K.D.K. College of Engineering, Nagpur

DEPARTMENT OF ELECTRICAL ENGINEERING

II-semester

Advanced Electrical engineering

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Syllabus

Unit – I : Introduction to Electrical Power System : (8Hrs)

Introduction to Power Generation (Thermal, Hydro, Nuclear, Wind, and Solar) with block schematic presentation only. Single line diagram for Generation, Transmission & Distribution through different voltage levels; Low voltage distribution system (Over head & Underground, single phase & three phase) Necessity of equipment earthings, Fuses (Rewirable & HRC), MCB, ELCB (Elementary concepts only), Basic operation of UPS & Invertors (Block schematic representation).

Sources Of Electrical Power Generation

We divide the power system into three parts; **power generation**, transmission and distribution. In this article, we will discuss **power generation**. Actually, in power generation, one form of energy gets converted into electrical energy. We produce electrical energy from various natural sources.
We classify these sources into two types renewable sources and non-renewable sources. In present power system, most of the electrical energy gets generated from non-renewable sources like coal, oil and natural gases. But these sources are limitedly available. So, we have to use these sources carefully and always to find an alternate source or move on renewable sources.

Conventional Sources (non-renewable)

1. Hydro Electric
2. Thermal (Coal)
3. Nuclear
4. Gas
5. Diesel

Non conventional Sources (renewable sources)

1. Wind
2. Solar- PV
3. Biomass

Hydro Electric power station

Principle:-
Hydro Electric stations are generally located in hilly areas where dam can be built and large water reservoir can be obtained.

Water head is created by constructing a dam across a river or lake.

From dam water led to a water turbine, flow of water produces mechanical Energy at the turbine shaft.

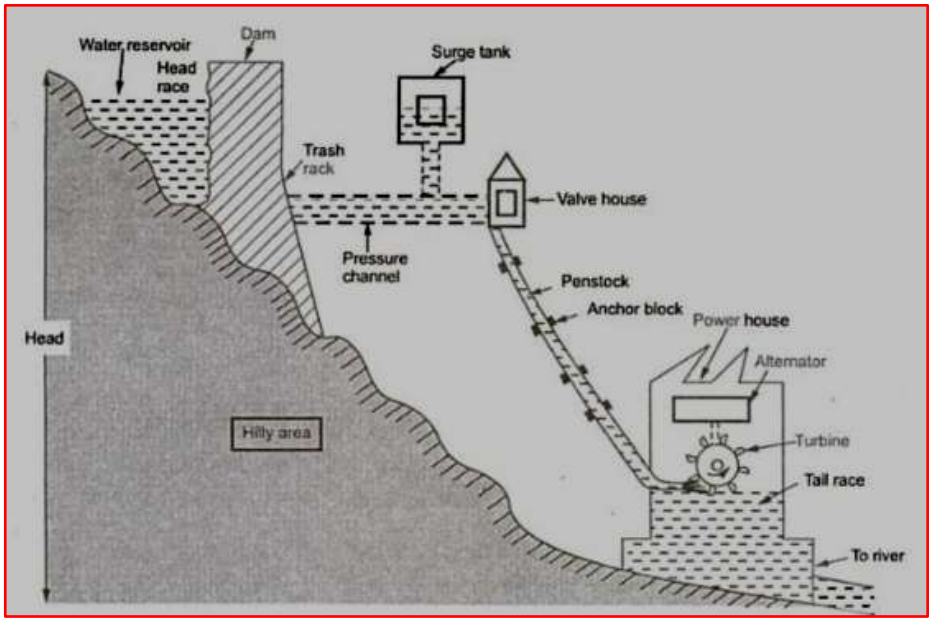
The turbine drives the Alternator which converts Mech. Energy to Electrical Energy.

Hydro-electric power is generated by the flow of water through turbine, turning the blades of the turbine.

A generator shaft connected to this turbine also rotates and hence generates electricity.

The main components of a hydro power plant are:

1. Dam/Reservoir/Large buffer tank
2. Penstock
3. Power House
    a. Turbines
    b. Generators
    c. Step-up Transformers



(1) Storage Reservoir → During rainy periods the run – off is high but the power requirements are low because of the absence of irrigation loads. It is, therefore, necessary to store water during excess flow periods so that the same may be used during lean flow periods.

(2) Dam→ The function of dam in a hydro-electric project, is to create an artificial head and storage. It diverts the flow of water so that the same could be used for generation of power. It is most expensive and important part of a hydro project.

(3) Forebay→ It is an enlarged body of water at the intake to store water temporarily to meet the hourly load fluctuations.

(4) Intake→ The function of intake is to provide a passage to water to flow into the water conduit, channel or penstock.

Intake structures can be classified as

(a) High pressure intake

(b) Low pressure intake

(a) *High pressure intake* → It used in the big storage reservoirs.
(b) *Low pressure intake* → It used for small ponds meant to store small quantity of water for daily or weekly load variations.

(5) Penstock→ A penstock carries water from the water storage system to the turbine. A penstock may be buried below earth surface or exposed.
It may be classified :-
(a) Low pressure type
(b) High pressure type

(a) *Low pressure type* →A low pressure penstock may be a canal, flume or a steel pipe.
(b) *High pressure type* → A High pressure penstock consists of thick steel pipes.

(6) Spillway
(a) Every dam is provided with an arrangement to discharge excess water during floods. This arrangement may be a spillway or a by-pass tunnel or conduit.
(b) The spillway should be so designed as to discharge the major flood waters without damage to the dam but at the same time maintain a predetermined head.

(7) Tail race → A tail race is required to discharge the water, leaving the turbine, into the river. It is necessary that the draft tube must remain water sealed all the time.

(8) Surge Tank →
(a) The load on a generator keeps on fluctuating. Therefore the water intake to the turbine has to be regulated according to the load.
(b) A reduction in load on the alternator causes to governor to close the turbine gates. Sudden closure of turbine gates creates an increased pressure, known as water hammer, in the penstock.
(c) When the governor opens the turbine gates suddenly to admit more water, there is a tendency to cause a vacuum in the penstock.
(d) The function of the surge tank is to absorb these sudden changes in water requirements so as to prevent water hammer and vacuum.

Advantages of Hydro Energy System

1. It can be used in the service instantly.
2. After this process, water can be used for irrigation and other purposes.
3. Dams are designed for an extended period and so it can contribute to the generation of electrical energy for many years.
4. Running and maintenance costs are low.
5. No fuel transportation is required.

Disadvantages of Hydro Energy System

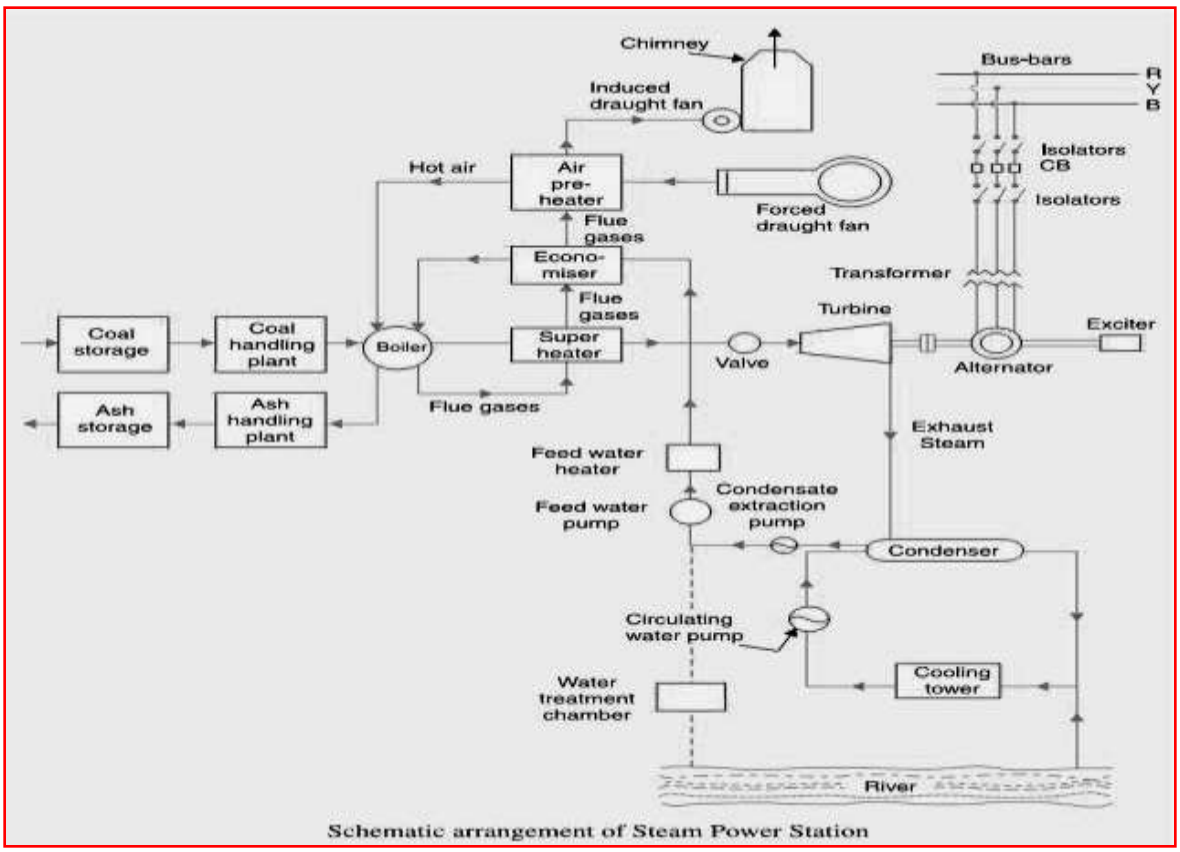
1. The initial cost of a hydel power plant is high.
2. Hydro power plants are located in the hilly area, and it is very far from the load. So, they require long transmission line.
3. Construction of dams can flood towns and cities.
4. It is also weather dependent.

Thermal (Steam) Power Plant

Thermal power plant produces electricity by burning coal in the boiler. Heat is used to convert water into steam. This high pressure and high-temperature steam flowing into the turbine spins a generator to produce electrical energy. After it passes through the turbine, the steam gets cooled in a condenser and reuse in the boiler to generate steam again. Thermal power plant works according to Rankine cycle.

The Main and Auxiliary equipments

1. **Coal Handling Plant**
2. **Pulverizing Plant**
3. **Draft or Draught fan**
4. **Boiler**
5. **Ash Handling Plant**
6. **Turbine and Generator**
7. **Condenser**
8. **Cooling Tower And Ponds**
9. **Feed Water Heater**
10. **Economizer**
11. **Super heater and Reheater**
12. **Air pre heater**
13. **Alternator with Exciter**
14. **Protection and control equipment**
15. **Instrumentation**



Schematic arrangement of Steam Power Station

In **coal thermal power plant**, the steam is produced in high pressure in thesteam boiler due to burning of fuel (pulverized coal) in boiler furnaces. This steam is further supper heated in a superheater. This superheated steam then enters into the turbine and rotates the turbine blades. The turbine is mechanically so coupled with alternator that its rotor will rotate with the rotation of turbine blades. After entering in turbine the steam pressure suddenly falls and corresponding volume of the steam increases.

After imparting energy to the turbine rotor, the steam passes out of the turbine blades into the condenser. In the condenser, the cold water is circulated with the help of a pump which condenses the low-pressure wet steam. This condensed water is further supplied to a low-pressure water heater where the low-pressure steam increases the temperature of this feed water; it is again heated in high pressure.

For better understanding we furnish every step of function of a **thermal power station** as follows,

1. First the pulverized coal is burnt into the furnace of steam boiler.
2. High pressure steam is produced in the boiler.
3. This steam is then passed through the super heater, where it further heated up.
4. This supper heated steam is then entered into a turbine at high speed.
5. In turbine this steam force rotates the turbine blades that means here in the turbine the stored potential energy of the high pressured steam is converted into mechanical energy.
6. After rotating the turbine blades, the steam has lost its high pressure, passes out of turbine blades and enters into a condenser.
7. In the condenser the cold water is circulated with help of pump which condenses the low pressure wet steam.
8. This condensed water is then further supplied to low pressure water heater where the low pressure steam increases the temperature of this feed water, it is then again heated in a high pressure heater where the high pressure of steam is used for heating.
9. The turbine in thermal power station acts as a prime mover of the alternator.

Coal handling plant :- Here, coal is pulverized i.e. ground to dust like size and carried to the furnace in a stream of hot air. Pulverization is a means of exposing a large surface area to the action of oxygen and consequently helping the combustion.

Boiler:- is a closed vessel in which water under pressure, is converted into steam. It is one of the major components of a thermal power plant. Always designed to absorb maximum amount of heat released in the process of combustion

Turbine:- converts heat energy of steam into mechanical energy and drives the generator.

Condenser:- Steam after rotating steam turbine comes to condenser. condensers are heat exchangers which convert steam from its gaseous to its liquid state

ADVANTAGES OF THERMAL POWER PLANT:

These are the following **advantages of thermal power plant**:

1. The fuel (i.e. coal) is used is quite cheap.

2. Less initial cost as compared to the other generating stations of the same capacity.

3. It requires less space as compared to the hydro-electric power station.

4. The cost of generation is lesser than the Diesel power station.

5. According to the demand, the load can be changed frequently without any difficulty.

6. Thermal Power plant can be installed anywhere irrespective of the availability of fuels. Fuel can be transferred to the site of the plant by rail, road etc.

7. This type of plants is installed near load centre.

8. Thermal Power plant can be run with overload condition (around 25%).

DISADVANTAGES OF THERMAL POWER PLANT:

The **disadvantages of thermal power plant** are:

1. It pollutes the atmosphere due to the production of a large amount of smoke.

2. Maintenance cost and operating cost is high.

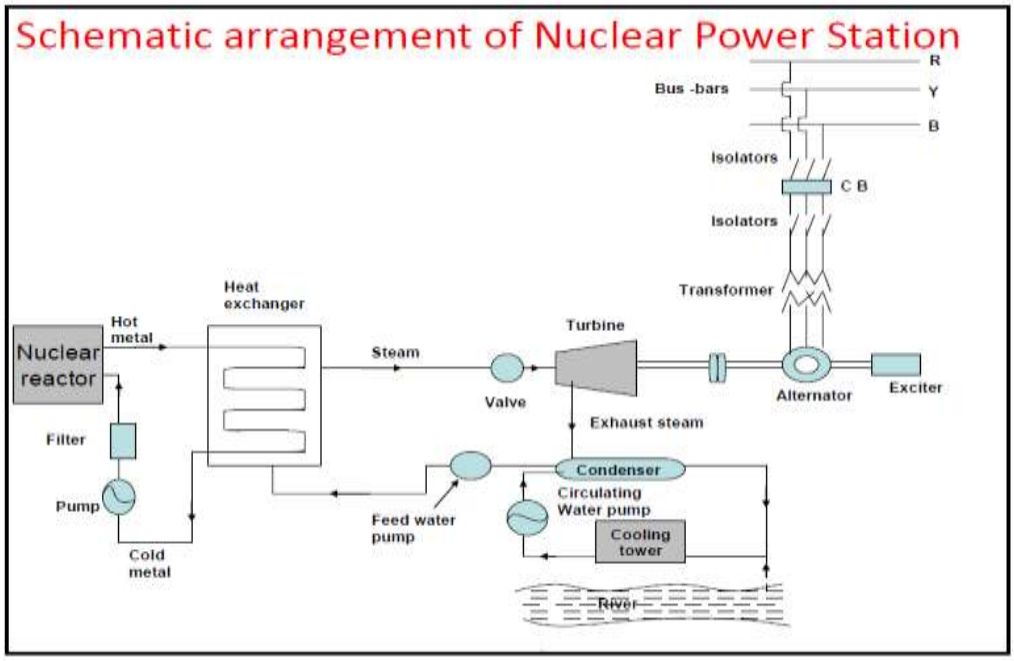
3. A Huge amount of water is required.

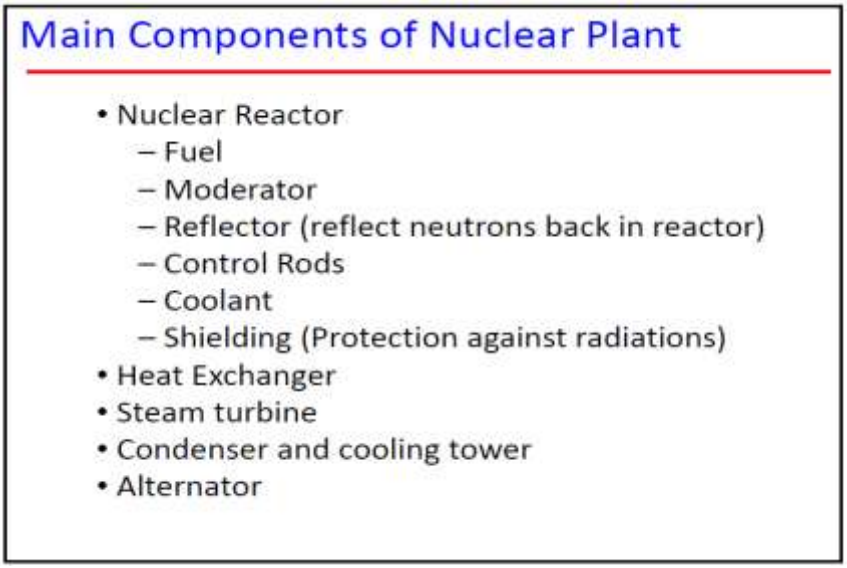
4. Running cost is high as compared to the diesel power plant.

5. Coal handling and ash disposal is quite difficult.

Nuclear Power plant

Nuclear power plants are a type of power plant that use the process of nuclear fission in order to generate electricity. They do this by using nuclear reactors in combination with the Rankine cycle, where the heat generated by the reactor converts water into steam, which spins a turbine and a generator.





Main Components of Nuclear Plant

- Nuclear Reactor
  - The nuclear fission of uranium is carried out in a nuclear reactor.
  - Nuclear fission is a "chain reaction" i.e it goes on and if not controlled, will lead to an explosion.
  - A nuclear reactor is a cylindrical pressure vessel and houses following parts :
    - –Fuel
    - – Moderator
    - – Reflector
    - – Control Rods
    - – Coolant
    - – Shielding

➢ Function : Carry out controlled nuclear fission

Main Components of Nuclear Plant

- Fuel rods
  - There are rods of nuclear matter. i.e U^{235}, Th^{232}, Pu^{239}.
  - **The fuel rods consist of the fission materials and release huge amount of energy when bombarded with slow moving neutrons.**

➢ Function : it is used for Heat generation

Main Components of Nuclear Plant

- Coolant
  - It carries heat from the reactor to the heat exchanger which generates steam.
  - Coolant is used to remove heat from fuel rods directly, if the moderator and coolant are of same materials.
  - In case where a separate moderator is used coolant passed through tubes.
  - **Water or air may be used as coolant. Sometimes heavy water, liquid metals or even gases may be used.**

➢ Function : Carry heat from reactor to heat exchanger.

Main Components of Nuclear Plant

- Moderator
  - Moderator in the reactor is used to moderate or reduce the speed of neutron.
  - HYDROGEN, HELIUM, BORON, NITROGEN, OXIGEN, WATER, **GRAPHITE**, DEUTERIUM are the common materials.
  - Sometimes the same material is used as a coolant.
  - Generally, graphite rods are used for this purpose.

➢ Function : Moderate Chain reaction to required level

Main Components of Nuclear Plant

- Control rods
  - Cadmium rods are used to control the chain reaction.
  - The control rods are made of such materials that can stop the nuclear reaction quickly by absorbing the neutrons.
  - Materials : boron carbide, silver, indium, **cadmium** and hafnium
  - By pulling out the control rods, power of the nuclear reactor is increased, whereas by pushing them in, it is reduced.

➢ Function : Controls Chain reaction

Main Components of Nuclear Plant

- Heat Exchanger
- It is used for converting water into steam by using the heat generated in nuclear reactor.
- The coolant takes heat from the reactor and gives it to the heat exchanger, where the steam is produced.
- Heat is transferred from one fluid to the other through the tube walls.
- In order to transfer heat efficiently, a large heat transfer area should be used, leading to the use of many tubes.
- The coolant is again fed to the reactor for completing the next cycle.

➢ Function : allows heat energy in one process fluid to pass to another process fluid in a control manner.

Main Components of Nuclear Plant

- Steam Turbine
  - The steam produced in the heat exchanger is made to strike the blades of the steam turbine.
  - After doing useful work in turbine the steam is exhausted to condenser.

➢ Function : Convert Heat energy of the steam into mechanical energy.

Main Components of Nuclear Plant

- Condenser
  - After doing function in turbine, steam is fed to condenser.
  - **The condenser condenses the steam which is fed to the heat exchanger through feed water pump.**

➢ Function : Condense steam(water) from turbine to reuse as a feed water to the heat exchanger.

Main Components of Nuclear Plant

- Cooling Tower
- It is a heat removal device used to transfer heat to the atmosphere.
- Cooling tower may either use the evaporation of water to remove heat and cool the working fluid.
- Common application include cooling the circulating water used in oil refineries, chemical plants, power stations.

➢ Function : Remove heat from the water discharged to the condenser so that the water can be reused.

Types of cooling towers:

Mechanical draft

Natural draft

Main Components of Nuclear Plant

- Alternator
- Alternator generate electricity by the same principle as a dc generator, namely when the magnetic field around a conductor changes, a current is induced in the conductor.
- Typically a rotating magnet called the rotor turns within a stationary set of conductors wound in coils on an iron core called the stator.
- The field cuts across the conductor, generating an electrical current, as the mechanical input causes the rotor to turn.

➢ Function : Converts mechanical energy of the turbine in to electrical energy.

Advantages

1. **Space:** A nuclear power plants needs less space compared to other power plant of equal size.
2. **Performance:** They are well suited (Economical) to meet large power demands.
3. **Fuel:** Since the fuel consumption is very small as compared to type of power plants. Therefore, there is a saving in cost of the fuel transportation.
4. **Operation:** The operation of the plant is more reliable.
5. **Condition:** It is not affected by the adverse weather condition. It can be operated in any type of weather condition.

Advantages

6. **Capacity:** high
7. **Expenditure:** The expenditure on metal structures piping, storage mechanisms is much lower for this plant then a coal burning power plant.
8. **Clean:** There is some greenhouse gas emission associated with the life cycle of uranium, as gases are emitted as it is mined and transported etc. However this is significantly, nuclear power would be "carbon-zero" if the uranium were mined and transported in a more efficient way.
9. **Efficient:** It can produce significant quantities of electricity, up to about 2GW. They are generally comparable in output to coal plants.
10. **Reliable:** they run constantly, rather than turning on and off to meet base load demand.

Disadvantages

1. **Waste:** High radioactive waste is very dangerous. A sophisticated method of storing the waste for this period of time must be designed.
2. **Terrorism:** Nuclear power plant would be very tempting target to anyone wanting to disrupt the power supply and destruct an entire region.
3. **Cost:** These types of plants are very expensive to install and run. The fuel is expensive and difficult to recover.
4. **Health of worker:** Working conditions in nuclear plants are always harmful to health of the workers.
5. **Staff** : highly qualified staff is required

Disadvantages

6. **Maintenance:** Maintenance charges are high due to lack of standardization. Moreover, high salaries of specially trained personal employed to handle the plant further raise the cost.
7. **Pollution:** The fission by products is generally radioactive and may cause a dangerous amount of radioactive pollution.
8. **Disposal:** The disposal of the product, which is radioactive, is a problem. They have either to be disposed off in a deep trench or at a common disposal point to which wastes are transported.
9. **Load:** Plants are not well suited for varying loads, as the reaction does not respond to the load fluctuation efficiently.

Single line Diagram of Generation, Transmission & Distribution with voltage level

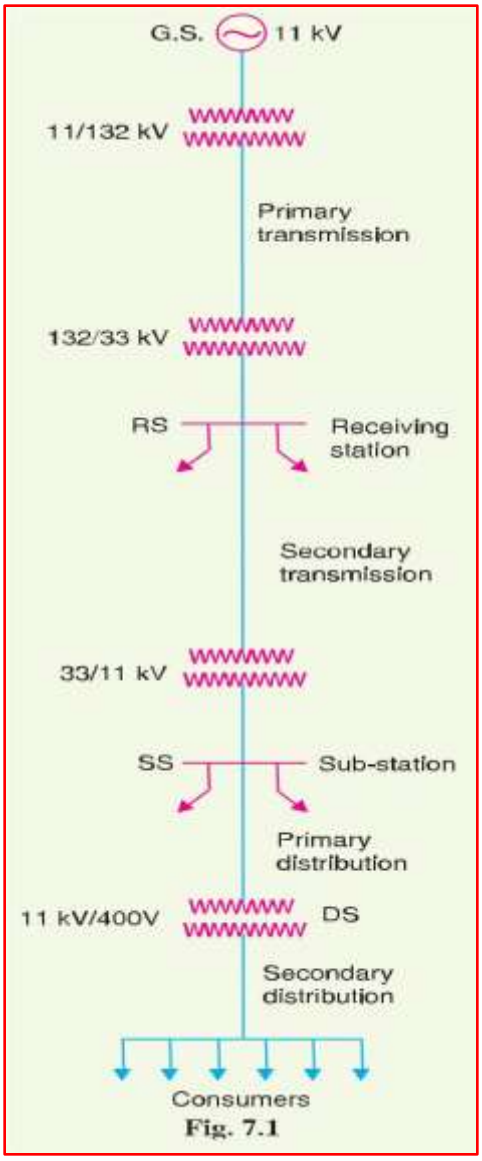


Fig. 7.1

(i) Generating station (G.S.):- here electric power is produced by 3-phase alternators operating in parallel. The usual generation voltage is 11 kV. For economy in the transmission of electric power, the generation voltage (i.e., 11 kV) is **stepped upto 132 kV** (or more) at the generating station with the help of 3-phase trans-formers.

(ii) Primary transmission:- The electric power at 132 kV is transmitted by 3-phase, 3-wire overhead system to the out-skirts of the city.

(iii) Receiving station (RS):- At the receiving station, the voltage is **re-duced to 33kV** by step-down transformers

(iv) Secondary transmission :- From **RS**, electric power is transmitted at 33kV by 3-phase, 3-wire over-head system to various sub-stations **(SS)** located at the strategic points in the city. This forms the secondary transmission.

(v) Primary distribution:- The secondary transmission line terminates at the sub-station (SS) where **voltage is reduced from 33 kV to 11kV**, 3-phase, 3-wire. The 11 kV lines run along the important road sides of the city.

(v) Secondary distribution:- The electric power from primary distribution line (11 kV) is delivered to distribution sub-stations (DS). These sub-stations are located near the consumers' localities and step down the voltage to 400 V, 3-phase, 4-wire for secondary distribution.

Comparison between Overhead & Underground system

S.No.	Particular	Overhead system	Underground system
1.	Public safety	It is less safe.	It is more safe.
2.	Initial cost	It is less expensive.	It is more expensive.
3.	Faults	Faults occur frequently.	Very rare chances of faults.
4.	Appearance	It gives shabby look.	Its appearance is good as wires are not visible.
5.	Flexibility	It is more flexible as new conductors can be laid along the existing conductors.	It is not flexible, as new conductors are to be laid in new channels.
6.	Location of fault	Fault point can be easily located.	Fault point cannot be easily located.
7.	Repair	Can be easily repaired.	Cannot be easily repaired.
8.	Working voltage	It can work upto 400 *kV*.	It can work only upto 66 *kV* due to insulation difficulty.
9.	Lightning thunder	More chances of being subjected to lightning.	Very little chances of being subjected to lightning.
10.	Supply interruption	More chances of supply interrruption.	Very little chances of supply interruption.
11.	Frequency of accidents	More chances of accidents.	Little chances of accidents.
12.	Interference with communication system	It interferes with communication systems.	No interference with communication system.
13.	Insulation cost	Less. The overhead conductor are bare. Supported on steel towers, insulated from the towers through insulators.	More insulation cost. Underground cables are provided with various wrappings of high grade tape etc. Lead sheath is also provided.
14.	Erection cost	Much less comparatively	Erection cost of high voltage cable is quite high.
15.	Uses	This is used for long distance transmission	The large charging current on high voltage limits the use of long distance transmission.

OR

(i) **Public safety.** The underground system is more safe than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.

(ii) **Initial cost**. The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.

(iii) **Flexibility**. The overhead system is much more flexible than the underground system. In the latter case, manholes, duct lines etc., are permanently placed once installed and the load expansion can only be met by laying new lines. However, on an overhead system, poles, wires, transformers etc., can be easily shifted to meet the changes in load conditions.

(iv) **Faults.** The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.

(v) **Appearance.** The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.

(vi) **Fault location and repairs**. In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.

(vii) **Current carrying capacity and voltage drop.** An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.

(viii) **Useful life.** The useful life of underground system is much longer than that of an overhead system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.

(ix) **Maintenance cost.** The maintenance cost of underground system is very low as compared with that of overhead system because of less chances of faults and service interruptions from wind, ice, lightning as well as from traffic hazards.

(x) **Interference with communication circuits.** An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system

EARTHING

What is Electrical Earthing or Grounding?

To connect the metallic (conductive) Parts of an Electric appliance or installations to the earth (ground) is called **Earthing** or **Grounding**.

In other words, to connect the metallic parts of electric machinery and devices to the earth plate or earth electrode (which is buried in the moisture earth) through a thick conductor wire (which has very low resistance) for safety purpose is known as ***Earthing or grounding*****.**

To earth or earthing rather, means to connect the part of electrical apparatus such as metallic covering of metals, earth terminal of socket cables, stay wires that do not carry current to the earth. Earthing can be said as the connection of the neutral point of a power supply system to the earth so as to avoid or minimize danger during discharge of electrical energy.

Why Earthing is Important?

The primary purpose of earthing is to avoid or minimize the danger of electrocution, fire due to earth leakage of current through undesired path and to ensure that the potential of a current carrying conductor does not rise with respect to the earth than its designed insulation.

When the metallic part of electrical appliances (parts that can conduct or allow passage of electric current) comes in contact with a live wire, maybe due to failure of installations or failure in cable insulation, the metal become charged and static charge accumulates on it**. If a person touches such a charged metal**, the result is a severe shock.

To avoid such instances, the power supply systems and parts of appliances have to be earthed so as to transfer the charge directly to the earth. *This is why we need Electrical Earthing or Grounding* in electrical installation systems.

Below are the basic needs of Earthing.

- To protect human lives as well as provide safety to electrical devices and appliances from leakage current.
- To keep voltage as constant in the healthy phase (If fault occurs on any one phase).

- To Protect Electric system and buildings form lighting.
- To serve as a return conductor in electric traction system and communication.
- To avoid the risk of fire in electrical installation systems.

Different Terms used in Electrical Earthing

- **Earth:** The proper connection between electrical installation systems via conductor to the buried plate in the earth is known as Earth.
- **Earthed:** When an electrical device, appliance or wiring systemsconnected to the earth through earth electrode, it is known as earthed device or simple "Earthed".
- **Solidly Earthed:** When an electric device, appliance or electrical installation is connected to the earth electrode without a fuse, circuit breaker or resistance/Impedance, It is called "solidly earthed".
- **Earth Electrode:** When a conductor (or conductive plate) buried in the earth for electrical earthing system. It is known to be Earth Electrode. Earth electrodes are in different shapes like, conductive plate, conductive rod, metal water pipe or any other conductor with low resistance.
- **Earthing Lead**: The conductor wire or conductive strip connected between Earth electrode and Electrical installation system and devices in called Earthing lead.
- **Earth Continuity Conductor:** The conductor wire, which is connected among different electrical devices and appliances like, distribution board, different plugs and appliances etc. in other words, the wire between earthing lead and electrical device or appliance is called earth continuity conductor. It may be in the shape of metal pipe (fully or partial), or cable metallic sheath or flexible wire.
- **Sub Main Earthing Conductor**: A wire connected between switch board and distribution board i.e. that conductor is related to sub main circuits.
- **Earth Resistance:** This is the total resistance between earth electrode and earth in Ω (Ohms). Earth resistance is the algebraic sum of the resistances of earth continuity conductor, earthing lead, earth electrode and earth.

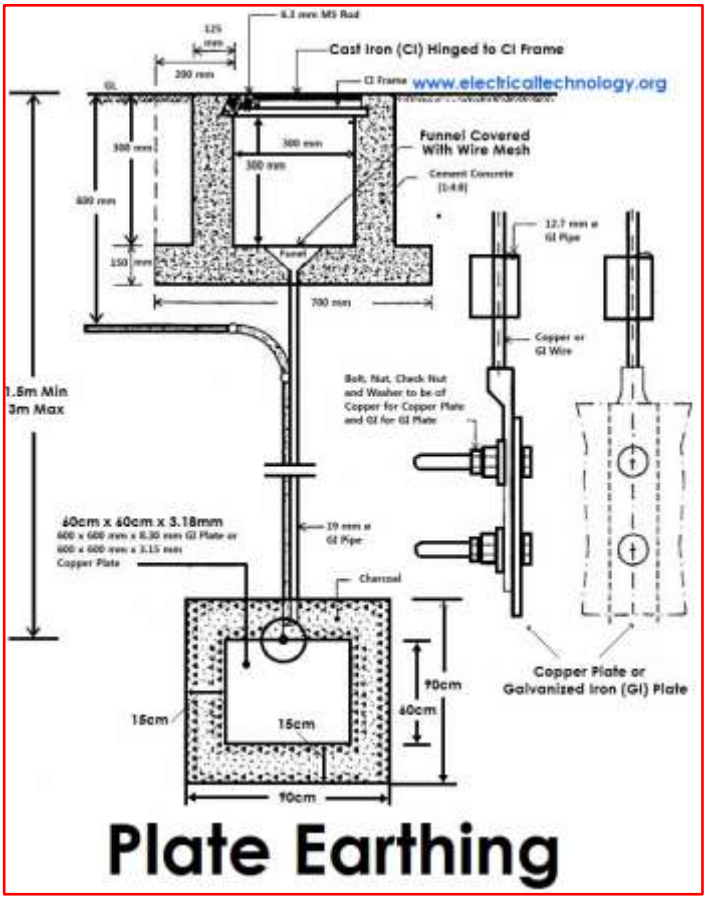
Methods of Conventional Earthing

Earthing can be done in many ways. The various methods employed in earthing (in house wiring or factory and other connected electrical equipment and machines) are

1. Plate Earthing
2. Pipe Earthing

Plate Earthing

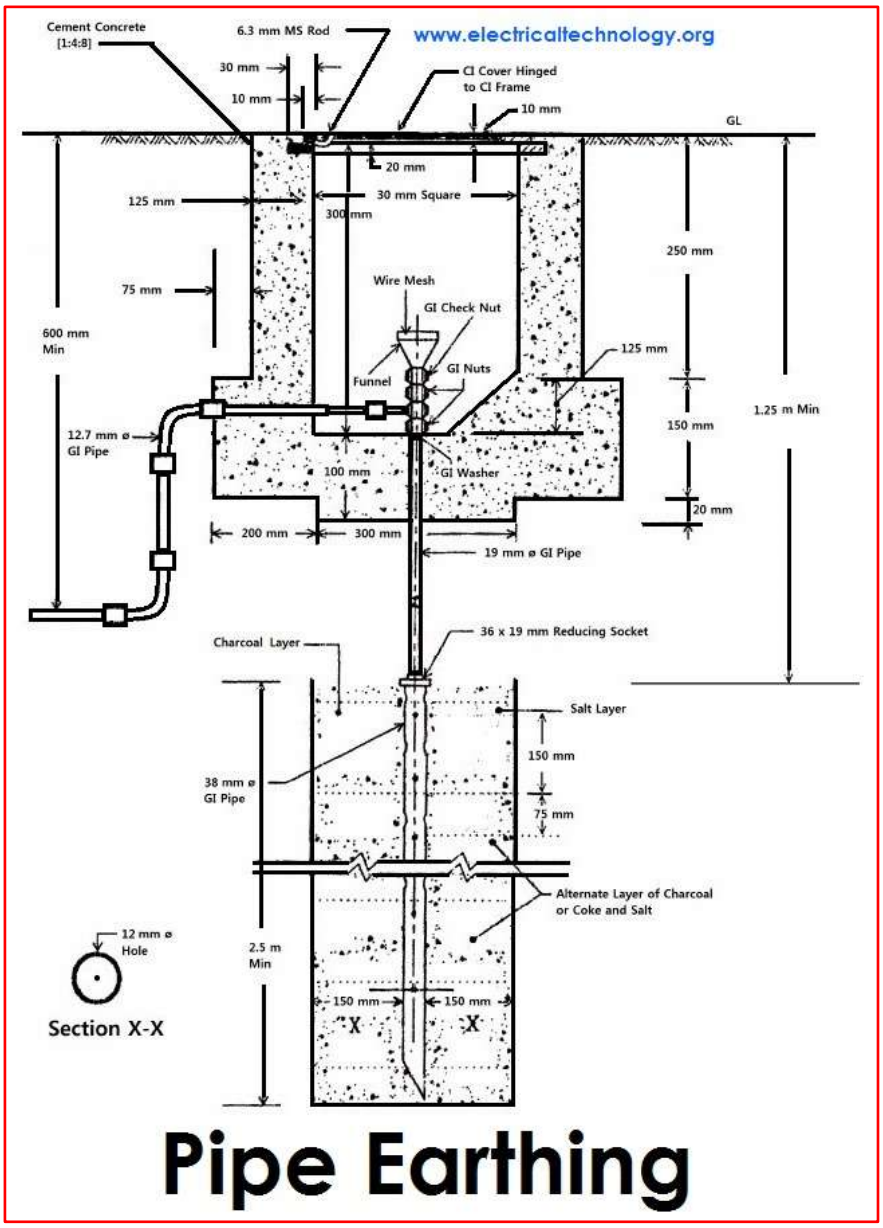
- In this type of earthing, plate either of copper or of G.I. is buried into the ground at a depth of max. 3 meter from the ground level.
- The earth plate is embedded in alternative layer of **coke and salts** for a minimum



thickness of about 15cm.The earth wire(copper wire for copper plate earthing and G.I. wire for G.I. plate earthing) is securely bolted to an earth plate with the help of bolt nut and washer made of copper, in case of copper plate earthing and of G.I. in case of G.I. plate earthing.

Pipe Earthing

- Pipe earthing is best form of earthing and it is cheap also in this system of earthing a **GI pipe** of upto 38 mm dia and 2.5 meters length is embedded **vertically in ground** to work as earth electrode but the depth depend upon the soil conditions, there is no hard and fast rule for this.
- But the **wire** is embedded upto the **wet soil**.
- The earth wire are fastened to the top section of the pipe with nut and bolts.

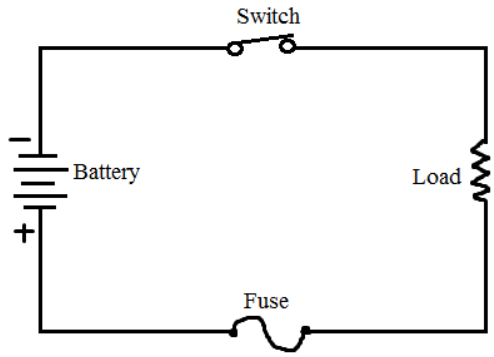


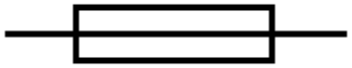
- The pit area around the GI pipe filled with **salt and coal mixture** for improving the soil conditions and efficiency of the earthing system.
- It can take **heavy leakage current** for the same electrode size in comparison to plate earthing
- The earth wire connection with GI pipes being above the ground level can be checked for carrying out **continuity test** as and when desired, while in plate earthing it is difficult.
- In summer season to have an effective earthing three or four bucket of water is put through the funnel for better continuity of earthing.

Fuses and Circuit Breakers

What are fuses?

Fuses are the protectors; these are the safety devices which are used to protect the home appliances like televisions, refrigerators, computers with damage by high voltage. The fuse is made up of thin strip or strand of metal, whenever the heavy amount of current or an excessive current flow is there in an electrical circuit, the fuse melts and it opens the circuit and disconnects it from the power supply. Also, it works as a **circuit breaker or stabilizer** which protects the device from damage. In the market, many types, features, and design of fuses are available nowadays. Their strips are made up of aluminum, copper, zinc & it is always connected in series with the **circuit to protect from overcurrent** in the running cables. Here is the basic circuit diagram & symbol of the fuse.





Circuit Diagram **Symbol**

Why do we Need Fuse?

Fuses are used for the prevention of home appliances from the short circuit and damage by overload or high current etc. If we don't use fuses, electrical faults occur in the wiring and it burns the wire and electric appliances and may starts fire at home. The lives of television, computers, radios and other home appliances may also put at risk. When the fuse goes, a sudden spark occurs which may lead to turning your home into sudden darkness by disconnecting the power supply which saves any further mishappenings. That's why we need fuses to protect our home appliances from harm.

How Does Fuse work?

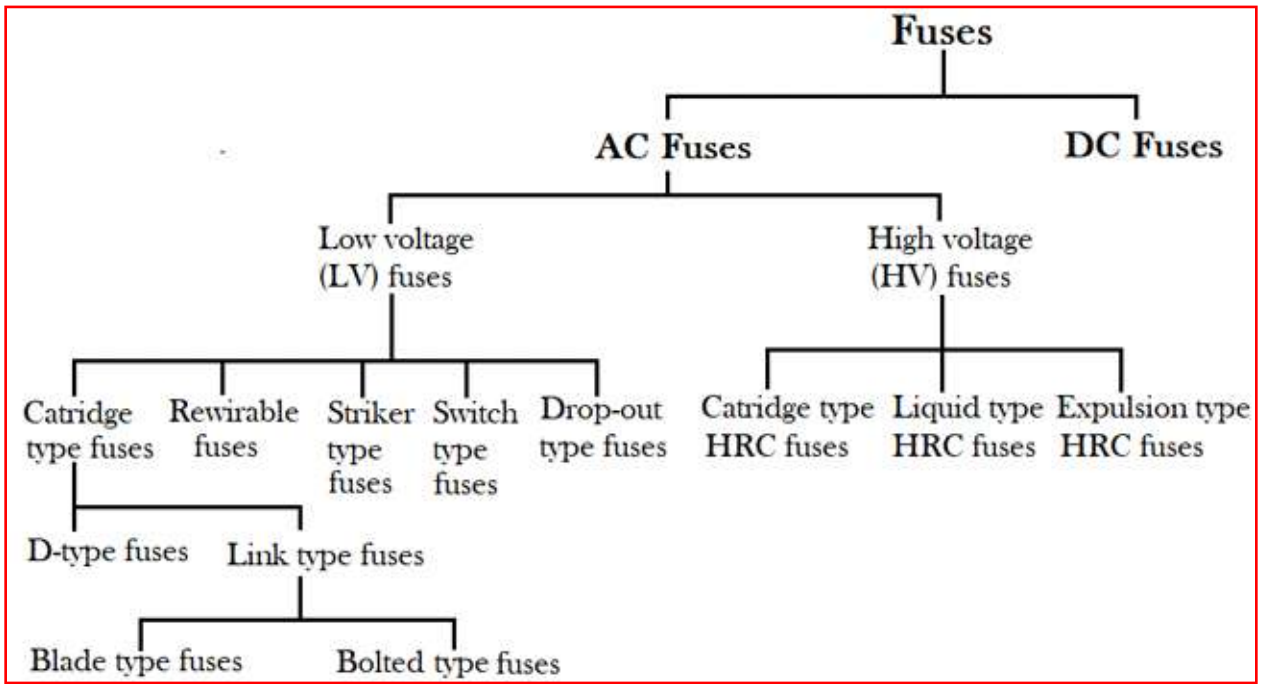
The fuses work on the principle of the **heating effect of the current**. It's made up of thin strip or strand of metallic wire with noncombustible material. This is connected between the ends of the terminals. Fuse is always connected in series with the electrical circuit.

When the excessive current or heat is generated due to heavy current flows in the circuit, the fuse melts down due to the low melting point of the element and it opens the circuit. The excessive flow may lead to the breakdown of wire and stops the flow of current. The fuse can be replaced or changed with the new one with suitable ratings. The fuse can be made up of the element like

zinc, copper, silver &aluminum. They also act as a circuit breaker which is used to break the circuit when the sudden fault occurs in the circuit. This is not only a protector but it is also used as a safety measure to prevent humans from hazards. So, this is how the fuse operates. Here is the figure is shown fuse operation, fuse barrel(container), fuse link.

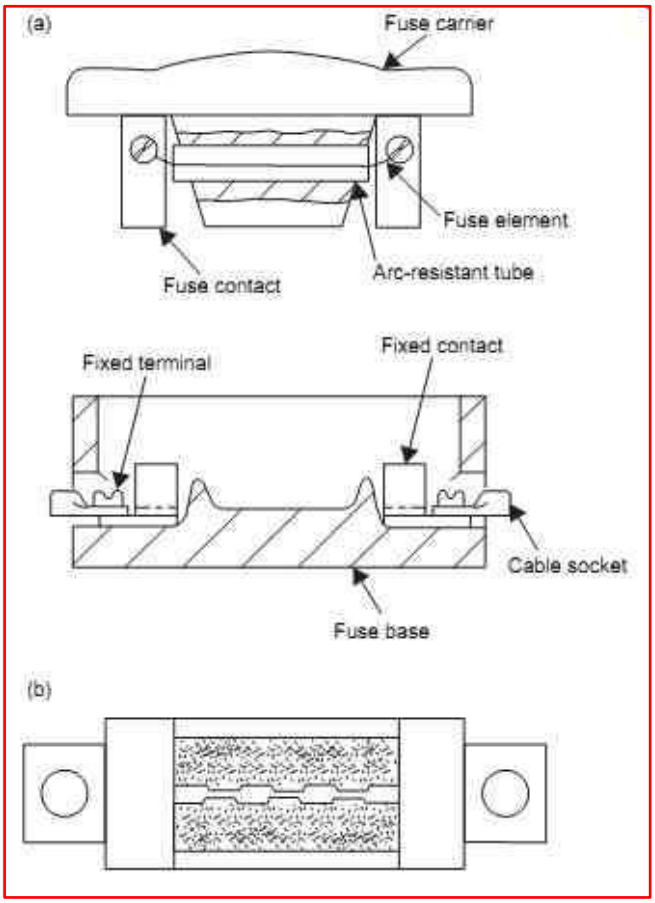
Classification of Fuses

Now we are discussing about **different types of fuses**. They are divided into two parts AC Fuses & DC Fuses. Further, they are divided into many categories given in the flowchart below:-



Rewirable Fuse

- This comprises a **fuse holder**, an element and a **fuse carrier**. The holder and carrier can be made of porcelain or bakelite.
- This type of fuse is popular for domestic appliances and small commercial units because of cheapness and ease of replacement.
- When there is an over surge that causes the fuse element to blow off, you can replace it. A new fuse carrier is inserted in the base.
- The main **advantage** of this type of fuse is that it is easy to install and also replace without risking any electrical injury.
- But there are certain shortcomings associated with it too. For instance, with this fuse you would have an element of **unreliability.** There is a level of lack of discrimination and a small time lag, which may hinder its functionality.
- With a slow speed of operation, you also get a low rupturing capacity.
- Other types have current limiting features, and this one does not.



- All this being said it is still a valuable fuse device for small scale usage.

HRC Fuse or High Rupturing Capacity Fuse

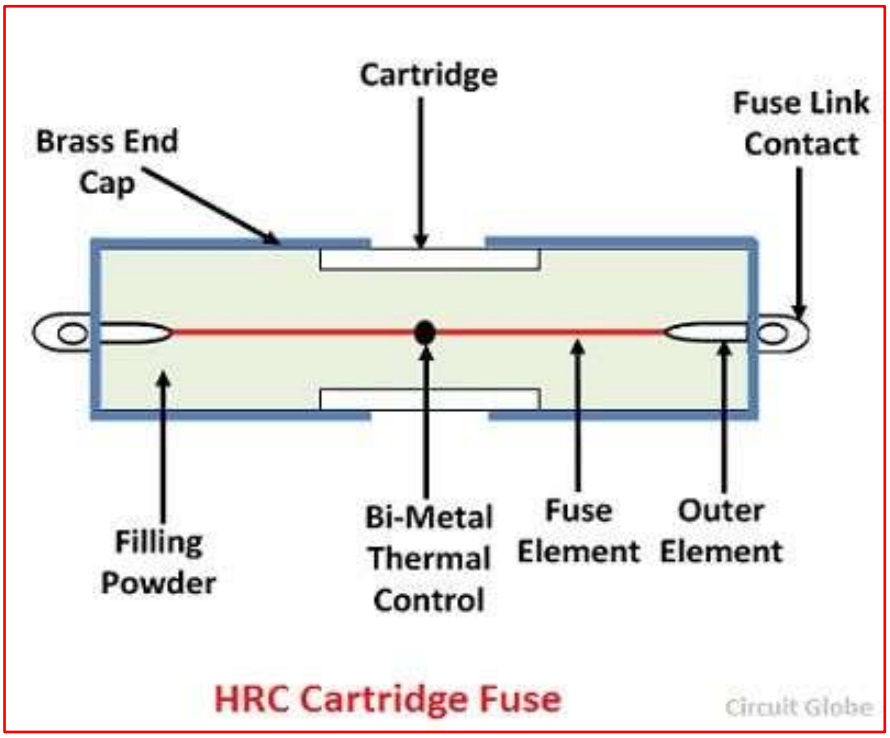
In this type of **fuse**, the **fuse wire or element** can carry short circuit heavy current for a known time period.

During this time if the fault is removed, then it does not blow off otherwise it blows off or melts.

Construction and Operations of HRC fuse:

It consists of highly heat resistant material (such as ceramic) body having **metal-end caps**, which is welded by silver current carrying element. The fuse body internal space is completely packed with a **filling powder**. The material, which has filled the insider space, may be plaster of Paris, quartz, chalk, marble, dust and cooling mediums etc.

That's why it carries normal current without overheating. The heat being produced vaporizes the silver melted element. Chemical reaction taking place between silver vapor and filling powder results in high resistance substance, which helps in quenching the arc in fuse.



Advantages of HRC Fuse:

- It clears high as well as low fault currents.
- Do not deteriorate with age.
- Having high-speed operation.
- Provides reliable discrimination.
- Require no maintenance.
- Cheaper than other circuit interrupting devices with same rating.
- Permit consistent performance
- Fusing operation is fast without Noise and Smoke

Disadvantages of H.R.C Fuse:

- After each operation, they have to be replaced.
- Heat being produced by the arc may affect the associated switches.

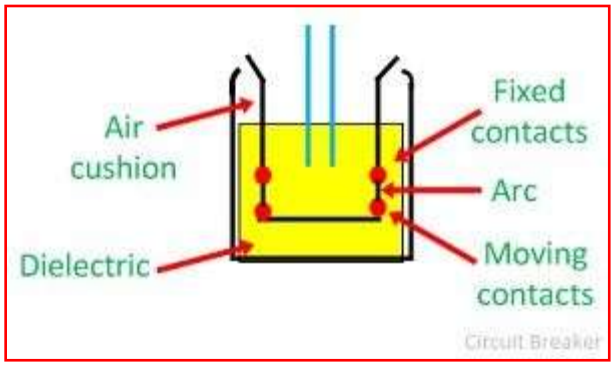
Circuit Breaker

A circuit breaker is a switching device that interrupts the abnormal or fault current. It is a mechanical device that disturbs the flow of high magnitude (fault) current and in additions performs the function of a switch. The circuit breaker is mainly designed for closing or opening of an electrical circuit, thus protects the electrical system from damage.

Working Principle of Circuit Breaker

Circuit breaker essentially consists of fixed and moving contacts. These contacts are touching each other and carrying the current under normal conditions when the circuit is closed. When the circuit breaker is closed, the current carrying contacts, called the electrodes, engaged each other under the pressure of a spring.

During the normal operating condition, the arms of the circuit breaker can be opened or closed for a switching and maintenance of the system. To open the circuit breaker, only a pressure is required to be applied to a trigger.



Whenever a fault occurs on any part of the system, the trip coil of the breaker gets energized and the moving contacts are getting apart from each other by some mechanism, thus opening the circuit.

Miniature Circuit Breakers (MCBs)

All fuses need to be replaced with MCB for better safety and control when they have done their job in the past. Unlike a fuse, an MCB operates as automatic switch that opens in the event of excessive current flowing through the circuit and once the circuit returns to normal, it can be reclosed without any manual replacement. MCBs are used primarily as an alternative to the fuse switch in most of the circuits. A wide variety of MCBs have been in use nowadays with breaking capacity of 10KA to 16 KA, in all areas of domestic, commercial and industrial applications as a reliable means of protection.

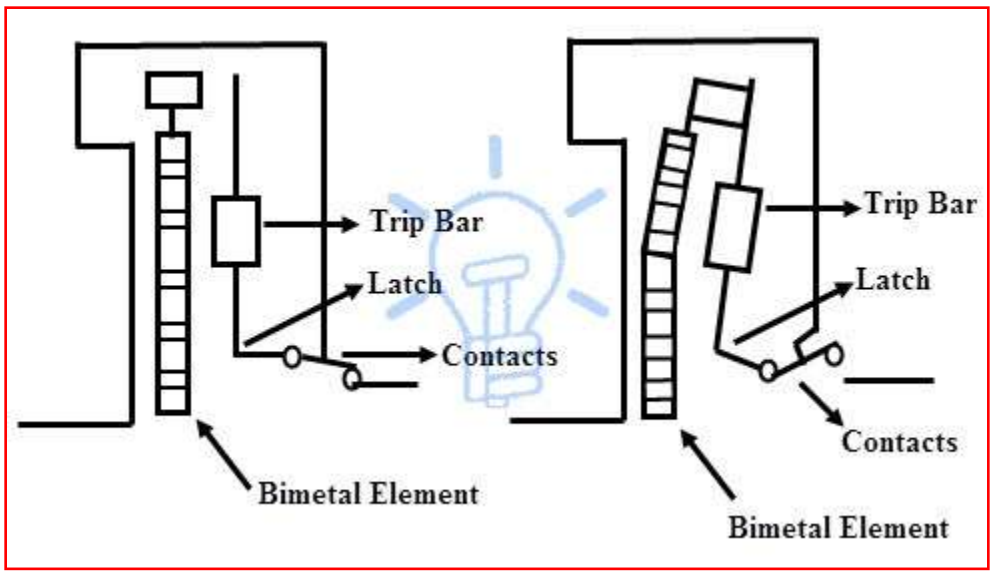
What is Miniature Circuit Breaker (MCB)?

An **MCB or miniature circuit breaker** is an electromagnetic device that embodies complete enclosure in a molded insulating material. The main function of an MCB is to switch the circuit, i.e., to open the circuit (which has been connected to it) automatically when the current passing through it (MCB) exceeds the value for which it is set. It can be manually switched ON and OFF as similar to normal switch if necessary.

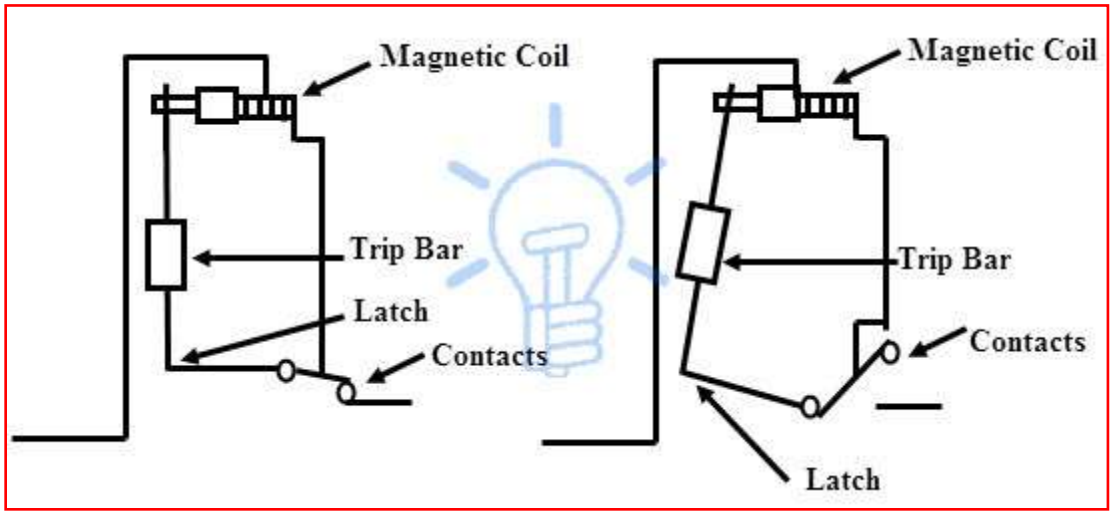
MCBs are used to perform many functions such as local control switches, isolating switches against faults and overload protection devices for installations or specific equipments or appliances.

Working & Operation of MCB

Under normal working conditions, MCB operates as a switch (manual one) to make the circuit ON or OFF. Under overload or short circuit condition, it automatically operates or trips so that current interruption takes place in the load circuit. The visual indication of this trip can be observed by automatic movement of the operating knob to OFF position. This automatic operation MCB can be obtained in two ways as we have seen in MCB construction; those are magnetic tripping and thermal tripping.



Under overload condition, the current through the bimetal causes to raise the temperature of it. The heat generated within the bimetal itself enough to cause deflection due to thermal expansion of metals. This deflection further releases the trip latch and hence contacts get separated. In some MCBs, magnetic field generated by the coil causes develop pull on bimetal such that it deflection activates the tripping mechanism.



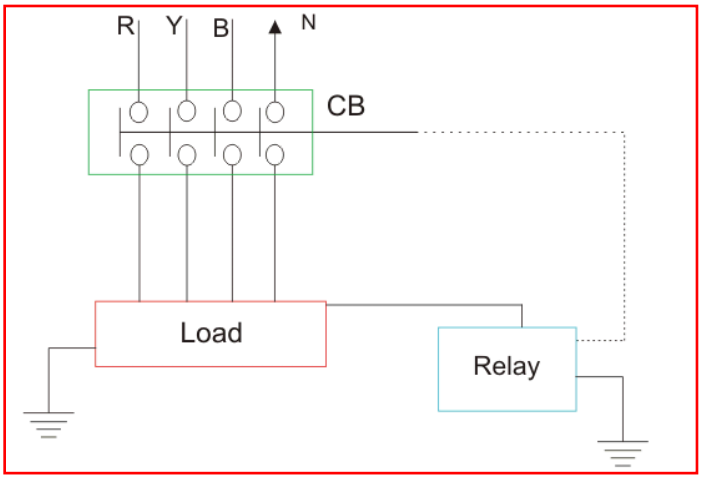
Earth Leakage Circuit Breaker or ELCB

If any current leaks from any electrical installation, there must-be any insulation failure in the electrical circuit, it must be properly detected and prevented otherwise there may be a high chance of electrical shock if-anyone touches the installation. An earth leakage circuit breaker does it efficiently. Means it detects the earth leakage current and makes the power supply off by opening the associated circuit breaker. There are two types of earth leakage circuit breaker, one is voltage ELCB and other is current ELCB.

Voltage Earth Leakage Circuit Breaker

The working principle of voltage ELCB is quite simple. One terminal of the relay coil is connected to the metal body of the equipment to be protected against earth leakage and other terminal is connected to the earth directly.

If any insulation failure occurs or live phase wire touches the metal body, of the equipment, there must be a voltage difference appears across the terminal of the coil connected to the equipment body and earth. This voltage difference produces a current to flow the relay coil.



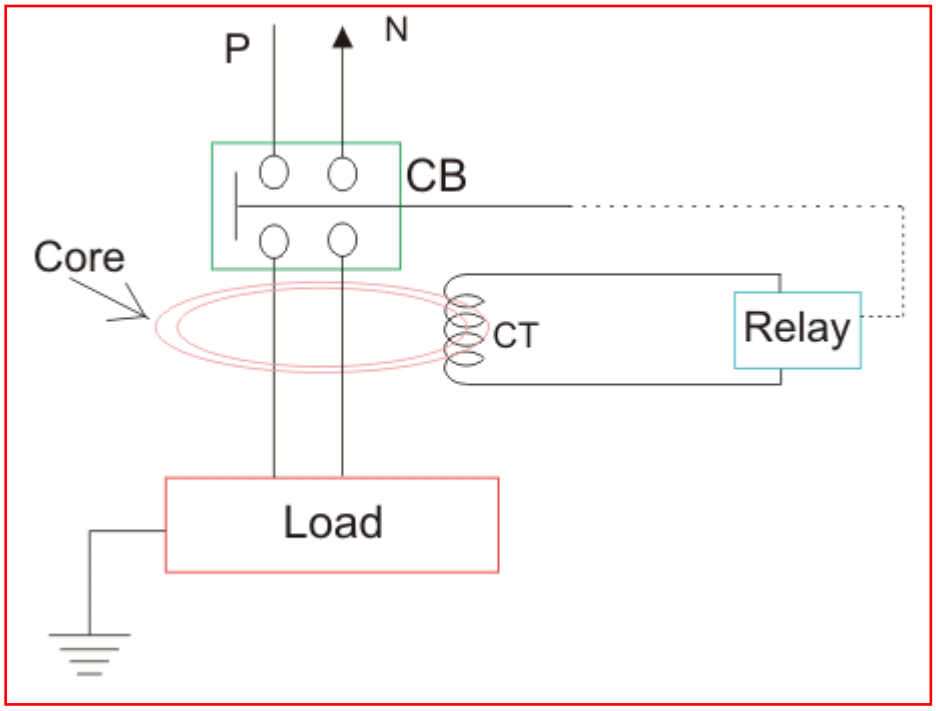
If the voltage difference crosses, a predetermined limit, the current through the relay becomes sufficient to actuate the relay for tripping the associatedcircuit breaker to disconnect the power supply to the equipment. The typicality of this device is, it can detect and protect only that

equipment or installation with which it is attached. It cannot detect any leakage of insulation in other parts of the system. Study our Electrical MCQs to learn more about the operation of ELCBs.

Current ELCB or RCCB or Residual Current Circuit Breaker

The working principle of current earth leakage circuit breaker or RCCBis also very simple as voltage operated ELCB but the theory is entirely different and residual current circuit breaker is more sensitive than ELCB.

Actually, ELCBs are of two kinds, but it is general practice to refer voltage based ELCB as simple ELCB. And current based ELCB is referred to as RCD or RCCB. Here one CT (Current Transformer) core is energized from both phase wise and neutral wire.



Single Phase Residual Current ELCB. The polarity of the phase winding and neutral winding on the core is so chosen that, in normal condition mmf of one winding opposes that of another. As it is assumed that, in normal operating conditions the current goes through the phase wire will be returned via neutral wire if there's no leakage in between. As both currents are same, the resultant mmf produced by these two currents is also zero-ideally.

UPS

An Uninterruptible Power Supply **(UPS) is defined as a piece of electrical equipment which can be used as an immediate power source to the connected load when there is any failure in the main input power source.**

In a **UPS**, the energy is generally stored in flywheels, batteries, or supercapacitors. When compared to other immediate power supply system, UPS have the advantage of immediate protection against the input power interruptions. It has very short on-battery run time; however this time is enough to safely shut down the connected apparatus (computers, telecommunication equipment etc) or to switch on a standby power source.
UPS can be used as a protective device for some hardware which can cause serious damage or loss with a sudden power disruption. Uninterruptible power source, Battery backup and Flywheel back up are the other names often used for UPS. The available size of UPS units ranges from 200 VA which is used for a solo computer to several large units up to 46 MVA.

Major Roles of UPS

When there is any failure in main power source, the UPS will supply the power for a short time. This is the prime role of UPS. In addition to that, it can also able to correct some general power problems related to utility services in varying degrees. The problems that can be corrected are voltage spike (sustained over voltage), Noise, Quick reduction in input voltage, Harmonic distortion and the instability of frequency in mains.

Types of UPS

Generally, the UPS system is categorised into On-line UPS, Off- line UPS and Line interactive UPS. Other designs include Standby on-line hybrid, Standby-Ferro, Delta conversion On-Line.

Off-line UPS

This UPS is also called as Standby UPS system which can give only the most basic features. Here, the primary source is the filtered AC mains (shown in solid path in figure 1). When the power breakage occurs, the transfer switch will select the backup source (shown in dashed path in figure 1). Thus we can clearly see that the stand by system will start working only when there is any failure in mains. In this system, the AC voltage is first rectified and stored in the storage battery connected to the rectifier.

When power breakage occurs, this DC voltage is converted to AC voltage by means of a power inverter, and is transferred to the load connected to it. This is the least expensive UPS system and it provides surge protection in addition to back up. The transfer time can be about 25 milliseconds which can be related to the time taken by the UPS system to detect the utility voltage that is lost. The block diagram is shown below.

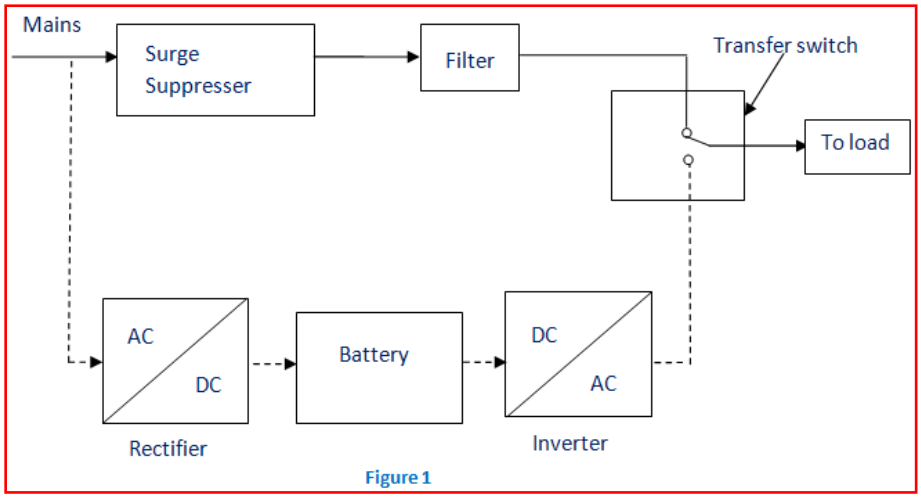


Figure 1

On-line UPS

In this **type of UPS**, double conversion method is used. Here, first the AC input is converted into DC by rectifying process for storing it in the rechargeable battery. This DC is converted into AC by the process of inversion and given to the load or equipment which it is connected (figure 2). This type of UPS is used where electrical isolation is mandatory. This system is a bit more costly due to the design of constantly running converters and cooling systems. Here, the rectifier which is powered with the normal AC current is directly driving the inverter. Hence it is also known as Double conversion UPS. The block diagram is shown below.

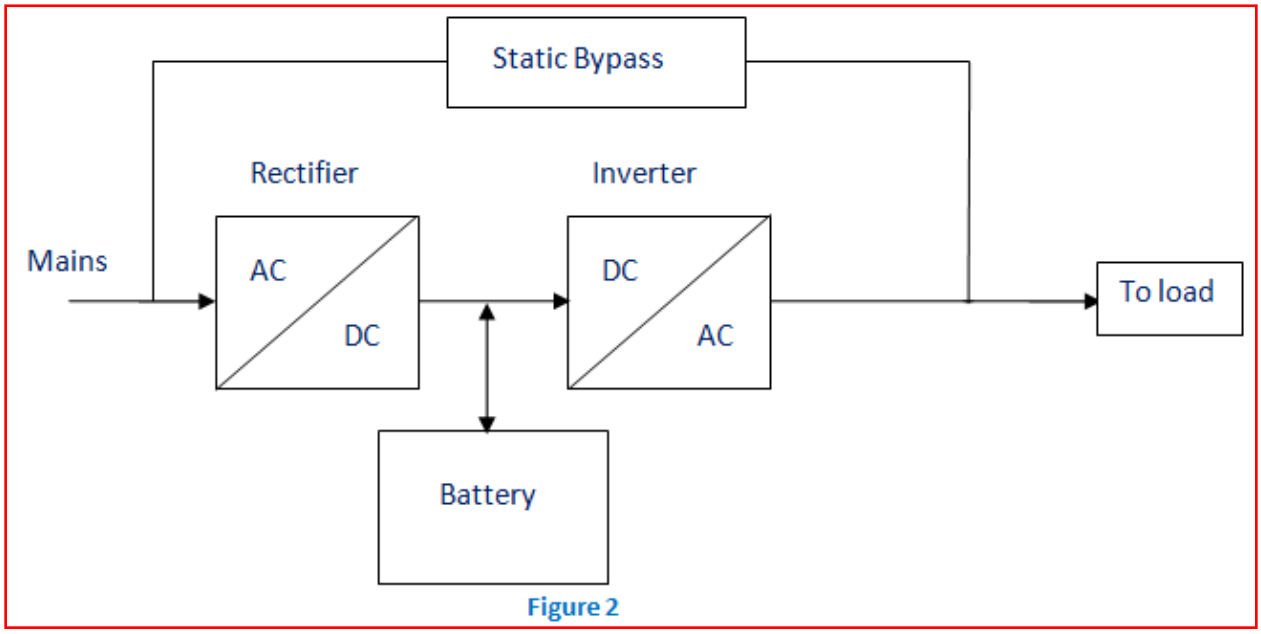


Figure 2

When there is any power failure, the rectifier have no role in the circuit and the steady power stored in the batteries which is connected to the inverter is given to the load by means of transfer switch. Once the power is restored, the rectifier begins to charge the batteries. To prevent the batteries from overheating due to the high power rectifier, the charging current is limited. During a main power breakdown, this UPS system operates with zero transfer time. The reason is that the backup source acts as a primary source and not the main AC input. But the presence of inrush current and large load step current can result in a transfer time of about 4-6 milliseconds in this system.

Applications of a UPS include:

- Data Centers
- Industries
- Telecommunications
- Hospitals
- Banks and insurance
- Some special projects (events)