UNIT –V: ELECTRICAL INSTALLATIONS

Components of LT Switchgear: Switch Fuse Unit (SFU)

Fuse:

The electrical equipment is designed to carry a particular rated value of current under normal conditions.Under abnormal conditions such as short circuits, overload, or any fault; the current rises above this value,damaging the equipment and sometimes resulting in fire hazard. Fuses come into operation under fault conditions.

A fuse is short piece of metal, inserted in the circuit, which melts when excessive current flows throughit and thus breaks the circuits. Under normal operating conditions it designed to carry the full load current. If the current increases beyond this designed value due to any of the reasons mentioned above, the fuse melts, isolating the power supply from the load.

(a) Desirable characteristics of a Fuse Element:

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

i. Low melting point e.g., tin, lead.
ii. High conductivity e.g., copper.
iii. Free from deterioration due oxidation e.g., silver.
iv. Low cost e.g., tin, copper.

(b) Materials:

Materials used are tin lead or silver having low melting points. Use of copper or iron is dangerous, though Tinned copper may be used.

(c) Types of Fuses:

Fuses are classified into following types

(i) Re-wireable or kit-Kat fuse and
(ii) High rupturing capacity (H.R.C) cartridge fuse

Re-wireable or Kit-Kat Fuse:

Re-wireable fuse is used where low values of fault current are to be interrupted. These fuses are simple in construction, cheap and available up to a current rating of 200A.They are erratic in operation and their performance deteriorates with time. An image of re-wireable fuse is as shown in figure

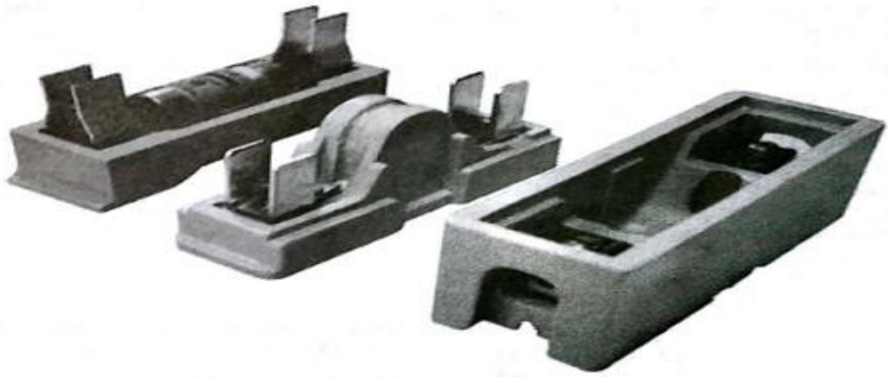

Fig. Re-wireable or Kit-kat Fuse

High Rupturing Capacity (HRC) Cartridge Fuse:

The image of HRC cartridge fuse as well as its cross section are shown in the figure. The essential parts of a typical HRC cartridge fuse consists of a heat resisting ceramic body having metal end-caps to which a silver current-carrying element is welded. The space within the body surrounding the elements is completely packed with a filling powder. The filling material may be chalk, plaster of Paris, quartz or marble dust and acts as an arc quenching and cooling medium. Therefore, it carries the normal current without overheating.

Under normal loading conditions, the fuse element is at a temperature below its melting point. When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak.The heat produced in the process vaporizes the melted silver element. The chemical reaction between the silver vapors and the filling powder results in the formation of a high resistance substance which helps in quenching the arc.

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Fig: HRC Cartridge Fuse

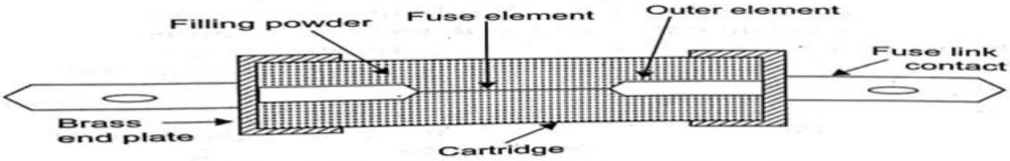

Fig: Cross-section of HRC cartridge fuse

Circuit Breaker:

Electrical circuits breaker is a switching device which can be operated manually and automatically for the controlling and protection of electrical power system, respectively. The modern power system deals with a huge power network and huge numbers of associated electrical equipment. During shirt circuits fault or any other type of electrical fault, this equipment, as well as the power network, suffer a high stress of fault current, which in turn damage the equipment and networks permanently. For saving this equipment and thepower networks, the fault current should be cleared from the system as quickly as possible. Again, after thecleared, the system must come to its normal working condition as soon is possible for supplying reliable quality power to the receiving ends. The circuits breaker is the special device all the required switching operations during current carrying condition. A circuits breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. The contacts can be opened manually or by remote control whenever desired. Whena fault occurs in any part of the system, the trip coils of the breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuits. The main types of circuits breakers are

i. Miniature circuits breakers (MCB)
ii. Earth leakage circuits breakers (ELCB) or Residual Current Breaker (RCCB)
iii. Molded Case circuit breaker

Miniature Circuit Breaker (MCB):

Minimum circuits breakers are electromechanical devices which protect an electrical circuit from over currents. Over currents in an electrical circuit may results from short circuits overload, or faulty design. An MCB is better alternative than fuse, since it does not require replacement once an overload is detected. An MCB functions by interrupting the continuity of electrical flow through the circuits once a fault is detected.In simple terms, MCB is a switch which automatically turns off when the current flowing through it passesthe maximum allowable limit. Generally, MCB is designed to protect against over current and over temperature faults (over heating).

Working Principle:

There are two contact - one is fixed and the other is moveable. When the current exceeds the predefined limit, a solenoid forces the moveable contact to open (i.e., disconnect from the fixed contact) and the MCBturns off, thereby stopping the current from flowing in the circuits.

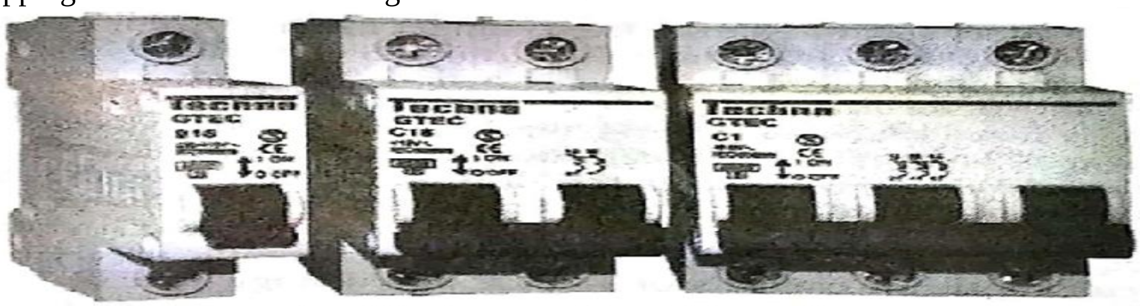

Fig: Miniature Circuit Breaker

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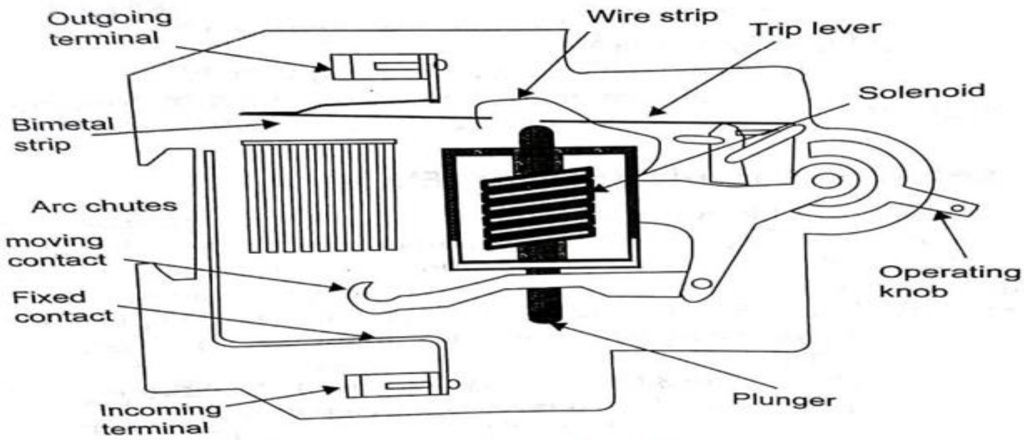

Fig: Cross-section of MCB

Operation: The image of MCB and its internal parts are shown in the figures. It mainly consists of one bi-metallic strip, one trip coil and one hand operated on-off lever. Electric current carrying path of a MCB is as follows - first left hand side power terminal-then bimetallic strip - then currentcoil - then moving contact - then fixed contact and – lastly right hand side power terminal, and all are arranged in series. If circuit is overload for a long time, the bi -metallic strip becomes over heated and deformed. This deformation of bi-metallic strip causes displacement of latch point. The moving contact of the MCB is so arranged by means of spring, with this latch point, that a little displacement of latch causes releases of spring and makes the moving contact to move for opening the MCB. The current coil or trip coil placed in such a manner that during SC faults, the MMF of that coil causes its plunger to hit the same latch point andforce the latch to be displaced. Hence, the MCB will open in the same manner. Again when operating lever of the MCB is operated by hand, that means when we make the MCB at off position manually, the same latch point is displaced as a result moving contact separated from fixed contact in same manner. So, whatever may be the operating mechanism, i.e., may be due to deformation of bi-metallic strip or may be due to increased MMF of trip coil or may be due to manual operation - actually the same latch point is displaced and the deformed spring is released, which is ultimately responsible for movement of the movingcontact.

When the moving contacts is separated from fixed contact, there may be a high chance of arc. Thisare then goes up thorough the arc runner and enters into arc splitters and is finally quenched. When we switch on the MCB, we actually reset the displaced operating latch to its previous on position and make theMCB ready for another switch off or trip operation. These are available in single pole, double pole, triple pole, and four pole versions with neutral poles, ifrequired. The normal current ratings are available from 0.5-63 A with a symmetrical short circuit rupturingcapacity of 3-10kA, at a voltage level of 230/440v. MCBs are generally designed to trip within 2.5 millisecond when an over current fault arises. In case of temperature rise or over heating it may take 2 seconds to 2 min. For the MCB to trip.

Advantages:

- MCBs are replacing the re-wireable switch i.e., fuse units for low power domestic and industrial applications.
- The disadvantages of fuses, like low SC interrupting capacity (say 3kA), Etc. Are overcome with high SC breaking capacity of 10kA.
- MCB is combination of all three functions in a wiring system like switching, overload and short circuits protection. Overload protection can be obtained by using bi-metallic strips whereas shorts circuits protection can be obtained by using solenoid

Earth Leakage Circuits Breaker (ELCB):

None of the protection devices like MCB, MCCB, etc. Can protect the human life against electric shocks or avoid fire due to leakage current. The human resistance noticeably drops with an increase in voltage. It also depends upon the duration of impressed voltage and drops with increase in time. As per IS code, a contact potential of 65V is within tolerable limit of human body for 10 seconds, whereas 250V can be withstood by human body for 100 milliseconds. The actual effect of current thorough human body varies from person to person with reference to magnitude and duration. The body resistance at 10V is assessed to be 19 kΩ for 1 second and 8kΩ for 15 min. At 240V, 3 to 3.6 kΩ for dry skin and 1-1.2 kΩ for wet skin. An Earth Leakage

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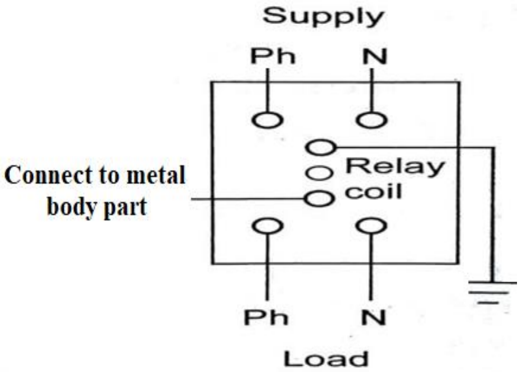
Circuits Breakers (ELCB) is a device used to directly detect currents leaking to earthfrom an installation and cut the power. There are two types of ELCBs:

(i) Voltage Earth Leakage Circuits Breaker (voltage -ELCB)

(ii) Current Earth Leakage Circuits Breaker (Current -ELCB)

Voltage Earth Leakage Circuits Breaker (voltage -ELCB):

Voltage –ELCB is a voltage operated circuits breaker. The device will functionwhen the current passes thorough the ELCB. Voltage-ELCB contains relay coil and one end of the coil is connected to metallic load body and the other end is connected to ground wire as shown in figure. Ifthe voltage of the equipment body rises (by touching phase to metal part or insulation failure of equipment),which could cause the difference between earth and load body voltage and the danger of electric shock will occur. This voltage difference will produce an electric current from the load metallic body and phase through the loop to the Earth. When voltage on the equipment metallic body rises to danger level i.e., whichexceed to 50V, the flowing current through relay loop could move the relay contact by disconnecting the supply current avoid from any danger electric shock. The ELCB detects fault currents from line to the earth (ground) wire within the installation it protects. If sufficient voltage appears across the ELCB's sensing coil, it will switch off the power, and remain off until manually reset. A voltage –sensing ELCB does not sense fault current from line to any other earthed body.



Current Earth Leakage Circuits Breaker (Current -ELCB):

Current –ELCB is a current operated circuits breaker which is a commonly used ELCB. Current-ELCB consists of a 3- winding transformer, which has two primary windings and 1 secondary winding as shown in figure. Neutral and line wires act as the two primary windings. A wire wound coil is the secondary winding. The current thorough the secondary winding is zero at the balanced condition. In the balanced condition, the flux due to current through the phase wire will be neutralized by the current through the neutral wire, since the current which flows from the phase will be returned back to the neutral. When a faultoccurs, a small current will flow to the ground also. This makes an unbalanced between line and neutral currents and creates an unbalanced magnetic field. This induces a current through the secondary winding, which is connected to the sensing circuits. This will sense the leakage and send a signal to the tripping system and trips the contact.

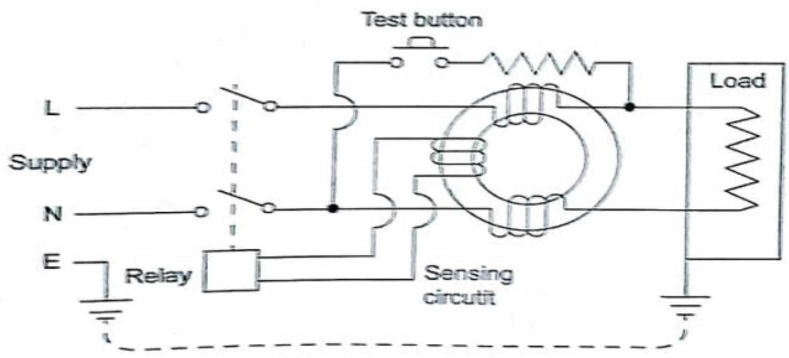


Figure : *Current earth leakage circuit breaker*

Molded Case Circuit Breaker (MCCB):

It is a type of electrical protection device that can be used for a wide range of voltages, and frequencies of both 50 Hz and 60 Hz, the main distinctions between molded case and miniature circuit breaker are that MCCB can have current rating up to 2500 amperes, and its trip setting are normally adjustable. MCCBs are much

larger than MCBs. An MCCB has three main functions:
Protection against overload.
Protection against electrical faults.
Switching a circuit ON and OFF.
These can be used for that purpose if there is not an adequate manual switch.
The wide range of current ratings available from molded-case circuit breakers allows them to be used in a wide variety of applications. MCCBs are available with current ratings that range from low values such as 15 amperes, to industrial ratings such as 2500 amperes. This allows them to be used in both low power and high power applications.
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 adjusted 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 is a normal part of operation for many devices. However, any over current conditions, that lasts more than what is normally expected represent an overload, and the MCCB is tripped to protect the equipment and personnel.
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:

Wire and cable:

The use of Conductors and their insulation is regulated by Indian Electricity (IE) regulation and Indian Standard (IS) Code of Practice. Wires and cables are the most common forms of conductors. They carry electric current through all types of circuits and systems. A conductor is a wire or cable or anyother form of mental, suitable for carrying current from generating station the point where it is used.
Difference Between Wire and Cable:
According to Bureau of Indian Standards (BIS), wire and cable can be defined as follows:
Bare Conductors: They have no covering. The best example is overhead transmission and distributionlines.
Wire: If bare conductors are provided with Insulation, then it is known as a wire. The insulation separatesthe conductor electrically from other conductors.
Cable: It consists of two or more conductors covered with suitable insulation and surrounded by a protecting cover. The necessary requirements of a cable are that it should conduct electricity efficiently, cheaply, and safely. This should neither be so small that it has a large internal voltage drop nor be too largeso that it costs too much. Its insulation should be such that it prevents leakage of current in unwanted direction to minimize risk of fire and shock.
The cable essentially consists of three parts :

- Conductor or core- the metal wire, or strand of wires, carrying the current
- Insulation of dielectric- a covering of insulating material to avoid leakage of current from the conductor
- Protective covering for protection of insulation from mechanical damage

Basically, there is no difference between a cable and a wire. It is a relative term. The term cable is used forall heavy section insulated conductors, whereas a wire means a thin (i.e., smaller) section insulated conductor used for carrying current from one point to another point.

Classifications of Wire / Cables:

The wires/ cables used for domestic or industrial wiring are classified into different groups as follows:

According to the conductor material used	• Copper conductor cables • Aluminum conductor cable
According to number of cores	• Single core cable • Double core or twin core cables (DCC)

	• Three core cables • four core cables • Two core with earth continuity conductor cables
According to type of insulation	• Vulcanized Indian rubber (VIR) insulated wires/cables • Tough rubber sheathed (TRS) or cable tyre sheathed (CTS) cables • Polyvinyl chloride (PVC) cables • Lead sheathed cables • Weather proof cables • Flexible cords and cables • XLPE cables
According to the voltage at which they are manufactured	• Low tension (LT) cables – up to 1000V • High tension (HT) cables – up to 11kV • Super tension (ST) cables – from 22-33kV • Extra high tension (EHT) cables – from 33-66kV • Extra super voltage cables – beyond 132 kV

Specifications of Cables:

Cables are specified by providing

- Size of the cable in metric system (e.g., 19/2.24, 7/1.70, 7/2.24, 7/2.50 etc) giving the Number of strands used and diameter of each strand, or giving the area of cross- sectionof conductor used.
- Type of conductor used in cables (copper or aluminium)
- Number of cores that cable consists of e.g. single core, twin core, three core, four core etc.
- Voltage grade (240/415V or 650/1100V grade)
- Type of cable with clear description regarding insulation, shielding, armouring, bedding etc.

A few specifications of a cable are given below:

7/20, VIR, aluminum conductor, twin core,650/1100 grade. in this case, the numerator 7 indicates the number of stands in cable and denominator 20represents the gauge number of each strand. The cable has two cores made with Aluminum, With VIR insulation and is used for 650/1100 voltage.

19/1.12, aluminium conductor,3 ½ core, 1100V, PVC cable, PVC sheathed in this case, the cable consists of 19 strands, each strand has a diameter of 1.12mm. Theconductor is made with aluminium, insulation is made with PVC, is covered with PVC sheathing, and is used for 1100Vsupply system.

EARTHING:

The process of connecting the metallic frame (i.e., non- current carrying part) of electrical equipment or some electrical part of the system (e.g., neutral point in a star-connected system, one conductor of the secondary of a transformer, etc.) to the earth (i.e., soil) is called grounding or Earthing. The potential of theearth is to be considered zero for all practical purposes. Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential, this ensures safe discharge of electrical energy due to failure of the insulation line coming in contact with the casing, etc. It brings the potential of the body of the equipment to zero i.e., to the earth's potential, thus ptotecting the operating personnel against electrical shock.

The earth resistance is affected by the following factors:

- Material properties of the earth, wire and the electrode
- Temperature and moisture content of the soil
- Depth of the pit
- Quantity of the charcoal used

Necessity of Earthing:

The requirement for provision of earthing can be listed as follows:

- To protect the operating personnel from the danger of shock.
- To maintain the line voltage constant, under unbalanced load condition.
- To avoid risk of fire due to earth leakage current through unwanted path.
- Protection of the equipment.
- Protection of large buildings and all machines fed from overhead linesagainst lighting.

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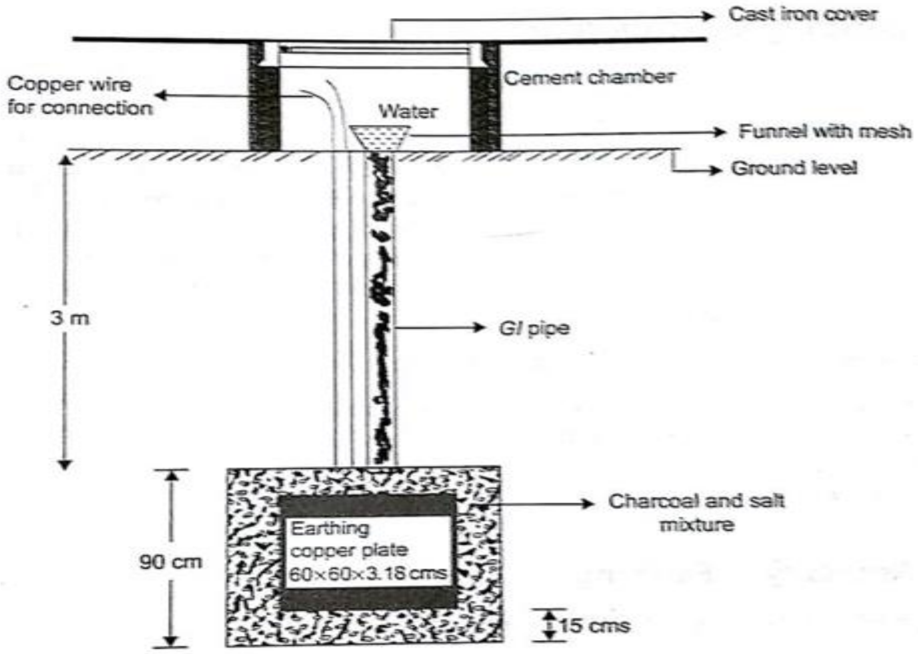
Methods of Earthing:

The various methods of earthing in common use are

- Plate earthing
- Pipe earthing
- Rod earthing
- Strip or wire earthing

Plate earthing:

In this method either a copper plate of 60cm × 60cm ×3.18 or GI plate of 60cm × 60cm × 6.35 is used for earthing. The plate is buried into the ground not less than 3m from the ground level. The earth plate is embedded in alternate layers of coal and salt for a thickness of 15cm as shown in figure. In addition, water is poured for keeping the earth's electrode resistance value below a maximum of 5Ω. The earth wire issecurely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.



Pipe earthing:

Earth electrode made of a GI (galvanized iron) pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75cm in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cm) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross-sectional area are run through a12.7mm diameter pipe (at 60cm below) from the 19mm diameter pipe and secured tightly at the top as shown in figure.

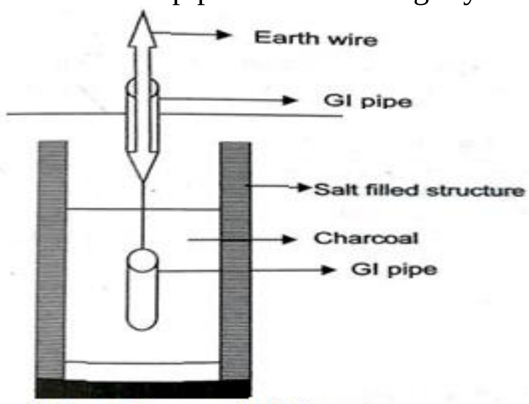


Fig: Pipe earthing

When compared to the plate earth system the pipe earth system can carry larger leakage currents due tolarger surface area is in contact with the soil for given electrode size. This system also enables easy maintenance as the earth wire connection is housed at the ground levels.

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Rod earthing:

It is the same method as pipe earthing, A copper rod of 12.5cm (1/2 inch) diameter or 16mm (0.6in) diameter of galvanized steel or hollow section 25mm (1 inch) of GI pipe of length above 2.5m (8.2 ft) areburied upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

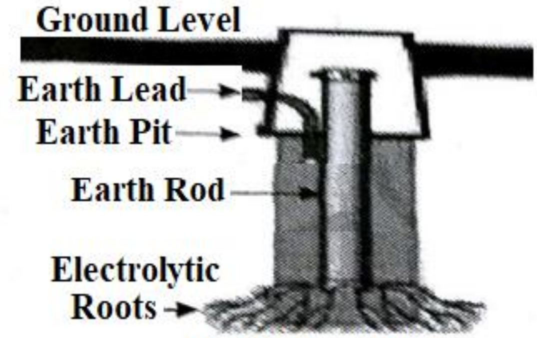

Fig: Rod earthing

Strip or wire earthing:

In this method of earthing strip electrodes of cross- section not less than 25mm × 1.6mm (1 in × 0.06in) is buried in a horizontal trench of a minimum depth of 0.5m. If copper with a cross-section of 25mm × 4mm(1in × 0.15in) is used and a dimension of 3.0 mm^2 if it's a galvanized iron or steel. If at all round conductors are used, their cross-section area should not be too small, say less than 6.0 mm^2 if it's a galvanized iron or steel. The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m. The electrodes shall be as widely distributed as possible in a single straight or circular trench radiating from a point. This type of earthing isused where the earth bed has a rocky soil and excavation work is difficult.

Selection of Earthing:

The type of earthing to be provided depends on many factors such as type of soil, type of installation, etc.The following table helps in selecting a type of earthing for a particular application.

S. No	Type of Earthing	Application
1	Plate earthing	Large installations such as transmission towers, all sub-stations generating stations
2	Pipe earthing	For domestic installations such as heaters, coolers,refrigerators, geysers, electric iron, etc. For 11kV/400V distribution transformers For induction motors rating upto 100HP For conduit pipe in a wall, all wall brackets
3	Rod earthing	In areas where the soil is loose or sandy
4	Strip or wire earthing	In rocky areas

Difference Between Earth Wire and Neutral Wire:

Neutral Wire:

In a 3-phase 4-wire system, the fourth wire is a neutral wire.

It acts a return path for 3-phase currents when the load is not balanced.

In domestic single phase AC circuit, the neutral wire acts as return path for the linecurrent.

Earth Wire:

Earth wire is actually connected to the general mass of the earth and metallic body of the equipment.

It is provided to transfer any leakage current from the metallic body to the earth.

Battery:

A Battery is a device consisting of one or more electrical cells that convert chemical energy into electrical energy. Every battery is basically a galvanic cell where redox reactions take place between two electrodes which act as the source of the chemical energy.

Types of Batteries: Batteries generally can be classified into different categories and types, ranging from chemical composition, size, form factor and use cases, but under all of these are two major battery types; Primary Batteries and Secondary Batteries

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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. A good example of which is in military grade devices and battery powered equipment. It will be impractical to use rechargeable batteries as recharging a battery will be the last thing in the mind of the soldiers. 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 other **examples of devices using primary batteries include**; Pace makers, Animal trackers, Wrist watches, remote controls and children toys to mention a few. 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 and can be carried on an aircraft without being subject to UN Transport and other regulations. 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.

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. Small capacity secondary batteries are used to power portable electronic devices like **mobile phones**, and other gadgets and appliances while heavy-duty batteries are used in powering diverse **electric vehicles** and other high drain applications like load levelling in electricity generation. They are also used as standalone power sources alongside **Inverters to supply electricity**. Although the initial cost of acquiring rechargeable batteries is always a whole lot higher than that of primary batteries but they are the most cost-effective over the long-term.

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 following are the **different types of rechargeable batteries** that are commonly used.

1. Lithium-ion(Li-ion)
2. Nickel Cadmium(Ni-Cd)
3. Nickel-Metal Hydride(Ni-MH)
4. Lead-Acid

Nickel-Cadmium Batteries:

The nickel–cadmium battery (NiCd battery or Ni Cad battery) is a type of rechargeable battery which is developed using nickel oxide hydroxide and metallic cadmium as electrodes. Ni-Cd batteries excel at maintaining voltage and holding charge when not in use. However, Ni-Cd batteries easily fall a victim of the dreaded "memory" effect when a partially charged battery is recharged, lowering the future capacity of the battery.

In comparison with other types of rechargeable cells, Ni-Cd batteries offer good life cycle and performance at low temperatures with a fair capacity but their most significant advantage will be their ability to deliver their full rated capacity at high discharge rates. They are available in different sizes including the sizes used for alkaline batteries, AAA to D. Ni-Cd cells are used individual or assembled in packs of two or more cells. The

small packs are used in portable devices, electronics and toys while the bigger ones find application in aircraft starting batteries, Electric vehicles and standby power supply.
Some of the properties of Nickel-Cadmium batteries are listed below.

- Specific Energy: 40-60W-h/kg; Energy Density: 50-150 W-h/L
- Specific Power: 150W/kg; Charge/discharge efficiency: 70-90%
- Self-discharge rate: 10%/month; Cycle durability/life: 2000cycles

Nickel-Metal Hydride Batteries:
Nickel metal hydride (Ni-MH) is another type of chemical configuration used for rechargeable batteries. The chemical reaction at the positive electrode of batteries is similar to that of the nickel–cadmium cell (NiCd), with both battery type using the same nickel oxide hydroxide (NiOOH). However, the negative electrodes in Nickel-Metal Hydride use a hydrogen-absorbing alloy instead of cadmium which is used in Ni Cd batteries.
NiMH batteries find application in high drain devices because of their high capacity and energy density. A NiMH battery can possess two to three times the capacity of a NiCd battery of the same size, and its energy density can approach that of a lithium-ion battery. Unlike the NiCd chemistry, batteries based on the **Ni-MH chemistry are not susceptible to the "memory"** effect that NiCads experience.
Below are some of the properties of batteries based on the Nickel-metal hydride chemistry;

- Specific Energy: 60-120h/kg; Energy Density: 140-300 Wh/L
- Specific Power: 250-1000 W/kg; Charge/discharge efficiency: 66% - 92%
- Self-discharge rate: 1.3-2.9%/month at 20^{o}C; Cycle Durability/life: 180 -2000

Lithium-ion Batteries:
Lithium-ion batteries are one of the most popular types of rechargeable batteries. There are many **different types of Lithium batteries**, but among all the lithium-ion batteries are the most commonly used. You can find these lithium batteries being used in different forms popularly among electric vehicles and other portable gadgets. If you are curious to know more about batteries used in Electric vehicles, you can check out this article on Electric Vehicle Batteries. They are found in different portable appliances including mobile phones, smart devices and several other battery appliances used at home. They also find applications in aerospace and military applications due to their lightweight nature.
Lithium-ion batteries are a type of rechargeable battery in which lithium ions from the negative electrode migrate to the positive electrode during discharge and migrate back to the negative electrode when the battery is being charged. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in non-rechargeable lithium batteries.
Lithium-ion batteries generally possess high energy density, little or no memory effect and low self-discharge compared to other battery types. Their chemistry alongside performance and cost vary across different use cases, for example, Li-ion batteries used in handheld electronic devices are usually based on lithium cobalt oxide ($LiCoO_2$) which provides high energy density and low safety risks when damaged while Li-ion batteries based on Lithium iron phosphate which offer a lower energy density are safer due to a reduced likelihood of unfortunate events happening are widely used in powering electric tools and medical equipment. Lithium-ion batteries offer the best performance to weight ratio with the lithium sulphur battery offering the highest ratio.
Some of the attributes of lithium-ion batteries are listed below;

- Specific Energy: 100: 265W-h/kg; Energy Density: 250: 693 W-h/L
- Specific Power: 250: 340 W/kg; Charge/discharge percentage: 80-90%
- Cycle Durability: 400: 1200 cycles; Nominal cell voltage: NMC 3.6/3.85V

Lead-Acid Batteries:
Lead-acid batteries are a low-cost reliable power workhorse used in heavy-duty applications. They are usually very large and because of their weight, they're always used in non-portable applications such as solar-panel energy storage, vehicle ignition and lights, backup power and load levelling in power generation/distribution. The lead-acid is the oldest type of rechargeable battery and still very relevant and important into today's world. Lead-acid batteries have very low energy to volume and energy to weight ratios but it has a relatively large power to weight ratio and as a result, can supply huge surge currents when needed. These attributes alongside its low cost make these batteries attractive for use in several high current applications like powering automobile starter motors and for storage in backup power supplies. You can also check out the article on Lead Acid Battery working if you want to know more about the different types of Lead-acid batteries, its construction and applications.

UNIT –V: ELECTRICAL INSTALLATIONS

Fig: Images of Ni-Cd, Ni-MH, Lithium-ion & Lead-Acid batteries

Power Factor:

In electrical engineering, the power factor (PF) of an AC electrical power system is defined as the ratio of working power (measured in kilowatts, kW) absorbed by the load to the apparent power (measured in kilovolt amperes, kVA) flowing through the circuit. Power factor is a dimensionless number in the closed interval of −1 to 1.

$$\cos\varphi = \frac{\text{Active power}}{\text{Apparent power}}$$

Hence when we consider the entire circuit consisting of a resistor, inductor, and capacitor, there exists some phase difference between the source voltage and current. The cosine of this phase difference is called the **electrical power factor**. This factor ($-1 < \cos\varphi < 1$) represents the fraction of the total power that is used to do the useful work. The other fraction of electrical power is stored in the form of magnetic energy or electrostatic energy in the inductor and capacitor respectively. This is called apparent power and its unit is VA (Volt-Amp) and denoted by ‘S’. A fraction of this total electrical power that does our useful work is called active power. We denote it as ‘P’.

P = Active power = Total electrical power. cosφ and its unit is watt.

The other fraction of power is called reactive power. Reactive power does no useful work, but it is required for the active work to be done. We denote it with ‘Q’ and mathematically is given by:

Q = Reactive power = Total electrical power. sinφ and its unit is VAR (Volt-Amp Reactive). This reactive power oscillates between source and load. To help understand this better all these power is represented in the form of a triangle shown in fig.

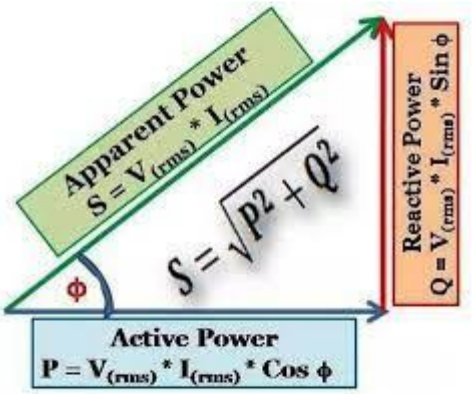

Fig : Power factor Triangle

Power Factor Improvement

The term power factor comes into the picture in AC circuits only. Mathematically it is the cosine of the phase difference between the source voltage and current. It refers to the fraction of total power (apparent power) which is utilized to do the useful work called active power.

$$\cos\varphi = \frac{\text{Active power}}{\text{Apparent power}}$$

Need for Power Factor Improvement:

- Real power is given by P = VIcosφ. The electrical current is inversely proportional to cosφ for transferring a given amount of power at a certain voltage. Hence higher the pf lower will be the current flowing. A small current flow requires a less cross-sectional area of conductors, and thus it saves conductors and money.

- From the above relation, we see having a poor power factor increases the current flowing in a conductor, and thus copper loss increases. A large voltage drop occurs in the alternator, electrical transformer, and transmission, and distribution lines – which gives very poor voltage regulation.
- The KVA rating of machines is also reduced by having a higher power factor, as per the formula ($\sqrt{3}V_L I_L \cos\varphi$)
- Hence, the size and cost of the machine are also reduced.
- This is why the electrical power factor should be maintained close to unity – it is significantly cheaper.

Methods of Power Factor Improvement

There are three main ways to improve power factor:

- Capacitor Banks
- Synchronous Condensers
- Phase Advancers

Capacitor Banks:

Improving power factor means reducing the phase difference between voltage and current. Since the majority of loads are of inductive nature, they require some amount of reactive power for them to function.

A capacitor or bank of capacitors installed parallel to the load provides this reactive power. They act as a source of local reactive power, and thus less reactive power flows through the line.

Capacitor banks reduce the phase difference between the voltage and current.

Synchronous Condensers:

Synchronous condensers are 3 phase synchronous motors with no load attached to their shaft.

The synchronous motor has the characteristics of operating under any power factor leading, lagging, or unity depending upon the excitation. For inductive loads, a synchronous condenser is connected towards the load side and is overexcited.

Synchronous condensers make it behave like a capacitor. It draws the lagging current from the supply or supplies the reactive power.

Phase Advancers:

This is an AC exciter mainly used to improve the PF of an induction motor. They are mounted on the shaft of the motor and are connected to the rotor circuit of the motor. It improves the power factor by providing the exciting ampere turns to produce the required flux at the given slip frequency. Further, if ampere-turns increase, it can be made to operate at the leading power factor.

Energy Consumption Calculation:

Energy and power are closely related. Electrical energy can be measured only when electrical power is known. So first we understand the electrical power. Electrical power it the amount of electrical current thatresults from a certain amount of voltage or we can say that power is the rate which energy is delivered. It ismeasured in watts. Mathematically it is written as

Power = Voltage × Current

The measurement of electrical energy is completely dependent on power which is measured in watt, kilowatts, megawatts, gigawatts, and time which is measured in an hour. Joule is the smallest unit of energy.But for some bigger calculation, some better unit it required. So, the unit used for electrical energy is watt- hour.

Electrical energy is the product of electrical power and time, and it measured in joules. It is defined as "1joule of energy is equal to 1 watt of power is consumed for 1 second". I.e.,

Energy = Power × Time

1 Joule = 1 watt × 1 second

Watts are the basic unit of power in which electrical power is measured or we can say that rate at which electrical current is being used at a particular moment.

Watt-hour is the standard unit used for measurement of energy, describing the amount of watts used over a time. It shows how fast the power is consumed in the period of time.

Energy in watt hours = Power in watts × Time in hours

Kilowatt-hour is simply a bigger unit of energy when large appliance drawn power in kilowatts. It can be described as one kilowatt hour is the amount of energy drawn by the 1000 watts appliance when used for an hour. Where, One kilowatt = 1000 watts;

Energy in kilowatt hours = Power in kilowatts × Time in hours

The electrical supply companies take electric energy charges from their consumer per kilowatt hour unitbasis.

This kilowatt hour is board of trade (BOT) unit.

Illustration for Energy Consumption:

A consumer uses a 10 kW geezer, a 6 kW electric furnace and five 100 W bulbs for 15 hours. How manyunits (kWh) of electrical energy have been used?

Given that

Load – 1 = 10 kW geezer

Load – 2 = 6 kW electric furnace

Load – 3 = 500 watt (five 100 watt bulbs)Total load = 10kW + 6kW + 0.5kW = 16.5kW

Time taken = 15 hours

Energy consumed = Power in kW × Time in hours = 16.5 × 15 = 247.5 kWh

For above electrical energy consumption, the tariff can be calculated as follows:1 unit = 1kWh

So, the total energy consumption = 247.5 units

If the cost per unit is 2.5, then the total cost of energy consumption is 247.5 × 2.5 = Rs. 618.75/-

Battery Backup:

All electronic access systems must plan for situations that involve the loss of the primary power source. A battery backup must be designed into the overall system plan so that it is part of the total system's functionality. The backup battery must power not only the processing system panels, but also the door locks, sensors, and all other peripheral equipment (for example, door contacts, motion detectors, touch bars, and push-button shunt devices). To avoid possible power spikes and data interruption of your access control system do not combine the powering of your processor panes with your electronic locking hardware. It is strongly recommended that you isolate the power of your processing panels; never attempt to combine power supplies! Be certain to carefully scrutinize the battery backups provided by many system manufacturers. They often fail to address the peripheral parts that play an integral part in the system functioning properly. Batteries are inexpensive; connect additional batteries in parallel for additional power backup.

The most popular business backup power supply option, depending on your power requirements, is an uninterruptible power supply (UPS).

This invaluable piece of business apparatus helps to prevent:

- Damage to electrical equipment
- Loss of stored data
- Early breakdown of power-sensitive equipment

Below we explore what a UPS is and the 3 different types of UPS.

Uninterruptible Power Supply (UPS)

A UPS works like a battery backup supply, using batteries that charge when the power is on. When the power cuts out it instantly uses the stored energy to power equipment. However, this uninterrupted power supply does not last long. Typically, your business may use a diesel generator in addition to a UPS to provide hours of backup (dependent on its size).

Benefits of having a UPS include:

- Immediate backup power supply
- Makes no noise
- Cheaper alternative to a generator
- Eco-friendly
- Portable in size
- Requires less maintenance