Unit-3

Electrical Energy Consumption and Safety Measures:

Major Electrical Loads, DC motor - Construction and Working principle, Torque equation, AC motor - Working principle of 3-phase Induction motor, slip - Other electrical machines: Stepper motor, BLDC Motor.

Electrical Safety: Electric Shock, Safety Precautions to avoid shock, Earthing and its types Domestic protective device: Fuse, Miniature circuit breaker(MCB) and Earth leakage circuit breaker (ELCB).

Major Electrical Loads

When we discuss the power and how it is used in technologically advanced power system applications, we commonly refer to the electrical load. One of the fundamental principles of electrical energy and transmission in any circuit is electrical loads.

What is an Electrical Load?

The electric load is the device that consumes electrical energy. In other words, it is a device that converts electrical energy from current into different forms, such as heat, light, work, and so on. The electrical load could be resistive, inductive, capacitive, or combined. The term load is used in a variety of contexts.

- To signify a device or a group of devices that use electrical energy.
- Demonstrate the power required from a given supply circuit.
- The electrical load represents the current or power flowing through the line or machine.

The Different Types of Electrical Loads

Resistive Load: Resistive loads include any type of heating element. Best examples are Incandescent lights, toasters, ovens, space heaters, and coffee makers. A purely resistive load draws current in a sinusoidal waxing-and-waning pattern in tandem with a sinusoidal variation in voltage - that is, the maximum, minimum, and zero points of the voltage and current values over time line up - and contains no other elements.

Inductive Load: Inductive loads provide power to electric motors. Examples are moving parts Fans, vacuum cleaners, dishwashers, washing machines, compressors in refrigerators and air conditioners, and other household items and gadgets. In contrast to resistive loads, purely inductive loads have maximum, minimum, and zero points out of phase because the current follows a sinusoidal pattern and peaks after the voltage sine wave.

Capacitive Load: Like an inductive load, the capacitive load has both current and voltage waves. The critical difference between a capacitive and inductive load is that the current peaks before the voltage. Capacitive load elements have the highest power factors and are frequently used to power up electrical circuits.

Unlike inductive and resistive loads, Capacitive loads will not exist in isolation. Capacitive loads are used in tandem with other electrical loads, particularly inductive loads.

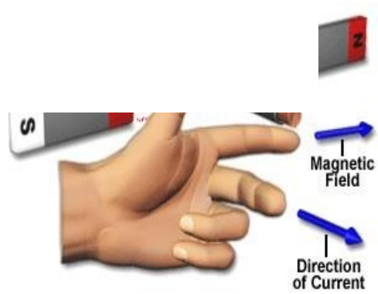
DC Motor:

A direct current motor (DC motor) is defined as an electrical machine that converts electrical energy into mechanical energy. Based on the definition above, we can conclude that a DC motor is defined as an electric motor that operates on direct current. A DC motor is an electric motor that runs on direct current (DC), unlike an induction motor that operates via an alternating current.
It operates on the Lorentz principle, which states that "a current-carrying conducter placed in a magnetic and electric field experiences a force." That force is known as the Lorentz force . Fleming's Left-hand Rule determines the direction of the mechanical force.

Working principle or Principle of Operation for DC Motor

The operation of a direct current (DC) motor is based on the principle that when a current-carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of force is given by Fleming's left-hand rule and the magnitude of this force is given by:

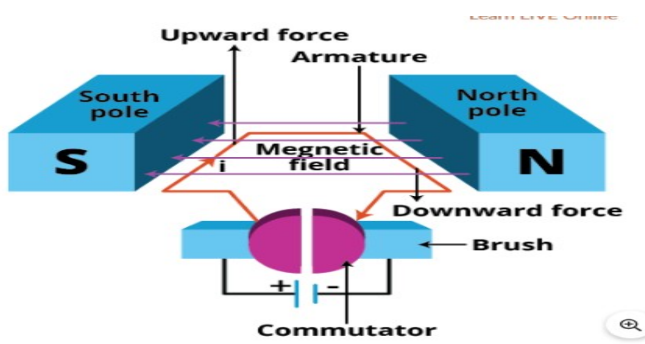
F= BIL Newtons
Where B is a magnetic field, I is current and L is the length of the conductor.
According to Fleming's Left Hand Rule, if we arrange our thumb, forefinger and middle finger of the left-hand perpendicular to each other, the thumb will point in the direction of the magnetic force, the forefinger will point in the direction of the magnetic field and the middle finger will point in the direction of the current.



Basic Motor Operation Function

The field magnets are excited, resulting in the formation of alternate North and South poles.Currents are carried by armature conductors.
A mechanical force acts on each armature conductor because it is carrying current and is placed in the magnetic field. Using Fleming's left-hand rule, it is clear that the force on each conductor tends to rotate the armature anticlockwise. All of these forces combine to create a driving torque that sets the armature to rotate.

The current in a conductor is reversed when it moves from one side of a brush to the other. At the same time, it is influenced by the next pole, which has the opposite polarity. As a result, the direction of the force on the conductor remains constant. It should be noted that the function of a commutator in a motor is the same as that of a commutator in a generator. It helps to develop a continuous and uni-directional torque by reversing the current in each conductor as it passes from one pole to another.



Simple DC motor

Application of DC Motor

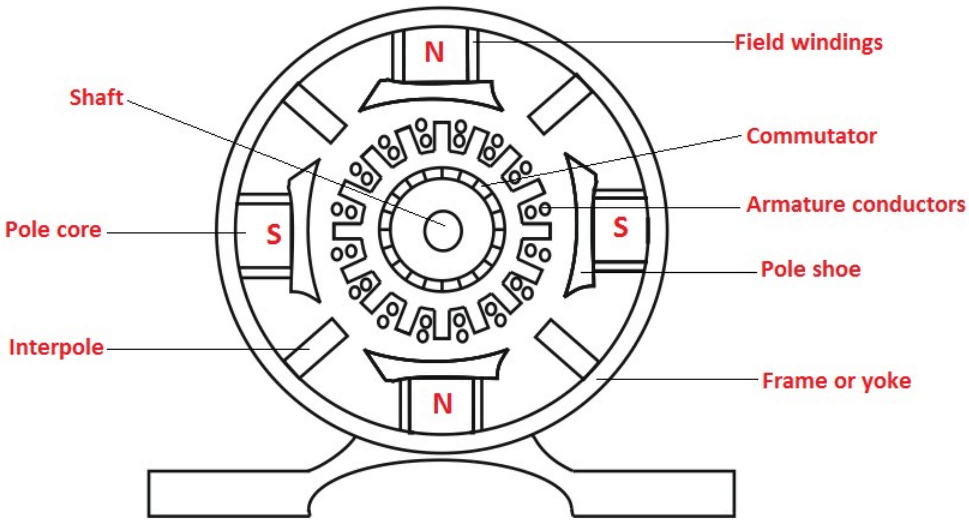
A direct current motor is a type of motor in which we use a permanent magnet to generate the necessary magnetic field. As this motor does not need to control the speed, it is used in applications like:

- Washer
- Automobiles as a starter motor
- Personal computer disc drives
- Toys
- Wheelchairs
- Blowers in heater and air conditioners.

CONSTRUCTION OF DC Motor:

Dc machines have five principal components:

1. **Magnetic frame or Yoke**
2. **Pole Cores, Pole Shoes and Field Coils**
3. **Armature core and Armature Winding**
4. **Commutator**
5. **Brushes and Bearings**



<u>Yoke (Magnetic Frame)</u>

The outer frame or yoke serves a double purpose:

1. **It provides mechanical support for the poles and acts as a protecting cover for the whole machine**
2. **It carries the magnetic flux produced by the poles.**

<u>Pole Cores and Pole Shoes</u>

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes:

1. **They spread out the flux in the air gap and, being of larger cross-section, reduce the reluctance of the magnetic path**
2. **they support the exciting coils (or field coils) as shown**

<u>Armature core</u>

- **Armature core is designed as the rotating part and is built in cylindrical or drum shape with slots on its outer periphery.**

- The purpose of armature is to house the winding and to rotate the conductors in the uniform magnetic field. It is mounted on the shaft.
- It is built up of steel lamination which are insulated by each other by thin paper or thin coating of varnish as insulation.
- The thickness of each lamination is about 0.5 mm. These lamination will reduce the eddy current loss.
- If silicon sheet is used for armature core, the hysteresis loss will also reduce.

Armature winding

- The armature winding or coil is placed on slots available on the armature's outer periphery.
- The ends of the coils are joined with commutator segments.
- Insulated higher conductivity copper wire is used for making the coils.
- There are two types of winding.
- lap winding – Lap winding is used for high current, low voltage generators.
- Wave winding – Wave winding is used for high voltage, low current generators.

Commutator

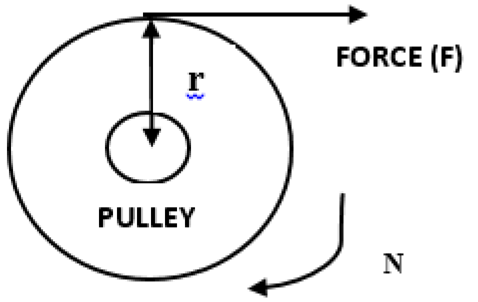
- The commutator provides the electrical connection between the rotating armature coil and the stationary external circuit.
- It is essentially a cylindrical structure and is built up of wedge-shaped copper segments insulated from each other by mica sheets and mounted on the shaft of the machine.
- The commutator is a mechanical rectifier which converts the alternating emf generator in the armature winding into direct voltage across the brushes.
- The ends of the armature coil or winding are connected to commutator segments

Brushes and Bearings

- The function of brush is to collect the current from the commutator and supply it to the external load circuit.
- The brushes are manufactured in a variety of compositions to suit the commutation requirements.
- It is made of carbon, graphite metal graphite or copper and is rectangular in shape.

Torque Equation of DC Motor

Torque is defined as twisting moment of force about an axis, it is the product of force and the radius at which the force acts.



Let us consider a pulley of radius 'r' meters acted upon by circumferential force 'F' newton's rotating at a speed of 'N' rpm

From the definition of Torque $T = F \times r$........................(1)

Work done by this this force in one revolution = Force$\times$distance

$$W = F \times 2\pi r \text{....................(2)}$$

Power developed in the Pulley= work done $\times$ speed in radians per sec

$$P = F \times 2\pi r \times \frac{N}{60} \; joule/\sec(\text{or}) \; watt$$

$$P = (F \times r)\frac{2\pi N}{60} \; watt$$

$$P = T \times \frac{2\pi N}{60} \; watt \text{.................(3)}$$

If T_a is the Torque developed in the armature and P_a is the power developed in the armature then from equation (3).

$$P_a = T_a \times \frac{2\pi N}{60} \; watt \text{..................(4)}$$

Torque in DC Motor ,

$$\boxed{\therefore T_a = 9.55 \times \frac{E_b I_a}{N} (N - m)}.$$

Where

Three Phase Induction Motor

Three-phase induction motors are the most common machines used in industry.

- simple design, rugged, low-price, easy maintenance.
- wide range of power ratings: fractional horsepower to 10 MW.
- run essentially as constant speed from zero to full load.
- not easy to have variable speed control

An induction motor has two main parts

1. **STATOR:** a stationary part of the motor is known as stator.

- It consist of a steel frame that supports a hollow, cylindrical core.
- The core, constructed from stacked laminations, having a number of slots, providing the space for the stator winding.

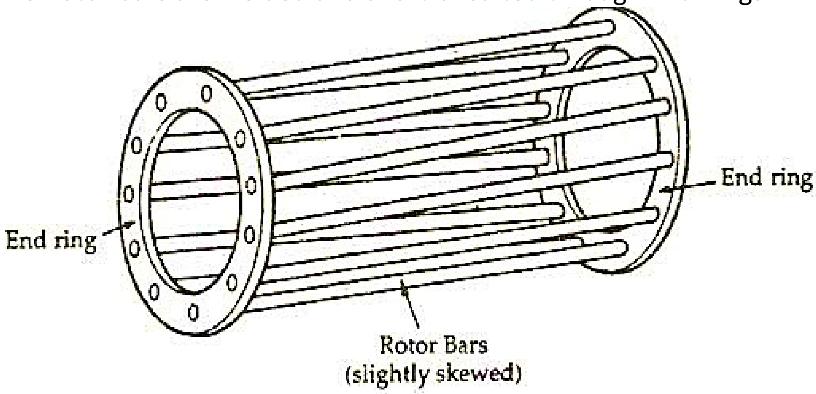
b) ROTOR: Rotating part in 3-ϕ Induction motor. – Rotor is classified into two types depending upon the starting torque.

(i) Squirrel-Cage Rotor

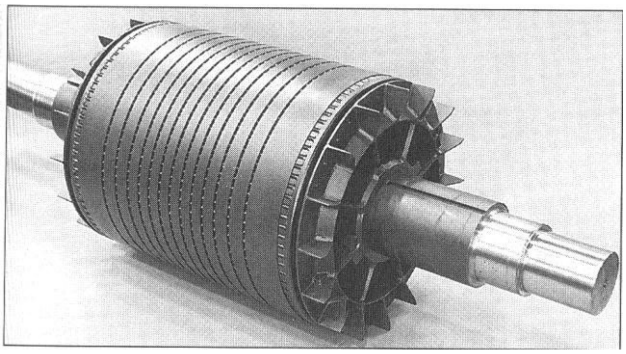
(ii) Slip-Ring (or) wound Rotor.

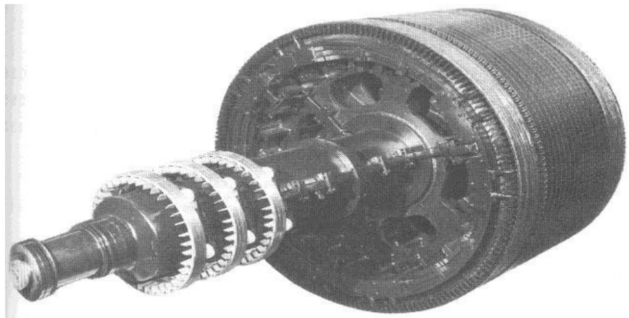
i. **Squirrel-Cage Rotor:** Almost 90 percent of Induction motors are SquirrelCage type because this type of Rotor has the simplest, most Rugged construction and almost indestructibleTwo basic design types depending on the rotor design .

- The Rotor consists of a cylindrical laminated core with parallel slots for carrying the Rotor conductors.
- Each slot consists of heavy bars of copper, aluminum (or) alloys.
- The Rotor bars are welded and short-circuited through End Rings.



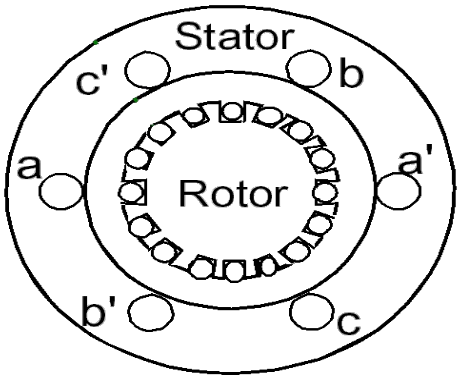
ii. **Slip-Ring (or) Wound Rotor:** Construction of wound Rotor is similar to Squirrel Cage type Rotor but the rotor conductors are not permanently short circuited by End Rings.It means there is a possibility of adding EXTERNAL Resistance through SlipRings and starting Torque can be improved.





Principle of operation:-

It works on the principle of "Mutual Induction". The Stator of three phase induction motor is connected to a balanced 3-ϕ supply from mains.



When a balanced 3-ϕ ac supply connected to Stator winding a rotating magnetic field is produced an speed of rotating magnetic field given by $N_s = 120f/P$ r.p.m

Where f - supply frequency, P – number of poles of Stator.

- This rotating magnetic field passes through air gap and cuts the stationary Rotor conductors
- According to Faraday's laws of Electro Magnetic Induction an EMF is induced in the Rotor conductors. As the Rotor circuit is a closed path i.e., short circuited. The induced EMF gives rise to flow of current in Rotor conductors.

- The interaction of the Rotor current with rotating magnetic field a Torque is produced in Rotor and as a consequence Rotor begins to ROTOR. Hence, the rotating magnetic flux (or) field produced in Stator induced EMF in Rotor shows the three phase induction motor works on "Mutual Induction" principle.
- Now, according to Lenz's law, 'Effect opposes the cause" here the effect is developed Torque and cause in flux cutting action by Rotor conductors. Therefore the developed Torque forces the Rotor to rotate in the direction of rotating magnetic field (STATOR field) as per Lenz's law.
- When this happens the relative speed between rotating flux and Rotor conductors reduces and therefore flux cutting action also reduces
- For example, if the rotor of 3-ϕ induction motor rotates at 'n_r' r.p.s in the direction of rotating magnetic field 'n_s' r.p.s.
- The relative speed between rotating flux and Rotor is (n_s-n_r) r.p.m and flux cutting action reduces from "p_{Ns}" at starting to "p (n_s-n_r)" during running condition as per Lenz's law.
- This shows that Rotor rotates in the direction of rotating magnetic field.
- If the speed of Rotor rotates is "n_s" as the Stator flux speed i.e., both Stator flux and Rotor rotates at same speed, the relative speed is [(n_s-n_s) =0] is zero and flux cutting action p(n_s-n_r)=0 i.e., no flux cutting action, hence no EMF induced and no Torque will produced.
- Hence, 3-ϕ induction motor never rotates at synchronous speed. Therefore, it is known as Asynchronous Motor.

Synchronous Speed N_s:

The speed at which the flux produced by stator of 3-ϕ induction motor rotates is called "synchronous speed" (or) speed of rotating magnetic field.

$$N_S = \frac{120 f_s}{P} \text{ r.p.m}$$

Where, f_S - supply frequency, P – number of poles of Stator.

Slip (s): The difference between the synchronous speed (N_S) (or) speed of rotating magnetic field and the actual Rotor speed (N_r) is known as slip. It is denoted by 's'.

$$\boxed{\% \quad \text{slip}(s) = \frac{(N_S - N_r)}{N_S} \times 100}$$

When $(N_s - N_r) \Rightarrow$ slip (s) =0 we know, $s = \frac{(N_s - N_r)}{N_s}$ $\Rightarrow$ $s = 1 - \frac{N_r}{N_S}$ $\Rightarrow$ $\frac{N_r}{N_S} = 1 - S$

$$\therefore \text{Rotor speed}\left(N_r\right) = N_S\left(1 - S\right)$$

Notice that: if the rotor runs at synchronous speed $s = 0$ if the rotor is stationary $s = 1$
Note: the slip is a ratio and doesn't have units

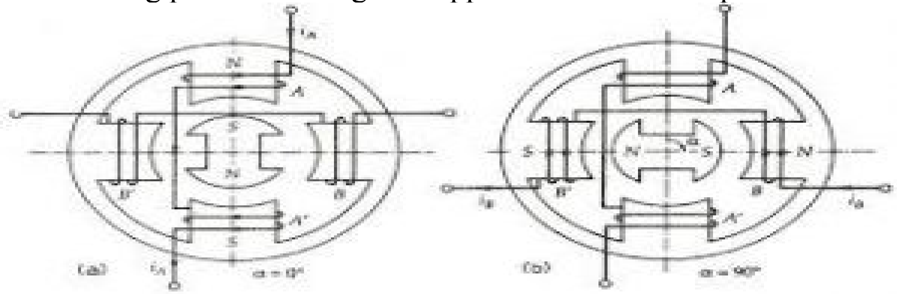
Other Electrical Machines:

Stepper Motor:

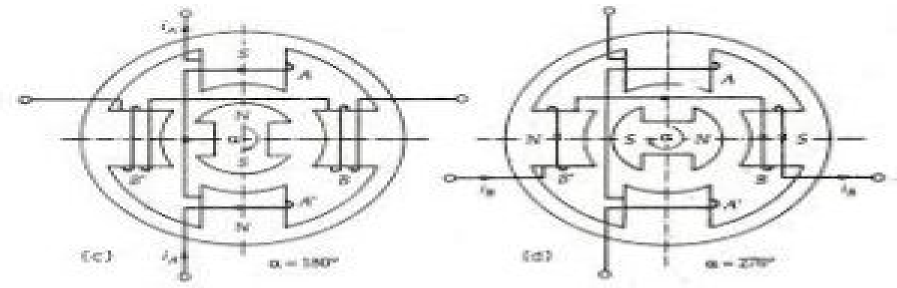
What is a stepper motor?
A **Stepper Motor** or a **step motor** is a brushless, synchronous motor which divides a full rotation into a number of steps. Unlike a brushless DC motor which rotates continuously when a fixed DC voltage is applied to it, a step motor rotates in discrete step angles. The **Stepper Motors** therefore are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in stepping angles of 30, 15, 5, 2.5, 2, and 1.8 degrees per step. The stepper motor can be controlled with or without feedback.
Types of Stepper Motor
By construction the step motors come into three broad classes:
1. Permanent Magnet Stepper
2. Variable Reluctance Stepper
3. Hybrid Step Motor

Principle of Stepper Motor:
The working principle of the stepper motor is similar to that of a conventional motor. It works on the principle of Lorentz Force law. According to which, whenever a current-carrying conductor is placed in a magnetic field, it experiences a force, due to the interaction of fluxes.
The flux which interacts is stator magnetic flux and rotor magnetic flux. The stator magnetic flux is created due to external excitations and the rotor magnetic flux is created due to permanent magnets. It is also to be noted that, the direction of the motor is governed due to Fleming's left-hand rule.
Working of Permanent Magnet Stepper Motor

The working permanent magnet stepper motor can be explained in the following modes



Mode 1– In this mode, the A phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the B phase is not excited at all. When the A phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles.
Mode 2 – In this mode, the B phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the A phase is not excited at all. When the B phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. Which makes the rotor rotate in the clockwise direction from Mode 1.



Mode 3 – Again In this mode, the A phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the B phase is not excited at all. When the A phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. It makes the rotor rotate in the clockwise direction from mode 2.
Mode 4– Again In this mode, the B phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the A phase is not excited at all. When the B phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. Which makes the rotor rotate in the clockwise direction from Mode 3.
In this manner, the rotor makes one complete revolution from mode 1 to mode 4.

Advantages:

The **advantages of stepper motor** include the following.

- Ruggedness
- Simple construction
- Can work in an open-loop control system
- Maintenance is low
- It works in any situation
- Reliability is high
- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill.
- Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is noncumulative from one step to the next.

The **disadvantages of stepper motor** include the following.

- Efficiency is low
- The Torque of a motor will declines fast with speed
- Accuracy is low
- Feedback is not used for specifying potential missed steps
- Small Torque toward Inertia Ratio

Applications:

The **applications of stepper motor** include the following.

1. **Industrial Machines** – Stepper motors are used in automotive gauges and machine tooling automated production equipment.
2. **Security** – new surveillance products for the security industry.
3. **Medical** – Stepper motors are used inside medical scanners, samplers, and also found inside digital dental photography, fluid pumps, respirators, and blood analysis machinery.
4. **Consumer Electronics** – Stepper motors in cameras for automatic digital camera focus and zoom functions.

And also have business machines applications, computer peripherals applications.

BLDC Motor:

What is Brushless DC motor?

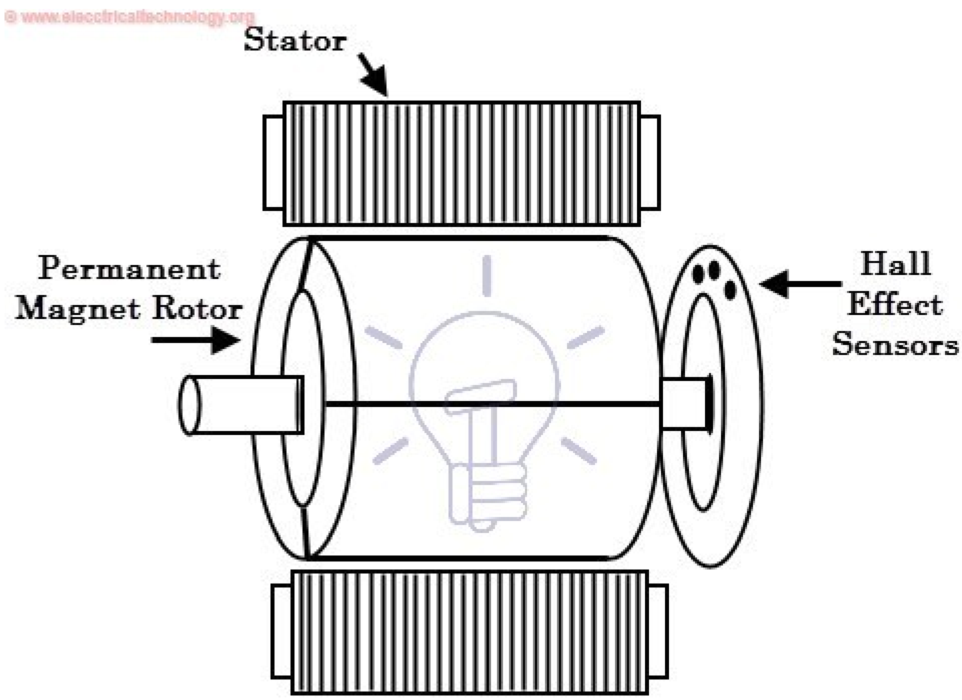
Brushless DC electric motors also known as electronically commutated motors (ECMs, EC motors).

Primary efficiency is a most importent feature for BLDC motors. Because the rotor is the sole bearer of the magnets and it doesn't require any power. i.e. no connections, no commutator and no brushes. In place of these, the motor employs control circuitry. To detect where the rotor is at certain times, BLDC motors employ along with controllers, rotary encoders or a Hall sensor.

Construction of Brushless DC motor

In this motor, the permanent magnets attach to the rotor. The current-carrying conductors or armature windings are located on the stator. They use electrical commutation to convert electrical energy into mechanical energy.

The main design difference between a brushed and brushless motors is the replacement of mechanical commutator with an electric switch circuit. A BLDC Motor is a type of synchronous motor in the sense that the magnetic field generated by the stator and the rotor revolve at the same frequency.



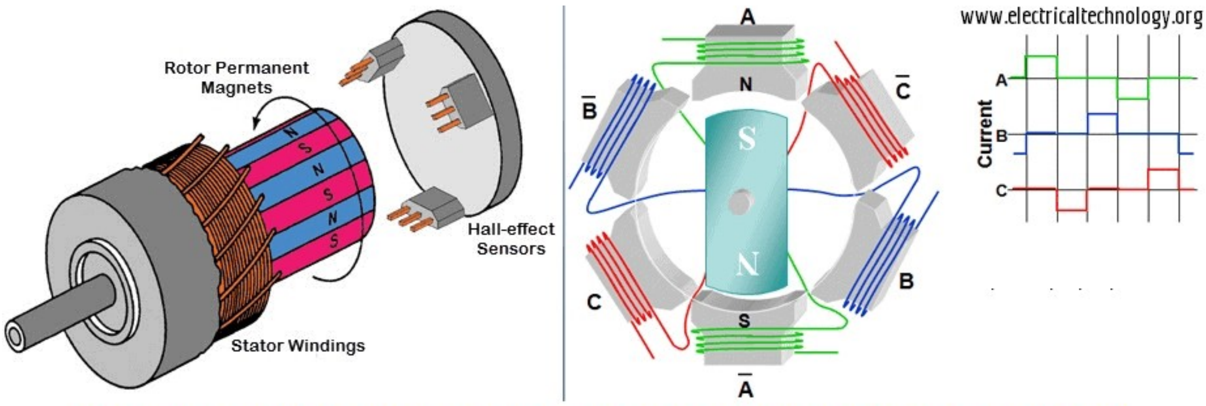
Brushless motor does not have any current carrying commutators. The field inside a brushless motor is switched through an amplifier which is triggered by the commutating device like an optical encoder.

The layout of a DC brushless motor can vary depending on whether it is in "Out runner" style or "Inrunner" style.

- **Outrunner** – The field magnet is a drum rotor which rotates around the stator. This style is preferred for applications that require high torque and where high rpm isn't a requirement.
- **In runner** – The stator is a fixed drum in which the field magnet rotates. This motor is known for producing less torque than the out runner style, but is capable of spinning at very high rpm.

Working Principle of Brushless DC motor

BLDC motor works on the principle similar to that of a **Brushed DC motor**. The Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force. In the BLDC motor, the current carrying conductor is stationary and the permanent magnet is moving.



Construction, Working Principle & Operation of BLDC Motor (Brushless DC Motor)

When the stator coils get a supply from source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate.

With the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles which causes the motor to rotate.

Advantages of Brushless DC motor

- Less overall maintenance due to absence of brushes
- Reduced size with far superior thermal characteristics
- Higher speed range and lower electric noise generation.
- It has no mechanical commutator and associated problems
- High efficiency and high output power to size ratio due to the use of permanent magnet rotor
- High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed
- Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors.
- Long life as no inspection and maintenance is required for commutator system
- Higher dynamic response due to low inertia and carrying windings in the stator
- Less electromagnetic interference
- Low noise due to absence of brushes

Limitations of Brushless DC motor

- These motors are costly
- Electronic controller required control this motor is expensive
- Requires complex drive circuitry
- Need of additional sensors

Applications of Brushless DC motor

Brushless DC motors (BLDC) use for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments etc.

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers
- Fans, pumps and blowers.

ELECTRIC SHOCK

When a person comes in contact with a live conductor, directly or indirectly, he gets a shock. The shock may be minor or severe. The severity of shock depends upon the following:
1. Nature of the current whether AC or DC: Since DC flows continuously and does not pass through zero current value as in AC, so DC is considered more dangerous than AC supply.

2. Duration of flow of current: Shock will be more severe if duration of contact with the live wire of a person is more. However, the severity of shock can be reduced by disengaging the person from live wire contact immediately.

3. Path of current through human body: Severity of shock also depends upon the path of the electric current through human body. A person has severe shock if current path involves his heart. The effect of electric current when passes through human body is given in Table

Effect of Electric Current Through Human Body

1–10 mA	Prickling sensations
10 mA	Muscle contraction: The person remains 'stuck' to the conductor
20–30 mA	Muscles contraction can cause respiratory paralysis
70–100 mA	Cardiac fibrillation: The heart begins to vibrate and no longer beats at steady rate. This situation is dangerous since it is irreversible.
500 mA	Immediate cardiac arrest resulting in death

PRECAUTIONS AGAINST ELECTRIC SHOCK

The following precautions should be taken as preventive measures from electric shock while dealing with electrical equipment fittings or appliances:

1. Never work on live circuit.

2. Always stand on the insulating material, such as rubber mat, wooden board, etc., while switching on the main switch, motor switch, etc.

3. While switching ON the circuit, equipment, etc., ensure that your hands and feet are dry.

4. Avoid working at all those places where your head is liable to touch the live parts.

5. While working with electrical circuits/equipments, never come in contact with the metallic casing, earth conductor, cross arms, etc.

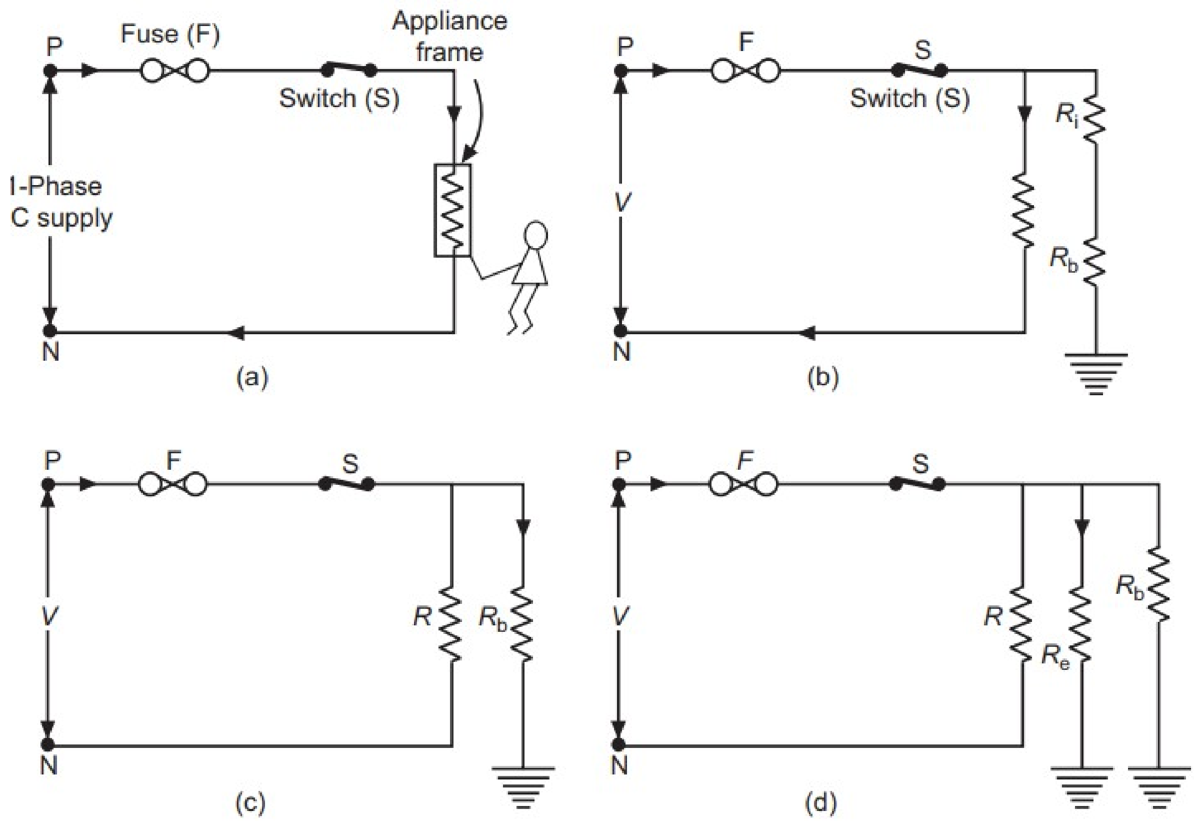
6. While working on the high-voltage circuit, avoid your direct contact with concrete flooring.
7. Never touch the person directly, while rescuing him from electric shock.

8. Consider all conductors as live, till you are not sure.

EARTHING

The process of connecting metallic bodies of all the electrical apparatus and equipment to the huge mass of earth by a wire of negligible resistance is called earthing.

When a body is earthed, it is basically connected to the huge mass of earth by a wire having negligible resistance. Therefore, the body attains zero potential, that is, potential of earth. This ensures that whenever a live conductor comes in contact with the outer body, the charge is released to the earth immediately.



(a) Operator touching the metallic body of the apparatus

(b) Under normal condition insulation and body resistance come in series

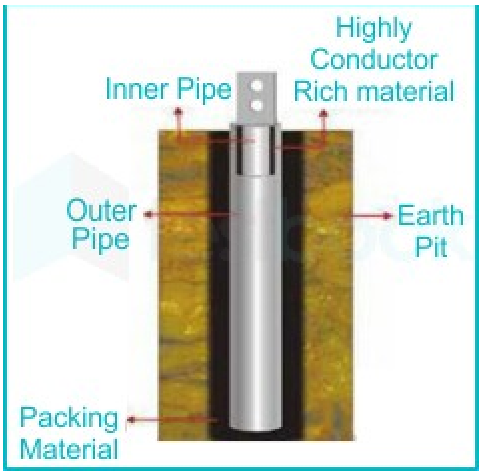
(c) When frame comes in contact with live wire, the insulation resistance vanishes

(d) When earthing is provided, low earth resistance come in parallel with body resistance.

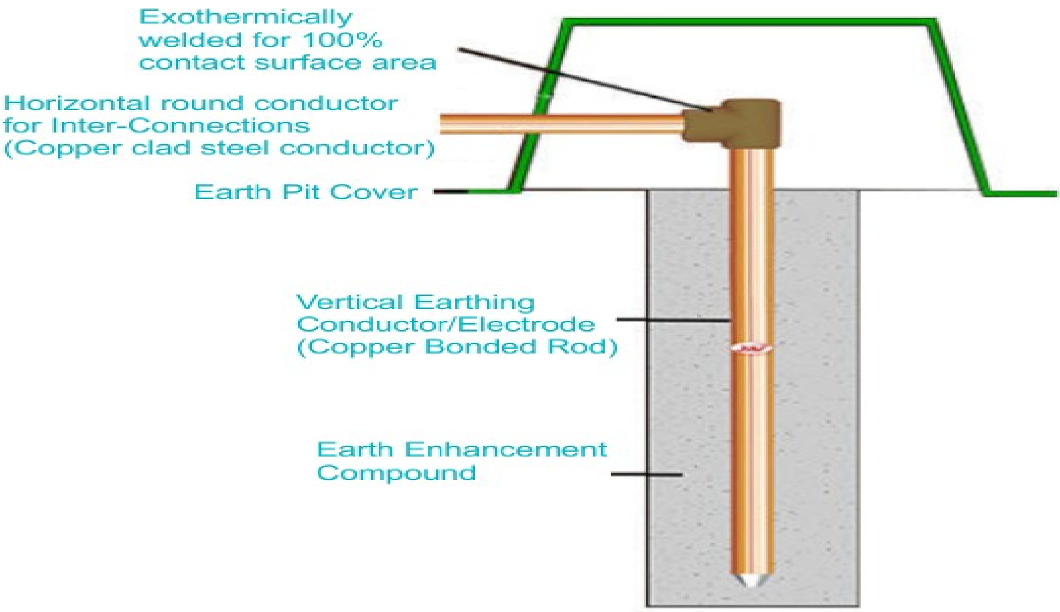
Methods of Earthing

As discussed earlier, earthing means to connect metallic bodies of the apparatus with the general mass of earth by a wire of negligible resistance. There are various methods of achieving this connection, some of them are given below:

1.Strip earthing: This system of earthing employs the use of 5 SWG (standard wire gauge) copper wire or strip of cross section not less than 25 mm × 1.6 mm. The strips or wires are buried in horizontal trenches. This type of earthing is used where the earth bed has a rocky soil and excavation work is difficult.

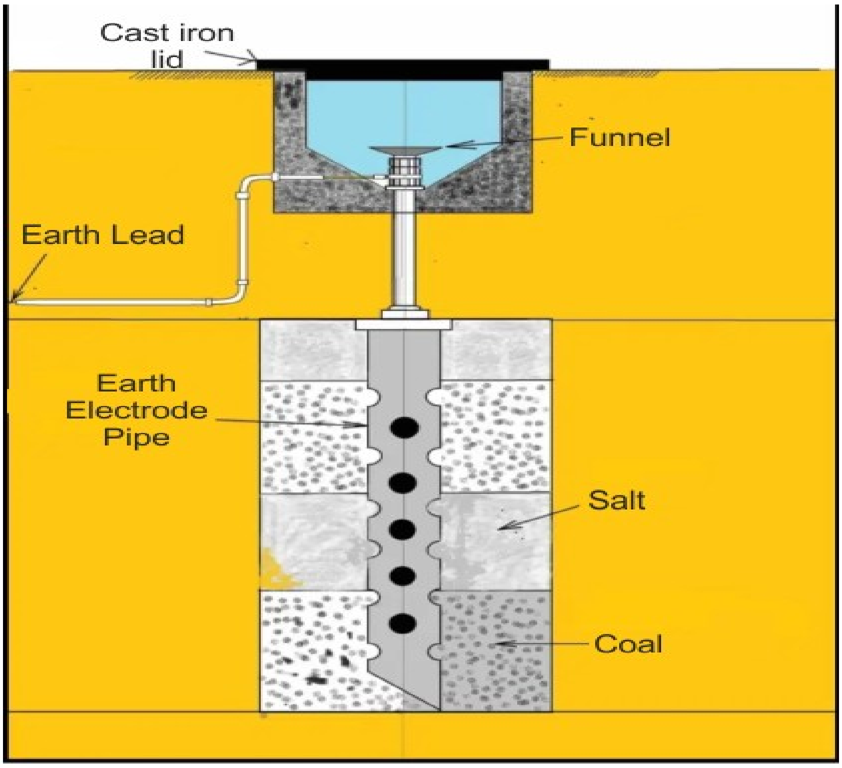


2. Rod earthing: It is the cheapest method of earthing and is employed in sandy areas. In this method, a copper rod is hammered directly into the ground, and no excavation work is required. The earthing lead is joined to this rod with the help of nuts and bolts.



3. Pipe earthing: Taking into consideration, the factors such as initial cost, inspection, resistance measurement, etc., G.I. pipe earthing is best form of ground connection. Iron is the cheapest material and remains serviceable even if put in salty mass of earth. The pipe used as earth electrode is galvanized and perforated.

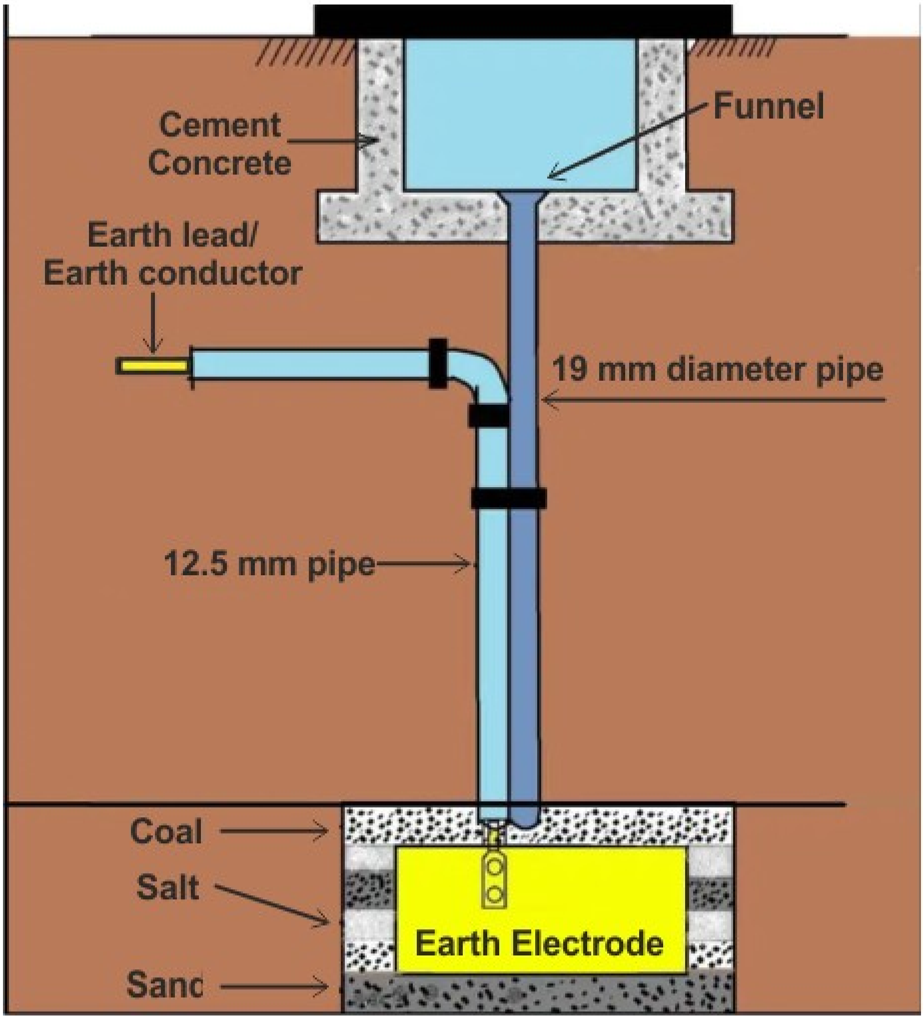
The earthing lead should be soldered and connected to the pipe. Alternate layers of charcoal and salt are provided around the G.I. pipe to keep the surroundings moist enough. The salt is poured at the bottom and thereafter alternate layers of charcoal and salt are arranged.



Pipe Earthing

4.Plate earthing: In this type of earthing, a copper or G.I. plate of dimensions not less than 60 cm × 60 cm × 3.18 mm or 60 cm × 60 cm × 6.35 mm is used as earth electrode instead of G.I. pipe. The plate is buried into ground in such a way that its face is vertical and the top is not less than 3 m below the ground level. The G.I. wire is used for G.I. plate and copper wire for copper plate earthing. The size of wire is selected according to the installation and fault current. The earthing lead is suitably protected placing it underground in a pipe. Alternate layers of charcoal and salt are used around the plate. The layers of charcoal shall be placed immediately over the plate, and thereafter, successive layers of salt and charcoal are laid to keep the surroundings sufficiently moist.

Plate Earthing



Note: Pipe earthing and plate earthing are considered to be the best as they have reasonably low value of earth resistance.

FUSE

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

A fuse is connected in series 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 the fuse wire to the extent that it melts and opens the circuit. This protects the machines or apparatus from damage that can be caused by the excessive current.

Electric circuit with fuse and switch

Advantages of Fuse

1. The cost of this protective device is very low.

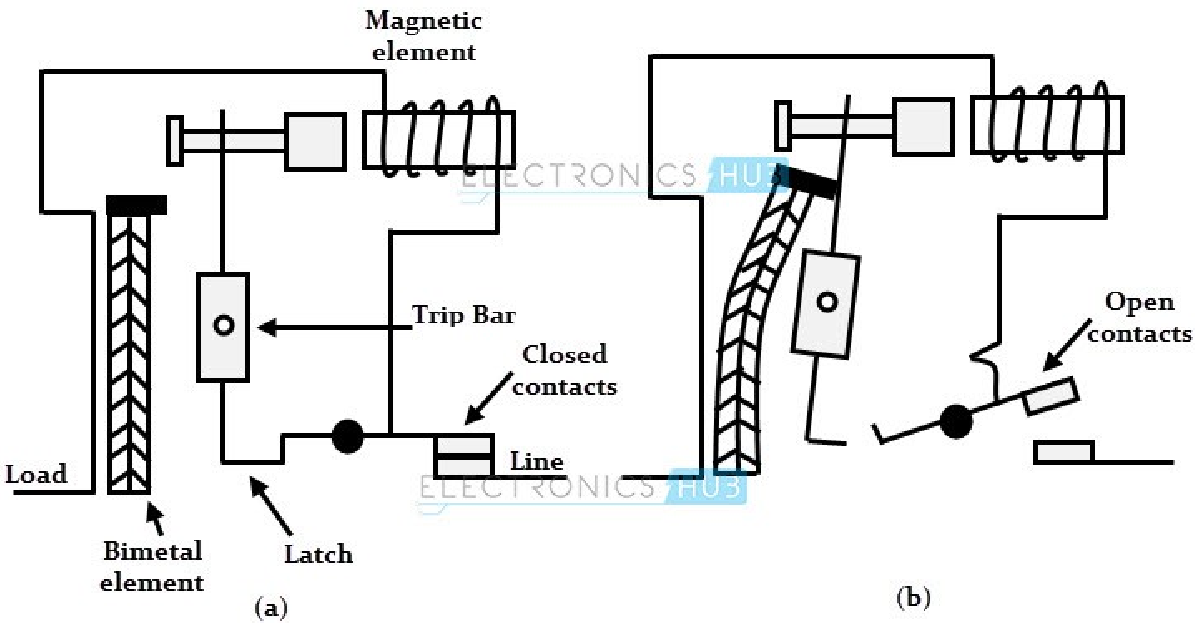
2. It requires no maintenance.
3. It interrupts heavy current without noise or smoke.
4. The smaller size of fuse element imposes a current-limiting effect under short circuit.
5. The minimum time of operation can be predetermined by selecting proper material of the fuse wire.
6. The inverse time–current characteristic makes it suitable for over current protection.

Disadvantages of Fuse

1. Considerable time is lost in rewiring or replacing fuses after every operation.
2. On short circuit, determination between fuses in series can only be obtained if there is considerable difference in the relative sizes of the fuse concerned.

MINIATURE CIRCUIT BREAKER (MCB)

Miniature circuit breaker (MCB) is a device that ensures definite protection of wiring system and sophisticated equipment against over current and short circuit faults.



Construction

Construction of an MCB can be explained by considering the following main parts:

1. Outer body or housing: The outer body or housing of an MCB is moulded from a special grade glass fibre-reinforced polyester with the help of an injection-moulding machine. The outer body and other polyester components of MCB are fire-retardant, anti-tracking and non-hygroscopic. These polyester parts and housing have the ability to withstand high-temperature and mechanical impacts.

2. Contacts: The contacts of an MCB are made of pure silver. This provides definite advantages such as long contact life, low contact resistance, ensures quick arc removal, and low-heat generation.

3. Operating mechanism: All the components of the operating mechanism are made of special plastic that they are self-lubricating that eliminates wear and tear, rust, and corrosion. These components are very light in weight and have low inertia, thereby ensure snap make the break ability. The reliability and ruggedness of the operating mechanism is, thus, maintained.

4. Arc extinguishing chamber: The arc produced during breaking of circuit is extinguished abruptly by providing a special arc chute chamber.

5. Fixing arrangement: The MCB-mounting clip gets easily snapped on to the Din-bar and can be removed easily by a simple operation with a screw driver. This saves the time that would have been required for fixing it with screws

6. Mechanical interlocking of multiple MCBs: The levers of all the (3 or 4) multiple MCBs are connected internally. This ensures simultaneous tripping of all poles even if the fault develops in any one of the phases.

Working

MCB may operate under the following two different conditions:

1. Moderate overload condition: Detection of moderate overload conditions is achieved by the use of a thermometal that deflects in response to the current passing through it. The thermometal moves against the trip lever, releasing the trip mechanism.

2. Short circuit conditions: When the current flowing through the MCB reaches a predetermined level (as per its setting or rating), it pushes the solenoid plunger that releases the trip mechanism and simultaneously separates the contacts.

EARTH LEAKAGE CIRCUIT BREAKER (ELCB)

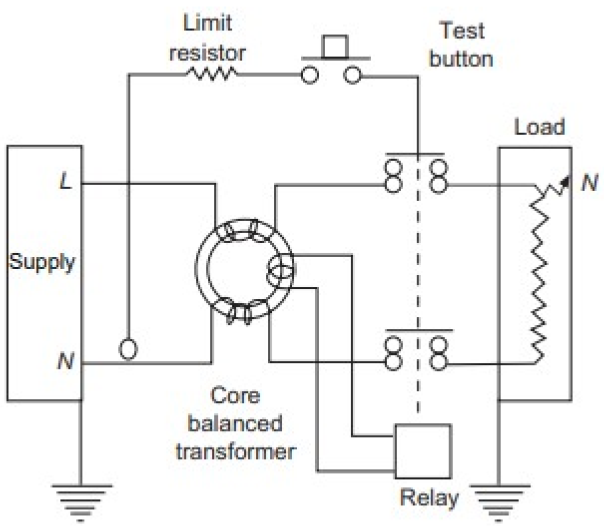
In the industrial, commercial, and domestic buildings, sometimes (usually in rainy season) leakage to earth occurs. This leakage may cause electric shock or fire. Hence, the leakage to earth is very dangerous and needs protection.

ELCB is a device that provides protection against earth leakage faults.

Construction and Internal Circuit Details

The enclosures of the ELCB is moulded from high-quality insulating material. The materials are fire-retardant, anti-tracking, non-hygroscopic, impact resistant and can withstand high temperatures. The body contains spring-loaded mounting arrangement on din-channel that ensures snap fitting of ELCB into position. However, these also have the facility to screw-on directly to any surface with the help of two screws. A two-pole ELCB is used for single-phase supply and a four-pole ELCB is used for three-phase, four-wire supply.

Internal wiring diagram of a two-pole ELCB is shown in Figure below



Electrical circuit of an earth leakage circuit breaker

Principle of Operation

Under normal conditions, the magnitude of currents flowing through the phase wire and neutral are the same and core of the core-balanced transformer does not carry any flux (i.e., two windings neutralize the flux). Therefore, no emf is induced in the operating coil of the relay wound on the same core. However, when the earth fault (earth leakage) occurs, the current in the phase wire becomes more than the neutral wire. This unbalancing sets up flux in the core of the core-balanced transformer, which in turn induces an emf in the operating coil of the relay. Hence, relay is energized and the plunger of the ELCB goes to the off position or disconnects the load from the supply. Therefore, ELCB protects the system against leakage.

Use of test knob

A test knob is provided for the periodic checking of the mechanism and function of ELCB.