WIRES AND CABLES

DEFINITIONS

According to Indian Bureau of Indian standards

Bare Conductors: Conductors without any covering are known as Bare Conductors

Eg: transmission line

Wire: A Bare conductor with insulation is known as Wire. Insulation separates the conductor electrically from other conductors.

Cable: It consists of 2 or more conductors covered with suitable insulation and surrounded by a protective cover.

CLASSIFICATION OF WIRES/CABLES

According to the conductor material used

a. Copper conductors cables

b. Aluminium conductor cables

According to the number of cores

a. Single core cables

b. Double core cables

c. Three core cables

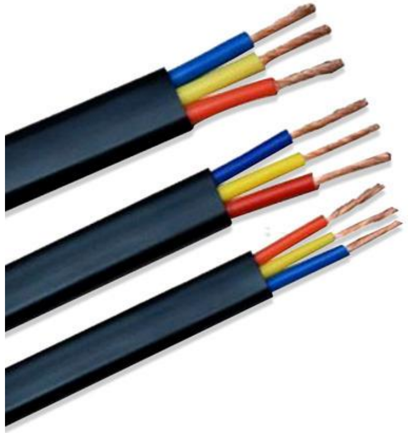
d. Four core cables

e. Two core with earth continuity conductor cables

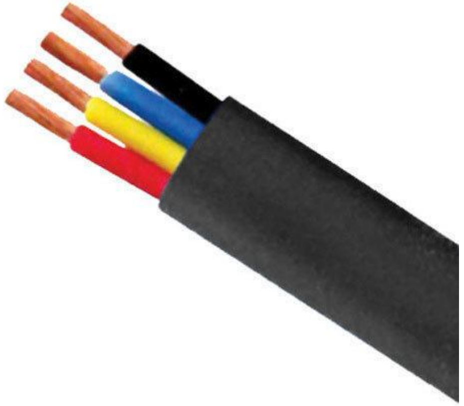
Types of Cables

Single core cables

Double core cable



Three core cables

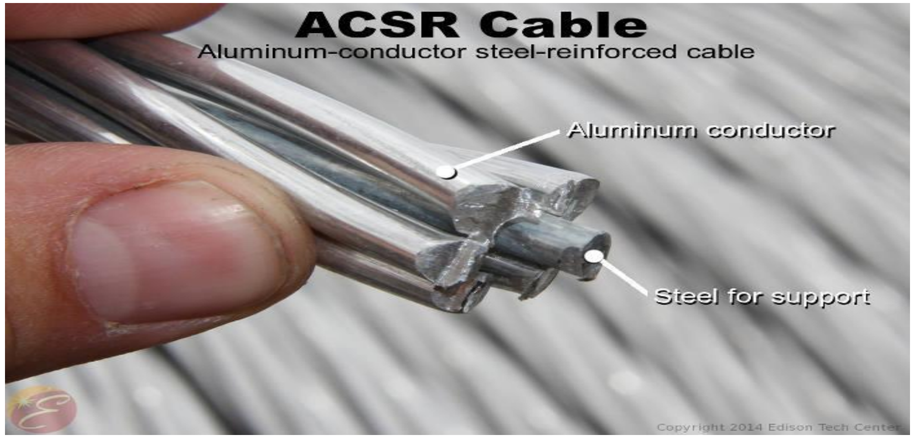


Four core cable

Two core with earth continuity conductor cables

Copper conductor cable

Aluminum conductor cable



Aluminum Conductor Steel Reinforced

CLASSIFICATION OF WIRES/CABLES

According to the type of insulation

a. VIR-Vulcanized Indian Rubber

b. Poly Vinyl Chloride Cables

c. Lead Sheathed Cables

d. Weather proof cables

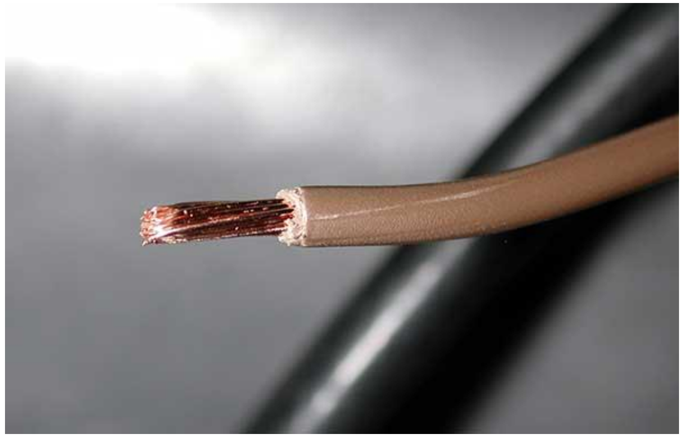
According to the operating voltage

a. Low Tension cables -1000 V   b. High Tension cables - up to 11kV

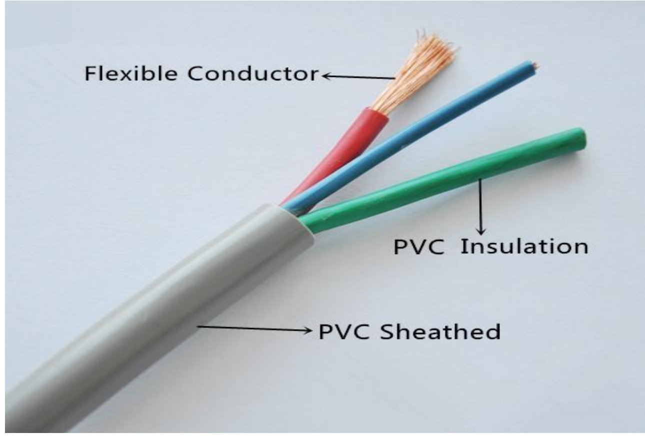
c. Super Tension Cables - 22 to 33 kV

d. Extra High Tension cable - 33 to 66 kV

e. Extra Super Voltage Cables - beyond 132 kV



VIR - Vulcanized Indian Rubber Cable



Poly Vinyl Chloride (PVC) Cables

Lead Sheathed Cables

ELECTRICAL WIRING

<u>Definition:</u>

A network of wires/cables connecting various electrical accessories for distribution of electrical energy from meter board to numerous electrical energy consuming devices such as lamps, fans, televisions and other domestic appliances through controlling and safety devices.

Factors Affecting the Choice of Wiring

1. Durability: Wiring should not be affected by abnormal weather.
2. Safety: Wiring should be safe against leakage, shock and firing hazards
3. Mechanical safety: Wiring should be protected against any mechanical damage.
4. Appearance: Wiring should give artistic look.
5. Accessibility: Switches and plug points must be easily accessible.
6. Cost: Wiring cost and maintenance cost must be minimum.

EARTHING

Definitions
Factors Affecting Earthing
Necessity for earthing
Types of Earthing

DEFINITIONS

- The process of connecting the electrical part of the system (e.g. neutral of a star connected system or one conductor of the secondary of a transformer) or metallic frame of an electrical equipment to the earth (i.e. Soil) with a low resistance wire is known as earthing or grounding.
- The potential of earth is assumed to be ZERO.
- Earthing brings the potential of the equipment connected to earth to zero and protects from electrical shock.

FACTORS AFFECTING EARTH RESISTANCE

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

NECESSITY OF EARTHING

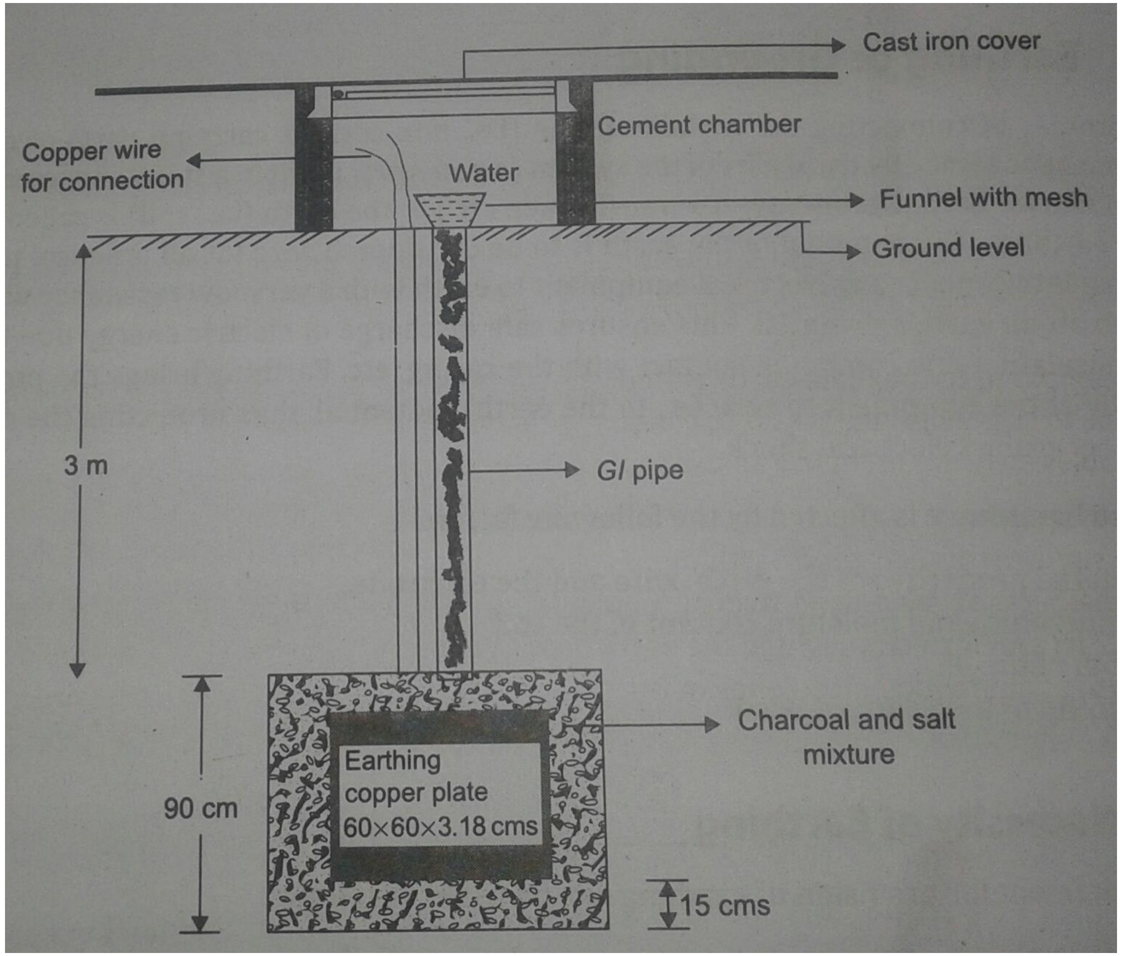
1. To protect electrical equipments.
2. To protect large buildings against lightning
3. To protect operating person from the danger of shock
4. To maintain constant line voltage
5. To avoid the risk of fire due to leakage current flow through unwanted path.

METHODS OF EARTHING

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

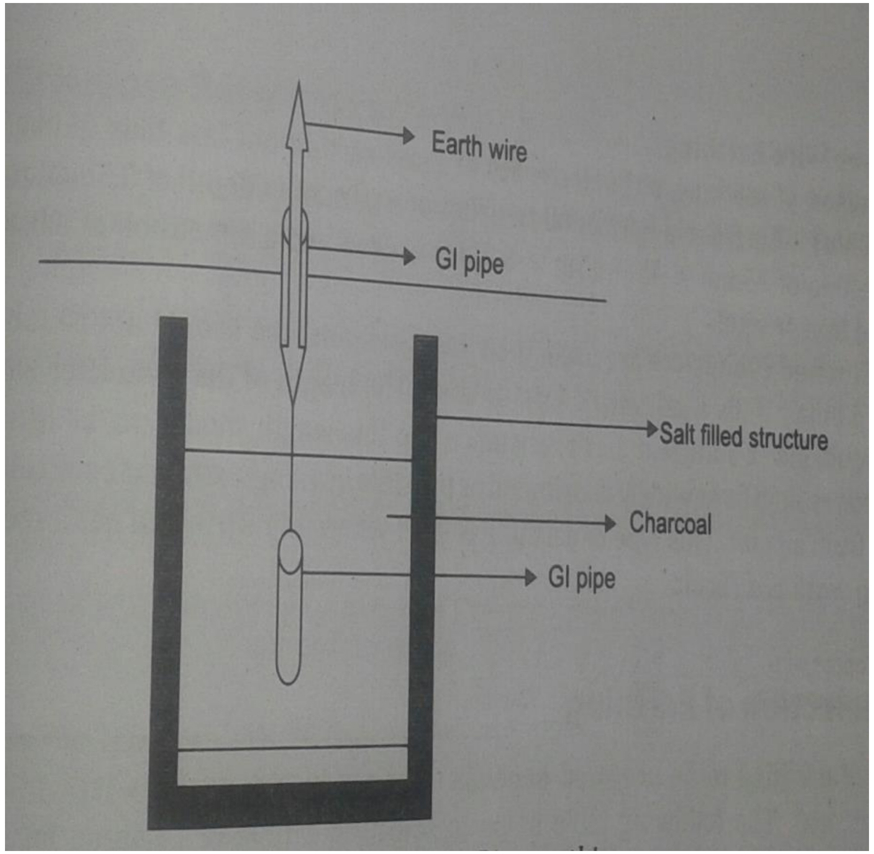
PLATE EARTHING

- A copper plate of 60cm x 60cm is used for earthing
- The plate is buried into the ground not less than 3m from ground level
- The earth plate is embedded in alternate layers of coal and salt for a thickness of 15cm
- Water is poured to maintain earth's electrode resistance < 5 ohm
- Earth wire is bolted to earth plate
- A cement masonry is built with cast iron for easy maintenance.



PIPE EARTHING

- Earth electrode made of GI pipe with 38mm diameter and length 2m with 12mm holes on the surface is placed at a depth of 4.75m in a permanently wet ground.
- Area surrounding the GI pipe is filled with a mixture of salt and coal to maintain the earth resistance at desired value.
- The efficiency can be increased by pouring water through tunnel periodically.
- GI earth wires of sufficient cross sectional area are run through 8.7mm diameter pipe at 60cm below from 19mm diameter pipe and secured tightly at the top.



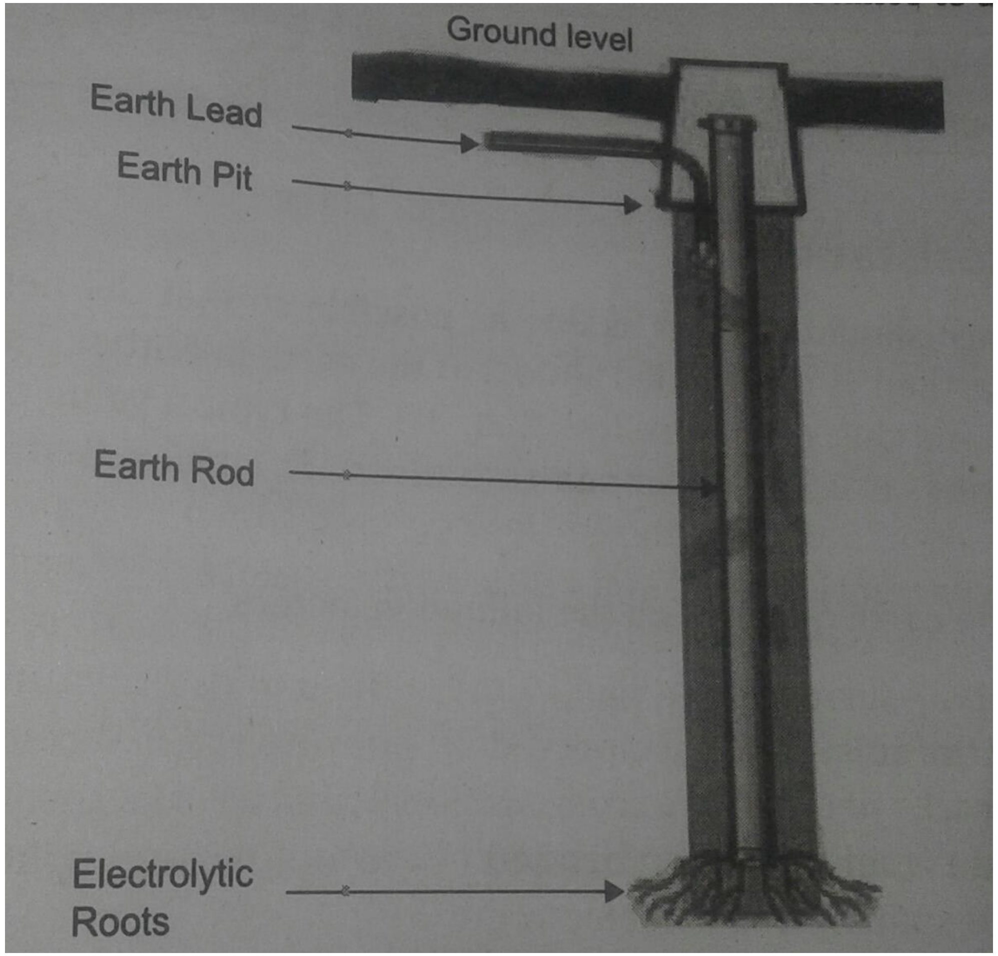
PIPE EARTHING

Advantages

- ✓ Pipe earthing can carry more leakage current due to larger surface area in contact with the soil for a given electrode size.
- ✓ Easy to maintain as the earth wire connection is housed at the ground level.

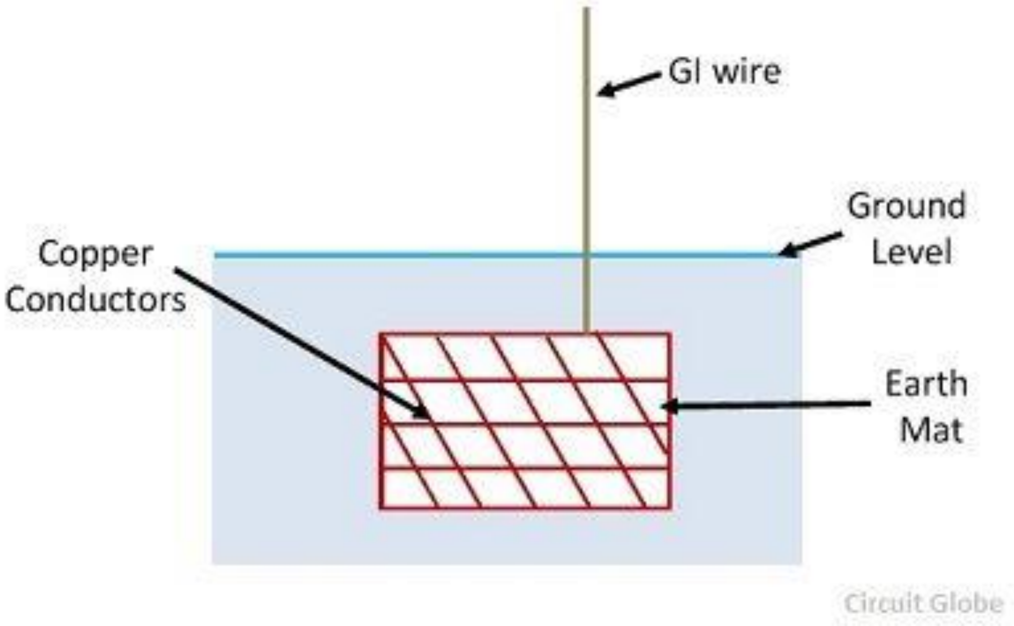
ROD EARTHING

- A copper rod of 8.5 mm diameter or 16mm diameter of galvanized steel or hollow section 25mm of GI pipe of length 2.5m are buries in the earth manually.
- The length of the embedded electrodes in the soil reduces earth resistance to a desired value.



STRIP OR WIRE EARTHING

- The strip electrodes of cross section 25mmx1.6mm is buried in horizontal trenches of 0.5m depth
- If copper is used then the desired cross section is 25mmX4mm and if galvanized steel/iron is used then the desired cross section is 3sq.mm.
- If round conductors are used the desired cross section is 3 sq.mm for copper and 6 sq.mm for galvanized iron or steel
- The 15m length of the conductor with buried in the ground gives sufficient earth resistance.
- This type is used in rocky areas.



STRIP OR WIRE EARTHING

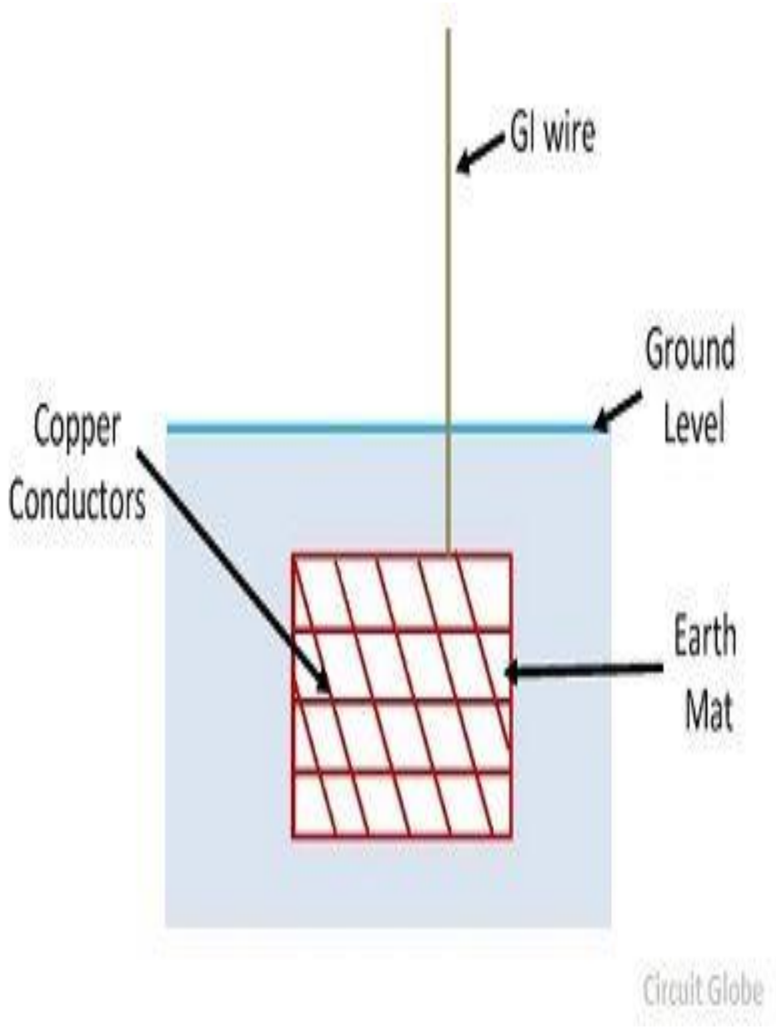
1.The strip electrodes of cross section 25mmx1.6mm is buried in horizontal trenches of 0.5m depth

2. If copper is used then the desired cross section is 25mmX4mm and if galvanized steel/iron is used then the desired cross section is 3sq.mm.

3.If round conductors are used the desired cross section is 3 sq.mm for copper and 6 sq.mm for galvanized iron or steel

4.The 15m length of the conductor with buried in the ground gives sufficient earth resistance.

5.This type is used in rocky areas.



SELECTION OF EARTHING

S. No.	Type of Earthing	Application
1.	Plate Earthing	Transmission Towers, substations
2.	Pipe Earthing	Induction Motors, transformers, heaters, coolers
3.	Rod Earthing	Loose or Sandy soil
4.	Strip or Wire Earthing	Rocky Areas

Batteries

DEFINITIONS

- A battery is device which converts chemical energy into electrical energy
- Batteries consist of two or more voltaic cells connected in series to provide a steady DC voltage at the output terminals
- Voltage is produced due to chemical reaction inside the cell.
- Battery’s output voltage and current rating depends on the elements used for the electrodes, size of electrodes and type of electrolyte.
- Whether a battery can be recharged or not, depends on the cells used to make battery.

CLASSIFICATION OF BATTERIES

PRIMARY BATTERIES

The batteries that are NOT RECHARGABLE are known as Primary batteries.

Eg: Disposable batteries(AA ,AAA type) used in wall clocks, television remote etc.

SECONDARY BATTERIES

The batteries that are RECHARGABLE are known as Secondary batteries.

Eg: batteries used in mobile phones,MP3 players etc.

TYPES OF PRIMARY BATTERIES/CELLS

I.CARBON-ZINC DRY CELL:

- It is the most popular primary cell
- Output voltage is 1.5V
- Negative electrode or cathode -zinc,
- positive electrode or anode-carbon
- Performance increases with intermittent operation

II.ALKALINE CELL:

- It is another popular cell.
- Output voltage is 1.5V
- Negative electrode or cathode –Manganese dioxide,
- positive electrode or anode-Zinc
- Due to low resistance,efficiency is high.

TYPES OF PRIMARY BATTERIES/CELLS

III.ZINC-CHLORIDE CELL:

- It is referred as heavy duty type battery
- It is a modifies zinc-carbon cell
- As it consumes water along with chemically active materials, liquid leakage may occur

IV.MERCURY CELL:

- Negative electrode or cathode –Mercury compound,
- positive electrode or anode-Zinc
- Electrolyte is sodium hydroxide
- As mercury is dangerous, it is outdated

TYPES OF PRIMARY BATTERIES/CELLS

V. SILVER-OXIDE CELL:

- Negative electrode or cathode –Mercury compound,
- positive electrode or anode-Zinc
- Electrolyte is sodium hydroxide
- Output voltage is 1.5V
- They are used in cameras, watches

VI.LITHIUM CELL:

- It is another popular cell.
- Output voltage is 1.5V
- Negative electrode or cathode –Manganese dioxide,
- positive electrode or anode-Zinc
- Due to low resistance, efficiency is high.

TYPES OF SECONDARY BATTERIES/CELLS

I.LEAD-ACID CELL:

1.Output voltage is 2.1 V

2.Negative electrode or cathode –Lead dioxide

positive electrode or anode-Porus lead

3.Electrolyte-Sulfuric acid

4.Used in inverters, automobiles(high load currents)

II.NICKEL CADMIUM CELL:

1.Output voltage is 1.2V and can be recharged many times

2. Negative electrode or cathode –Cadmium hydroxide,

positive electrode or anode-Nickel hydroxide

3.Electrolyte-Potassium hydroxide

4.Used in alarm systems, portable audio and TV

TYPES OF SECONDARY BATTERIES/CELLS

III.LITHIUM ION BATTERY:

1.Negative electrode or cathode –Lithium manganese dioxide

positive electrode or anode-Graphite

3.Electrolyte-Mixture of lithium salts

4.Most compact, safe and energy density is 2 times that of Ni-Cd cell.

IV.NICKEL METAL HYDRIDE CELL:

1.Anode,cathode are same as Ni-Cd cell

2.Capacity is 40% more than Ni-Cd cell

3.Used in applications requiring long battery hour usage

4.Most expensive and cannot be cycled as frequently as Ni-Cd cell

TYPES OF SECONDARY BATTERIES/CELLS

V.NICKEL IRON(EDISON)BATTERY:

1.Anode-Nickel hydroxide, cathode-Iron

2.Electrolyte- Potassium hydroxide

3.Used where the rate of charge and discharge is high

4.Applications:Emergency lamps in hospitals

VI.FUEL CELL:

1.Fuel cell is an electrochemical device that converts chemicals(hydrogen and oxygen) into water and produces electricity

2.Fuel cells are used extensively in space program as a source of DC power

3.They are very efficient and produced 100s of KW power

TYPES OF SECONDARY BATTERIES/CELLS

VII.SOLAR CELL:

- Solar cell converts sun's light energy into electric energy
- Solar cells are semiconductor materials
- Solar cells are arranged in modules, assembled into a large solar array to produce the required power
- Voltage capacity increases with series connection of solar cells
- Current capacity increases with parallel connection of solar cells
- To increase both current and voltage capacity, solar cells are connected in both series and parallel.

CHARACTERISTICS OF BATTERIES

CHEMISTRY

- The main battery chemistries are lead, nickel and lithium
- They must be charged with specified charger to eliminate misoperation

RATED VOLTAGE

The rated voltage must be verified before connecting in circuit

BATTERY CAPACITY

- Battery capacity(Ampere-hours) is a measure of the charge stored by the battery and is determined by the active material in the battery
- Ampere hour is defined as the amount of energy charge in a battery that will allow one ampere of current to flow for one hour.

COLD CRANKING AMPERES(CCA)

- Every battery is numbered with CCA.
- The number denotes the current the battery is able to provide at -18°C

CHARACTERISTICS OF BATTERIES

- The energy stored in a battery is known as battery capacity and is also measured in Watt-hour or Kilo watt hour
- Battery capacity represents the maximum energy that can be extracted from the battery
- The actual battery capacity depends on it’s age, past history, charging time and discharging time and thus can vary from the rated capacity
- Eg: A **12V**,**7Ah battery** is supposed to provide 7A @12V during one hour

COMPARISON OF PRIMARY AND SECONDARY CELLS

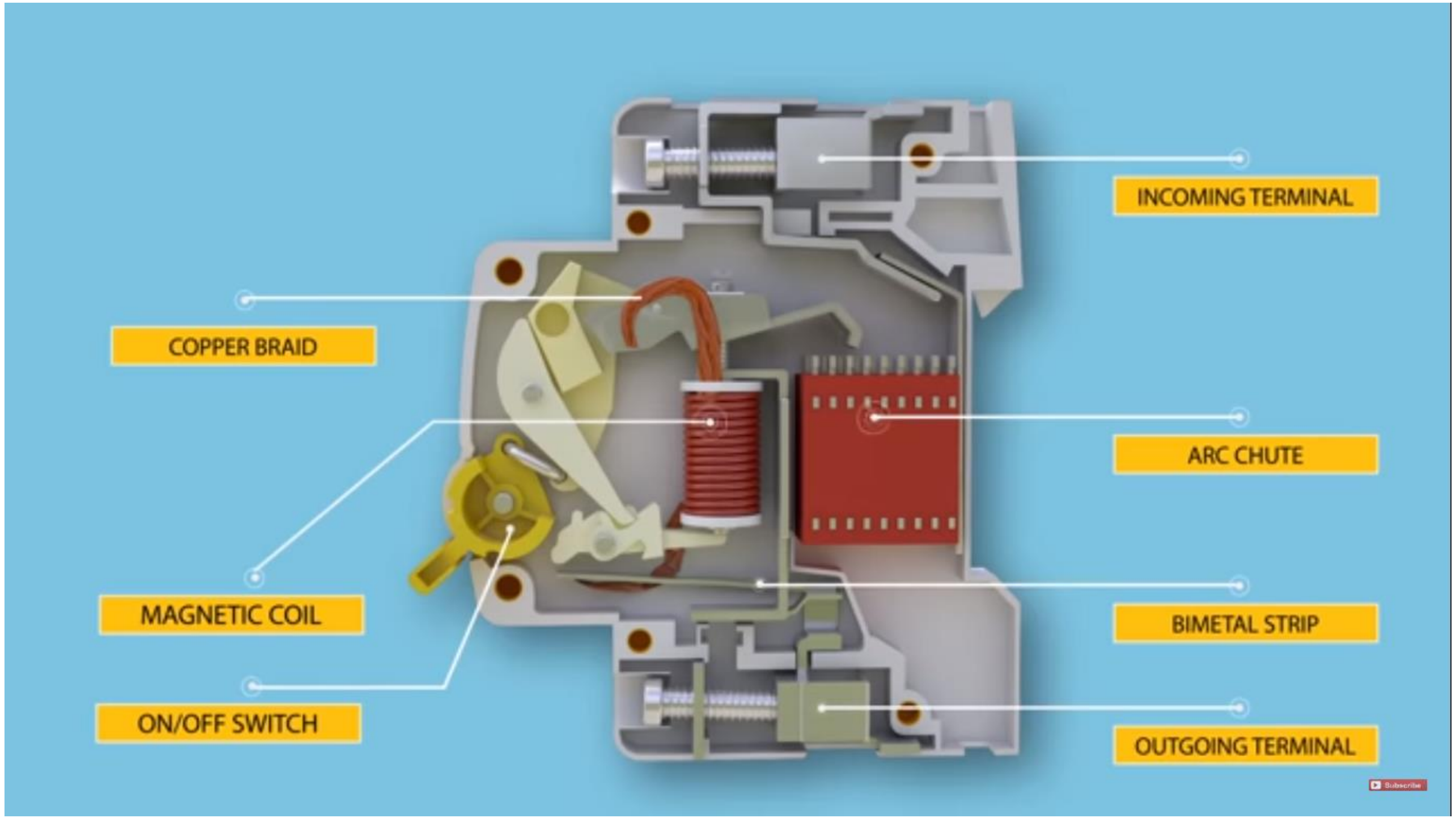
S.NO.	PRIMARY CELLS	SECONDARY CELLS
1	Cannot be recharged	Can be recharged
2	Light weight	Heavy weight
3	Short life and low cost	Long life and high cost
4	Low power output and low efficiency	High power output and high efficiency
5	Not used continuously	Used continuously
6	Less maintenance	High maintenance

MINIATURE CIRCUIT BREAKER

Introduction

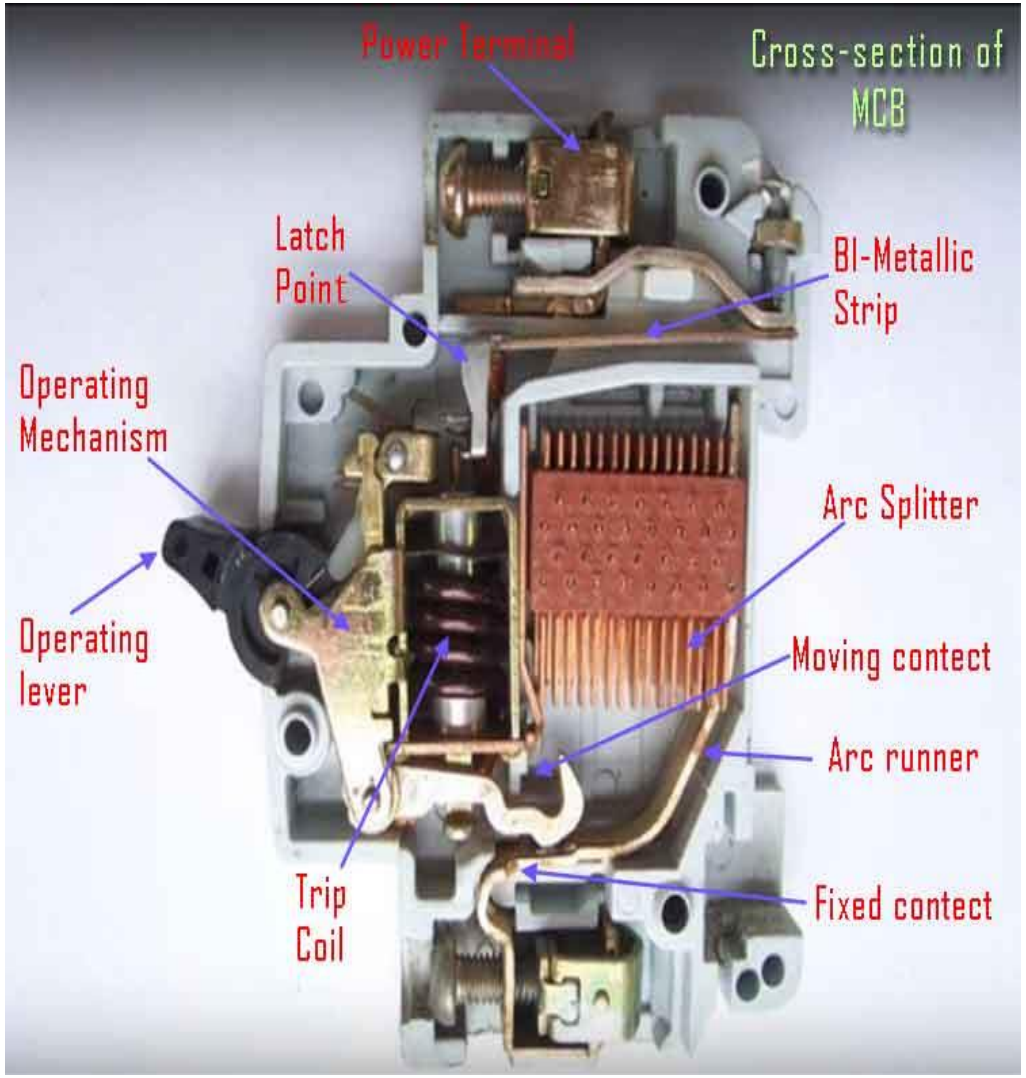
- Electrical Circuit Breaker is a switching device which can be operated manually and/or automatically to control and protect electrical network.
- During abnormal condition electrical equipments like transformers, transmission lines and induction motors are subjected to severe disturbance.
- A Circuit Breaker consists of fixed and moving contacts known as electrodes.
- During normal conditions, the contacts remain closed and opens during abnormal condition.

Components of an MCB



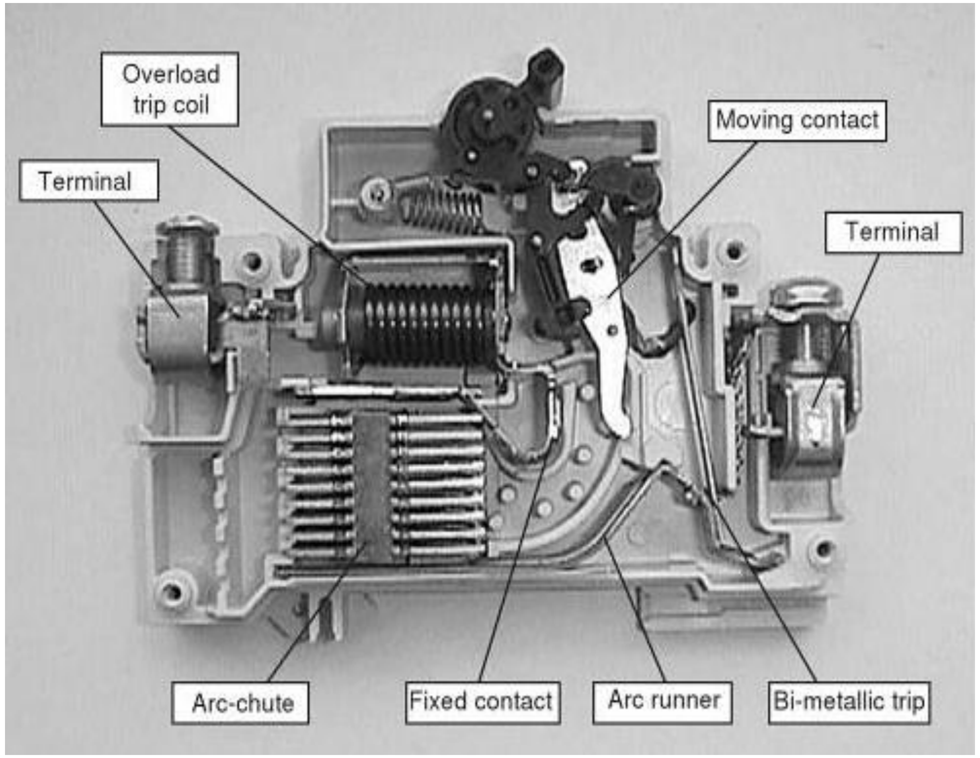
Components of an MCB

1. Bimetallic Strip
2. Fixed Contact
3. Moving Contact
4. Trip Coil
5. Latch Point
6. Arc Splitter or Arc Chute
7. Arc Runner



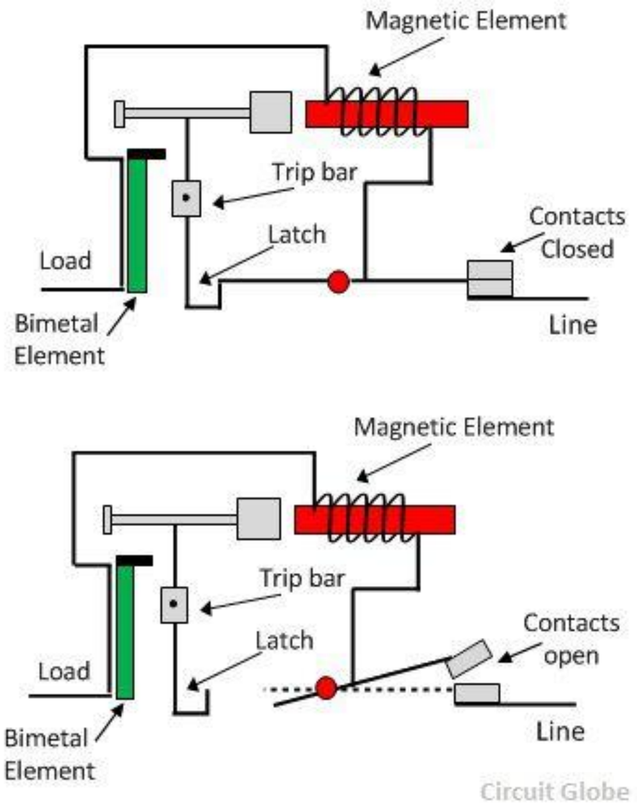
Miniature Circuit Breaker

- A Miniature Circuit Breaker is a switching device to protect electrical network from short circuits.
- A Miniature Circuit Breaker operates by interrupting the flow of short circuit or high currents.



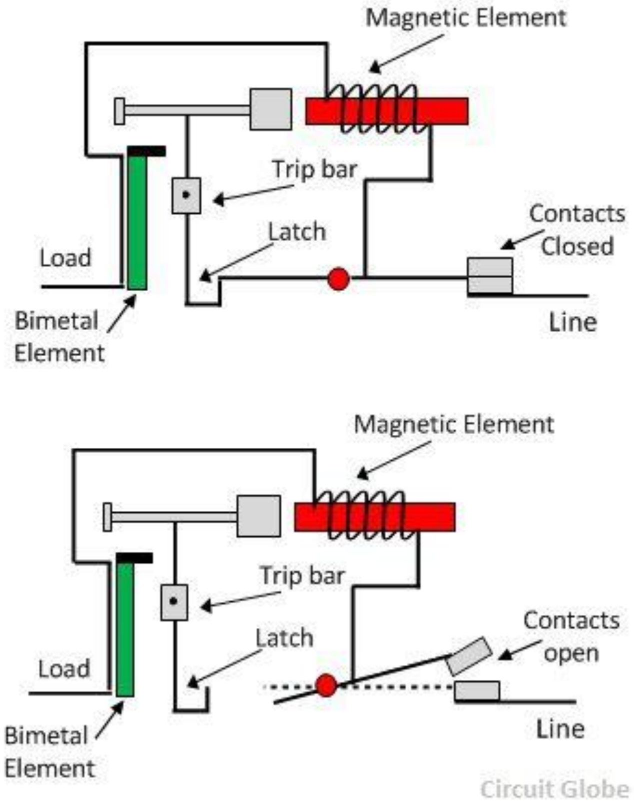
Working Principle

- MCB consists of a moving contact and a fixed contact.
- When current exceeds a specified limit, a solenoid forces the movable contact to open and the MCB turns off, thereby stopping the flow of current in the circuit.

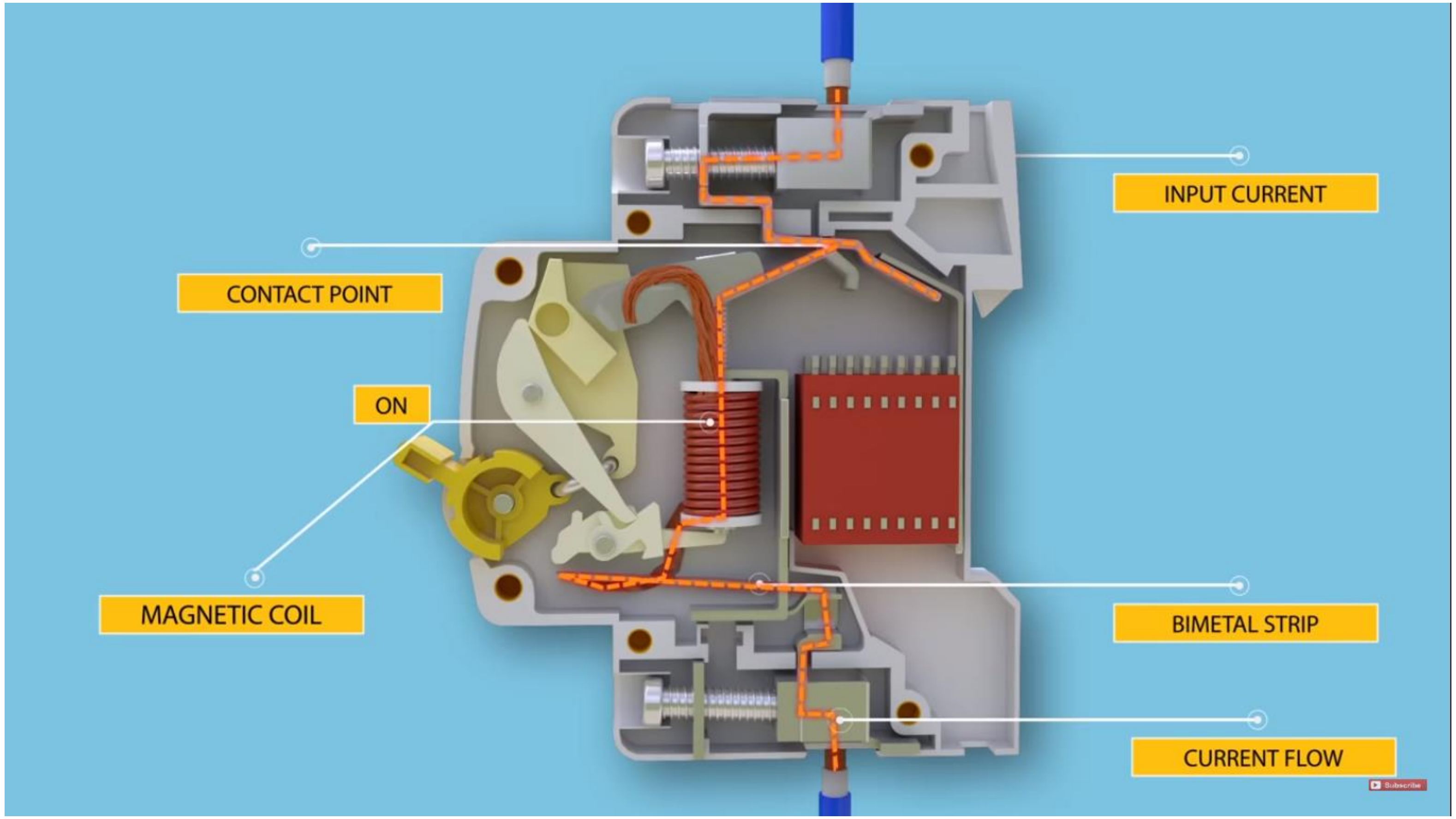


Working Principle

- MCB consists of one bi-metallic strip, one trip coil and one hand operated on-off lever.
- Electric current carrying path of a MCB is as follows:
- Incoming power terminal-bimetallic strip-current coil or trip coil-moving contact-fixed contact- outgoing power terminal and all are connected in series.

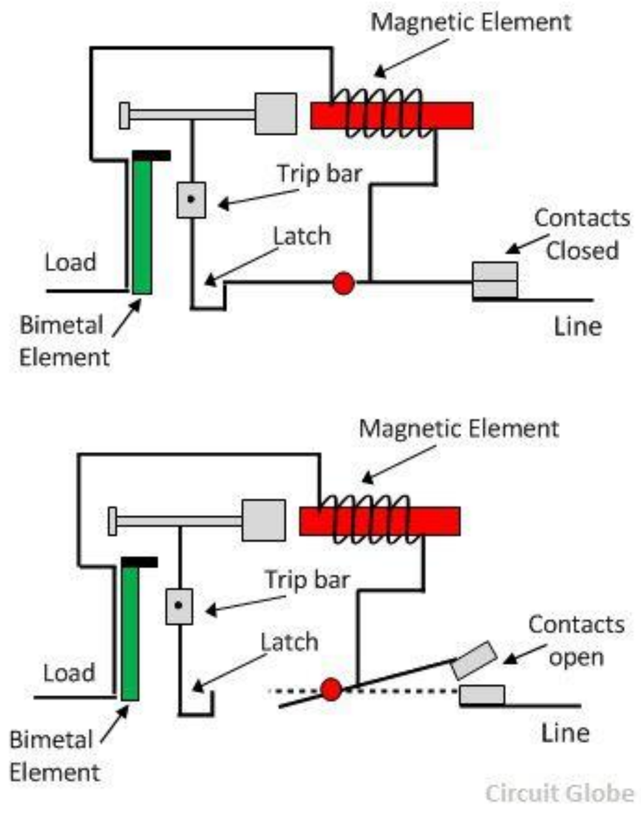


Current Path in MCB

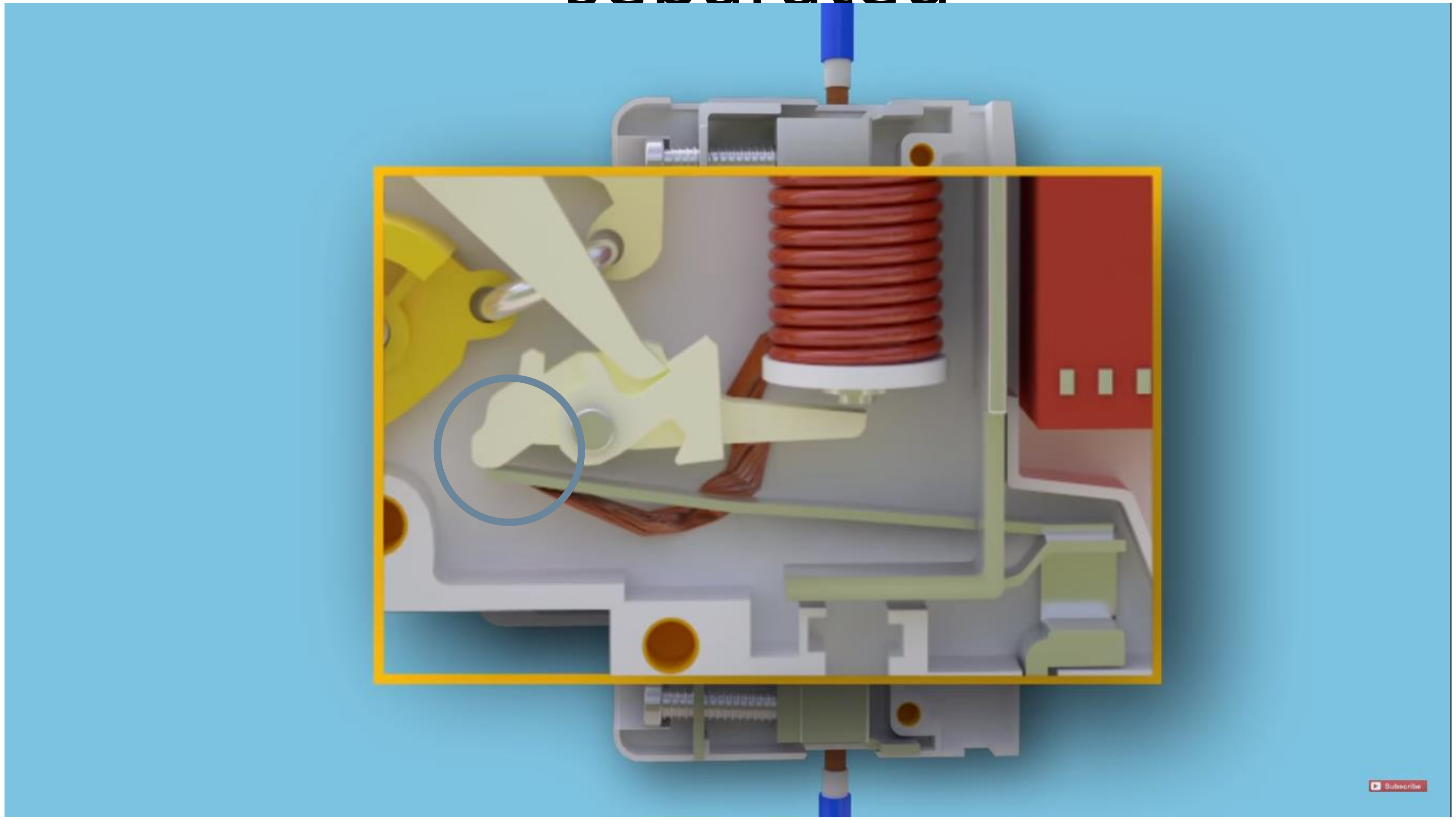


Working Principle

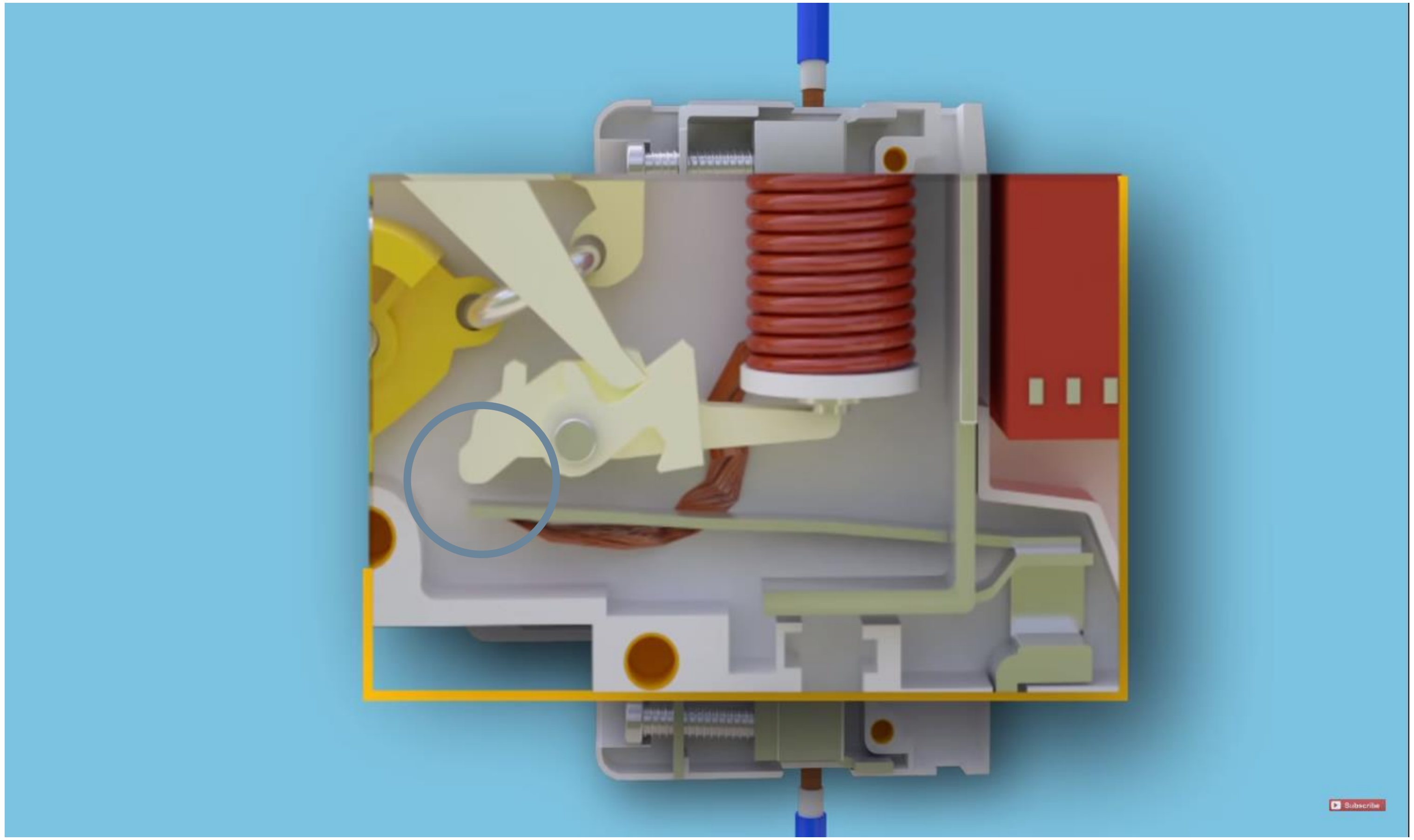
- If the circuit is overloaded for long time then bimetallic strip becomes overheated and deformed.
- MMF of the trip coil causes the plunger to hit the latch point and force the latch to be displaced.
- The moving contact of the MCB is arranged such that with the displacement of latch point moving contact is separated from fixed contact.
- Arc is produced at the instant of separation of fixed contact from moving contact.
- Arc goes through arc runner and enters into arc splitters and thereby arc is eliminated.



Tripping mechanism – Contacts not separated



Tripping mechanism – contacts separated



Advantages :

- ✓ Replacement is not required as in fuse.
- ✓ MCB can interrupt 100A current.
- ✓ MCB can protect the electrical network from all abnormal conditions.

How an MCB works?

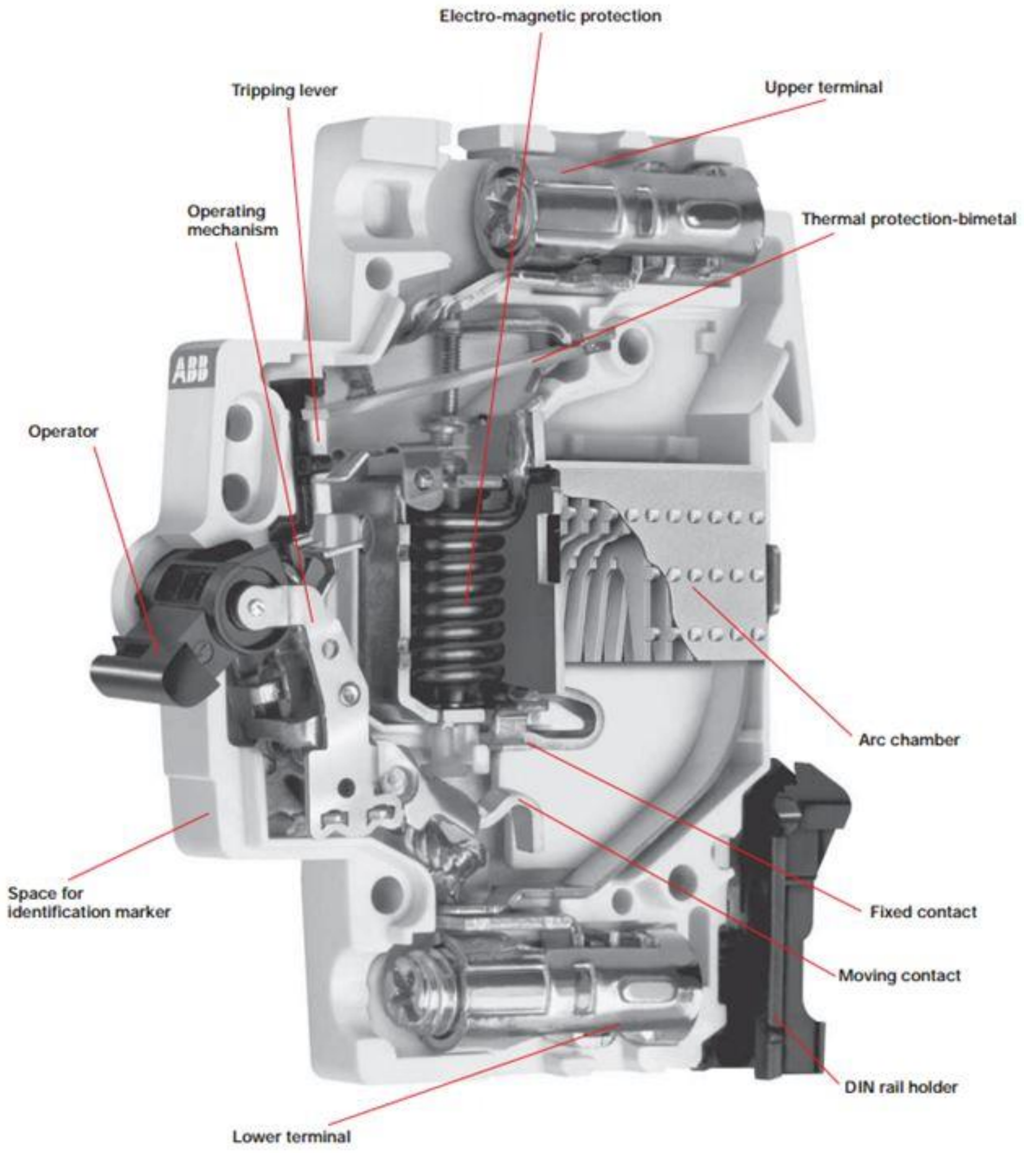
MOULDED CASE CIRCUIT BREAKER(MCCB)

MOULDED CASE CIRCUIT BREAKER(MCCB)

1. A Molded Case Circuit Breaker is an electromechanical device to protect the electrical network from over current and short circuit.
2. MCCBs provide over current and short circuit protection from 63A to 3000A.
3. The circuit can be opened manually or automatically during abnormal condition.

MCCBs consist of 5 components.

1. Moulded case or frame
2. Operating mechanism
3. Arc extinguishers
4. Contacts
5. Trip components

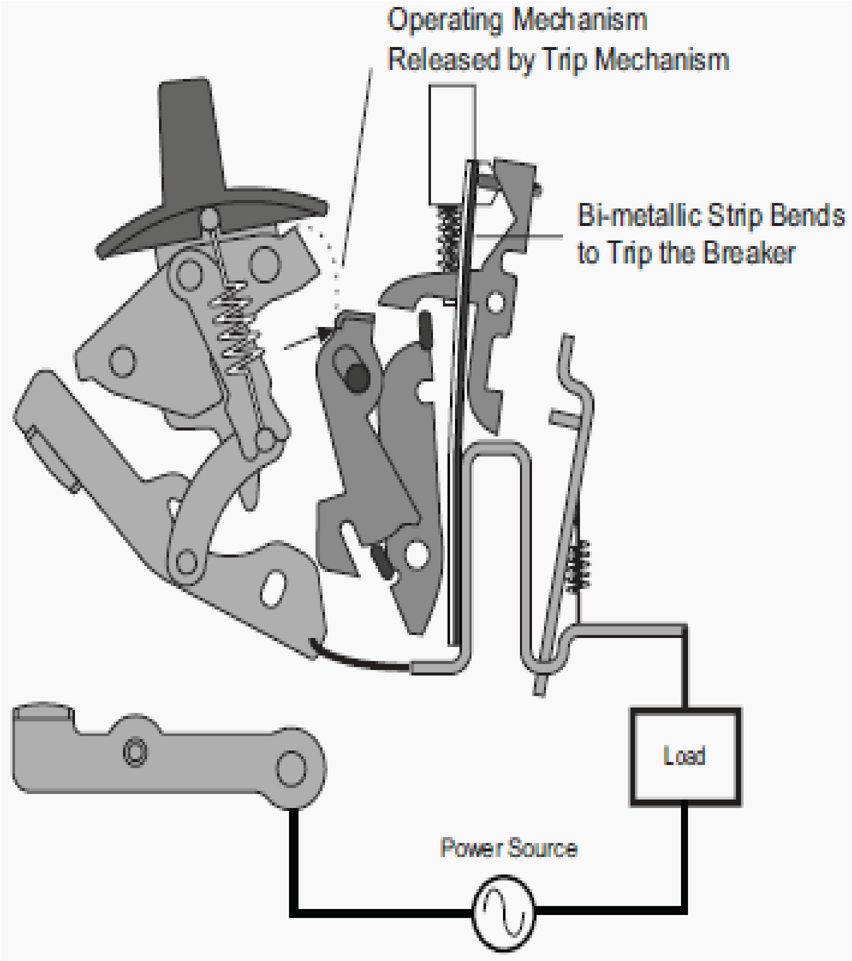


Construction

1. MCCB is constructed of two pieces of heavy duty electrically insulated plastic riveted together.
2. Series connected thermal elements and spring loaded trigger are inside the plastic shell.
3. The thermal element gets warm due to over current, spring trips and isolates the circuit.

Operation

- Overload protection is obtained by thermal mechanism.
- The high magnitude short circuit current induces high magnetic field in a solenoid inside the breaker which trips the contact and short circuit current is interrupted.
- As the temperature changes, the bimetallic contact of MCCB expands and contracts.
- As current exceeds specified value, bimetallic contact gets heated, expanded till the circuit is interrupted.



Applications

- MCCBs can interrupt currents from 100 to 1000A.
- Thus, MCCBs are used in the protection of generators, transmission lines and transformers.

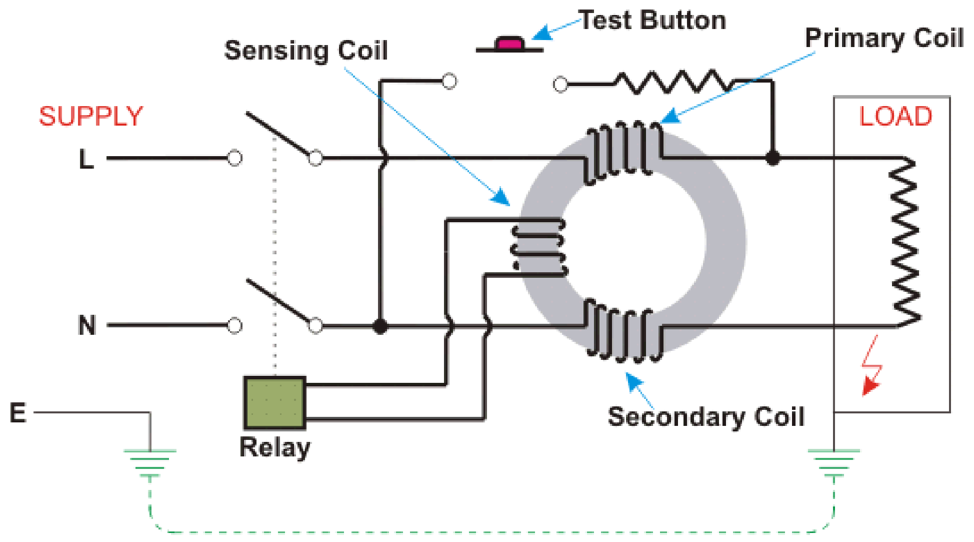
EARTH LEAKAGE CIRCUIT BREAKER(ELCB)

EARTH LEAKAGE CIRCUIT BREAKER(ELCB)

ELCB is a device to directly detect leakage current to earth from an electrical equipment.

ELCB operation

- Current ELCB is a current operated circuit breaker.
- Current ELCB consists of a 3 winding transformer (2 primary windings and 1 secondary winding)
- Neutral and line wires acts as the two primary windings.
- A wire wound coil is the secondary winding.
- The current flowing through secondary winding is zero at the balanced condition.
- In the balanced condition, the flux due to the current through the phase wire will be neutralised by the current flowing through the neutral wire because the current flowing through phase returns back as neutral.



Working Principle of Residual Current Circuit Breaker

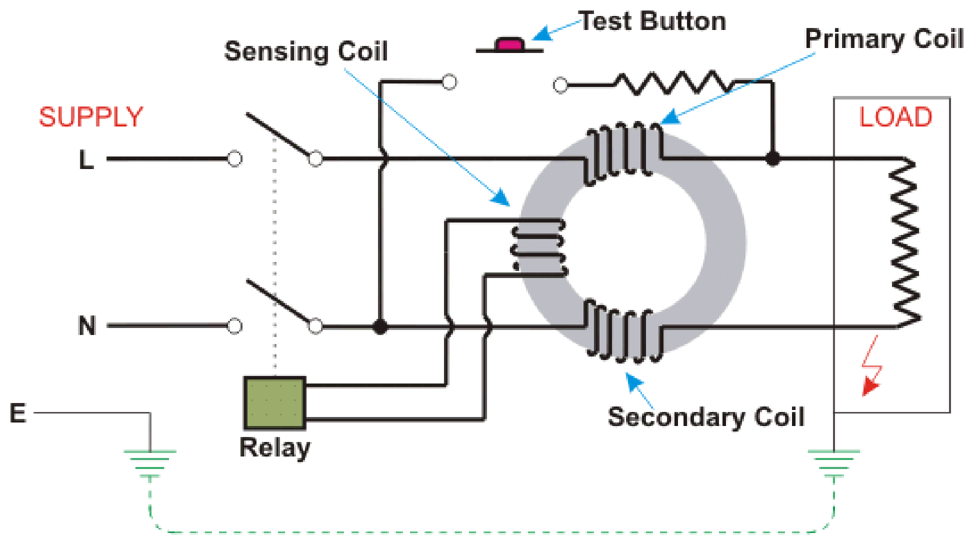
ELCB operation

•During any disturbance small current flows to ground also.

•Thus an unbalance exists between line and neutral currents and creates an unbalanced magnetic field.

•This induces current through the secondary winding, which is connected to the sensing circuit.

•Sensing circuit senses the leakage and send a signal to the tripping system and trips the contact.



Working Principle of Residual Current Circuit Breaker

Power Factor

Definition

Causes of Low Power Factor

Disadvantages of low power factor

Power Factor Improvement

Power in DC Circuits

- In general power is the capacity to do work. In electrical domain, electrical power is the amount of electrical energy that can be transferred to some other form (heat, light etc) per unit time.
- Mathematically it is the product of voltage drop across the element and current flowing through it.
- Considering first the DC circuits, having only DC voltage sources, the inductors and capacitors behave as short circuit and open circuit respectively in steady state.
- Hence the entire circuit behaves as resistive circuit and the entire electrical power is dissipated in the form of heat. Here the voltage and current are in same phase and the total electrical power is given by:

$$Electrical\ power = Voltage\ across\ the\ element \times Current\ through\ the\ element.$$
$$Its\ unit\ is\ Watt = Joule/sec.$$

Power in AC Circuits

- Now coming to AC circuit, here both inductor and capacitor offer a certain amount of impedance given by:

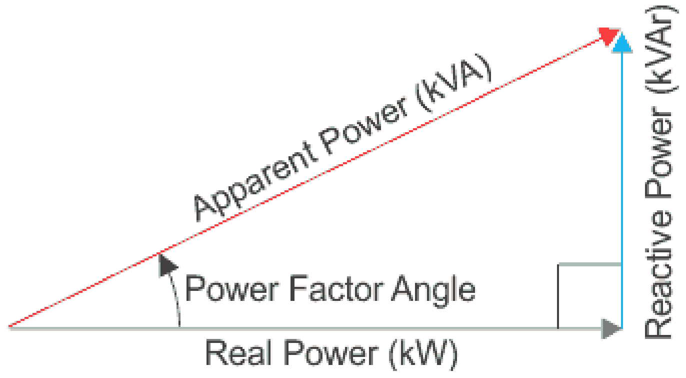
$$X_L = 2\pi f L \ and \ X_C = \frac{1}{2\pi f C}$$

- The inductor stores electrical energy in the form of magnetic energy and capacitor stores electrical energy in the form of electrostatic energy. Neither of them dissipates it.
- Further, there is a phase shift between voltage and current.
- Hence when we consider the entire circuit consisting of a resistor, inductor, and capacitor, there exists some phase difference between the source voltage and current.

What is Power Factor?

- The cosine of this phase difference is called **electrical power factor**.
- This factor ($-1 < \cos\phi < 1$) represents the fraction of the total power that is used to do the useful work.
- The other fraction of electrical power is stored in the form of magnetic energy or electrostatic energy in the inductor and capacitor respectively.

Power Triangle



Mathematically, $S^2 = P^2 + Q^2$

and

$$Power\ Factor = \frac{Active\ Power}{Apparent\ Power}$$

$$Total\ electrical\ power = Voltage\ across\ the\ element \times current\ through\ the\ element$$

This is called **apparent power** and its unit is VA (Volt Amp) and denoted by '**S**'.

A fraction of this total electrical power which does our useful work is called **active power**. We denote it as '**P**'.

P = Active power = Total electrical power × cosφ and its unit is Watt.
The other fraction of power is called reactive power.
Reactive power does no useful work, but it is required for the active work to be done.

We denote it with '**Q**' and mathematically is given by:
Q = Reactive power = Total electrical power × sinφ and its unit is VAR (Volt Amp Reactive).
This reactive power oscillates between source and load. To help understand this better all these power are represented in the form of a triangle.

Causes of Low Power Factor

- The usual reason for the low power factor is because of the inductive load.
- The current in the inductive load lag behind the voltage. The power factor is therefore lagging.
- The important inductive loads responsible for the low power factor are the three-phase induction motors (which operate at a 0.8 lagging power factor), transformer, lamps and welding equipment operate at low lagging power factors.
- Power factor improvement methods are used for improving the value of power factor in a power system.

Disadvantages of Low Power Factor

- Power in a Single Phase AC Circuits, $P = V \times I \cos\Phi$
- $I \propto 1/\cos\Phi$
- Current "I" is inversely proportional to CosΦ i.e. Power Factor.
- In other words, When Power Factor increases, Current Decreases, and when Power Factor decreases, Current Increases.
- Now, In case of Low Power Factor, Current will be increased, and this high current will cause to the following disadvantages.

1. Large Line Losses (Copper Losses)

- We know that Line Losses is directly proportional to the squire of Current "I^2"
- Power Loss = $I^2 x R$ i.e., the larger the current, the greater the line losses i.e. I>>Line Losses
- Thus, if Power factor = 0.8, then losses on this power factor $= 1/\cos\Phi^2 = 1/\ 0.8^2 =$ 1.56 times will be greater than losses on Unity power factor.

Disadvantages of Low Power Factor

2. Large kVA rating and Size of Electrical Equipments

- As we know that almost all Electrical Machinery (Transformer, Alternator, Switchgears etc) rated in kVA. But, it is clear from the following formula that Power factor is inversely proportional to the kVA i.e.

$$\cos\Phi = kW / kVA$$

- Therefore, The Lower the Power factor, the larger the kVA rating of Machines also, the larger the kVA rating of Machines, The larger the Size of Machines and The Larger the size of Machines, The Larger the Cost of machines.

3. Greater Conductor Size and Cost

- In case of low power factor, current will be increased, thus, to transmit this high current, we need the larger size of conductor. Also, the cost of large size of conductor will be increased.

Disadvantages of Low Power Factor

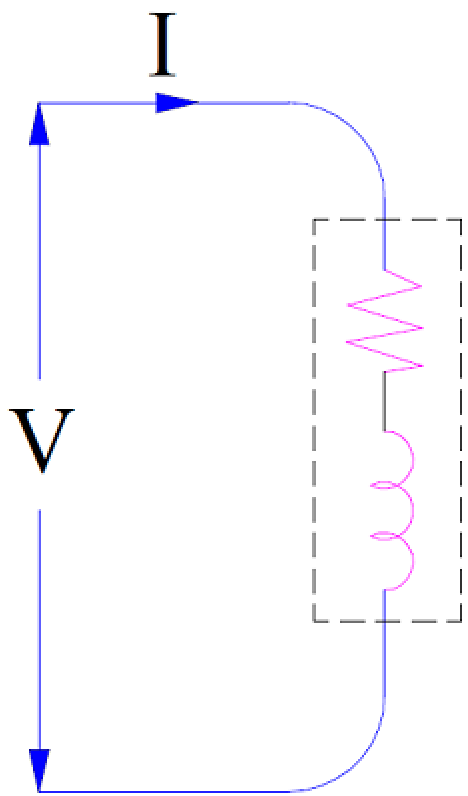
4. Poor Voltage Regulation and Large Voltage Drop

- Voltage Drop = V = IZ
- Now in case of Low Power factor, Current will be increased. So the Larger the current, the Larger the Voltage Drop.
- Also Voltage Regulation = V.R = $(V_{No\ Load} - V_{Full\ Load}) / V_{Full\ Load}$
- In case of Low Power Factor (lagging Power factor) there would be large voltage drop which cause low voltage regulation.
- Therefore, keeping Voltage drop in the particular limit, we need to install Extra regulation equipment i.e. Voltage regulators.

5. Low Efficiency

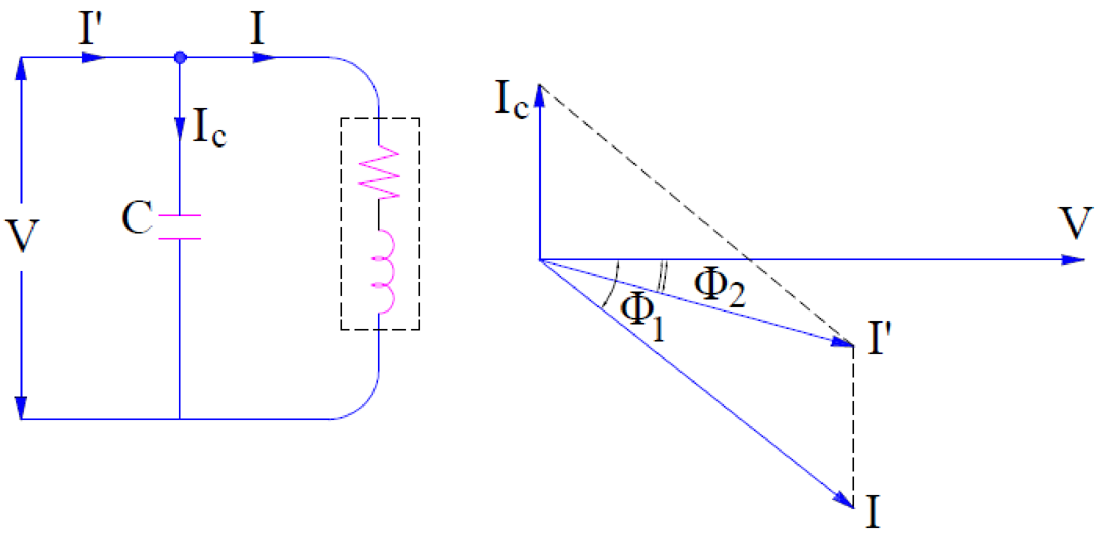
- In case of low Power Factor, there would be large voltage drop and large line losses and this will cause the system or equipment's efficiency too low.
- For instant, due to low power factor, there would be large line losses; therefore, alternator needs high excitation, thus, generation efficiency would be low.

Power Factor Improvement Principle



- The basic principle for power factor improvement is to connect a device which take leading current in parallel with inductive loads to neutralize the effect of lagging current.
- Capacitor is one such device. Let us consider this with an example for better understanding of power factor improvement.
- Figure shows a single phase inductive load connected to single phase supply voltage V.
- This inductive load is taking lagging current at a power factor of $\cos\phi_1$.

Power Factor Improvement Principle



- When a capacitor is connected across this load, it will takes current I_c leading by an angle 90 degree with the supply voltage V as shown in figure.
- Therefore, the net line current I' is the phasor sum of load current I and capacitor current I_c.
- Since the reactive current component (i.e. $I\sin\emptyset_1$) of load is partially neutralized by the leading capacitor currentI_c, therefore the resultant line current I' will lag with the supply voltage by an angle less than $\emptyset_1$.
- This current I' is shown to be lagging by an angle $\emptyset_2$ in the figure. Since $\emptyset_2 < \emptyset_1$, this means that $\cos\emptyset_1 < \cos\emptyset_2$.
- Thus power factor of the load is corrected to $\cos\emptyset_2$ from earlier value of $\cos\emptyset_1$.