MODULE 1

Electrical Power Generation, Transmission and Distribution

Syllabus:

Electrical Power Generation, Transmission and Distribution: General structure of electrical power system using single line diagram approach, Electric power generation, Concept of power transmission and power distribution with single line diagram.

Domestic Wiring & Safety Measures: Brief discussion on Service mains, Meter board, Distribution board; Types of wiring, Elementary discussion on Circuit protective devices: Fuses and Circuit Breaker; Electric shock, Precautions against shock. Earthing: Pipe and Plate earthing.

Electricity Billing & Need for Energy Saving: Measuring the electricity consumption, Two-part electricity tariff, Block rate tariff, Calculation of energy consumption for given set of loads, Calculation of electricity bill for domestic consumers.

INTRODUCTION

Electrical energy is the most popular form of the energy. Some features of electrical energy are as follows:

- Electric energy is most convenient and efficient for production of light and rotational mechanical motion.
- It can be transported easily and efficiently over long distance from production site to a large number of points of use.
- Electric energy must be generated centrally and instantly transported to vast geographical regions within and beyond national boundaries.
- It cannot be stored in large quantities, except in batteries for limited use.

Electric energy is obtained by conversion from other forms of energy. Basically, energy is stored in some materials in the form of chemical energy or it is directly available from the sun as solar energy or a manifestation of solar energy like wind (kinetic energy), water at high altitudes (potential energy) etc

Sources of generating electricity

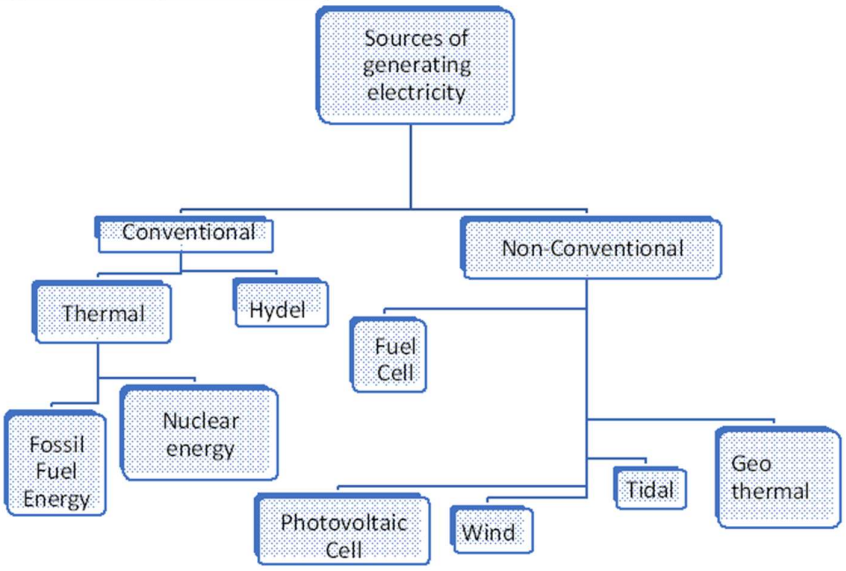


Fig 1.1: Sources of electrical energy

SIMPLE ELECTRICAL POWER SYSTEM

A simple electrical system can be represented by using different symbols for different components and devices. It also indicates the connection between the components and the path of flow of signals from input to output.
Figure 1.2 shows the diagram of a simple power system.

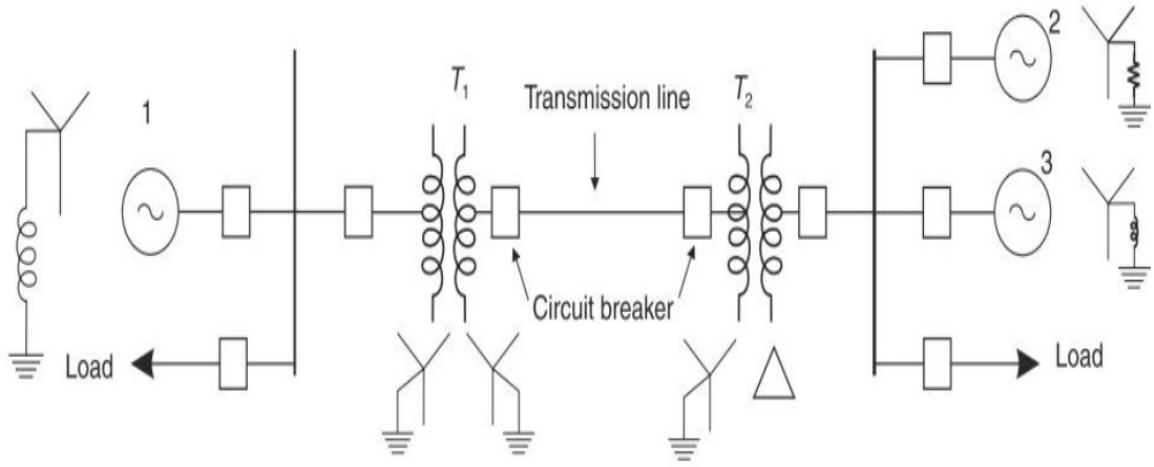
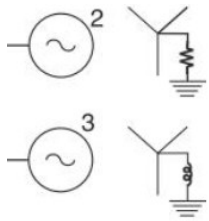
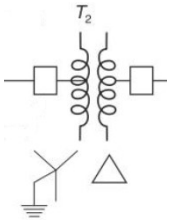


Fig 1.2 Simple electrical power system

The meanings of some blocks are given below:

	Indicates a generator with Y (Star) connection grounded through resistance and inductance
	Indicates a transformer with star-delta connection, with star connection directly grounded. Square blocks indicate the circuit breaker.

ELECTRIC POWER GENERATION

1. Hydel power Generation

Water-reservoir at higher altitudes is a prerequisite for this purpose. Power-house is located at a lower level. The difference in these two levels is known as “Head.”
A schematic diagram of hydroelectric generating system is shown in Fig.1.3 given below

Working principle:

- In this method of generation, water from higher height is passed into the water turbine through the pen stock.

- As the water reaches the turbine, it gains speed after losing the Potential energy. (Potential energy gets converted into kinetic energy)

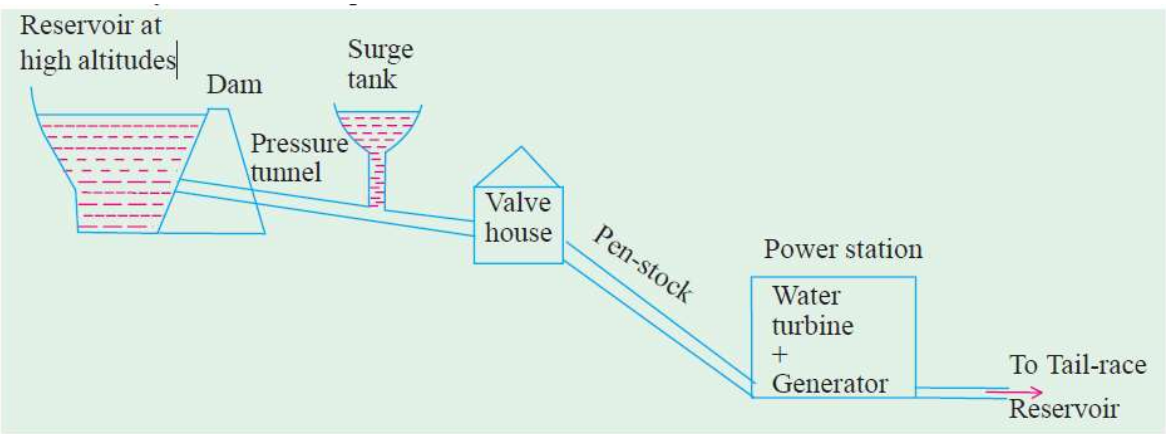


Fig 1.3 Hydroelectric power generation

- Kinetic energy of this speedy water drives the water turbine, which converts this into mechanical output.
- It drives the coupled generator, which gives Electrical energy output.

Penstocks are pipes or long channels that carry water down from the hydroelectric reservoir to the turbines inside the actual power station. Generally, they are made of steel and water under high pressure flows through the penstock. (Fig 1.4) Grates or filters can be attached to the ends of penstocks to trap large debris such as branches. This ensures that debris cannot enter the channel and block it.

Fig. 1.4 View of penstock

- The amount of water that flows through the pen stock is controlled by the valves present in the valve house.
- The valve house has a controlling valve (=main sluice valve) and a protecting valve (= an automatic, isolating, “butterfly” type valve).
- The power control is done by the main sluice valve. Main sluice is a gate that can be raised or lowered to increase or decrease the amount of water allowed to flow through. When the sluice is fully open, water flows freely down through the penstock. However, when it is closed slightly there is a limitation to how much water can flow, and thus less water enters the penstock.
- The “butterfly” valve comes into action if water flows in the opposite direction as a result of a sudden drop in load on the generator. (The pen stock may burst under this condition)
- After the falling water imparts its energy to the water turbine, the water is allowed to pass into the tail-race reservoir.

- The water turbines are essentially low-speed prime movers.
- Alternators coupled to water turbines have a large number of poles.

GENERAL STRUTURE OF AN ELECTRICAL POWER SYSTEM USING SINGLE LINE DIAGRAM APPROACH (POWER TRANSMISSION SYSTEM)

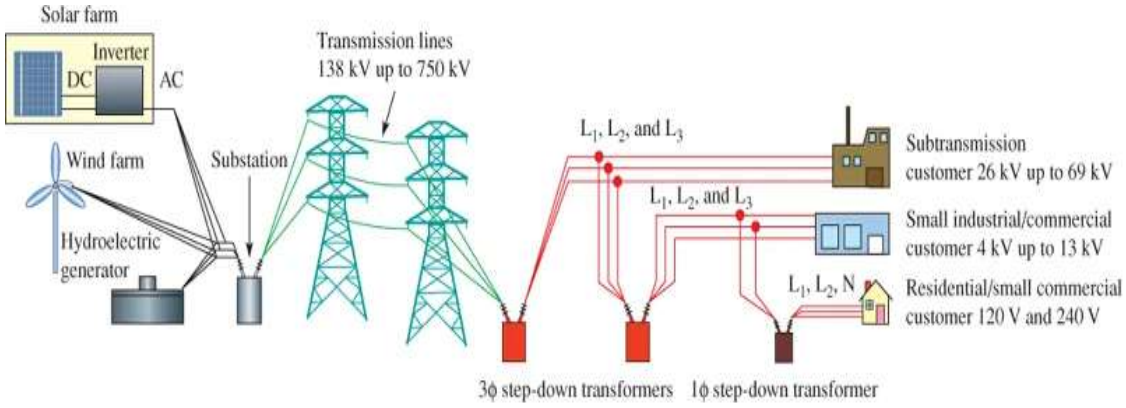


Fig 1.5: General structure of a power distribution system

A one - line diagram of a power system shows the main connections and arrangement of different components in three phase power systems

- These line diagrams use symbols for generators, motors, transformers and loads. Example: Circuit breakers are represented as rectangular blocks.
- Any particular component may or may not be shown depending on the information required in a system study, e.g. circuit breakers need not be shown in a load flow study but are a must for a protection study

Generating Station: Electric power is commonly (or usually) generated at 11 kV in generating stations in India and Europe.

Primary Transmission: This generating voltage is then stepped up to 132kV, 220kV, 400kV or 765kV etc. Stepping up the voltage level depends upon the distance at which power is to be transmitted. Longer the distance, higher will be the voltage level. Stepping up of voltage is to reduce the I^2R losses in **transmitting the power** (when voltage is stepped up, the current reduces by a relative amount so that the power remains constant, and hence I^2R loss also reduces).

Secondary transmission: The voltage is the stepped down at a receiving station to 33kV or 66kV. The transmission lines from this station connect substations located near load centers (cities etc.).

Primary distribution: The voltage is stepped down again to 11kV at a substation. Large industrial consumers can be supplied at 11kV directly from these substations. Also, feeders emerge from these substations.

Secondary distribution: This system consists of feeders, distributors and service mains. Feeders are either overhead lines or underground cables which carry power close to the load points (end consumers) up to a couple of kilometers. Finally, the voltage is stepped down to 415 volts by a pole-mounted distribution transformer and delivered to the distributors. End consumers are supplied through a service mains line from distributors.

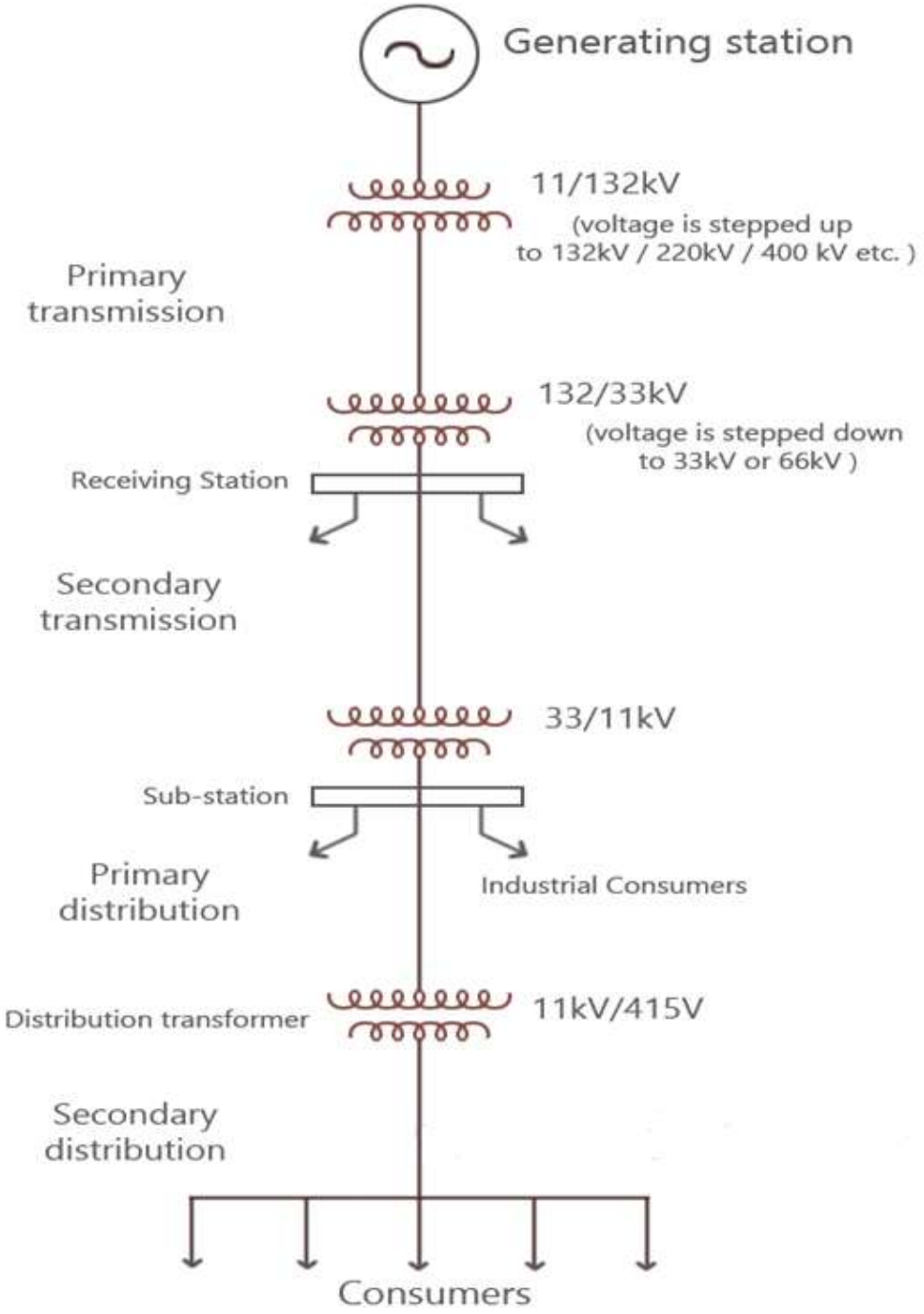


Fig 1.6 : General structure of a power distribution system using single line diagram approach

DOMESTIC WIRING & SAFETY MEASURES

Domestic Wiring:

- A network of wires drawn connecting the meter board to the various energy consuming loads (lamps, fans, motors etc) through control and protective devices for efficient distribution of power is known as electrical wiring.
- Electrical wiring done in residential and commercial buildings to provide power for lights, fans, pumps and other domestic appliances is known as domestic wiring.

Specification of Wires

The conductor material, insulation, size and the number of cores, specifies the electrical wire.

- The conductors are usually of either copper or aluminium.
- Various insulating materials like PVC, TRS, and VIR are used.
- The wires may be of single strand or multi strand.
- Wires with combination of different diameters and the number of cores or strands are available.

Wiring Materials

Electrical wire is made of materials like copper, aluminum and silver. As silver is expensive, mostly copper and aluminium are used in wiring. Materials are classified into three types according to their properties: 1. Conducting materials 2. Insulating materials 3. Semiconductor materials

Conducting Material

(a) Copper: It is a good conductor of electricity. It is used in wiring materials in cables. Its has low resistance and is used for conduction of electricity at high, medium and low voltage. It is used in wiring and cable making.

(b) Aluminium: It is light weight and cheaper in comparison to copper. Therefore, this type of conducting material is mostly used in electrical wiring. It is silvery–white in colour and it has a soft texture. It is often used in wiring and making cable.

Insulating Materials Insulating materials are used for insulating purpose. These types of materials are bad conductors of current. For example, rubber, paper, mica, wood, glass and cotton.

Semiconductors Materials are materials which have a conductivity between conductors (generally metals) and nonconductors or insulators (such as most ceramics). Semiconductors can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.

Domestic wiring standards

Domestic wiring standards are a set of rules and regulations that govern the design and installation of electrical wiring in homes and other residential buildings. These standards are designed to ensure the safety and reliability of electrical systems, and to protect people and property from electrical hazards.

Domestic wiring standards vary from country to country, but they all share some common principles. In India, Indian Electricity Rules (IER) standards are used. For example, most standards require the use of color-coded wires to identify different types of conductors, and the use of overcurrent protection devices such as circuit breakers and fuses to prevent electrical fires.

Some of the key elements of domestic wiring standards include:
Wire sizing: Wires must be sized appropriately for the amount of current they will carry. Using undersized wires can lead to overheating and fire.

- Circuit protection: All circuits must be protected by overcurrent protection devices such as circuit breakers or fuses. These devices trip when the current exceeds a safe level, preventing damage to the wiring and appliances.
- Grounding: All metal parts of electrical systems must be grounded to protect people from electrical shock. Grounding provides a safe path for electricity to flow to the ground in the event of a fault.
- Insulation: All electrical wires must be insulated to prevent electric shock. Insulation also helps to protect wires from damage.
- Workmanship: Electrical wiring must be installed in a neat and workmanlike manner. This helps to ensure that the wiring is safe and reliable.

BRIEF DISCUSSION ON SERVICE MAINS, METER BOARD, DISTRIBUTION BOARD

The AC supply is supplied by electric companies to the consumer. The supply is brought to local distribution stations from the generating stations where its voltage level is reduced to 400V between the lines and 230V between a line and a neutral. The small cables used between the distribution stations and consumer premises are called **service mains**.
The supply is given first to the meter board which consists of energy meter, service cable, sealing end box, bus bar arrangement, service fuse and neutral link. All these are the property of the supply company and its installation and maintenance are the sole responsibility of the supply company. From the meter board, the supply is taken to the main switch board where the

consumer's fuse is installed along with the main switch.

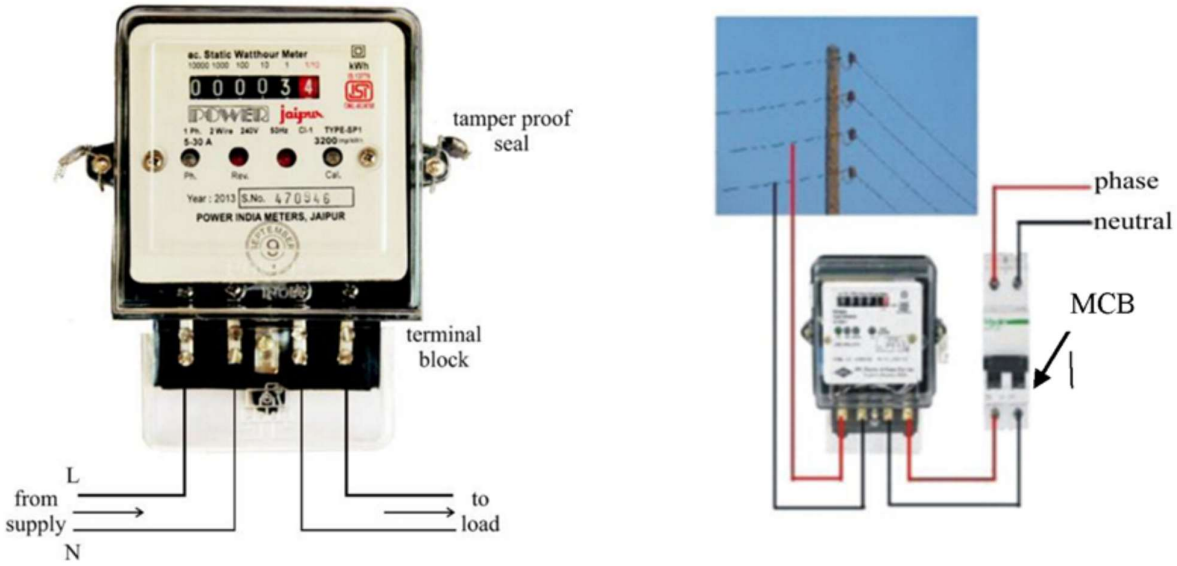


Fig. 1.7a Incoming and outgoing connections to a single=phase meter

Then supply is given to the main distribution board from where it is given to the number of subcircuits.

The various loads such as fans, tube lights and other electric appliances are connected in parallel across the subcircuit.

The 3 pin, 5A socket outlets are used for all light and fan subcircuits while 3 pin, 15A socket outlets are used for all the power circuits which are used to provide supply to the loads like mixers , electric ovens, refrigerators etc.

The Fig.1.7b shows a typical layout of domestic consumer panel wiring scheme.

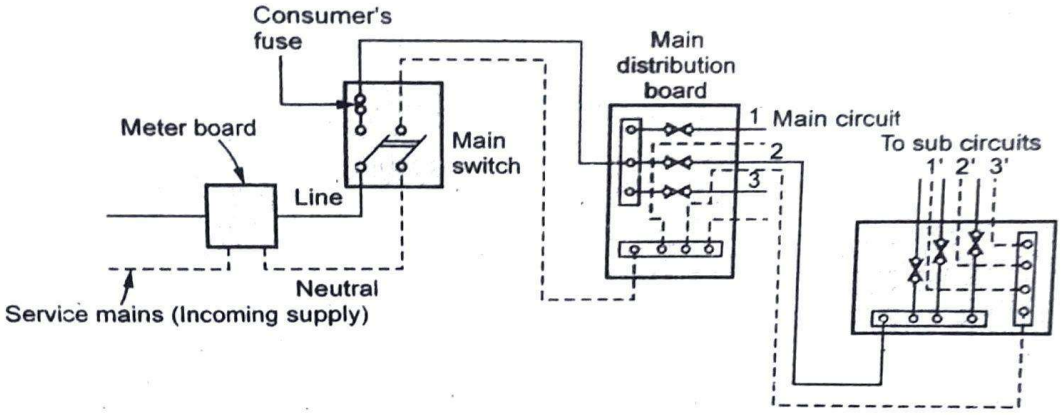


Fig 1.7b Typical layout of domestic consumer panel wiring scheme.

Thus, the domestic wiring installation consists of distribution of electrical energy from the meter board to the various subcircuits connected to electrical appliances through protective

devices and a network of wires.

TWO WAY CONTROL OF LAMP

Normally, only a single lamp is provided in a staircase which is controlled by either of the two switches- one installed at the top and other at the bottom.

This can be achieved by using two two-way switches S1 and S2, as shown in Fig. below. In the given position, the central terminal A1 of switch S1 is connected to its upper terminal B1, whereas the central terminal A2 of switch S2 is connected to its lower terminal C2. The circuit is not complete and the lamp is off.

Now, changing any one of the switches will complete the circuit to make the lamp glow. Similarly, the lamp can be switched OFF by changing the position of any one switch. Thus, a person climbing up the stairs or going down the stairs can switch ON on one end and switch it OFF on reaching the other end.

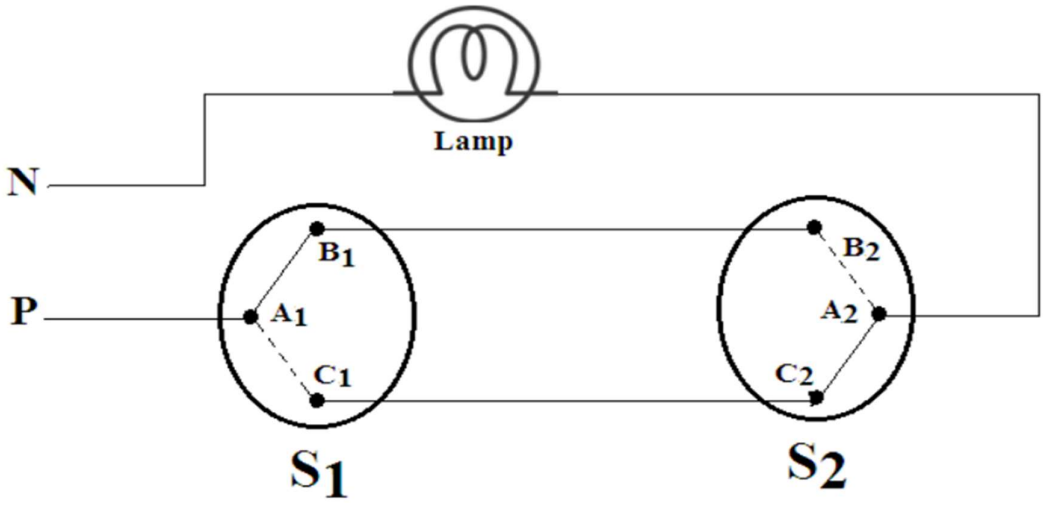


Fig 1.8 Two-way lamp control

Sl. No.	Switch S1	Switch S2	Lamp
1	$A_1 - B_1$	$A_2 - B_2$	ON
2	$A_1 - B_1$	$A_2 - C_2$	OFF
3	$A_1 - C_1$	$A_2 - B_2$	OFF
4	$A_1 - C_1$	$A_2 - C_2$	ON

THREE WAY CONTROL OF LAMP

If any one of the switches S1/S2/S3 is operated, the state of the bulb changes from ON to OFF or vice-varsa

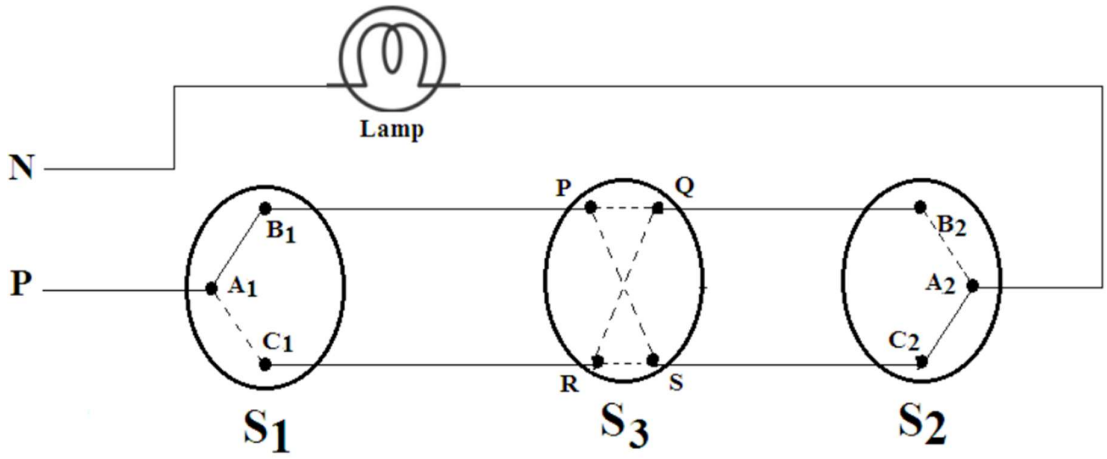


Fig. 1.9 Three way lamp control

Sl. No.	Switch S1	Intermediate Switch S3	Position of S3	Switch S2	Lamp
1	$A_1 - B_1$	P – S & Q – R	Cross Connection	$A_2 - B_2$	OFF
2	$A_1 - B_1$	P – S & Q – R		$A_2 - C_2$	ON
3	$A_1 - C_1$	P – S & Q – R		$A_2 - B_2$	ON
4	$A_1 - C_1$	P – S & Q – R		$A_2 - C_2$	OFF
5	$A_1 - B_1$	P – Q & R – S	Straight Connection	$A_2 - B_2$	ON
6	$A_1 - B_1$	P – Q & R – S		$A_2 - C_2$	OFF
7	$A_1 - C_1$	P – Q & R – S		$A_2 - B_2$	OFF
8	$A_1 - C_1$	P – Q & R – S		$A_2 - C_2$	ON

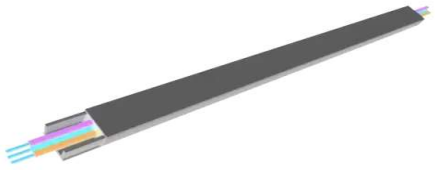
TYPES OF WIRING

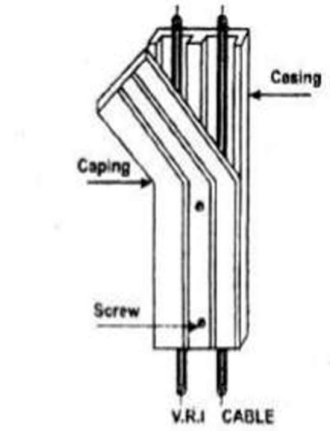
Depending upon the various factors various types of wiring used in practice are:

- Cleat wiring
- Casing and Capping Wiring
- Surface Wiring
- Metal Sheathed wiring
- Conduit System

Casing - Capping Wiring:

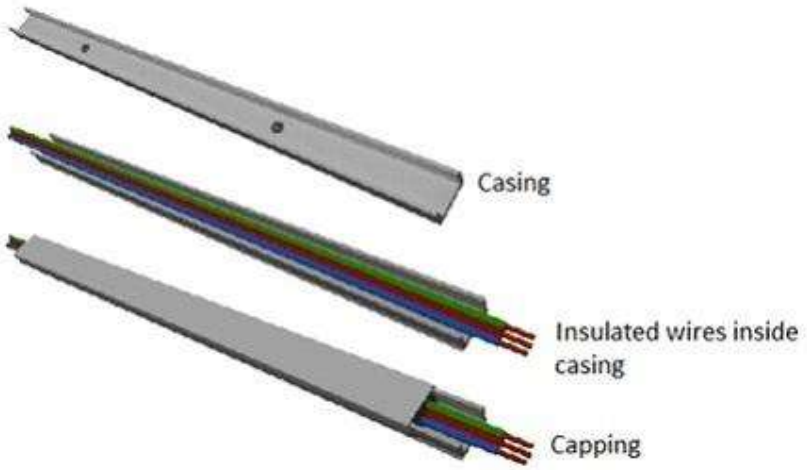
- It's an electrical wiring method where PVC (polyvinyl chloride) insulated wires are placed in plastic casings and covered with a cap
- The casing is commonly a rectangular strip, and its channel and cap are usually grey or white.
- Casing have grooves through which wires can be run
- Before installing, a 3mm round insulator is used between casing and the wall to prevent the humidity of the wall affecting the casing.
- This wiring can be installed in both vertical and horizontal positions. Different types of joints are used in this type of wiring system such as T joint, L-joint and Bridge joint etc.

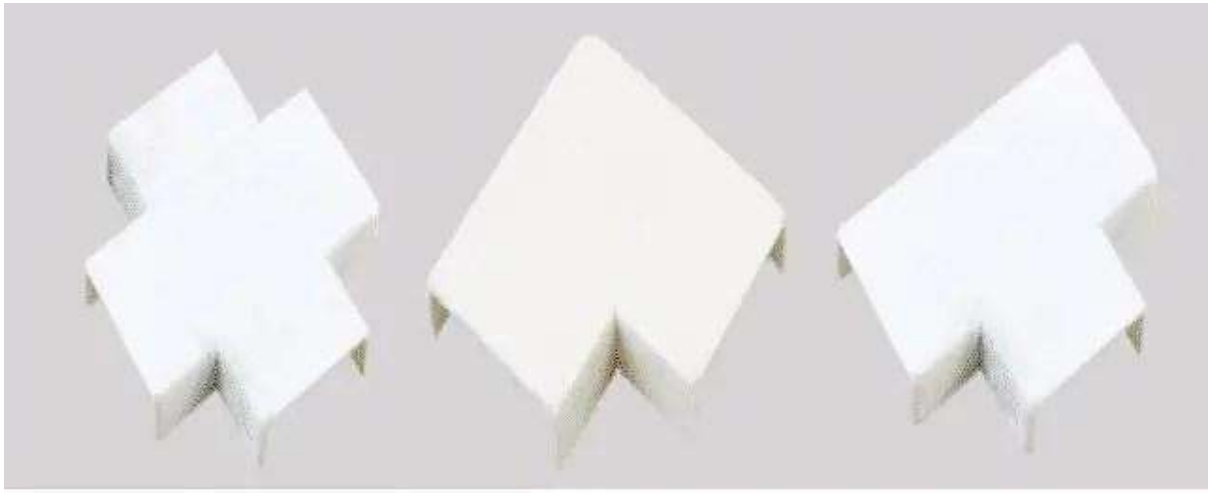




Wooden Casing & Capping Wiring System

Fig. 1.10 Casing and Capping Wiring





Advantages:

- Good Appearance
- Low quality wires/cables can be used as they are laid inside.
- No atmospheric effect on wires (smoke, humidity etc)
- Easy to install and rewire. (phase and neutral wires will be in separate slots)
- By opening the capping, we can easily inspect the wiring in case of any fault.
- Much cheaper than other wiring systems such as sheathed and conduit
- Durable and long lasting system

Disadvantages:

- There lies a risk of fire
- Requires better workmanship and hence labour cost is high.
- It is not damp proof and hence it cannot be used in wet and damp places.
- Needs painting or varnishing to improve life span.
- Not suitable for industries as the system doesn't work in acidic conditions

Conduit Wiring

- In this method, metallic tubes called as conduit are used to run the wires.
- It gives full mechanical protection to the wires. This is most desirable for workshops and public buildings.
- Depending on whether the conduits are laid inside the walls or supported on the walls, there are two types of conduits wiring which are:
    1) Surface conduit wiring
    2) Concealed conduit wiring
- The conduits are made up of mild steel which is annealed so that it can be bent without breaking. The standard length of conduit is generally 4m.

- The conduits are threaded at both ends with one coupler attached. Based on the outer diameter, various sizes of conduits from 12mm to 63mm are available. The conduits are supplied with black enamel coating on its internal and external surface.
- The conduits are to be erected completely before laying any cable in it.
- The rigid conduits are always terminated at outlets into a box which may be round, square or octagonal.
- These boxes are used to provide connections for lights, fans, heaters etc and are called outlet boxes.
- Inspection boxes are used to facilitate the pulling of conductors while junction boxes are used to house the junctions of the conductors.

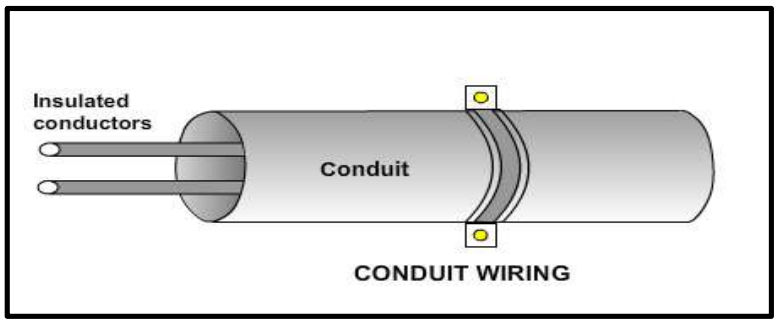


Fig 1.11. Conduit Wiring

Advantages

- The beauty of the premises is maintained due to conduit wiring.
- It is durable.
- It has a long life. It requires very less maintenance.
- It protects the wires from mechanical shocks, moistures and fire hazards.
- Proper earthing of conduits makes the method electrical shock proof.
- No risk of fire and good protection against mechanical injury.
- The lead and return wires can be carried in the same tube.
- Earthing and continuity is assured.
- Waterproof and troubleshooting is easy.

Disadvantages

- The repairs are very difficult in case of concealed conduit wiring.
- This method is costly.
- The erection requires highly skilled workmanship and is time consuming
- In concealed conduit wiring keeping conduit at earth potential is must. Without proper earthing there is danger of electric shocks.
- If the manufacturing of conduits is not proper then sharp edges of the metal conduits can cause damage of the insulation of the wires.
- Risk of short circuit under wet conditions (due to condensation of water in tubes).

ELEMENTARY DISCUSSION ON CIRCUIT PROTECTIVE DEVICES: FUSES AND CIRCUIT BREAKER

The electrical equipments are designed to carry a particular rated value of current under normal circumstances. Under abnormal conditions such as short circuit, overload or any fault, the current raises above this value, damaging the equipment and sometimes resulting in fire hazard.

Hence a protection circuit is necessary for all electrical equipments and installations. The protective circuit or device must be fast acting and isolate the faulty part of the circuit immediately when the fault occurs. It also helps in isolating only required part of the circuit without affecting the remaining circuit during maintenance.

The following devices are usually used to provide the necessary protection:

- Fuse
- Relays
- Miniature Circuit Breaker (MCB)
- Earth Leakage Circuit Breaker (ELCB)
- Residual Current Circuit Breaker (RCCB)

Fuse

- The fuse is a protecting device of simplest form.
- It consists of a small piece of metal called as fusing element.
- The fusing element carries the normal working current safely.

Working principle of Fuse

- When excessive current flows through a fuse, heat generated in the fuse element increases and the metal element melts. Hence, the current flow is interrupted and the electrical appliance gets disconnected from the supply.
- The fuse is always connected in series with the circuit or the appliance to be protected, so that in case of any fault, the fusing element melts and the electrical appliance is isolated from the source
- It is used for overload and short circuit protection in medium voltage range up to 66kV.
- Fuse element is usually made of Zinc, Silver, Aluminium, copper, lead-tin alloy etc.
- Fuses cannot be used for large currents as they bear low breaking capacity.

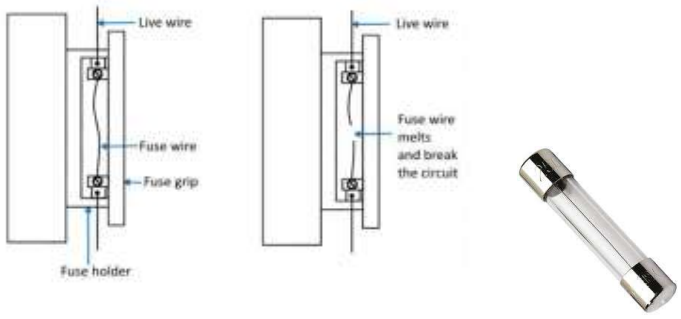


Fig 1.12 Structure of a fuse

Fuse Element : The part of the fuse which melts when excessive current flows through it is called fuse element or fuse wire.

Rated current of fuse: It is that maximum current which fusing element can normally carry without any undue overheating or melting.

Fusing Current: The minimum value of the current at which the fuse elements melts to interrupt the circuit current is called fusing current. Its value is always more than the current rating of the fuse.

Desirable Characteristics of Fuse Element

- Low melting point
- High Conductivity
- Free from deterioration due to oxidation
- Low cost

Advantages of Fuse

- It is the simplest and cheapest form of protecting device.
- It requires no maintenance.
- The operation of fuse is automatic.
- The minimum operating time is much smaller.
- Inverse time current characteristic enables it to use for the overload protection.
- Heavy currents can be interrupted without noise, smoke, gas and flame.

Disadvantages of Fuse

- The fuse is required to be replaced or rewired after its operation.
- The replacement or rewiring takes a lot of time.
- Discrimination between fuses in series cannot be obtained.
- It is not possible to provide secondary protection to fuses.

Miniature Circuit Breaker (MCB)

- MCB is an automatically operated electrical switch.
- It is designed to protect an electrical circuit from the dangers caused by excessive current resulting from an overload or short circuit.
- Its basic function is to interrupt the current flow as soon as fault occurs.
- In case of a fuse, if the fusing element melts, the fuse has to be replaced. But MCB can be reset to normal operation (either manually or automatically) when the current value comes to normal value
- MCB's are rated for ac voltage of 240V for single phase, 415V for three phase or 220V dc.
- The current rating available is from 0.5A to 63A.
- It is available as Single Pole, Double Pole and Triple Pole with short circuit breaking capacity from 1kA to 10kA with a rated frequency.

Working Principle of MCB

MCB safely and reliably switches off electrical circuit during abnormal conditions, such as over load or short circuit conditions. An MCB has two types of tripping:

- Thermal tripping
- Magnetic tripping

Thermal tripping: When continuous overload current flows through the bimetallic strip of the MCB, it gets heated up and the contact gets separated. This is a slow process (heating). Tripping time is few seconds.

Magnetic tripping: This occurs when suddenly the current rises to a very high value due to a fault (short circuit). The circuit breaks and current flow is interrupted. This is a rapid process. The tripping time is few milliseconds.

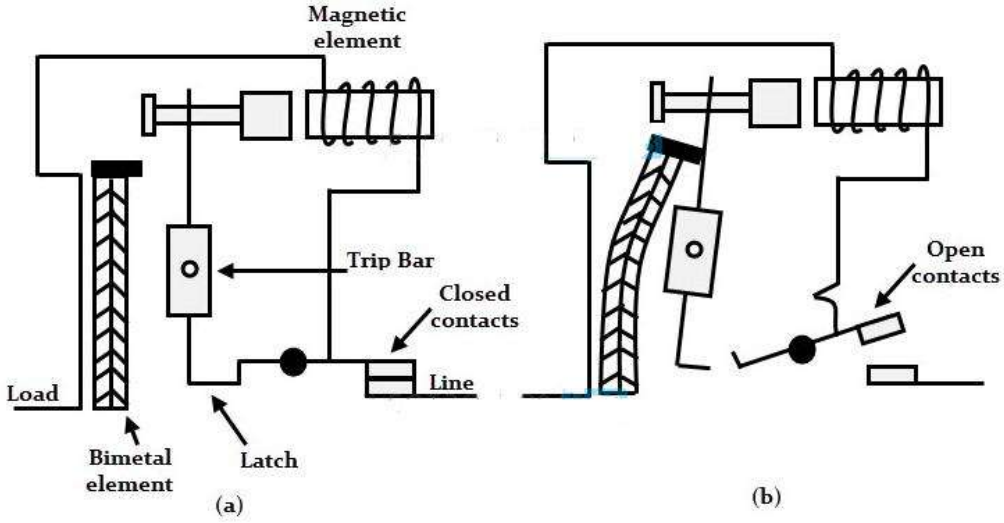


Fig. 1.13 Working of MCB

Advantages of MCB

- Its operation is very fast and opens in less than 1milli second.
- Provides protection against overload and short circuit without noise, smoke or flame.
- It can be reset very quickly after correcting the fault, just by switching a button.
- No rewiring is required.
- It cannot be reclosed if fault persists.
- The mechanical life is more than one lakh operating cycles.

Disadvantages of MCB

- MCBs are very costly
- MCBs are designed to protect circuits against over-currents, but they may not be able to provide protection against other types of electrical hazards, such as voltage surges or lightning strikes.
- For high power appliances like air conditioner or large home appliances that draw high current, MCBs are not able to handle it alone

Comparison of MCB and Fuse

Sl. No	Fuse	MCB
1	The operation of fuse is highly dependent on selection of its proper rating.	MCB instantly disconnects the supply automatically in the event of short circuit or overload. It thus eliminates the risk of fire and prevents damage to wiring scheme.
2	If the fuse wire after operation is replaced with newer one but go loose then it may be dangerous.Also to replace a blown fuse in between current carrying points is dangerous specially in dark.	Restarting power supply after tripping due to overload or short is easy
3	During replacement of fuse wire, the exact size of fuse wire may not be available. Also for a kit of hand tools must be kept ready	No maintenance and repairs is required for MCB. The distribution system employing MCBs provides satisfactory operation and lasts for years.
4	The board employing fuse is not compact.	The board employing MCBs give beautiful look as it is compact and elegant.

ELECTRIC SHOCK

A sudden agitation of the nervous system of a body, due to the passage of an electric current is called as an electric shock.

The effects of electric current passing through the human body are as follows

- 1mA causes only a faint tingle.
- 5mA causes slight shock, but may not be painful at all.
- 10 to 30mA causes painful causes leading to loss of muscular control.
- 50 to 150mA causes extremely painful shock, leading to death.

The factors affecting the severity of electric shock are,

- Magnitude of current through the body.
- Path of the current through the body.
- Time for which current is passed through the body.
- Frequency of the current.
- Physical and psychological condition of the person.

First Aid against Shock

The first aid can save the life and reduce the severity of the accidents. Hence elementary first aid is important. The first aid against an electric shock involves following steps:

- Do not panic
- Do not touch the person, if the person is still in contact with the electrical source. If possible, use a nonconducting object made of wood, cardboard, or plastic to move the source away.
- If possible, turn off the source of electricity.
- After removing the electrical source, check the person for a pulse, and determine whether they are breathing. If he is breathing, see that he gets sufficient fresh air to breathe, and take the doctor's help immediately
- If the person has no pulse, begin CPR (Cardiopulmonary Resuscitation) immediately.
- If the person is faint or pale, lay them down with their head lower than their body and elevate their legs.
- A person should neither touch any burns nor remove burned clothing.

SAFETY PRECAUTIONS TO AVOID SHOCK

- Make sure that all metallic parts of the electrical equipments are effectively earthed.
- Broken switches, plugs, etc., should be replaced immediately.
- Use a 'line tester' to check whether a terminal is live. Still better is to use a 'test lamp', as the line tester can show a glow even with a small voltage.
- Before replacing a broken switch, plug or blown fuse, always put off the main supply.
- Never use equipments and appliances with damaged or frayed lead wires.
- Never insert bare wires in the holes of a socket, for taking a connection. Always use a proper plug.
- Use rubber-sole shoes while repairing/testing electrical equipments. If this is not possible, use some dry-wooden support under your feet, so that your body has no direct contact with earth.
- Use rubber gloves while touching any terminal or while removing insulation layer from a conductor.
- Always use well insulated tools (such as screwdrivers, pliers, cutters, etc.).
- Never touch two different terminals at the same time.
- Be careful that your body does not touch the wall or any other metallic frame having contact with earth.
- Use correct rating of fuse wire.
- While repairing an electrical appliance (such as table fan, iron, heater, geyser, etc.), be sure that its plug has been taken out from the socket. Switching OFF may not be sufficient, since leaky insulation can give serious shock.
- Never try to connect machines or equipments to a voltage supply other than the rated one.
- Strictly follow all the precautions and instructions given on the 'name plate' of the machine you are working.
- In case of electric fire, use only 'soda-acid' fire extinguisher. Do not throw water on live conductors or equipments. Best remedy is to first disconnect the electric supply and then throw sand on fire.
- While working on an electric pole or tower, use safety belt and a rubber padded ladder.

- It is preferable to work in the presence of an 'assistant', so that he can immediately disconnect the supply whenever needed. The assistant should have the knowledge of providing first-aid in case of an electric shock.

EARTHING

The connection of electrical machinery to the general mass of earth with a conducting material of very low resistance is called earthing or grounding.

This makes the equipment to attain the earth's potential and avoids causing shock to the living beings. Almost all machinery, electric poles, towers, neutral wires are connected to earth.

Necessity of Earthing:

- To maintain the line voltage constant under load unbalanced conditions
- To protect tall buildings and structures from atmospheric lightning strikes.
- To serve as return conductor for telephone and traction work.
- To protect the human being and animals from shock. (The protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation)

Methods of Earthing

- In an earthing system, the metal plate or metal pipe which is embedded in the earth is called earth electrode.
- For effective earthing, the resistance offered by the earth electrode along with the soil in which the electrode is embedded should be quite low.
- Galvanised iron (GI) or copper is used to make an earth electrode.
- Copper, although costly, is a better choice as it is least affected by moisture and is not easily rusted.
- Furthermore, to increase the conductivity of the soil around the earth electrode, alternate layers of common salt and charcoal are filled.
- Charcoal retains the moisture for a long time and salt increases the conductivity of the soil.

There are following two earthing methods commonly used.

i)Plate Earthing

ii)Pipe Earthing

Plate Earthing:

A plate of following dimensions is used as earth electrode

(i) Copper Plate: 0.3 mx 0.3 m x 6.35 mm

(ii) GI Plate: 0.3 mx 0.3 mx 3.2 mm

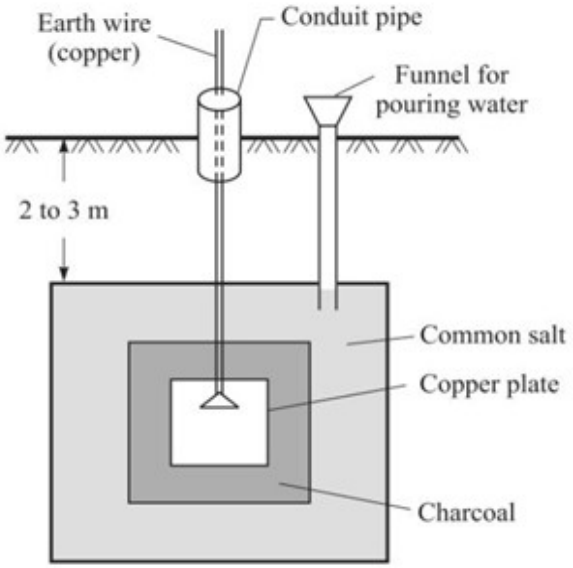


Fig 1.14 Plate earthing

The plate is placed in a vertical position inside the earth and is embedded in the alternate layers of coal and salt. In addition, salt water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.

The earthing efficiency increases with the increase of the plate area and depth of embedding. If the resistivity of the soil is high, then it is necessary to embed the plate vertically at a greater depth into the ground.

The disadvantage of this method is that the discontinuity of the earth wire from the earthing plate below the earth cannot be observed physically. This may result in heavy losses under fault conditions.

Pipe Earthing:

A GI pipe with a few holes at its lower end is buried to a depth not less than 2 m and at least 0.6 m away from the foundation of any building. The pipe surface is placed upright at a depth of 4.75 m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cm) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross-sectional area are run through a 12.7 mm diameter pipe (at 60 cms below) from the 19 mm diameter

pipe and secured tightly at the top as shown in the following figure.

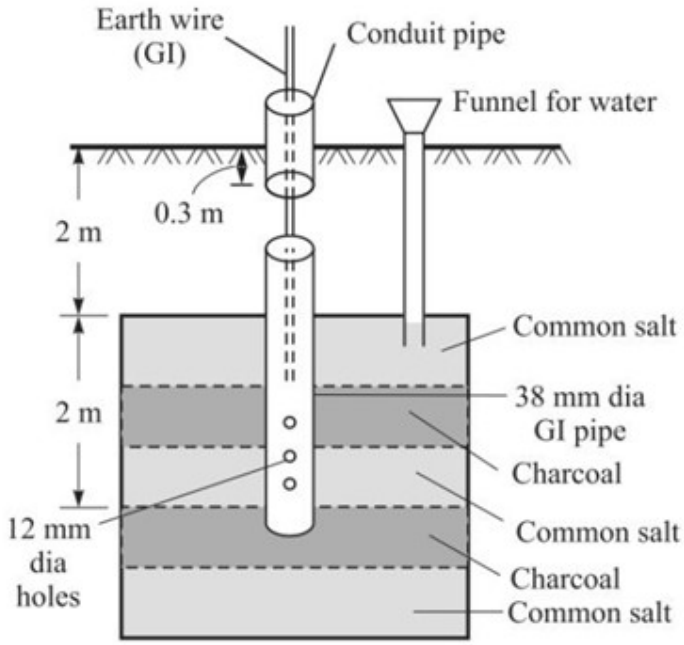


Fig 1.15 Pipe Earthing

When compared to the plate earth system, the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.

The only disadvantage of pipe earthing is that the embedded pipe length has to be increased sufficiently in case the soil specific resistivity is of high order. This increases the excavation work and hence increased cost.

ELECTRICITY BILLING & NEED FOR ENERGY SAVING

ELECTRICITY BILL

The amount we pay for consumption of electrical energy is called Electricity Bill.

The amount of money frame by the supplier for supply of electrical energy to various types of consumers is known as an electricity tariff. In other words, the tariff is the method of charging a consumer for consuming electric power. Electricity tariff is the amount your electricity provider charges you for 1 unit of electricity.

Unit – Definition as applied to electric bill

Electrical energy consumption is always represented in watt (W) or kilowatt (kW).

kWH or Kilowatt Hour = power consumed in kW x time of consumption (in hours)

1 unit = 1 kWH

If you use 1000 Watts or 1 Kilowatt of power for 1 hour then you consume 1 unit or 1 Kilowatt-Hour (kWh) of electricity.

Example: If a 100-Watt bulb if kept on for 10 hours will consume:

Units consumed=100 x 10 = 1000 Watt-Hour = 1 Kilowatt-Hour (kWH) = 1 unit

TARIFF

The amount of money frame by the supplier for supply of electrical energy to various types of consumers is known as an electricity tariff.

In other words, ***the tariff is the method of charging a consumer for consuming electric power.*** Electricity tariff is the amount your electricity provider charges you for 1 unit of electricity.

The tariff covers the total cost of producing and supplying electric energy plus a reasonable cost.

• The actual tariffs that the consumer pay depends on the consumption of the electricity.

• The consumer bill varies according to their usage.

• The industrial consumers pay more electricity bill because they use more power for long times than the domestic consumers.

The electricity tariffs depend on the following factors:

- **Type of load:** The load is mainly classified into three types namely domestic, commercial or industrial loads. The industrial consumers use more energy for a longer time than domestic consumers. Hence, the bill for the industrial consumers is more than the domestic consumers.

- **Maximum Demand:** The maximum power value during a specified time interval, usually the average of 15 minutes (may vary, 10,15 or 30 min) reached during the billing period. Maximum Demand is usually measured in kW or kVA.

- **Time at which load is required:** The time at which the maximum load required is also essential for the electricity tariff.

- **The power factor of the load:** The power factor plays an important role in plant economics. The load power factor increases the load current which increases the losses in the system. Hence the regulation in the system becomes poor.

- **The amount of energy used:** The major part of the tariff is the amount or the units consumed by the consumer.

TWO-PART TARIFF

When the electrical energy is charged on the maximum demand of the consumer and the units consumed, it is called two-part tariff.

- In two-part tariff, the cost to be charged is divided into two parts.
- The first one is the fixed charge and the second one is the running charge
- The fixed charge depends on the maximum demand and the second charge depends on the energy consumption by the load. Thus, the consumer is charged at a certain amount per kW of maximum demand plus a certain amount per kWh of energy consumed.

$$C = Ax + By$$

Where C = Total cost for a period say a month

x = Maximum demand during the period

A = Cost per kW of maximum demand

y = Total energy consumed during the period

B = Cost per kWh of energy consumed.

BLOCK RATE TARIFF

In this tariff, the first block of the energy consumed (consisting of a fixed number of units) is charged at a given rate and the succeeding blocks of energy (each with a predetermined number of units) are charged at progressively increased rates.

The rate per unit in each block is fixed.

For example, the first 50 units (1st block) may be charged at 3 rupees per unit; the next 30 units (2nd block) at 4.50 rupees per unit and the next 30 units (3rd block) at 6 rupees per unit.

Graphically, it can be represented as follows:

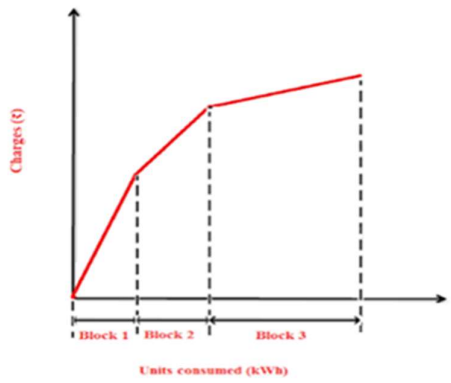


Fig 1.17: Block rate Tariff

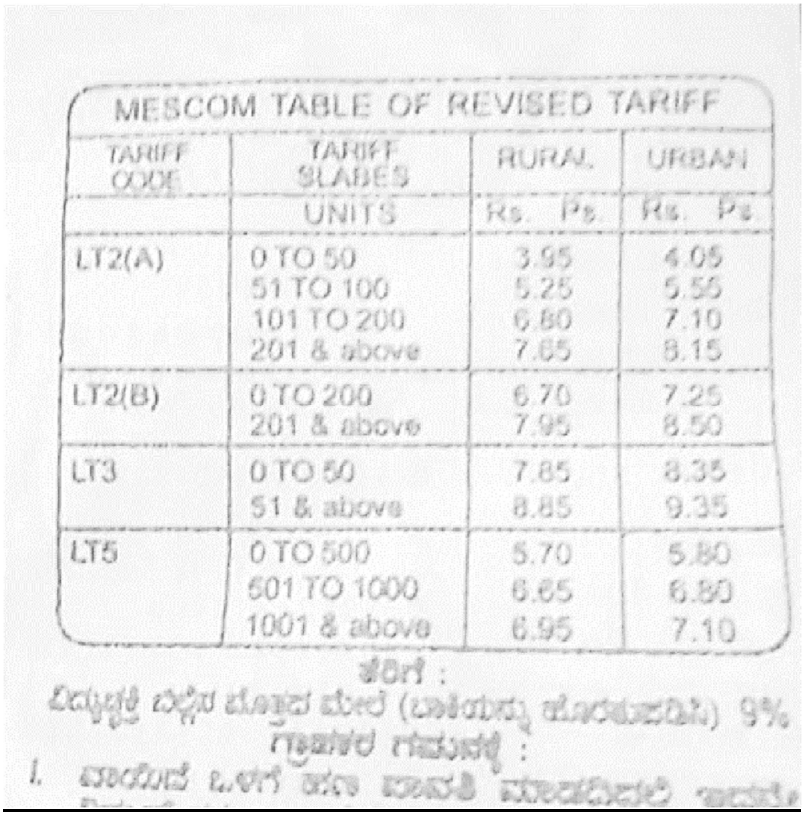
CALCULATION OF ENERGY CONSUMPTION FOR GIVEN SET OF LOADS

Power rating of common house-hold appliances

Appliance	Min Wattage	Max Wattage	Min units (kWh) consumed in an hour	Max units (kWh) consumed in an hour
1 Ton air conditioner	800W	1000W	0.8kWh	1kWh
1.5 Ton Air Conditioner	1000W	1500W	1kWh	1.5kWh
24-inch LCD TV	40W	60W	0.04kWh	0.06kWh
24-inch LED TV	30W	50W	0.03kWh	0.05kWh
Electric Iron	800W	1500W	0.8kWh	1.5kWh
Fridge/Freezer	150W	400W	0.15kWh	0.4kWh
Washing Machine	500W	2200W	0.5kWh	2.2kWh
Laptop	40W	120W	0.04kWh	0.12kWh
LED light Bulb	7W	10W	0.007kWh	0.01kWh
Phone Charger	4W	7W	0.004kWh	0.007kWh
Desktop Computer	60W	250W	0.06kWh	0.25kWh
Printer	10W	50W	0.01kWh	0.05kWh

CALCULATION OF ELECTRICITY BILL FOR DOMESTIC CONSUMERS

A sample electricity bill with split up of blocks is shown in Fig 1.18.(As per block rate tariff with fixed charge)



MESCOM TABLE OF REVISED TARIFF

TARIFF CODE	TARIFF SLABES	RURAL	URBAN
	UNITS	Rs. Ps.	Rs. Ps.
LT2(A)	0 TO 50	3.95	4.05
	51 TO 100	5.25	5.55
	101 TO 200	6.80	7.10
	201 & above	7.65	8.15
LT2(B)	0 TO 200	6.70	7.25
	201 & above	7.95	8.50
LT3	0 TO 50	7.85	8.35
	51 & above	8.85	9.35
LT5	0 TO 500	5.70	5.80
	501 TO 1000	6.65	6.80
	1001 & above	6.95	7.10

EXAMPLE: In a 4-BHK flat, total 8 persons are residing. The average consumption of electricity per day is as follows

No.	Appliance(s)	Wattage	Hours
1	4 Geysers	1.5 kW	15 min
2	4 Air-conditioners	1.8 kW	1 h
3	3 Televisions	110 W	2 h
4	1 Mixie	750 W	15 min
5	1 OTG	1000 W	30 min
6	1 Refrigerator	450 W	3 h
7	1 Induction heater	1500 W	30 min
8	8 LED Tube-lights	20 W	6 h
9	4 Electric bulbs	60 W	3 h
10	7 Ceiling fans	100 W	2 h

If the tariff of electric supply company is as follows, estimate the total electricity bill for this flat for the month of March

(i) Up to 100 units Rs. 4.00 per unit

(ii) From 101 to 200 units Rs.5.00 per unit

(iii) From 200 to 400 units Rs.6.50 per unit

(iv) Above 400 units Rs. 8.00 per unit.

Solution

Energy consumption (in Wh)	= Count x Power in W x Time in hours
1. For 4 Geysers	4 × 1500 × 0.25 = 1500Wh
2. For 4 Air-conditioners	4 × 1800 × 1 = 7200Wh
3. For 3 Televisions	3 × 110 × 2 = 660Wh
4. For 1 Mixie	1 ×750 × 0.25 = 187.5Wh
5. For 1 OTG	1000 × 0.5 = 500Wh
6. For 1 Refrigerator	1 × 450 × 3 = 1350Wh
7. For 1 Induction heater	1 × 1500 × 0.5 = 750Wh

8. For 8 LED Tube-lights	8 × 20 × 6 = 960Wh
9. For 4 Electric bulbs	4 × 60 × 3 = 720Wh
10. For 7 Ceiling fans	7 × 100 × 2 = 1400Wh
Total consumption per day	15227.5 Wh

calculate per day energy consumption (in kWh) of each appliance.

total consumption per day or units (in kWh) = 15227.5/1000 =15.2275kWh ()

there are 31 days in the month of March,

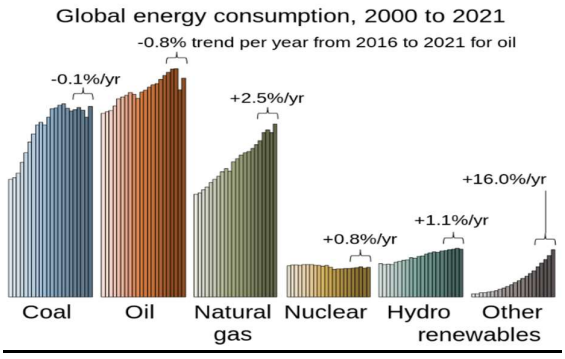
Total consumption per month = 15.2275×31 = 472 units

(i) For first 100 units	= Rs. 100 x 4 = 400.
(ii) From 101 to 200 units (200-100=100 units)	= Rs. 100 x 5 = 500.
(iii) From 201 to 400 units (400-200=200 units)	= Rs. 200 × 6.5 = 1300.
(iv) From 400 to 472 units (472-400=72 units)	= Rs. 72 x8 = 576.
Total	= Rs. 2776.

GLOBAL ENERGY SCENARIO

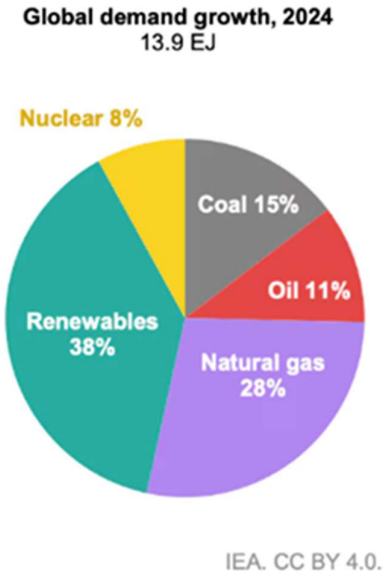
The global energy scenario is currently in a state of flux, with a number of factors driving change. These include:

- The transition to clean energy: There is a growing global consensus on the need to reduce greenhouse gas emissions and transition to a clean energy future. This is leading to a rapid increase in investment in renewable energy and energy efficiency technologies.
- The emerging economies: Energy demand is growing rapidly in emerging economies, driven by population growth and economic development. This is putting increasing strain on global energy resources.



The IEA (International Energy Agency) , in its Global Energy Review 2025 has stated that the Global Energy demand grew by 2.2% in 2024 resulting in higher demand for all energy sources, including oil, natural gas, coal, renewables and nuclear power (Between 2013-2023, the annual average increase was about 1.3%).

(Note: EJ means ExaJoules (a unit of energy)
1 EJ=10^{18} Joules)



The other key facts from the report are as follows:

- Electricity demand grew more rapidly because of higher demand for cooling, rising consumption by the industries, electrification of transport and growth of data centers and Artificial Intelligence.
- The extra electricity demand was met by low emission sources like Solar energy followed by other renewable energy sources and nuclear power.
- Natural gas usage was increased substantially, while coal and oil usage increased at a lesser rate compared to the year 2023.
- Renewables accounted for the largest share of the growth in total energy supply (38%), followed by natural gas (28%), coal (15%), oil (11%) and nuclear (8%)
- CO2 emissions from the energy sector continued to increase in 2024 but at a slower rate than in 2023.
- A key driver was record-high temperatures.
- China stood in first place in terms of energy demand followed by India

NEED FOR ENERGY SAVING

Environmental benefits

- Reduce greenhouse gas emissions: Energy saving helps to reduce greenhouse gas emissions from power plants and other industrial sources. This is important for combating climate change and protecting the environment.
- Reduce air and water pollution: Energy saving also helps to reduce air and water pollution from power plants and other industrial sources. This can improve public health and protect ecosystems.
- Conserve natural resources: Energy saving helps to conserve natural resources, such as coal, oil, and natural gas. These resources are finite and cannot be replaced, so it is important to use them wisely.

Economic benefits

- Save money: Energy saving can save you money on your energy bills. This can be a significant savings, especially for businesses and industries.
- Create jobs: The energy efficiency sector is a growing industry that creates jobs in a variety of fields, such as research and development, manufacturing, and installation.
- Boost the economy: Energy saving can boost the economy by reducing energy costs for businesses and consumers. This can lead to increased investment and spending, which can create jobs and grow the economy.

Social benefits

- Improve energy security: Energy saving can help to improve energy security by reducing our reliance on imported energy. This can make us more resilient to energy price shocks and supply disruptions.
- Promote energy equity: Energy saving can help to promote energy equity by making energy more affordable for everyone. This is especially important for low-income households and communities.
- Improve public health: Energy saving can improve public health by reducing air and water pollution. This can lead to lower rates of asthma, heart disease, and other respiratory and cardiovascular illnesses.

In short, energy saving is important for a variety of reasons. It can help to protect the environment, save money, boost the economy, improve energy security, promote energy equity, and improve public health.

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