induced voltage to the brushes of the generators. When an armature is rotating in the magnetic field, voltage is generated in each half of the armature coil. This voltage is in the form of a sine wave as shown in Fig. 8.11.

Practical Activity 1

Demonstrate the working of an AC generator

Material required

AC generator, turbine

Procedure

1. Connect the shaft of the AC generator and turbine.
2. Use a mechanical force, which will exert force on the blades of the turbine. Let water fall on the blades of the turbine. This will rotate the shaft of the generator.
3. When the shaft of the generator rotates, action will begin inside the generator.

NOTES

The action is explained in the following points.

4. Consider a single coil of the AC generator which is 0 degree to the magnetic lines of flux as shown in Fig. a. In this case, no voltage will be induced in the coil, resulting in no current as no magnetic lines of force are cutting the conductor of coil.

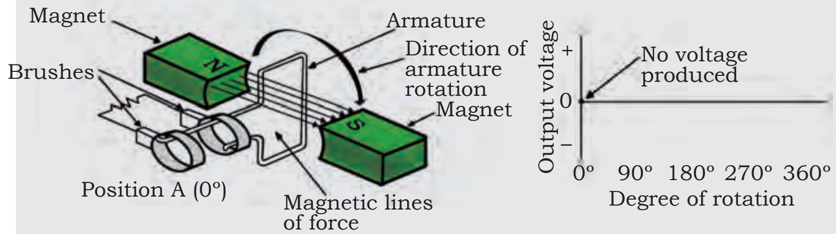

Fig. a

5. Now, a single coil of the AC generator is 90 degree to the magnetic lines of flux as shown in Fig. b. In this case, maximum voltage (positive half) will be induced in the coil, resulting in maximum current (negative half), as maximum magnetic lines of force are cutting the conductor of coil.

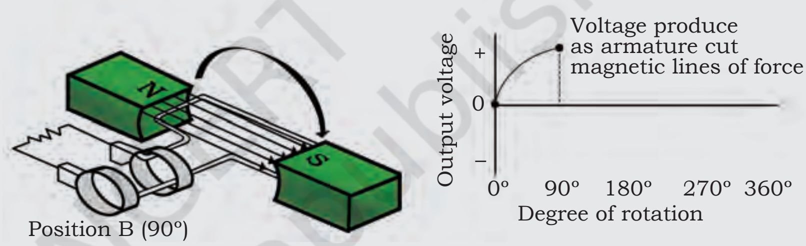

Fig. b

6. Now, a single coil of the AC generator is 180 degree to the magnetic lines of flux as shown in Fig. c. In this case, again no voltage will be induced in the coil, resulting in no current, as no magnetic lines of force are cutting the conductor of coil.

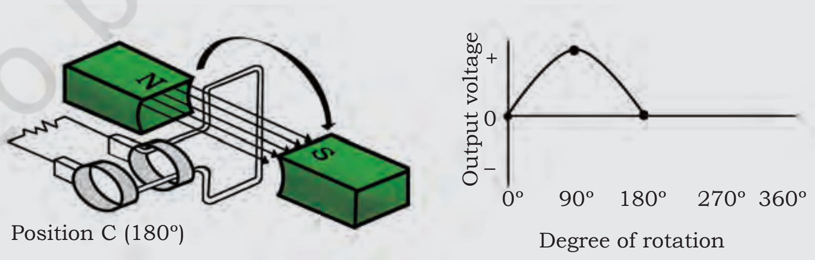

Fig. c

7. Now, a single coil of the AC generator is 270 degree to the magnetic lines of flux as shown in Fig. d. In this case, maximum voltage (positive half) will be induced in the coil, resulting in maximum current (negative half), as maximum magnetic lines of force are cutting the conductor of coil.

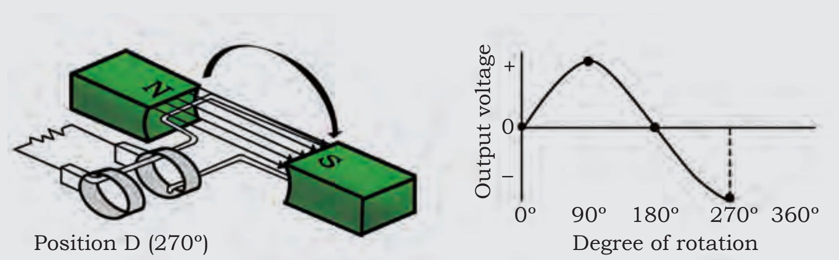

Fig. d

8. Now, a single coil of the AC generator is 360 degree to the magnetic lines of flux as shown in Fig. e. In this case, again no voltage will be induced in the coil, resulting in no current, as no magnetic lines of force are cutting the conductor of coil.

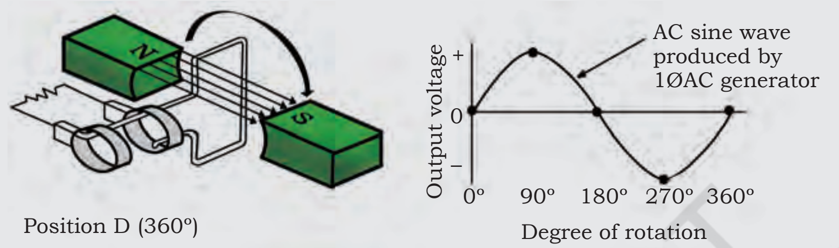

Fig. e

In DC generators, a commutator (split ring) is used to provide an output whose current always flows in the positive direction, as illustrated in Fig. 8.12.

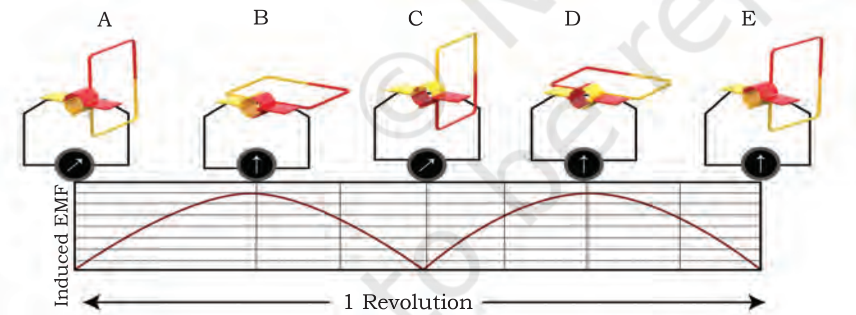

Fig. 8.12: A two piece slip ring, or commutator, allows brushes to transfer current that flows in a single direction (DC)

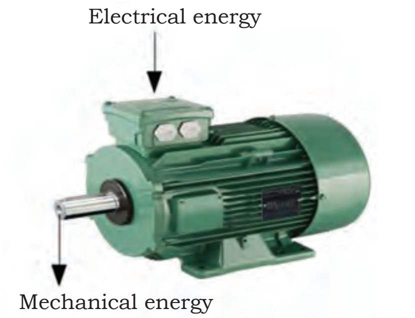

Fig. 8.13: Conversion of electrical energy into mechanical energy

Motor

An electric motor (Fig. 8.13) is a device that converts electrical energy into mechanical energy. This conversion is usually obtained through the generation of a magnetic field by means of current flowing into one or more coils. The cut section of the motor is shown in Fig. 8.14.

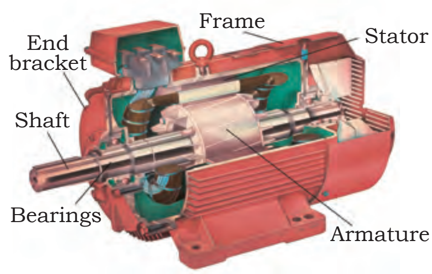

Fig. 8.14: Cut section of a motor

NOTES

Practical Exercises

Activity 1

Understand the principle of a simple DC motor

Material required

Small square piece of wood, small magnet (fridge magnet), wood glue, copper wire, knife and stapler, battery

Note: Commutator and brushes are not needed in this model

Procedure

1. The assembly of a motor begins from the winding of a coil of copper wire. The coil should have 10-16 turns. For winding, use a battery cell, as shown in Fig. a.

Fig. a: Copper wire winding

2. Tie the coil ends carefully, leaving them outwards as shown in Fig. b.

Fig. b: Tie the coil

3. Remove the insulation coating from the ends of the copper wire, as shown in Fig. c.

Fig. c: Remove insulation coating

4. Use rubber bands to attach safety pins and a magnet, as shown in Fig. d. Insert coil ends into the safety pin holes and the motor is ready.

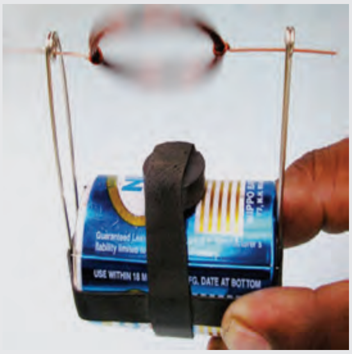

Fig. d: Place the coil between the loops and see the rotation of the coil

5. Hold another magnet on top of the rotating coil, as shown in Fig. e. This will control the rotational speed of the coil.

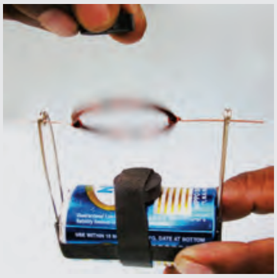

Fig. e: Hold a magnet on top of the coil and see speed change

Activity 2

Check an electric motor

Material required

Electric motor, oil, grease, screw driver

Procedure

1. Visually inspect the motor for the following problems, as shown in Fig. a:
    - Broken mounting holes or feet
    - Discoloured paint in the middle of the motor indicating excessive heat
    - Evidence of dirt and other foreign matter pulled into the motor windings through openings in the motor body

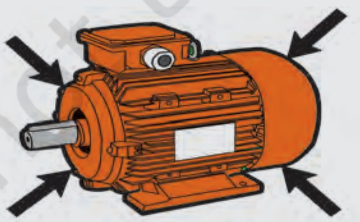

Fig. a: Visual inspection of the motor

2. Read the specifications of the motor from the plate affixed on the motor body called the 'stator' or 'frame', as shown in Fig. b.

Notes

3. Read and note the following information:
   - Manufacturer's name
   - Model and serial number
   - RPM — the number of revolutions the rotor makes in one minute
   - Horsepower — how much work it can perform
   - Wiring diagram — how to connect for different voltages, speeds and direction of rotation
   - Voltage — voltage and phase requirements
   - Current — amperage requirements
   - Frame style — physical dimensions and mounting pattern
   - Type — describes if the frame is open, drip proof, total enclosed fan cooled, etc.

Fig. b: Specification plate on the motor

4. Check if the bearing balls are moving smoothly or not. Bearings are located at both ends of the motor, as shown in Fig. c. Many electric motor failures are caused by bearing failures. The bearings allow the shaft or rotor assembly to turn freely and smoothly in the frame.

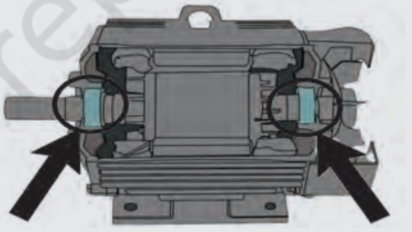

Fig. c: Bearing of the motors

5. Check whether the shaft is rotating smoothly or not, as shown in Fig. d. For this, place one hand on top of the motor, spin the shaft/rotor with the other hand. The rotor should spin quietly, freely and evenly.

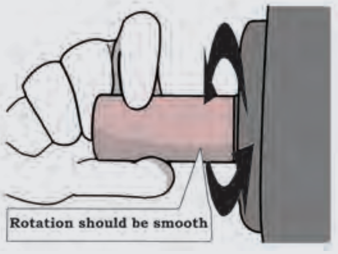

Fig. d: Rotation of the shaft/ armature/ rotor

6. Push and pull the shaft in and out of the frame, as shown in Fig. e. Observe the movement of the shaft. A small amount of movement is permissible. If the movement is severe, replace the rotor or armature.

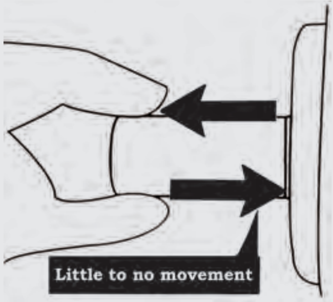

Fig. e: Push and pull the motor for any misalignment

7. Check whether the windings are shortened to the frame or not, as shown in Fig. f.

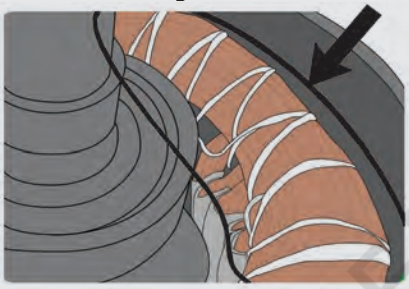

Fig. f: Winding shortened to the body

8. Check continuity of winding using a continuity tester, as shown in Fig. g.

Fig. g: Ensure that the winding is not open or blown

9. Test the capacitor or run motor. Use a continuity tester to check if the capacitor is working properly, as shown in Fig. h.

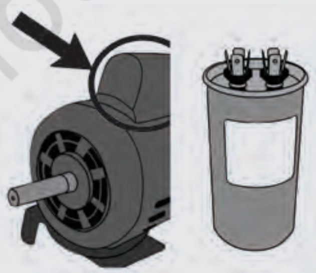

Fig. h: Capacitor in the motor to help it start safely

Notes

10. Observe the fan of the motor for dust and dirt. Check the blades of the fan for any damage, as shown in Fig. i.

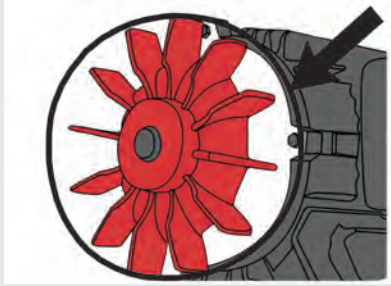

Fig. i: Fan in the motor for cooling

Types of Motors

Motors are classified based on the electric power supply they are using for their operation that is, AC or DC. Fig. 8.16 shows the various types of motors.

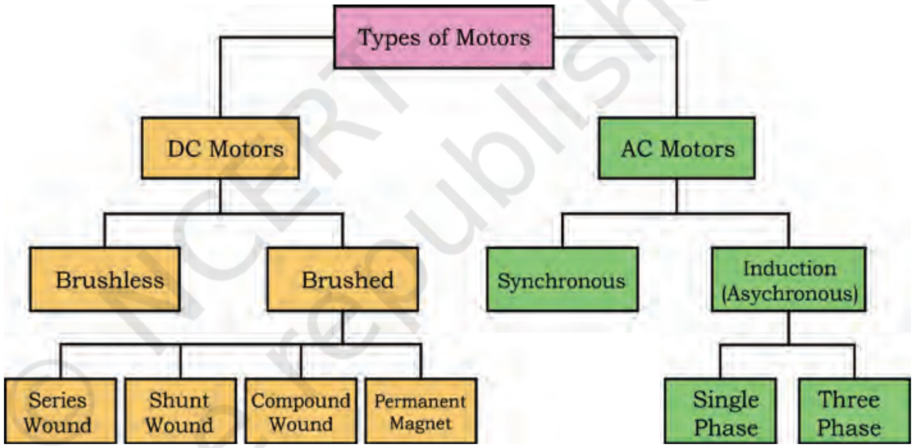

Fig. 8.15: Types of motors

DC Motor

DC motors require DC supply for their operation. It works on the principle that "when a current carrying conductor is placed in a magnetic field, it experiences a force". This rotating force is called torque. DC motors are classified as brushed DC motor, and brushless DC motor.

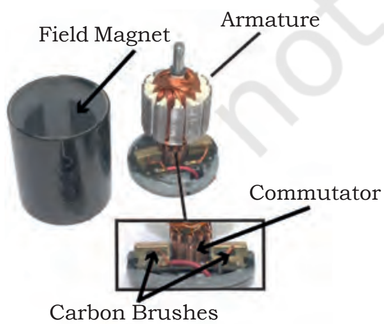

Fig. 8.16: Brushed DC motor

Brushed DC Motor

A brushed DC electric motor is an internally commutated electric motor designed to be run from a direct current power source.

Brushless DC Motor

In a brushless DC motor, the permanent magnets are fitted to the rotor, with the electromagnets on the stator.

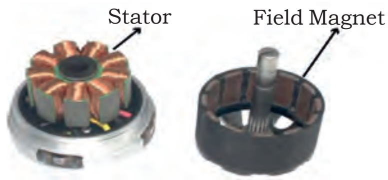

Fig. 8.17: Brushless DC motor

AC Motor

AC motors require AC supply for their operation. It works on the principle that "when a current carrying conductor is placed in a magnetic field, it experiences a force". This rotating force is called torque. AC motors are classified as synchronous motor, and asynchronous motor.

In synchronous motor, the rotating speed of the rotor is the same as the rotating speed of the magnetic field. For instance, if the magnetic field is rotating at a speed of 1000 rotations per minute (RPM) and the rotor is rotating at nearly equal, 998 rotations per minute (RPM), then the motor is said to be synchronised. A permanent magnet on the rotor of a synchronous motor is shown in Fig. 8.18.

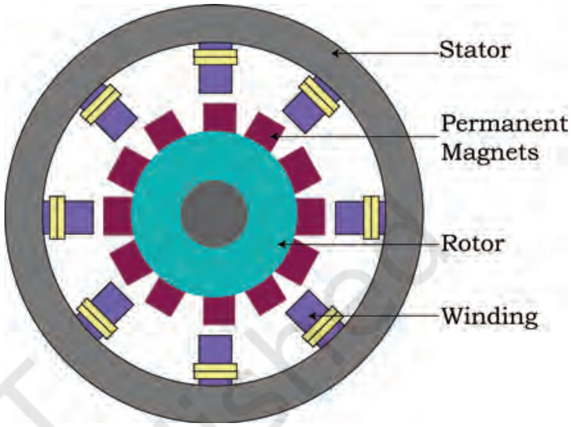

Fig. 8.18: Permanent magnet on rotor in synchronous motors

In asynchronous motor, the rotating speed of the rotor is less than the rotating speed of the magnetic field. For instance, if the magnetic field is rotating at a speed of 1000 rotations per minute (RPM) and the rotor is rotating at 800 rotations per minute (RPM), the motor is said to be asynchronised. An asynchronous motor is also known as an induction motor, as shown in Fig. 8.19.

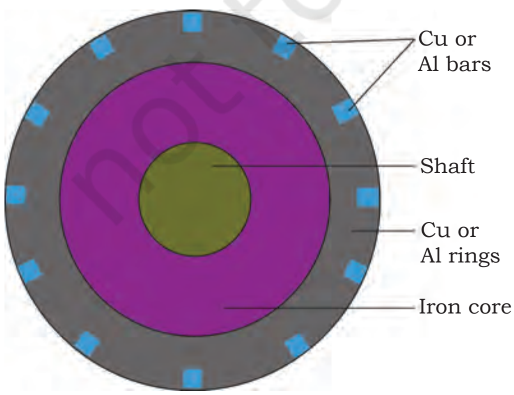

Fig. 8.19: Asynchronous motor

Squirrel Cage Induction Motor

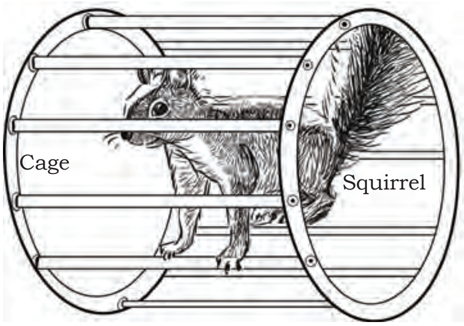

Fig. 8.20: Squirrel cage

Fig. 8.21: Rotor structure in a squirrel cage induction motor

The word squirrel cage defines that the structure of the rotor is like the cage of a squirrel as shown in Fig. 8.20. Fig. 8.21 shows the internal structure of the rotor of the squirrel cage induction motor.

When a three-phase supply is connected to the stator of a squirrel cage induction motor, it produces a rotating magnetic field in the air gap between the stator and rotor, as shown in Figs 8.23 and 8.24. This rotating magnetic field cuts the conductors of the squirrel cage rotor.

Fig. 8.22: Squirrel cage induction motor

Fig. 8.23: Three-phase input supply to the squirrel cage induction motor

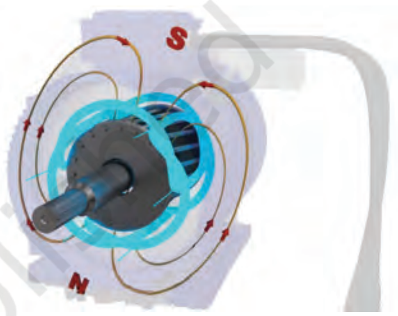

Fig. 8.24: Rotating magnetic field in the squirrel cage induction motor

According to Faraday's Law of Electromagnetic Induction, an emf is induced in the conductor of the squirrel cage rotor. The rotor conductors are shortened by the end ring, as shown in Fig. 8.25. An emf will get induced across the rotor conductors, which will result in electric current.

According to Lorentz law, if a current carrying conductor is placed in a magnetic field it will experience a force, as shown in Fig. 8.26. This collective force will make the rotor to rotate.

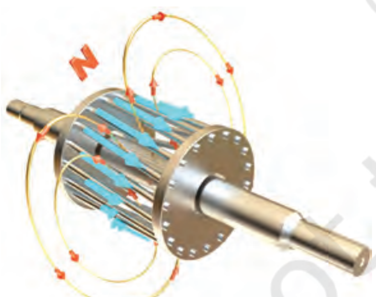

Fig. 8.25: EMF is induced in the rotor conductor

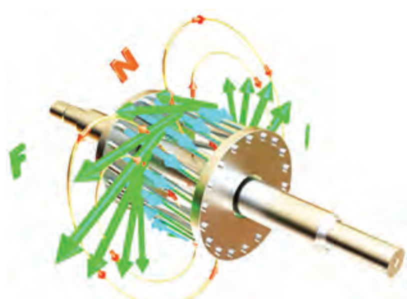

Fig. 8.26: Torque generated as per Fleming's left hand rule

The squirrel cage induction motor comes with some issues too. It has a low starting torque, which means it starts slowly. The reason for the low starting torque is the phase difference between voltage and current as inductive action takes place. Pure inductive effect produces a phase difference between voltage and current. In squirrel cage induction motor, total inductive effect increases due to the presence of rotor bars. These conductor bars act as inductors and produce more phase difference between current and voltage. This phase difference results in a low starting torque, as shown in Fig. 8.27.

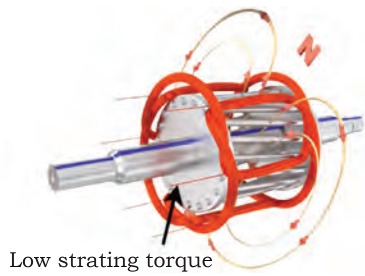

Fig. 8.27: Low starting torque in the squirrel cage induction motor

Slip Ring Induction Motor

In slip ring motor, the drawback of the squirrel cage motor is eliminated by using the slip ring in series with the rotor winding. In this section, we will discuss the slip ring motor.

In slip ring motor, inductor coils are connected in series with the inductive effect of the rotor winding. This will reduce the inductive effect of the rotor as well as rectify the phase difference problem of the squirrel cage motor. Fig. 8.28 shows that three slings are used in series with the rotor winding. This will increase its starting torque of the slip ring motor. Therefore, slip ring motor is used where high stating torque is required.

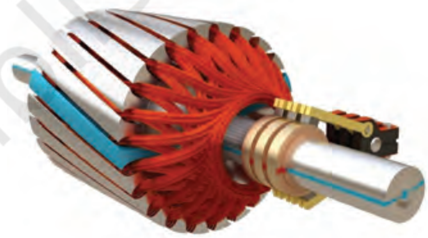

Fig. 8.28: Rotor of slip ring induction motor

Starter

Since an induction motor draws more current while starting, various starting methods are used to start the motor. By using one of the starting techniques, the winding can be saved from damage from high starting current. Different types of starters are used to safely start the induction motor. The commonly used starters are direct online starter (DOL), and star-delta starter.

Direct online starter (DOL) is the simplest form of motor starter. DOL is used to safely start the induction motor. DOL consists of a circuit breaker, contactor and an overload relay for protection. In DOL starter, electromagnetic contactors are used. This contactor will

Fig. 8.29: Direct online starter

open, when thermal relay is overloaded due to fault conditions. Typically, the contactor will be controlled by separate start and stop buttons, as shown in Fig. 8.29.

Working Principle of DOL

The internal parts of the DOL starter are shown in Fig. 8.30. DOL starter connects the three-phase main with the motor as shown in Fig. 8.31. The control circuit is connected to any two phases to energise them. When we press the start button, the current flows through the contactor coil (magnetising coil) and control circuit. The current energises the contactor coil and leads to close the contacts. The three-phase supply is then available for the three-phase motor. When we press the stop button, the current through the contact is discontinued, making supply to the motor unavailable and stopping the machine.

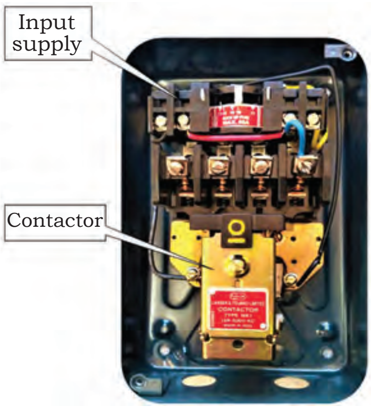

Fig. 8.30: Inside a DOL starter

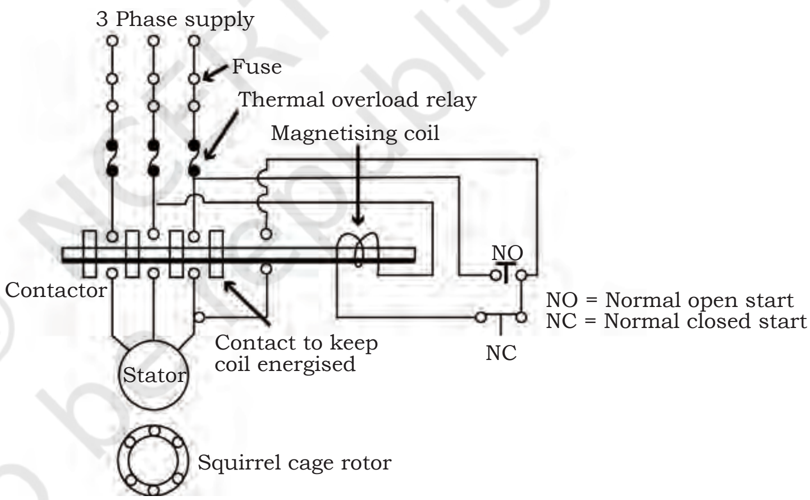

Fig. 8.31: Internal operation of DOL

Star delta starter helps to reduce initial voltage induction as in a three-phase induction motor high starting current is drawn by the motor and this could destroy the stator winding. To reduce initial voltage induction, the motor has to be connected in a star manner. After it achieves 1/3 of its maximum speed, it will switch to delta configuration. For this, a star-delta starter is needed. A star-delta starter will initially make the motor run in a star form, and then switch to delta.

Practical Exercises

Activity 1

Demonstration of star, delta connections of coils

Material required

Six coils for star and delta connection, combination plier

Procedure

1. Take three coils and connect them in a star pattern by connecting terminal A of coil 1, terminal B of coil 2 and terminal 3 of coil 3 together as shown in Fig. a.

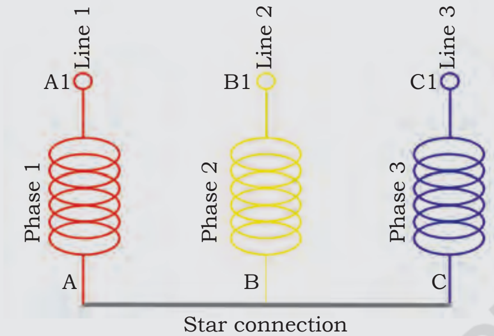

Fig. (a:) Coils are connected in star pattern

2. Take three coils and connect them in a star pattern by connecting terminal A1 of coil 1 to terminal B1 of coil 2, terminal B of coil 2 to terminal C of coil 3, and terminal C1 of coil 3 to terminal A of coil 1 as shown in Fig. b.

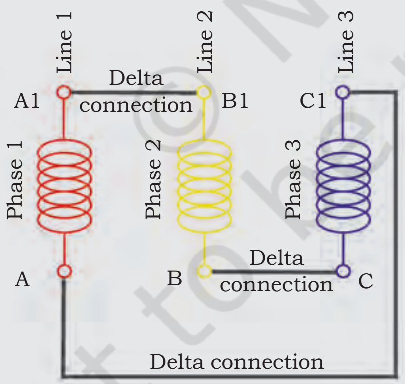

Fig. b: Coils are connected in a delta pattern

Activity 2

Star-delta connection of coils in three-phase induction motor using metal strips

Material required

Three-phase induction motor, screwdriver, combinational plier, insulation tape

Caution: Disconnect power while making the connection

Notes

Notes

Procedure

1. For making star-delta connection, place an induction motor. Fig. a represents the rotor, stator and input power supply to the induction motor. Fig. b shows the rotating magnetic field inside the stator.

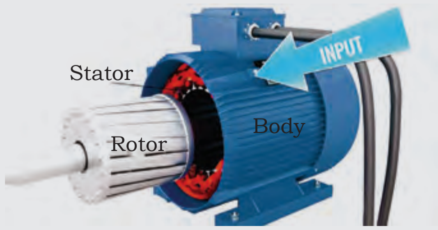

Fig. a: Rotor stator and input terminals in the induction motor

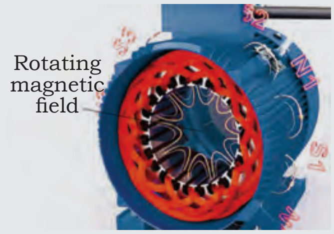

Fig. b: Rotating magnetic field in the stator that makes the rotor rotate

2. Fig. c shows the number of coils a stator has. To understand the concept of star-delta, consider three coils for three-phases. Coil 1 is labelled as 'U', coil 2 as 'V', coil 3 as 'W'. Each coil has two terminals that is, 1 and 2 as shown in Fig. c.

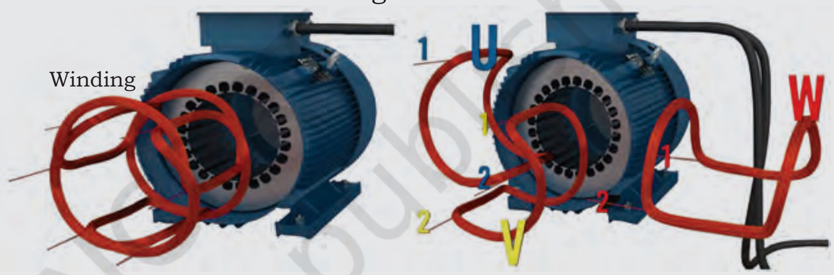

Fig. c: Three coils in the stator represented by 'U' in blue colour, 'W' in red colour, 'V' in yellow colour

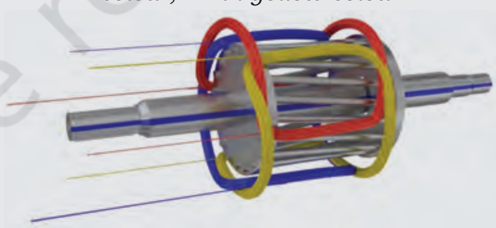

Fig. d: Blue coil represents 'U' coil, red coil represents 'V' coil, yellow coil represents 'W' coil

3. The coils are represented as blue coil in 'U, red coil in 'V' and yellow coil in 'W', as shown in Fig. d. To connect the coils in star connection, connect terminal 2 of coil 'U', coil 'V' and coil 'W' together, as shown in Fig. e.

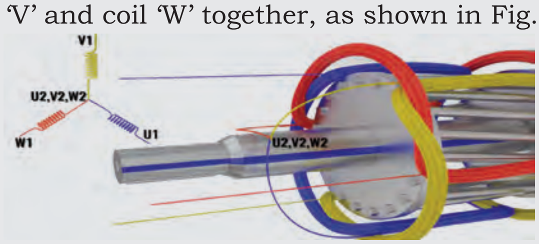

Fig. e: Connect terminal 2 of coil 'U', coil 'V', coil 'W' together

4. To connect the coils in delta connection, connect terminal 1 of coil ‘U’ to terminal 2 of coil ‘V’, terminal 1 of coil ‘V’ to terminal 2 of coil ‘W’, terminal 1 of coil ‘W’ to terminal 2 of coil ‘U’, as shown in Fig. f.

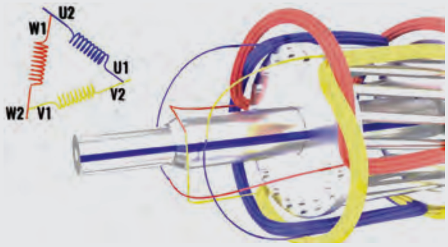

Fig. f: Delta connection

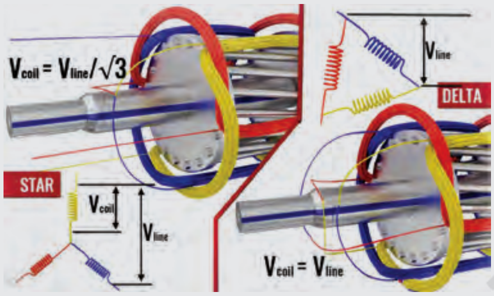

Fig. g: Relation of line and coil voltage in star and delta connection

5. Figs g and h show how, conceptually, coils are connected in delta and star configuration. In actual practise, coils are connected with the help of external terminals.

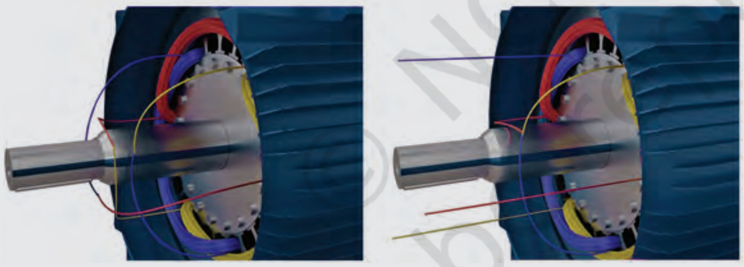

Fig. h: Three-phase wires connected directly in star and delta pattern inside the stator

6. Each coil, ‘U’, ‘V’ and ‘W’ have two terminals. Hence, in total there will be six terminals in the terminal box as shown in Fig. i.

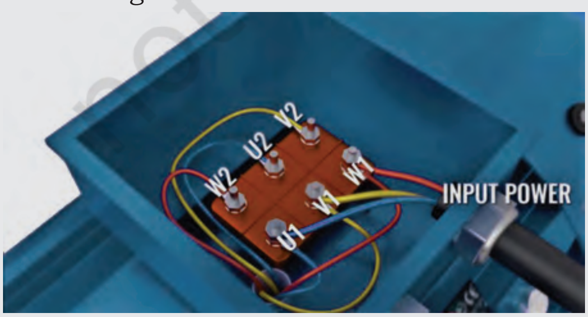

Fig. i: Six terminals for three coils for three-phase induction motor

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7. When terminals W2, U2 and V2 in the terminal box are connected together using a metal strip as shown in Fig. j, it forms a star connection of coils in the stator.

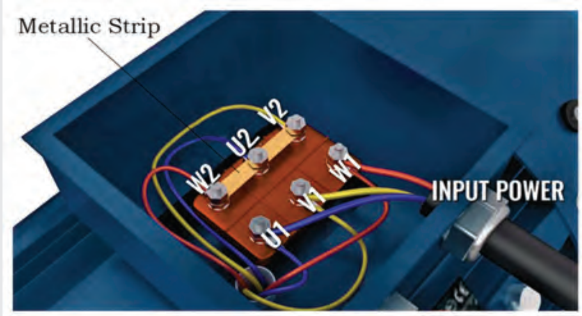

Fig. j: Star connection using a metal strip in the terminal box

8. When terminals W2 and U1, U2 and V1, V2 and W1 are connected in the terminal box using a metal strip as shown in Fig. k, it makes the stator coil into a delta connection.

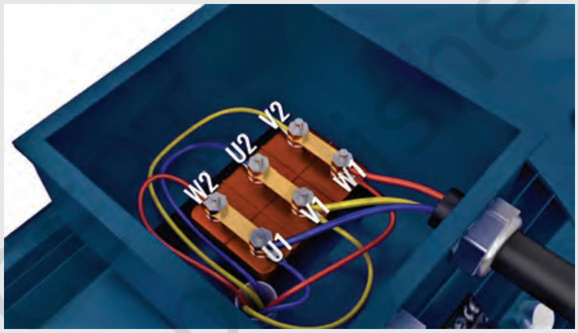

Fig. k: Delta connection using a metal strip in the terminal box

Activity 3

Connecting star-delta starter in three-phase induction motor

Material required

Star-delta starter, three-phase induction motor, screwdriver, combinational plier, insulation tape

Procedure

1. Take a star-delta starter, which has two contactors and one timer. One contactor is used for star connection as shown in Fig. a. Take three wires from U2, V2 and W2 and connect them to the contactor dedicated for the star connection.

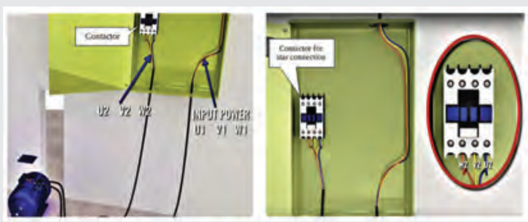

Fig. a: Contactor for star connection

2. Connect the other contactor in the delta connection as shown in Fig. b. Take three more wires other than those used for the star connection. These three will be taken from terminals U2, V2 and W2 of the induction motor.

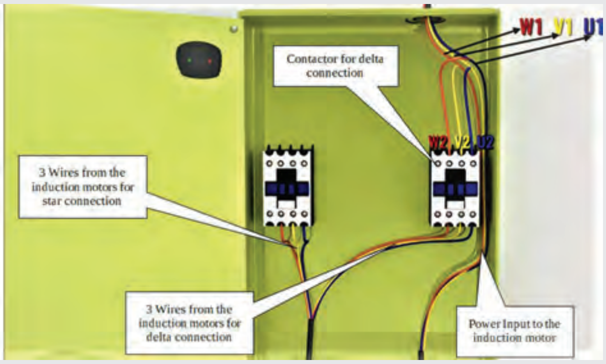

Fig. b: Delta contactor in the starter

3. The star-delta starter requires a timer to switch the star connection to delta connection. This is used to control the switching requirement in star-delta starter, as shown in Fig. c.

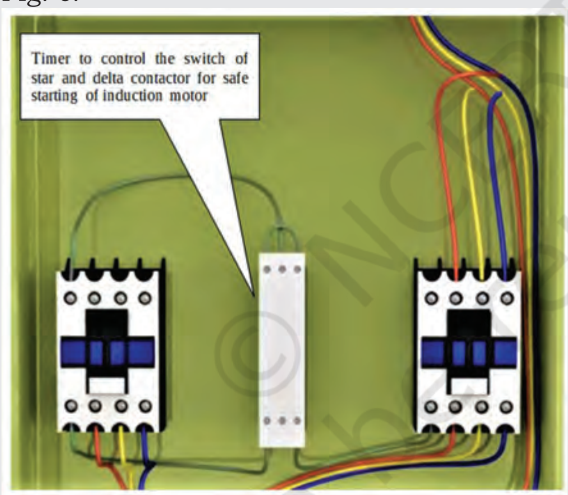

Fig. c: Timer to regulate the switching

Check Your Progress

A. Multiple choice questions

1. The electrical device that converts mechanical energy into electrical energy is ____________.
   (a) motor
   (b) generator
   (c) starter
   (d) transformer

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2. The rotating part of a motor is ____________.
   (a) starter
   (b) carbon brush
   (c) armature
   (d) stator
3. The slip ring is used in ____________.
   (a) AC machines
   (b) DC machines
   (c) transformer
   (d) stator
4. The electrical device that converts electrical energy into mechanical energy is ____________.
   (a) motor
   (b) generator
   (c) starter
   (d) transformer
5. In which type of motor is the rotating speed of rotor less than the rotating speed of magnetic field?
   (a) Synchronous motor
   (b) Asynchronous motor
   (c) DC motor
   (d) Stepper motor
6. Squirrel cage motor is a type of ____________.
   (a) synchronous motor
   (b) asynchronous motor
   (c) DC motor
   (d) stepper motor
7. Which of the following motors overcome the drawback of a squirrel cage motor?
   (a) Stepper motor
   (b) DC motor
   (c) Slip ring motor
   (d) Series motor
8. Which of the following device is used for safe starting of the induction motor?
   (a) Starter
   (b) Relay
   (c) Circuit breaker
   (d) Ground fault detector
9. Which of the following is a component of direct on line starter?
   (a) Relay
   (b) Contactor
   (c) Input supply
   (d) Energy meter
10. Which of the following is used to connect the wire winding of a motor into star and delta form?
   (a) Thread
   (b) Copper wire
   (c) Rubber
   (d) Metal strip

B. Fill in the blanks

1. A generator transforms ____________ into ____________.
2. Fleming's ____________ rule is used for electric motor.
3. Fleming's ____________ rule is used for generator.
4. Electromagnet is an ____________ magnet.
5. AC generator is also known as ____________.
6. DOL is used to safely start the ____________ motor.

C. State whether the following statements are True or False

1. Electromotive force is an electrical force, which is exerted on the electrons. This force is responsible for the movement of electrons.
2. In an AC generator, current is collected by using a slip ring. While in a DC generator, current is collected by a split ring.
3. Armature is the rotating part of a motor or generator.
4. Brush is the stationary or fixed part of a generator.
5. An electric motor is a device that converts electrical energy into mechanical energy.
6. This rotating force is called torque.
7. In synchronous motor the rotating speed of the rotor is the same as the rotating speed of the magnetic field.
8. As per Lorentz law, if a current carrying conductor is placed in a magnetic field it will experience a force.
9. In slip ring, motor inductor coils are connected in series with the inductive effect of the rotor winding.

D. Short answer questions

1. What type of energy is input to an electric generator?
2. What type of energy is output from an electric generator?
3. Give the functions of an alternator.
4. What is brush?
5. Discuss the use of a slip ring.
6. Discuss the principle behind the alternator.
7. What is the principle behind the motor?
8. Explain the principle of direct online starter.
9. What are the steps for checking the motor?

NOTES

Chapter 9

Programmable Logic Controller

171202CH09

INTRODUCTION

Control engineering has evolved over time. In the past, humans were the resource for controlling a system manually. Nowadays, advanced technology is used for controlling the equipment and electricity is the resource for running most of the equipment. Fig. 9.1 shows a household electric heater, which uses relay. This relay makes the simple logical control decision. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of PLC began in the 1970s, and has become the most common choice for manufacturing controls.

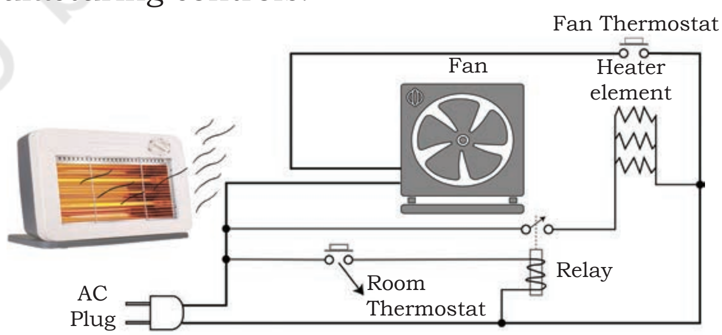

Fig. 9.1: A household electric heater serves as a simple example of process control

PLCs have been an integral part of factory automation and industrial process control for decades. It performs many functions, such as providing analog and digital input/output interfaces, signal processing, data conversion, and various communication protocols. Fig. 9.2 shows some of the operations, which can be performed by using PLC.

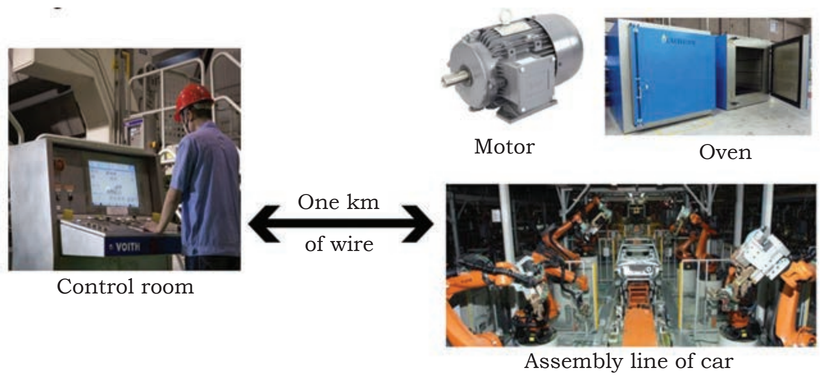

Fig. 9.2: Longer-range factory communications

Programmable Logic Controller (PLC)

Programmable means 'able to provide coded instructions for the automatic performance of a task'. Logic means 'a system or set of principles underlying the arrangements of elements in a computer or electronic device so as to perform a specified task'. Controller means 'a thing that directs or regulates something'. Hence, PLC is a set of instructions in an electronic device that help perform the regulatory task. It is an industrial computer that contains hardware and software used to perform control functions. PLC is used for automation of industrial processes to control machinery placed on assembly lines of manufacturing units, and food processing. They can accept digital and analog inputs. A PLC consists of two basic sections, input/output (I/O) interface system, and central processing unit (CPU).

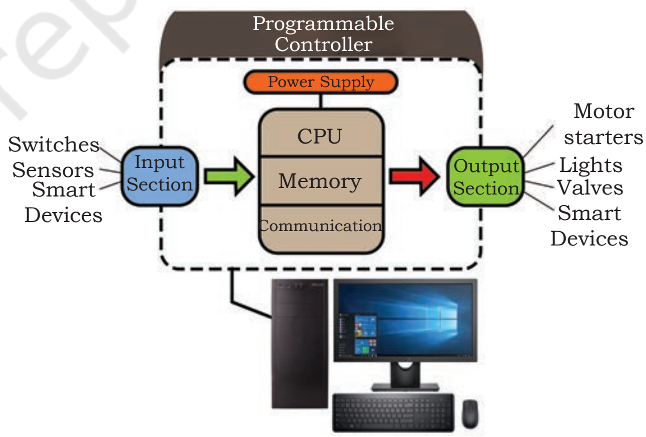

Fig. 9.3: Block diagram of PLC

Input and Output System

Input and output are the physical interface between a processing unit and user. There are four basic steps in the operation of all PLCs: input scan, program scan, output scan, and housekeeping. These steps take place in a repeating loop.

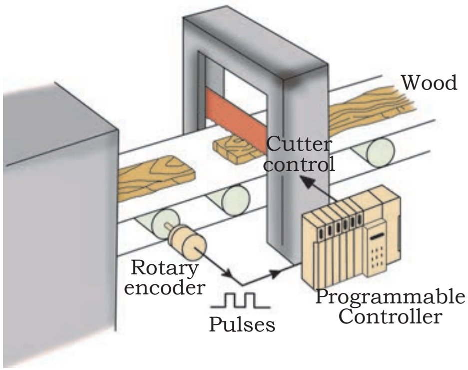

Fig. 9.4: Operation of PLC in the cutter control

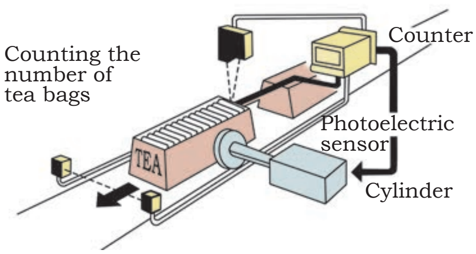

Fig. 9.5: PLC counting the number of tea bags

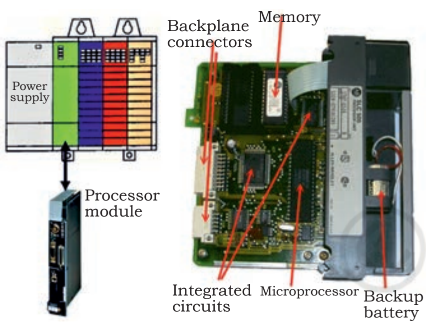

Fig. 9.6: Central processing unit of PLC

Input scan detects the state of all input devices that are connected to the PLC. **Program scan** executes the user created program logic. **Output scan** energises or de-energises all output devices that are connected to the PLC. **Housekeeping** includes communication with programming devices and performing internal diagnostics.

It is easier to create and change a program in a PLC than to wire and rewire a circuit. End-users can modify the program in the field, for example, a PLC used for controlling speed of rotation, as shown in Figs 9.4 and 9.5.

Processor (CPU)

Processor is the brain of the PLC. It consists of microprocessor for implementing logic and controlling communication among the modules, as shown in Fig. 9.6. The processor accepts input data from various sensing devices, executes stored user program and sends appropriate output commands to control devices.

PLC Architecture

The structure of a PLC is based on the same principles as those employed in computer architecture.

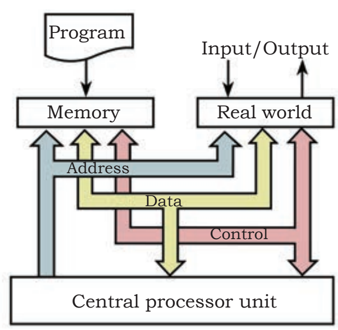

Fig. 9.7: Architecture of PLC

Human Machine Interface

In programmable logic controller, electronic components are used. These electronic components work on digital signal. This digital code, such as '101101010', is not understood by a human. In such a condition, there is a gap between the machine and the human. To cover this gap, human machine interface is used. Human machine interface is user interface that connects an operator to the controller for an industrial system.

There are three basic types of HMIs, push-button replacer, data handler and overseer.

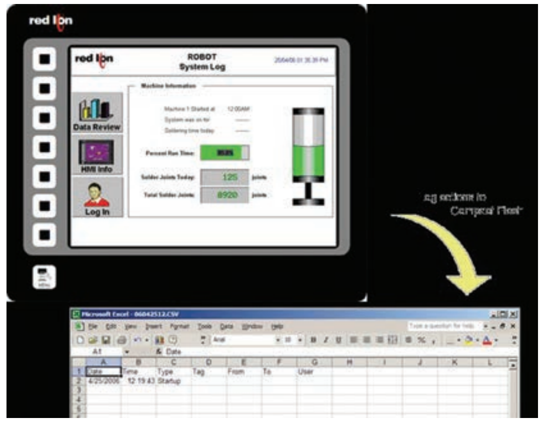

Fig. 9.8: Human machine interface

HMI and PLC Wiring

To connect human machine interface and programmable logic controller, USB, RS-232, RS-485 are used, as shown in Fig. 9.10. A wiring schematic from the production line to the PLC is highly recommended. Fig. 9.11 shows RS-485 connector.

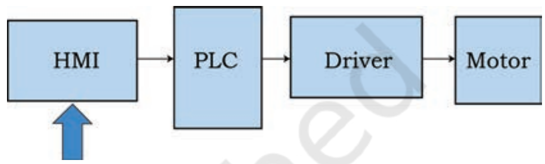

Fig. 9.9: Block diagram showing the interconnection of HMI, PLC, driver, motor

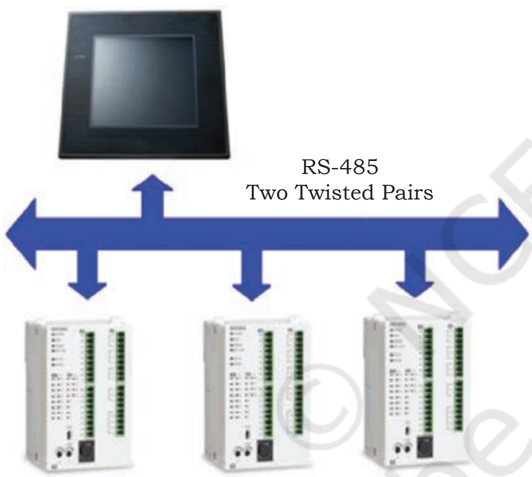

Fig. 9.10: RS-485 is used to connect human machine interface and programmable logic controller

Fig. 9.11: RS-485

Fig. 9.12: USB

Fig. 9.13: RS-232

Practical Exercise

Demonstrate the pin allotment of RS-232

Material required

RS-232 connector

Procedure

1. Take a RS-232 connector. Observe the number of pins in it, as shown in Fig. a.

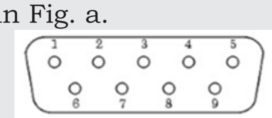

Fig. a: RS-232 pin

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2. Observe Table 1 to understand the pins of RS-232.

Table1: Serial Port Pin and Signal Assignments

Pin	Label	Signal Name	Signal type
1	CD	Carrier Detect	Control
2	RD	Received Data	Data
3	TD	Transmitted Data	Data
4	DTR	Data Terminal Ready	Control
5	GND	Signal Ground	Ground
6	DSR	Data Set Ready	Control
7	RTS	Request to Send	Control
8	CTS	Clear to Send	Control
9	RI	Ring Indicator	Control

Check Your Progress

A. Multiple choice questions

1. PLC stands for ___________.
   (a) Programmable logic controlling
   (b) Programmable logic contact
   (c) Programmable logical control
   (d) Programmable logic control
2. Which of these is not a human machine interface mechanism?
   (a) Push button replacer
   (b) Data handler
   (c) Overseer
   (d) Circuit breaking
3. Which of the following is not a part of the PLC?
   (a) Input stage
   (b) Output stage
   (c) Processor
   (d) Storage
4. PLC is used in which type of industries?
   (a) Mechanical industries
   (b) Automation industries
   (c) Electronic industries
   (d) Chemical industries
5. PLC was invented in the year ___________.
   (a) 1977
   (b) 1970
   (c) 1985
   (d) 1980

6. Which of following is known as the brain of PLC?
   (a) Input
   (b) Output
   (c) Processor
   (d) Memory
7. Which of the following device is used for taking input?
   (a) Sensor
   (b) Keyboard
   (c) Joystick
   (d) Mouse
8. Which of the following connector is used for connecting HMI and PLC?
   (a) USB
   (b) RS-232
   (c) RS-485
   (d) All of the above
9. Identify the name of the connector in the following figure.
   (a) RS-232
   (b) RS-234
   (c) RS-482
   (d) RS-485

10. Identify the name of the connector in the following figure.
   (a) RS-232
   (b) RS-234
   (c) RS-482
   (d) RS-485

B. Fill in the blanks

1. In programmable logic controller, electronic components are used. This electronic component works on ___________ signal.
2. In order to provide physical interface between the processing unit and the user __________ and ___________ interfacing is used.
3. A __________ is the brain of the PLC.
4. To connect human machine interface and programmable logic controller USB, ___________, ___________ are used.
5. The three basic types of HMIs are push-button replacer, ___________, and ___________.

C. State whether the following statements are True or False

1. Input scan detects the state of all input devices that are connected to the PLC.
2. Program scan do not executes the user created program logic.

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3. Output scan energises or de-energises all output devices that are connected to the PLC.
4. PLC is also utilised to process digital signal.
5. HMI stands for human machine interface.

D. Short answer questions

1. What is PLC?
2. Into how many sections can a PLC be divided?
3. Discuss the architecture of PLC.
4. What is the role of HMI?
5. List out the areas where PLC is used for controlling the operation.
6. In PLC, what is the role of a processor?
7. List the connectors that are used for the connection of PLC and HMI.

Chapter 10

Testing and Measurement in an Electrical Panel

171202CH10

Introduction

To run a system smoothly, routine testing, monitoring and metering is required. Basically, electrical and electronic circuit requires voltage and current. For proper operation and consistency, it is essential to maintain and monitor the correct value of voltage and current. For this purpose, testing and metering is mounted on the panels. In this chapter, you will learn about the various testing methods and meter.

Testing

Testing is checking how well the system is working. Testing is the checkpoint in the overall process to determine whether objectives are being met.

Types of Testing in a Control Panel

Various types of testing are performed in a control panel system, such as testing power supply, and testing Current Transformer (CT) and Potential Transformer (PT).

High tension lines and sub-stations have very high voltage. The voltage could be as high as 11kV, 33kV, 66kV. To measure such high voltage, a current transformer and voltage or potential transformer is used.

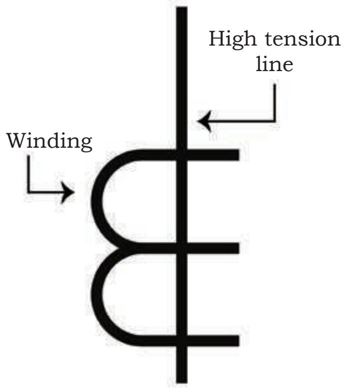


Fig. 10.1: Symbolic representation of a current transformer

Current transformer is used to measure heavy current in high tension lines, low tension lines and sub-stations. A symbolic representation of a current transformer is shown in Fig.10.1.

Construction of a Current Transformer

A current transformer has one winding, which is called secondary winding, as shown in Fig. 10.2. The phase wire of high tension line acts as the primary winding, as shown in Figs 10.3 and 10.4. So, this current transformer acts as a step up transformer, which increases the voltage. Therefore, in the secondary winding of a step up transformer, the voltage is high, but current is low. Ammeter, which measures the current, is connected in the secondary winding of the transformer.

Fig. 10.2: Current transformer in an electrical sub-Station

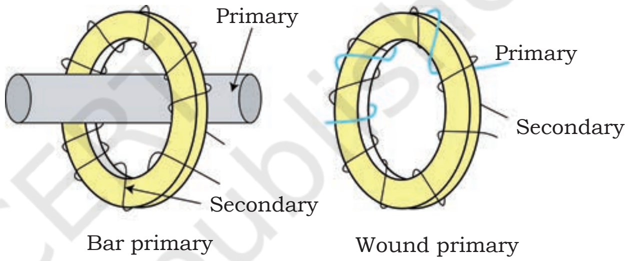


Fig. 10.3: Primary and secondary winding in the current transformer

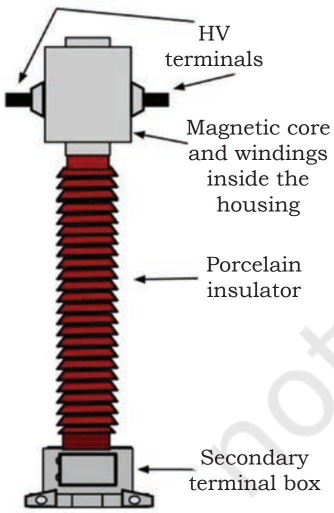


Fig. 10.4: Sketch of a current transformer

Working of a Current Transformer

High tension lines act as a primary coil of transformer and are not curved. They are kept straight in space, as shown in Fig. 10.5. While the secondary winding in a current transformer makes up a step up transformer, in secondary winding, the voltage is high and current is low. This results in low current at the secondary winding of the transformer. This makes the current measurable with an ammeter as shown in Fig. 10.6. Fig. 10.7 shows a representation of a potential transformer.

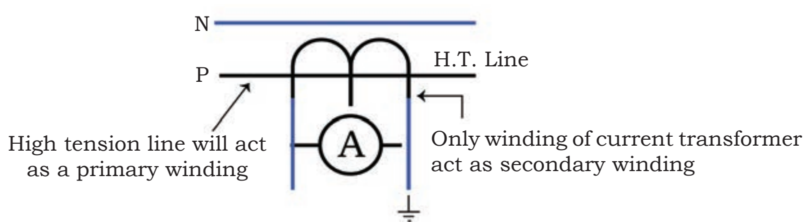


Fig. 10.5: Circuit diagram of a current transformer

Potential transformer has high measuring capabilities. It is used to measure the high voltage of high tension lines, low tension lines, and sub-stations.

Fig. 10.6: Potential transformer

Construction of a potential transformer

A potential transformer is a step down transformer. It has two windings, primary and secondary. Primary winding has more coils compared to secondary winding.

(a) Working of a potential transformer: in the electrical system, there are two wires. One is a phase/live wire and other is neutral. Fig. 10.8 shows a primary coil of a potential transformer connected parallel to the supply. One end of the primary winding is connected to the phase wires and the other end to the neutral wire. In the secondary winding a voltmeter is connected that will measure voltage in the secondary.

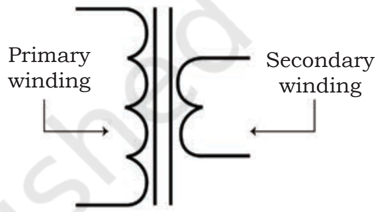


Fig. 10.7: Representation of a potential transformer

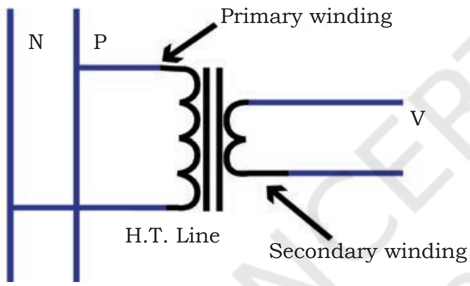


Fig. 10.8: Circuit diagram of a potential transformer

Assignment 1

1. What is the role of a potential transformer?
2. List out the areas where a current transformer is used.

Practical Activity

Activity 1

Testing the coil and terminals of relay

Material required

Relay, multimeter, datasheet of relay

Procedure

Step 1. To test the coil of relay.

- Refer to the relay datasheet for resistance value and tolerance value of the coil. Note down the resistance value. For example, if the resistance is 320Ω and the tolerance value is ±10%, then we should get resistance values somewhere between 288Ω to 352Ω.

Notes

- Now, use a multimeter to measure the resistance. After this, connect the multimeter's to the terminals of the relays. Note down the reading. If the resistance value falls within the range mentioned in the datasheet, then the coil is working properly. However, if you get readings that are either very high or very low, then there is a problem with the coil. If the coil is not proper, replace the relay.

Step 2. Test the terminals of the relay.

- Measure the resistance between the terminals such as normally closed terminal (NO), normally open terminal (NC), common terminal (COM), as shown in Fig. a.

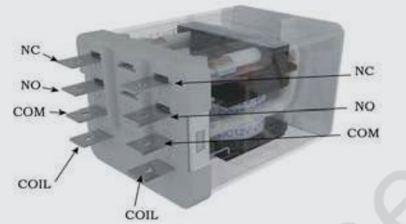


Fig. a: Different terminals of relay

Step 3. Test the normally closed (NC) terminal of relay.

- Put the multimeter in the ohmmeter setting.
- Place one of the multimeter probes on the NC terminal and the other on the COM terminal.
- Read the resistance.
- If the resistance value is around 0Ω, the NC terminal is working fine.

Step 4. Test the normally open (NO) terminal of relay.

- Put the multimeter in the ohmmeter setting.
- Place one of the multimeter probes on the NO terminal and the other on the COM terminal.
- Read the resistance.
- If the resistance value is around several MΩ, the NO terminal is working fine.

Activity 2

Testing the contactor of direct online starter

Material required

Contactor, test lamp

Procedure

1. Take a test lamp. First, check the test lamp by touching its terminals as shown in Fig. a. If the lamp glows then it is working properly.

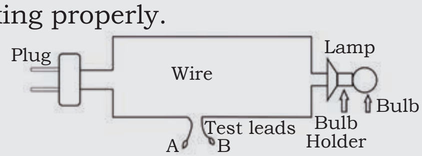


Fig. a: How to check the test lamp

2. Now, touch the test lamp terminals A and B to contactor terminals, as shown in Fig. b. If the lamp glows, it means the contactor is working properly.

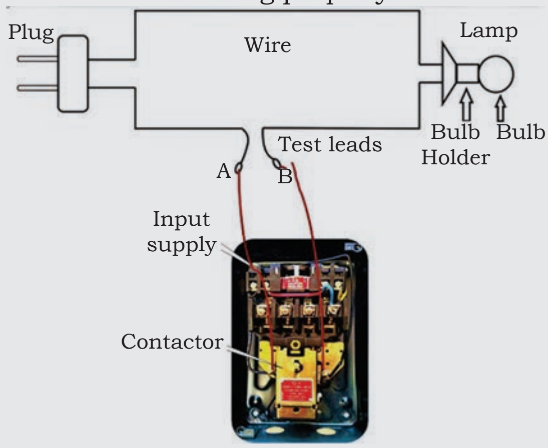


Fig. b: Test circuit for testing the contactor

Activity 3

Test the push button

Material required

Push button, test lamp

Procedure

1. Take a test lamp. First, check the test lamp by touching its terminals, as shown in Fig. a. If the lamp glows then it is working properly.

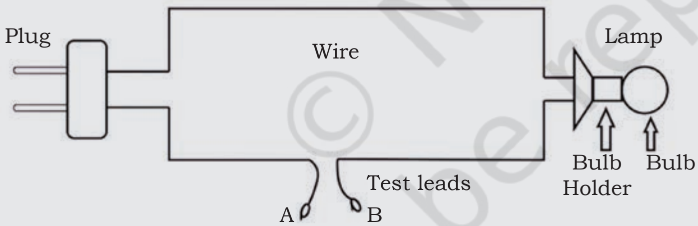


Fig. a: How to check the test lamp

2. Now, touch the test lamp terminals A and B to push button terminals, as shown in Fig. b. If the lamp glows when the button is pushed, then the push button is working properly.

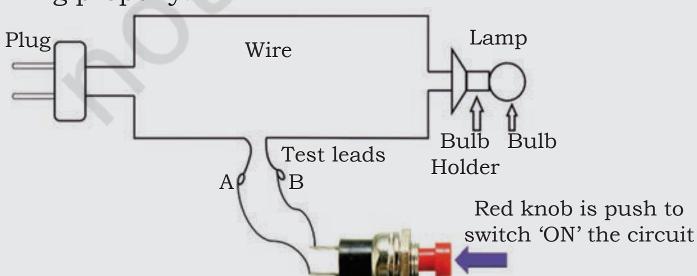


Fig. b: Testing circuit of a push button

Notes

Activity 4

Test the indicating lamp

Material required

Indicator, test lamp

Procedure

1. Take a test lamp. First, check the test lamp by touching its terminals, as shown in Fig. a. If the lamp glows then it is working properly.

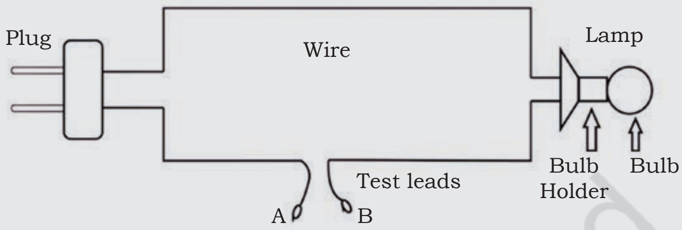


Fig. a: How to check the test lamp

2. Now, touch the test lamp terminals A and B to indicator terminals, as shown in Fig. b. If the lamp glows, then the indicator is working properly.

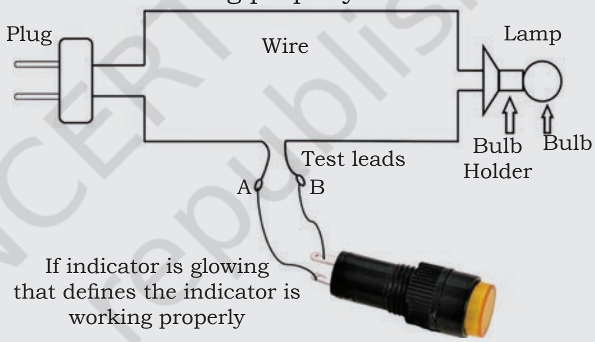


Fig. b: Testing circuit for indicator

Activity 5

Test the voltmeter

Material required

Multimeter, test lamp

Procedure

1. Take a multimeter and set it to measure voltage by rotating the knob of the multimeter, as shown in Fig. a.

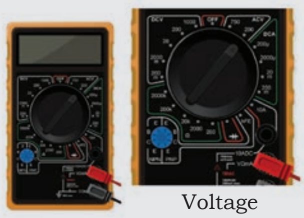


Fig. a: Setting up the multimeter in voltage measuring mode

2. Choose a range above the maximum expected voltage, as shown in Fig. b.

Fig. b: Setup the range of the voltmeter

3. Insert the test cords into the multimeter, as shown in Fig. c.

Fig. c: Insertion of the measuring cords in the multimeter

4. Touch the red and black test leads to the socket to measure the voltage supply, as shown in Fig. d.

Fig. d: Cautiously insert the cords in the socket

5. If the multimeter is displaying proper reading, then it is working properly.

Activity 6

Test the ammeter

Material required

Multimeter, test lamp

Procedure

1. Take a multimeter and set it to measure voltage by rotating the knob of the multimeter, as shown in Fig. a.

NOTES

Notes

Fig. a: Setting up the multimeter in ammeter mode

2. Choose a range above the maximum expected voltage, as shown in Fig. b.

Fig. b

3. Break the circuit, as shown in Fig. c.

Fig. c: Breaking an electric circuit

4. Connect the ammeter leads to the circuit, as shown in Fig. d.

Fig. d: Connect the ammeter leads in the circuit

5. Restore power to the circuit and take the reading.

Fig. e: Observe the reading in the ammeter

TESTING ENERGY METER

Energy meters are used in houses, malls, industries, etc., to measures electricity consumption. For better reliability, energy meters, have to pass through various electromagnetic compatibility (EMC) tests where meters are compared under various normal and abnormal conditions, in a laboratory, to ensure its accuracy in the field.

Standard Tests for Energy Meters

The performance tests of an energy meter as per IEC standards are divided into three segments, which are mechanical aspects, electrical circuiting and climatic conditions.

1. Mechanical aspects test the components.
2. Climatic conditions test include those limits, which influence the performance of the meter externally.
3. Electrical circuit test the continuity of the circuit.

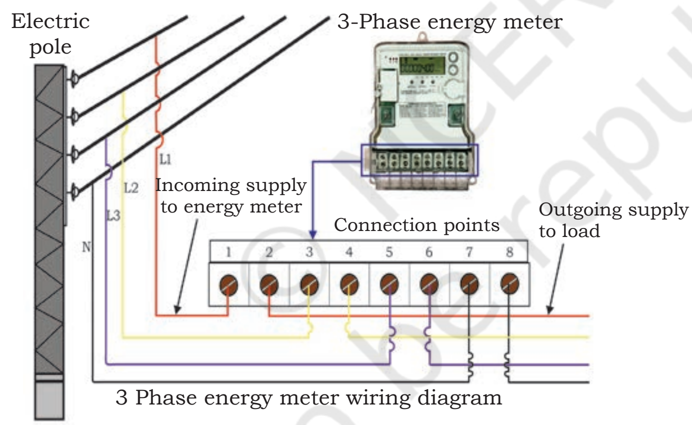


Fig. 10.9: Circuit connection of a three-phase energy meter

Check Your Progress

A. Multiple choice questions

1. The amount of electricity consumed is measured by ___________.
   (a) multimeter
   (b) ammeter
   (c) voltmeter
   (d) energy meter
2. The amount of current flowing in the circuit is measured by ___________.

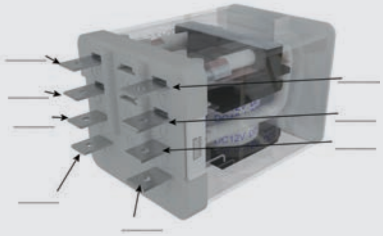
NOTES

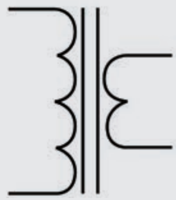
(a) multimeter
(b) ammeter
(c) voltmeter
(d) energy meter

3. The amount of voltage drop across the load is measured by a ____________.
   (a) multimeter
   (b) ammeter
   (c) voltmeter
   (d) energy meter
4. Which of the following is an electromagnetic coil?
   (a) Contactor
   (b) Ammeter
   (c) Current transformer
   (d) Potential transformer
5. In relay NO stands for ____________.
   (a) Normally out
   (b) Noise out
   (c) Neutral open
   (d) Normally open
6. In relay NC stands for ____________.
   (a) Normally close
   (b) Noise cut
   (c) Neutral close
   (d) Normally open
7. Which type of transformer is used in a current transformer?
   (a) Step up transformer
   (b) Step Down transformer
   (c) Step up transformer or Step Down transformer
   (d) Power transformer
8. Which type of transformer is used in a potential transformer?
   (a) Step up transformer
   (b) Step down transformer
   (c) Step up transformer or step down transformer
   (d) Power transformer

B. Fill in the blanks

1. Energy meters are used to measure the __________ energy consumed.
2. Current transformer (CT) acts as a __________ transformer.
3. Potential transformer (PT) acts as a __________ transformer.
4. In primary winding of step up transformer voltage is __________ but current is __________.
5. In secondary winding of step up transformer voltage is __________ current is __________.





C. State whether the following statements are True or False

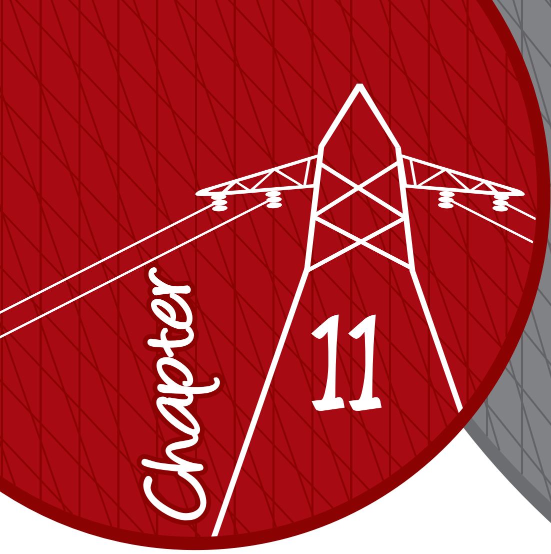
1. Current transformer has only one winding.
2. To measure high voltage, current transformer and voltage transformer are used.
3. In step-up transformer primary winding has less number of turns as compared to the secondary winding.
4. In step-down transformer primary winding has less number of turns as compared to the secondary winding.
5. Energy meter is tested on the basis of three segments, mechanical aspects, electrical circuiting, and climatic conditions.

D. Short answer questions

1. Write down the steps to test an ammeter.
2. Write down the steps to test a voltmeter.
3. Write down the steps to test an energy meter.
4. What is current transformer test?
5. What is potential transformer?

Chapter 11

Occupational Health and Safety Measures



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Introduction

Workplace safety system is designed to protect the health and safety of workers. Information must be provided about the safe handling, storage and disposal of hazardous items. Workplace hazards can cause harm and everyone at a workplace must share the responsibility of identifying and controlling hazards. In fact, a technician should be the first to recognise a hazard at the workplace.

A technician may face hazards while installing or assembling components at the workplace. Many of the hazards can be avoided by awareness and appropriate precautions.

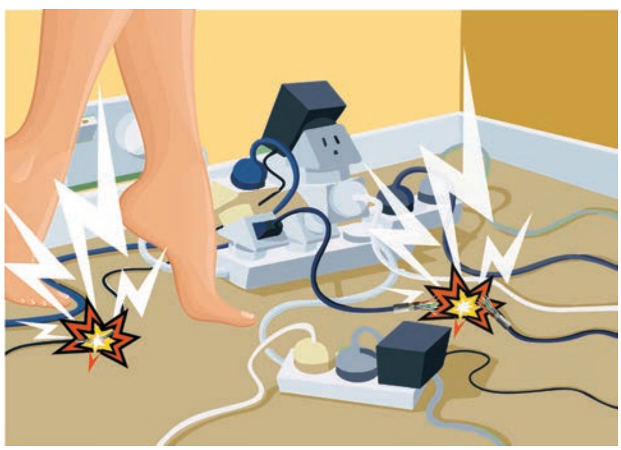

Fig. 11.1: Unsafe work in an electrical system

Electrical Hazard

An electrical hazard is related to energised equipment or conductor at the workplace (Fig. 11.1). Upon coming in contact with an energised equipment, the technician can get severely injured. Hazard may include electric shock, arc flash burn, thermal burn, or even blast injury. When assembling components in a unit, many of the hazards can be avoided by taking appropriate precautions. This will ensure safety at the workplace.

Work Safely Around an Electrical Panel and Cabinet

Check Cords and Wires

Loose cords and wires can trip a person and trigger a short circuit, as shown in Fig. 11.2.

A loose cord or wire should be marked with hazard tape, as shown in Fig. 11.3.

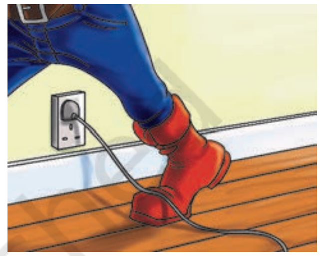

Fig. 11.2: Loose cord can be hazardous

Fig. 11.3: Hazard tape

Wear Personal Protective Equipment (PPE)

One must wear personal protective equipment (PPE) while working on a machine. The PPE depends on the machine and the task being performed by the employee. Safety gloves, safety helmets, safety glasses, earplugs and other gear are important to use where necessary. Safety signs can be posted near panels reminding employees to wear PPE, as shown in Fig. 11.4. Alertness while working is also important for safety. An absent mind can cause accidents (Fig. 11.5).

Fig. 11.4: Personal protection equipment (PPE)

Fig. 11.5: State of mind in workplace

Use Caution Around Heat Sources

Some equipment get heated while operating. The technician should be aware of this areas and use caution. PPE like gloves or flame-resistant clothing are required in these areas (Fig. 11.6).

Fig. 11.6: Flame resistant clothing

Be Careful When Cleaning

When cleaning around a panel or equipment (Fig. 11.7), one should be aware of fire and explosion hazards, the need for PPE during cleaning, and risk of electric shock.

Fig. 11.7: Equipment cleaning spray

Follow Visual and Written Instructions

Panel, equipment has signs and labels on them alerting employees of hazards (Figs 11.8 and 11.9).

Fig. 11.8: Warning instruction while cleaning

Fig. 11.9 (a) and (b): Written instructions and warning on a control panel

Caution While Testing, Replacing Components in a Panel

Necessary precautions should be taken while handling equipment with all range of voltage, as anything can cause injury. Do not ignore voltage range that cannot produce electrical shock. Always confirm that the circuit is dead before touching it for repairing, maintenance or any other work.

Keep water or liquids away from electricity (Figs 11.11 and 11.12). Never touch or try to repair any electrical equipment or circuits with wet hands. It increases electrical conductivity of the body for the flow of electric currents.

Fig. 11.10: Warning of electric shock

Fig. 11.11: Do not plug in cable directly into a socket, use a plug

Fig. 11.12: Avoid water while working with electricity

Never use equipment with damaged insulation or broken plugs, as shown in Fig. 11.13.

If you are repairing an electrical device always turn off the mains supply, as shown in Fig. 11.14.

Always use insulated tools while working, as shown in Fig. 11.15.

Never try repairing energised equipment.

The technician must know the color coding of electric wire or cable.

Fig. 11.13: Damaged conductor

Fig. 11.14: Miniature circuit breaker

Fig. 11.16: Phase tester

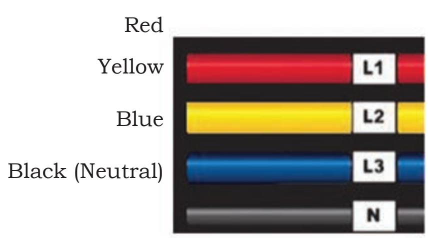

Fig. 11.17: Colour code on the wire

Fig. 11.15: Insulated tools

CHEMICAL HAZARDS

Fig. 11.18: Improper storage of chemicals

Improper storage of chemicals can lead to chemical leakage, as shown in Fig. 11.18.

If the technicians do not take safety measures, these chemicals may cause damage. Figs 11.19 and 11.20 shows how a technician is filling oil in the transformer carefully and Fig. 11.22 shows how transformer oil is being drained out.

Fig. 11.19: Filling oil in a transformer using an oil filling machine

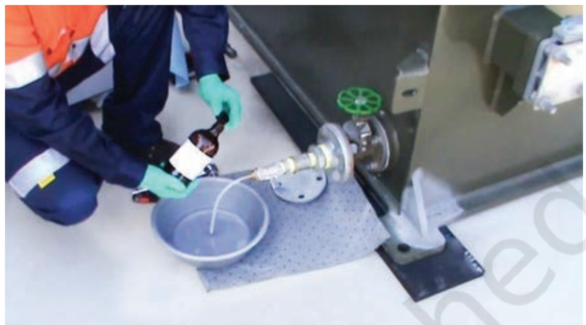

Fig. 11.22: Draining oil from a transformer

Inadequate training or negligence can lead to mishandling of chemicals, as shown in Fig. 11.21.

Exposure to toxic substance at workplace may lead to severe diseases or illness (Fig. 11.23). To avoid this one must carefully read the labels of the substance as shown in Fig. 11.24.

Fig. 11.20: Manual filling of oil in a transformer

Fig. 11.23: Exposure to toxic substance can cause illness

Some of the symptoms of exposure to toxins in the workplace include, chemical burns, itchy burning eyes, nausea, vomiting and diarrhoea, headaches, fever and rapid heart rate.

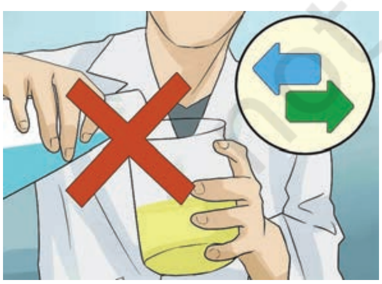

Fig. 11.21: Mishandling of chemicals

Fig. 11.24: Read all labels to work safely

Fire Extinguisher

A fire extinguisher is a protection device used to extinguish and control fire. A fire extinguisher is a cylindrical pressure vessel containing an agent that can be discharged to extinguish fire. A fire extinguisher should always be available in areas where people work with electrical equipment.

Different parts of a fire extinguisher are shown in Fig. 11.25.

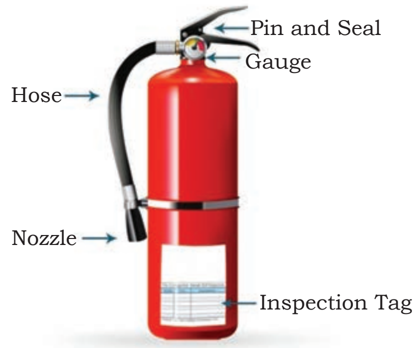

Fig. 11.25: Fire extinguisher and its parts

Practical Exercises

Activity 1

Demonstrate how to operate a fire extinguisher

Material required

Fire extinguisher, burning emergency setup

Procedure

1. To use the fire extinguisher, first identify the safety pin of the fire extinguisher, as shown in Fig. a. It is generally present in its handle.
2. Break the seal and pull the safety pin from the handle.
3. Squeeze the lever.
4. Sweep it over the burning area.

Fig. a: Steps to use the fire extinguisher

Activity 2

Demonstration of various types of fire extinguishers and their extinguishing material

Material required

Different types of fire extinguishers

Procedure

1. Observe different class of fire

   Class A – Use to extinguish burning paper, wood, cloth, plastic.

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Class B – Used to extinguish burning gasoline, grease, oil, petrol.
Class C – Used to extinguish burning electrical cables, wires, equipment.
Class D – Used to extinguish burning magnesium, sodium, and potassium.

2. Different fire extinguishers are used depending on the cause of fire. The use of different fire extinguishers is shown in Table 1 below.

	Water CO_2	**Dry chemical powder**	**Carbon dioxide**	**Mechanical foam**	**ABC dry powder**
Class A	Suitable	Not suitable	Not suitable	Suitable	Suitable
Class B	Not suitable	Suitable	Suitable	Suitable	Suitable
Class C	Not suitable	Suitable	Suitable	Not suitable	Suitable
Class D	Not suitable	Suitable	Not suitable	Not suitable	Suitable

First Aid for Electrical Emergencies

Electrical accidents and injuries can be minimised and lives saved, if proper rescue techniques and treatments are used. Electrical accidents may occur at any time or place. Timely response and treatment of victims is a major concern. When an electrical accident occurs, a victim is often incapable of moving or releasing the electrical conductor, due to muscle cramping, as shown in Fig. 11.26. So caution should be the primary consideration during any electrical accident or emergency. There should always be an emergency response plan for scheduled electrical maintenance or work.

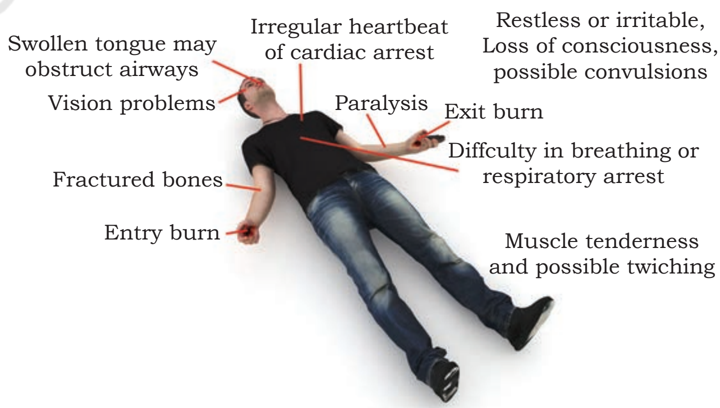

Fig. 11.26: Wireman unconscious due to electric shock

Electrical Rescue Techniques

(a) Approaching the accident

- Never rush into an accident situation.
- Call 108 as soon as possible.
- Approach the accident place cautiously.

(b) Examining the scene

- Visually examine victims to determine if they are in contact with energised conductors, as shown in Fig. 11.27.
- Metal surfaces, objects near the victim may become energised.
- So you may become a victim if you touch an energised victim or conductive surface. Therefore, do not touch the victim or conductive surfaces while they are energised.
- Switch off the electrical circuits if possible.

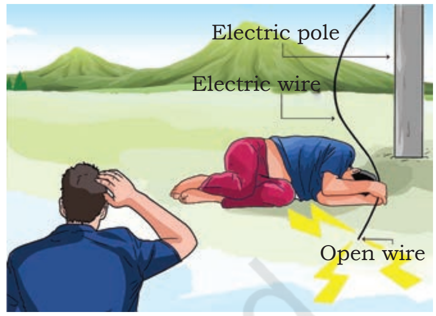

Fig. 11.27: Victim in contact with energised conductor

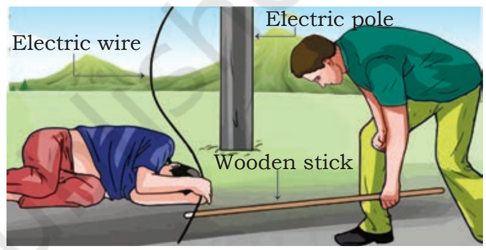

Fig. 11.28: Use non-conductive material to remove the electric wire in order to rescue the victim

(c) Hazards and solutions

- Be alert for hazards, such as heated surfaces and fire, etc.
- In case you cannot switch off the power source, take extreme care.
- Ensure that your hands and feet are dry.
- Wear protective equipment, such as gloves and shoes. Stand on a clean dry surface.
- Use non-conductive material to remove a victim from the conductor.

Fig. 11.29: Beware of high voltage

(d) High voltage rescue

- If high voltage is present on the scene, special training is required for rescue.
- Protective equipment, such as gloves and shoes must be worn, as shown in Fig. 11.30.

Fig. 11.30: Gloves and shoes for safety

First Aid

While working on control panel, lack of safety measures may result in an electric shock. In case of medical

Fig. 11.31: Chest Compression

Fig. 11.32: Opening the mouth for airway

Fig. 11.33: Rescue breathing

emergency, Cardiopulmonary resuscitation (CPR) can help save a life during a cardiac or breathing emergency. Steps to perform CPR are shown in Figs 11.31, 11.32, 11.33.

- If the victim is breathing and has a heartbeat, give first aid for injuries and treat for shock.
- Ensure the victim gets medical care as soon as possible.
- The physician attending to the victim must have detailed information to properly diagnose and care for the victim.

Assignment 1

Identify and name the step shown in the pictures.

______________ ______________ ______________

Check Your Progress

A. Multiple choice questions

1. What are the steps to operate a fire extinguisher?
   (a) Identify the safety pin of the fire extinguisher, which is generally present in its handle
   (b) Break the seal and pull the safety pin from the handle
   (c) Use the fire extinguisher by squeezing the lever
   (d) All of the above
2. A fire extinguisher is used in a situation of during ______________.
   (a) flood
   (b) electric shock
   (c) fire
   (d) burn injury
3. Which of the following safety item is not essential for a wireman while working?
   (a) Safety boots
   (b) Gloves
   (c) Helmet
   (d) Belt

4. Class B extinguisher is used to extinguish fire caused by ____________.
   (a) gasoline, grease, oil
   (b) plastic, paper, cloth
   (c) combustible metal
   (d) kitchen material
5. Class A extinguisher is used to extinguish fire caused by ____________.
   (a) gasoline, grease, oil
   (b) plastic, paper, cloth
   (c) combustible metal
   (d) kitchen material
6. Class C extinguisher is used to extinguish fire caused by ____________.
   (a) gasoline, grease, oil
   (b) plastic, paper, cloth
   (c) combustible metal
   (d) electrical cable and wire
7. Class D extinguisher is used to extinguish fire caused by ____________.
   (a) gasoline, grease, oil
   (b) plastic, paper, cloth
   (c) combustible metal
   (d) kitchen material
8. Which of the following steps are not required to perform CPR?
   (a) Chest compression
   (b) Open airway
   (c) Rescue breathing
   (d) Turn the victim
9. What are the steps to use a fire extinguisher?
   (a) Squeeze the handle, aim the nozzle, pull the pin
   (b) Pull the pin, squeeze the handle, aim the nozzle
   (c) Aim the nozzle, squeeze the handle, pull the pin
   (d) Squeeze the handle, pull the pin, aim the nozzle
10. Which of the following is the emergency number in case of electric shock?
   (a) 101
   (b) 102
   (c) 105
   (d) 108

B. Fill in the blanks

1. While working with electricity, a technician must wear ____________ gloves and shoes.
2. Defective or inadequate insulation may result in ____________.
3. Class C fire is caused due to ____________.
4. CPR stands for ____________.

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5. Electrical tools have two parts: conductors and ________.
6. Class A fire is caused due to ____________.
7. If a computer system starts burning due to overload, then ____________ fire extinguisher is preferred.
8. If burning is caused due to petrol, this will cause a Class ____________ type fire.
9. Improper location of chemicals may increase the risk of ____________.
10. While working near a heated machine, which has been running for a long time, one must wear ____________.

C. State whether the following statements are True or False

1. Rubber is a good conductor of electricity.
2. Fire extinguisher is used in case of an earthquake.
3. Copper is a good conductor of electricity.
4. When a wireman touches an electric panel, the hands should be wet.
5. A fire extinguisher is used to provide heat to the electrical system.
6. Use non-conductive material to remove a victim from the conductor.
7. Electric wires have a different colour code.
8. While repairing an electrical device, a wireman should always turn off the mains supply.
9. Do touch the victim or conductive surfaces while they are energised.
10. K-type fire extinguisher is used when fire is due to material like wood, paper, plastic.

D. Short answer questions

1. What are the factors that result in an accident?
2. List out the various precautions to be taken at a workplace.
3. What are the precautions to be taken for preventing electric shock while on the job?
4. How is CPR performed?
5. Write down the steps necessary for correctly operating a fire extinguisher in case of a fire emergency.
6. What can be the various hazards while installing an electrical panel?
7. Compare the different types of fire extinguishers.
8. Brief about the different classes of fire.
9. What first aid measure should be taken in case of electric shock?
10. In India, what is the specific colour code for wire?

Answer Key

Notes

Chapter 1: Electrical Power

A. Multiple choice questions

1.(b) 2.(d) 3.(c) 4.(c) 5.(d)
6.(b) 7.(a) 8.(c) 9.(c) 10.(b)

B. Fill in the blanks

1. short circuit and ground faults
2. surge arrester
3. trim
4. generating, distributing
5. static
6. surge
7. turbine
8. fault, interrupter
9. arc, fault, interrupter
10. switchgear

C. State whether the following statements are True or False

1.(T) 2.(F) 3.(T) 4.(T) 5.(T)

6.(T) 7.(T) 8.(F) 9.(F) 10.(T)

Chapter 2: Busway in Control Panel Design

A. Multiple choice questions

1.(b) 2.(c) 3.(c) 4.(b) 5.(c)

6.(c) 7.(b) 8.(d)

B. Fill in the blanks

1. switchboard
2. busway
3. busbar
4. aluminium or copper
5. glass wrap
6. flange
7. offset
8. feeder and plugin
9. crosses
10. 3 and 1

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(F) 4.(T) 5.(T)
6.(T) 7.(T) 8.(T) 9.(F) 10.(F)

Chapter 3: Circuit Breaker

A. Multiple choice questions

1.(b) 2.(a) 3.(d) 4.(d) 5.(d)
6.(a) 7.(a) 8.(d) 9.(d) 10.(c)

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B. Fill in the blanks

1. steel, brass
2. copper or aluminium
3. electromechanical
4. low resistance
5. ground
6. line to line or line to neutral
7. 1090
8. 50
9. hertz
10. heat absorbing

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(T) 4.(T) 5.(F)

6.(T) 7.(T) 8.(T) 9.(T) 10.(T)

Chapter 4: Installation of Residential Control Panel

A. Multiple choice questions

1.(d) 2.(a) 3.(a) 4.(d) 5.(a)
6.(d) 7.(c) 8.(d) 9.(d) 10.(c)

B. Fill in the blanks

1. power distribution
2. trim assembly
3. breaker, lug
4. secondary or downstream panel
5. series
6. galvanised steel
7. knockouts
8. moisture
9. trim
10. amperage

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(F) 4.(T) 5.(T) 6.(F) 7.(F) 8.(T) 9.(F)

Chapter 5: Installation of Industrial Control Panel

A. Multiple choice questions

1.(d) 2.(d) 3.(c) 4.(a) 5.(d) 6.(c) 7.(d)

B. Fill in the blanks

1.industrial
2.aluminium, copper
3.fusible disconnect switch
4.power
5.main breaker, main lug only

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(F) 4.(T) 5.(T)

Chapter 6: Installation of a Switchboard

A. Multiple choice questions

1.(d) 2.(d) 3.(a) 4.(d) 5.(a) 6.(c) 7.(b)

B. Fill in the blanks

1.front, rear
2.90 inches, 38 inches
3.switch board
4.load devices
5.metal bus

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(F) 4.(F) 5.(T) 6.(T)

Chapter 7: AC Drives and Soft Starters

A. Multiple choice questions

1.(d) 2.(d) 3.(d) 4.(c) 5.(d)
6.(d) 7.(d) 8.(d) 9.(d) 10.(d)

B. Fill in the blanks

1.tapped
2.pulsating DC
3.capacitor, resistor
4.microcontroller or microprocessor
5.scalar, vector, direct torque

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(T) 4.(T) 5.(F)

Chapter 8: Electrical Machines

A. Multiple choice questions

1.(b) 2.(c) 3.(a) 4.(a) 5.(b)
6.(b) 7.(c) 8.(a) 9.(b) 10.(d)

B. Fill in the blanks

1. mechanical energy, electrical energy
2. left
3. right
4. artificial
5. alternator
6. induction

C. State whether the following statements are True or False

1.(T) 2.(T) 3.(T) 4.(F) 5.(T) 6.(T) 7.(T) 8.(F) 9.(T)

Chapter 9: Programmable Logic Controller

A. Multiple choice questions

1.(d) 2.(d) 3.(d) 4.(b) 5.(b)
6.(c) 7.(a) 8.(d) 9.(a) 10.(d)

B. Fill in the blanks

1. digital
2. input and output
3. processor
4. RS-232, RS-485
5. data handler, overseer

C. State whether the following statements are True or False

1.(T) 2.(F) 3.(T) 4.(T) 5.(T)

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Chapter 10: Testing and Measurement in an Electrical Panel

A. Multiple choice questions

1.(d) 2.(b) 3.(c) 4.(c) 5.(d)
6.(a) 7.(a) 8.(b) 9.(d) 10.(a)

B. Fill in the blanks

1.electrical
2.step-up
3.step-down
4.less, high
5.high, less

C. State whether the following statements are True or False

1.(T) 2.(F) 3.(T) 4.(F) 5.(T)

Chapter 11: Occupational Health and Safety Measures

A. Multiple choice questions

1.(d) 2.(c) 3.(d) 4.(a) 5.(b)
6.(d) 7.(d) 8.(d) 9.(d) 10.(d)

B. Fill in the blanks

1. insulating
2. electric shock
3. electrical equipment
4. Cardio-Pulmonary Resuscitation
5. insulators
6. plastic, paper, cloth
7. carbon-di-oxide or dry powder
8. Class B
9. chemical leakage
10. safety gears

C. State whether the following statements are True or False

1.(F) 2.(F) 3.(T) 4.(F) 5.(F)
6.(T) 7.(T) 8.(T) 9.(T) 10.(F)

Glossary

Alternating Current (AC): *refers to an electric current that reverses direction at regular intervals. The abbreviation AC is commonly used.*

Ammeter: *meter which is used to measure the amount of electric current flowing in an electric circuit.*

Amperage: *refers to the strength of an electrical current. It is measured in amperes.*

Amplitude: *is the maximum absolute value reached by a voltage or current waveform.*

ANSI: *stands for American National Standards Institute. It is an institute for the development of technology standards in the United States.*

Architecture: *computing, it is the description of basic components and basic operations of chip. Each processor family has its own architecture. Assembly language is a programming language used in particular processor.*

Armature: *is a rotating part of motor which is used to generate the magnetic field in the motor.*

Automation: *is the creation and application of technologies to produce and deliver goods and services with minimal human intervention.*

Bearing Ball: *is rolling element, which is used to reduce the friction in a rotating part of a machine.*

Cabinet: *is a closed box, which acts a safety box for the electrical and electronic components.*

Cable: *alternatively referred to as a cord, connector or plug, a cable consists of one or more wires covered with plastic. A cable transmits power or data to devices or locations.*

Capacitor: *is a device used in electrical circuits. A capacitor stores an electrical charge for a short duration, and then, returns it to the circuit. Common types of capacitor includes tantalum, electrolytic, ceramic and film capacitors.*

Capacitance: *is the property of a capacitor to hold charge. It is measured in Farad.*

Cathode: *is a type of electrode through which electrons move.*

Charging: *is a time required to charge the capacitor.*

Clampmeter: *is an electrical test tool that combines a basic digital multimeter with a current sensor. It is also called as tong tester.*

Coil: *refers to a series of circles formed by the winding of an insulated wire, which creates a magnetic field when electric current passes through the circles.*

Conductor: *is a substance that allows electricity or heat to pass through it.*

Conduit: *is a pipe, channel, tube or trough for protecting electrical wires or cables from environmental effects.*

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Conveyor: *is a system in which mechanical devices or assemblies is used to transport material with minimal effort.*

CPU: *is the processor of computer. It is also acts heart of computing system.*

Direct Current (DC): *refers to electric current flowing in one direction only (i.e., current produced using a battery). The abbreviated form DC is commonly used.*

Discharging: *is a time required for the discharging of capacitor.*

Drill Machine: *is a hand handle tool primarily used for making round holes.*

Driver: *in computing, a device driver is a computer program that operates or controls a particular type of device that is attached to a computer.*

Electro Motive Force (EMF): *is the measurement of energy that causes current to flow through a circuit. It can also be defined as the potential difference in charge between two points in a circuit.*

Earth: *is the connection between electrical installation systems via a conductor to the buried plate in the ground.*

Earthed: *when an electrical device, appliance or wiring system is connected to the earth through earth electrode, it is known as earthed device or 'earthed'.*

Electricity: *is a form of energy produced from charged elementary particles, usually, supplied as electric current through cables, wires, etc., for lighting, heating, driving machines, etc.*

Electromagnet: *is a coil of wire, usually, wound on an iron core, which produces a strong magnetic field when current is passed through the coil.*

Enclosure: *an area that is surrounded by a barrier*

Fault Current: *is the electrical current, which flows through a circuit during an electrical fault condition.*

Filter: *is a circuit, which allow particular range of frequency signals.*

Frequency: *is the rate at which a sound or electromagnetic wave vibrates per unit of time. It is expressed in Hertz (Hz).*

Fuse Box: *houses the fuse used in control panel.*

Galvanized Steel: *is a manufacturing process where a coating of zinc is applied to steel or iron to offer protection and prevent rusting*

Ground Fault: *refers to inadvertent contact between an energised conductor and ground or equipment frame.*

IEEE: *is the abbreviated form of the Institute of Electrical and Electronic Engineers.*

Indicator: *is used to indicate the state or level of something.*

Insulator: *is a material or device used to prevent heat, electricity or sound from escaping something. In other words, it is a material whose internal electric charges do not flow freely. Little electric* *current will flow through it under the influence of an electric field. This is opposite to other material, semiconductors and conductors, which conduct electric current easily.*

Inverter: *is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC).*

kWh: *is a measure of electrical energy equivalent to power consumption of one watt for one hour.*

LED: *stands for Light Emitting Diode. Semiconductor material is used in their manufacturing.*

Load: *is an electrical component or portion of a circuit that consumes (active) electric power.*

Lug: *is used to connect electrical devices and cables. This ensures safe handling of cables and wires. Usually one end of the electrical lug is used for connecting a cable to an electrical device.*

Magnetic Flux: *is defined as the number of magnetic field lines passing through a given closed surface.*

Microcontroller: *is a compact integrated circuit designed to execute a specific operation in a system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.*

Microprocessor: *is an electronic component that is used by a computer to do its work. It is a central processing unit on a single integrated circuit chip containing millions of very small components including transistors, resistors, and diodes that work together.*

Electric Motor: *is an electrical machine converts electrical energy into mechanical energy.*

Multimeter: *is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current and resistance.*

Mutual Induction: *is a phenomenon in which an EMF is induced across a coil, due to rate of change current in adjacent coil.*

NEC: *is a standard for safe installation of electrical wiring and equipment.*

NEMA: *stands for "National Electrical Manufacturers Association".*

Power Supply: *is an electrical device that supplies electric power to an electrical and electronic loads.*

Pulley: *is a wheel on an axle or shaft that is used to transfer the power between the shaft and cable or belt.*

Push Button: *is a simple button which is used to control the switch mechanism in a machine or a process*

Rectifier: *circuit that converts AC power supply to DC power supply.*

Relay: *refers to an electrically controlled device that opens and closes electrical contacts to affect the operation of other devices in same or another electrical circuit.*

Rotor: *is the rotating part of an electric generator and motor.*

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RS-232: *is a standard connector used for transmission of data. It is widely used in industrial communication devices. It is used for point to point transmission of data.*

RS-485: *is a standard connector used for transmission of data. It is widely used in industrial communication devices. It is used for point to multipoint transmission of data.*

Semiconductor: *is a solid material, whose electrical conductivity at room temperature is between that of a conductor and insulator. The most common semiconductor material is silicon.*

Sensor: *a device detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure and many more.*

Silicon: *is a chemical element with the symbol 'Si' and atomic number 14. It is a hard, brittle crystalline solid with a blue-grey metallic lustre. It is a tetravalent metalloid and semiconductor.*

Sine wave: *also called sinusoid, sine wave is a mathematical curve that describes smooth periodic oscillation. A sine wave is a continuous wave.*

Single-phase: *in electrical engineering, single-phase electric power is the distribution of alternating current electric power. It is a two wire system. It has one phase and one neutral.*

Stator: *is a stationary part of a rotary system found in electric generators and motors.*

Surge: *is the sudden rise in the flow of charge due to thundering and lightning effect.*

Semiconductor: *is a solid material, whose electrical conductivity at room temperature is between that of a conductor and insulator. The most common semiconductor material is silicon.*

Test lamp: *is a portable lamp with free leads to connect to various points of a faulty circuit to locate a defect.*

Three phase: *in electrical engineering, three-phase electric power is the distribution of alternating current electric power. It is a four wire system. It has three phase and one neutral. It is used for high voltage requirement.*

Toggle: *is defined as the unstable state of a device, circuit, network.*

Torque: *is the measure of the force that can cause an object to rotate about an axis.*

Transistor: *is a small electronic device, containing a semiconductor and at least three electrical contacts used in a circuit as an amplifier, detector or switch.*

Transmission towers: *are large structures that support the high-voltage transmission lines. Transmission lines carry electricity over long distances.*

Trip: *refers to automatic opening (turning off) of a circuit by a circuit breaker*

Turbine: *is a device that extracts thermal energy from pressurized steam or kinetic energy of fluid and uses it to do mechanical work on a rotating output shaft.*

USB: *stands for Universal Serial Bus. It also establishes specifications for cables and connectors and protocols for connection, communication and power supply between computers, peripherals and other computers*

Volt: *is the unit of electric potential and its symbol is 'V'.*

Voltmeter: *is a meter used to measure the supply voltage.*

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Chapter 1

Fig.1.2, Fig.1.3, Fig.1.4, Fig.1.6, Fig.1.7, Fig.1.8, Fig.1.9, Fig.1.10, Fig.1.12, Fig.1.13, Fig.1.14, Fig.1.15, Fig.1.16, Fig.1.17, Fig.1.18, Fig.1.19, Fig.1.20, Fig.1.21, Fig.1.22, Fig.1.23, Fig.1.24, Fig.1.25, Fig.1.26, Fig.1.27, Fig.1.28, Fig.1.29, Fig.1.30, Fig.1.31, Fig.1.32, Fig.1.33, Fig.1.34, Fig.1.35, Fig.1.36, Fig.1.37, Fig.1.38, Fig.1.39, Fig.1.40, Fig.1.41, Fig.1.42, Fig.1.43, Fig.1.44

Practical Activity 1

Fig. a, Fig. b

Practical Activity 2

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e, Fig. f, Fig. g, Fig. h, Fig. i, Fig. j, Fig. k, Fig. l, Fig. m, Fig. n, Fig. o

Chapter 2

Fig.2.1, Fig.2.2, Fig.2.4, Fig.2.5, Fig.2.7, Fig.2.8, Fig.2.9, Fig.2.10, Fig.2.12, Fig.2.13, Fig.2.14, Fig.2.15, Fig.2.16, Fig.2.17, Fig.2.18, Fig.2.19, Fig.2.20, Fig.2.21, Fig.2.22, Fig.2.23, Fig.2.24, Fig.2.25, Fig.2.26, Fig.2.27, Fig.2.28, Fig.2.29, Fig.2.30, Fig.2.31

Practical Activity 1

Fig. a, Fig. b, Fig. c

Practical Activity 2

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e, Fig. f, Fig. g, Fig. h

Chapter 3

Fig.3.1, Fig.3.2, Fig.3.3, Fig.3.4, Fig.3.5, Fig.3.6, Fig.3.7, Fig.3.8, Fig.3.9, Fig.3.10, Fig.3.11, Fig.3.12, Fig.3.13, Fig.3.14, Fig.3.15, Fig.3.16, Fig.3.17, Fig.3.18, Fig.3.19, Fig.3.20, Fig.3.21, Fig.3.22, Fig.3.23

Practical Activity 1

Fig. a

Practical Activity 2

Fig. a

Practical Activity 3

Fig. a

Practical Activity 4

Fig. a, Fig. b, Fig. c

Chapter 4

Fig.4.1, Fig.4.2, Fig.4.3, Fig.4.4, Fig.4.5, Fig.4.6, Fig.4.7, Fig.4.8, Fig.4.9, Fig.4.10, Fig.4.11, Fig.4.12, Fig.4.13, Fig.4.14, Fig.4.15, Fig.4.16, Fig.4.17, Fig.4.18, Fig.4.19

Practical Activity 1

Fig. a, Fig. b, Fig. c

Practical Activity 3

Fig. a

Practical Activity 4

Fig. a, Fig. b, Fig. c, Fig. d

Chapter 5

Fig.5.1, Fig.5.2, Fig.5.3, Fig.5.4, Fig.5.5, Fig.5.6, Fig.5.7, Fig.5.8, Fig.5.9, Fig.5.10, Fig.5.11, Fig.5.12, Fig.5.13, Fig.5.14, Fig.5.15, Fig.5.16, Fig.5.17, Fig.5.18, Fig.5.19, Fig.5.20, Fig.5.21

Practical Activity 1

Fig. a, Fig. b, Fig. c, Fig. d

Practical Activity 2

Fig. a, Fig. b, Fig. c, Fig. d

Chapter 6

Fig.6.1, Fig.6.2, Fig.6.3, Fig.6.4, Fig.6.5, Fig.6.6, Fig.6.7, Fig.6.8, Fig.6.9, Fig.6.10, Fig.6.11, Fig.6.12, Fig.6.13, Fig.6.14, Fig.6.15, Fig.6.16, Fig.6.17

Practical Activity 1

Fig. a

Chapter 7

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Chapter 8

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Practical Activity 1

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e

Practical Activity 2

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e

Practical Activity 3

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e, Fig. f, Fig. g, Fig. h, Fig. i

Practical Activity 4

Fig. a, Fig. b

Practical Activity 5

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e, Fig. f, Fig. g, Fig. h, Fig. i, Fig. j, Fig. k,

Notes

Practical Activity 6

Fig. a, Fig. b, Fig. c

Chapter 9

Fig.9.1, Fig.9.2, Fig.9.3, Fig.9.4, Fig.9.5, Fig.9.6, Fig.9.7, Fig.9.8, Fig.9.9, Fig.9.10, Fig.9.11, Fig.9.12, Fig.9.13

Practical Exercise

Fig. a

Chapter 10

Fig.10.1, Fig.10.2, Fig.10.3, Fig.10.4, Fig.10.5, Fig.10.6, Fig.10.7, Fig.10.8, Fig.10.9

Practical Activity 1

Fig. a

Practical Activity 2

Fig. a, Fig. b

Practical Activity 3

Fig. a, Fig. b

Practical Activity 4

Fig. a, Fig. b

Practical Activity 5

Fig. a, Fig. b, Fig. c, Fig. d

Practical Activity 6

Fig. a, Fig. b, Fig. c, Fig. d, Fig. e

Chapter 11

Fig.11.1, Fig.11.2, Fig.11.3, Fig.11.4, Fig.11.5, Fig.11.6, Fig.11.7, Fig.11.8, Fig.11.9, Fig.11.10, Fig.11.11, Fig.11.12, Fig.11.13, Fig.11.14, Fig.11.15, Fig.11.16, Fig.11.17, Fig.11.18, Fig.11.19, Fig.11.20, Fig.11.21, Fig.11.22, Fig.11.23, Fig.11.24, Fig.11.25, Fig.11.26, Fig.11.28, Fig.11.29, Fig.11.30, Fig.11.31, Fig.11.32, Fig.11.33, Fig.11.34

Practical Activity 1

Fig. a

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