Brushless DC Motors

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Brushless DC Motors

1. Introduction

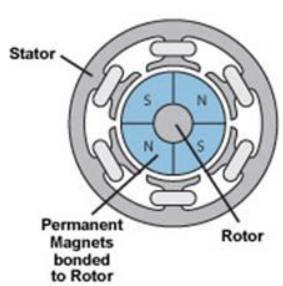
Brushless Direct Current (BLDC) motors are one of themotor types rapidly gaining popularity. BLDC motors are used in industries such as Automotive,Aerospace, Consumer, Medical, Industrial AutomationEquipment and Instrumentation.As the name implies, BLDC motors do not use brushesfor commutation; instead, they are electronically commutated. BLDC motors have many advantages overbrushed DC motors and induction motors. A few ofthese are:

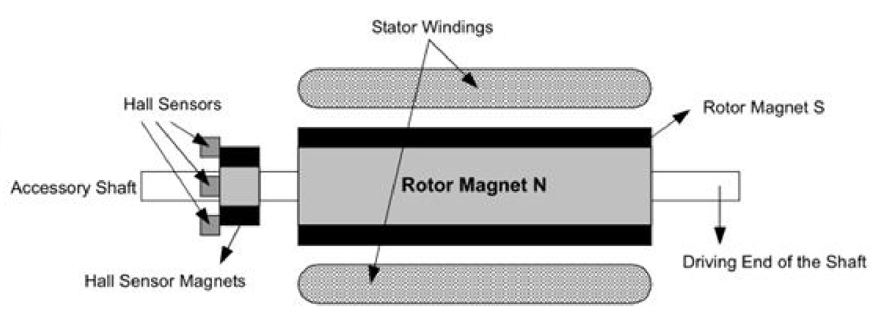
- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

In addition, the ratio of torque delivered to the size ofthe motor is higher, making it useful in applicationswhere space and weight are critical factors.

2. Construction

BLDC motors are a type of synchronous motors. Thismeans the magnetic field generated by the stator andthe magnetic field generated by the rotor rotates at thesame frequency. BLDC motors do not experience the“slip” that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and3-phase configurations. Corresponding to its type, thestator has the same number of windings. Out of these,3-phase motors are the most popular and widely used.





(a) **(b)**

Figure.1 Construction of a BLDC motor (a) front view (b) transverse sectional view

2.1. Stator

Stator of a BLDC motor made up of stacked steel laminations to carry the windings. These windings are placed in slots which are axially cut along the inner periphery of the stator. These windings can be arranged in either star or delta. However, most BLDC motors have three phase star connected stator.Each winding is constructed with numerous interconnected coils, where one or more coils are placed in each slot. In order to form an even number of poles, each of these windings is distributed over the stator periphery.

There are two types of stator windings variants:

- Trapezoidal motors
- Sinusoidal motors

2.2. Rotor

The rotor is made of permanent magnet and can varyfrom two to eight pole pairs with alternate North (N) andSouth (S) poles.Based on the required magnetic field density in therotor, the proper magnetic material is chosen to makethe rotor. Ferrite magnets are traditionally used to makepermanent magnets. Rare earth alloys are also being used now-a-days for making the permanent magnets. Neodymium, Samarium Cobalt and the alloy of Neodymium, Ferrite and Boron are some of the examples of rare earth alloy magnets.

2.3. Hall Sensors

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energizedin a sequence. It is important to know the rotor positionin order to understand which winding will be energizedfollowing the energizing sequence. Rotor position issensed using Hall effect sensors embedded into thestator.

The Hall sensors are normally mounted on a PCboard and fixed to the enclosure cap on the non-drivingend. This enables users to adjust the complete assembly of Hall sensors, to align with the rotor magnets, inorder to achieve the best performance.Based on the physical position of the Hall sensors,there are two versions of output. The Hall sensors maybe at 60° or 120° phase shift to each other. Based onthis, the motor manufacturer defines the commutationsequence, which should be followed when controlling
the motor.

3. Theory of Operation

Each commutation sequence has one of the windingsenergized to positive power (current enters into thewinding), the second winding is negative (current exitsthe winding) and the third is in a non-energized condition. Torque is produced because of the interactionbetween the magnetic field generated by the statorcoils and the permanent magnets. Ideally, the peaktorque occurs when these two fields are at 90° to eachother and falls off as the fields move together. In orderto keep the motor running, the magnetic field producedby the windings should shift position, as the rotormoves to catch up with the stator field.

4. Advantages of BLDC motors to other motors

Compared to brushed DC motors and induction motors, BLDC motors have many advantages:

- Brushless motors require less maintenance, so they have a longer life
- Produce more output power per frame size
- The rotor inertia is less as the rotor is made of permanent magnets
- Provides improved acceleration anddeceleration characteristics
- The linear speed/torque characteristics produce predictable speed regulation
- Operate much morequietly

5. Typical BLDC motor applications

BLDC motors find applications in every segment of themarket. Automotive, appliance, industrial controls, automation and aviation have applications for BLDC motors. Out of these, we can categorize the type of BLDC motor control into three major types:

a) Constant load
b) Varying loads
c) Positioning applications

Some of the applications based upon these categories are listed below:

- Fans
- Pumps andblowers
- Washers
- Dryers
- Compressors
- Fuel pump control
- Electronic steering control
- Centrifuges
- Robotic armcontrols
- Gyroscope controls
- Computer Numeric Controlled machines (CNC)

6. Summary

In conclusion, BLDC motors have advantages overbrushed DC motors and induction motors. They havebetter speed versus torque characteristics, highdynamic response, high efficiency, long operating life,noiseless operation, higher speed ranges, rugged construction and so on. Also, torque delivered to the motorsize is higher, making it useful in applications wherespace and weight are critical factors. With these advantages, BLDC motors find wide spread applications inautomotive, appliance, aerospace, consumer, medical, instrumentation and automation industries.

STEPPER MOTORS

Contents

STEPPER MOTORS

1. Introduction

A stepper motor is an electromechanicaldevice which converts electrical pulses intodiscrete mechanical movements. The shaftor spindle of a stepper motor rotates indiscrete step increments when electricalcommand pulses are applied to it in theproper sequence. The motors rotation hasseveral direct relationships to these appliedinput pulses. The sequence of the appliedpulses is directly related to the direction ofmotor shafts rotation. The speed of themotor shafts rotation is directly related tothe frequency of the input pulses and thelength of rotation is directly related to thenumber of input pulses applied.

2. Stepper Motor Types

There are three basic stepper motortypes. They are :

- Variable-reluctance
- Permanent-magnet
- Hybrid

2.1. Variable-reluctance (VR) :

This type of stepper motor has beenaround for a long time. It is probablythe easiest to understand from astructural point of view. Figure.1shows a cross section of a typical VR.stepper motor. This type of motorconsists of a soft iron multi-toothedrotor and a wound stator. When thestator windings are energized

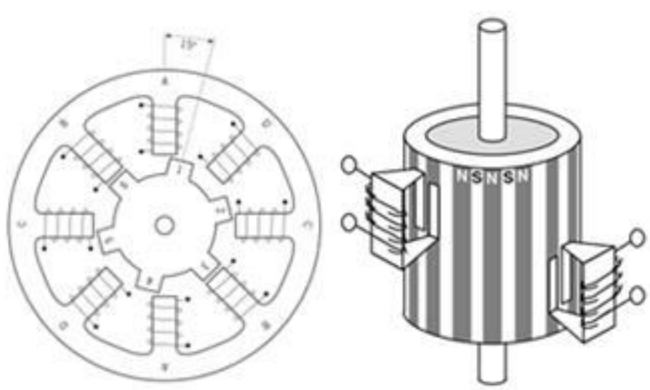


Figure.1: Variable-reluctance stepper motor

with DCcurrent the poles become magnetized.Rotation occurs when the rotor teethare attracted to the energized statorpoles.

2.2. Permanent Magnet (PM):

Often referred to as a “tin can” or “canstock” motor the permanent magnet step motor is a low cost and low resolution type motor with typical step angles of 7.5° to 15° (48 – 24 steps/revolution). PM motors as the name implies have permanent magnets added to the motor structure as shown in Figure.2.

The rotor no longer has teeth as withthe VR motor. Instead the rotor ismagnetized with alternating northand south poles situated in a straightline parallel to the rotor shaft. Thesemagnetized rotor poles provide anincreased magnetic flux intensity andbecause of this the PM motor exhibitsimproved torque characteristics whencompared with the VR type.

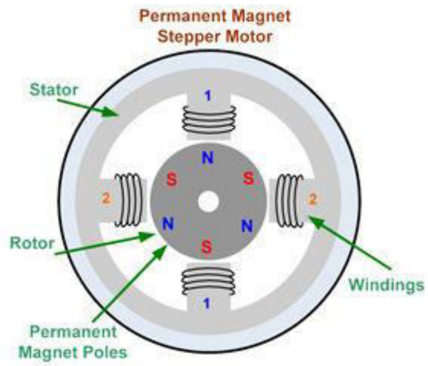


Figure.2 Permanent magnet stepper motor

2.3. Hybrid (HB):

The hybrid stepper motor is moreexpensive than the PM stepper motorbut provides better performance withrespect to step resolution, torque andspeed. Typical step angles for the HB stepper motor range from 3.6° to 0.9°(100 – 400 steps per revolution). Thehybrid stepper motor combines thebest features of both the PM and VRtype stepper motors. Figure.3 shows the cut-sectional view of a hybrid stepper motor. The rotor ismulti-toothed like the VR motor andcontains an axially magnetized concentric magnet around its shaft. Theteeth on the rotor provide an evenbetter path which helps guide themagnetic flux to preferred locations in the airgap. This further increases thedetent, holding and dynamic torquecharacteristics of the motor when compared with both the VR and PMtypes.

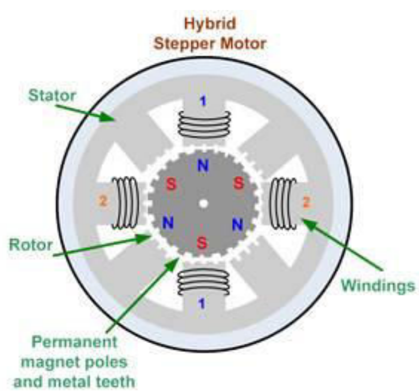


Figure.3 Hybrid stepper motor

The two most commonly used typesof stepper motors are the permanentmagnet and the hybrid types. If adesigner is not sure which type willbest fit his applications requirementshe/she should first evaluate the PM type, asit is normally several times less expensive. If not then the hybrid motor maybe the right choice.

3. Torque Generation

The torque produced by a steppermotor depends on several factors.

- Step rate
- Drive current in the windings
- Drive design or type

In a stepper motor,torque is developed when the magnetic fluxes of therotor and stator are displaced fromeach other. The stator is made up of ahigh permeability magnetic material.The presence of this high permeabilitymaterial causes the magnetic flux tobe confined for the most part to thepaths defined by the stator structurein the same fashion that currents areconfined to the conductors of an electronic circuit. This serves to concentrate the flux at the stator poles. The torque output produced by the motoris proportional to the intensity of themagnetic flux generated when thewinding is energized.The basic relationship whichdefines the intensity of the magneticflux is defined by:

$$\boldsymbol{H} = \frac{\boldsymbol{Ni}}{\boldsymbol{l}}$$

where,

N = The number of winding turns
i = current
H = Magnetic field intensity
l = Magnetic flux path length

This relationship shows that themagnetic flux intensity and consequently the torque is proportional tothe number of winding turns and thecurrent and inversely proportional tothe length of the magnetic flux path.From this basic relationship one cansee that the same frame size steppermotor could have very different torqueoutput capabilities simply by changing the winding parameters.

4. Open Loop Operation

One of the most significant advantages of a stepper motor is its ability to be accurately controlled in an open loop system. Open loop control means no feedback information about position is needed. This type of control eliminates the need for expensive sensing and feedback devices such as optical encoders. The position of the rotor can be known by simply keeping track of the input step pulses.

5. Stepping Modes

The following are the most commondrive modes.

- Wave Drive (1 phase on)
- Full Step Drive (2 phases on)
- Half Step Drive (1 & 2 phases on)
- Microstepping (Continuouslyvarying motor currents)

6. Advantages and Disadvantages

The stepper motors have a variety of advantages and a few disadvantages. These are listed below:

Advantages:

- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill (if the windings are energized)

- Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non-cumulative from one step to the next.
- Excellent response to starting/stopping/reversing.
- Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependent on the life of the bearing.
- The motors response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
- It is possible to achieve very low speed synchronous rotation with a load that is directly coupled to the shaft.
- A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

Disadvantages:

- Resonances can occur if not properly controlled.
- Not easy to operate at extremely high speeds.

7. When to Use a Stepper Motor

A stepper motor can be a good choicewhenever controlled movement isrequired. They can be used to advantage in applications where you need tocontrol rotation angle, speed, positionand synchronism. Because of the inherent advantages listed previously,stepper motors have found their place in many different applications. Someof these include printers, plotters,highend office equipment, hard diskdrives, medical equipment, faxmachines, automotive and many more.

UNIT V

Protection and Safety of Electrical Systems:
Introduction to domestic wiring, Fuse, MCB, ELCB and Relay.
Necessity of earthing, difference between earthing and grounding and types of grounding.
Electric shocks, hazards and safety precautions.

NOTES:

Protection

- Fuses
- Circuit Breakers
  - MCB
  - ELCB
- Relays

Electrical Fuse

A fuse is a part of the circuit which consists of a conductor which melts easily and breaks the connection when current exceeds the predetermined value. An electrical fuse is the weakest part of an electrical circuit which breaks when more than predetermined current flows through it.

Fuse Wire

The function of **fuse wire** is to carry the normal current without excessive heating but more than normal current when passes through fuse wire, it rapidly heats up and melts.

Materials used for Fuse Wires

The **materials used for fuse wires** are mainly tin, lead, zinc, silver, antimony, copper, aluminum etc.

Fuse Wire Rating

The melting point and specific resistance of different metals used for fuse wire

Some Important Terms

1. **Minimum Fusing Current**
   It is minimum value of current due to which fuse melts.

2. **Current Rating of Fuse**
   It is maximum value of current due to which fuse does not get melt.

3. **Fusing Factor**
   This is the ratio of minimum fusing current and current rating of fuse. Therefore, fusing factor = Minimum fusing current or current rating of the fuse. The value of fusing factor is always more than 1.

4. **Prospective Current in Fuse**
   Before melting, the fuse element has to carry the short circuit current through it. The prospective current is defined as the value of current which would flow through the fuse immediately after a short circuit occurs in the network.

5. **Melting Time of Fuse or Pre-arcing Time of Fuse**
   This is the time taken by a fuse wire to get broken by melting. It gets counted from the instant; the overcurrent starts flowing through the fuse, to the instant when fuse wire gets just broken by melting.

6. **Arcing Time of Fuse**
   After breaking of fuse wire there will be an arcing between both melted tips of the wire which will be extinguished at the current zero. The time accounted from the instant of arc initiated to the instant of the arc gets extinguished is known as arcing time of fuse.

7. **Operating Time of Fuse**
   Whenever overrated current starts to flow through a fuse wire, it takes time to be melted and disconnected, and just after that the arcing stars between the melted tips of the fuse wire, which finally gets extinguished. The operating time of fuse is the time gap between the instant when the overrated current starts to flow through the fuse and the instant when the arc in fuse finally gets extinguished. That means operating time of fuse = melting time + arcing time.

8. **Current Carrying Capacity of Fuse Wire**
   Current carrying capacity of a fuse wire depends upon numbers of factors like, material used, the dimension of wire, i.e., diameter and length, size and shape of terminals used to connect it, and the surrounding.

Fuse Law

Fuse law determines the current carrying capacity of a fuse wire. We can establish the law in the following way. At steady state condition that is when fuse carries normal current without increasing its temperature to the melting limit. That means at this steady state condition, heat generated due to the current through fuse wire is equal to heat dissipated from it. Heat generated = I^2R. Where, R is the resistance of the fuse wire.

Types of Fuses:

Rewirable or Kit Kat Fuse Unit

Rewirable or Kit Kat Fuse Unit is most commonly used fuse in our day to day life. This fuse has mainly two parts. The unit in which the incoming and outgoing line or phase wire connected permanently is known as fuse base. The removable part which holds the fuse wire and fits into the base is known as fuse carrier. The fuse carrier is also known as **cutout**.

Cartridge Fuse

In **cartridge fuse** the fuse wire is enclosed in a transparent glass tube or bulb, the whole unit is sealed off. In case the fuse blows, it is to be replaced by new one as the **cartridge fuse** cannot be rewired due to its sealing.

Lead - tin Alloy Fuse Wire or Eutectic Alloy Fuse Wire

For small value of current interruption lead – tin alloy fuse wire has been used in past. The most preferred lead – tin alloy for fuse wire containing 37% lead and 63% tin. This alloy fuse wire is also known as known as Eutectic Alloy Fuse Wire. This type of alloy has some specific characteristics due to which this is preferred as fuse wire.

1. It has the high brinnel hardness and has less tendency to spread over.
2. The alloy metal is quite homogeneous.

3. If the fusing characteristics of eutectic alloy and other composition of alloys is studied there is only one arrest point in eutectic alloy as compared to two other types of alloys.

HRC Fuse or High Rupturing Capacity Fuse

HRC fuse or **high rupturing capacity fuse**- In that type of fuse, the fuse wire or element can carry short circuit heavy current for a known time period. During this time if the fault gets removed, then it does not blow off. Otherwise, it blows off or melts. The enclosure of **HRC fuse** is either of glass or some other chemical compound. This enclosure is sufficiently airtight to avoid the effect of the atmosphere on the fuse materials. The ceramic enclosure having metal end cap at both heads, to which fusible silver wire gets welded. There is a space within the enclosure, surrounding the fuse wire or fuse element, completely packed with a filling powder. This type of fuse is reliable and has inverse time characteristic, that means if the fault current is high then rupture time is less, and if fault current is not so high, then rupture-time is long.

Circuit Breakers

All fuses need to be replaced with MCB for better safety and control when they have done their job in the past. Unlike a fuse, an MCB operates as automatic switch that opens in the event of excessive current flowing through the circuit and once the circuit returns to normal, it can be reclosed without any manual replacement. MCBs are used primarily as an alternative to the fuse switch in most of the circuits. A wide variety of MCBs have been in use nowadays with breaking capacity of 10kA to 16 kA, in all areas of domestic, commercial and industrial applications as a reliable means of protection

What is Miniature Circuit Breaker (MCB)?

An **MCB or miniature circuit breaker** is an electromagnetic device that represents complete enclosure in a molded insulating material. The main function of an MCB is to switch the circuit, i.e., to open the circuit (which has been connected to it) automatically when the current passing through it (MCB) exceeds the value for which it is set. It can be manually switched ON and OFF as similar to normal switch if necessary.

MCBs are of time delay tripping devices, to which the magnitude of overcurrent controls the operating time. This means, these get operated whenever overload exist long enough to create a danger to the circuit being protected. Therefore, MCBs doesn’t respond to transient loads such as switches surges and motor starting currents. Generally, these are designed to operate at less than 2.5 milliseconds during short circuit faults and 2 seconds to 2 minutes in case of overloads (depending on the level of current).

Construction of MCB

An MCB embodies complete enclosure in a molded insulating material. This provides mechanically strong and insulated housing. The switching system consists of a fixed and a moving contact to which incoming and outgoing wires are connected. The metal or current carrying parts are made up of electrolytic copper or silver alloy depending on the rating of the circuit breaker.

As the contacts are separated in the event of an overload or short circuit situation, an electric arc is formed. All modern MCBs are designed to handle arc interruption process where arc energy extraction and its cooling are provided by metallic arc splitter plates. These plates are held in a proper position by an insulating material. Also, arc runner is provided to force the arc that is produced between the main contacts.

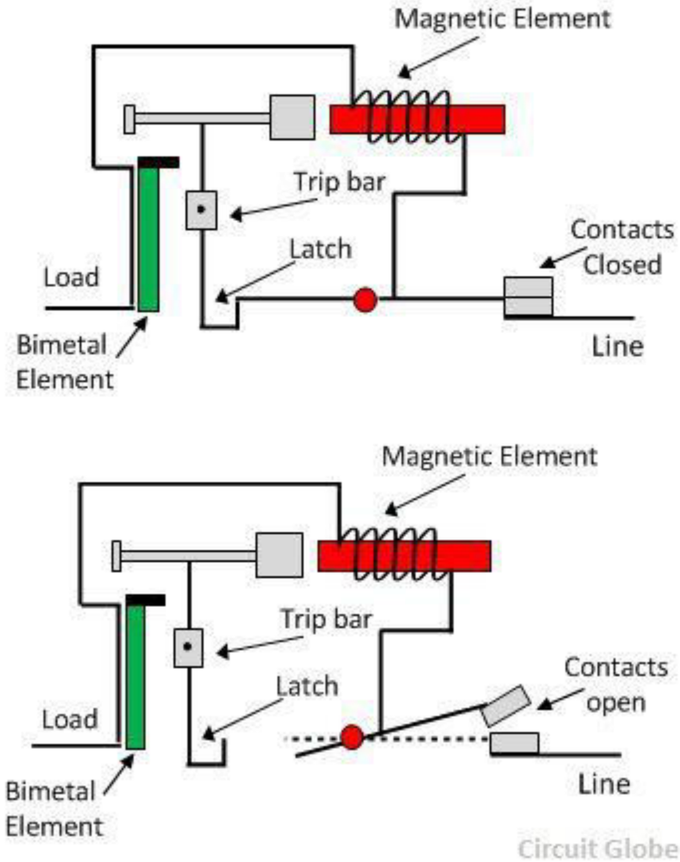
The operating mechanism consists of both magnetic tripping and thermal tripping arrangements.

The magnetic tripping arrangement essentially consists of a composite magnetic system that has a spring loaded dashpot with a magnetic slug in a silicon fluid, and a normal magnetic trip. A current carrying coil in the trip arrangement moves the slug against spring towards fixed pole piece. So the

magnetic pull is developed on the trip liver when there is a sufficient magnetic field produced by the coil. In case of short circuits or heavy overloads, strong magnetic field produced by the coils (Solenoid) is sufficient to attract the armature of trip liver irrespective of the position of slug in the dashpot.
The thermal tripping arrangement consists of a bimetallic strip around which a heater coil is wounded to create heat depending on the flow of current. The heater design can be either direct where current is passed through bimetal strip which effect part of electric circuit or indirect where a coil of current carrying conductor is wound around the bimetallic strip. The deflection of bimetallic strip activates the tripping mechanism in case of certain overload conditions.
The bimetal strips are made up of two different metals, usually brass and steel. These metals are riveted and welded along their length. These are so designed such that they will not heat the strip to the tripping point for normal currents, but if the current is increased beyond rated value, strip is warmed, bent and trips the latch. Bimetallic strips are chosen to provide particular time delays under certain overloads.

Working & Operation of MCB

Figure shows the general line diagram of MCB.



Under normal working conditions, MCB operates as a switch (manual one) to make the circuit ON or OFF. Under overload or short circuit condition, it automatically operates or trips so that current interruption takes place in the load circuit. The visual indication of this trip can be observed by automatic movement of the operating knob to OFF position. This automatic operation MCB can be obtained in two ways as we have seen in MCB construction; those are magnetic tripping and thermal tripping.
Under overload condition, the current through the bimetal causes to raise the temperature of it. The heat generated within the bimetal itself enough to cause deflection due to thermal expansion of metals. This deflection further releases the trip latch and hence contacts get separated. In some MCBs, magnetic field generated by the coil causes develop pull on bimetal such that it deflection activates the tripping mechanism.

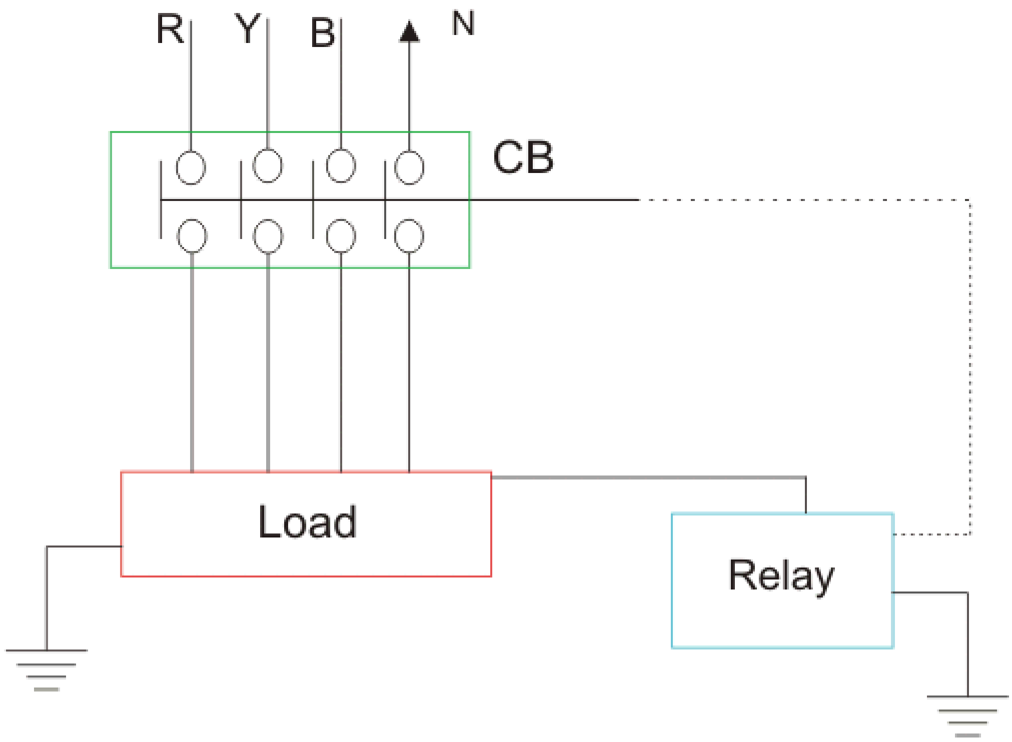
Under short circuit or heavy overload conditions, magnetic tripping arrangement comes into the picture. Under normal working condition, the slug is held in a position by light spring because magnetic field generated by the coil is not sufficient to attract the latch. When a fault current flows, the magnetic field generated by the coil is sufficient to overcome the spring force holding slug in position. And hence slug moves and then actuate the tripping mechanism.
A combination of both magnetic and thermal tripping mechanisms are implemented in most of MCBs. In both magnetic and thermal tripping operations, an arc is formed when the contacts start separating. This arc is then forced into arc splitter plates via arc runner. These arc splitter plates are also called arc chutes where arc is formed into a series of arcs and at the same time energy extracted and cools it. Hence this arrangement achieves the arc extinction.

Earth Leakage Circuit Breaker (ELCB)

If any current leaks from any electrical installation, there must-be any insulation failure in the electrical circuit, it must be properly detected and prevented otherwise there may be a high chance of electrical shock if-anyone touches the installation. An **earth leakage circuit breaker** does it efficiently. Means it detects the earth leakage current and makes the power supply off by opening the associated circuit breaker. There are two types of **earth leakage circuit breaker**, one is **voltage ELCB** and other is **current ELCB**.

Voltage Earth Leakage Circuit Breaker
The **working principle of voltage ELCB** is quite simple. One terminal of the relay coil is connected to the metal body of the equipment to be protected against **earth leakage** and other terminal is connected to the earth directly.

If any insulation failure occurs or live phase wire touches the metal body, of the equipment, there must be a voltage difference appears across the terminal of the coil connected to the equipment body and earth. This voltage difference produces a current to flow the relay coil.

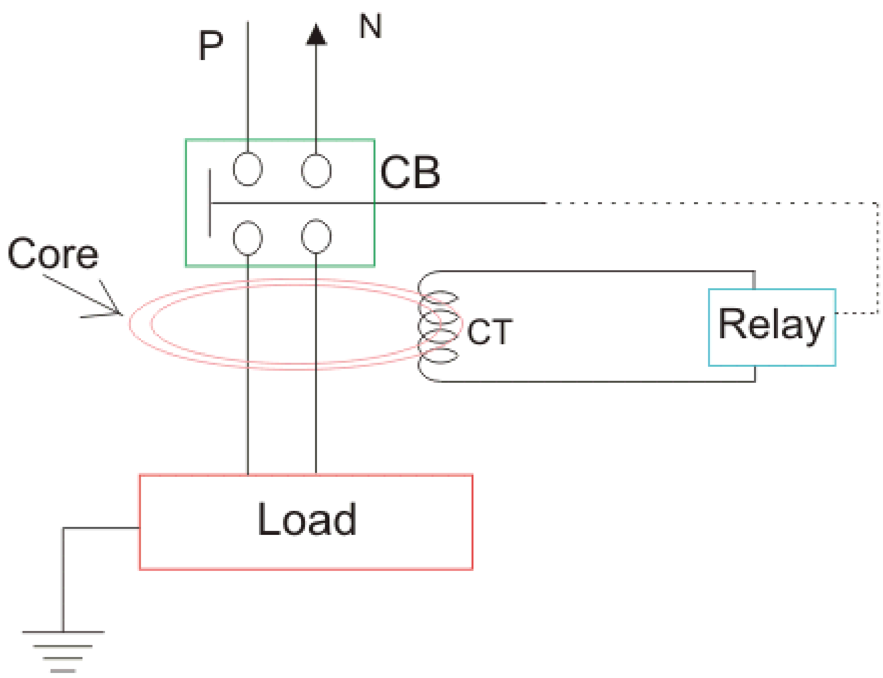


If the voltage difference crosses, a predetermined limit, the current through the relay becomes sufficient to actuate the relay for tripping the associated circuit breaker to disconnect the power supply to the equipment. The typicality of this device is, it can detect and protect only that equipment or installation with which it is attached. It cannot detect any leakage of insulation in other installation of the system.

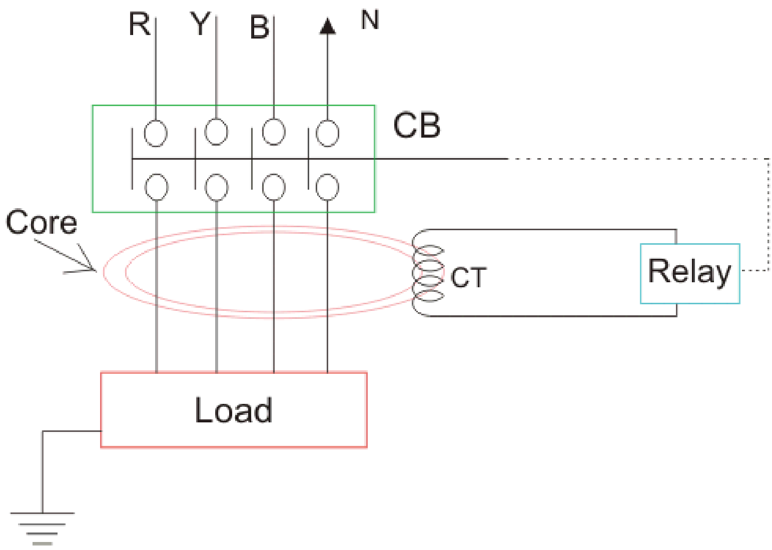
Current ELCB or RCCB or Residual Current Circuit Breaker

The **working principle of current earth leakage circuit breaker** or **RCCB** is also very simple as voltage operated ELCB but the theory is entirely different and **residual current circuit breaker** is more sensitive than ELCB.

Actually, ELCBs are of two kinds, but it is general practice to refer voltage based ELCB as simple ELCB. And current based ELCB is referred as RCD or RCCB. Here one CT core is energized from both phase wise and neutral wire.



Single Phase Residual Current ELCB. The polarity of the phase winding and neutral winding on the core is so chosen that, in normal condition mmf of one winding opposes that of another. As it is assumed that, in normal operating conditions the current goes through the phase wire will be returned via neutral wire if there's no leakage in between. As both currents are same, the resultant mmf produced by these two currents is also zero-ideally. The relay coil is connected with another third winding wound on the CT core as secondary. The terminals of this winding are connected to a relay system. In normal operating condition there would not be any current circulating in the third winding as here is no flux in the core due to equal phase and neutral current. When any earth leakage occurs in the equipment, there may be part of phase current passes to the earth, through the leakage path instead of returning via mental wire. Hence the magnitude of the neutral current passing through the RCCB is not equal to phase current passing through it.



Three Phase Residual Current Circuit Breaker or Current ELCB. When this difference crosses a predetermined value, the current in the third secondary winding of the core becomes sufficiently high to actuate the electromagnetic relay attached to it. This relay causes tripping of the associated circuit breaker to disconnect the power supply to the equipment under protection. Residual current circuit breaker is sometimes also referred as residual current device (RCD) when we consider the device by disassociating the circuit breaker attached to **RCCB**. That means, the entire parts of RCCB except circuit breaker are referred as RCD.

Relay

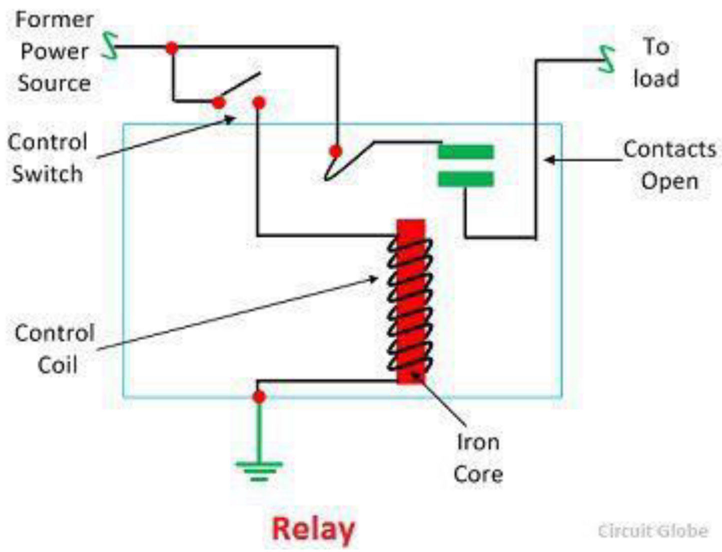
Definition: The relay is the device that open or closes the contacts to cause the operation of the other electric control. It detects the intolerable or undesirable condition with an assigned area and gives the commands to the circuit breaker to disconnect the affected area. Thus protects the system from damage.

Working Principle of Relay

It works on the principle of an electromagnetic attraction. When the circuit of the relay senses the fault current, it energises the electromagnetic field which produces the temporary magnetic field. This magnetic field moves the relay armature for opening or closing the connections. The small power relay has only one contacts, and the high power relay has two contacts for opening the switch.

The inner section of the relay is shown in the figure below. It has an iron core which is wound by a control coil. The power supply is given to the coil through the contacts of the load and the control switch. The current flows through the coil produces the magnetic field around it.

Due to this magnetic field, the upper arm of the magnet attracts the lower arm. Hence close the circuit, which makes the current flow through the load. If the contact is already closed, then it moves oppositely and hence open the contacts.



Pole and Throw

The pole and throws are the configurations of the relay, where the pole is the switch, and the throw is the number of connections. The single pole, the single throw is the simplest type of relay which has only one switch and only one possible connection. Similarly, the single pole double throw relay has a one switch and two possible connections.

Construction of Relay

The relay operates both electrically and mechanically. It consists electromagnetic and sets of contacts which perform the operation of the switching. The construction of relay is mainly classified into four groups. They are the contacts, bearings, electromechanical design, terminations and housing.

The Difference between Relay and Circuit Breaker are given below

Basis	Relay	Circuit Breaker
Principle	The Relay is a switching device which gives a signal to the circuit breaker as soon as the fault occurs in the power system.	Circuit breaker breaks the circuit automatically when receives the signal from the relay.
Working	The Relay does not break the contact. It only senses the error and send the signal to the circuit breaker.	It breaks the circuit contacts.
Type of device	The Relay is a switching and sensing device.	The Circuit breaker is an isolating or disconnecting device.
Voltage	Relays operate on low power input voltage.	The Circuit breaker is an automatic on load device
Usability	It is used to control or select one among many circuits.	It uses one per circuit.

Earthing

- **Definition:** The process of transferring the **immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire** is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.
- Mostly, the galvanised iron is used for the earthing. The **earthing provides the simple path to the leakage current**. The short circuit current of the equipment passes to the earth which has zero potential. Thus, protects the system and equipment from damage.

Types of Electrical Earthing

Neutral Earthing

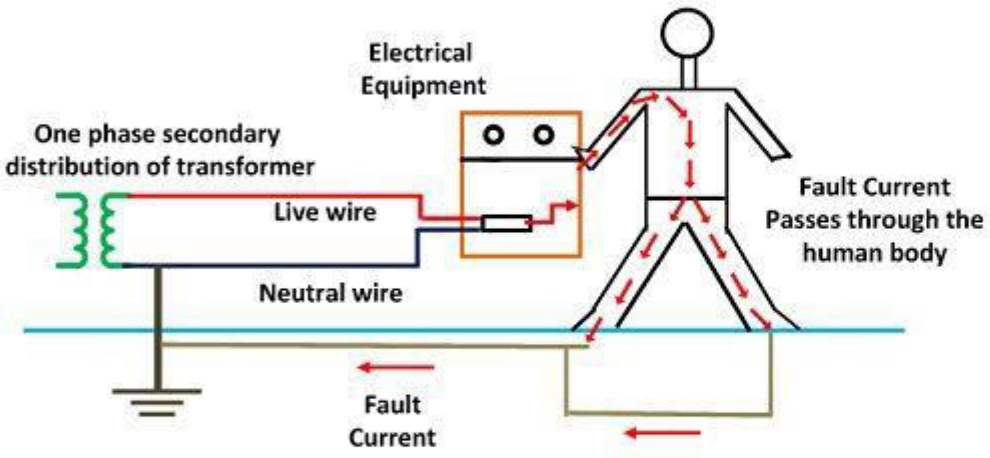
- In neutral earthing, the neutral of the system is directly connected to earth by the help of the GI wire. The neutral earthing is also called the system earthing. Such type of earthing is mostly provided to the system which has star winding. For example, the neutral earthing is provided in the generator,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

Equipment Earthing

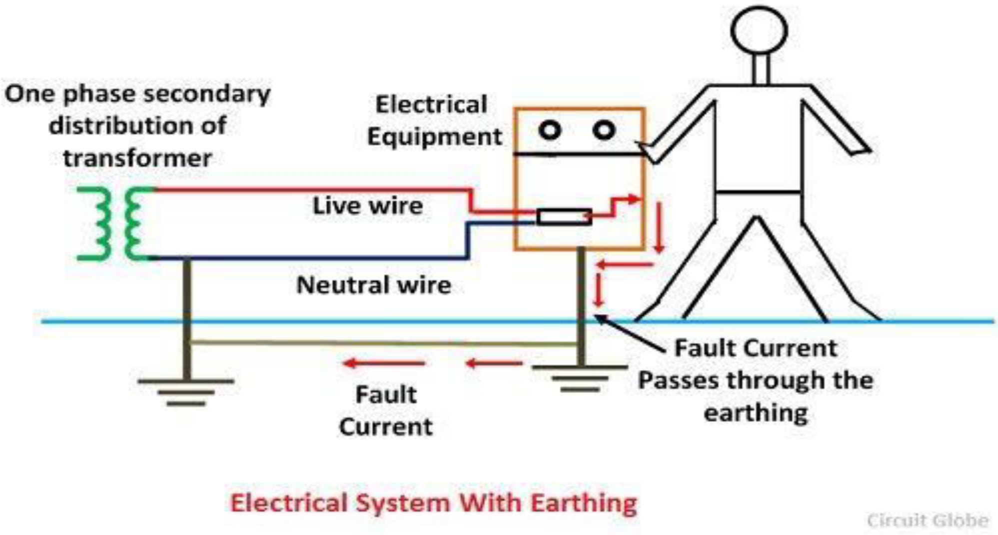
- Such type of earthing is provided to the electrical equipment. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire. If any fault occurs in the apparatus, the short-circuit current passes to the earth by the help of wire.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

Importance of Earthing

Following figures show the importance of earthing. In case of electrical system without earthing, fault current flows through the human body whereas in case of system with earthing it is diverted to ground/earth.



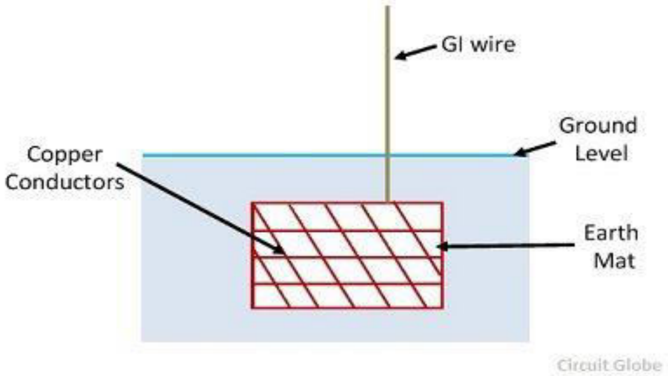
Electrical System Without Earthing



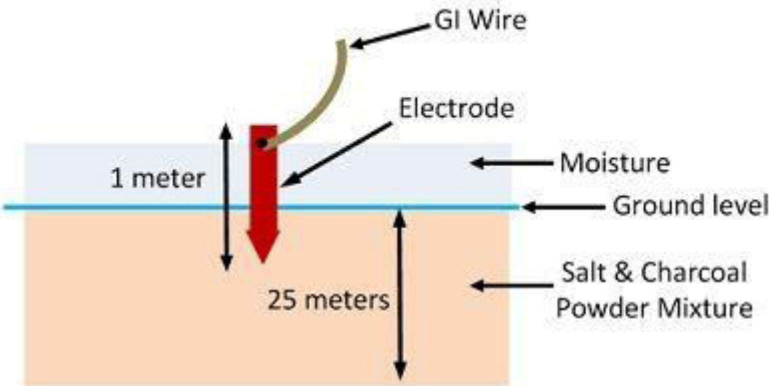
Electrical System With Earthing

Methods of Earthing

- **Earthing Mat**

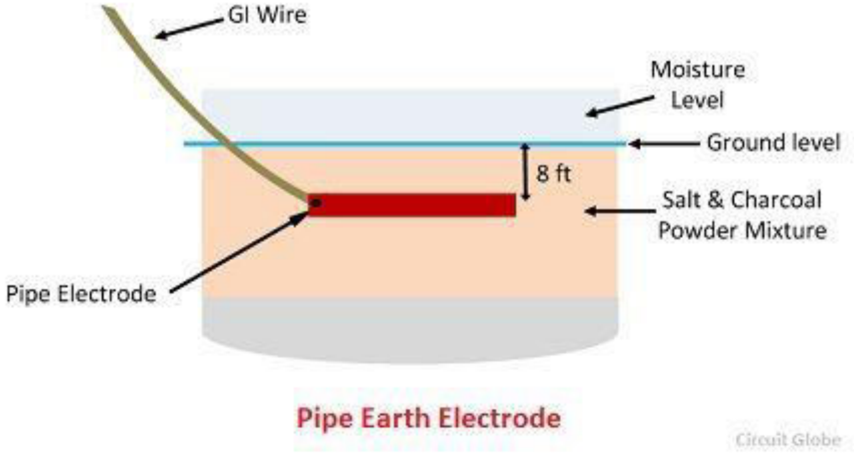


- **Earthing Electrode**

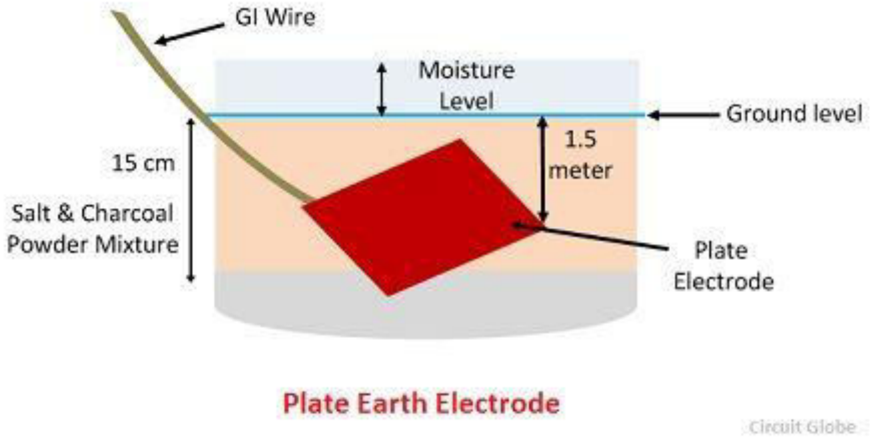


Earthing Through Electrode

➨ **Pipe Earthing**



➨ **Plate Earthing**



Grounding

The grounding includes measures for protecting the part of the circuit, which provides the desired function or the working feature of that circuit.

Grounding can be performed directly or indirectly. Direct grounding is carried out by direct connection of the grounding system. Indirect grounding is performed by binding to the grounding system through impedance (active resistance, inductance, capacitance, or combinations thereof).

Difference between Earthing and Grounding

Characteristics	Earthing	Grounding
Condition	The circuit part that does not carries current under normal condition	The circuit part that does carries current under normal condition
Protection	Protection of people and animals from an electric shock if touching	Protections of power system equipment
Wire	Generally green wire	Generally black wire
Path	Providing a path to a large surface of zero volt potential	Providing a return path to the current in case of faulty/abnormal conditions.

ELECTRICAL HAZARDS

- **SHOCK**. Electric shock occurs when the human body becomes part of the path through which current flows.
- **BURNS.** Burns can result when a person touches electrical wiring or equipment that is energized.
- **ARC-BLAST**. Arc-blasts occur from high- amperage currents arcing through the air. This can be caused by accidental contact with energized components or equipment failure.
- **EXPLOSIONS**. Explosions occur when electricity provides a source of ignition for an explosive mixture in the atmosphere.
- **FIRES**. Electricity is one of the most common causes of fires both in the home and in the workplace. Defective or misused electrical equipment is a major cause.

Safety Precautions while working with Electricity

It is necessary to observe safety precautions while using the electric supply to avoid the serious problems like shocks and fire hazards. Some of the safety precautions are listed below:

1. Insulation of the conductors used must be proper and in good condition.
2. Periodically Megger tests should be conducted and insulation must be checked.
3. Earth connection should be always maintained in proper condition.
4. Make the mains supply switch off and remove the fuses before starting work with any electrical installations.
5. Fuses and circuit breakers must have correct ratings
6. Use dry rubber soled shoes while working.
7. Use rubber gloves while touching any terminals or removing insulation layer from a conductor
8. Use a line tester to check whether a live terminal carries any current still better method is to use a test lamp.
9. Always use insulated screw drivers, pliers, line testers etc.
10. Never touch two different terminals at the same time.
11. Never remove the plug by pulling the wires connected to it
12. The sockets should be fixed at a height beyond the reach of the children.
13. Never touch the switch, sockets and any other electrical appliance with wet hand.
14. For more sensitive equipment, use RCCB or ELCB