Unit-V

Power transmission and distribution: Concept of power transmission and power distribution. through block diagrams only.

Electricity bill: Calculation of electricity bill for domestic consumers.

Equipment Safety measures: Working principle of Fuse and Miniature circuit breaker (MCB), merits and demerits.

Personal safety measures: Electric Shock, Earthing and its types, Safety Precautions to avoid shock.

Introduction

Electric power is the product of two quantities, current and voltage. These two quantities can vary with respect to time (AC power) or be kept at constant levels (DC power). Most refrigerators, air conditioners, pumps and industrial machinery use AC power, whereas most computers and digital equipment use DC power. The digital devices you plug into the mains typically have an internal or external power adapter to convert from AC to DC power). AC power has the advantage of being easy to transform between voltages and can be generated and utilized by brushless machinery. DC power remains the only practical choice in Digital systems can be more economical to transmit over long distances at very high voltages.

The ability to quickly transform the voltage of AC power is essential for two reasons: Firstly, power can be transmitted over long distances with less loss at higher voltages. So in power systems where generation is distant from the load, it is desirable to step up (increase) the voltage ofpower at the generation point and then step-down (decrease) the voltage near the load. Secondly, it is often more economical to install turbines that produce higher voltages than would be used by most appliances, so the ability to easily transform voltages means this mismatch between voltages can be easily managed Solid state devices, which are products of the semiconductorrevolution, make it possible to transform DC power to different voltages, build brushless DC machines and convert between AC and DC power. Nevertheless, devices utilizingsolid state technology are often more expensive than their traditional counterparts, so AC power remains in widespread use. **Figure 5.1 (a) and (b)** shows Power Generation and Transmission and Distribution System

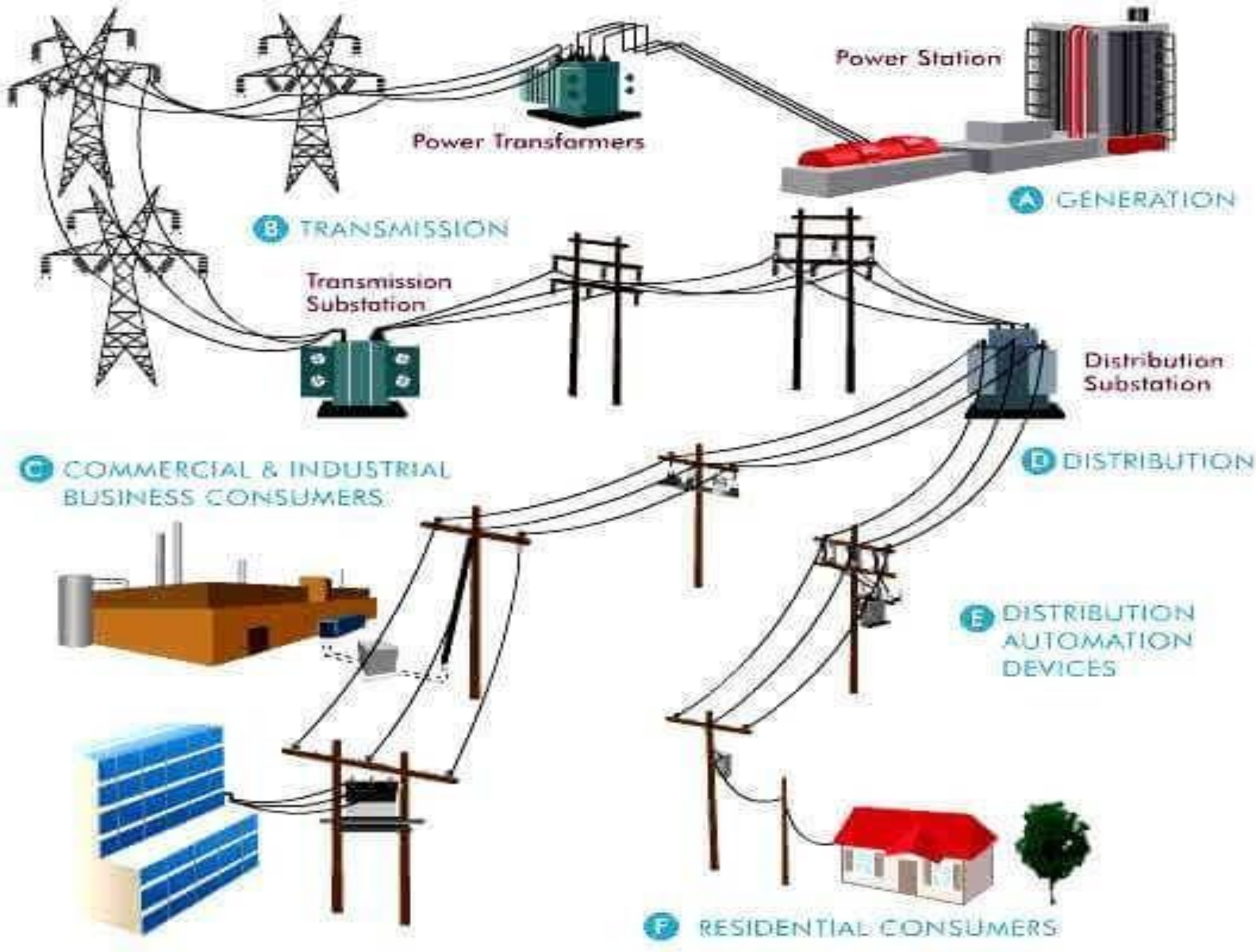

Figure 5.1(a): Generation, Transmission and Distribution System

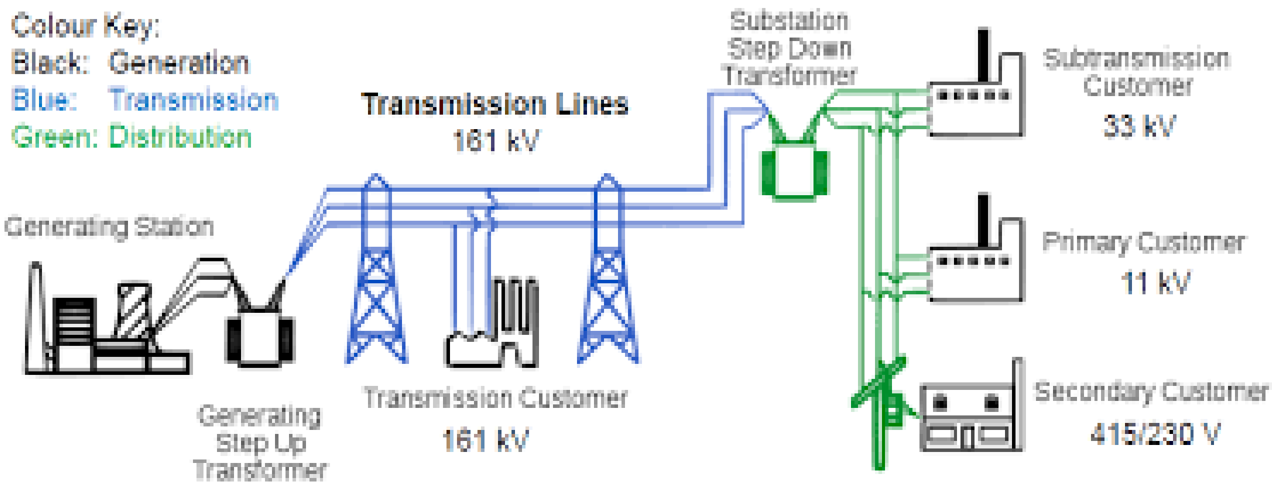

Figure 5.1 (b): Generation, Transmission and Distribution System

Figure 5.2 shows the single line diagram of an AC power Transmission System

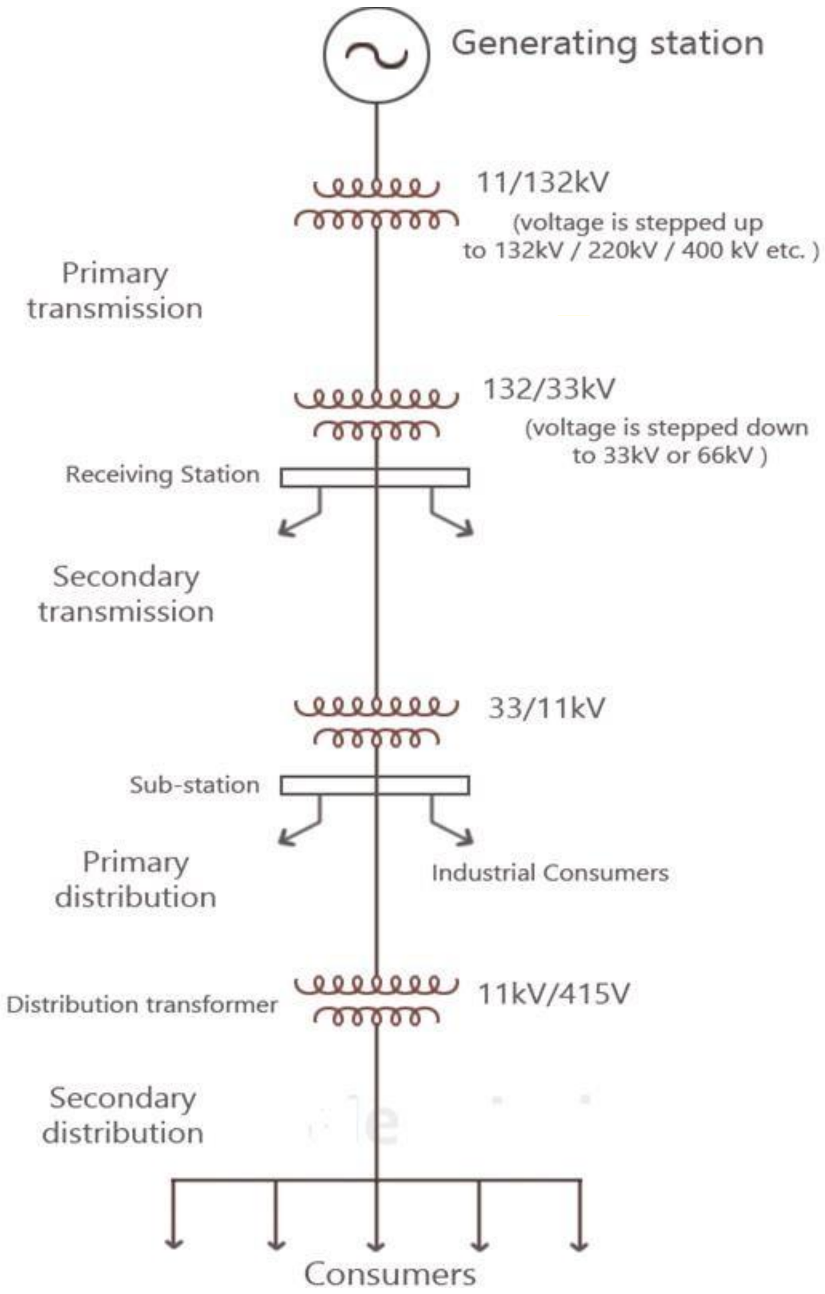

Figure 5.2 Single Line Diagram of a AC Power Transmission System

Elements of Power systems

Power transformers: Power transformers are used generation and transmission network for stepping-up the voltage at generating station and stepping-down the voltage for distribution. Auxiliary transformers supply power to auxiliary equipments at the substations. **Current transformers (CT):** The lines in substations carry currents in the order of thousands of amperes. The measuring instruments are designed for low value of currents. Current transformers are connected in lines to supply measuring instruments and protective relays. **Potential transformers (PT):** The lines in substations operate at high voltages. The measuring instruments are designed for low value of voltages. Potential transformers are connected in lines to supply measuring instruments and protective relays. These transformers make the low voltage instruments suitable for measurement of high voltages. For example, a 11kV/110V PT is connectedto a power line and the line voltage is 11kV then the secondary voltage will be 110V. **Circuit breaker (CB):** Circuit breakers are used for opening or closing a circuit under normal as well as abnormal (faulty) conditions. Different types of CBs which are generally used are oil circuitbreaker, air-blast circuit breaker, and vacuum circuit breaker and SF6 circuit breaker. **Isolators or Isolating switches:** Isolators are employed in substations to isolate a part of the systemfor general maintenance. Isolator switches are operated only under no-load conditions. They are provided on each side of every circuit breaker Bus-bar: When the number of lines operating at the same voltage levels needs to be connected electrically, bus bars are used. Bus bars are conductors made of copper or aluminum, with very low impedance and high current carrying capacity.

Different types of bus-bar arrangements

- Single bus bar arrangements
  - Single bus-bar with sectionalization
- Double bus-bar arrangements
  - Double bus-bar with Sectionalization
- Double main and auxiliary bus-bar arrangement
- Breaker and a half scheme/1.5 Breaker scheme,
- Ring bus-bar scheme

Energy Estimation of Common Household Loads:

The Electrical energy consumed is metered by an energy meter connected to the premises of the residence, residential complex or Industry. The energy is measured in terms of “Units”. One unit of energy is the energy consumed when a load of one kilowatt runs for one hour i.e.,**1 unit =1kWh.** The domestic consumer is billed for the energy consumed. An industrial consumer is billed both for the load as well as for the energy consumed. **Table 3.1** shows a few common appliances and calculate the energy they consume.

Sl. No.	**Name of The Appliance**	**Range of Power (Watts)**	**No. of Appliances**	**Total Power = (W x No. of Appliance) in W**	**No. of Hours**	**Total Energy= (Total Power X No. of Hours) in Wh**
1	Incandescent Lamp	15 - 100				
2	Tube Light	30 - 50				
3	CFL	3 30				
4	Ceiling Fan	30 - 70				
5	AC(Room)	1000 - 1500				
6	AC(Central)	2000 - 5000				
7	CD Player	15 - 20				
8	TV	60 - 300				
9	Laptop	50 -75				
10	Desktop	80 - 250				
11	Washing Machine	500 -1000				
12	Refrigerator	50 - 300				
13	Geyser	1000-3000				
14	Iron Box	270-350				

Table 3.1 Common Household Appliances & their ratings

Example 1: Estimate Total Daily Energy Requirement for the following loads.

Name of the Appliance	Power Rating (W)	Avg. Daily Usage Hrs.	No. of Appliances
CFL	12	6	3
Fan	50	8	2

TV(21”)	150	2	1
Computer	250	3	1

Take electricity cost to be Rs.6 per unit.

Solution:

Name of the Appliance	Power Rating (W)	Avg. Daily Usage Hrs.	No. of Appliances	Daily Energy Required (Wh)
CFL	12	6	3	216
Fan	50	8	2	800
TV (21”)	150	2	1	300
Computer	250	3	1	750
Total Energy				2066 Wh

Hence Monthly Energy Requirement = Daily Energy Required X Days per Month

= 2066 X 30
= 61980 Wh
= 61.98 kWh or 61.98 Units

Therefore, the monthly electricity bill is, Monthly Bill = 61.98 units X Rs.6/- per unit
= **Rs.371.88 /-**

Exercise 1*: Repeat example 1 if the billing tariff is*

Rs.6/- per unit for the first 20 units, Rs.4/- per unit for the next 30 units and Rs.2/- per unit for the next 50 units.

Example 2: A geyser is rated at 3kW, 230V, 50Hz. If it is switched ON for one hour daily, what would be the energy cost saving, at the rate of Rs. 2.50 per unit if it is replaced by a solar water heater?

Solution:
Solar water heaters use energy from the Sun. Though their initial investment is high, the running cost is very low and are environmentally friendly. A 3kW geyser running for 1 hour daily would consume 3 units daily. The energy consumed per month is 3 units X 30 days = 90 units per month. The cost of energy per month is 90 units per month X Rs. 2.50 per unit = Rs. 225.This would be the saving in electricity bill if solar water heater replaces the electric geyser.

Exercise 2*: Find out the wattage of the appliances in your house, their average use per month and estimate the electricity bill of your house based on the BESCOM tariff.*

Elementary Ideas of Fuses

Fuse

The electrical equipment is 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. Fuses are pressed into operation under such situations.

Fuse is a safety device used in any electrical installation, which forms the weakest link between the supply and the load. It is a short length of wire made of lead / tin /alloy of lead and tin/ zinc having a low melting point and low ohmic losses. Under normal operating conditions it is designed to carry the full load current. If the current increases beyond this designed value due any of the reasons mentioned above, the fuse melts (said to be blown) isolating the power supply from the load as shown in the following **figures 5.3 and 5.4.**

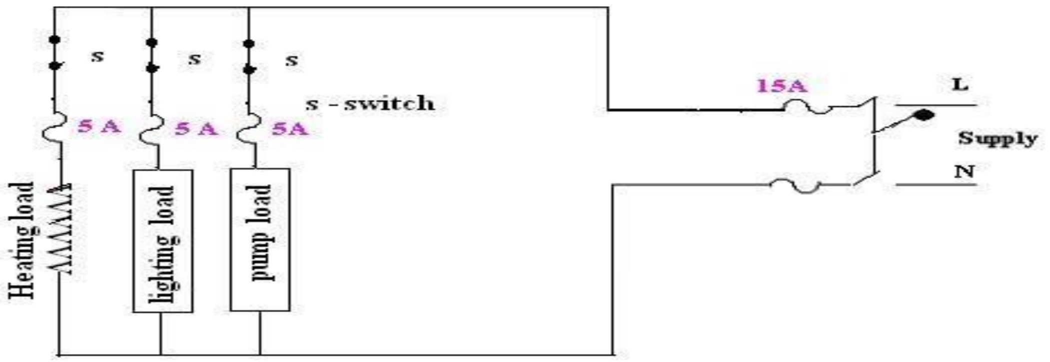

Figure 5.3: Under Normal Conditions

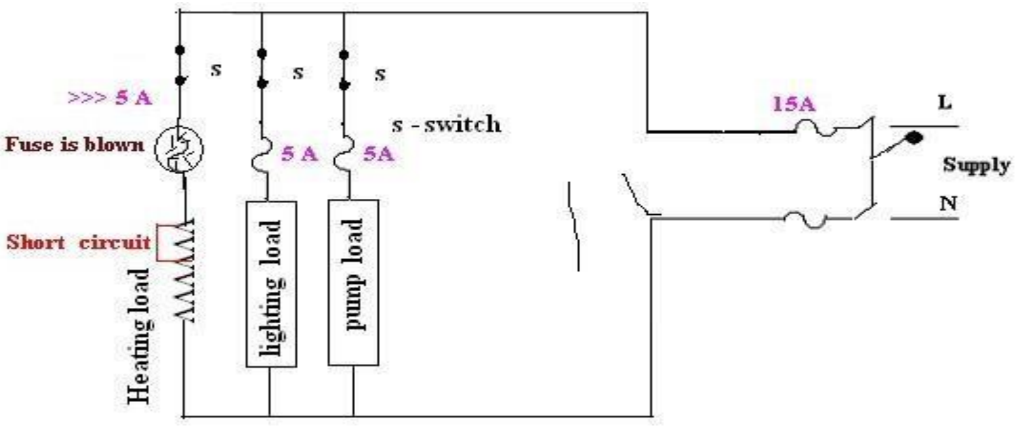

Figure 5.4: Under Abnormal Conditions

Terms Related with Fuses

Rated current: It is the maximum current, which a fuse can carry without undue heating or melting. It depends on the following factors:

- Permissible temperature rise of the contacts of the fuse holder
- Fuse material
- Degree of deterioration due to oxidation

Fusing current: The minimum current at which the fuse melts is known as the fusing current. It depends on the material characteristics, length, diameter, cross- sectional area of the fuse element and the type of enclosure used.

Fusing Factor: It is the ratio of the minimum fusing current to the rated current. It is always greater than unity.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Current rating of fuse}}$$

Characteristics of Fuse Material

The material used for fuse wires must have the following characteristics:

- Low melting point
- Low ohmic losses
- High conductivity
- Lower rate of deterioration

?

Fuse Characteristics

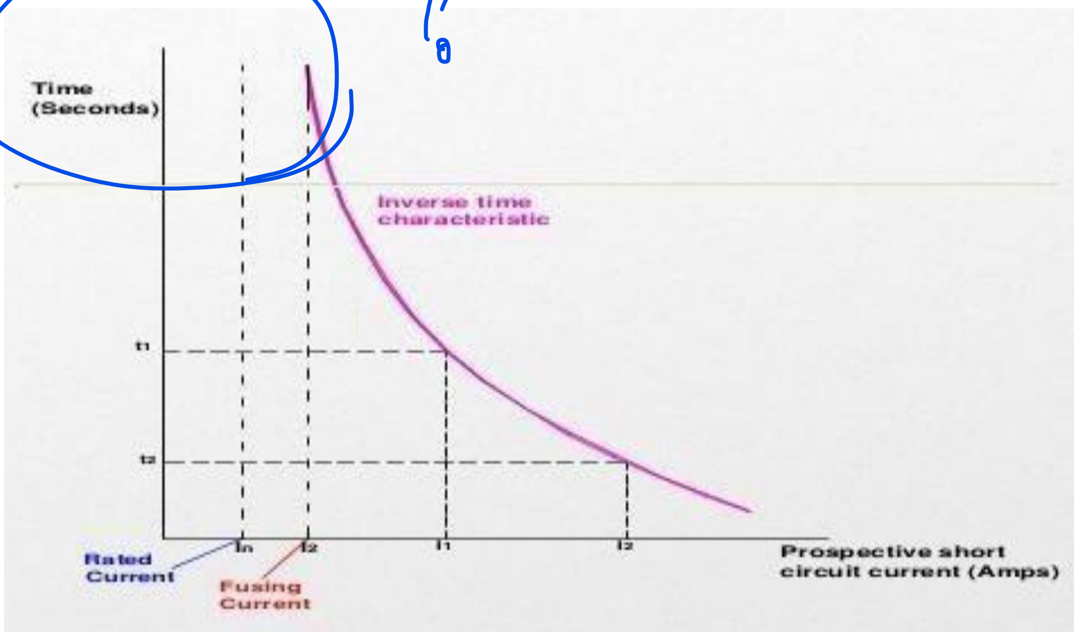

Figure 5.5: Time-Current Characteristics of a Fuse

This time-current characteristic chart (**figure 5.5**) shows how fast the fuse responds to different levels of overcurrent condition. The fuse does not open if the current is within the limits (i.e. less than the fuse rating). The current at which the fuse starts melting is called the fusing current. All fuses have an *inverse time/current characteristic*. As overcurrent increases, time-to-open the fuse decreases. Put more simply, the fuse will open faster when the overcurrent problem is severe.

Advantages of Fuses

- Fast acting
- Highly reliable
- Relatively cheaper in comparison to other high current interrupting device

Disadvantages of Fuses:

- Requires replacement
- The associated high temperature rise will affect the performance of other devices.

Miniature Circuit Breaker (MCB)

Nowadays we use more commonly **miniature circuit breaker** or **MCB** in low voltage electrical network instead of fuse.

Working Principle Miniature Circuit Breaker

There are two arrangements of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip.Whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts. But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. A simple explanation of miniature circuit breaker working principle is shown in **figure 5.6** and **figure 5.7**.

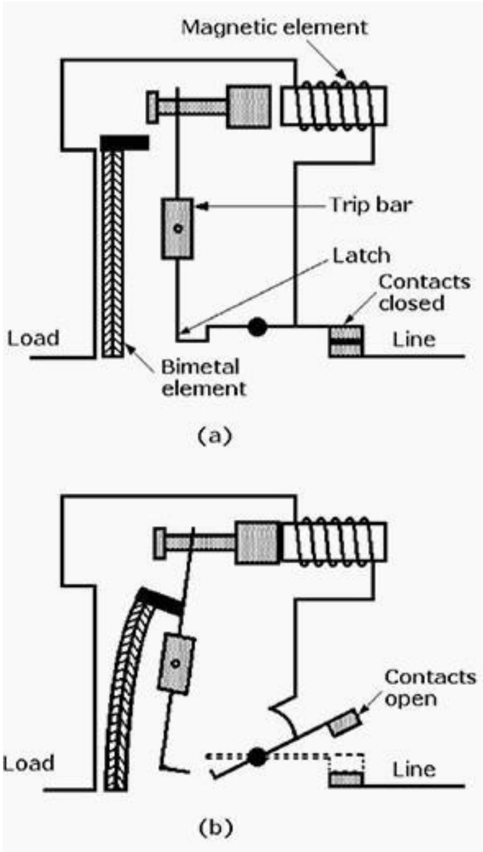

Figure 5.6: MCB Operation

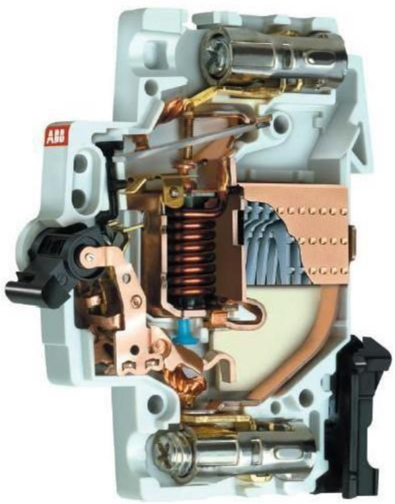

Figure 5.7: Cross-sectional view of an MCB

The **MCB** has some advantages compared to fuse.

- It automatically switches off the electrical circuit during abnormal condition of the network means in over load condition as well as faulty condition. The fuse does not sense but **miniature circuit breaker** does it in more reliable way. MCB is much more sensitive to over current than fuse.
- Another advantage is, as the switch operating knob comes at its off position during tripping, the faulty zone of the electrical circuit can easily be identified. But in case of fuse, fuse wire should be checked by opening fuse grip or cutout from fuse base, for confirming the blow of fuse wire.
- Quick restoration of supply cannot be possible in case of fuse as because fuses have to be rewirable or replaced for restoring the supply. But in the case of MCB, quick restoration is possible by just switching on operation.
- Handling MCB is more electrically safe than fuse.

Because of the many advantages of MCB over fuse units, in modern low voltage electrical network, miniature circuit breaker is mostly used instead of backdated fuse unit. Only one disadvantage of MCB over fuse is that this system is ~~more costlier~~ than fuse unit system.

Electric Shock and Precautions:

Electrical Shock & Its Effects

Electric shock occurs when the body becomes part of an electrical circuit. Shocks can happen in three ways.

- A person may come in contact with both conductors in a circuit.
- A person may provide a path between an ungrounded conductor and the ground.
- A person may provide a path between the ground and a conducting material that is in contact with an ungrounded conductor.

The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors:

- The amount of current flowing through the body
- The path of the current through the body
- The length of time the body is in the circuit.

Table 3.5 shows the effect of electrical current on human body

Current in milliamperes	Effects
1 or less	No sensation; probably not noticed
1 to 3	Mild sensation not painful
3 to 10	Painful shock.
10 to 30	Muscular control could be lost or muscle clamping
30 to 75	Respiratory paralysis
75mA to 4 **amps**	Ventricular Fibrillation
Over 4 **amps**	Tissue begins to burns. Heart muscles clamp and heart stops beating

Effects of Electrical Current On the Human Body

Table 3.5 shows the effect of electrical current on human body

Precautions against Electric Shock

- Avoid water at all times when working with electricity. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of electric current.
- Never use equipment with frayed cords, damaged insulation or broken plugs.
- If you are working on any receptacle at your home then always turn off the mains. It is also a good idea to put up a sign on the service panel so that nobody turns the main switchON by accident.
- Always use insulated tools while working.
- Electrical hazards include exposed energized parts and unguarded electrical equipment, which may become energized unexpectedly. Such equipment always carries warning signs like “Shock Risks”. Always be observant of such signs and follow the safety rules established by the electrical code followed by the country you are in.
- Always use appropriate insulated rubber gloves and goggles while working on any branch circuit or any other electrical circuit.
- Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire. Check all the wires, the outer metallic covering of the service panel and any other hanging wires with an electrical tester before proceeding with your work.
- Never use an aluminum or steel ladder if you are working on any receptacle at height in

your home. An electrical surge will ground you and the whole electric current will pass through your body. Use a bamboo, wooden or a fiberglass ladder instead.

- Know the wire code of your country.
- Always check all your GFCIs once a month. A GFCI (Ground Fault Circuit Interrupter) is an RCD (Residual Current Device). They have become very common in modern homes, especially damp areas like the bathroom and kitchen, as they help avoid electrical shock hazards. It is designed to disconnect quickly enough to avoid any injury caused by over current or short circuit faults.
- Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential. Normally for protection against short circuits, a fuse rated of 150% of the normal circuit current is selected. In the case of a circuit with 10 amperes of current, a 15A fuse will protect against direct short circuits whereas a 9.5A fuse will blow out.
- Working outside with underground cabling can be dangerous. The damp soil around the cable is a good conductor of electricity and ground faults are quite common in the case of underground cabling. Using a spade to dig at the cable can damage the wiring easily so it is better to dig at the cable by hand while wearing insulated gloves.
- Always put a cap on the hot/live wire while working on an electric board or service panel as you could end up short-circuiting the bare ends of the live wire with the neutral. The cap insulates the copper ends of the cable thus preventing any kind of shock even if touched mistakenly.
- Take care while removing a capacitor from a circuit. A capacitor stores energy and if it is not properly discharged when removed, it can easily cause an electric shock. An easy way to discharge low voltage capacitor is that after removal from the circuit is to put the tip of two insulated screwdrivers on the capacitor terminals. This will discharge it. For high voltage ones a 12 Volts light bulb can be used. Connecting the bulb with the capacitor will light up the bulb using up the last of the stored energy.
- Always take care while soldering your circuit boards. Wear goggles and keep yourself away from the fumes. Keep the solder iron in its stand when not in use; it can get extremely hot and can easily cause burns.

Necessity and Types of Earthing

Introduction to Earthing:

Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential. The body of any electrical equipment is connected to the earth by means of a wire of negligible resistance to safely discharge electric energy, which may be due to failure of the insulation, line coming in contact with the casing etc. Earthing brings the potential of the body of the equipment to ZERO i.e. to the earth's potential, thus protecting the operating personnel against electrical shock. The body of the electrical equipment is not connected to the supply neutral because due to long transmission lines and intermediate substations, the same neutral wire of the generator will not be available at the load end. Even if the same neutral wire is running it will have a self-resistance, which is higher than the human body resistance. Hence, the body of the electrical equipment is connected to earth only.

Necessity of Earthing:

To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
To maintain the line voltage constant under unbalanced load condition.
Protection of the equipments Protection of large buildings and all machines fed from overhead lines against lightning.

Methods of Earthing:

The earth resistance for copper wire is 1 ohm and that of Galvanized Iron (G I) wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the earth potential. The typical value of the earth resistance at powerhouse is 0. 5 ohm and that at substation is 1 ohm.

- Plate earthing
- Pipe earthing

Plate Earthing

In this method, a copper plate of 60cm x 60cm x 0.32cm or a GI plate of the size 60cm x 60cmx 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, 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. **Figure 5.8** shows the detailed diagram.

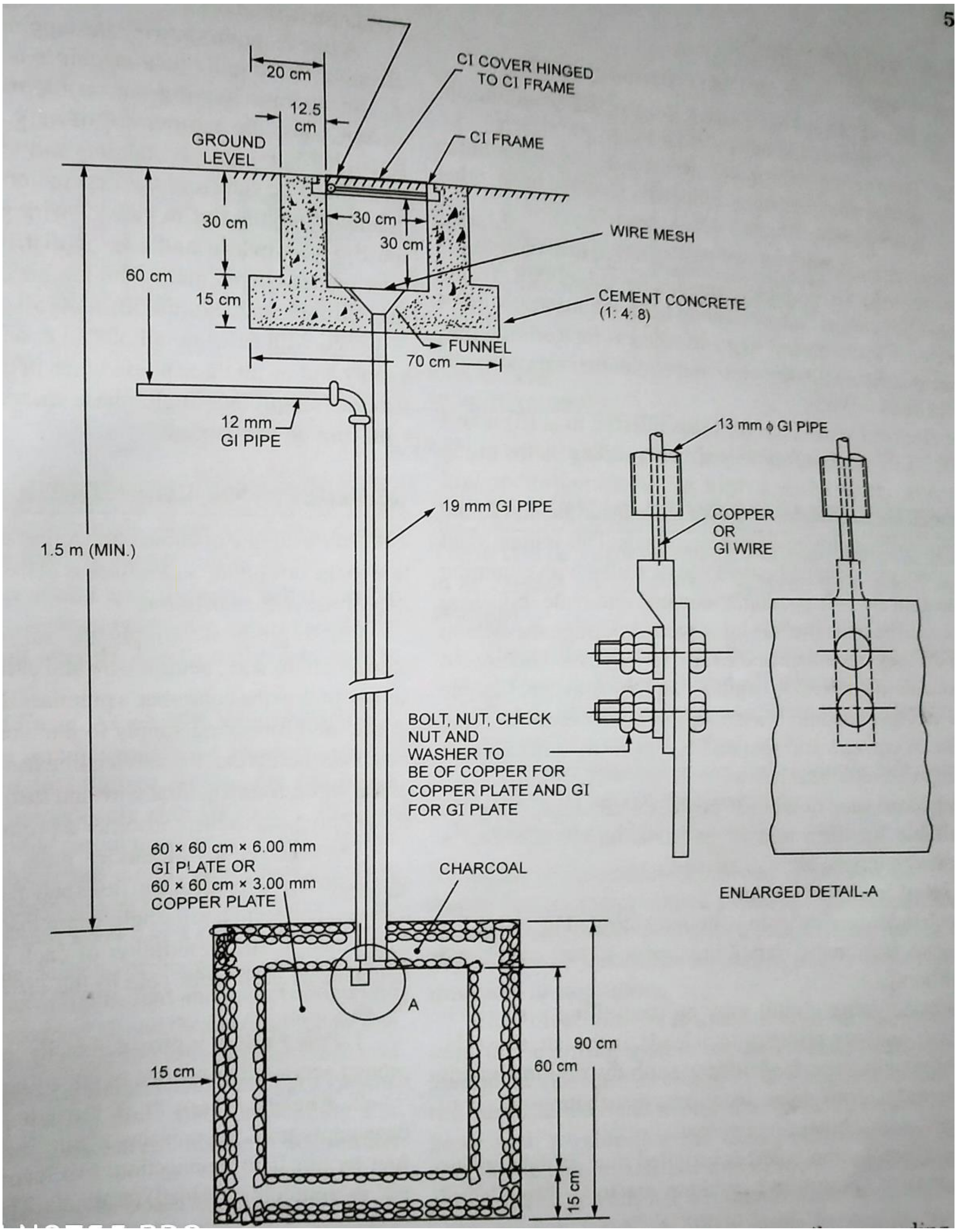

Figure 5.8: Plate Earthing

Pipe Earthing

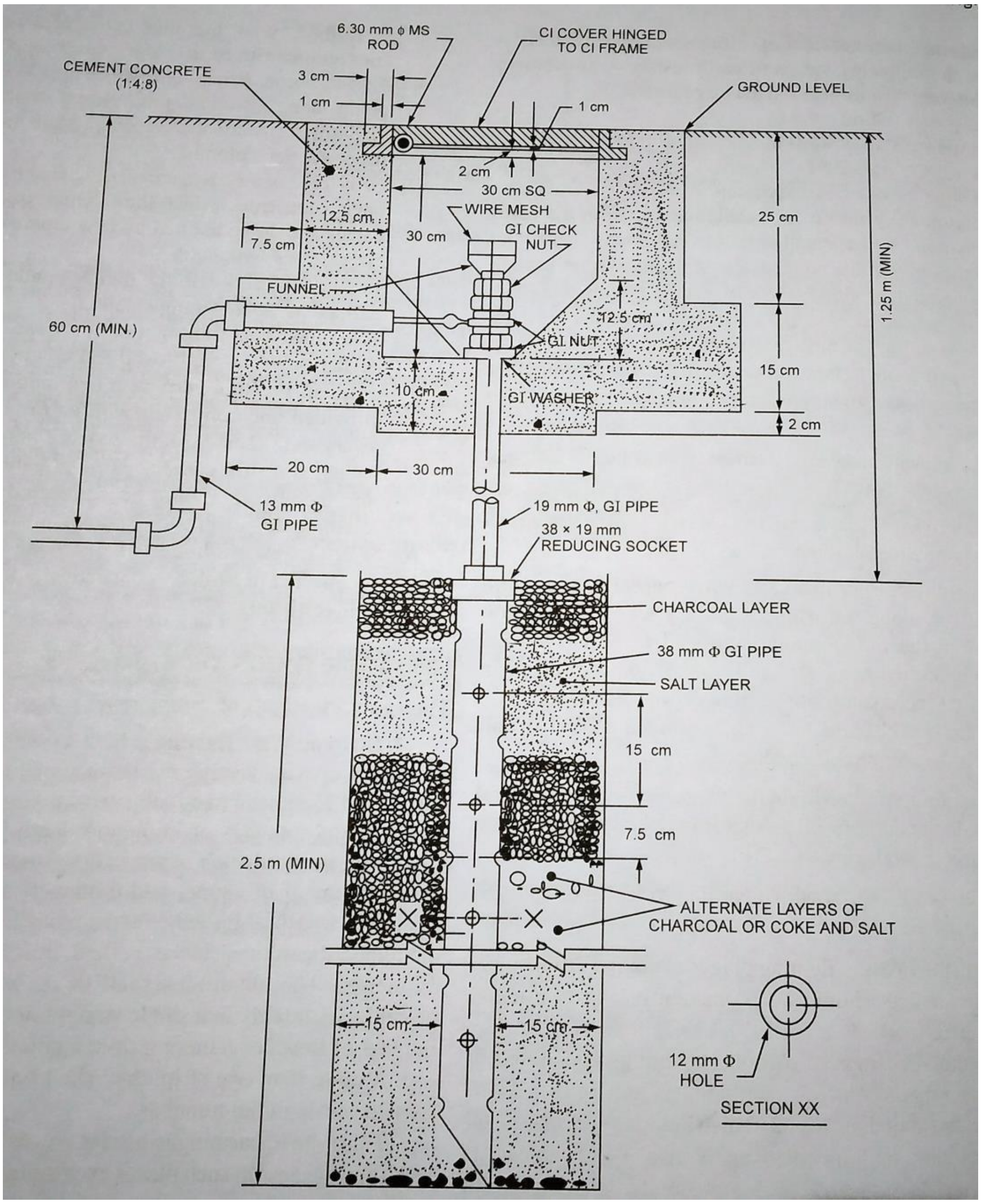

Figure 5.9: Pipe Earthing

Earth electrode made of a GI (galvanized) iron pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15cm) 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 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the **figure 5.9**

Note: 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.

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