ELECTRICAL INSTALLATION

An electrical installation is a combination of electrical equipment installed from a common electrical supply to fulfill a particular purpose.

ELECTRICAL WIRING:

A network of wires/cables connecting various electrical accessories for distribution of electrical energy from the supplier meter board to the numerous electrical energy consuming devices such as lamps, fans, television, refrigerator and other domestic appliances through controlling and safety devices is known as wiring system.

The supply used in houses for lighting and power purposes is single phase AC Supply, whereas for Industries 3 phase AC Supply is employed. The single phase Circuit is connected to 220 volts across one phase and neutral.

Factors affecting the choice of wiring:

Durability: Type of wiring selected should conform to standard specifications so that it is durable i.e., without being affected by weather conditions and Etc.

Safety: The wiring must provide safety against leakage, shock and fire hazards for operating personnel.

Appearance: Electrical wires should give an artistic appeal to the Interiors.

Cost: Electrical wiring should not be expensive and maintenance costs should be minimum.

Accessibility: The switches and plug points provided should be easily accessible. There must be provision for further extension of electrical system, if necessary.

Mechanical safety: The wiring must be protected against my Mechanical damage.

Types of electrical wiring:

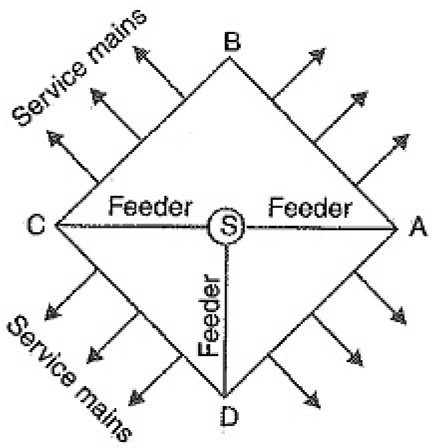
Electrical wiring is classified as:

1. Cleat wiring
2. CTS wiring or TRS wiring or Batten wiring
3. Metal sheathed wiring or Lead sheathed wiring
4. Casing & Capping
5. Conduit wiring

SERVICE MAINS:

The overhead line or U.G cable connecting the supplier's distribution line to the consumer's premises is called service mains or service connection or service line.

The service line terminates at the point where the supply conductor enters the consumer meter.



There are two types of Service Mains:

To transmit electricity from low tension lines to the consumer meter board there are two ways to transmit electricity:

1. Overhead service mains.

2. Underground service mains.

Overhead Service connection means conductors are drawn or taken above the ground level. Overhead service mains are the most common type in India. In overhead service mains, there are some materials used like insulators, conductors and etc.

Advantages of Overhead connection compared with underground connection are:

1. Extension of service line capacity is easy

2. Fault location and rectification are easy

3. Easy to Erection

4. It is Cheap

Disadvantages of Overhead connection with underground connection are:

1. Over head space is affected.

2. Affected by weather such as sun heat and rain lightening

3. Faults due to falling of trees and etc.

Underground Service Connection means conductors are drawn or taken below the ground level. It is very difficult to install underground service mains compared to overhead service mains. The materials used in underground service mains are GI pipes, underground cables etc.

Advantages of underground connection compared with overhead connection are:

1. Long-life.

2. Not affected by weather such as sun light, rain, and lightning, etc.

3. Safety to the public.

4. It is used in metro and corporate cities where overhead connection construction is very difficult.

5. Good Appearance.

Disadvantages of underground connection compared with overhead connection are:

1. Fault location and rectification is difficult.

2. It is costly

3. It requires more time for erection and dismantling.

Meter board:

An electricity meter, Meter board, electrical meter, or energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device.

Electric utilities use electric meters installed at customer premises for billing and monitoring purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour (kWh).

Distribution board:

A distribution board (also known as panel board, breaker panel, or electric panel) is a component of an electricity supply system that divides an electrical power feed into subsidiary circuits, while providing a protective fuse or circuit breaker for each circuit in a common enclosure. Normally, a main switch, and in recent boards, one or more residual-current devices (RCD) or residual current breakers with overcurrent protection (RCBO), are also incorporated.

ELECTRIC SHOCK:

The human body has an electrical conducting property. Without sweating, the resistance of the human body is approximately 80,000Ω and during sweating resistance of the human body is approximately 1000Ω. If you touch the current-carrying conductors, the current is conducted through our body to the Earth. So electric circuit is closed and we get the electric shock due to which Nervous structure, heart, lungs and brain are affected. If the current is large, death may occur. Therefore we must know that even through current is essential, if it is used in a wrong manner it will cause heavy loss i.e., death and economical losses.

To prevent the electric shock, we should adopt some preventive care and protective method for safety precautions.

Preventive methods to avoid electric shock:

1. The operation of electrical equipment must be known
2. Damaged wire not be used for wiring works are electrical connections.
3. The electrical instruments used for connection should not have any scratch or break.
4. Proper Earthing is provided.
5. Depending upon the load, rated ampere fuse wire is used.
6. The electrical equipment is repaired after the main source is switched off.

First aid for electric shock

If anyone suffers an electric shock, the electricity Source should be cut off immediately. Conduct the first aid only after the victim is in safe place. Check the victims Breath and Pulse. If the person is unconscious but in breathing normally, he or she should be placed in a recovery position. If the victim is not breathing and has no pulse. Cardiopulmonary resuscitation (i.e., **Cardiopulmonary resuscitation** (**CPR**) is an emergency procedure that combines chest compressions often with artificial ventilation in an effort to manually preserve intact brain function until further measures are taken to restore spontaneous blood circulation and breathing in a person who is in cardiac arrest) should be conducted.

Cardiopulmonary resuscitation :
1. Open the airway
2. Check the Breaths
3. Check the pulse.
4. Recovery position
5. Mouth-to-mouth air resuscitation.
6. External chest compression

EARTHING OR GROUNDING:

The process of connecting the metallic frame (i.e., Non-current carrying part) of electrical equipment or some electrical part of system (i.e., Neutral point in a star connected system, one conductor of the secondary of a Transformer, etc) to the earth is called Earthing or Grounding.

The potential of the earth 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 attend Earth's potential. This ensures safe discharge of electrical energy due to the failure of the insulation line coming in contact with the casing, etc. Earthing brings the potential of body to of the equipment to zero i.e., to the earth potential, thus product protecting the operating personnel against electric shock.

The Resistance is affected by the following factors:

1. Material property of the earth wire and the electrode
2. Temperature and moisture content of the soil
3. Depth of the pit
4. Quantity of the charcoal used.

Necessity of earthing:

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

1. To protect the operating Personnel from the danger of shock.
2. To maintain the line voltage constant under unbalanced load condition.
3. To avoid the risk of fire due to earthing leakage current through unwanted path.
4. Protection of the equipment's
5. Protection of large building and all machines fed from overhead lines against lightning.

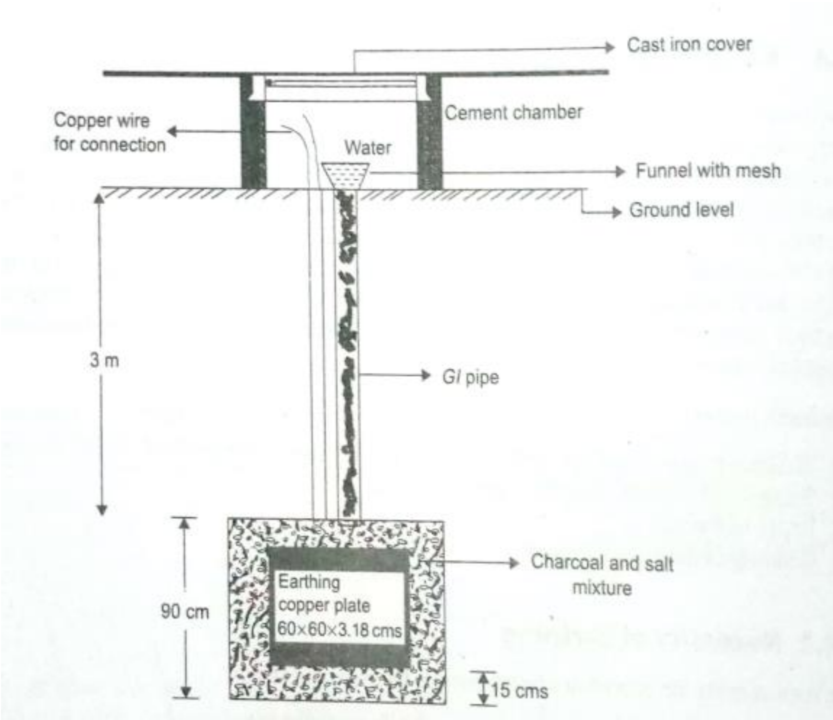
METHODS OF EARTHING

The various methods of earthing are:

1. Plate earthing.
2. Pipe earthing.
3. Rod earthing.
4. Strip or Wire earthing.

1. Plate earthing

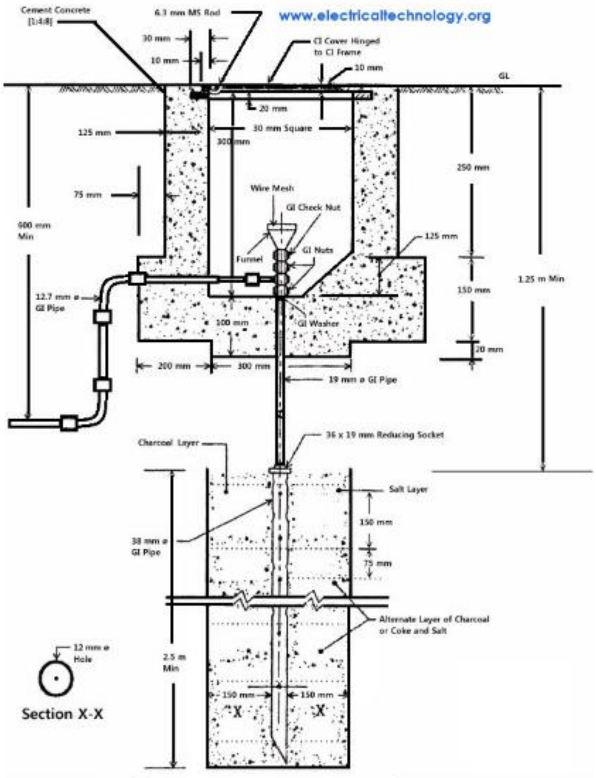
In this method either a copper plate of 60cm*60cm*3.18 or GI (galvanized iron) plate is used for earthing. The plate is buried into the ground not less than 3 meters from the ground level. The Earth plate is embedded in alternate layers of coal and salt of thickness of 15cms. In addition, water is poured for keeping the Earth electrode resistance value below a maximum of 5Ω. The Earth wire is securely bolted to at the plate. A cement masonry chamber is built with a cast-iron cover for easy maintenance.



2. Pipe Earthing

A galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil in this kind of system of earthing. It is the most common system of earthing.

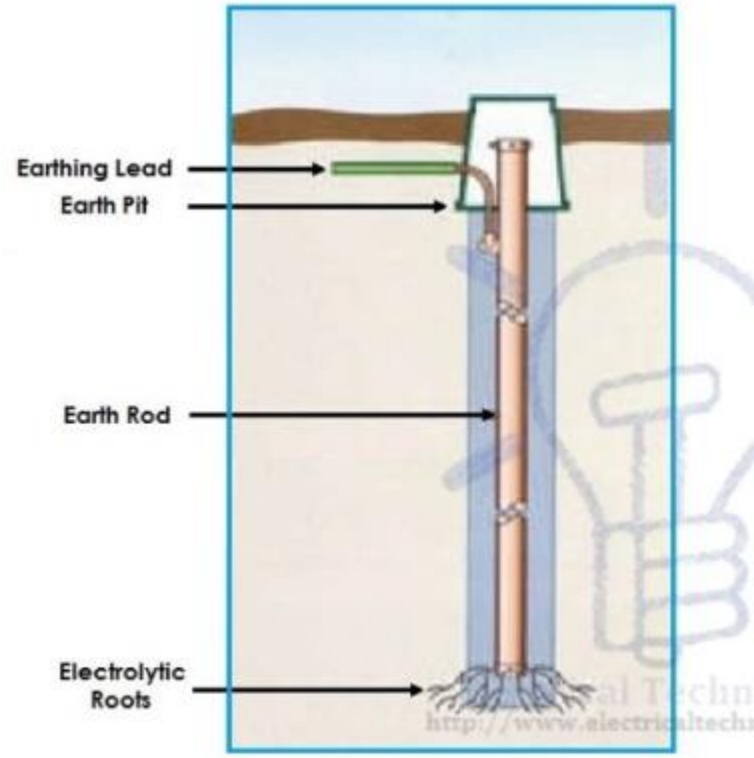
The size of pipe to use depends on the magnitude of current and the type of soil. The dimension of the pipe is usually 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. The moisture of the soil will determine the length of the pipe to be buried but usually it should be 4.75m (15.5ft).



When compared to the plate earth system the pipe earth system can carry large leakage currents due to large surround area in contact with the soil for a given electrode size. This system also enables easy maintenance as the earth wire connected is house at ground level.

3. Rod Earthing

It is the same method as pipe earthing. A copper rod of 8.5mm diameter or 16 mm diameter of galvanized steel of GI pipe is of length above 2.5 meters are buried upright in the earth manually or with the help of pneumatic hammer. The length of the embedded electrode in the soil reduces at the resistance to your desired value.



4. Strip or Wire Earthing

In this method of earthing, strip electrodes of cross-sectional not less than 25mm*1.6mm is buried in a horizontally trenches of minimum depth of 0.5 m.

The length of the conductor buried in the ground would give a sufficient earth resistance and this length not less than 15m. This type of earthing is used where the earth bed has a rocky soil and Excavation work is difficult.

EARTH RESISTANCE:

The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the Earth potential. The earth resistance for a copper wire is 1ohms and GI wire less than 3 ohms. The typical value of earth resistance at a large Power Station is 0.5 ohms, major sub stations is 1 ohm and small subsection is 2 ohms and in all other cases 5ohms.

The resistance of the earth depends upon the following factors:

1. Condition of a soil
2. Moisture content of the soil
3. Temperature of the soil
4. Depth of the electrode at which it is embedded
5. Size, material and the space of the earth electrode
6. Quality and quantity of the coal and salt in the air pipe.

Difference between the earth wire and neutral wire:

Neutral wire:

In a 3 phase 4 wire systems, the fourth wire is the neutral wire, it acts as a return path for three phase currents when the load is not balanced.

In domestic single phase AC circuit the neutral wire act as a return path for the line current.

Earth wire:

Earth wire is actually connected to the general mass of the earth and metallic body of the argument. It is provided to transfer any leakage current from the metallic body together.

WIRE AND CABLE

Wires and cable are the most common forms of conductors. They carry electrical current through all types of circuits and systems. A conductor is a wire or a cable or any form of a metal, suitable for carrying current from generating stations to the point where it is used. The use of conductors and their insulation is regulated by Indian electricity (IE) regulation and Indian Standard (IS) code of practice.

Difference between wire and cable

According to Bureau of Indian standards (BIS), wire and cable are defined as follows:

1. Bare conductors: They have no covering. The best example is overhead transmission and distribution lines.
2. Wire: If a bare conductor is provided with insulation, then it is known as a wire. The insulation separates the conductor electrically from other conductors.
3. 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. There should be no small or large internal voltage drop. The insulation should be Prevents the leakage of currents in unwanted direction to minimize the risk of fire and sharks.

The cable consists of three parts:
1. Conductor: The metal wire or strand of wires, carrying the current.
2. Insulation or dielectric: A covering of insulation material to avoid leakage of current from the conductor
3. Protective covering for protection the insulation from mechanical damage.

Basically, there is no difference between the cable and a wire, it is a relative term. The term cable is used for all heavy section insulator conductors, whereas the wire means he thin.

Classification of wires/cables

The wires/cables are domestic or industrially wiring are classified into different groups as follows:

1. According to conductor material used

i. Copper conductor cables
ii. Aluminium conductor cables

2. According to number of cores

i. Single core cables
ii. Double core cables
iii. Triple core or twin core cables
iv. Three core cables
v. Four core cables
vi. Two core with earth continuity conductor cables.

3. According to type of insulation

i. Vulcanized Indian Rubber (VIR) insulated wire/cables.
ii. Tough rubber sheathed (TRS) or cable tyre sheathed (CTS) cables
iii. Polyvinyl chloride (PVC) cables.
iv. Lead sheathed cables
v. Weather proof cables
vi. Flexible cords and cables
vii. XLPE cables

4. According to the voltage at which they are manufactured.

i. Low Tension cables – up to 1000V
ii. High tension cables – up to 11KV
iii. Super tension cables -- from 22 to 33 KV
iv. Extra High tension (EHT) cables -- From 33 to 66 KV
v. Extra super voltage cables -- beyond 132KV cable

FUSE

The electrical equipments are designed to carry a particular rated value of current under normal conditions. Under abnormal conditions such as short circuit, overload or any fault the current rises above this value, damaging the equipment and something resulting in fire hazards. Fuse come into operation under fault conditions.

Fuse is short piece of a metal, inserted in the circuit which melts when excessive current flows through it and thus breaks the circuit. Under normal operating conditions it is designed to carry the full load current. If the current increases beyond the designed value, the fuse melts which isolates the power supply from the load.

Material used are tin, lead our silver having low melting point. use of copper and iron is dangerous though tinned copper May be used.

Desired characteristics of fuse element:

Low melting point

High conductivity

Free from deterioration due to oxidation

Low cost

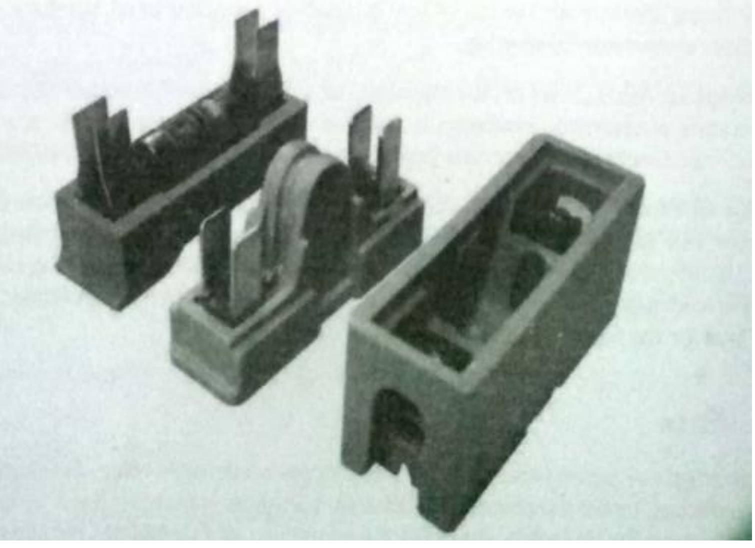
Types of fuses

1. Re-wireable fuse or kit-kat fuse

2. High rupturing fuse (H.R.C) cartridge fuse

1. Re-wireable fuse or kit-kat fuse

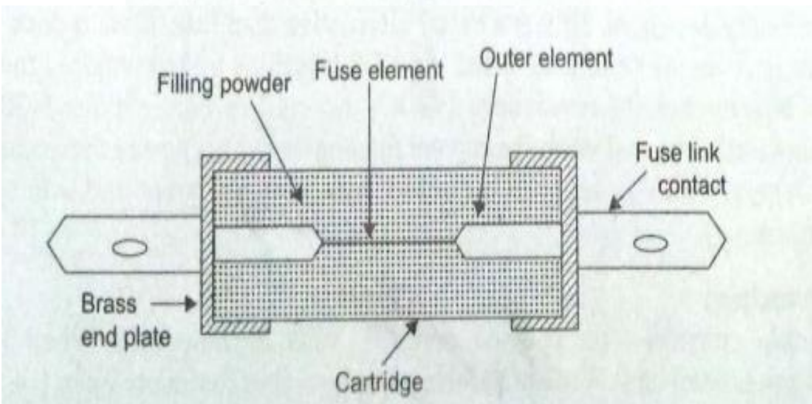
Re-wireable fuse is used for low value of fault current are to be interrupted. These fuses are simple in construction cheap, and available up to the current rating of 200 amps.



2. High rupturing fuse (H.R.C) cartridge fuse

It consists of heat resisting ceramic body having metal and-caps to which silver current-carrying element is welded. The space within the body surrounding the element is completely packed with filling powder. The Filling material may be chalk, plaster of Paris, quartz or marble dust and act as an arc quenching and cooling medium. Therefore, it carries the normal current without overheating

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



S.F.U

It is Switched Fuse Unit. It has one switch unit and one fuse unit. When we operate the breaker, the contacts will get closed through switch and then the supply will pass through the fuse unit to the output.

Whereas in a Fuse Switch Unit there is no separate switch and fuse unit. There is only the fuse unit which itself acts as a switch. When we operate it the fuse unit will close the input and output of the breaker. SFU has been used to trip the circuit, particularly for high capacity tripping.

CIRCUIT BREAKER

A circuit breaker is an automatic operated electrical switch designed to protect an electrical circuit from damage caused by excess current, typically resulting from an overload or short circuit. It's basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset either manually or automatically to resume normal operation.

A circuit breaker essentially consists of fixed and moving contacts called electrodes. Under normal operating conditions, these contacts remain closed until and unless the system becomes faulty the contacts are opened manually or by remote control. When a fault occurs in any part of the system the trip coils of this breaker get energised and moving contacts are pulled apart by some mechanism, thus operating the circuit.

MINIATURE CIRCUIT BREAKER:

Miniature circuit breakers are electromechanical devices which protect an electrical circuit from over currents. Over currents in an electric circuit may result from short circuit, overload or faulty design. An MCB is a better alternative than fuse, since it does not require any replacement once an overload is detected. MCB is a switch which automatically turns off when the current flowing through it passes the maximum allow-able limit. Generally MCB is designed to protect against overcurrent and over temperature faults.

Working principle:

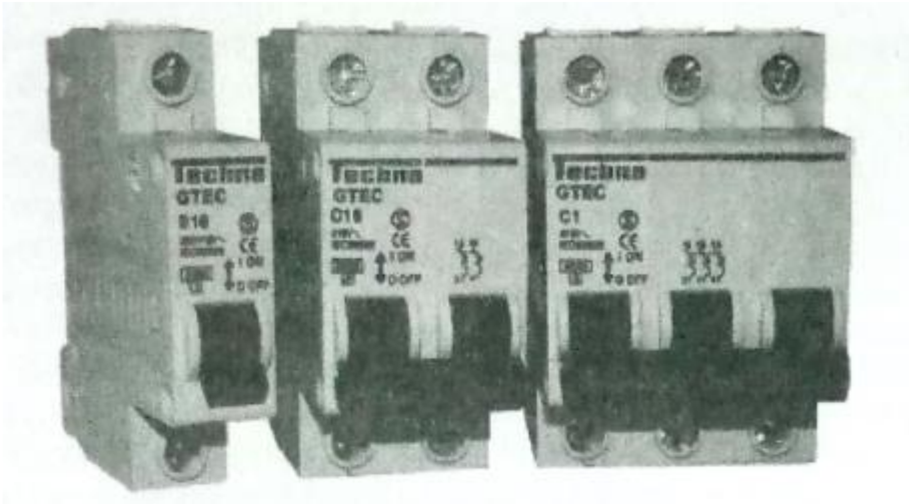
There are two contacts i.e., one is a fixed and other is movable. When a current exceeds the predefined limit, a solenoid forces the movable contact to open and the MCB gets turned off, thereby stopping the current flow from flowing in the circuit.

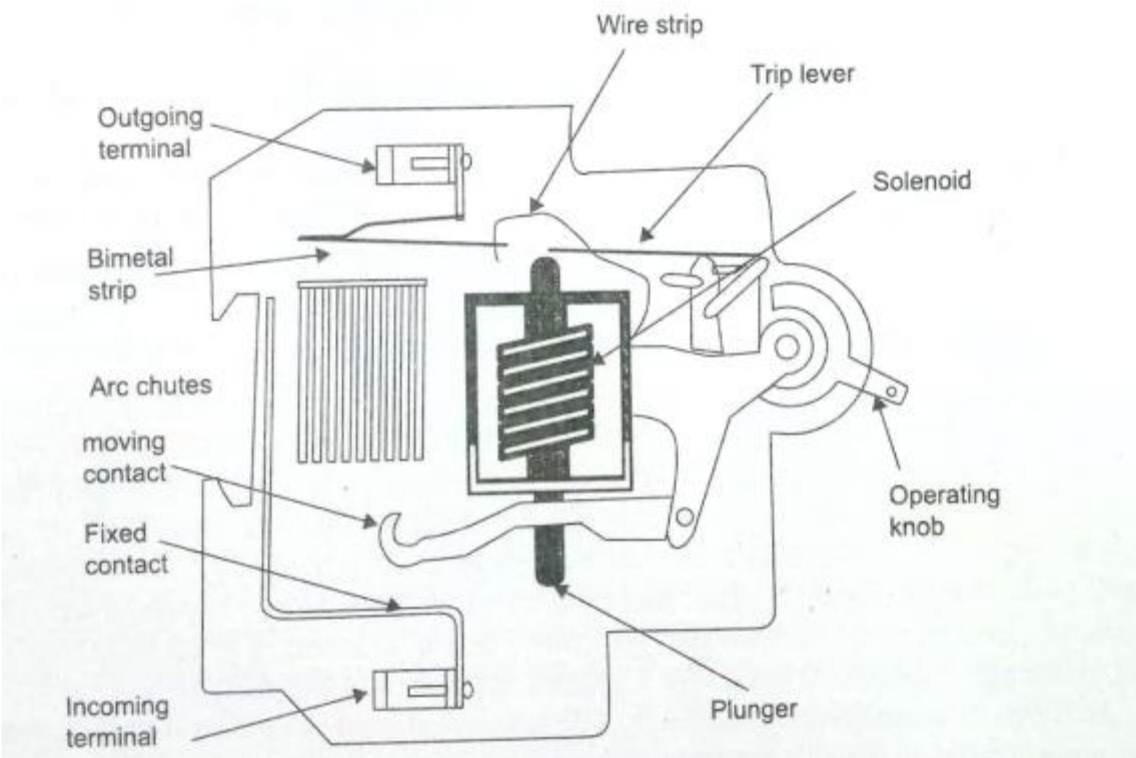
Operation:

It's mainly consists of bimetallic strip, one trip coil and one hand operated on-off lever.

If the circuit is overloaded for a long time the bimetallic strip becomes over heated and deformed. This deformation of bimetallic 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 release of spring and makes the moving contact to move for opening the MCB. The current coil our trip coil is placed in such a manner that during short circuit fault, the MMF of the coil causes its plunger to hit the same latch point and force the latch to be displaced. Hence, the MCB is opened in same manner.

When the moving contact is separated from the fixed contact, there may be a high chance of Arc. This Arc then goes up through the arc Runner and enters into the arc splitters and then finally quenched.





Advantages:

MCB are replacing the re-wearable switch.

MCB is a combination of three functions in a wiring system like switching, overloading and short circuit protection.

EARTH LEAKAGE CIRCUIT 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. An earth circuit breaker is a device used to directly detect currents leaking to earth from an installation and cut the power.

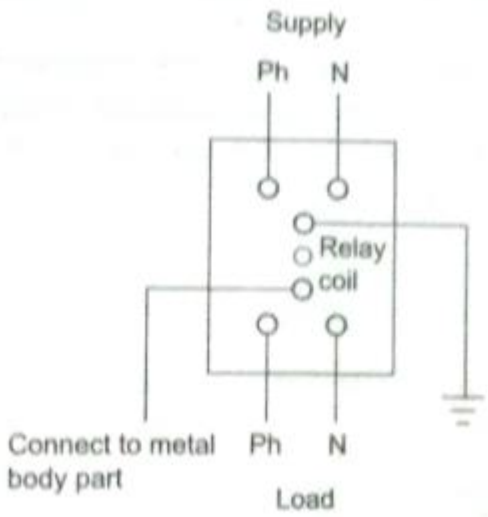
There are two types of ELCBs:

1. Voltage earth leakage circuit breaker

2. Current earth leakage circuit breaker

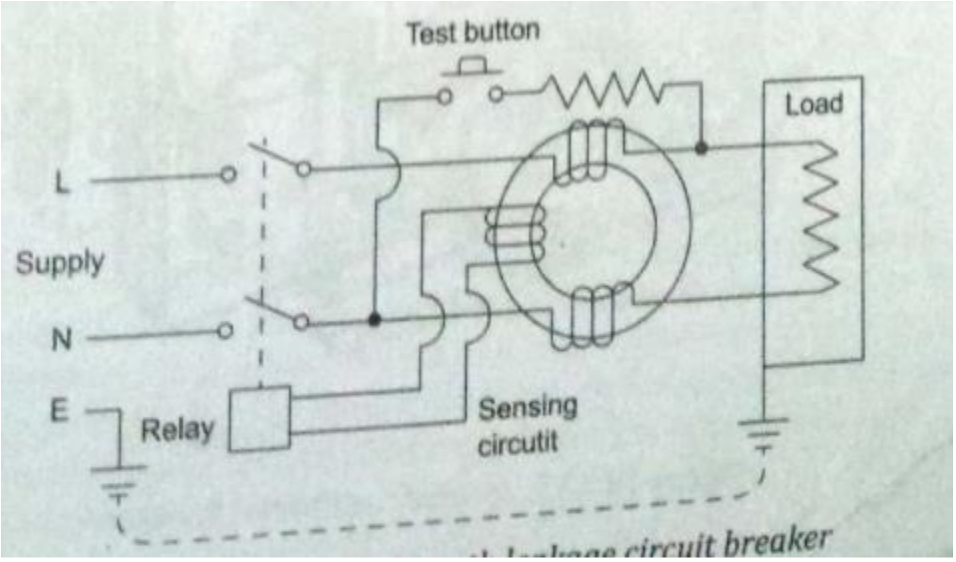
1. Voltage earth leakage circuit breaker

It is a voltage operated circuit breaker. The voltage-ELCB constricts relay coil and one end of the coil is connected to metallic load body and the other end is connected to the ground wire. If the voltage of the equipment body rises, which causes the difference between earth and load body voltage and the danger of electric shock will occur. This voltage differences will produce an electric current from the load metallic body and passes through the relay Loop to the earth. When the voltage on the equipment metallic body rises to danger level i.e., which exceeds 50V, the flowing current through the relay loop could move the relay contact by disconnecting the supply current to avoid from any danger electric shock.



2. Current earth leakage circuit breaker

It is the current operated circuit breaker which is commonly usually ELCB. Current-ELCB consists of a three winding transformer, which has two primary winding and one secondary winding. Neutral and line wires act as two primary winding. A wire wound coil is a secondary winding.



The current through the secondary winding is zero at a balanced condition. In the balance condition the flux due to the 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 written back to the neutral. When a fault occurs, a small current will flow through the ground also. This makes an imbalance between line and neutral currents and creates an unbalanced and magnetic field. This includes a current through secondary winding which is connected to secondary winding.

This will sense the leakage and sends a signal to the tripping system to trip the circuit.

MOLDED CASE CIRCUIT BREAKER (MCCB)

Molded case circuit breakers are electromechanical devices which protect a circuit from over current and short circuit. They provide over current and short circuit protection for circuit ranges from 63A to 3000A. The primary functions are to provide a means to manually open a circuit and automatically open a circuit under the overload and short circuit conditions respectively.

MCB is an alternative to your fuse, since it does not require replacement once and overload is detected.

Molded case circuit breaker generally have a

Thermal element for over current and

Magnetic element for short circuit, which has to be operated faster.

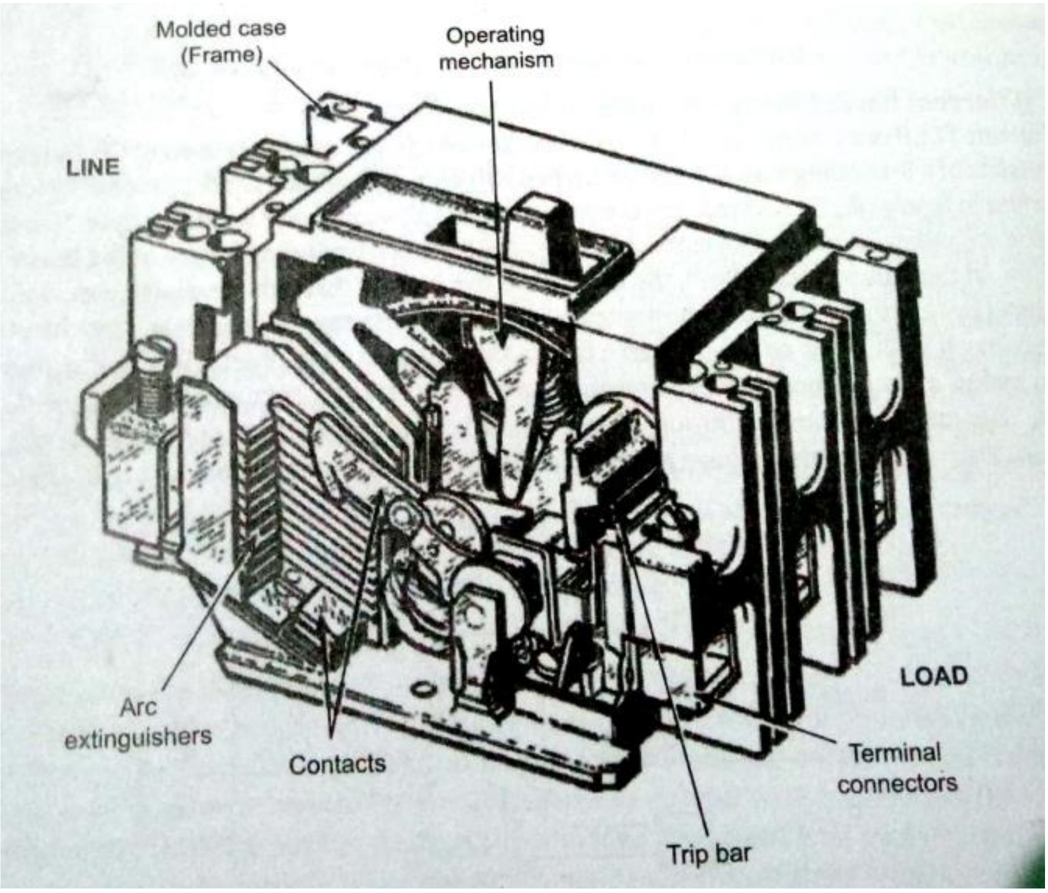
Operating mechanism:

MCCB is based on the same physical principle used by all type of thermal magnetic circuit breakers.

Overload protection is accomplished by means of a thermal mechanism. MCCBs have by metallic contact that expands and contracts in respond to change in temperature. Under normal operating current conditions the contacts allow electrical current flow 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 time delay to allow short duration of over current, which is a normal part of operation for many devices.

And the other hand, fault protection is accomplished by with electromagnetic induction and response is instant. 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.

MCCB includes a disconnection switch, which is used to trip the breaker manually. It is used whenever the Electric Supply must be disconnected to carry out fieldwork such as maintenance and equipments upgraded.



Applications:

Molded case circuit breaker can have very high current rating which allows them to be used in heavy duty applications such as main Electric feeder protection, capacitor Bank protection, generator protection, building applications, low current applications that require adjustable trip setting and motor protection.

BATTERY:

A battery is a device which converts chemical energy into electrical energy and is made up of a number of cells. Batteries consist of two or more voltaic cells that are connected in series to provide a steady DC voltage at the battery output terminals. The voltage is produced by a chemical reaction inside the cells. Electrodes are immersed in the electrolyte which forces the electric charge to separate in the form of ions and free electrons. A battery's voltage output and current ratings are determined by the elements used for the electrodes, the size of the electrodes and the type of electrolyte used.

Batteries are classified into two types such as primary batteries and secondary batteries.

Primary batteries:

These batteries are meant for single usage. Once these batteries are used they cannot be recharged as the devices are not easily reversible and active materials may not return to their original forms. Other name of these batteries is disposable batteries. Some of the examples for the Disposable batteries are the normal AA, AAA batteries which are used in wall clocks, television remote Etc.

Secondary batteries:

Secondary batteries are known as rechargeable batteries. These batteries can be used and charged simultaneously. A secondary battery or storage battery can be recharged because it's chemical reaction is reversible. Rechargeable batteries are recharged by applying electrical current which reverses the chemical reaction that occurs during discharging. Some of these examples are rechargeable batteries are batteries using mobile phones MP3 players Etc.

Types of Primary Cells/Batteries:

There are several types of primary cells are:

1. Carbon zinc Dry cell

2. Alkaline cell

3. Zinc chloride cell

4. Mercury cell

5. Silver oxide Cell

6. Lithium cell

(i) Carbon-zinc dry cell

- This is one of the most popular primary cells (often used for type AAA, AA, C, D).
- The negative electrode is made of zinc.
- The positive electrode is made of carbon.
- The output voltage of a single cell is about 1.5 V.
- Performance of the cell is better with intermittent operation.

(ii) Alkaline cell

- The alkaline cell is another popular type also used for type AA, C, D, etc.
- It has the same 1.5V output as carbon-zinc cells, but they are longer-lasting.
- It consists of a zinc anode and manganese dioxide cathode in an alkaline electrolyte (potassium hydroxide).
- It works with high efficiency even with continuous use, due to low internal resistance.

(iii) Zinc chloride cell

- This cell is also referred to as a "heavy-duty" type battery.
- It is a modified zinc-carbon cell.
- It has little chance of liquid leakage because the cell consumes water along with the chemically active materials. The cell is usually dry at the end of its useful life.

(iv) Mercury cell

- This cell consists of a zinc anode, mercury compound cathode, and potassium or sodium hydroxide electrolyte.
- It is becoming obsolete due to the hazards associated with proper disposal of mercury.

(v) Silver oxide cell

- This cell consists of a zinc anode, silver oxide cathode, and potassium or sodium hydroxide electrolyte.
- It is typically available as 1.5V, miniature button form.
- Applications include hearing aids, cameras, and watches

(vi) Lithium cell

- This cell offers high output voltage, long shelf life, low weight, and small volume.
- It comes in two forms of 3V output in widespread use:
  (a) Lithium-sulfur dioxide ($LiSO_2$).
  (b) Lithium-thionyl chloride.
- $LiSO_2$ type batteries contain methyl cyanide liquid solvent; if its container is punctured or cracked, it can release toxic vapors.
- Safe disposal of these cells is critical.

8.8.2 Types of Secondary Cells/Batteries

There are several types of secondary cells in use today, such as

(i) Lead-acid cell
(ii) Nickel cadmium (NiCd) cell
(iii) Lithium-ion battery
(iv) Nickel-metal-hydride (NiMH) cell
(v) Nickel-iron (Edison) cell
(vi) Fuel cell
(vii) Solar cell

(i) Lead-acid cell

- This cell is a widely applied type of secondary cell, used extensively in automobiles, inverters, backup power systems, etc. requiring high values of load current.
- Anode: Porous lead
- Cathode: Lead-dioxide
- Electrolyte: Sulfuric acid, 6 molar H_2SO_4
- The output is about 2.1 V per cell.
- Cells are typically used in series combinations of 3 (6V battery) or 6 (12V battery).

(ii) Nickel Cadmium (NiCd) cell

- This type of cell delivers high current.
- It can be recharged many times.
- Anode: Nickel hydroxide, $Ni(OH)_2$
- Cathode: Cadmium hydroxide, $Cd(OH)_2$
- Electrolyte: Potassium hydroxide, KOH
- Maintain a steady voltage of 1.2V per cell until completely depleted
- It can be stored for long periods of time.
- Its specific gravity does not change with the state of charge.
- Applications include portable power tools, alarm systems, portable radio and TV equipment.

(iii) Lithium-Ion Battery

- Li-based cells are most compact ways of storing electrical energy.
- Lower in energy density than lithium metal, lithium-ion is safe.
- Anode: Graphite
- Cathode: Lithium manganese dioxide
- Electrolyte: mixture of lithium salts
- Energy density is twice of the standard nickel-cadmium.
- No memory and no scheduled cycling is required to prolong battery life.

(iv) Nickel-Metal-Hydride (NiMH) cell

- These cells are used in applications demanding long-running battery performance (e.g., high-end portable electrical or electronic products like power tools).
- They offer 40% more capacity over a comparably-sized NiCd cell.
- They contain the same components as a NiCd cell, except for the negative electrode.
- They are more expensive than NiCd cells, self-discharge more rapidly, and cannot be cycled as frequently as NiCd cells.

(v) Nickel-Iron (Edison) cell

- Anode: Nickel hydroxide, $Ni(OH)_2$
- Cathode: iron
- Electrolyte: potassium hydroxide
- The specific gravity of electrolyte remains unaffected during the charging and discharging process.
- They are now almost obsolete due to lead-acid batteries.
- These are used in emergency lamps in hospitals and at places where the rate of discharge and charge are rapid.

(vi) Fuel cell

- A fuel cell is an electrochemical device that converts chemicals (such as hydrogen and oxygen) into water and produces electricity in the process.
- As long as the reactants (H and O) are supplied to the fuel cell, it will continually produce electricity and never go dead, unlike conventional batteries.
- Fuel cells are used extensively in the space program as sources of DC power.
- They are very efficient; capable of providing hundreds of kilowatts of power.

(vii) Solar cell

- Solar cells convert the sun's light energy into electric energy.
- They are made of semiconductor materials.
- They are arranged in modules that are assembled into a large solar array to produce the required power.
- An applied voltage higher than the voltage of one cell can be obtained by connecting cells in series.
- The total voltage available across the battery of cells is equal to the sum of the individual values for each cell.
- Parallel cells have the same voltage as one cell but have more current capacity.
- To provide a higher output voltage and more current capacity, cells can be connected in series-parallel combinations.

8.8.3. Comparison of Primary and Secondary Cells

S. No.	Primary Cell	Secondary Cell
01	If discharged once cannot be charged again	If discharged once can be charged again
02	Light in weight	Heavy in weight
03	Used for intermittent use with low load current rating	Used for continuous rating with high load current rating
04	Short life	Long life
05	Low cost	High cost
06	Low efficiency	High efficiency
07	Low power output	High power output
08	Less maintenance	More maintenance

8.8.4 Battery Characteristics

There are many characteristics that can help to identify a battery and we can distinguish the three main ones as: chemistry, battery capacity and voltage. However, if the battery is only a starter, it also delivers cold cranking amps (CCA), which permits to offer high current at cold temperatures.

(i) Chemistry

The main battery chemistries are lead, nickel and lithium. They all need a specific designated charger, this is why charging these batteries on a different charger from their own might cause an incorrect charge, despite it seeming to work at first. This happens because of the different regulatory requirement of each chemistry.

(ii) Battery Capacity

Battery capacity is a measure (typically in Amp-hr) of the charge stored by the battery, and is determined by the mass of active material contained in the battery. The battery capacity represents the maximum amount of energy that can be extracted from the battery under certain specified conditions. However, the actual energy storage capabilities of the battery can vary significantly from the "nominal" rated capacity, as the battery capacity depends strongly on the age and past history of the battery, the charging or discharging regimes of the battery and the temperature.

The energy stored in a battery, called the battery capacity, is measured in either watt-hours (Wh), kilowatt-hours (kWh), or ampere-hours (Ahr). The most common measure of battery capacity is Ah, defined as the number of hours for which a battery can provide a current equal to the discharge rate at the nominal voltage of the battery. The unit of Ah is commonly used when working with battery systems as the battery voltage will vary throughout the charging or discharging cycle.

(iii) Voltage

A battery features a nominal voltage. Along with the amount of cells connected in series, chemistry provides the open circuit voltage (OCV), which is about 5-7% higher on a fully charged battery. It is important to check the correct nominal voltage of a battery before connecting it.

(iv) Cold Cranking Amps (CCA)

Every starter battery is marked with cold cranking amps, also abbreviated CCA. The number denotes the amount of amps that the battery is able to provide at $-18°C$.

8.9 Power Factor Improvement

The cosine of angle between voltage and current in an AC circuit is known as power factor. It refers to the fraction of total power (apparent power) which is utilized to do the useful work called active power. In an AC circuit, there is generally a phase difference ϕ between voltage and current. The term $\cos\phi$ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and power factor is said to be leading.

$$\cos\phi = \frac{\textit{Active power}}{\textit{Apparent power}}$$

8.9.1 Disadvantages of Low Power Factor

The power factor plays an importance role in AC circuits since power consumed depends upon this factor.

$$P = VI\cos\phi$$

$$\Rightarrow \cos\phi = \frac{P}{VI}$$

It is clear from above that for fixed power and voltage, the load current is inversely proportional to the power factor. Lower the power factor, higher is the load current and vice versa. A power factor less than unity results in the following disadvantages:

(i) Overloading of cables and transformers
(ii) Greater conductor size
(iii) Large copper losses
(iv) Poor voltage regulation i.e., decreased line voltage at point of application
(v) Reduces the handling capacity of all the elements of the system.

8.9.2 Causes of Low Power Factor

Low power factor is undesirable from economic point of view. Normally, the power factor of the whole load on the supply system in lower than 0.8. The following are the causes of low power factor:

(i) Most of the AC motors are of induction type (1-phase and 3-phase induction motors) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0.2–0.3) and rises to 0.8 or 0.9 at full load.
(ii) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.
(iii) The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetisation current. This results in the decreased power factor.

8.9.3 Methods of Improving Power Factor

Normally, the power factor of the whole load on a large generating station is in the region of 0.8–0.9. However, sometimes it is lower and in such cases it is generally desirable to take special steps to improve the power factor. This can be achieved by the following methods:

(i) Static capacitors

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. The 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. They reduce the phase difference between the voltage and current.

(ii) Synchronous Condenser

A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load. Thus the power factor is improved.

(iii) Phase Advancer

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

8.10 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 is the amount of electrical current that results from a certain amount of voltage or we can say that power is the rate at which energy is delivered. It is measured in watts. Mathematically it is written as

$$Power = Voltage \times Current$$

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 is required. So, the unit used for electrical energy is watt-hour.

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

$$Energy = Power \times Time$$

$$1\ Joule = 1\ watt \times 1\ \text{second}$$

Watts are the basic unit of power in which electrical power is measured or we can say that rate at which electric 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.

$$\textit{Energy in watt hours} = \textit{Power in watts} \times \textit{Time in hours}$$

Kilowatt-hour is simply a bigger unit of energy when large appliances 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

$$\textit{Energy in kilowatt hours} = \textit{Power in kilowatts} \times \textit{Time in hours}$$

The electrical supply companies take electric energy charges from their consumer per kilowatt hour unit basis. 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 many units (kWh) of electrical energy have been used?

Explanation: 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

$$\therefore \textit{Energy consumed} = \textit{Power in kW} \times \textit{Time in hours}$$
$$= 16.5 \times 15 = 247.5\ kWh$$

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

$= 247.5 \times 2.5 =$ ₹ 618.75/-

EXAMPLE - 6

A house has the following loads (Oct/Nov. 2011)

(a) 10 Lamps of 60 W working for 5 hour a day.

(b) 4 lamps of 100 W each working

(c) 2 Heaters of 1000 W each working for 3 hour a day.

(d) 5 Fans of 100 W each working for 12 hour a day.

Solution :

S.No.	Particular	Quantity	No. of hours per day	Wattage (w)	Total power in watts	Total energy in watt-hour
1	2	3	4	5	6 = 3 × 5	7 = 4 × 6
1	Lamps	10	8	60	600	4800
2	Lamps	4	5	100	400	2000
3	Heaters	2	3	1000	2000	6000
4	Fans	5	12	100	500	6000
					Total	18,800

Total energy consumption / day $= 18800 \text{ w-h} = \frac{18800}{1000} = 18.8 \text{ kwh}$

$= 18.8$ units ($\because$ 1kwh = 1 unit)

Total energy consumption/month $= 18.8 \times 30 = 564$ units

Cost of energy @ 50 paise/unit $= \frac{564 \times 50}{100} =$ **Rs. 282/-.**

EXAMPLE - 3

A heater immersed in water has a resistance of 125 Ω and is connected to a 500V d.c. supply. Calculate

(i) The current taken

(ii) The power in watts

(iii) The kilowatt - hours of energy taken into the water in 45 minutes.

Solution :

Given data :

$R = 125\,\Omega$

$V = 500\text{ V}$

$t = 45$ min

(i) Current $I = \frac{V}{R} = \frac{500}{125} = 4\text{ A}$

(ii) power $P = VI = 500 \times 4 =$ **2,000 watts**

(iii) Kilowatt-hour,

$$kwh = \frac{2000}{1000} \times \frac{45}{60} = 1.5\ kwh$$

(or) $= 1.5$ unit ($\because$ 1 kwh = 1 unit)