Components of LT Switchgear

5.1 Fuse: A short piece of metal wire, inserted in series with the circuit, which melts when predetermined value of current flow through it and breaks the circuit, is called a fuse.

- A fuse is connected in series (see Fig.5.1) with the circuit to be protected and carries the load current without overheating itself under normal conditions.
- However when abnormal condition occurs, an excessive current (more or equal to the predetermined value for which the fuse is designed) flows through it.
- This raises the temperature of fuse wire to the extent that it melts and opens the circuit. This protects the the machines or apparatus from damage which can be caused by the excessive current.

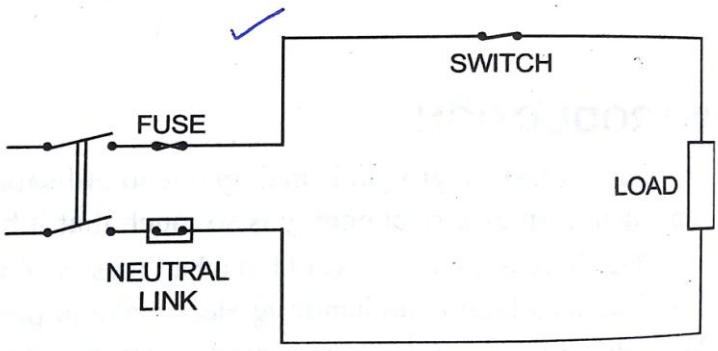


Fig .5.1: Circuit with fuse

5.2 SWITCH FUSE UNIT (SFU): Switch fuse unit comprises of various porcelain rewireable fuses or HRC (High Rupturing Capacity) complete with their conducting parts. The switch is fitted with sturdy side operating handle with quick break type mechanism as shown in fig.5.2.

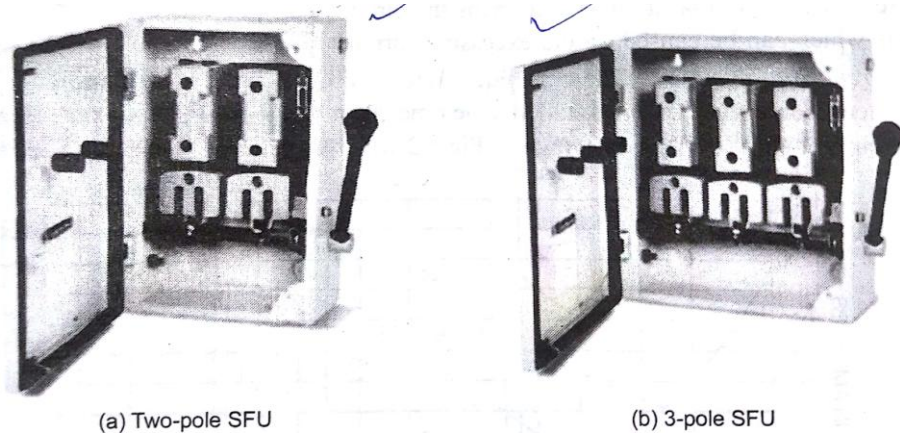


Fig.5.2: Switch fuse Unit (SFU)

Contacts are made of electrolytic copper silver-plated. The fixed contacts are provided with removable shield. Switch Fuse Units are provided with rewireable fuse or HRC fuse links. All these parts are assembled in an enclosure. The enclosure is made of sheet steel duly phosphatised and powder-coated. They are provided with conduit knock-outs. Door inter-clock is provided to prevent opening when the switch is 'ON' condition.

5.3 Miniature Circuit Breaker (MCB):

- MCB is a device that provides definite protection to the wiring installations and sophisticated equipment against over currents and short-circuits faults. The outer and interior views of an MCB are shown in Fig.5.3.

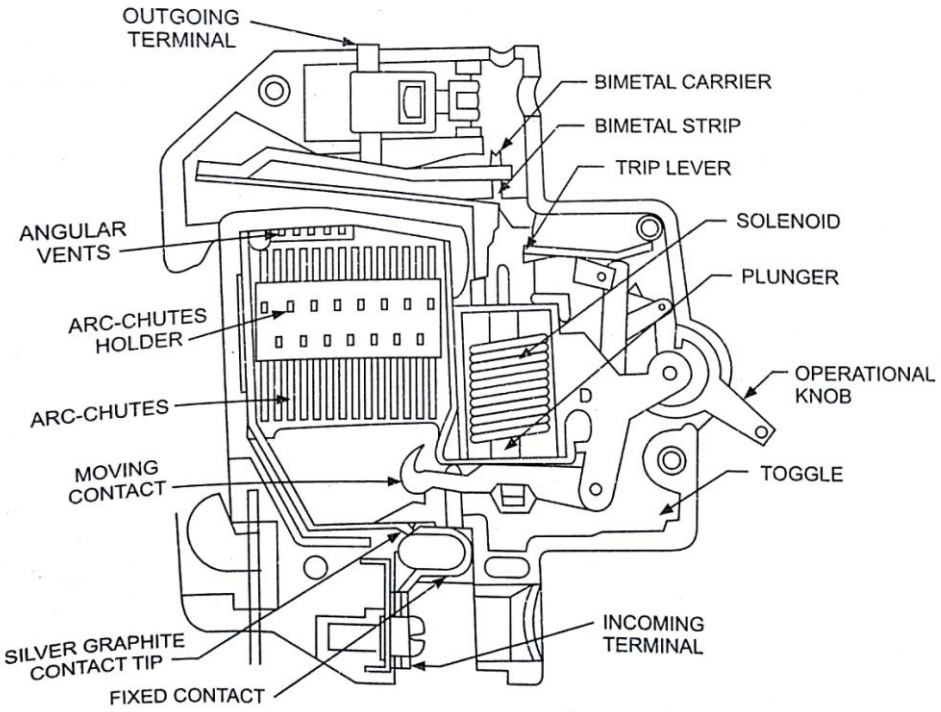
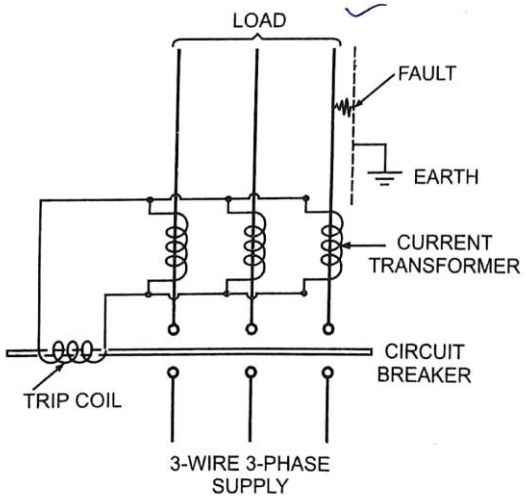


Fig.5.3: Miniature Circuit Breaker

- Thermal operation (overload protection) is achieved with a bimettalic strip, which deflects when heated by any overcurrents flowing through it. In doing so, releases the latch mechanism and causes the contacts to open.
- Inverse time-current characteristics result, i.e. greater the overload or excessive current, shorter the time required to operate the MCB. On the occurrence of a short circuit, the rising current energizes the solenoid, operating the plunger to strike the trip lever causing immediate release of the latch mechanism. Rapidity of the magnetic solenoid operation causes instantaneous opening of contacts.
- Miniature circuit breakers are available with different current ratings of 0.5, 1, 2, 2.5, 3, 4, 5, 6, 7.5, 10, 16, 20, 25, 32, 35, 40, 63, 100, 125, 160 A and voltage ratings of 240/415 V ac and up to 220 V dc. Operating time is very short (less than 5 ms.). So they are very suitable for the protection of important and sophisticated equipment, such as air-conditioners, refrigerators, computer etc.

5.4 Earth-Leakage Circuit Breaker (ELCB): It is a device that provides protection against earth leakage. These are of two types: the current operated type and the voltage operated type.

- **Current operated earth-leakage circuit breaker** is used when the product of the operating current in amperes and the earth-loop impedance in ohms does not exceed 40. Where such a circuit breaker is used, the consumer's earthing terminal is connected to a suitable earth electrode. A current-operated earth leakage applied to a 3-phase,3-wire circuit is shown in Fig.5.4. In normal conditions when there is no earth leakage the algebraic sum of currents in the three coils of the current transformers (CTs) is zero, and no current flows through the trip coil. In case of any earth leakage, the currents are unbalanced and trip coil is energized and thus the circuit breaker is tripped.
- **Voltage-operated earth leakage circuit breaker** is suitable for use when the earth-loop impedance exceeds the values applicable to fuses or excess-current circuit breaker or to current-operated earth-leakage circuit breaker. Such an earth-leakage trip in a 2-wire circuit is shown in Fig.5.4. When the voltage between the earth continuity conductor (ECC) and earth electrode rises to a sufficient value, the trip coil will carry the required current to trip the circuit breaker.



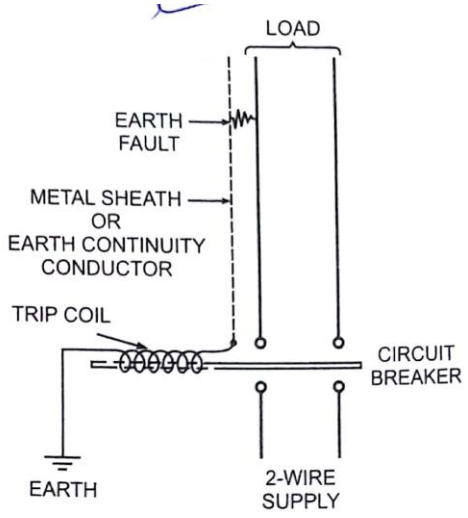


Fig.5.4: (a) Current-operated Earth-leakage Trip **(b) Voltage-operated Earth-leakage Trip**

5.6 Molded Case Circuit Breaker (MCCB): The main distinctions between molded-case and miniature circuit breaker are that the MCCB can have current ratings up to 2500 amperes, and its trip settings are normally adjustable. An additional difference is that MCCBs tend to be much larger than MCBs. An MCCB has three main functions:

- **Protection against overload**: Currents above the rated value last longer than what is normal for the application.
- **Protection against electrical faults**: During a fault such as a short circuit or line fault, there are extremely high currents that must be interrupted immediately.
- **Switching a circuit on and off**: This is a less common function of circuit breakers, but they can be used for that purpose if there isn't an adequate manual switch.

➢ **Operating Mechanism:** At its core, the protection mechanism employed by MCCBs is based on the same physical principles used by all types of thermal-magnetic circuit breakers.

- Overload protection is accomplished by means of a thermal mechanism. MCCBs have a bimetallic contact what expands and contracts in response to changes in temperature. Under normal operating conditions, the contact allows electric current through the MCCB. However, as soon as the current exceeds the adjustable trip value, the contact will start to heat and expand until the circuit is interrupted. The thermal protection against overload is designed with a time delay to allow short duration overcurrent, which ia a normal part of operation for many devices. However, any overcurrent conditions that last more than what is normally expected represent an overload, and the MCCB is tripped to protect the equipment and personnel.

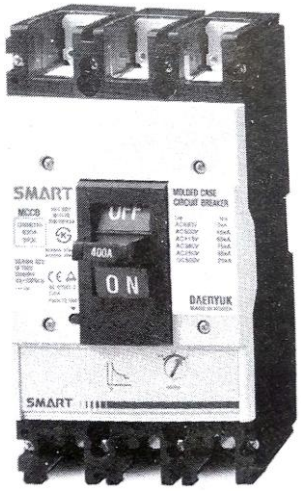


Fig. 5.5 Molded Case Circuit Breaker (MCCB)

- On the other hand, fault protection is accomplished with electromagnetic induction, and the response is instant. Fault currents should be interrupted immediately, no matter if their duration is short or long. Whenever a fault occurs, the extremely high current induces a magnetic field in a solenoid coil located inside the breaker – this magnetic induction trips a contact and current is interrupted. As a complement to the magnetic protection mechanism, MCCBs have internal arc dissipation measures to facilitate interruption.

Types of Wires and Cables: The wires employed for internal wiring of buildings may be divided into different groups according to (i) conductor used (ii) number of cores used (iii) voltage grading (iv) types of insulation used.

- According to the conductor material used in cables , these may be divided into two classes known as copper conductor cables and aluminum conductor cables.

- According to the number of cores, the cable consists of, the cables may be divided into classes known as single core cables; twin core cables; three core cables; two core with ECC (earth continuity conductor) cables etc.
- According to voltage grading the cables may be divided into two classes: (i) 250/440 volt cables and (ii) 650/1100 volt cables.
- According to type of insulation the cables are of the following types:
  1. Vulcanized Indian Rubber (VIR) insulated cables.
  2. Tough rubber sheathed (TRS) or cab tyre sheathed (CTS) cables.
  3. Lead sheathed cables.
  4. Polyvinyl chloride (PVC) cables.
  5. Weatherproof cables.
  6. Flexible cords and cables.
  7. XLPE cables.
  8. Multi-strand cables.

1. Vulcanized Indian Rubber (VIR) Cables:

- VIR, cables are available in 240/415 volts as well as in 650/1100 volt grades.
- VIR cable consists of either tinned copper conductor covered with a layer of vulcanized Indian rubber insulation. Over the rubber insulation cotton tap sheathed covering is provided with moisture resistant compound bitumen wax or some other insulating material for making the cables moisture proof.
- The thickness of rubber insulation depends upon the voltage grade for which the cable is required.

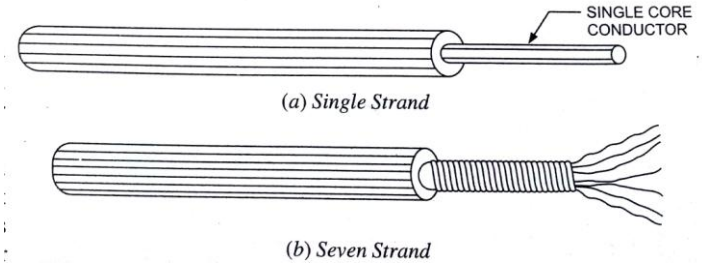
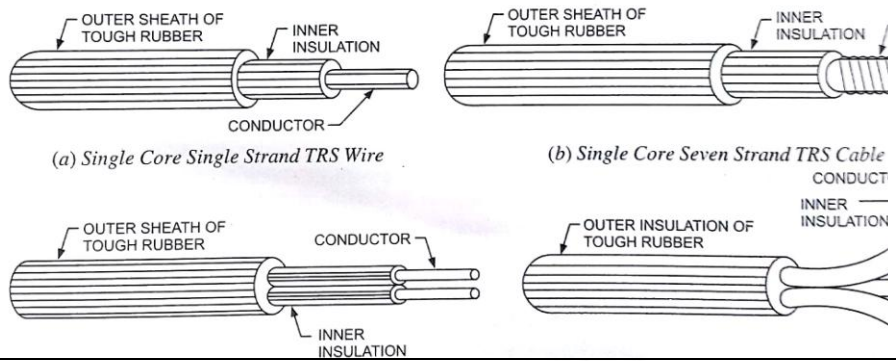


Fig. 6.1: Single core VIR Cables

2. Tough Rubber Sheathed (TRS) or Cab Tyre Sheathed (CTS) Cables:

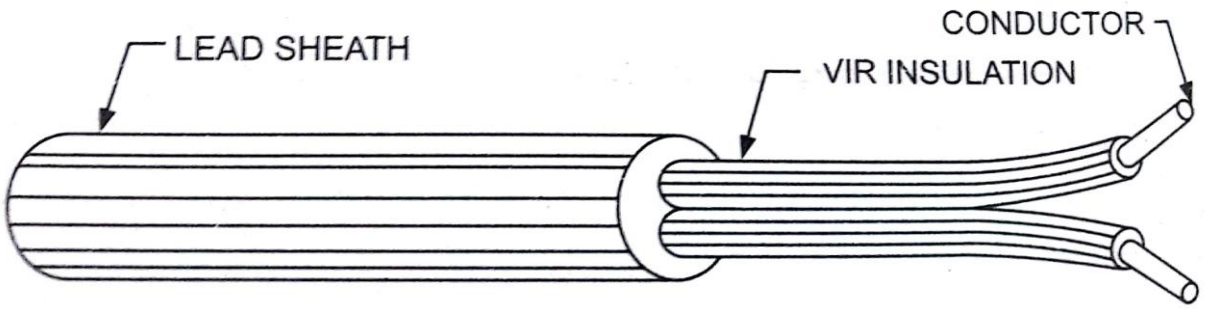
- These cables are available in 250/440 volt and 650/1100 volt grades and used in CTS (or TRS) wiring.
- TRS cable is nothing but a vulcanized rubber insulated conductor with an outer protective covering of tough rubber, which provides additional insulation and protection against wear and tear.



- These cables are waterproof, hence can be used in et conditions. These cables are available as single core, circular twin core, circular three core, flat three core, twin or three core an earth continuity conductor (ECC).
- The cores are insulated from each other and covered with a common sheathing. Different types of TRS cables are shown in figure.

3. Lead Sheathed Cables:

- These cables are available in 240/415 volt grade. The lead sheathed cable is vulcanized rubber insulated conductor covered with a continuous sheath of lead.
- The lead sheath provides very good protection against the absorption of moisture and sufficient protection against mechanical injury and so can be used without casing or conduit system.
- It is available as a single core, flat twin core, flat three core and flat twin or three core with an earth continuity conductor. Two-core lead sheathed cable is shown in below figure.



2-Core Lead Sheathed Cable

4. Polyvinyl Chloride (PVC) Insulated Cables :

- These cables are available in 250/440 volt and 650/1100 volt grades and are used in casing-capping, batten and conduit wiring system.
- In this type of cable conductor is insulated with PVC insulation. Since PVC is harder than rubber, PVC cable does not require cotton taping and braiding over it for mechanical and moisture protection.

PVC insulation is preferred over VIR insulation because of the following reasons:

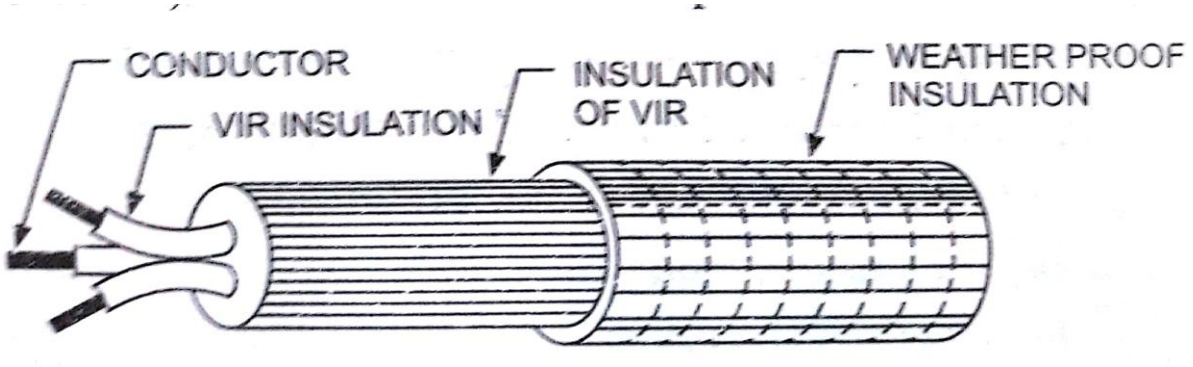
(i) PVC insulation has better insulating qualities.
(ii) PVC insulation provides better flexibility.
(iii) PVC insulation has no chemical effect on metal of the wire.
(iv) Thin layer of PVC insulation will provide the desired insulation level.

(v) PVC coated wire gives smaller diameter of cable and, therefore, more number of wires can be accommodated in the conduit of a given size in comparison to VIR or CTS wires.

- PVC cables are most widely used for internal wiring these days. Though the insulation resistance of PVC is lower than that of VIR but its effect is negligible for low and medium voltages, below 600 V.
-

5. Weather Proof Cables:

- These cables are used for outdoor wiring and for power supply or industrial supply. These cables are either PVC insulated or Vulcanized rubber insulated conductor being suitably taped (only in case of vulcanized rubber insulated cable) braided and then compounded with weather resisting material.



3-core Weather Proof Cable

- These cables are available in 240/415 volt and 650/1100 volt grades. These cables are not affected by heat or sun or rain.

6. Flexible Cords and Cables:

- The flexible cords consist of wires silk/cotton/plastic covered. Plastic cover is popular as it is available in different pleasing colors.
- Flexible cords have tinned copper conductors. Flexibility and strength is obtained by using conductors having larger number of strands.
- These wires or cables are used as connecting wires for such purposes as from ceiling rose to lamp holder, socket outlet to portable apparatus such as radios, fans, lamps, heaters etc.
- The flexibility of such wires facilitates in handling the appliances and prevents the wires from breakage.

7. XLPE Cables:

- PVC and XLPE cables are built of insulation made of polymers. Polymers are substances consisting of long macromolecules built up of small molecules or groups of molecules as repeated units.
- These are divided into homopolymers and copolymers. Homopolymers are built by reactions of identical monomers.
- Copolymers are built up of at least two different kinds of monomers.

Advantage of PVC cables Over Other Types of Cables:

1. Non-hygroscopic insulation almost unaffected by moisture.

2. Non-migration of compound allowing vertical installation.
3. Complete protection against most forms of electrolytic/chemical corrosion.
4. Tough/Resilient sheath with excellent fire resisting qualities.
5. Good ageing characteristics.
6. Not affected by vibrations.

Advantage of XLPE Cables Over Both PVC and All Other Types of Cables:

1. Higher Current rating.
2. Higher short-circuit current rating.
3. Longer service life.
4. Can withstand 130 degree Celsius (maximum) for short time is favorable to endure short-circuit stresses.
5. It is less sensitive to the setting of network protection.
6. Because of thermosetting process taking place through cross-linking, crack resistance is increased.
7. Due to chemical cross-linking internal stresses are reduced. Consequently material is less sensitive, during manufacture, to the setting of the cooling gradient.

8. Multi-Strand Cables:

- Multi-strand cables have got the following advantages with respect to the single conductor and hence preferred.

(i) The multi-strand cables are more flexible and durable and, therefore, can be handled conveniently.

(ii) The surface area of multi-strand cable is more as compared to the surface area of equivalent single solid conductor, so heat radiating capacity, being proportional to the surface area, is more.

(iii) Skin effect is better as the conductors are tubular, specially in case of high frequency.

- The number of strands in stranded cable must be 3, 7, 19, 37, 61, 91 and so on in order to obtain a circular contour.
- The section of a 3-strand cable at right angle to its length is three circles touching one another, the centers of which are the corners of an equilateral triangle.
- All other have a centrally disposed conductor with all the other around it. Thus a 7-strand cable has one central wire with 6 wires surrounding it; the 19-strand cable has another12 wires surrounding the 7-strands; the 37-strand cable has another 18 wires surrounding the 19-strands and so on. It is seen that each layer of wires has always 6 more wires in it than the layer beneath it.

Earthing: The connection of frame or external body of Electrical Machinery to the general mass of earth, with a conducting material of very low resistance is called earthing.

The earthing of electrical equipment brings the equipments to zero potential and avoid the shock to the operator, under any fault condition.

Importance of Earthing:

i. To maintain the line voltage constant.

ii. To protect tall buildings and structures from atmospheric lightening strikes.

iii. To protect all the machines, fed from overhead lines, from atmospheric lightening.
iv. To serve as the return conductor for telephone and traction work. In such case all the complications in laying a separate wire and the actual cost of the wire, is thus saved.
v. To protect human being from disability or death from shock in case the human body comes into the contact with the frame of any electrical machinery, appliances or components, which is electrically charged due to leakage current or fault.

Methods of Earthing: Earthing is achieved by connecting the frame or external body of electrical appliances or components to earth by employing a good conductor called "Earth Electrodes". This Ensures very low resistance path from appliance to the earth.

The various methods of earthing are:

(1) Plate Earthing (2) Pipe Earthing (3) Earthing to water main (4) Horizontal Strip Earthing (5) Rod Earthing

Types of Batteries:

Batteries are either primary or secondary.

1) Primary batteries can be used only once because the chemical reactions that supply the current are irreversible.

- Primary batteries are the most common batteries available today because of their low cost and simplicity in use.
- Carbon-zinc dry cells and alkaline cells dominate portable consumer battery applications where currents are low and usage is occasional.
- Other primary batteries, such as those using mercury or lithium-based chemistries, may be used in applications when high energy densities, small sizes, or long shelf life are especially important.
- In general, primary batteries have dominated two areas: consumer products where the initial cost of the battery is very important and electronics products (such as watches, hearing aids and pacemakers) where drains are low or recharging is not feasible.

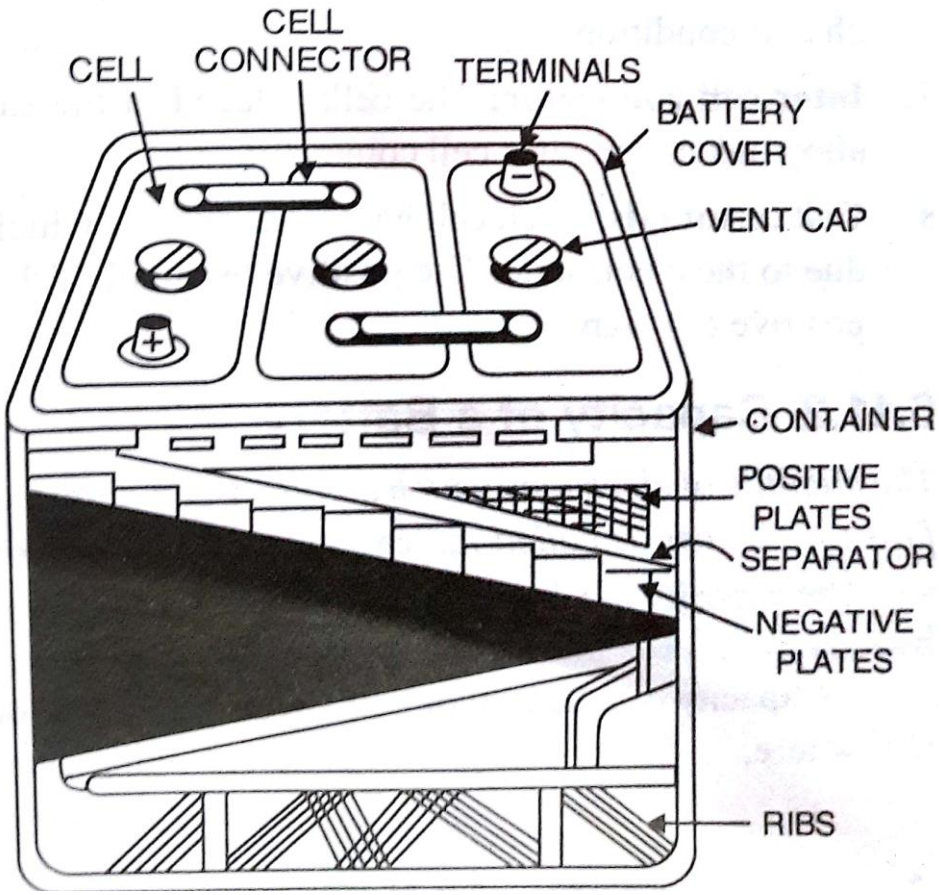
2) Secondary batteries, sometimes called storage batteries or accumulators, can be used, recharged and reused. In these batteries, the chemical reactions that provide current from the battery are readily reversed when current is supplied to the battery.

- The process of inducing or storing energy in an accumulator is called the charging, and the process of giving out energy in the form of an electric current, the discharging.
- Accumulator or storage batteries owe their name "secondary" due to the fact that they can supply electrical energy after they have been charged.
- Secondary batteries, which are rechargeable, have traditionally been most widely used in industrial and automotive applications. Here users are willing to trade higher initial cost and additional handling and care requirements for high current delivery and the economies of a rechargeable product.

- Only two rechargeable battery chemistries, lead acid and nickel-cadmium, have, to-date, achieved significant commercial success, The recently introduced nickel-metal hydride couple currently shows promise of supplementing nickel-cadmium cells in many commercial applications.

Lead- Acid Battery

Figure below shows the cut-away view of 6V commercial lead-acid battery. The following are the important part of the battery.

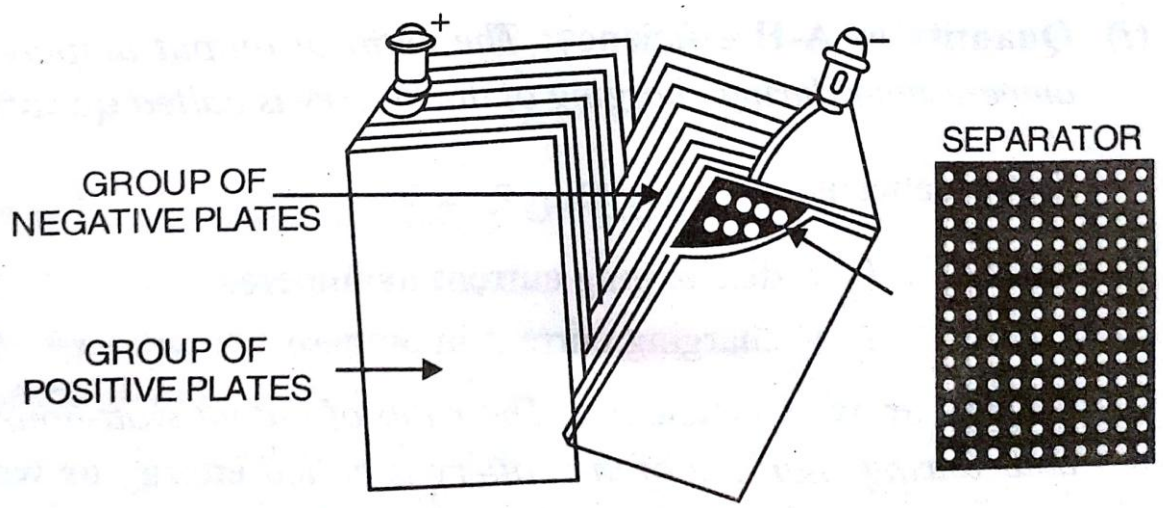


Lead-acid battery

- **Container:** It is the outer body of the battery. It is made of a hard rubber or plastic material and is sealed at the top to prevent spilling of the electrolyte. A large space is left at the bottom of the container so that the sediments that drop form the plates are collected here and may not short circuit the positive and negative plates.
- **Plates:** Generally, alloy of lead-antimony sheets covered with lead-peroxide and spongy lead forming positive and negative plates respectively are used as electrodes. To increase the capacity of the battery,

we use a large number of plates in each cell instead of only two plates. The number of positive and negative plates (i.e. 11, 13, 15 or 17) of each cell are alternatively placed and sandwiched with an insulator called separator as shown in figure below. One group of positive and negative plates forms a cell which develops an emf of 2.0 volt. A separate compartment is provided for each cell in the container of the battery.

- **Separator:** To reduce the internal resistance of the cell and to save the space, the plates are placed very close to each other. To prevent the plates touching each other if they wrap or buckle, they are separated by a rubber sheet (non-conducting material) having large number of small holes called separator



Battery plates and separator

- **Electrolyte:** Dilute sulphuric-acid (H_2SO_4) is used as an electrolyte in lead-acid batteries. Sulphuric-acid is added to water in such a proportion that with a fully charged battery, its specific gravity is about 1.28 to 1.29.
- **Battery Cover:** Each cell compartment is covered usually with a molded hard rubber and the joints between covers and containers are sealed with an acid-resistance material. In each cell cover openings are provided- two for positive and negative terminals, and third for a vent. The whole container is fitted with a leak proof cover.
- **Vent caps:** The vent-cap has a vent hole to allow free exit of the gases formed in the cell during charging. The vent caps can be easily removed for adding water. The vent cap is also removed to insert the nozzle of hydrometer for checking the specific gravity of electrolyte to check the battery charge condition.
- **Inter-cell connector:** The cells, placed in the same container are connected in series with a lead alloy link called inter-cell connector.
- **Cell terminals:** Each cell has two terminals which are generally made of lead as it does not corrode due to the electrolyte. The positive terminal of the battery is marked with a red color or by a large positive (+) sign.

- **Capacity of a Battery**

  The quantity of electricity which a battery can deliver during single discharge until its terminal voltage falls to 1.8 V per cell is called the capacity of a battery.

  The capacity of a battery or cell is commercially expressed in ampere-hour and is generally denoted by A-H.

  Capacity of a battery or cell = $I_d T_d \; apmere - hour$

  Where, $I_d = discharging\ current\ in\ ampere$

  $T_d = discharging\ time\ of\ battery\ or\ cell\ in\ hour$

Efficiency of a Battery

The efficiency of a battery (or cell) can be defined in the following two ways:

(i) Quantity or A-H efficiency: The ration of output ampere-hour during discharging to the input ampere-hour during charging of the battery is called quantity or ampere-hour efficiency of the battery.

Mathematically, $\eta_{AH} = \frac{I_d T_d}{I_c T_c}$, Where, $I_D = discharging\ current\ in\ ampere$,

$T_d = discharging\ time\ in\ hour$

$I_c = charging\ current\ in\ ampere$,

$T_c = charging\ ime\ in\ hour$

(ii) Energy or W-H efficiency: The ratio of output watt-hour during discharging to the input watt-hour during charging of the battery is called energy or watt-hour efficiency of the battery.

Mathematically, $\eta_{WH} = \frac{I_d T_d V_d}{I_c T_c V_c}$, Where,

$V_d = Average\ terminal\ voltage\ during\ discharging$

$V_c = Average\ terminal\ volatge\ during\ charging$

Battery Back-up

The time (in hrs) for which a battery can deliver the desired current is called battery back -up of the battery bank.

Charge Indication of a lead-acid Battery or Cell

The values of specific gravity for different condition of charge are given below:

Specific gravity	Condition
1.280 to 1.290	100% charged
1.230 to 1.250	75% charged
1.190 to 1.200	50% charged
1.150 to 1.160	25% charged
Below 1.130	Fully discharged

- To check the specific gravity of electrolyte (H_2SO_4), an instrument called hydrometer is used which works on Archmedeies principle. In common use, the decimal point is omitted from the value of specific gravity i.e. 1.280 specific gravity is spoken as 1280 and so on.
- However, the state of battery can also be checked by checking.

(i) Voltage: When the terminal voltage of the battery on load is 2.1to 2.5 V per cell, the battery is said to be fully charged. Whereas, when the voltage of the battery falls below 1.8 V per cell, the battery is considered to be fully discharged and it is immediately put on charging.

(ii) Color of plates: When lead-acid cell or battery is fully charged, its anode is PbO_2 which is chocolate brown in color and cathode is of Pb which is grey in color. However, when the battery is fully discharged, both the plates attain $PbSO_4$ as active material which is whitish in color.

Characteristics of Lead-acid Battery

(i) The emf of a fully charged lead-acid cell is 2.2 V decreases to 2.0 V rapidly. However the average emf of the cell is 2.0 V which decreases to 1.8 V when fully discharged.

(ii) The internal resistance of this cell is quite low.

- The A-H efficiency of this cell is nearly 80% whereas; the W-H efficiency is 60%.
- The specific gravity of electrolyte is 1.280 to 1.290 but to 1.150 when the battery is fully discharged.

Care and Maintenance of lead-acid Batteries

The average life of lead-acid battery is two to four years depending upon its manufacturing qualities and technique. However, to obtain longer life and efficient service, the following points must be kept in view:

1. The battery should not be allowed to use when the emf of the battery falls to 1.8 V per cell. Otherwise, the lead sulphate of the plates partly changes to non-active lead sulphate and reduces he life of the battery.
2. The specific gravity to the electrolyte should not be allowed to fall below 1.15.
3. The battery should never be left standing in a discharged condition, otherwise sulphation will occur and the battery cells are permanently damaged.
4. When not in use, the battery must be fully charged and stored in a cool and dry place.
5. Great care should be taken that the acid used as electrolyte should not contain any substantial impurity. It should be colorless when viewed through a 12 cm column.
6. The electrodes must remain completely immersed in the electrolyte, preferably the level of electrolyte should always be about 10 mm above the electrodes.
7. Whenever the level of the electrolyte decreases due to evaporation or gassing, distilled water should be added so as to keep the same concentration of electrolyte.
8. The battery terminal should never be short circuited.

Applications of lead-acid Batteries

Lead-acid batteries have innumerable commercial applications. Some of the important application are given below:

1. Used in automobiles for starting and lighting.

2. For lighting on steam and diesel railway trains.
3. Used at telephone exchanges.
4. Used for lighting purpose in remote rural areas.
5. Used at generating stations and sub-stations for operation of protective devices and for emergency lighting.
6. Used for emergency lighting at important places such as hospitals, theaters, banks etc.

Note: The charging and discharging of a lead acid cell may be represented by a single reversible equation given below:

$$\underset{\text{Positive plate}}{PbO_2} + 2H_2SO_4 + \underset{\text{Negative plate}}{Pb} \underset{\text{Discharge}}{\overset{\text{Charge}}{\leftrightarrows}} \underset{\text{Positive plate}}{PbSO_4} + 2H_2O + \underset{\text{Negative plate}}{PbSO_4} + Electrical\ Energy$$

EXERCISE

1. **What is the function of SFU?**
2. **What are the important elements of LT switchgear?**
3. **What is the major function of MCB and ELCB?**
4. **How will you differentiate between MCCB and MCB?**
5. **What is CTS and VIR wire?**
6. **What do you mean by earthing?**
7. **What is the importance of earthing?**
8. **What is the function of container of a lead-acid battery?**
9. **Why large number of holes is provided in the separator?**
10. **Mention five important applications of lead-acid battery.**
11. **What do you mean by capacity of a battery? What are its units?**
12. **What are the charge indications of a lead-acid battery?**
13. **Define ampere-hour efficiency of a battery.**
14. **A battery has taken a charging current of 5.2 A for 24 hours at a voltage of 2.25 A, while discharging it gave a current of 4.5 A for 24 hours at an average voltage of 1.85 V. Calculate the quantity efficiency and the energy efficiency of the battery. Ans: 86.54%, 71.15%**