Switchgear

Switchgear refers to electrical devices that regulates the flow of electricity within an electrical system. In an electric power system, switchgear is the combination of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used for both purposes to energize equipment to allow work to be done and to de-energize equipment to clear faults downstream.

The switchgear consists of two main components:

- Power switching/conducting component that can connect and disconnect the flow of power for on off operations and in case of a fault.
- Power control components such as protective relays, control panels, current transformers and other devices to monitor the flow of power and other parameters of the circuit.
- Some examples of switchgear are switches, fuses, circuit breaker, isolater, relay , current transformer & potential transformers and lightning arresters.

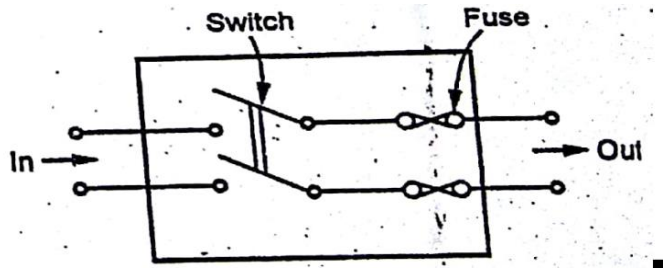
Properties of A Switchgear

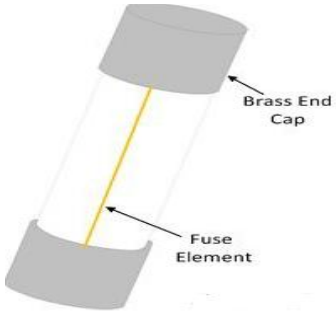
The essential features of a switchgear is

1. ***Complete reliability****:* When fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit.
2. ***Absolutely certain discrimination****:* When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the system without affecting the healthy section.
3. ***Quick operation****:* When fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents. If fault is not cleared by switchgear quickly, it is likely to spread into healthy parts, thus endangering complete shut down of the system
4. ***Provision for manual contro****l:* A switchgear must have provision for manual control. In case the electrical (or electronics) control fails, the necessary operation can be carried out through manual control.

Fuse

In normal working condition of electrical network, the current flows through the network is within the rated limit. If a fault occurs in the network current crosses the rated limits. This high current may have a very high thermal effect which will cause permanent damage to equipment connected to the electrical network. So this high fault current should be interrupted as fast as possible. A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the circuit to be protected.





Advantages:

- Fuse is cheapest type of protection in an electrical circuit
- Fuse needs zero maintenance
- Operation of fuse is simple and no complexity is involved
- The operation time of fuse can be made much smaller than operation of circuit breaker. It is the primary protection device against short circuits
- It affords current limiting effect under short-circuit conditions.

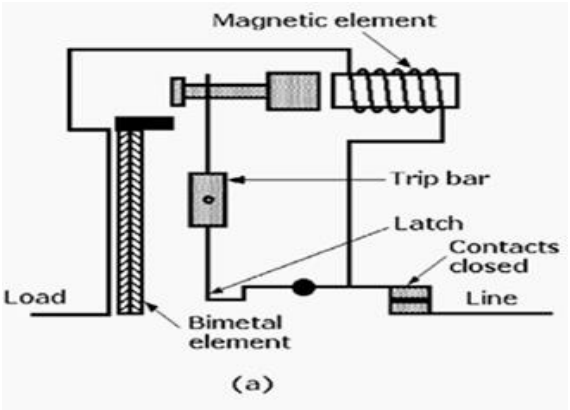
Disadvantage:

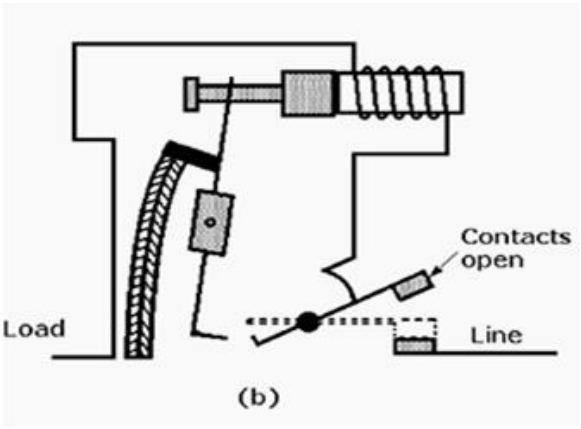
- During short circuit or overload once fuse blows off replacing of fuse takes time. During this period the circuit remain disconnected.
- It is difficult to find the fuse of proper current rating for a circuit failing which faulty operation of fuse can occur.

Miniature Circuit Breaker (MCB)

Now a days we use more commonly miniature circuit breaker or MCB in low voltage electrical network instead of fuse. A miniature circuit breaker basically is an electromagnetic device that automatically operates (or breaks) the circuit, if the current in the circuit reaches to a predetermined value. It can operate accurately under both overloading and short circuit conditions.

Miniature circuit breaker construction is very simple, robust and maintenance free. Generally a MCB is not repaired or maintained, it just replaced by new one when required. The main constructional parts of a MCB are one bi-metallic strip, one solenoid coil, latch connected switch and one hand operated on-off lever.





The MCB provides protection against over load current and short circuit current. The overload protection is based on the thermal effect of current while the short circuit protection is based on the electromagnetic effect of current.

With the use of bimetallic strip, over protection is achieved in case overload conditions. When overload current flows through the MCB, the bimetallic strip gets heated and causes to deflect. In doing so, it moves the trip bar and releases the latch mechanism and hence open the contacts.

During the short circuit conditions, the large fault current energizes the magnetic element (solenoid) and the magnetic field of the solenoid attracts the plunger which in turn strikes the trip bar and hence the immediate release of the latch mechanism.

Generally, MCBs are designed to trip less than 2.5 milliseconds when a short circuit occurs or over current fault arises. In case of overheating or overload condition, MCB may take 2 seconds to 2 minutes for tripping based on the level of the overload.

The MCB has some advantages compared to fuse.

1. 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.

2. 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.

3. Quick restoration of supply can not 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 moving the lever to on position.

4. Handling MCB is more electrically safe than fuse.

5. The MCB can not be restored if the fault exist in the circuit

6. The MCB has ability to interrupt enormous short circuit current without producing flame, gas or smoke.
   Only one disadvantage of MCB over fuse is that this system is more costlier than fuse unit system.

   MCCB-Molded Case Circuit Breaker

   The MCCB is used to control electric energy in distribution network and is having short circuit and overload protection. This circuit Breaker is an electromechanical device which guards a circuit from short circuit and over current. They offer short circuit and over current protection for circuits ranges from 63 Amps-3000 Amps. The primary functions of MCCB is to give a means to manually open a circuit, automatically open a circuit under short circuit or overload conditions.

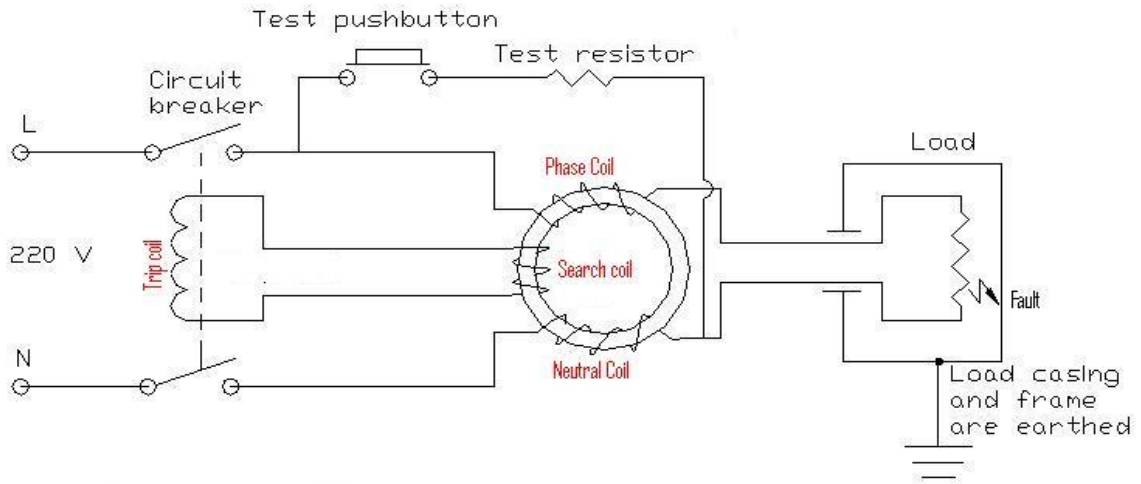
   The traditional molded-case circuit breaker uses electromechanical (thermal magnetic) trip units that may be fixed or interchangeable. An MCCB provides protection by combining a temperature sensitive device with a current sensitive electromagnetic device. Both these devices act mechanically on the trip mechanism.

   Depending upon the application and required protection, an MCCB will use one or a combination of different trip elements that protect against the following conditions:

- Thermal overloads
- Short circuits
  Ground faults
  The MCCB is equivalent to a MCB of higher current rating with adjustable trip characteristics.
  Characteristics of MCCB
  The characteristics of an MCCB mainly include the following

- The range of rated current is up to 1000 amperes
- Trip current may be adjusted
- Thermal/thermal magnetic operation

Earth-leakage circuit breaker (**ELCB**) :



ELCB circuit

The supply coil, the neutral coil and the search coil all wound on a common transformer core. On a healthy circuit the same current passes through the phase coil, the load and return back through the neutral coil. Both the phase and the neutral coils are wound in such a way that they will produce an opposing magnetic flux. With the same current passing through both coils, their magnetic effect will cancel out under a healthy circuit condition.

Net MMF in Core = MMF by phase winding – MMF by neutral winding

In a situation when there is fault or a leakage to earth in the load circuit, or anywhere between the load circuit and the output connection of the ELCB circuit, the current returning through the neutral coil has been reduced. Then the magnetic flux inside the transformer core is not balanced anymore. The total sum of the opposing magnetic flux is no longer zero. This net remaining flux is what we cause a residual flux. This action produces an electromotive force (e.m.f.) across the search coil. The induced voltage across the search coil produces a current inside the wiring of the trip circuit. It is this current that operates the trip coil of the circuit breaker.

Since the trip current is driven by the residual magnetic flux (the resulting flux, the net effect between both fluxes) between the phase and the neutral coils which depends on current difference in phase and neutral the assembled system is also called Residual Current Circuit Breaker (RCCB) or residual current devise (RCD).

Earthing

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

Types of Electrical Earthing

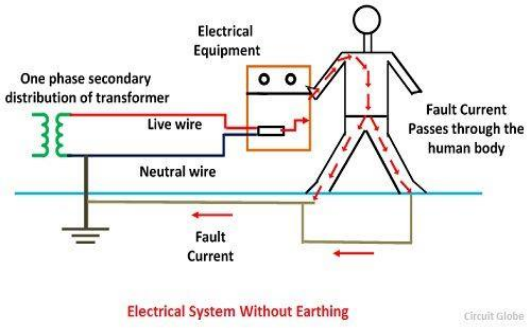
- **Neutral Earthing**

  In neutral earthing, the neutral of the system is directly connected to earth by the help of the GI wire. The neutral earthing is also called the system earthing. Such type of earthing is mostly provided to the system which has star winding. For example, the neutral earthing is provided in the generator, transformer, motor etc.

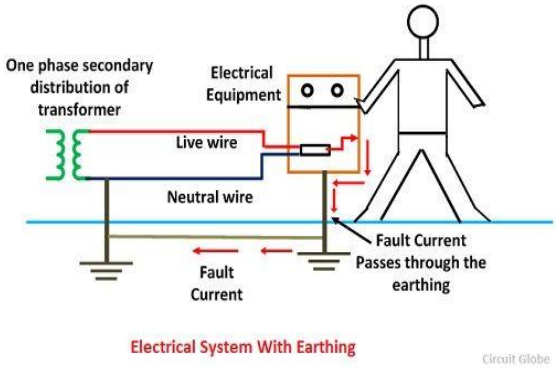
- **Equipment Earthing**

  Such type of earthing is provided to the electrical equipment. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire. If any fault occurs in the apparatus, the short-circuit current to pass the earth by the help of wire. Thus, protect the system from damage.

Mostly, the galvanised iron is used for the earthing. The earthing provides the simple path to the leakage current**.** The short circuit current of the equipment passes to the earth which has zero potential. Thus, protects the system and equipment from damage



Electrical System Without Earthing



Electrical System With Earthing

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Under normal operating condition if a person touches the outer part of a machine, due to insulation the person is not going to get any electrical shock.

In case of fault or insulation damage in a machine without earthing, when a person touches the outer part of machine carry current the fault current flows through the human body or person receive electrical shock. But when the machine is earthed and a person touches the machine the body resistance and the earth resistance are in parallel. Due to small earth resistance almost all the fault current is passed through the earth wire and the human operator is safe.

Advantages of earthing

1. Safety for Human Life, Electrical Devices and Buildings

It saves the human life from the danger of electrical shock which can cause death. It protects our electric equipment or devices. It provides a safe path for lighting and short circuit currents and saves the building from structural damage and fire accident.

2. Voltage Stabilization

Electricity comes from many sources, every transformer can be considered as a separate source. If there is no point which will act as a common point, then it is impossible to make a calculation

between these sources. In an electrical distribution system, Earth is at the zero potential, which makes it a universal standard for all-electric systems.

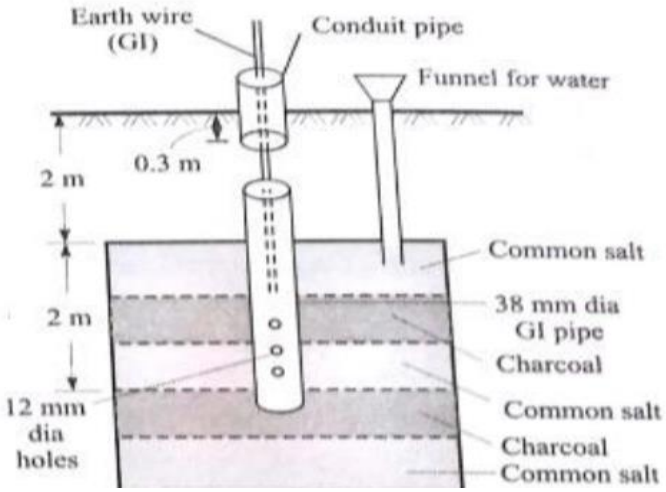
3. Over Voltage Protection

Earthing System provides an alternative path in the electrical system to minimize the dangerous effect in the electrical system which happens at the time of lighting and unintentional contact with high voltage lines.

Types of Earthing methods

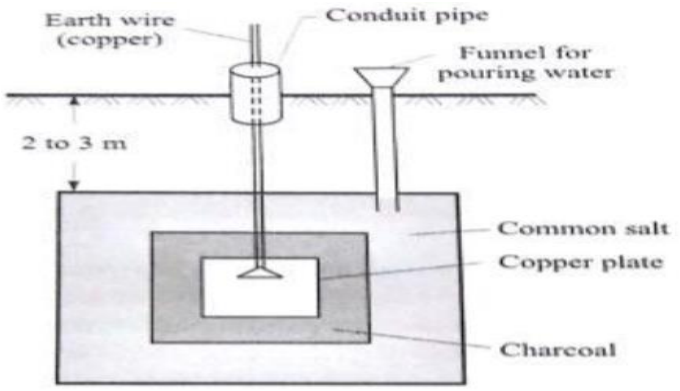
1. Strip or Wire Earthing: In this system of earthing, strip electrodes of cross section not less than 25 mm X 1.6 MM if of copper and 25 mm X 4 mm if of galvanized iron or steel are buried in horizontal trenches of minimum depth 0.5 metre. This type of earthing is used at places which have rocky soil earth bed because at such places excavation work of earth plate is difficult.

2. Pipe Earthing: In the given figure, a GI pipe with a few holes at its lower end is buried to a depth not less than 2 m and atleast 0.6 m away from the foundation of any building. Normally, the size of pipe is either 2m long and 38 mm diameter or 1.37 m long and 51 mm diameter. However, for dry and rocky soil, we use longer pipes. Alternate layers of common salt and charcoal have thickness of 30 mm and 80 mm, respectively. To maintain good conductivity of the soil, an arrangement is made for pouring water into the earth pit surrounding the earth electrode. This is especially needed during summer. As the pipe has much larger contact area with soil, it can handle larger leakage currents than the plate earthing of same electrode size.



3. **Plate Earthing:** In plate earthing an earthing plate either of copper of dimensions 60cm X 60cm X 3mm or of GI of dimensions 60cm X 60cm X6mm is buried into the ground with its face vertical at a depth of not less than 3 metres from ground level. The earth plate is embedded in alternate layers of coke and salt for a minimum thickness of 15cm. The earth wire (GI wire for GI plate earthing and copper wire for copper plate earthing) is securely bolted to an earth plate with the help of a bolt, nut and washer made of material of that of earth plate. A small masonry brick wall enclosure with a cast iron cover on top or an RCC pipe

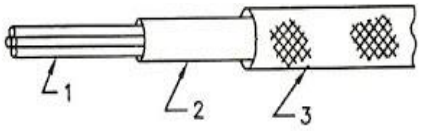
round the earth plate is provided to facilitate its identification and for carrying out periodical inspection and tests.



Types of Wires: Based on the type of insulation used electrical wires are mainly classified into the following types:

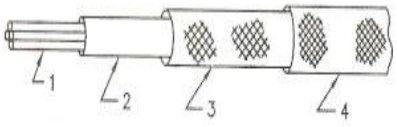
1) V.I.R.(Vulcanized India Rubber) wire.
2) C.T.S. or T.R.S. (Cab Tyre Sheathed or Tough Rubber Sheathed) wire.
3) Weather proof wire.
4) L.C.(Lead Covered) wire.
5) MICC (Mineral insulated copper covered) wire.
6) PVC (Poly Vinyl Chloride) wire.
7) Flexible wire.

3.1) VIR (Vulcanized India rubber) wire:



1. CONDUCTOR 2. RUBBER INSULATION 3. BRAIDING

Single Braided VIR Wire



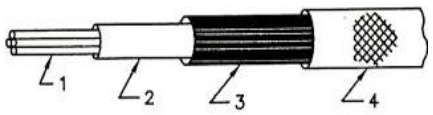
1. CONDUCTOR 2. RUBBER INSULATION 3. BRAIDING
4. SECOND LAYER OF BRAIDING

Double Braided VIR Wire

In this type of wires conductors are made up of aluminum or copper. A layer of vulcanized rubber is provided over it. There may one or two layers. Over this a cotton tape is wound and braiding of impregnated cotton is wound over it. Single braided wire and double braided wire is shown in figure. These types of wires can bear little mechanical stress. Due to the effect of water, moisture etc. its insulation properties are reduced. Chemicals also effect the insulation and it may be cut due to the sharp tools etc. Due to excessive heat the rubber may melt.

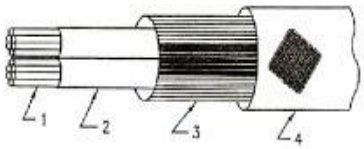
3.2) CTS or TRS (Cab tire Sheath or tough rubber sheath) wire:

In this type of wire layer of strong and durable rubber is provided over the conductor. Its mechanical strength is more than that of the VIR wire. Effect of heat, moisture and water is less in it. This type of wire is available in varieties of single core, twin cores and three cores. It is used in house wiring and industrial wiring. Single core and twin core wire is shown in figure.



1. CONDUCTOR 2. RUBBER INSULATION
3. RUBBER SHEATH 4. BRAIDING

Single Core TRS Wire



1. CONDUCTOR 2. RUBBER INSULATION 3. RUBBER SHEATH 4. BRAIDING

Twin Core TRS Wire

3.3) Weather proof wire:

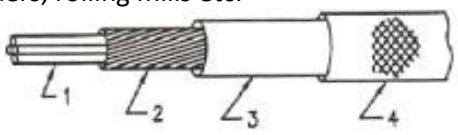
On this type of wire there is no effect of atmosphere. A layer of rubber is provided on copper conductor. Braiding of cotton is provided on this. It is made waterproof by dipping it into waterproof compound. This type of wire is available in single core or double core types. Mainly used as service wire for homes from distribution pole.

3.4) LC (Lead Covered) wire:

In this type of wire coating of insulated rubber is provided on the conductor. A tube made of lead is kept over it. Due to there is no effect of moisture on the rubber. So it is used in the place where there is presence of moisture. As Lead is soft. It is easily affected by mechanical stresses. So care has to be taken while using it. This wire can be used directly on wooden batten.

3.5) MICC (Mineral insulated copper covered) wire:

In this type of wire coating of magnesium oxide is provided as insulation on the copper conductor. Over this copper sheath is provided. When this wire has to be used in moist atmosphere, a serving made of PVC is provided over this. This wire is less affected by temperature. This type of wire is used in wiring in mines, factories, refineries, furnace, boilers, rolling mills etc.

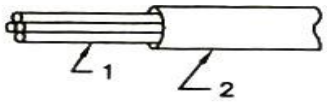


1. CONDUCTOR 2. COATING OF MAGNESIUM OXIDE 3. COPPER SHEATH 4. PVC SHEATH

MICC Wire

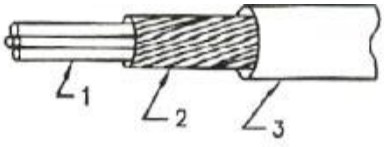
3.6)PVC (Poly Vinyl Chloride) Wire:

In this type of wire insulation made of poly vinyl chloride is provided over copper or aluminum conductor. PVC wires are widely used and use of paper and rubber insulated wires is reduced. This type of wire is manufactured for voltage rating of 11 KV. It is available in single PVC and double PVC Types. This type of wire is also available in twin core and three core circular and two core flat types.



1. CONDUCTOR 2. PVC INSULATION

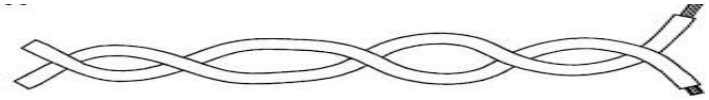
Single PVC Wire



1. CONDUCTOR 2. PVC INSULATION 3. PVC SHEATH

Double PVC Wire

3.7) Flexible wire:



Flexible Wire

In this type of wire instead of using thick conductor many thin copper conductors of 36 gauges are used. This is called stranding. These wires are available in the size of 14/36, 23/36, 40/36 etc. These strands are twisted and PVC insulation is provided over it. Such two wires of different colors of insulation are twisted together and coil is prepared. As the flexible wire is used instead of thick wire, the wire can be bent in any direction. This type of wire is used in giving connections to table lamp, fan, tube light etc.

4. Color Codes – Different color wires serve different purposes, like:

- **Black:** Hot wire, for switches or outlets.
- **Red:** Hot wire, for switch legs. Also for connecting wire between 2 hardwired smoke detectors.
- **Blue and Yellow:** Hot wires, pulled in conduit. Blue for 3-4 way switch application, and yellow for switch legs to control fan, lights etc.
- **White:** Always neutral.
- **Green and Bare Copper:** Only for grounding.

5 Wire Gauge, Ampacity and Wattage Load – To determine the correct wire, it is important to understand what ampacity and wattage a wire can carry per gauge. Wire gauge is the size of the wire, ampacity is how much electricity can flow through the wire and wattage is the load a wire can take, which is always mentioned on the appliances.

Electrical Cable

Purpose of different layers used in construction of cable

1. Core or Conductor: A cable may have one or more core depending upon the type of service for which it is used. The conductors are made up of tinned copper or aluminium and are usually stranded in order to provide flexibility.
2. Insulation: Around the conductor, it is necessary to provide insulation in order to prevent the electrical short circuit.
3. Metallic Sheath: In order to protect cable from moisture, gases, and harmful chemicals, in the soil and atmosphere, a metallic sheath is required.
4. Bedding: over the metallic sheath is applied a layer of bedding which consists of fibrous material like jute or hessian tape.
5. Armoring: Over the bedding, armoring is provided which consists of one or two layers of galvanized steel wire.
6. Serving: In order to protect armoring from atmospheric conditions, a layer of serving is required.

Types of Electrical Cables –

CABLES: Cables are classified according to basis of construction.

(1)Low tension cable
(2) Screened or H type cable
(3) Belted cable
(4) SL type cable
(5) HSL type cable
(6)Super tension Cable

(1) Low Tension cable:

Vulcanized India rubber (VIR) cables are manufactured for the voltage ratings of 250/440V and 650/1100V. Aluminium or copper core is used. Insulation of VIR Or PVC is provided on the core. Braiding of cotton, tough rubber sheath or metal sheath is used.

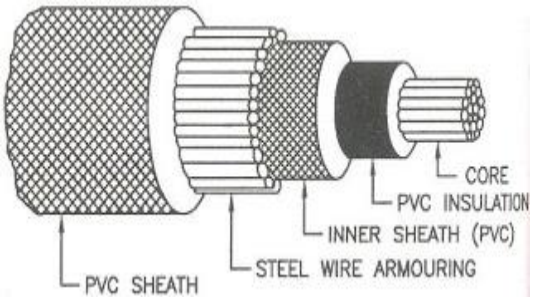


Figure 9 Construction of Single Core PVC Cable

PVC cables are becoming popular. In this, there is insulation of PVC over the copper or aluminium core. Sheath of PVC is provided over the insulation. There is armoring of steel tape or steel wire over the sheath. There is covering of PVC over the armoring which works as the serving.

(2) Belted cables:

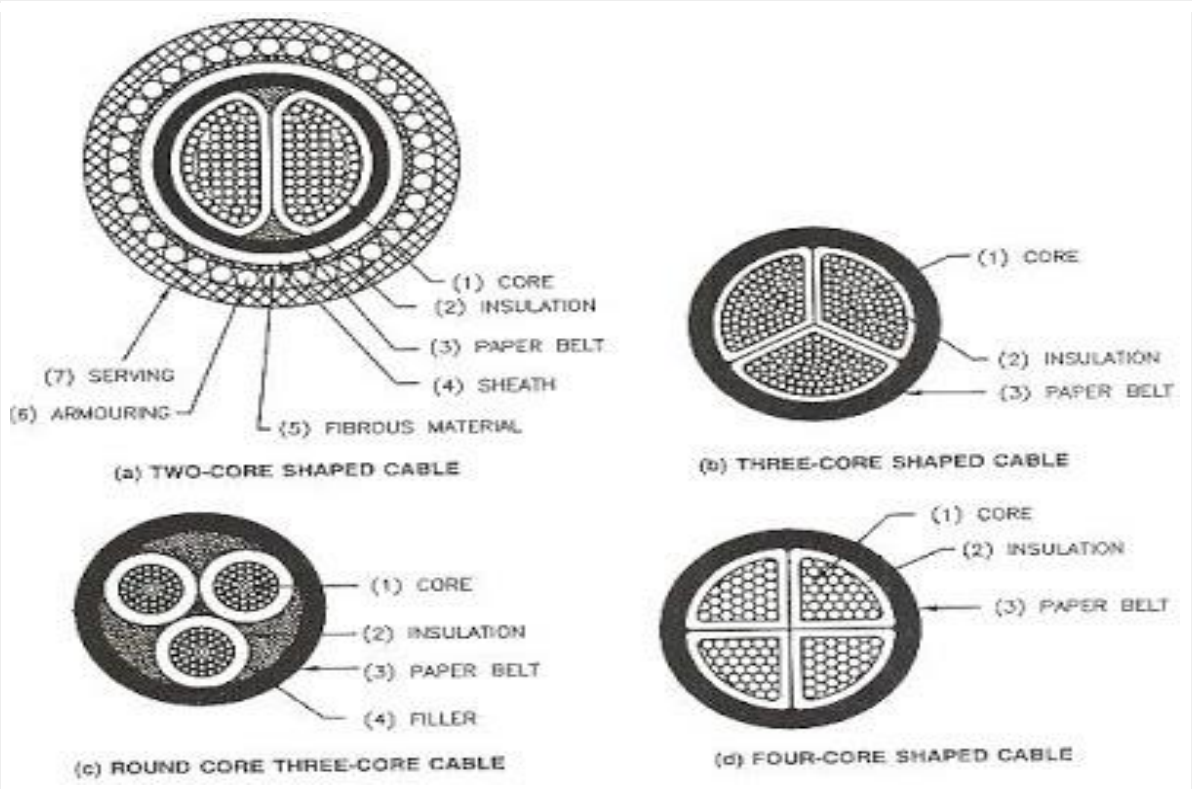


Figure 11 Belted Cables

Belted cables are used for the low voltages up to 22 KV. In these cables the core is not circular which is called the belt. There is paper insulation surrounding the core. Figure (a) shows two-core shaped cable. Figure (b) shows three core shaped cable. Figure (c) shows the round core three-core cable while figure (d) shows four-core shaped cable.

(3) Screened or H type Cable:

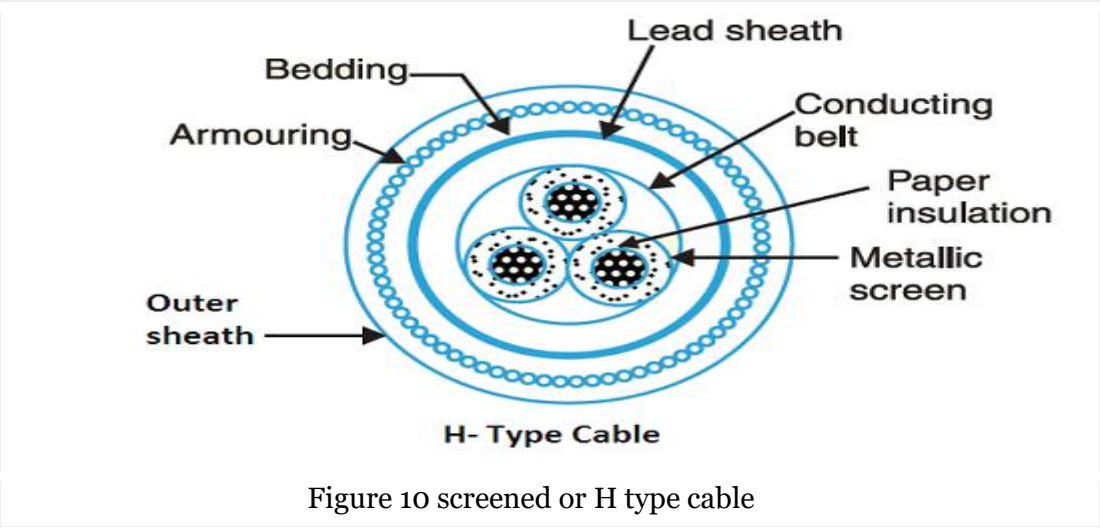
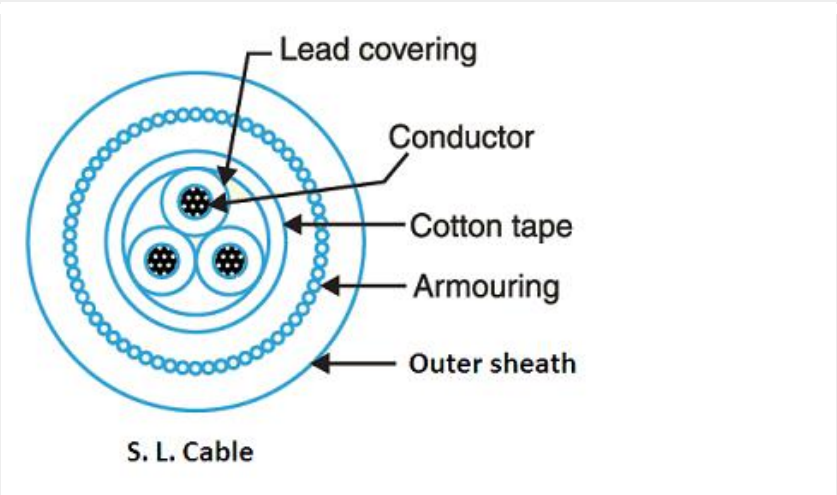


Figure 10 screened or H type cable

These cables are used for the voltage levels of 22 kV and 33 kV. But in special cases, their use can be extended up to 66 kV. This type of cable was developed by M Hochstadter so this type of cable is known as the H type Cable. Figure shows the telescopic view of this type of cable. Each core is insulated and then a screen of metalized paper is wound round it. So this type of cable is called the screened type cable. Each conductor, in this case, is insulated with impregnated paper, covered with a metallic screen which is usually an aluminum foil. The metallic screen touches each other. Instead of a paper belt, the three cores are wrapped with a conducting belt which is generally copper woven fabric tape. Then there is an inner sheath made of lead. After lead sheath, there are layers of bedding, armouring and the outer sheath.

(4) SL cable: SL cable means separate lead sheathed cable. In this Type of cable, there is paper insulation surrounding the core. There is Separate lead sheath over each core. So all the three cores work as separate cable. No overall lead sheath is used surrounding the three cores. Bedding, armoring and serving are provided like other cables**.**



(5) HSL Cable:

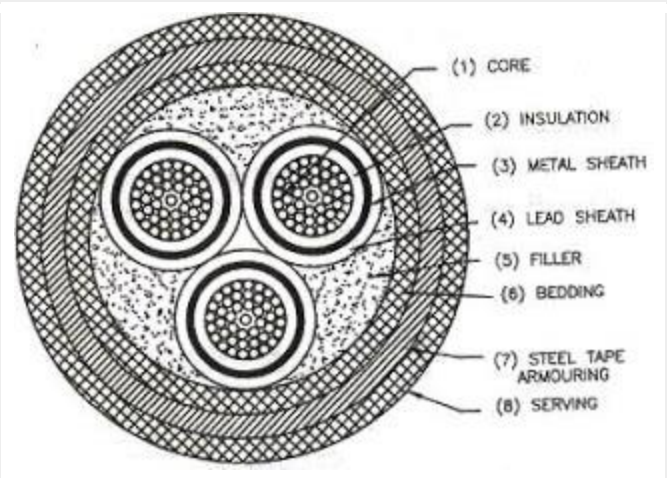


Figure 13 HSL Cable

This type of cable is the combination of H type and SL type cables. Paper insulation is provided over each core. Metalized paper is wound over the insulation and lead sheath is provided over this. Filler space is filled with copper woven fiber material. Bedding, armoring and serving are provided as usual.

(6) Super Tension Cable:

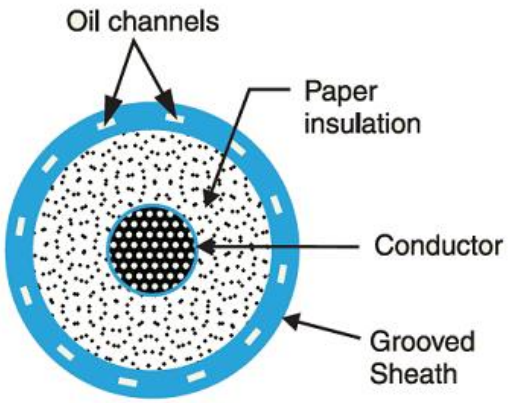
These cables are to be used for 132 KV or 220 KV and arrangement has to be made to prevent the formation of voids and to increase the dielectric strength. This can be achieved by two ways.

(1)By using the oil filled cables

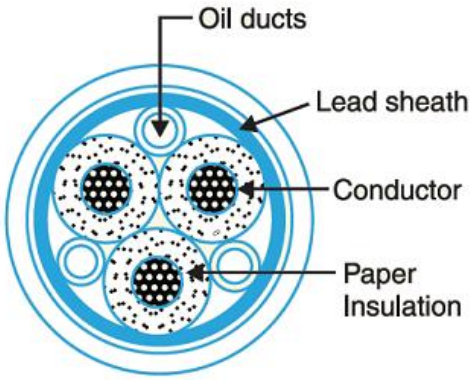
(2) By using the gas filled cables.

Oil Filled Cables: In these cables, oil ducts are made within or adjacent to the cores, oil under pressure is circulated in these ducts. The cable is filled with oil and the pressure is maintained in the cable by connecting the oil channels to the tanks which are placed at the suitable distances along the path of the cable. The oil pressure compresses the paper insulation and completely removes the possibility of void formation. Due to the elimination of voids, dielectric strength of insulation is such cables become very high. Operating voltage of these cables ranges from 66 kV to 230 kV.

Gas Pressure Cables: In these cables, an inert gas like nitrogen at high pressure is used to create pressure in the cable. The gas pressure is about 12 to 15 atmospheres. Due to such a high pressure, radial compression of insulation takes place which eliminates the possibility of void formation and ionization. The construction of cable is shown in Figure, it is triangular in shape and installed in a steel pipe. The pipe is filled with gas.



Single Core Cable with conductor
Oil Channel in Conductor Sheath



Three Core Cable with three Oil Channel along

Gas Pressure Cables

Types of Batteries :

Batteries generally can be classified into different categories and types, ranging from chemical composition, size, and application, but under all of these are two major battery types;

1. Primary Batteries
2. Secondary Batteries

1. Primary Batteries

Primary batteries are batteries that cannot be recharged once depleted. Primary batteries are made of electrochemical cells whose electrochemical reaction cannot be reversed.

Primary batteries exist in different forms ranging from coin cells to AA batteries. They are commonly used in standalone applications where charging is impractical or impossible. Primary batteries always have high specific energy and the systems in which they are used are always designed to consume low amount of power to enable the battery last as long as possible.

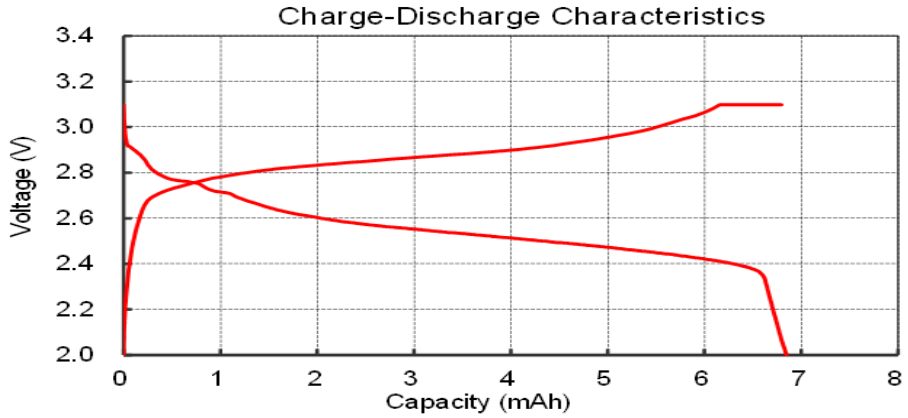
Some examples of devices using primary batteries include; Pace makers, Animal trackers, Wrist watches, remote controls and children toys etc.

The most popular type of primary batteries are alkaline batteries. They have a high specific energy and are environmentally friendly, cost-effective and do not leak even when fully discharged. They can be stored for several years, have a good safety record. The only downside to alkaline batteries is the low load current, which limits its use to devices with low current requirements like remote controls, flashlights and portable entertainment devices.

2. Secondary Batteries

Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction. Also referred to as rechargeable batteries**,** secondary cells unlike primary cells can be recharged after the energy on the battery has been used up. They are typically used in high drain applications and other scenarios where it will be either too expensive or impracticable to use single charge batteries. Although the initial cost of acquiring rechargeable batteries is always a lot higher than that of primary batteries but they are the most cost-effective over the long term.

C- and E- rates – In describing batteries, discharge current is often expressed as a C-rate in order to normalize against battery capacity, which is often very different between batteries. A C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. A 1C rate means that the discharge current will discharge the entire battery in 1 hour. For a battery with a capacity of 100 Amp-hrs, this equates to a discharge current of 100 Amps. A 5C rate for this battery would be 500 Amps, and a C/2 rate would be 50 Amps. Similarly, an E-rate describes the discharge power. A 1E rate is the discharge power to discharge the entire battery in 1 hour.



Important characteristics of batteries.

The various important characteristics of batteries are

1. Nominal Voltage (V) – The reported or reference voltage of the battery, also sometimes thought of as the “normal” voltage of the battery. It depends on the amount of the cell connected in series. It is the open circuit voltage of battery.
2. Cut-off Voltage – The minimum allowable voltage. It is this voltage that generally defines the “empty” state of the battery.

3. Battery Capacity or Battery Life : It is specified in ampere hours (AH). Mathematically it is the product of discharge current in amperes and the discharge time in hours. The battery capacity is calculated at a particular value of C rate and it decreases with increasing value of C rate
4. Specific Energy (Wh/kg) – The nominal battery energy per unit mass, sometimes referred to as the gravimetric energy density. Specific energy is a characteristic of the battery chemistry and packaging.
5. Discharge Curve The discharge curve is a plot of voltage against percentage of capacity discharged. A flat discharge curve is desirable as this means that the voltage remains constant as the battery is used up. Again the discharge curve depends on the C rating. At higher C ratings the cell voltage tends to decrease and vice versa

6. State of Charge (SOC)(%) – An expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time.
7. Depth of Discharge (DOD) (%) – The percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity. A discharge to at least 80 %DOD is referred to as a deep discharge
8. Battery Efficiency : it is defined as the ratio of the battery output during charging to the input required for charging of the battery.

   Efficiency = (AH for Discharging / Ah for charging)x 100

   For lead acid battery it is around 80 to 90 %
9. Cycle Life (number for a specific DOD) – The number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria. Cycle life is estimated for specific charge and discharge conditions. The actual operating life of the battery is affected by the rate and depth of cycles and by other conditions such as temperature and humidity. The higher the DOD, the lower the cycle life.

Secondary batteries can be further classified into several other types based on their chemistry. This is very important because the chemistry determines some of the attributes of the battery including its specific energy, cycle life, shelf life, and price to mention a few.

The different types of rechargeable batteries are as follows:-

The Nickel Cadmium (NiCd) battery

The NiCd is used where long life, high discharge rate and economical price are important. Main applications are two-way radios, biomedical equipment, professional video cameras and power tools. The NiCd prefers fast charge to slow charge and pulse charge to DC charge. In fact, the NiCd is the only battery type that performs well under rigorous working conditions. A periodic full discharge is so important that, if omitted, large crystals will form on the cell plates (also referred to as *memory*) and the NiCd will gradually lose its performance. The NiCd contains toxic metals and is environmentally unfriendly.

Advantages

- Fast and simple charge.
- High number of charge/discharge cycles
- Good load performance
- Long shelf life
- Simple storage and transportation
- Economically priced

- Available in a wide range of sizes and performance options

Limitations

- Relatively low energy density
- Memory effect
- Environmentally unfriendly
- Has relatively high self-discharge

The Nickel-Metal Hydride (NiMH) battery

Research of the NiMH system started in the 1970s as a means of discovering how to store hydrogen for the nickel hydrogen battery. New hydride alloys were developed in the 1980s that were stable enough for use in a cell. Since the late 1980s, NiMH has steadily improved. The success of NiMH has been driven by its high energy density and the use of environmentally friendly metals. The modern NiMH offers up to 40 percent higher energy density compared to NiCd.

The NiMH is less durable than the NiCd. Cycling under heavy load and storage at high temperature reduces the service life. The NiMH suffers from high self-discharge, which is considerably greater than that of the NiCd.

The NiMH has been replacing the NiCd in markets such as wireless communications and mobile computing. In many parts of the world, the buyer is encouraged to use NiMH rather than NiCd batteries. This is due to environmental concerns about careless disposal of the spent battery.

Advantages

- 30 – 40 percent higher capacity over a standard NiCd.
- Less prone to memory than the NiCd.
- Simple storage and transportation
- Environmentally friendly

Limitations

- Limited service life
- Limited discharge current
- More complex charge algorithm needed
- High self-discharge
- Performance degrades if stored at elevated temperatures
- High maintenance
- About 20 percent more expensive than NiCd — NiMH batteries designed for high current draw are more expensive than the regular version

The Lithium Ion battery Lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest energy density per weight. Today, the Li-ion is the fastest growing and most promising battery chemistry. The energy density of the Li-ion is typically twice that of the standard NiCd. In addition to high capacity, the load characteristics are reasonably good and behave similarly to the NiCd in terms of discharge characteristics (similar shape of discharge profile, but different voltage). The flat discharge curve offers effective utilization of the stored power in a desirable voltage spectrum. The high cell voltage allows

battery packs with only one cell. Most of today's mobile phones run on a single cell, an advantage that simplifies battery design.

The Li-ion is a low maintenance battery, an advantage that most other chemistries cannot claim. There is no memory and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to NiCd, making the Li-ion well suited for modern fuel gauge applications. Li-ion cells cause little harm when disposed.

Despite its overall advantages, Li-ion also has its drawbacks. It is fragile and requires a protection circuit to maintain safe operation. Built into each pack, the protection circuit limits the peak voltage of each cell during charge and prevents the cell voltage from dropping too low on discharge. In addition, the cell temperature is monitored to prevent temperature extremes.

Advantages

- High energy density.
- Relatively low self-discharge.
- Low Maintenance
- Nominal Cell voltage 3.7 volts and can be as high up to 4.5 volts

Limitations

- Requires protection circuit Limited discharge current
- Subject to aging, even if not in use
- Moderate discharge current
- Subject to transportation regulations
- Expensive to manufacture

The Lithium Polymer battery

Lithium Polymer batteries use a solid or gelatin-like electrolyte between the electrodes to transfer the ions. Lithium Polymer batteries are robust and flexible compared to other battery types and can be built in various shapes. They are lightweight, low profile and have low chances of suffering from leakages. But they are costly and have a low energy density.

Comparison of Lithium Ion batteries with Lithium Polymer battery

1. Energy Density:

Lithium Ion batteries have a higher energy density compared to Lithium Polymer batteries hence they can store a greater amount of charge per unit volume compared to Lithium Polymer batteries and similarly dish out more power too.

2. Charge Conversion Rate:

Charge conversion rate refers to how much of the energy stored in the battery can be converted into actual power. In case of a Lithium-Ion Batteries, the conversion rate is 85-95% which is higher than the 75-85% conversion rate coupled with the Lithium Polymer batteries.

3. Weight:

Lithium Ion batteries are generally heavy batteries meanwhile the Lithium Polymer batteries are light weight compared to them.

4. Charging Duration(Fast charging):

Lithium-Ion Batteries take longer amounts of time to charge, while it is generally seen that the Lithium Polymer batteries take comparatively short amounts to time to full charge.

5. Safety:

While Lithium Polymer batteries are considered mostly safe batteries, the Lithium Ion batteries are susceptible to explosions.

6. Aging:

Lithium Polymer Batteries usually retain their charging capacity over time while Lithium Ion batteries are known to age and lose their charging capacity when not in use.

7. Charge Cycles or Lifespan

Charge Cycles refer to the number of times a battery can be charged and then discharged without serious changes in total charge storing capacity. Lithium Ion batteries are known to last from anywhere between 500-1500 cycles. On the other hand, Lithium Polymer batteries work for 500 cycles where they are usually left with about 75% charging capacity after 200 cycles.

8. Cost:

Cost is a major factor while we are making purchases. Lithium-Ion batteries tend to be cheaper compared to Lithium Polymer batteries which are expensive to make for the manufacturers.

9. Design Flexibility:

When it comes to design flexibility, Lithium Polymer batteries are better than Li-Ion because they are readily available in different shapes and simmer models than Li-Ion.

Advantages

- Very low profile , Fast charging
- Can be developed in any shape & size
- Light weight
- Improved safety & leak proof.

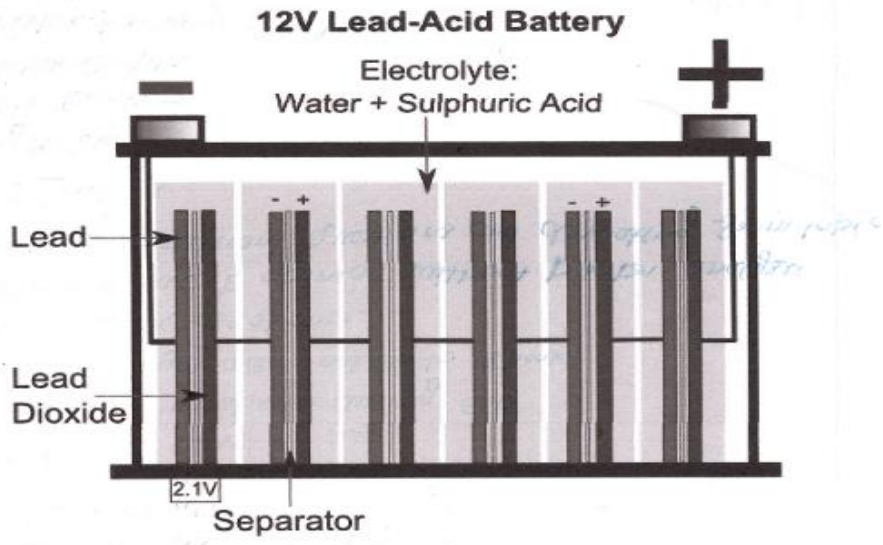
Limitations

- Lower energy density and decreased cycle count compared to Li-ion — potential for improvements exist Subject to aging, even if not in use
- Expensive to manufacture

The Lead Acid battery

Invented by the French physician Gaston Planté in 1859, lead acid was the first rechargeable battery for commercial use. Today, a large no. of lead acid batteries are used in automobiles, fork lifts and large uninterruptible power supply (UPS) systems. The main parts of the lead acid battery are container and the plates. The container stores chemical energy which is converted into electrical energy by the help of the

plates. The container of the lead acid battery is made of glass, lead lined wood, ebonite, the hard rubber of bituminous compound, ceramic materials or moulded plastics and are seated at the top to avoid the discharge of electrolyte. At the bottom of the container, there are four ribs, on two of them rest the positive plate and the others support the negative plates.



Lead is the main raw material of lead-acid batteries. Lead accounts for more than 60% of the battery quality. Lead used in lead-acid batteries accounts for more than 80% of the total lead used globally. Lead is a heavy metal and Poor management will cause environmental pollution and harm to human health. So emphasis is given on Sealed Lead Acid battery (SLA.) The SLA does not lend itself to fast charging — typical charge times are 8 to 16 hours. The SLA must always be stored in a charged state. Leaving the battery in a discharged condition causes sulfation, a condition that makes the battery difficult, if not impossible, to recharge. Unlike the flooded lead acid battery, the SLA are designed with a low over-voltage potential to prohibit the battery from reaching its gas-generating potential during charge. Excess charging would cause gassing and water depletion. In terms of disposal, the SLA is less harmful than the NiCd battery but the high lead content makes the SLA environmentally unfriendly.

The main active materials required to construct a lead acid battery are.

- Lead Peroxide (PbO_2)
  The positive plate is made of lead peroxide. This is dark brown, hard and brittle substance.
- Sponge Lead (Pb)
  The negative plate is made of pure lead in soft sponge condition.
- Dilute Sulfuric Acid (H_2SO_4)
  Dilute sulfuric acid used for lead acid battery has a ratio of water to acid is 3:1.

The **lead acid storage battery** is formed by dipping lead peroxide plate and sponge lead plate in dilute sulfuric acid. A load is connected externally between these plates. In diluted sulfuric acid the molecules of

the acid split into positive hydrogen ions (H^+) and negative sulfate ions (SO_4^{--}). The hydrogen ions when reach at PbO_2 plate, they receive electrons from it and become hydrogen atom which again attack PbO_2 and form PbO and H_2O (water). This PbO reacts with H_2 SO_4 and forms $PbSO_4$ and H_2O (water).

$$PbO_2 + 2H \rightarrow PbO + H_2O$$

$$\frac{PbO + H_2SO_4 \rightarrow PbSO_4 + H_2O}{PbO_2 + H_2SO_4 + 2H \rightarrow PbSO_4 + 2H_2O}$$

SO_4^{--} ions are moving freely in the solution so some of them will reach to pure Pb plate where they give their extra electrons and become radical SO_4. As the radical SO_4 cannot exist alone it will attack Pb and will form $PbSO_4$. As H^+ ions take electrons from PbO_2 plate and SO_4^{--} ions give electrons to Pb plate, there would be an inequality of electrons between these two plates. Hence there would be a flow of current through the external load between these plates for balancing this inequality of electrons. This process is called discharging of lead acid battery. The lead sulfate ($PbSO_4$) is whitish in color. During discharging,

1. Both of the plates are covered with $PbSO_4$.
2. Specific gravity of sulfuric acid solution falls due to formation of water during reaction at PbO_2 plate.
3. As a result, the rate of reaction falls which implies the potential difference between the plates decreases during discharging process.

Now we will disconnect the load and connect $PbSO_4$ covered with PbO_2 plate with positive terminal of an external DC source and PbO_2 covered with Pb plate with negative terminal of that DC source. During discharging, the density of sulfuric acid falls but there still sulfuric acid exists in the solution. This sulfuric acid also remains as H^+ and SO_4^{--} ions in the solution. Hydrogen ions (cation) being positively charged, move to the electrode (cathode) connected with negative terminal of the DC source. Here each H^+ ion takes one electron from that and becomes hydrogen atom. These hydrogen atoms then attack $PbSO_4$ and form lead and sulfuric acid.

$$PbSO_4 + 2H \rightarrow H_2SO_4 + Pb$$

SO_4^{--} ions (anions) move towards the electrode (anode) connected with positive terminal of DC source where they will give up their extra electrons and become radical SO_4. This radical SO_4 cannot exist alone hence reacts with $PbSO_4$ of anode and forms lead peroxide (PbO_2) and sulfuric acid (H_2SO_4).

$$PbSO_4 + 2H_2 + SO_4 \rightarrow PbO_2 + 2H_2SO_4$$

Hence by charging the lead acid storage battery cell,

1. Lead sulfate anode gets converted into lead peroxide.
2. Lead sulfate of cathode is converted to pure lead.
3. Terminal; potential of the cell increases.
4. Specific gravity of sulfuric acid increases.

Advantages

- Inexpensive and simple to manufacture
- Mature, reliable and well-understood technology
- Low self-discharge
- Low maintenance requirements
- Capable of high discharge rates

Limitations

- Cannot be stored in a discharged condition
- Low energy density
- Allows only a limited number of full discharge cycles
- Environmentally unfriendly
- Transportation restrictions on flooded lead acid
- Thermal runaway can occur with improper charging

NUMERICALS

Q.1 Calculate the backup of battery of 100AH connected to load of 100 watts and supply voltage is 12V.

Q2. Calculate the energy consumption per day, per week and per year in a house using 5 CFLs of 20 W each for 5 hrs, 3 fans of 60 W each for 3 hrs and an iron of 200 W for 30 minutes in a day.

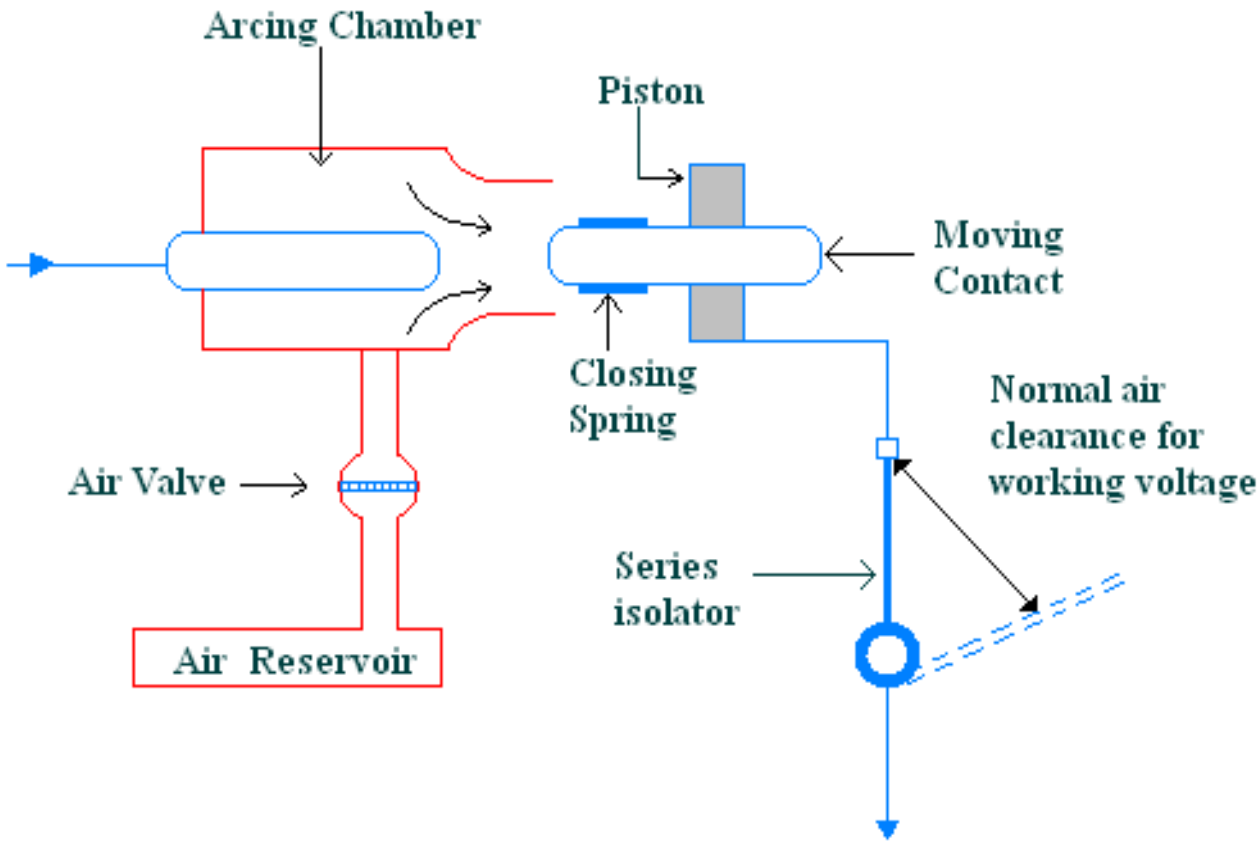
Q3. A battery has taken a charging current of 5.2 A for 24 hours at a voltage of 2.25 V, while discharging it gave a current of 4.5 A for 24 hours at an average voltage of 1.85 volts. Calculate the quantity efficiency and the energy efficiency of the battery. **(86.54%, 71.15 %)**

Q4. An alkaline cell is discharged at a steady current of 4 A for 12 hours, the average terminal voltage being 1.2 V. To restore it to original state of voltage, a steady current of 3 A for 20 hours is required, the average terminal voltage being 1.44 V. Calculate the ampere-hour and watt-hour efficiency in this particular case. **(80%, 66.7 %)**

Air Blast Circuit Breakers (ABCB)

Principle of Air Blast Circuit Breaker (ABCB)

The Air Blast Circuit Breaker is an external extinguishing energy type in which the high-pressure air is employed for arc extinction. The auxiliary compressed air system of an air blast circuit breaker is shown below.



An auxiliary compressed air system of an air blast circuit breaker consists of a fixed contact and a moving contact, enclosed in an arc extinction chamber. Under normal operating conditions, both the contacts are closed. Whenever a fault occurs, high currents are induced which raises the temperature. When the air is submitted into the arc extinction chamber the air pushes away the moving contact establishing an arc. The air inside the arc extinction chamber will have high pressure than the atmospheric pressure. The air blast cools the arc and sweeps away all the ionized gases along with it. Because of this, the dielectric builds up rapidly, between the contacts, which prevent the reestablishment of arc. Thus, the flow of current is interrupted.

Air Blast Circuit Breakers are two types

1. Axial Blast Air Circuit Breaker
2.Cross Blast Air Circuit Breaker

The main difference between two types of Air Blast Circuit Breakers is just air flow direction with respect to the arc. In axial type air flows in direction of arc whereas in cross blast type air flows in direction perpendicular with respect to the arc.

Construction of a Typical EHV Air Blast Circuit Breaker

A typical EHV air blast circuit breaker is shown in figure, which consists of the following components.

1. Air reservoir
2. Hallow insulator columns
3. Double arc extinction chamber
4. Valves
5. Current carrying conductors.

1. Air Reservoir

In air reservoir, the air of high pressure with an atmospheric pressure of 20-30 atm is stored.

2. Hallow Insulator Columns

The hallow insulator columns are mounted on air reservoir with valves provided at base. It carries air from reservoir to an arc extinction chamber.

3. Double Arc Extinction Climber

The arc extinction chamber is mounted on the top of the hallow insulators columns. It consists of a fixed contact and a moving contact with a spring mechanism. Depending upon the pressure of air the moving contact opens (or) closes the ail outlet valves.

4. Valves

The purpose of valves used is to supply the air from the air reservoir to hallow insulator columns and an arc extinction chamber. This occurs when the valves are kept open. Similarly, when the valves are closed it stops supplying the insulator columns and are extinction chambers.

5. Current Carrying Conductors

The current carrying conductors link all the arc extinction chambers in series and the poles of neighboring equipment.

Working Operation of Air Blast Circuit Breakers

When a breaker receives a signal either pneumatic or electrical the rod connected to valves gets opened. During tint instant. the air enters into the hallow insulator column and further enters into arc extinction chambers. Because of high pressure in are extinction chamber, the pressure increases on the moving contact and becomes more than the spring pressure. Hence the contacts are separated. Because of high pressure on moving contact, it travels a short distance against the spring pressure and closes the air outlet valves. As a result-the high-pressure air in the arc extinction chamber is not let to go out However during the arcing period the air goes out through the air outlet valves with all ionized gases.

Later, if the valves are closed, then the air in the insulator column is let into the atmosphere, due to which the pressure on the moving contact is dropped to atmospheric pressure. Hence the moving contact closes over the fixed contact by virtue of its spring pressure. In the applications of high voltage installations, air blast circuit breakers are very much preferred and by using these circuit breakers the electrical hazards are eliminated.

Advantages of Air-blast Circuit Breakers

1. Due to absence of oil in air-blast circuit breaker, risk of fire and maintenance of oil is eliminated.
2. Deterioration of oil is eliminated and the arcing products produced are completely removed.
3. Fast operation is possible and suitable for indoor installation.
4. Suitable for rapid reclosing at successive operation and has a very high rupturing capacity.
5. It is easily accessible. It has relatively less weight.

Disadvantages of Air-blast Circuit Breakers

1. The construction of air-blast circuit breaker is very complicated.
2. Compressed air system consisting of electric motor, air compressors etc. are required for installation which increases the cost.
3. They are very sensitive to variations in RRRV (Rate of Rise of Recovery Voltage).
4. Maintenance of plant requires highly trained personnel.
5. Cost of operation is high.

Bus Bar arrangement

Bus-bar is one of the vital elements in electric power stations and substations. The term bus is derived from the word *omnibus* which means collector of things. Thus, the electrical bus bar is the collector of electrical energy at one location. Bus bar is convenient means of connecting switches and other equipment's into various arrangements.

Bus-bar used in substations is usually bare rectangular cross-section bars. Aluminum is used for the construction of bus bar as it has several advantages over copper such as higher conductivity on weight basis, lower cost for equal current capacity, excellent corrosion resistance. For proper reliable electrical connections aluminum buses are coated with silver. Whenever the fault occurs in bus bar, considerable damage and disruption of supply will occur and system stability is adversely affected. Hence, the proper protection of bus bar is needed.
There are several types of bus-bar arrangements. The choice for the particular arrangements depends upon system voltage, position of substation in the system, reliability of supply, flexibility and cost.

The factors for the **selection of the bus bar arrangements** are:

1. Simplicity
2. Maintenance possibility without interruption of the power supply.
3. Provision of extension with the load growth.
4. Economical
5. In case of the outage other alternative arrangements must be possible.
6. Load and local conditions.

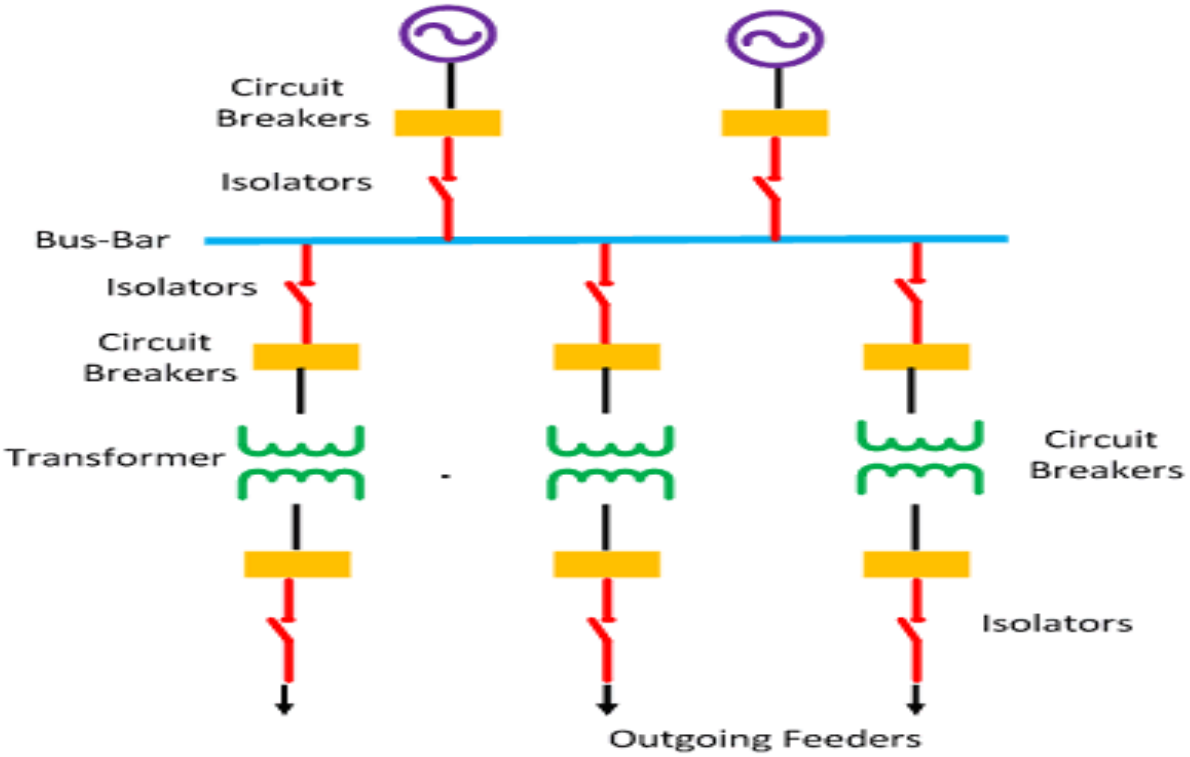
The **various bus bar arrangements** are as follows:

1. Single Bus-bar arrangement
2. Single Bus-bar arrangement with bus sectionalization
3. Main and transfer Bus Arrangement
4. Double Bus Double Breaker Arrangement
5. Sectionalized Double Bus Arrangement

6. One –and –a Half Breaker Arrangement
7. Ring Main Arrangement
8. Mesh Arrangement

1. **Single Bus-bar arrangement**

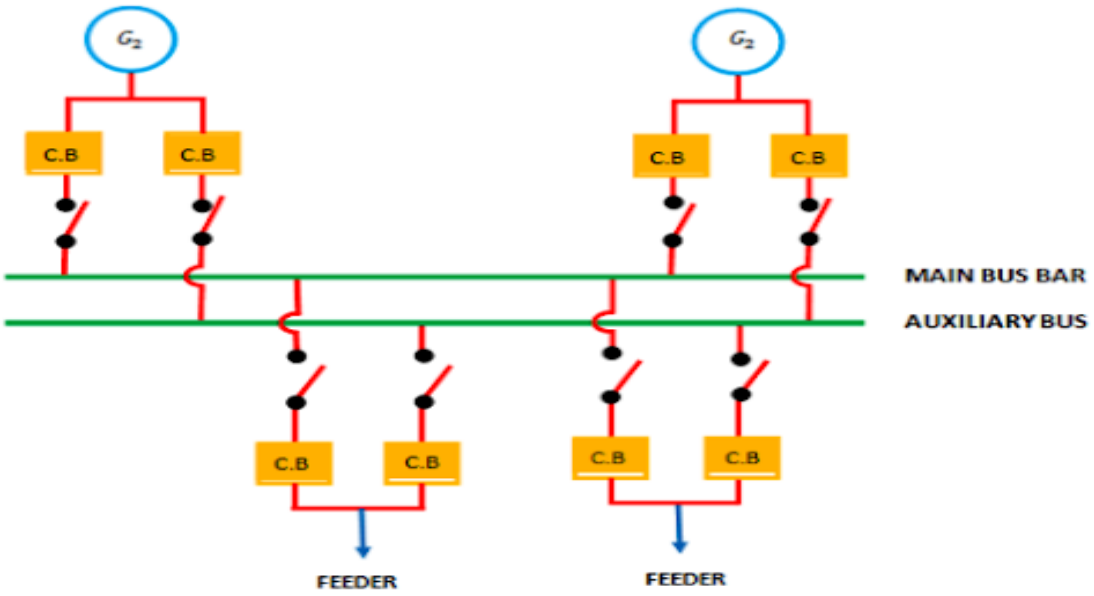
- This is the simplest arrangement consisting of a single set of bus bar for the full length of switch board and to the set of generator, transformers and feeder.
- The main drawback of this system is that in case of fault in bus bar whole of the system is collapsed and all the healthy feeders are disconnected.
- It is employed for switchboards, small and medium size substation, small power station and DC station.



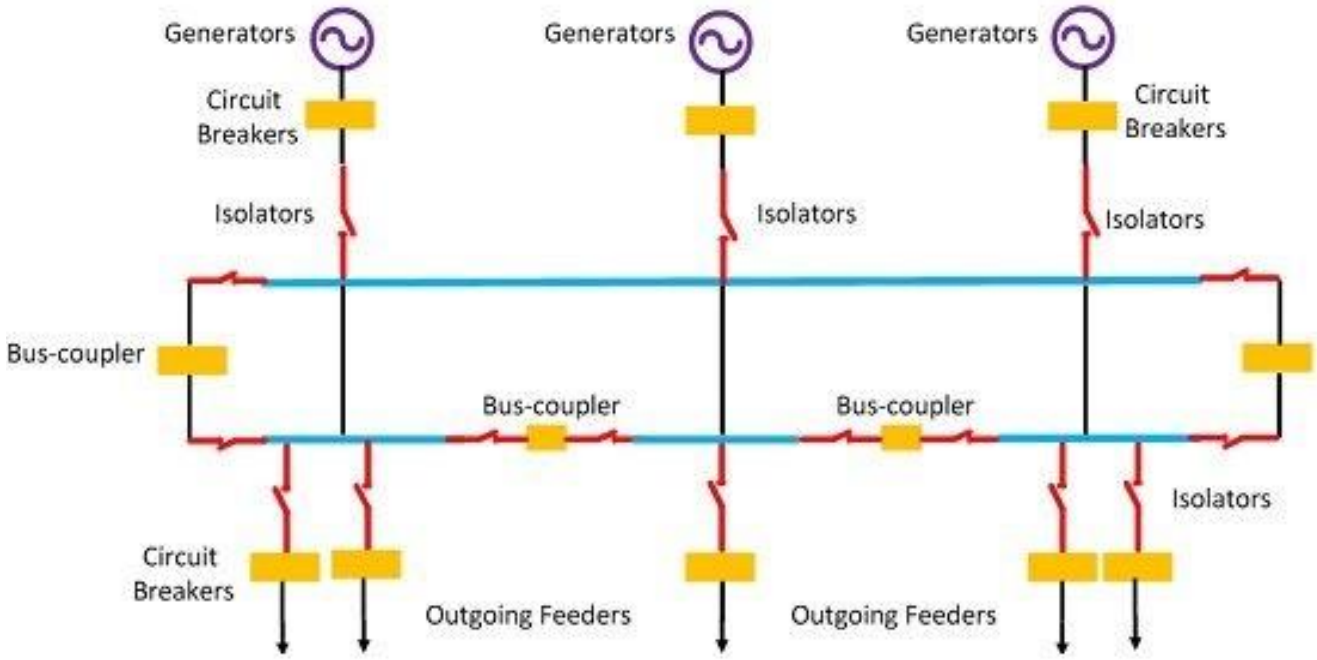
Single Bus-Bar Arrangement

2. **Double Bus Double Breaker Arrangement**

- Two circuit breakers are employed for each circuit.
- This type of arrangement doesn't require any bus coupler.
- This type of arrangement can permit switch-over from one bus to other bus without interruption.
- Costly and maintenance cost is high.
- Provides maximum flexibility and reliability.
- In case of maintenance of a circuit breaker load can be shifted to other circuit breaker.



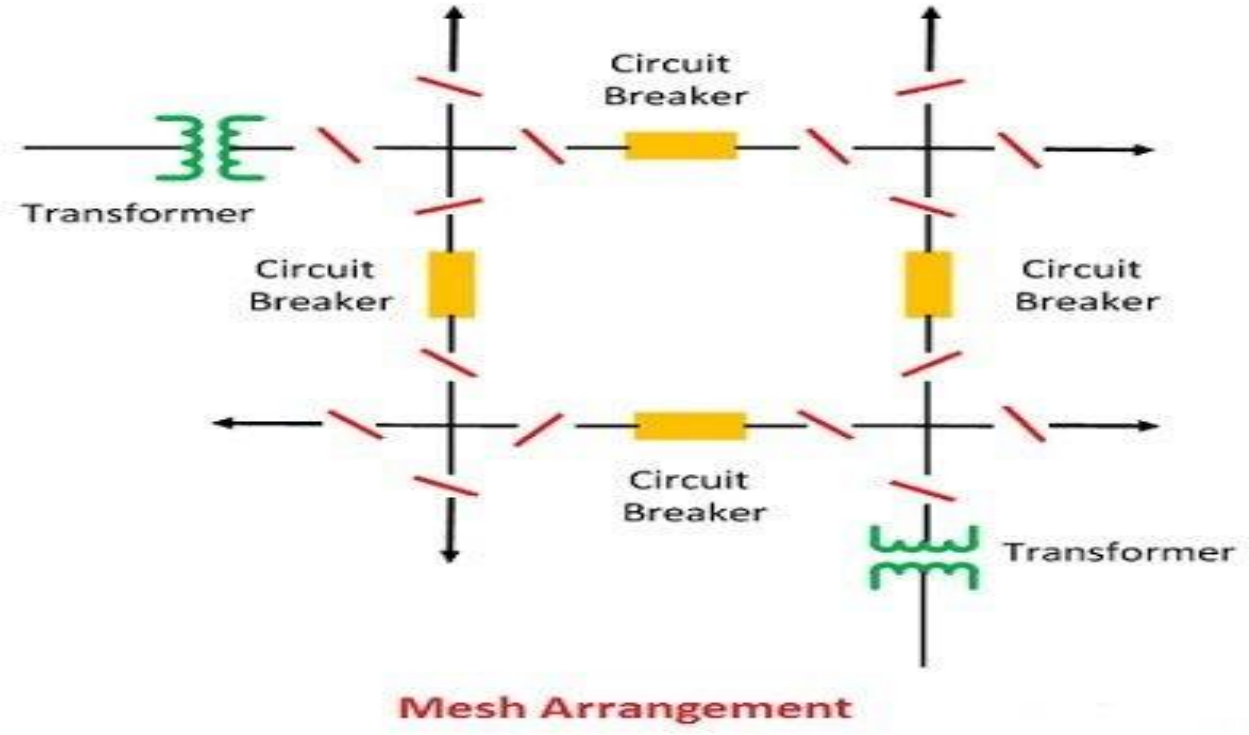
3. **Ring Main Arrangement**



Ring Main Arrangement

- Higher reliability.
- Less number of circuit breaker is needed.
- Difficulties in addition of any new circuit in the ring.
- Possibilities of overloading of circuit in opening of any of section of breaker.
- Necessity of supplying demand potential to relay separately to each of the circuit.
- This arrangement provides greater flexibility as each feeder is supplied by two paths, so the failure of the section doesn't cause any interruption of supply.

4. **Mesh Arrangement**



Mesh Arrangement

- Economical use of circuit breaker in the substation.
- Circuit breaker are installed in the mesh formed by the buses.
- When the fault occurs in any section two circuit breakers have to open resulting in opening of the mesh.
- Provides the security against bus-bar faults.
- Lacks switching facility.
- Needs a smaller number of circuit breakers than required by one-and –a –half breaker arrangement.
- Used in substations having large number of circuits.

LIGHTNING

Qu: What is Lightning?

When tiny ice-particles in cloud collide with each other, they build up positive electrical charge.

When potential difference between ground and cloud is more than breakdown voltage of air: lightning strikes.

✡ LIGHTNING FACTS:

Lightning heats up the surrounding air to 20000°C.

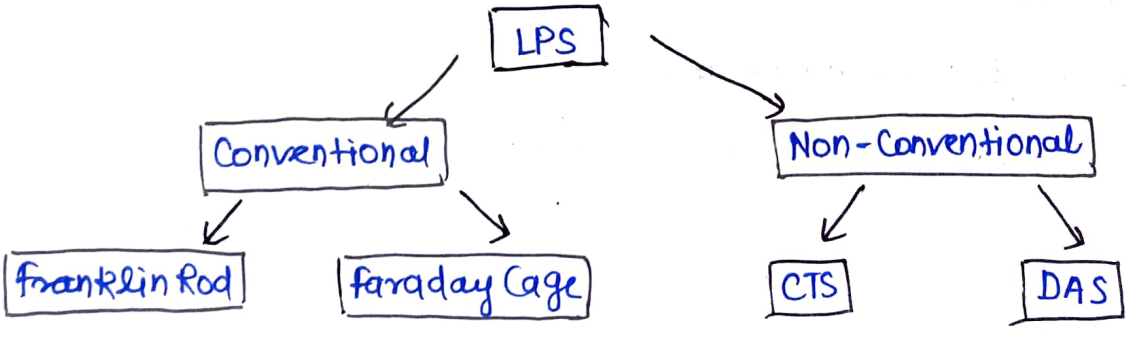
Can hit with 500 kV of voltage and more than 10000 A of current.

240000 people are struck by lightning each year and 24000 are killed.

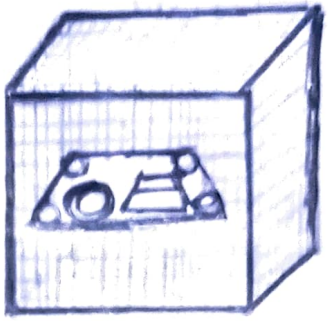
Lightning Protection

A Lightning Protection System is designed to protect a structure or building and contents from damage caused by the intensely high voltage currents of a lightning strike.

TYPES of Lightning Protection System



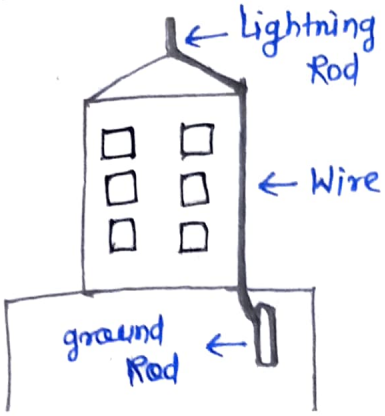
* Faraday Cage:



1. Faraday cage is based on Electric ~~field~~ shield principle.
2. The charge will pass through the conductive cage thereby not harming the devices in the cage.
3. Faraday cages can be used to protect sensitive electronics from lightning.

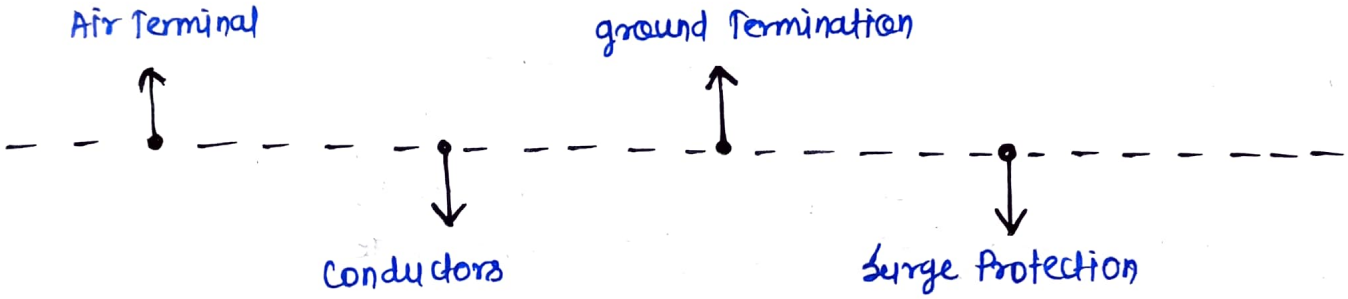
☆ Faraday cage used to protect sensitive equipments in power plant

** FRANKLIN RODS

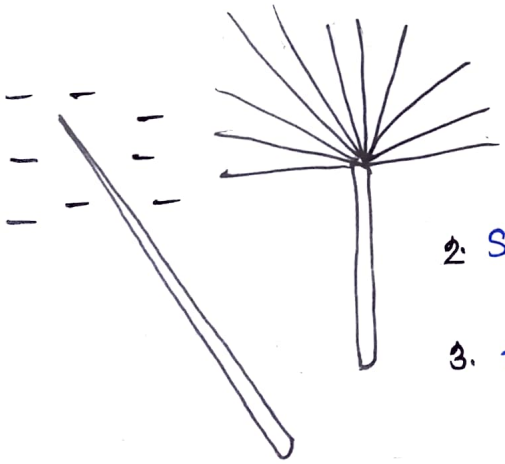


1. Lightning rod provides a low-resistance path to ground that can be used to conduct the enormous electrical currents when lightning strikes occur.
2. The lightning-rod system is an excellent conductor and thus allows the current to flow to ground without causing any heat damage.
3. for structures less than 75ft. height class-I material needed to be used, normally houses and small office building use these.
4. for structures more than 75ft. such as stack, transmission towers, cellphones, antennas class-II material must be used.

* ELEMENTS OF LIGHTNING PROTECTION SYSTEM:



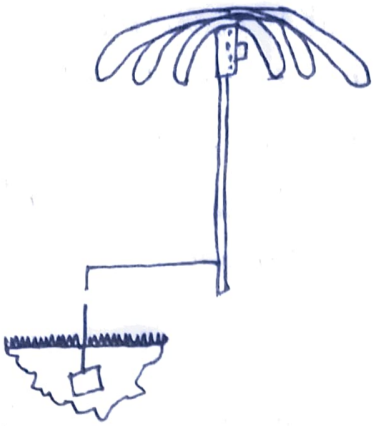
* CHARGE TRANSFER SYSTEM (CTS):



Spline Ball Terminal

1. A Pin point can't hold charge, it will immediately discharge this phenomenon is called Natural Dissipation.
2. So Pin point can be used to neutralize charge in cloud.
3. Spline Ball Terminal (SBT) consists of 80 such pin points.
4. SBT can act as both Lightning Protection and Prevention.

* DISSIPATION ARRAY SYSTEM (DAS)



1. The conventional designs transfer the current to the ground they do nothing to prevent lightning.
2. But since large current is flowing close, the electronic circuits could still damage.
3. Large magnetic feild could erase data.
4. DAS is a advancement of CTS.

A 'storm Protector' By
Nicola Tesla US Patent 1266175

* DISSIPATION ARRAY SYSTEM (DAS)