Utilization of Electrical Energy

SEMESTER-5TH ELECTRICAL ENGINEERING

Electric Welding

Welding

- Welding is a **process of joining two similar metals** by using heat

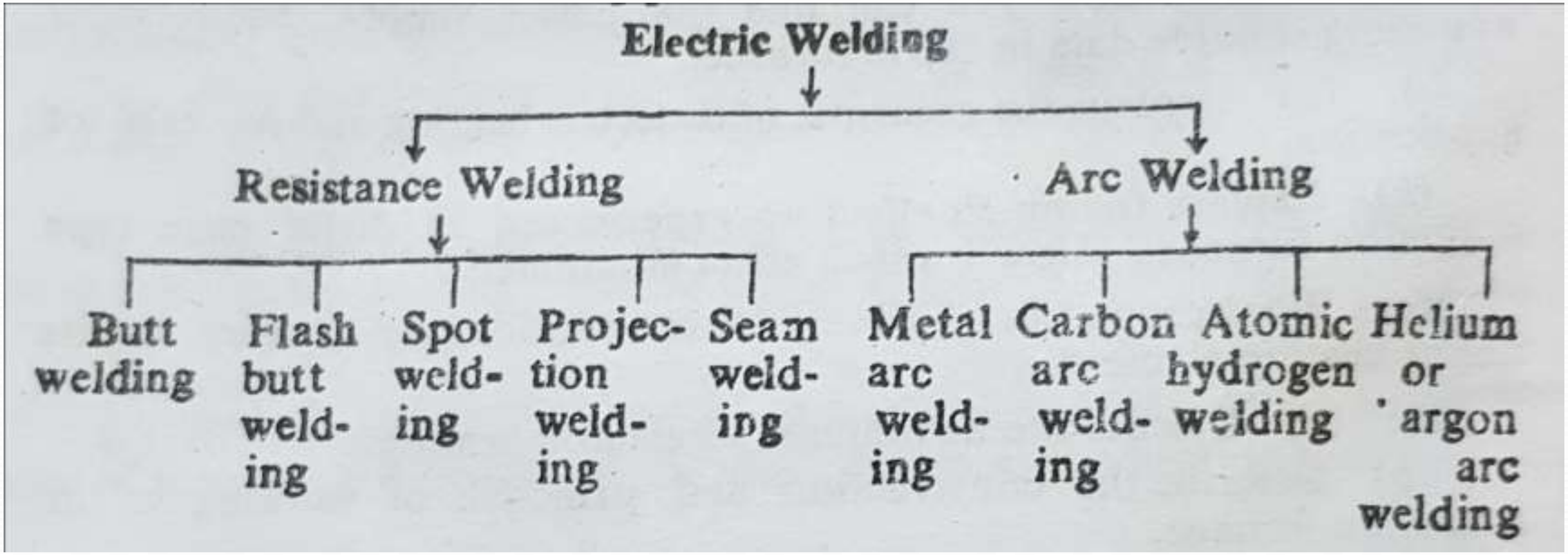
Advantages

- **Uniform weld** is obtained
- Greater mechanical **strength**
- Flexibility for doing welding work as welding equipment can be carried to remote place
- Electric weld does not produce smoke, ash, toxic gasses etc. So it **clean** from the welding
- **Efficient** and **economic** form of welding
- **Quick Operation**-Welding work can be started immediately when needed

Advantages

- **Ease of Control** –The welding current and hence temperature can be controlled easily

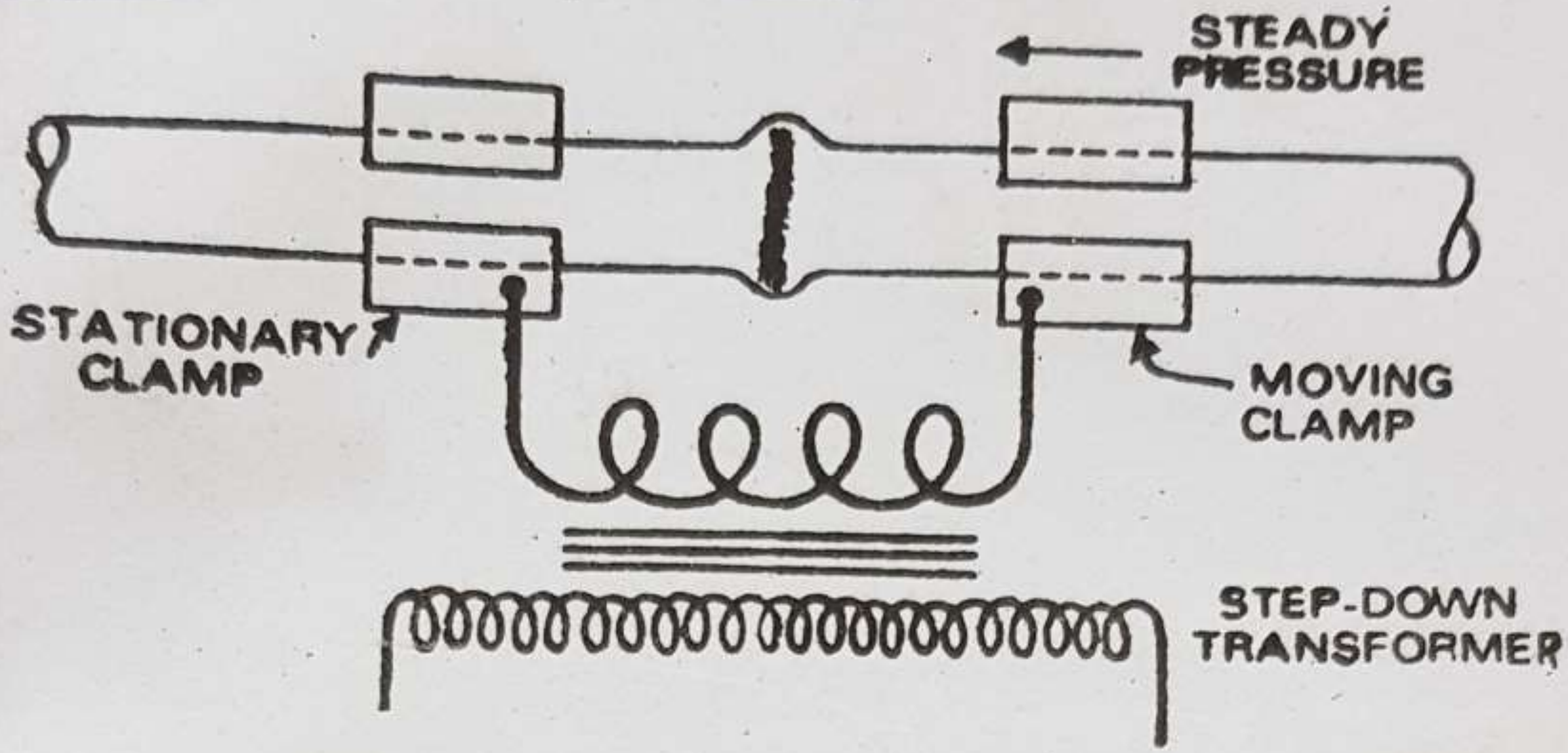
Electric Welding



Resistance Welding

- **Heavy current is passed** through the joint
- **Heat is produced** due to flow of current through joint
- **Metal is melted** due to heat and welding is performed

Butt Welding

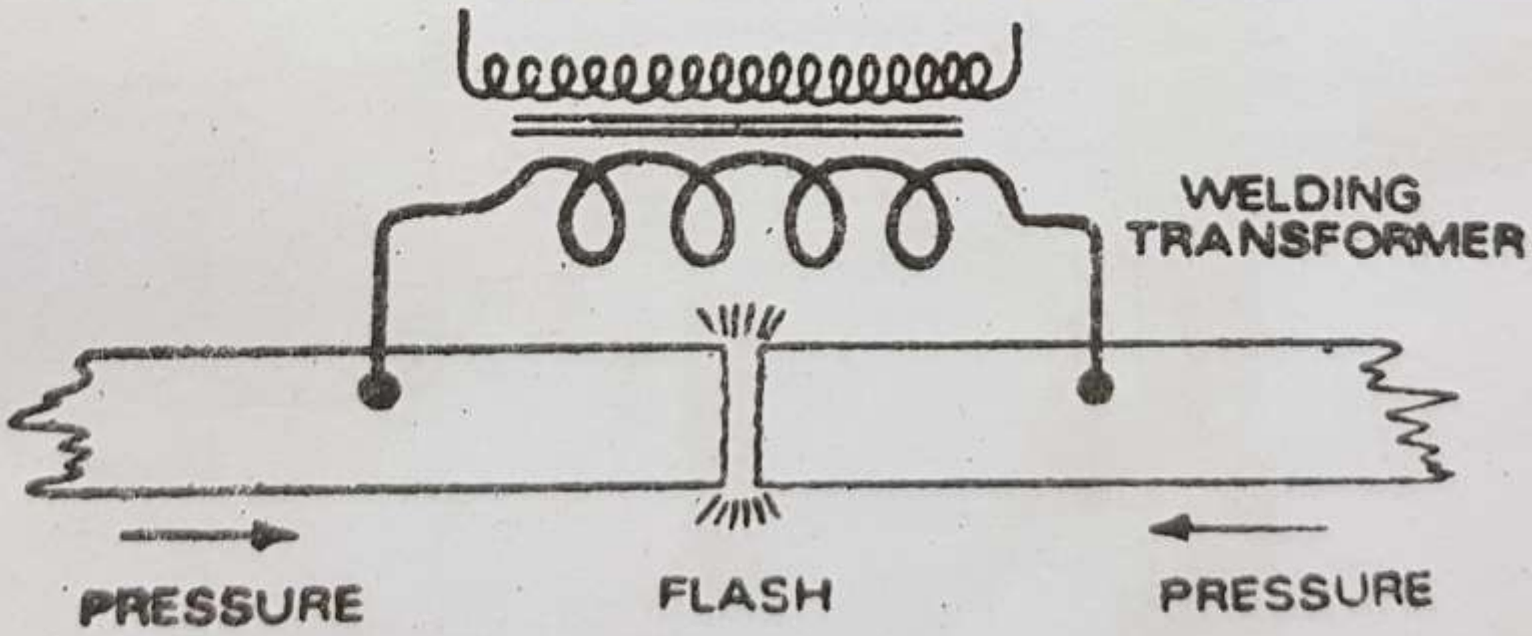


BUTT WELDING

Butt Welding

- The two **parts are brought together** and **pressure is applied** by using spring
- Voltage required is **2-10 volts**
- Current varies from **50 A to several 100 Amperes**

Flash Butt Welding

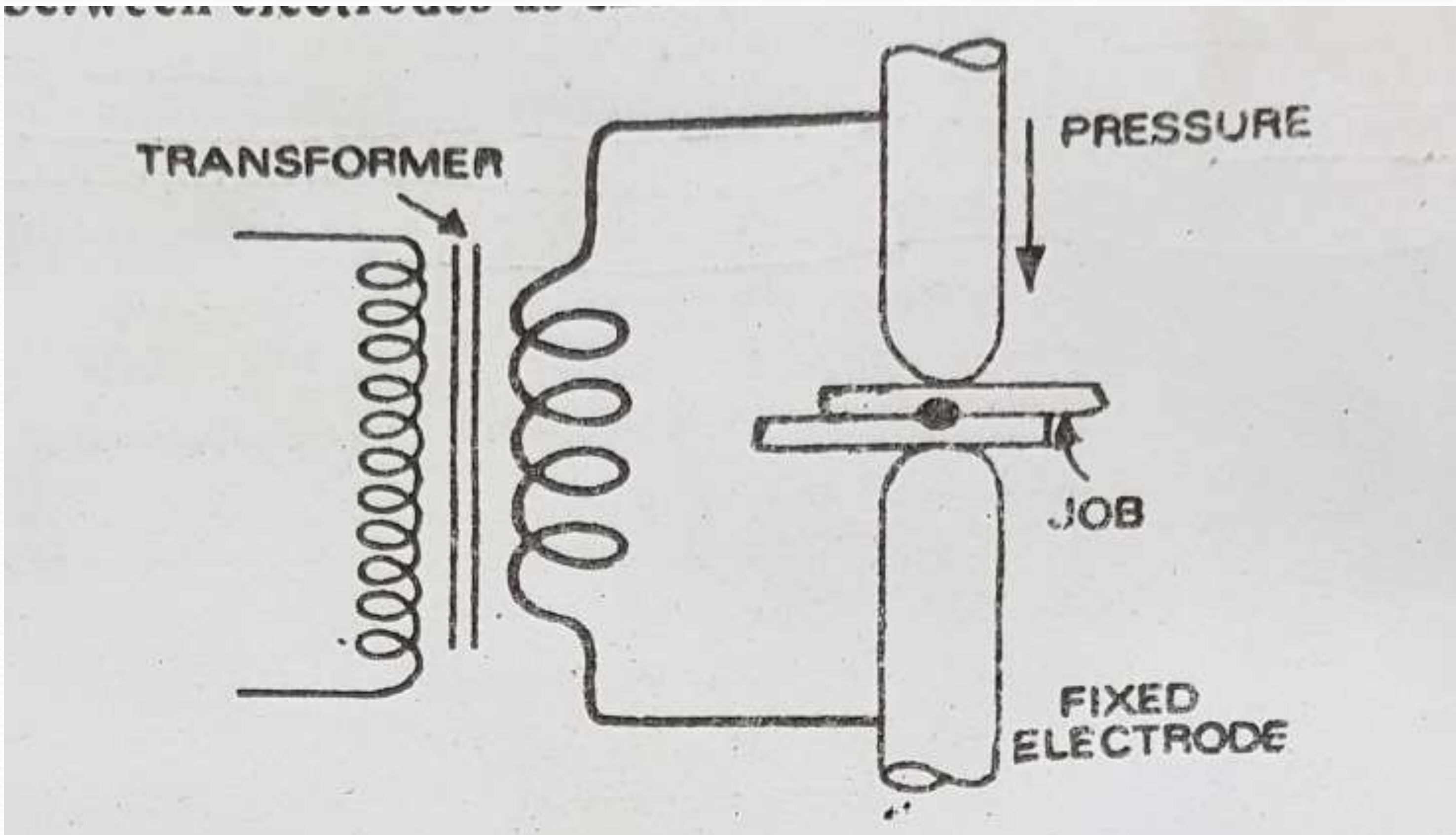


FLASH BUTT WELDING

Flash Butt Welding

- Two parts are **put together under light pressure**
- Due to heavy current, **arcing at joint takes place**
- After attaining desired temperature, **more pressure is applied**

Spot Welding

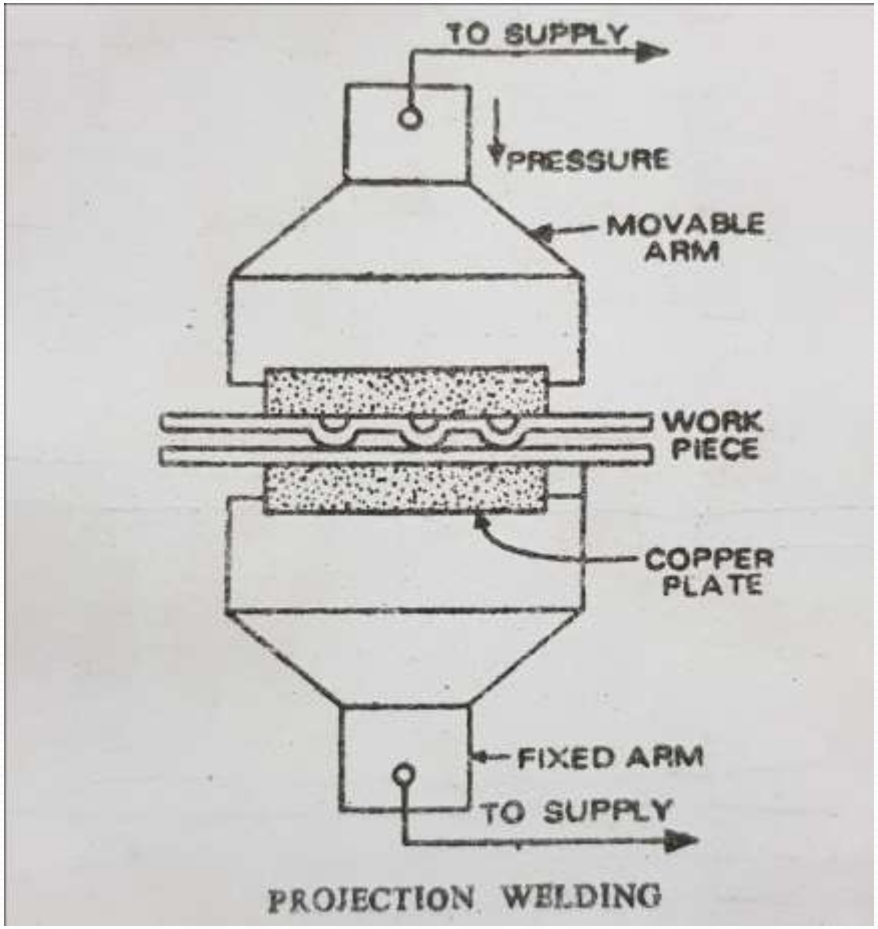


SPOT WELDING

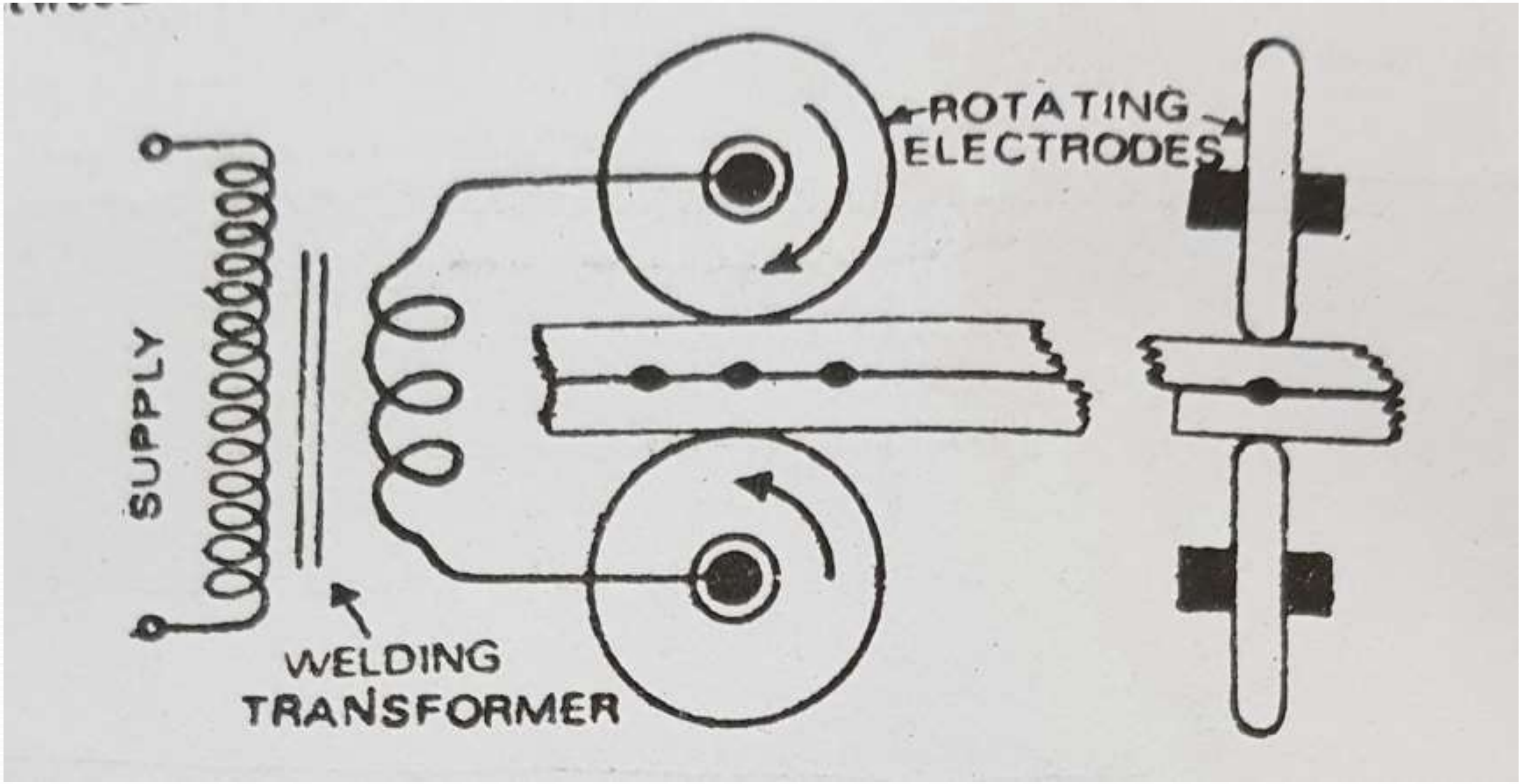
Spot Welding

- Magnitude of **current depends upon the thickness and composition** of plates
- The current for spot welding may be from **1000 to 10000 Amp**
- The current may **flow for a fraction of second**
- Used for manufacture of **Automobiles, Refrigerators and other metal stamping** assemblies

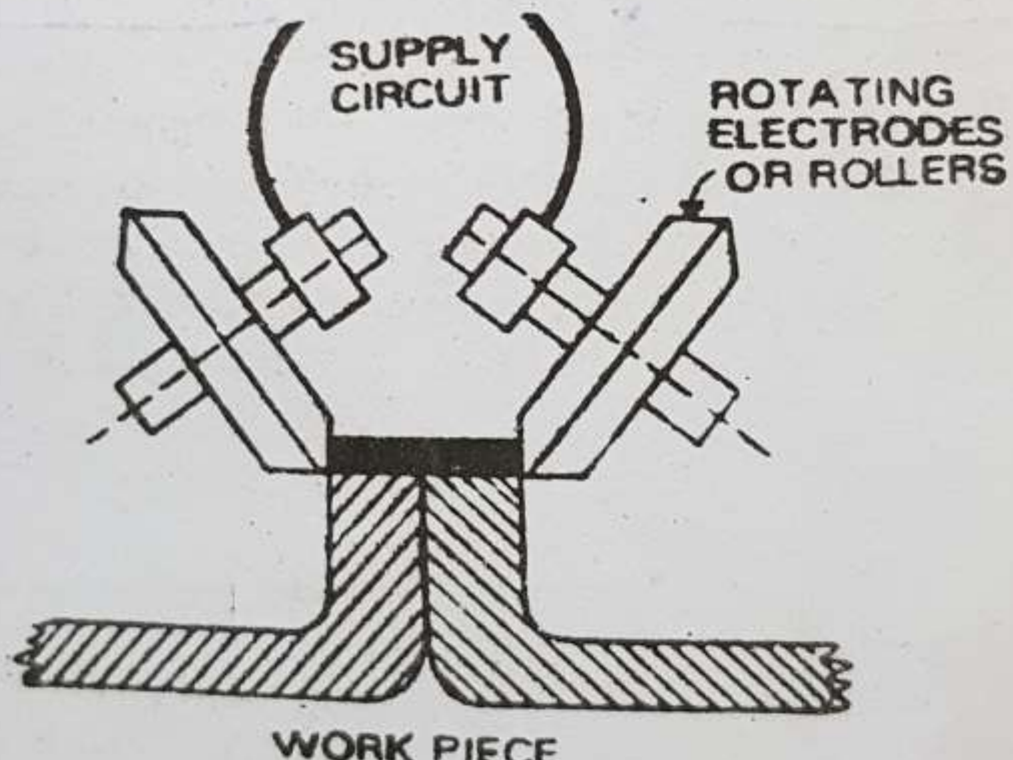
Projection Welding



Seam Welding



Seam Welding



SEAM WELDING

Seam Welding

- Principle is **similar to spot welding**
- Difference is that **Wheels or Roller types electrodes are used**
- Speed of roller is **4-5 m per min**

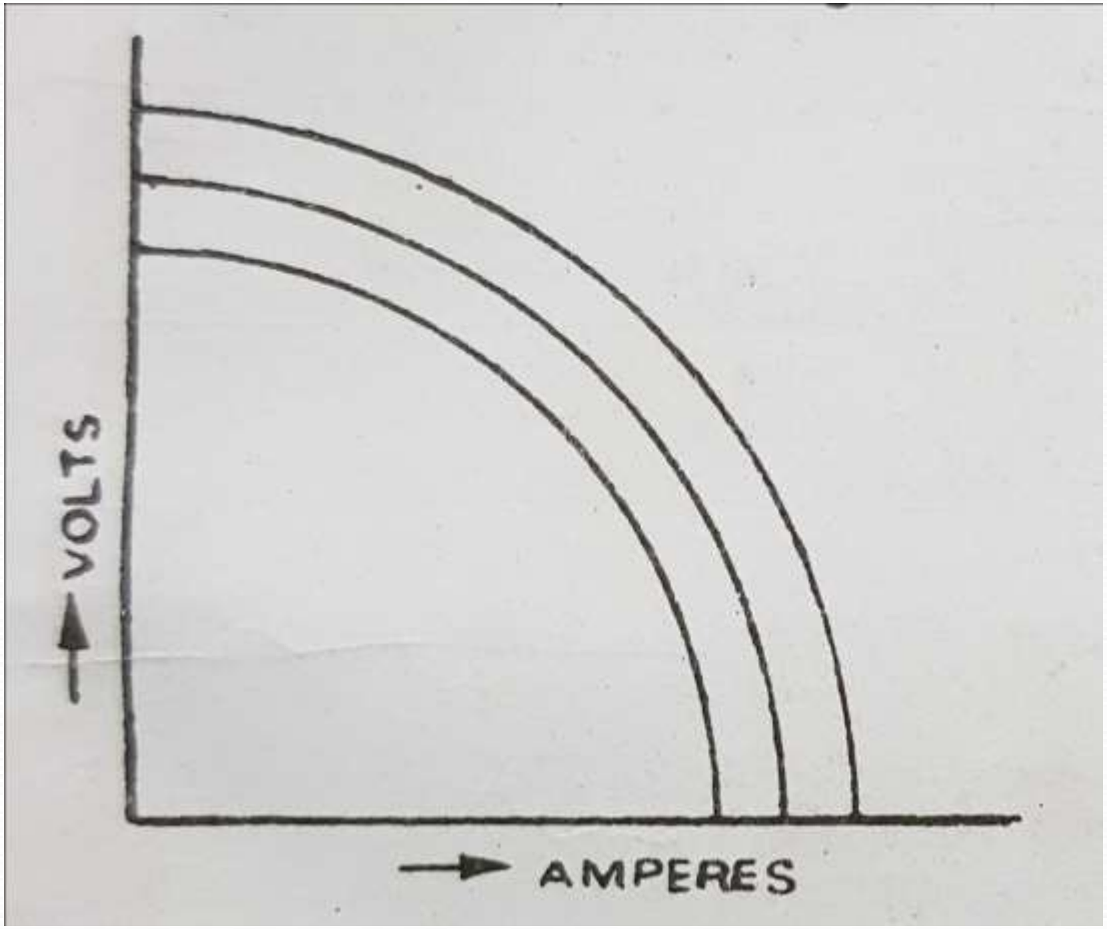
Arc Welding

- Arc welding is done by using heat of the **arc produced between an electrode and work piece** or **between two electrodes**
- The arc is struck by **ionizing the air between the electrodes**
- Due to resistance of ionized air and heavy current, **high temperatures are obtained**
- The arc has **negative temperature coefficient** of resistance

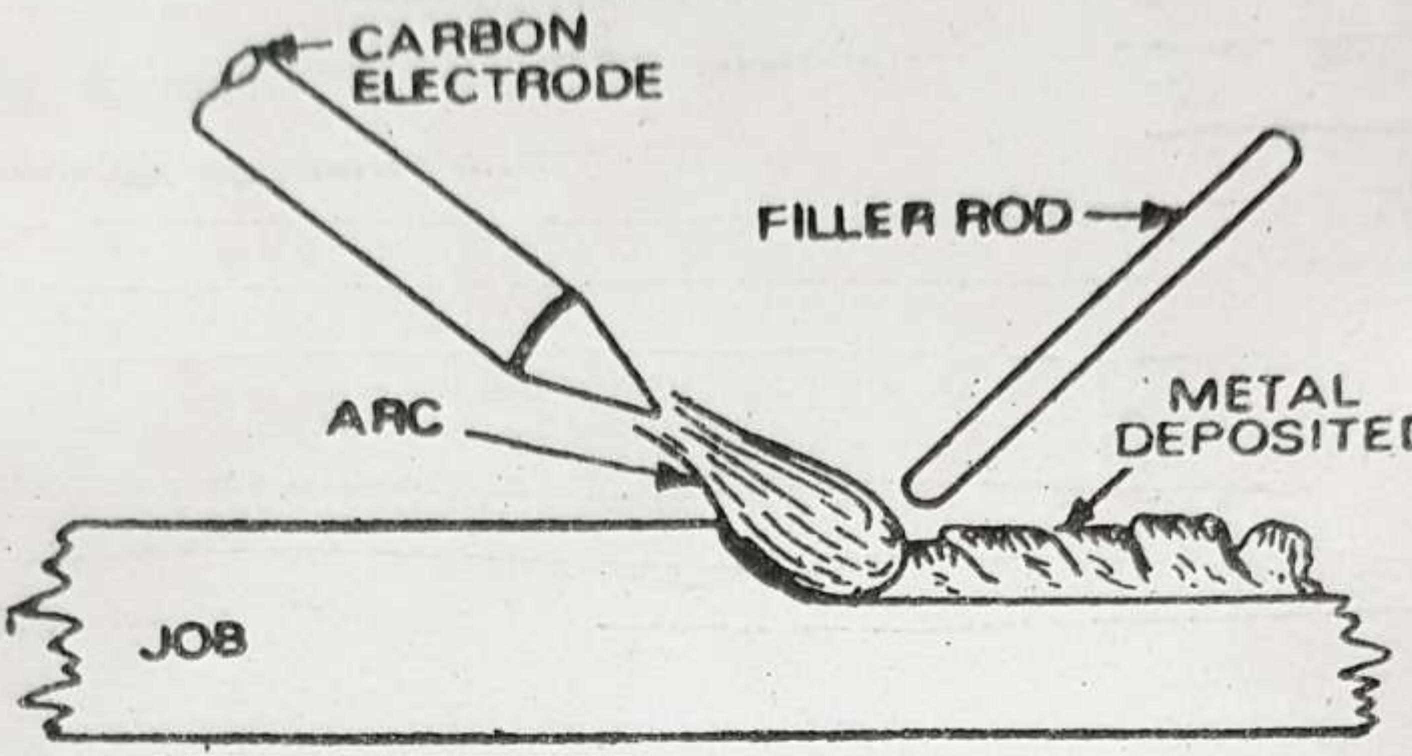
Arc Welding

- To stabilize the arc, either **stabilizing resistance or reactance** is used or **high leakage reactance transformer** is used
- The open circuit voltage supplied to the arc should not exceed about **60V for DC and 100V for AC** otherwise there will be danger of shock to the operator
- Widely used for **joining the metal parts, repair of fractured casting** etc.

Source Characteristics for Arc Welding



Carbon Arc Welding

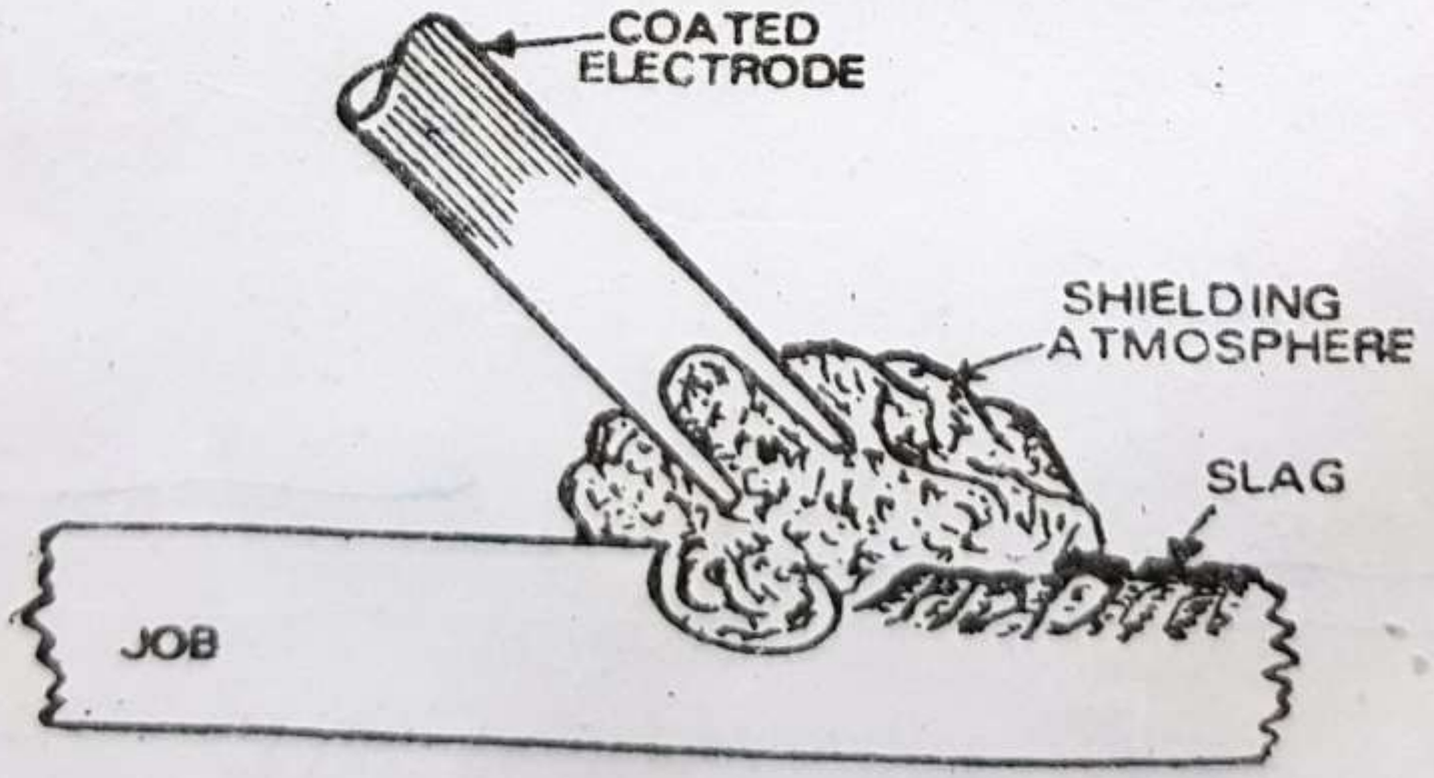


CARBON ARC WELDING

Carbon Arc Welding

- Arc is struck between **carbon electrode** & job
- When additional metal is required, a **filler rod** is used
- **Filler rod melts** in the joint
- **Carbon particles** from the electrodes **reduce the oxidation** effect of atmospheric oxygen
- **Used for** welding of **non ferrous metals** such as brass, copper and their alloys

Metal Arc Welding



METAL ARC WELDING

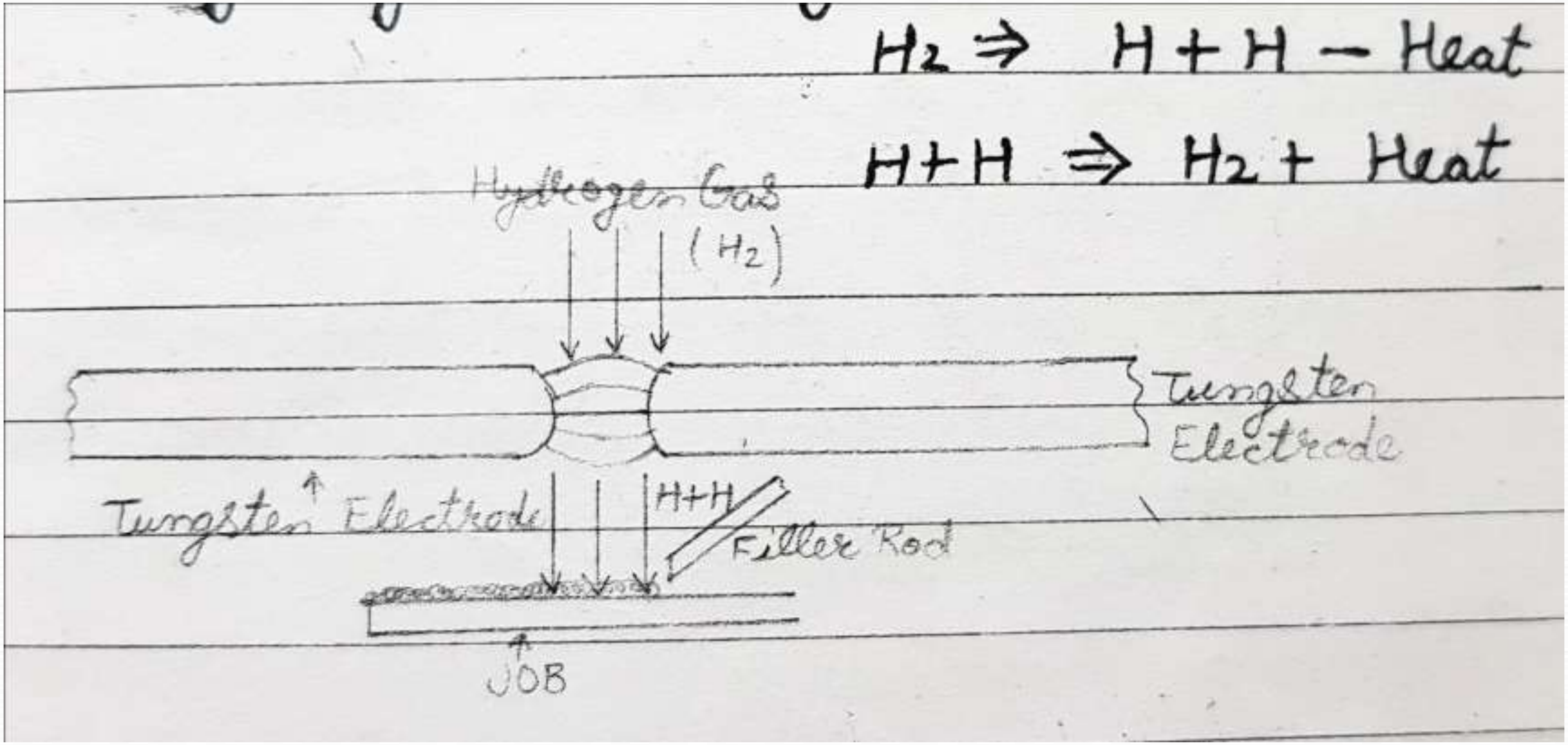
Metal Arc Welding

- **Metal electrodes** are used
- Electrodes may be **bare or coated** with flux
- **Coated electrodes** are used for **better quality & good strength**
- **Shielding** of joint from atmosphere is achieved from the gas which is produced a result of **decomposition of the flux** coated on electrode
- **Slag** left behind the electrode covers the weld and is allowed to remain for sometime in order that the joint **cool down gradually**

Atomic Hydrogen Welding

- Arc is struck between two **tungsten electrodes & hydrogen gas is passed** through the arc
- Due to high temperature, **hydrogen breaks up** into atomic form
- In this process, it **takes up a lot of heat** from the arc
- **H_2 => H + H – Heat**
- The atoms of hydrogen have a great tendency to **recombine** to form hydrogen molecules
- Sufficient **heat is liberated** which welds the job
- **H = H => H_2 + Heat**

Atomic Hydrogen Welding



Gas Shielded Arc Welding

- Arc is struck between a **consumable or non consumable electrode** and job in an atmosphere of some inert gas like organ or helium
- The inert **gas shields the weld pool** and the electrode from the atmosphere
- When electrode is non consumable, the process is known as **TIG Welding** i.e. Tungsten arc Inert gas Welding
- The non consumable electrode is of **Tungsten**

Gas Shielded Arc Welding

- The other process is known as **MIG Welding** i.e. Metal arc Inert Gas welding
- In this the electrode is in the form of a **wire fed from a coil**

Electric Welding Equipment

- Basic requirement of welding equipment is that the **voltage of source should be high in open circuit** to struck the arc
- This voltage is around **50 to 60 volts in case of D.C.** and between **70 to 100 volts in case of A.C**.
- A voltage of **20 to 30V** is needed to **maintain** the arc

D.C. Welding Equipment

- Generally **motor generator set** is used
- The motor is **squirrel cage I.M.** and generator is **differential compound**, which gives dropping characteristics

A.C Welding Equipment

- This uses a **transformer** which reduces the voltage from that of supply mains to about **100 volts**
- To get **dropping** characteristics, a series **resistance** or **reactance** may be used
- The **resistance** reduces the **efficiency** of system
- The **reactance** reduce the **power factor**
- **Reactance** is preferred
- The open circuit voltage of welding T/F ranges from **80 to 100 volts** at nearly **0.35 lagging P.F.**

Advantages of Coated Electrodes

- When metals come in molten state, these have a tendency to **absorb oxygen and nitrogen** to form oxides and nitrites
- This makes the weld **brittle**
- This difficulty is overcome by using the **flux coated electrodes**
- The flux has certain compound which break up in the arc and gives a harmless **atmosphere of carbon monoxide**
- It **keeps away the oxygen and nitrogen** from the arc

Advantages of Coated Electrodes

- The flux melts with the metal and provides a protective coating of **slag**
- Being lighter, it **floats on the molten metal**
- It serves as a **cover** for solidifying weld metal
- It cools down uniformly thus **avoiding** any tendency of **cracking**
- Flux also **stabilizes** the arc

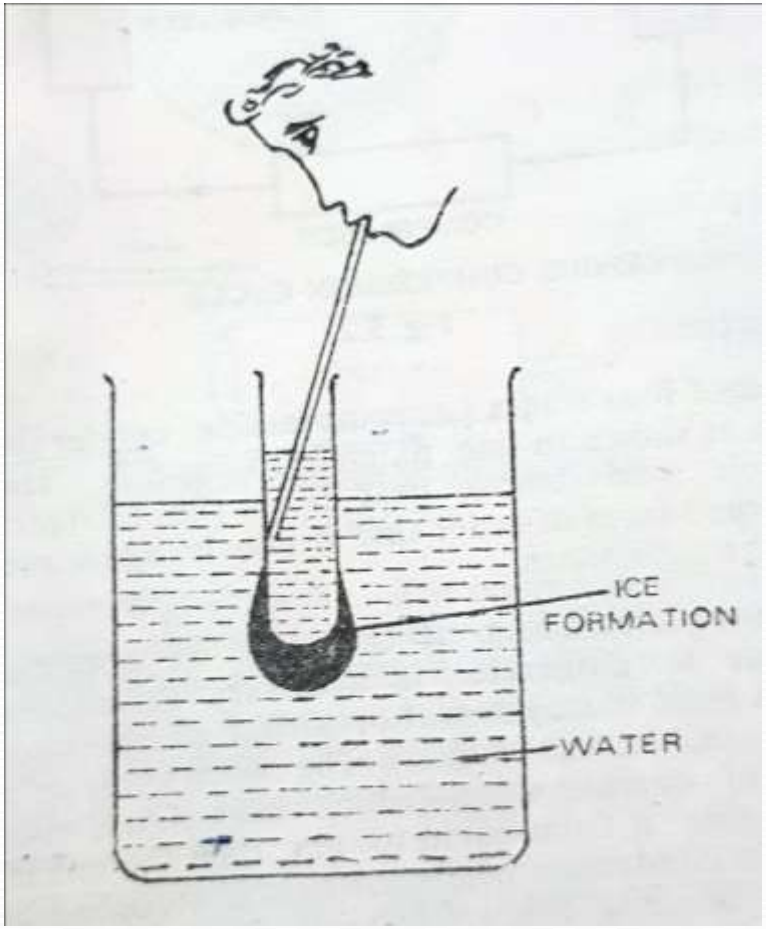
Welding Of Cu and Al

- Generally **TIG** welding is used
- Copper and aluminium are very **good conductors**
- The current **rating** of equipment should be **high** enough so that the required temperature is obtained for welding

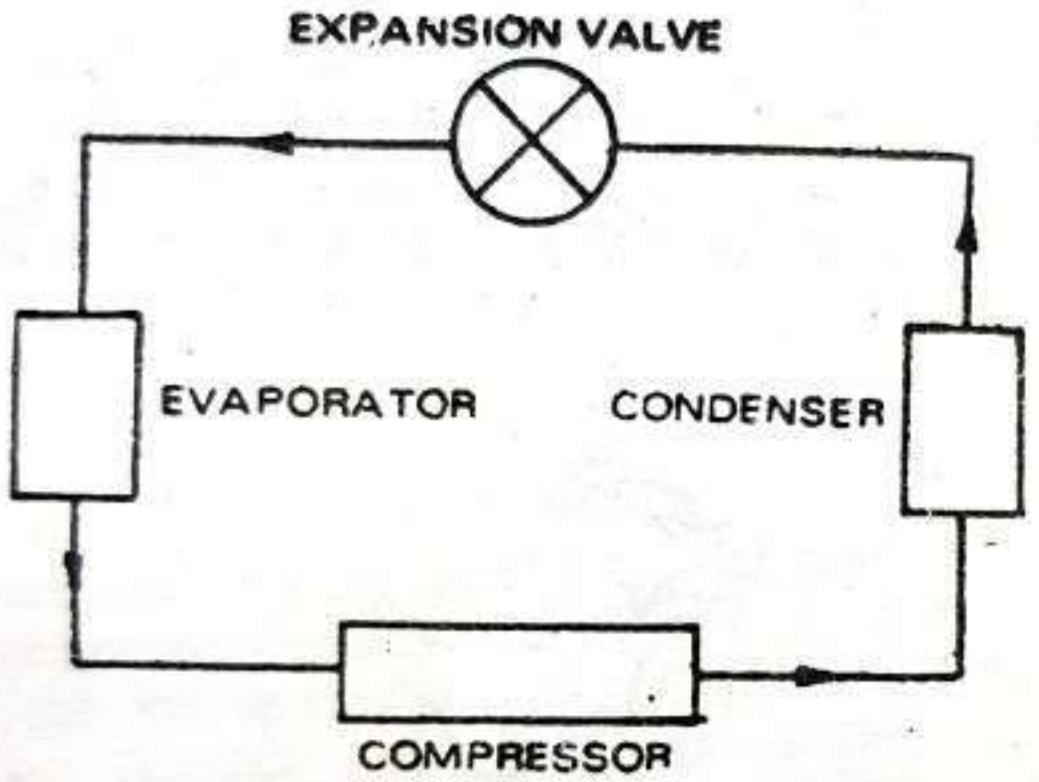
Electrical Circuits of Refrigerator, Air Conditioner and Water Cooler

- The process of reducing the temperature of a body from the general level of temperature of the surroundings is called refrigeration
- Works on the principle of cooling caused by evaporation

Refrigeration

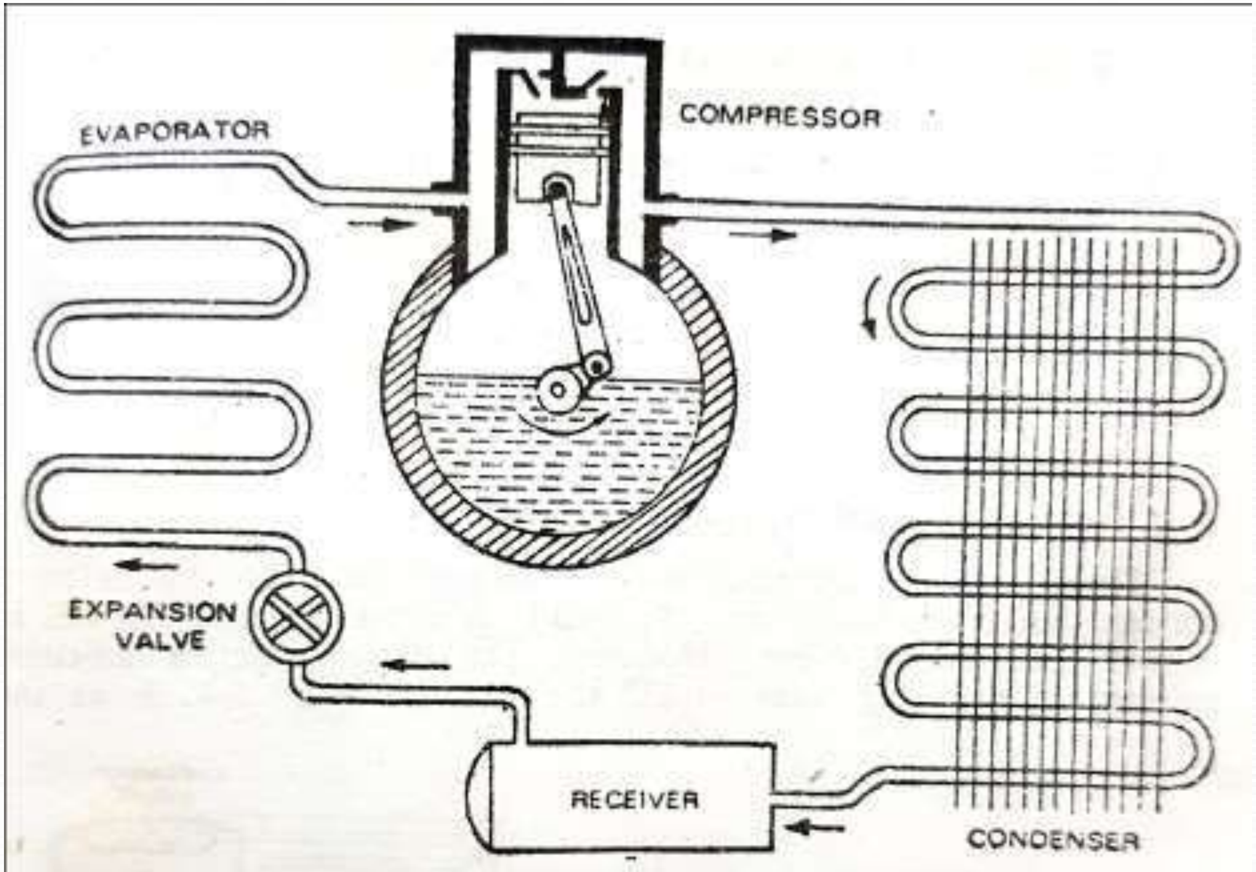


Vapour Compression Cycle



VAPOUR COMPRESSION CYCLE

Vapour Compression Cycle



VAPOUR COMPRESSION PROCESS

Vapourising Process

- Before entering the evaporator, the refrigerant is in liquid state
- It absorbs heat from the material to be refrigerated
- It is transformed from liquid to vapour state
- The process is called **Evaporation**

Compression Process

- Compressor draws the vapours from the evaporator
- It compresses the vapours until their temperature is raised above that of condensing medium
- The process is called **Compression**

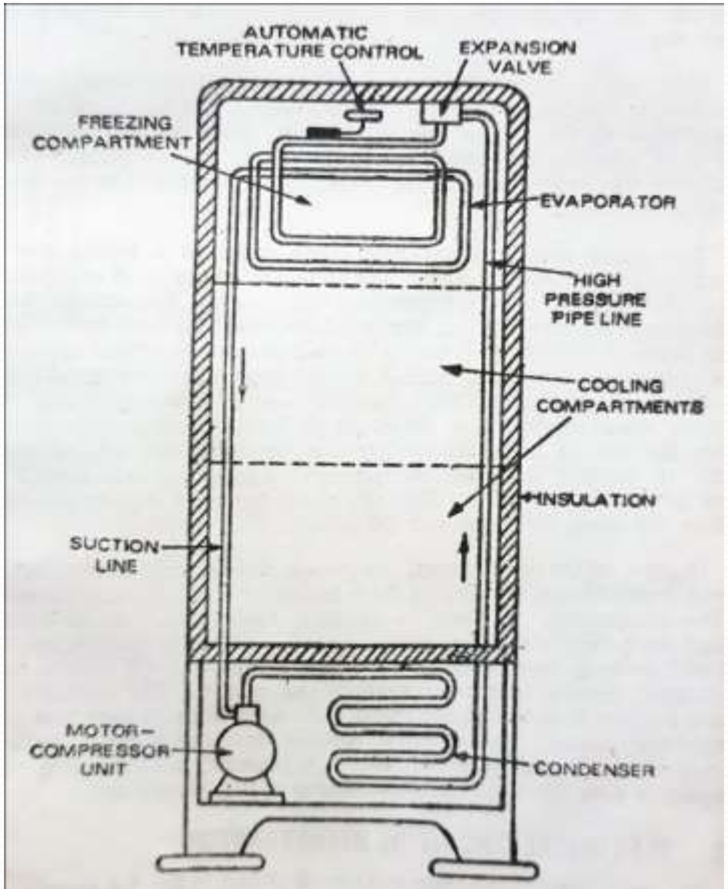
Condensing Process

- As the temperature is raised, the heat of vapourisation will flow from vapours tocondensing medium
- It condenses the refrigerant to high pressure liquid
- This high pressure liquid flows to receiver, where it is stored until it is supplied to cooling unit through the expansion valve
- This process is completed in condenser

Pressure reducing process

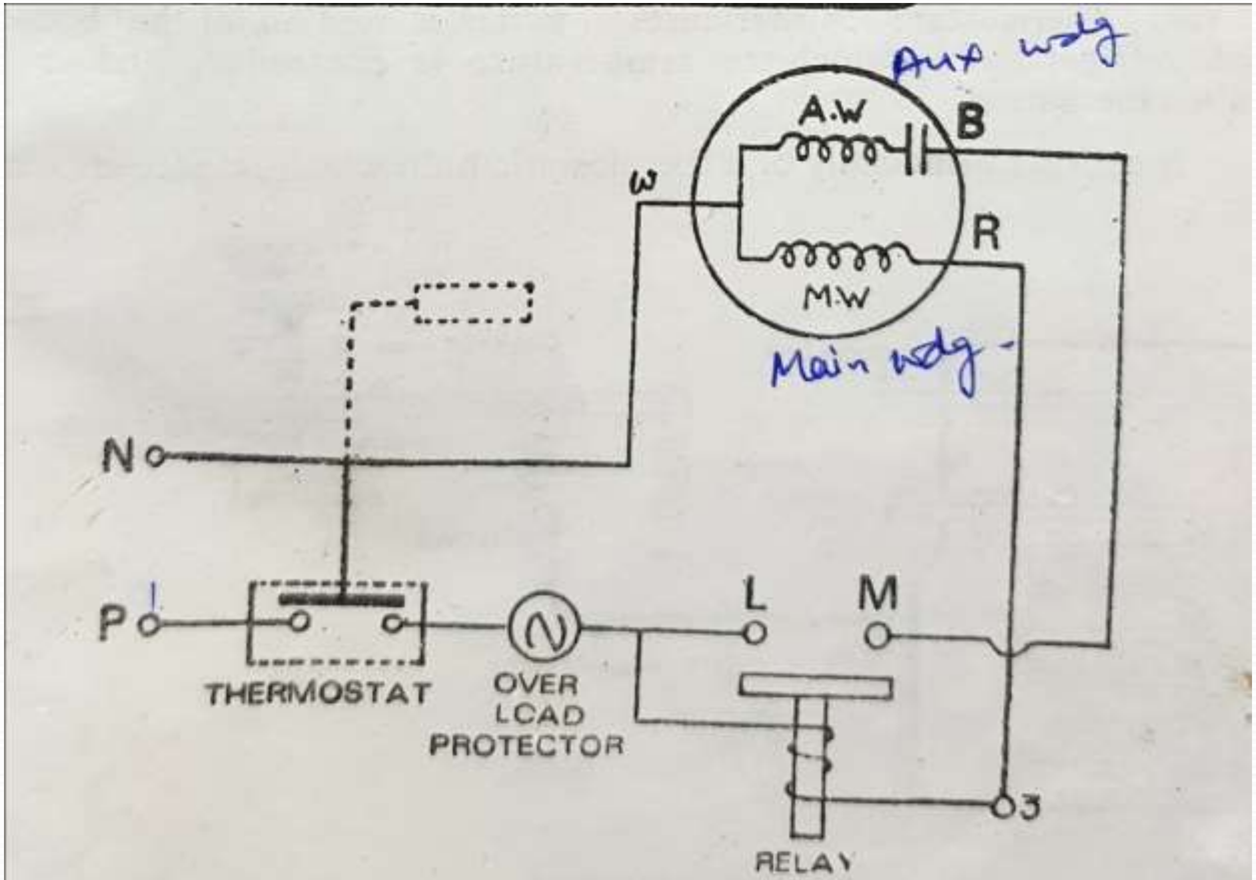
- The expansion valve reduces the pressure of high pressure liquid from the receiver to a low pressure liquid capable of absorbing heat
- The process is called expansion

Refrigerator



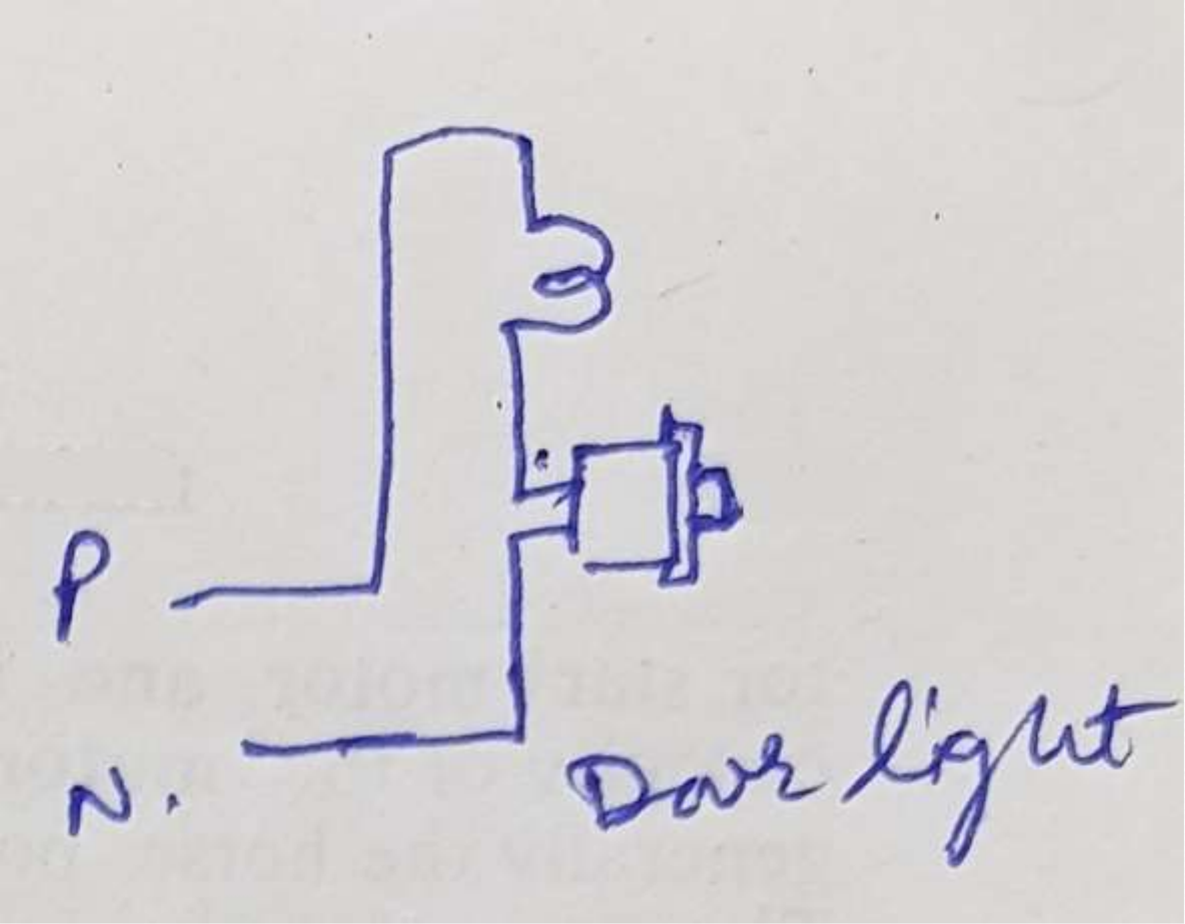
LAYOUT OF COMPONENTS

Electrical Circuit of Refrigerator

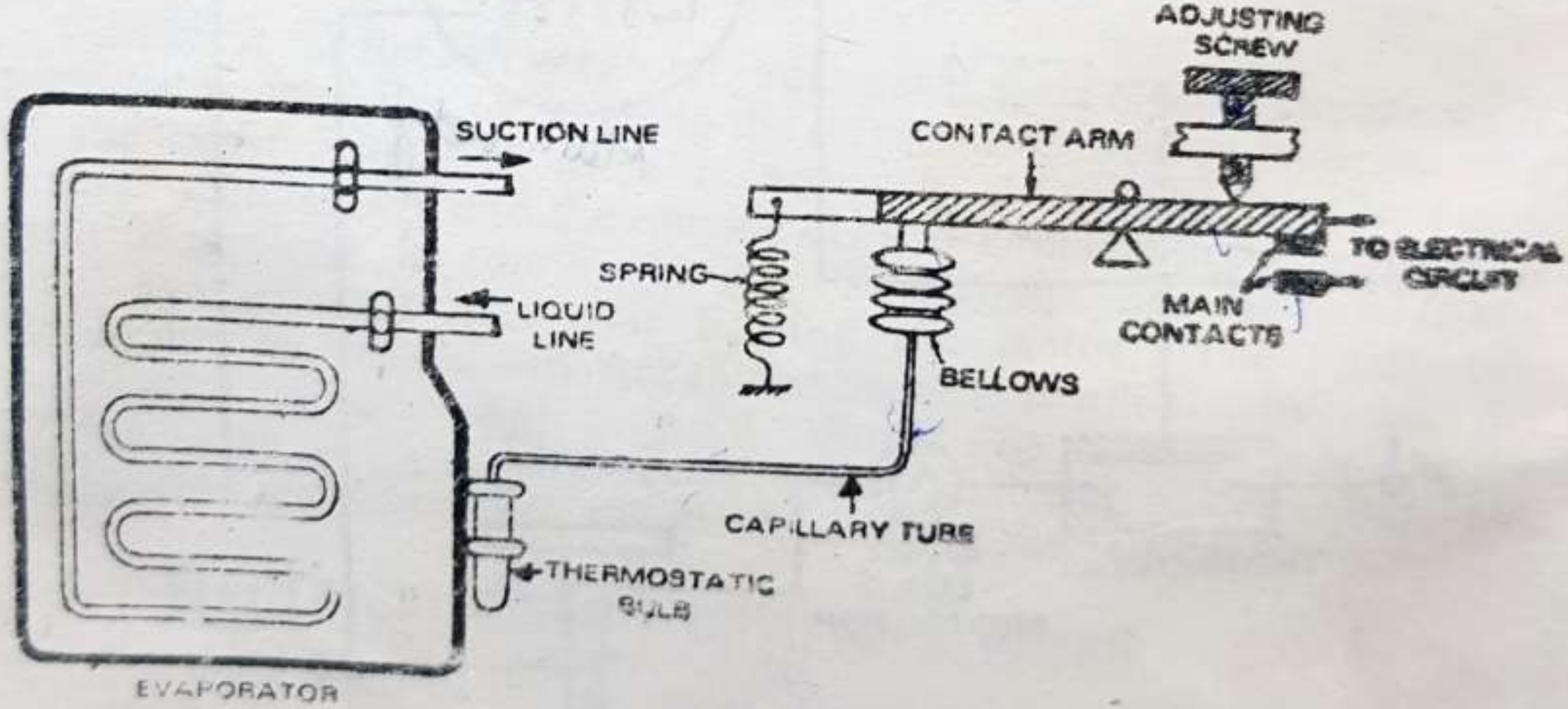


ELECTRICAL CIRCUIT

Electrical Circuit of Refrigerator

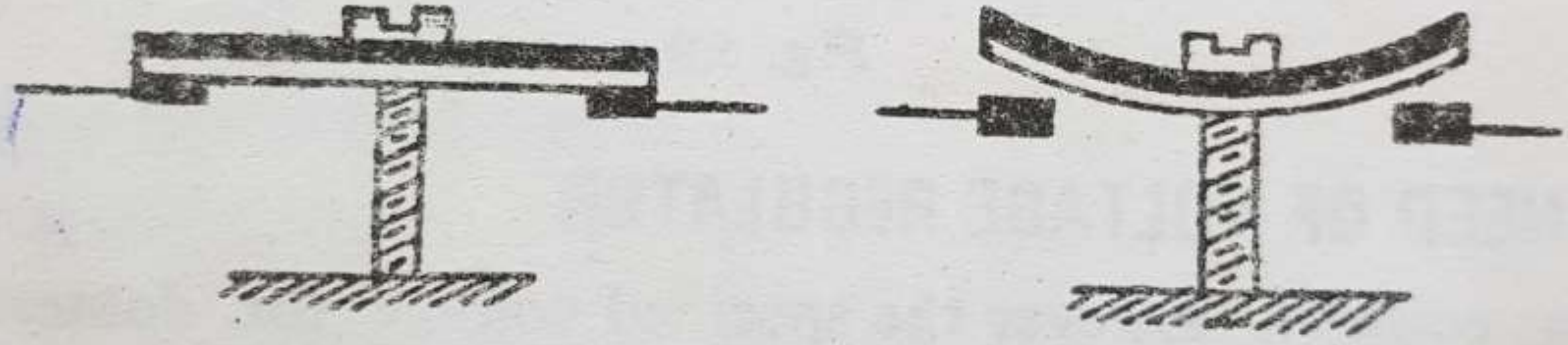


Thermostat



THERMOSTAT

Overload Protector

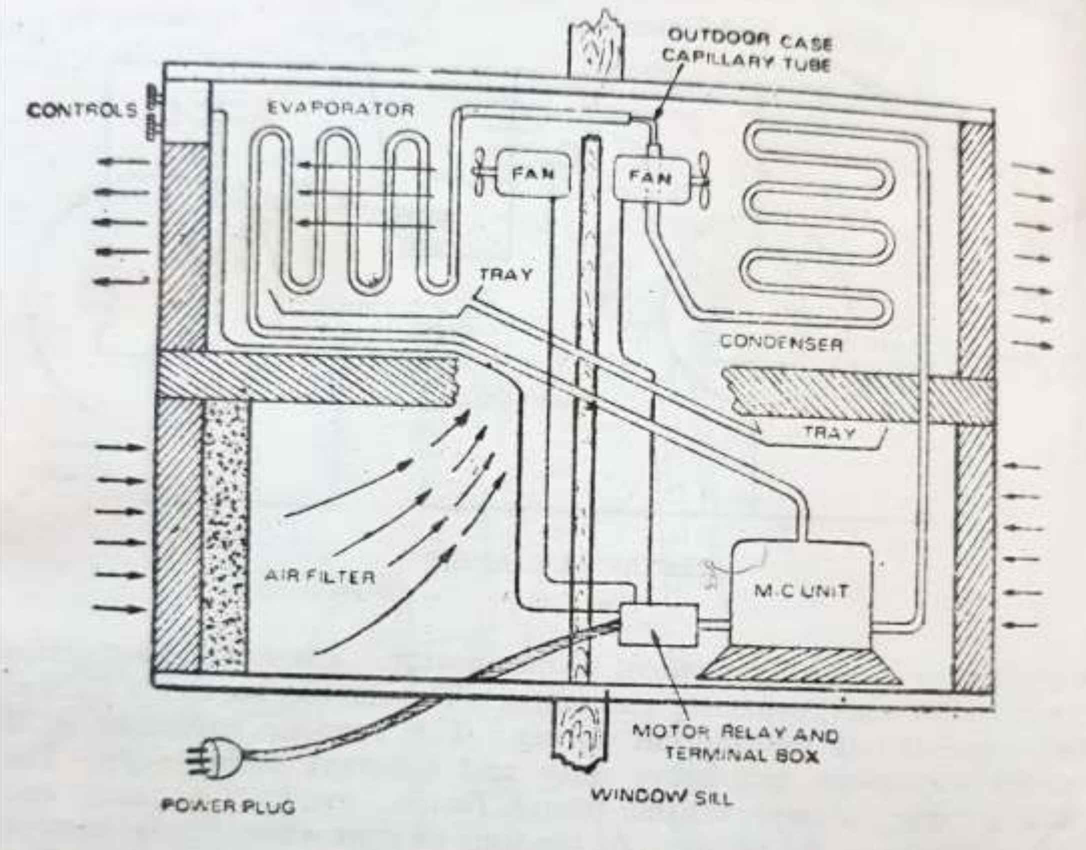


OVERLOAD PROTECTOR

Air Conditioner

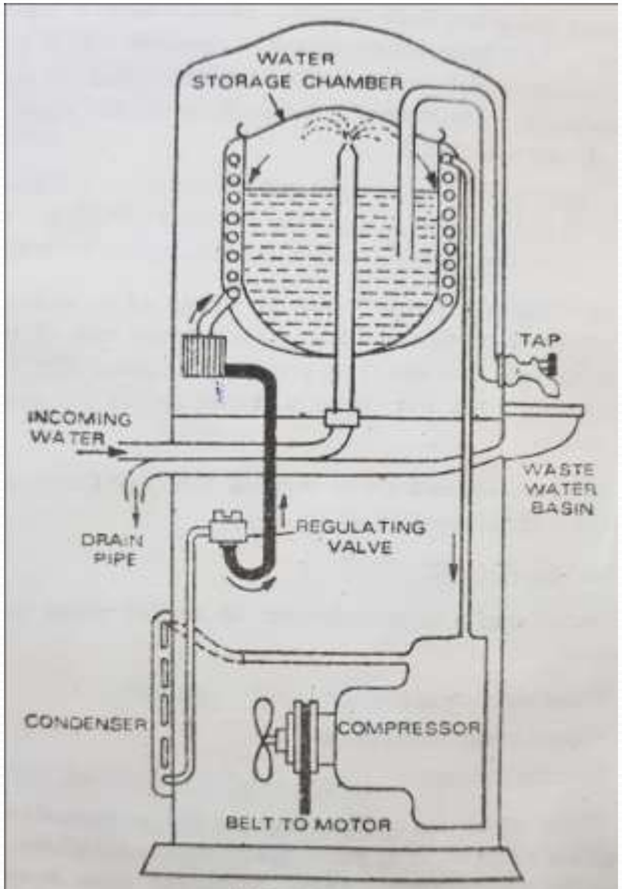
- It involves control of **Temperature, Humidity, Purity and movement of Air**
- Working conditions and comfort for human being is improved
- Air, after necessary control and adjustment is circulated throughout the building
- Humidity is maintained at about 60%, being most suitable for human beings

Air Conditioner

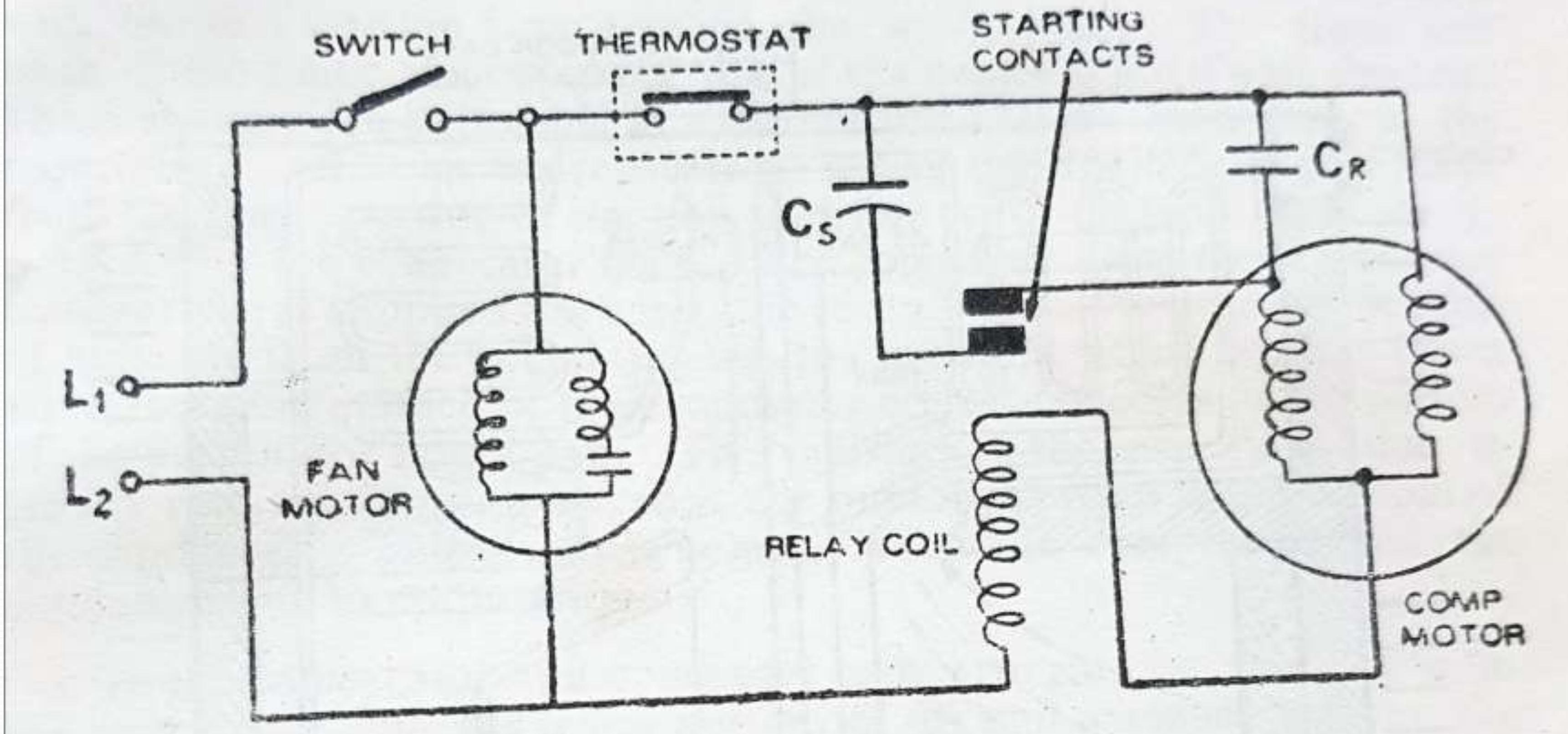


ROOM AIR CONDITIONER

Water Cooler



WATER COOLER



ELECTRICAL CIRCUIT

Electric Traction

Advantages

- **Cleanest** System
- Only **suitable method for underground system**
- **Higher Acceleration** and **quick breaking**
- Electric Locomotive require **less maintenance**
- Electric Locomotive **can be put into service immediately**
- Electric **motors provide continuos torque**, so less vibrations
- **Electric breaking** is **superior** than mechanical breaking

Advantages

- **Speed control** is better
- **Separate generator not required** for lighting and fans
- Most **economical** in high traffic density areas

Systems of Electric Traction

- **DC System**
  - DC **Series motors** are used
  - Voltage rating is **600V for sub urban** railway
  - Voltage rating is **1500V – 3000V for main line** railway
  - Motor receive power from overhead line through **pentograph**
  - **Steel track** is used as **return conductor**

Systems of Electric Traction

- **3Ø AC System**
  - **3Ø slip ring induction** motors are used
  - **Rotor resistance and pole changing** methods are used for speed control
  - **Regenerative breaking** is immediately obtained as speed exceeds the synchronous speed
  - Operating voltage is about **3600V at** $16\,^{2}/_{3}$ **Hz**
  - **Two overhead conductors** are required, **third being rail** itself. Therefore rarely used.

Systems of Electric Traction

- **1Ø standard frequency system**
  - Single overhead wire at **25 KV, 50Hz** is used
  - A **transformer** is mounted on locomotive
  - The supply is **stepped down, rectified**, and supplied to traction motors

Systems of Electric Traction

- **1Ø low frequency system**
  - **1Ø ac series motors** are used
  - Due to **commutation problems**, **low frequency** is used
  - **15KV at** $16\frac{2}{3}$ **Hz, 11KV at 25 Hz** supply is used
  - Transformer is used to **step down voltage to 400V**

Systems of Electric Traction

- **1Ø to 3Ø system**
  - Locomotive carries a **phase converter**
  - It converts **1Ø to 3Ø AC**
  - 3Ø AC is supplied to **3Ø Induction Motors**
  - **16000V at 50Hz** is used

Categories of Railway Service

- **City Service**
  - **Distance of stops** is of the **order of a kilometre**
  - **High rate of acceleration** and **breaking** is required to maintain the **scheduled speed**

Categories of Railway Service

- **Suburban Service**
  - Distance between **stops** is about **5-6 kilometre**
  - **High rate of acceleration** and **breaking** is required

Categories of Railway Service

- **Main line service**
  - Distance between **stops** is about **20 to 40Km**
  - Operating **speeds are high**
  - **Acceleration and breaking are not much important**

Speed-Time Curve for Main Line Service

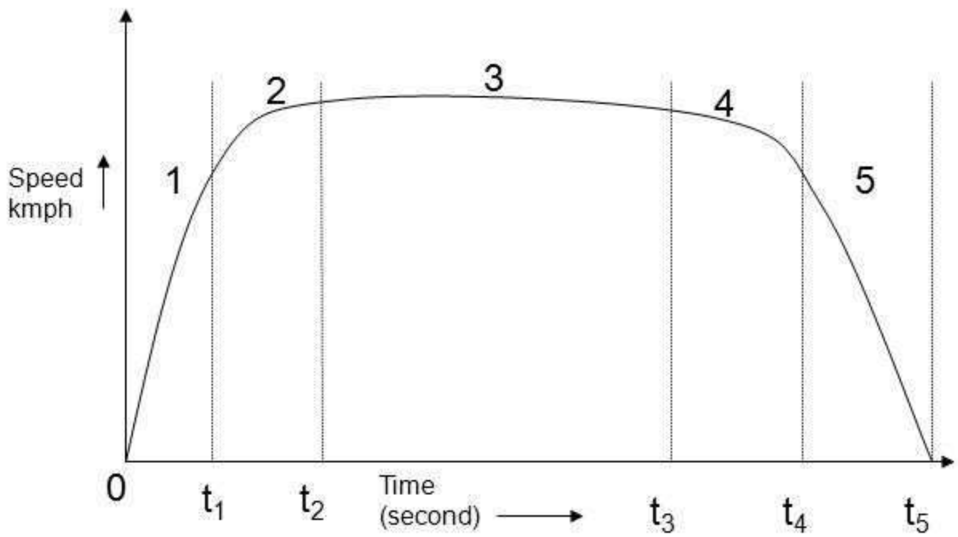


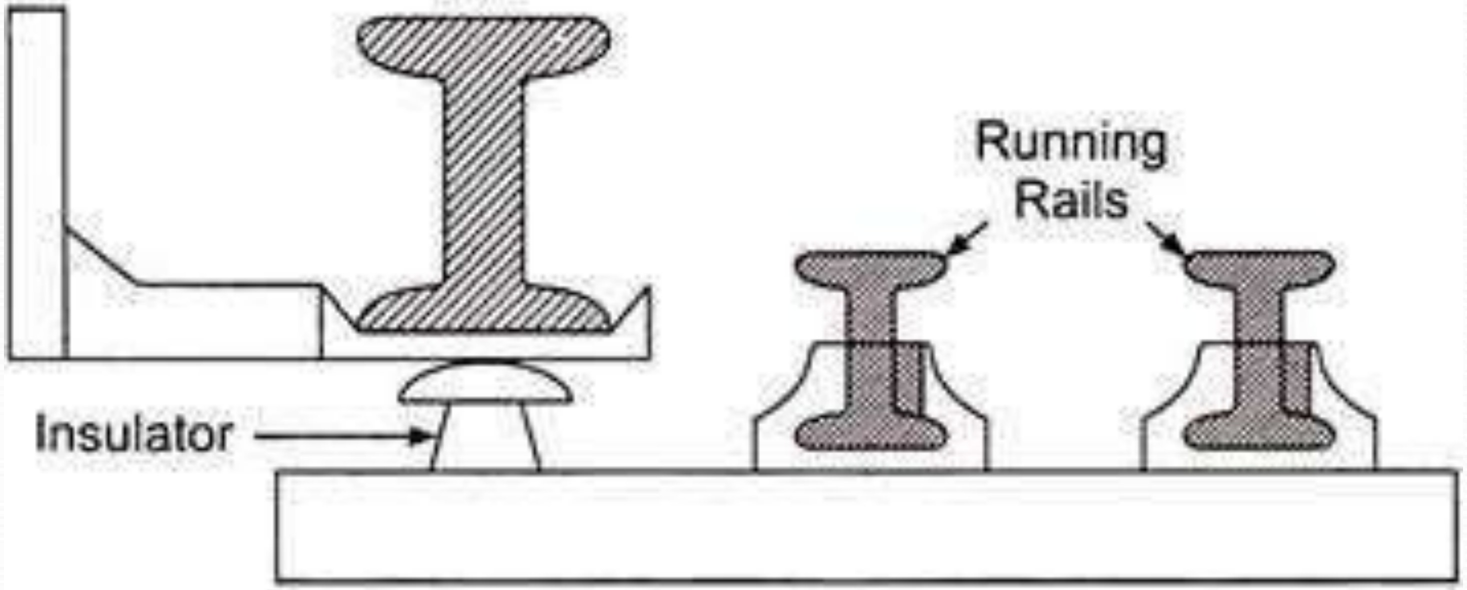
Fig.1

1. Notching up or Rheostatic acceleration.
2. Acceleration on speed curve.
3. Free running curve
4. Coasting or coasting retardation curve.
5. Braking curve.

Accessories for Track Electrification

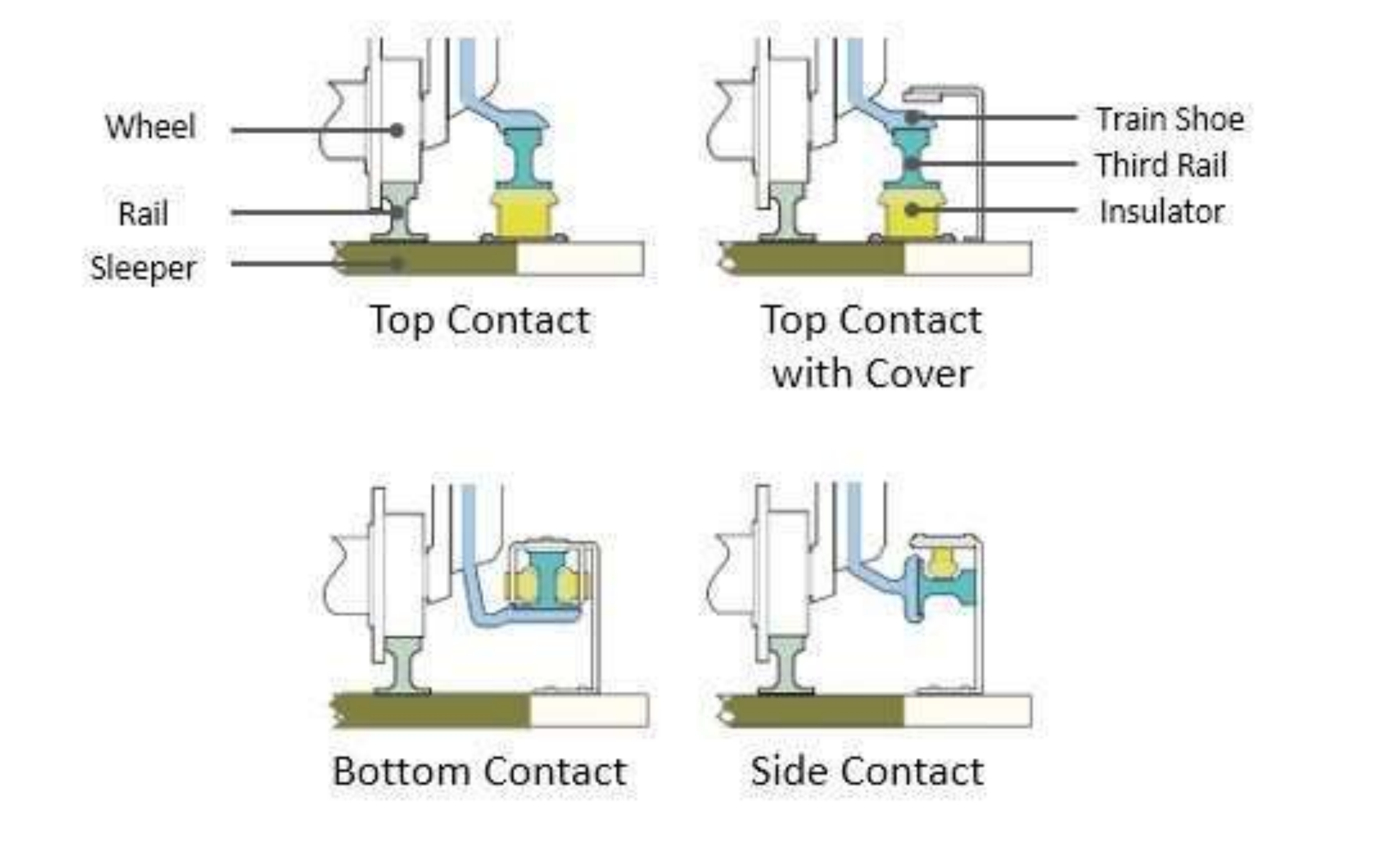
- **Power Supply**
  - Power is supplied to locomotives using different methods:

Conductor Rails



Conductor Rail System

Conductor Rails



Conductor Rails

Conductor Rails

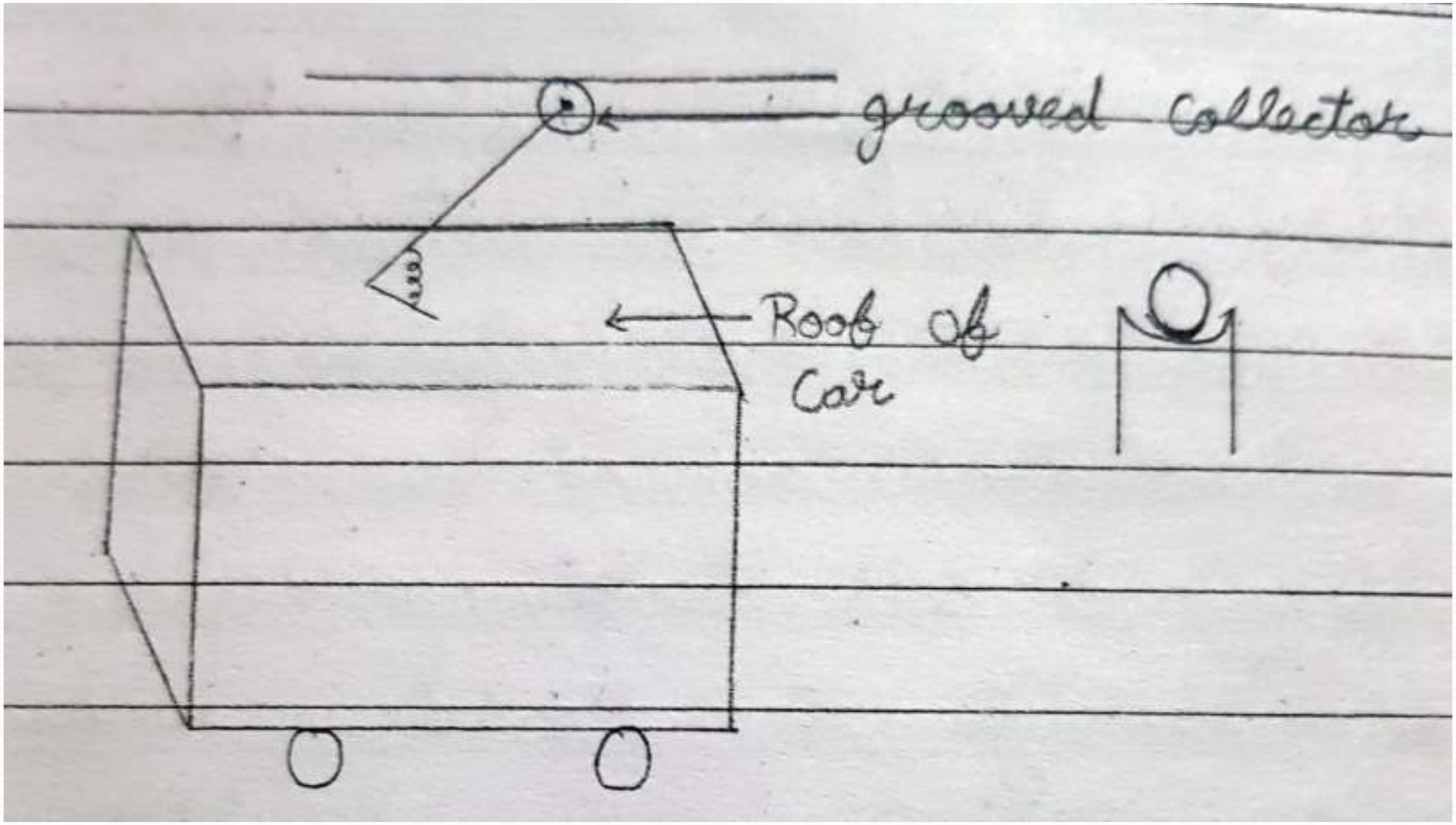
Conductor Rails

Conductor Rails

Overhead Systems

- **Trolley Collector**
  - Used in **Trams** and **Trolley Buses**
  - Uses **grooved gun metal wheel** or **grooved slider shoe** with carbon insert, carried at the **end of a long pole**
  - The other end of pole is **hinged to a base** fixed to the roof of the vehicle
  - Disadvantage is that **it has to be rotated through 180° for reversing** the direction of motion of vehicle
  - Drawback is that there is **poor contact** between wheel and trolley wire

Trolley Collector



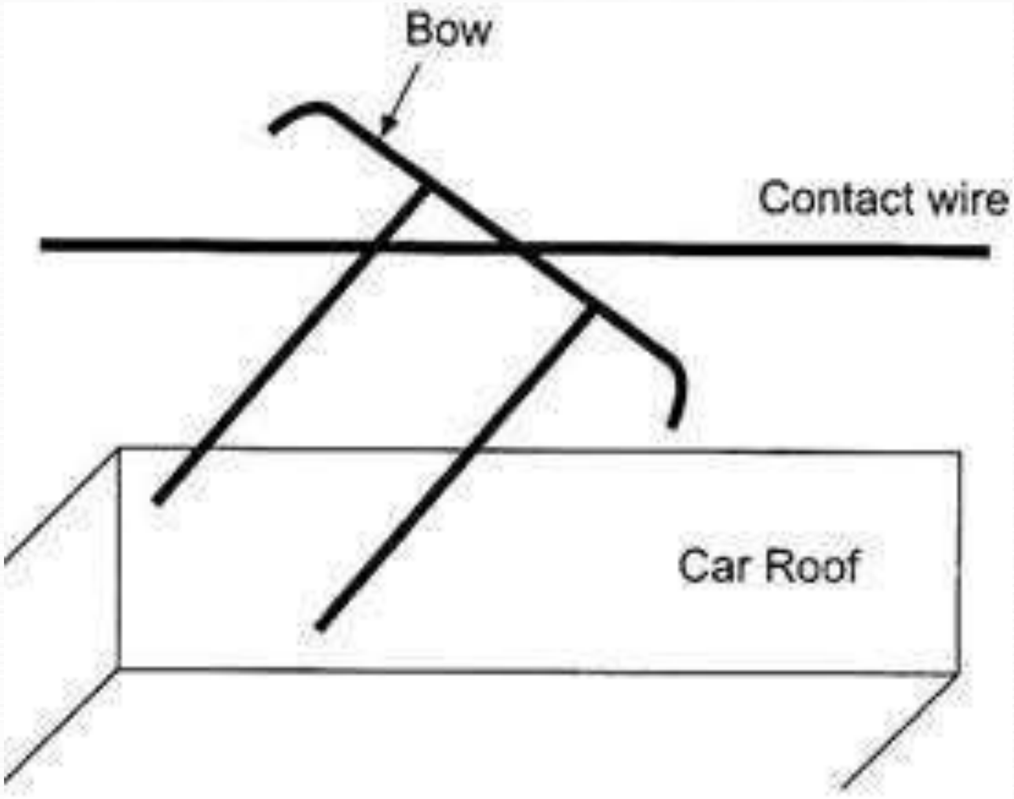
Trolley Collector

Trolley Collector

Overhead Systems

- **Bow Collector**
  - Used in **Tramways**
  - Consists of a **metal bow 0.6 to 0.9m wide**
  - Mounted on the **roof of the vehicle**
  - Presses against the trolley wire
  - **At high speed** there is possibility of **leaving the contact**
  - **Not suitable for trolley buses**
  - Upward pressure is obtained by using **spring**

Bow Collector



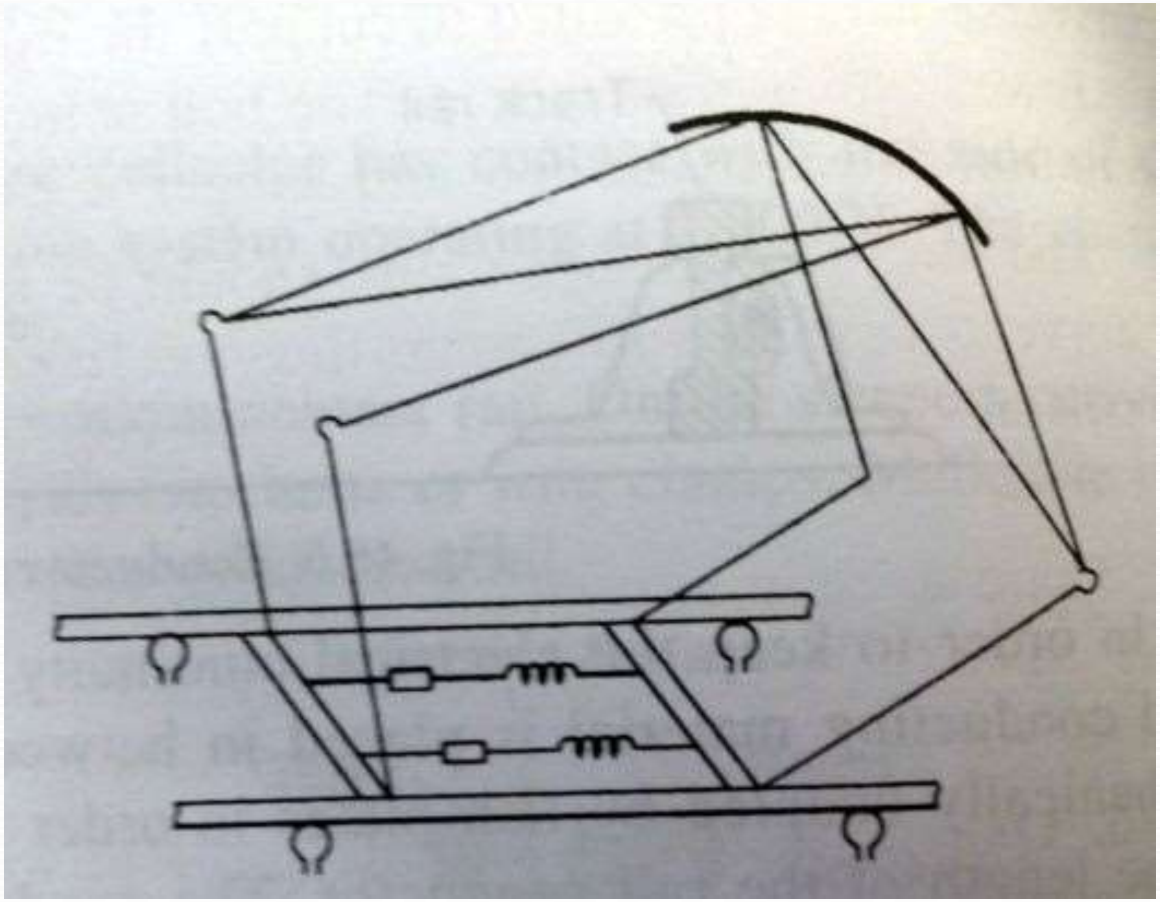
Bow Collector

Bow Collector

Overhead Systems

- **Pantograph Collector**
  - Employed in **Railways** to collect current
  - Operating speed is as high as **100 to 130Km/Hr**
  - Current to be collected is as large as **2000 to 3000A**
  - **Mounted on roof** of the vehicle
  - Carries a **sliding shoe** for contact with trolley wire
  - **Advantages**:
    - Can operate in **either direction**
    - **No risk of leaving the contact**
    - **Height can be varied** from driver's cabin

Pantograph Collector

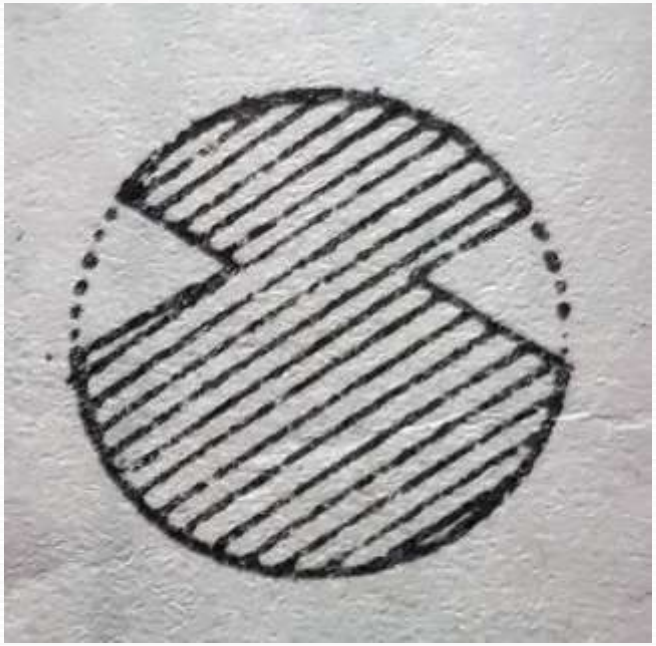


Pantograph Collector

Pantograph Collector

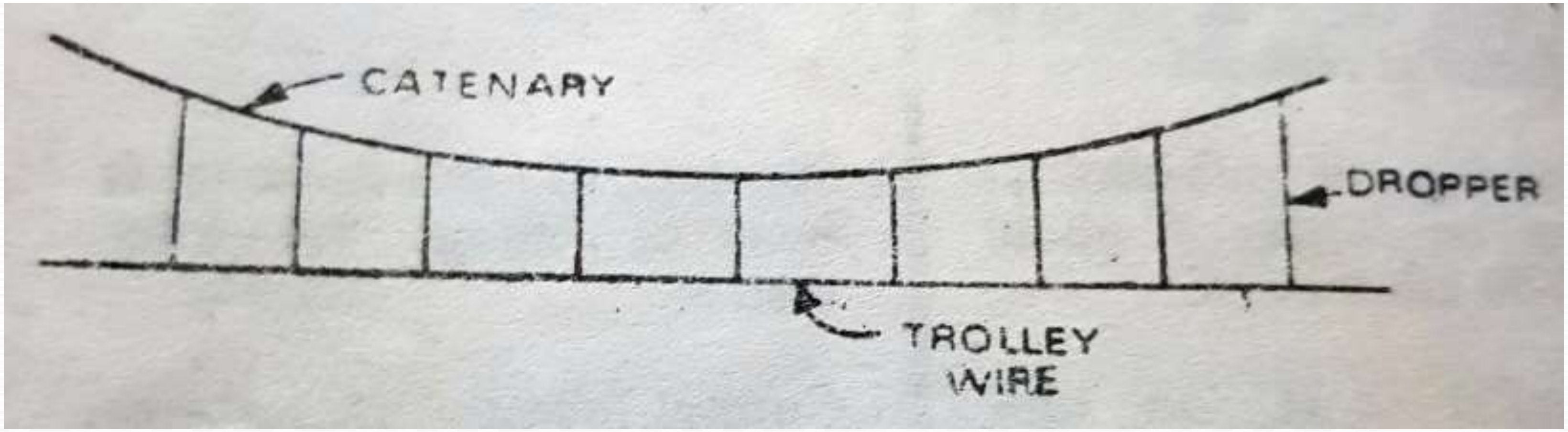
Overhead Conductor

- For **Tramways** and **Trolley Buses**
  - **Hard drawn copper** and alloys of copper are used
  - Cross section area of standard trolley wire is **$80mm^2$**



Overhead Conductor

- **Railways**
  - **Good contact is required** at high speeds
  - **Sag should remain small** to maintain good contact
  - **Short spans** are created by suspending trolley wire with support of other wire known as **Catenary**



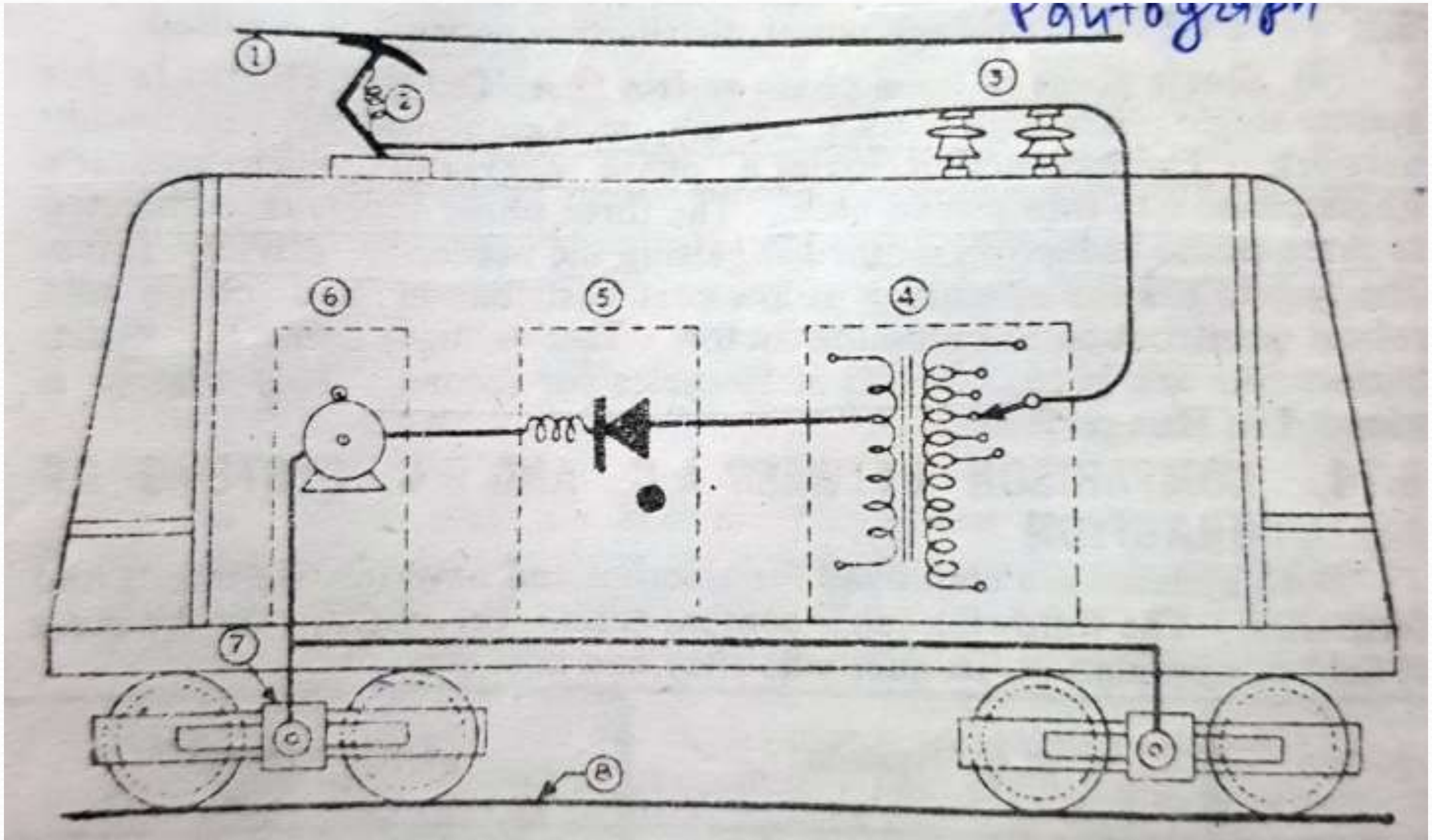
Factors Affecting Scheduled Speed

- **Average Speed** = $\frac{Distance\ between\ the\ stops}{Actual\ time\ of\ run}$

- **Scheduled Speed** = $\frac{Distance\ between\ the\ stops}{Actual\ time\ of\ run + Stop\ time}$

- **Crust Speed** (Maximum speed of vehicle during run)
- **Acceleration**
- **Braking** Retardation
- **Duration** of Stoppage

Electric Locomotive



BLOCK DIAGRAM OF A.C. LOCOMOTIVE

Motors Used in Traction

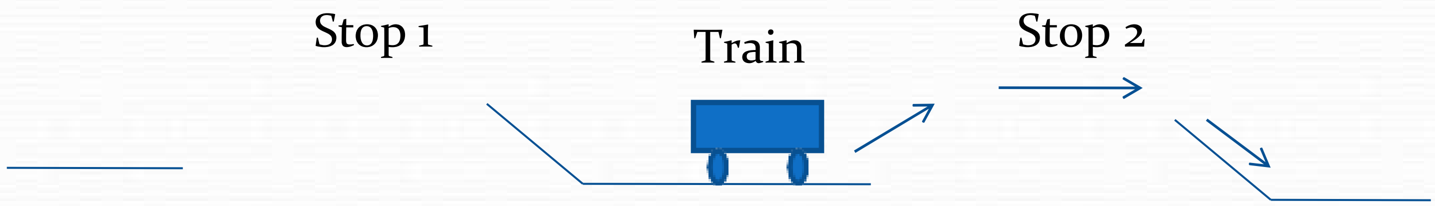
- **DC Traction**
  - DC **Series** and **Compound** Motors
- **AC Traction**
  - **AC series** motors and **3Ø Slip Ring Induction motors**
- The motors **should be robust** and **totally enclosed** type for protection against **water** etc
- The motors should have **speed control mechanism**

Braking

- Electric Braking
  - **Plugging**
  - **Rheostatic** Braking
  - **Regenerative** Braking

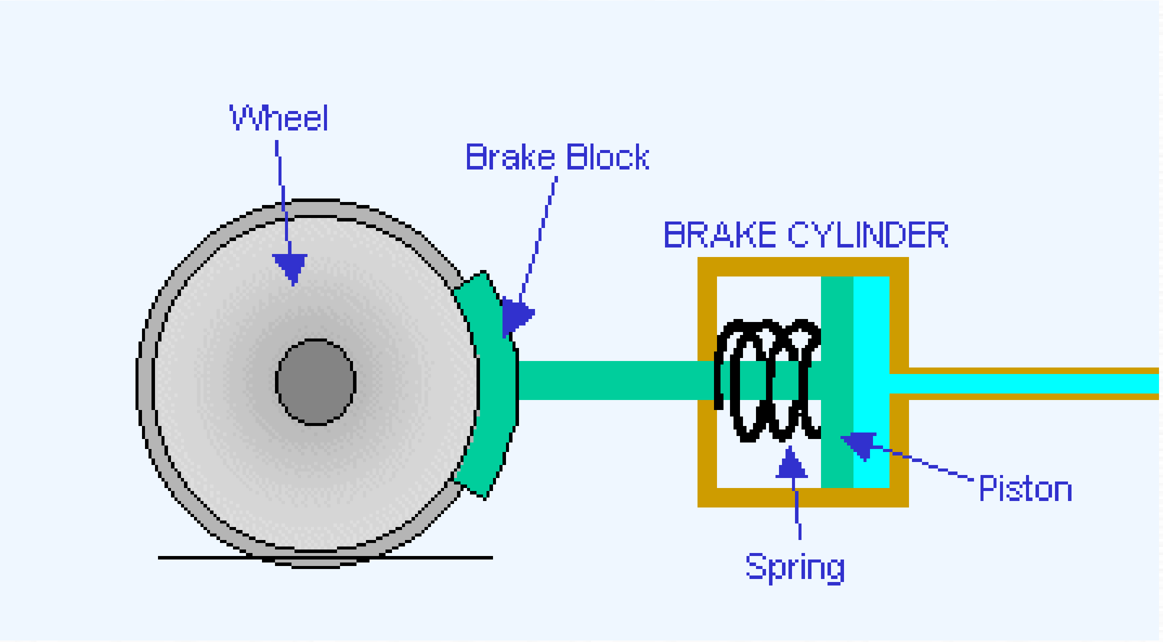
Braking

- Mechanical Braking
  - **Mechanical Regenerative Braking**

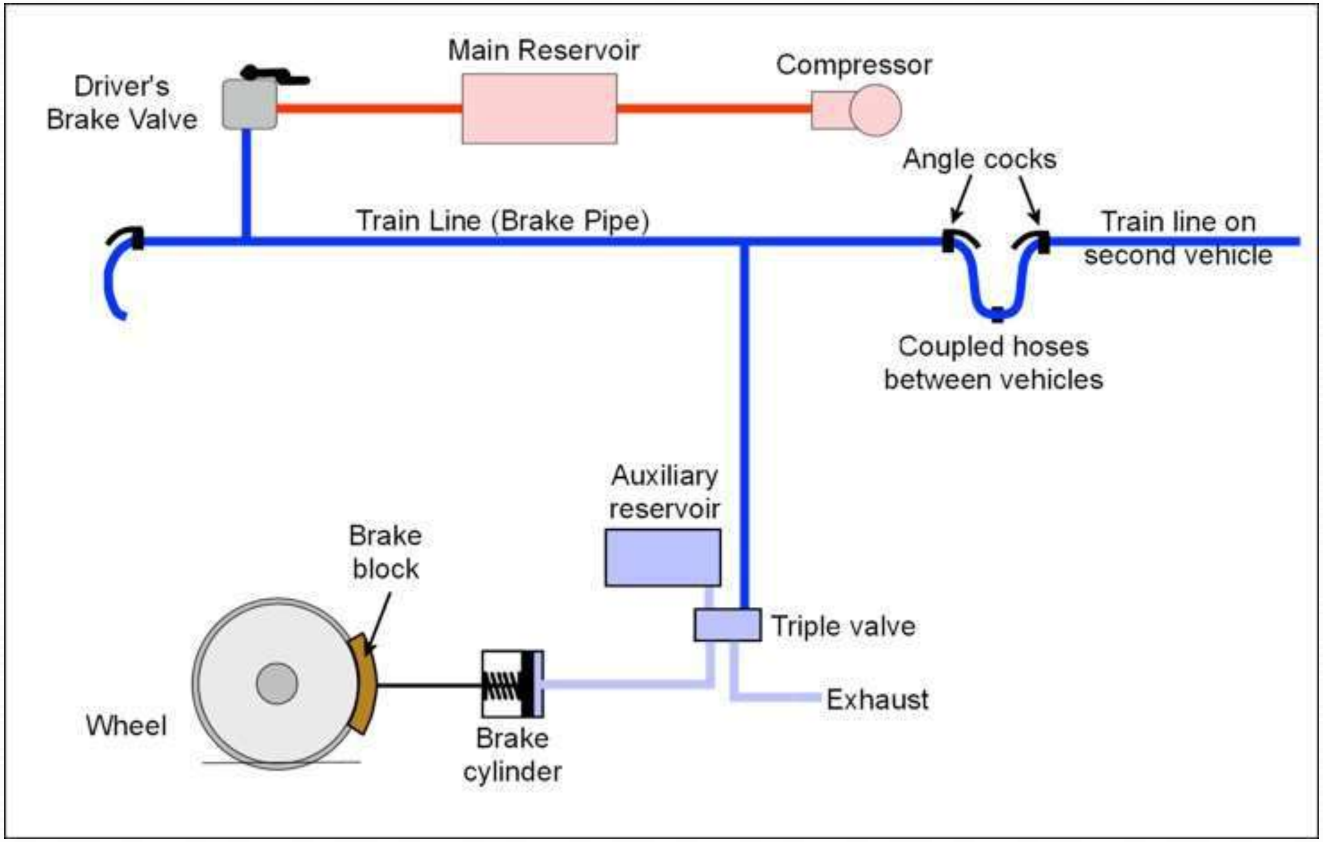


Braking

- Mechanical Braking
  - **Compressed Air Brake**

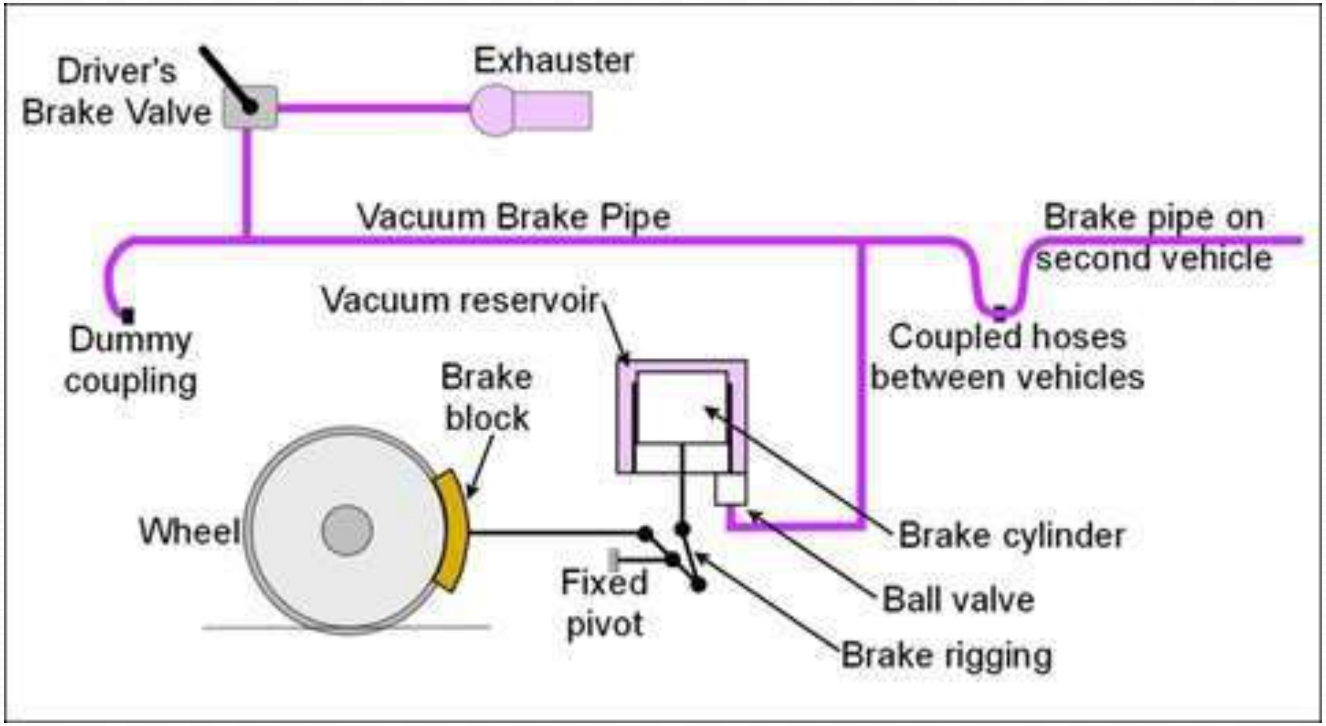


Compressed Air Brake



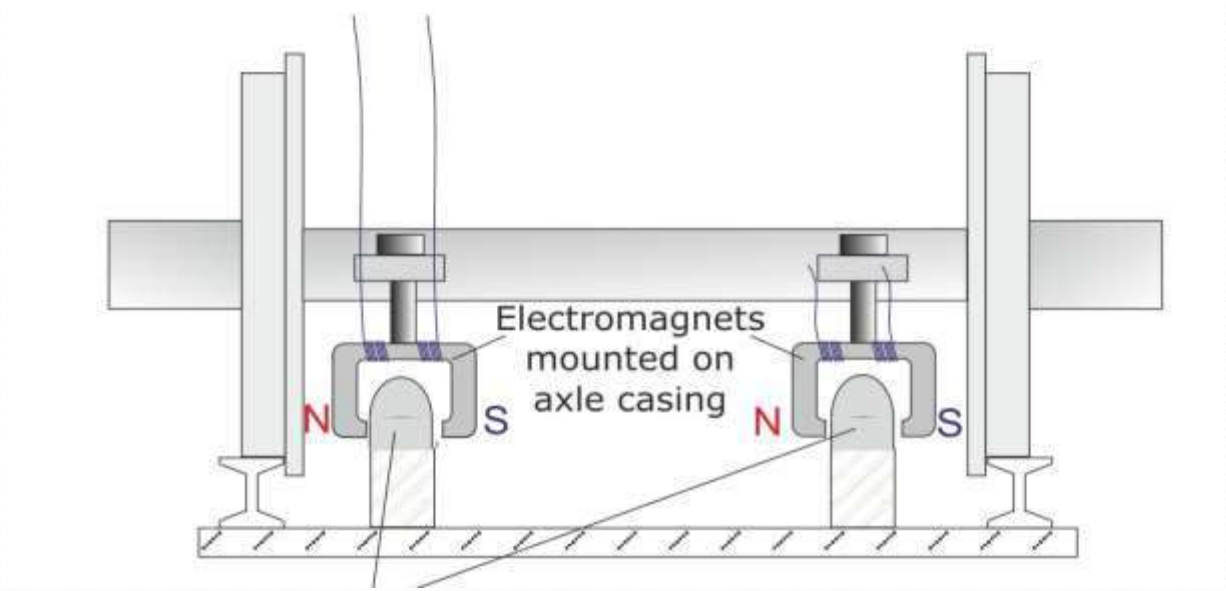
Braking

- Mechanical Braking
  - **Vacuum Brakes**



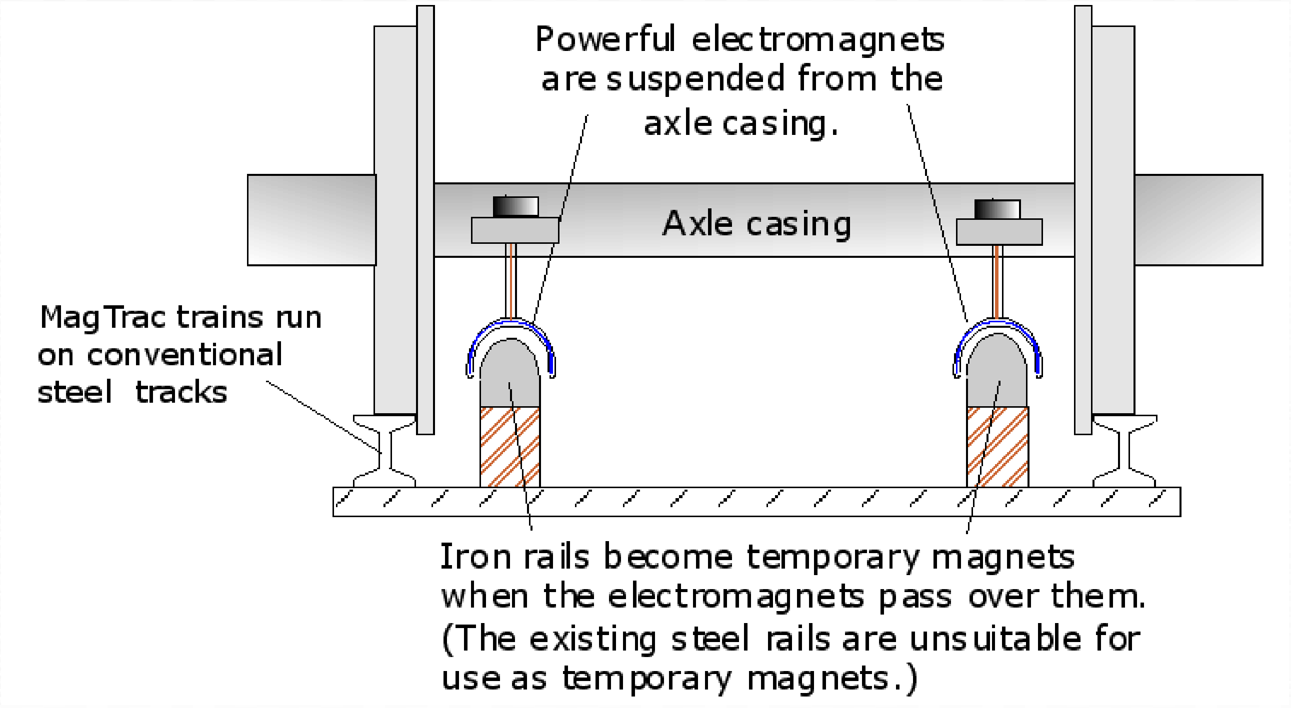
Braking

- Mechanical Braking
  - **Magnetic Track Brakes**
    - **Pole faces are strongly attracted** to rail and provide a retarding force



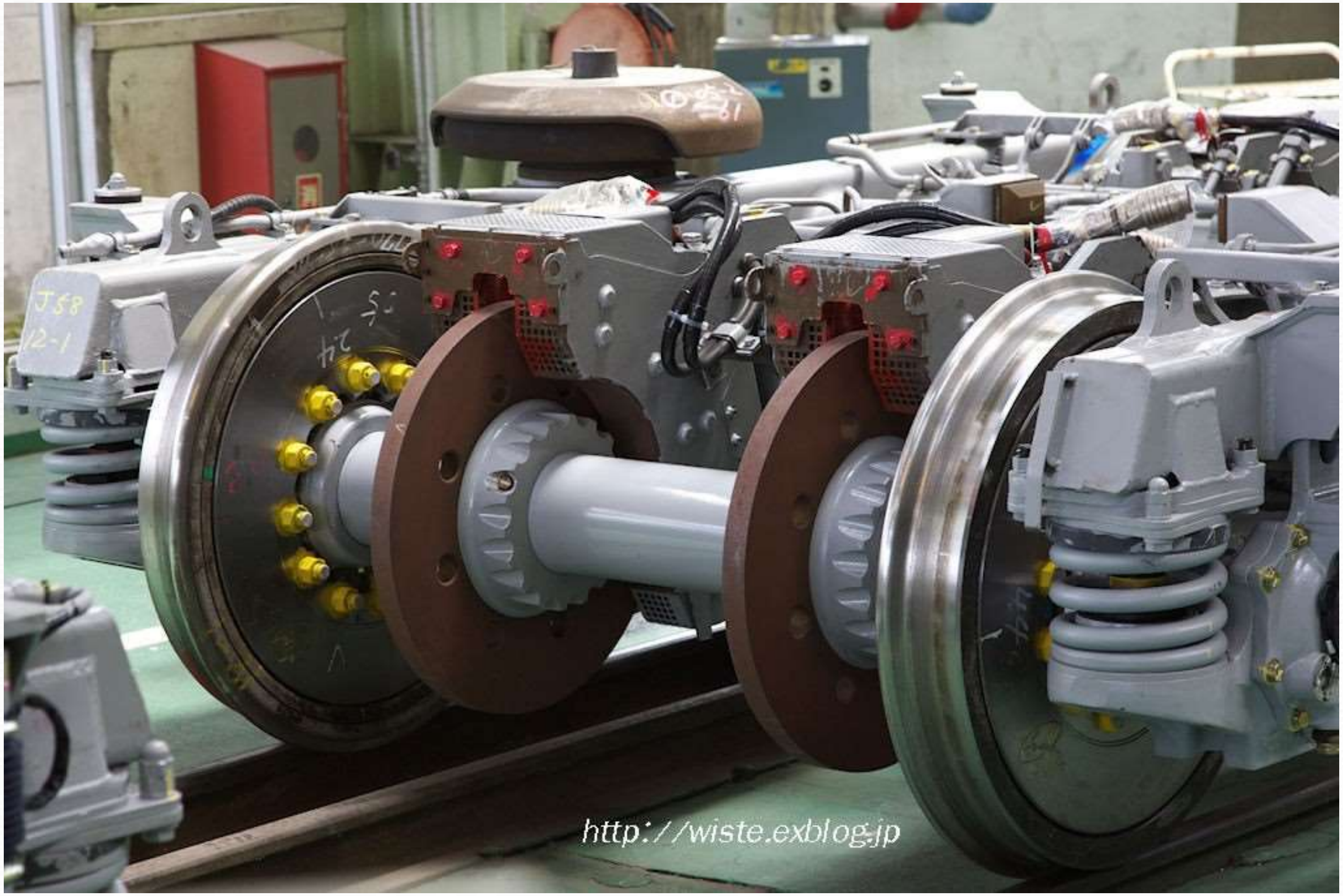
Braking

- Mechanical Braking
  - **Magnetic Track Brakes**



Braking

- **Eddy Current Braking**
  - A **conductive surface moving past a stationary magnet** will have circular electric currents called **eddy currents**
  - By Lenz's law, the circulating currents will create their own magnetic field which **opposes the field of the magnet**
  - The **moving conductor will experience a drag force** from the magnet that **opposes its motion**, proportional to its velocity
  - The kinetic energy of the moving object is **dissipated as heat** generated by the **current flowing through the electrical resistance** of the conductor

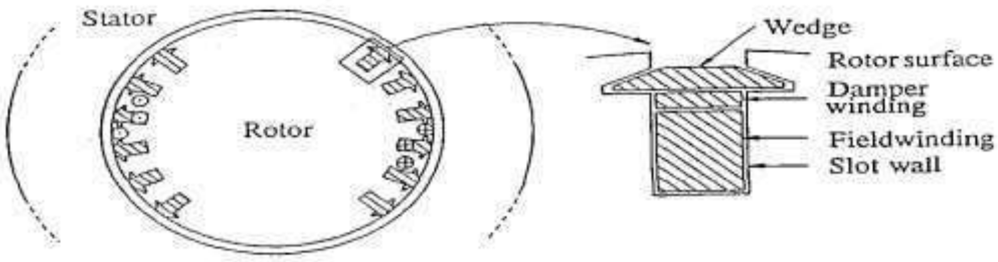

http://wiste.exblog.jp

ELECT. M/C-II
5TH SEMESTER
ELECTRICAL ENGG.

Construction of Synchronous Machines

- **Consists of two sets of windings:**
  - 3 phase armature winding on the stator distributed with centres 120° apart in space
  - field winding on the rotor supplied by DC
- **Two basic rotor structures used:**
  - salient or projecting pole structure for hydraulic units (low speed)
  - Cylindrical/round rotor structure for thermal units (high speed)

- Salient poles have concentrated field windings; usually also carry damper windings on the pole face.
- Cylindrical/Round rotors have solid steel rotors with distributed windings
- Nearly sinusoidal space distribution of flux wave shape obtained by:
- distributing stator windings and field windings in many slots (round rotor);
- shaping pole faces (salient pole)

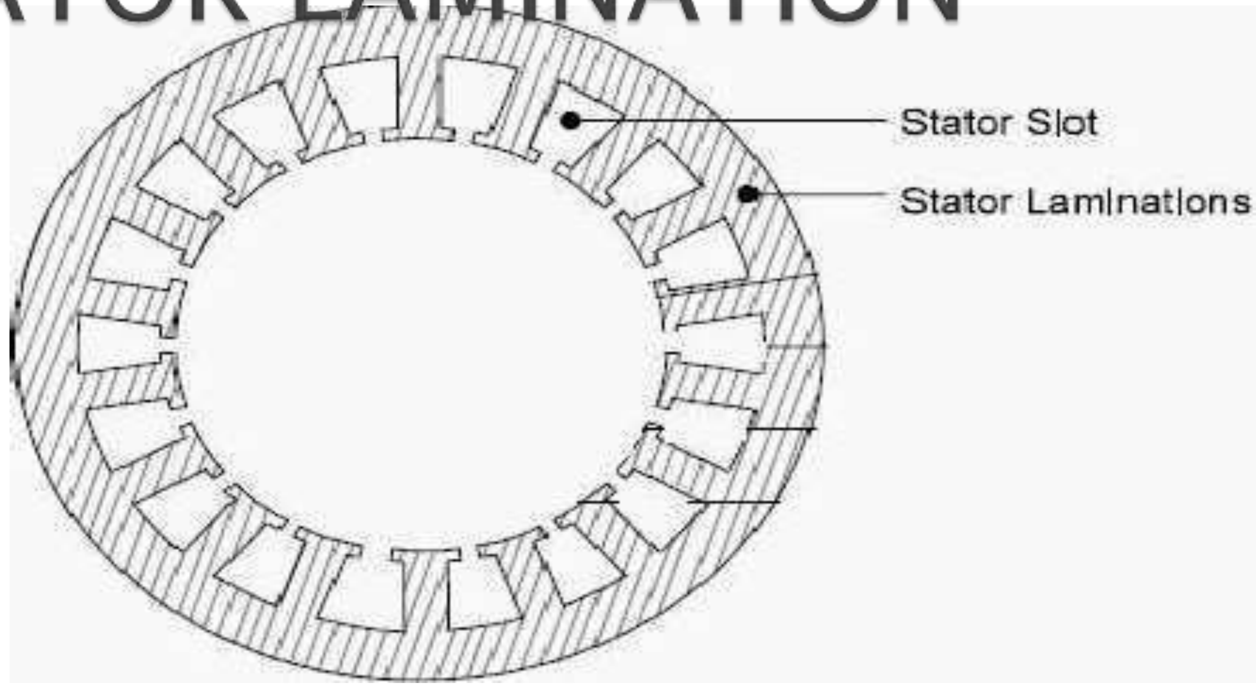


(a) Rotor structure (b) Rotor slot and windings

- **Types of Synchronous Machine**
- **Hydrogenerators** : The generators which are driven by hydraulic turbines are called hydrogenerators.These are run at lower speeds less than 1000 rpm.
- **Turbogenerators:** These are the generators driven by steam turbines.These generators are run at very high speed of 1500rpm or above.
- **Engine driven Generators:** These are driven by IC engines. These are run at a speed less than 1500 rpm.
- Hence the prime movers for the synchronous generators are Hydraulic turbines, Steam turbines or IC engines.
- **Hydraulic Turbines:**
- Pelton wheel Turbines:Water head 400 m and above Francis turbines:Water heads up to 380 m
- KeplanTurbines:Water heads up to 50 m
- **Steam turbines:** The synchronous generators run by steam turbines are called turbogenerators or turbo alternators. Steam turbines are to be run at very high speed to get higher efficiency and hence these types of generators are run at higher speeds.
- **Diesel Engines:** IC engines are used as prime movers for very small rated generators.

- Stator
- The stator is the outer stationary part of the machine, which consists of
  - The outer cylindrical frame called yoke, which is made either of welded sheet steel, cast iron.
  - The magnetic path, which comprises a set of slotted steel laminations called stator core pressed into the cylindrical space inside the outer frame. The magnetic path is laminated to reduce eddy currents; reducing losses and heating. CRGO laminations of
- 0.5 mm thickness are used to reduce the iron losses.
- A set of insulated electrical windings are placed inside the slots of the laminated stator. In case of generators where the diameter is too large stator lamination can not be punched in on circular piece. In such cases the laminations are punched in segments. A number of segments are assembled together to form one circular laminations. All the laminations are insulated from each other by a thin layer of varnish.

STATOR LAMINATION



- **For a given slot mmf, reluctance offered by (i) open slots is more**
- (ii) semi-closed slots is less and (iii) closed slots is still less. Consequently the open slots have less leakage reactance than semi-closed slots, whereas the closed slots have more leakage reactance than semi closed.
- The wide open type slot has the advantage of permitting easy installation of form wound coils and their easy removal in case of repair. But it has the disadvantage of distributing the air gap flux into bunches or tufts, that produces ripples in the wave of the generated emf.
- The semi closed type slots are better in this respect, but do not make the use of form wound coils.

- The wholly closed slots do not disturb the air gap flux but
- they tend increase the inductance of the windings
- The armature conductors have to be threaded through, thereby increasing initial labour and cost of winding and
- They present a complicated problem of end connection. Hence they are rarely used.

The stator winding of all synchronous generator is star connected with neutral earthed. This arrangement has the advantage that the winding has to be insulated to earth for the phase voltage and not the line voltage. Star connection also has the advantage that it eliminates all triple frequency harmonics from the line voltage.

Synchronous machines are AC machines that have a field circuit supplied by an external DC source.
In a synchronous generator, a DC current is applied to the rotor winding producing a rotor magnetic field. The rotor is then turned by external means producing a rotating magnetic field, which induces a 3-phase voltage within the stator winding.
In a synchronous motor, a 3-phase set of stator currents produces a rotating magnetic field causing the rotor magnetic field to align with it. The rotor magnetic field is produced by a DC current applied to the rotor winding.

Field windings are the windings producing the main magnetic field (rotor windings for synchronous machines); armature windings are the windings where the main voltage is induced (stator windings for synchronous machines).

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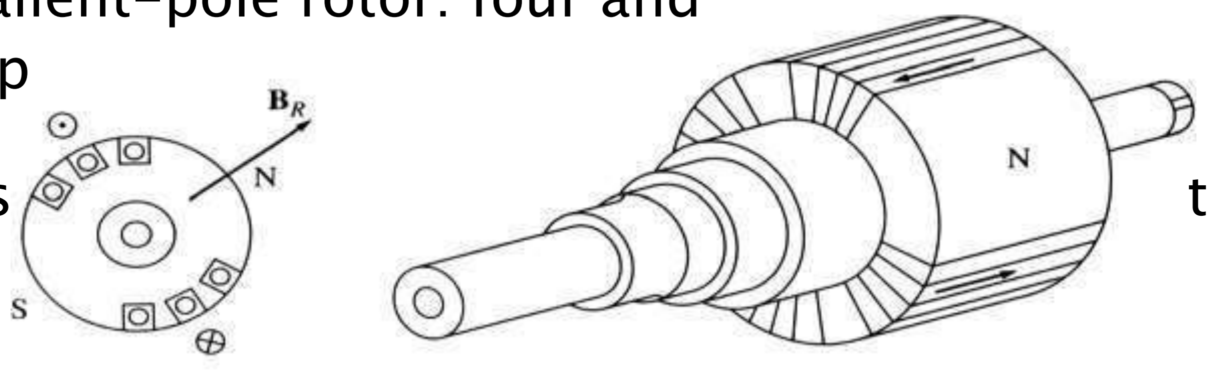
- The rotor of a synchronous machine is a large electromagnet.The magnetic poles can be either salient (sticking out of rotor surface) or non-salient construction.
- Non-salient-pole rotor: usually two- and four-pole rotors. Salient-pole rotor: four and
- more p
- Rotors t losses.



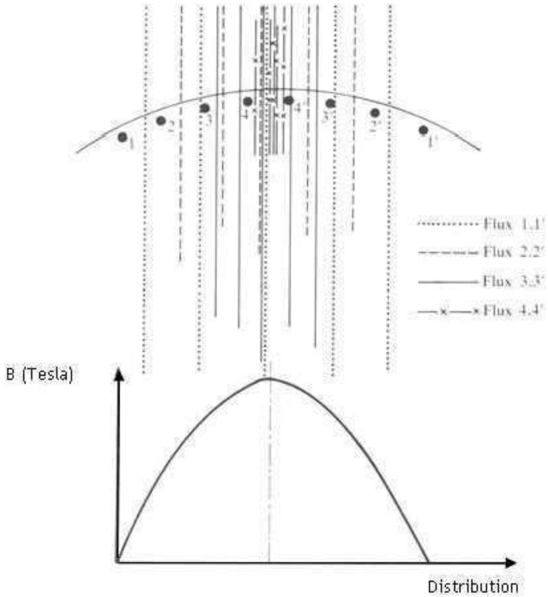
End view

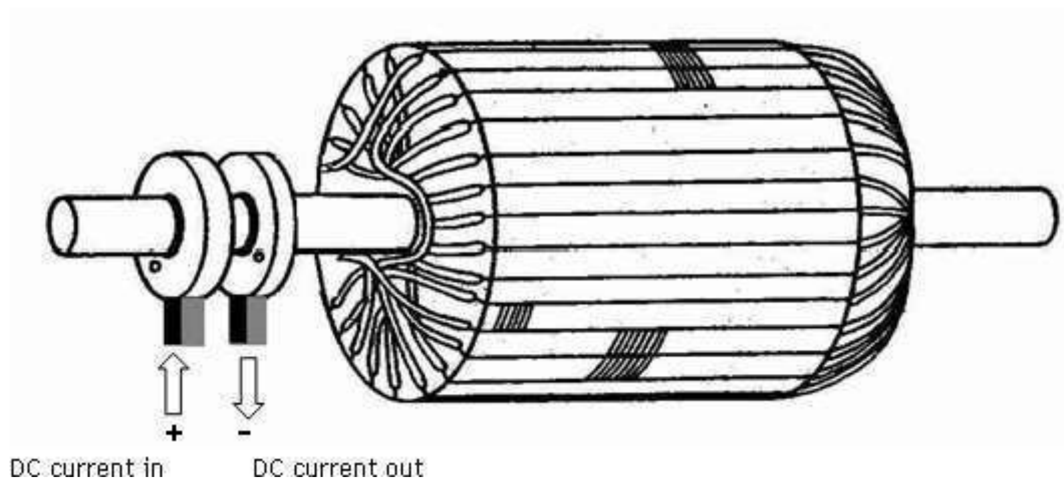
Side view

- Rotor
- Traditionally, North American manufacturers normally did not provide special “damper windings”
  - solid steel rotors offer paths for eddy currents, which have effects equivalent to that of amortisseur currents
- European manufacturers tended to provide for additional damping effects and negative sequence currents capability
  - wedges in the slots of field windings interconnected to form a damper case, or
  - separate copper rods provided underneath the wedges

Solid round rotor construction

Rotor Costruction



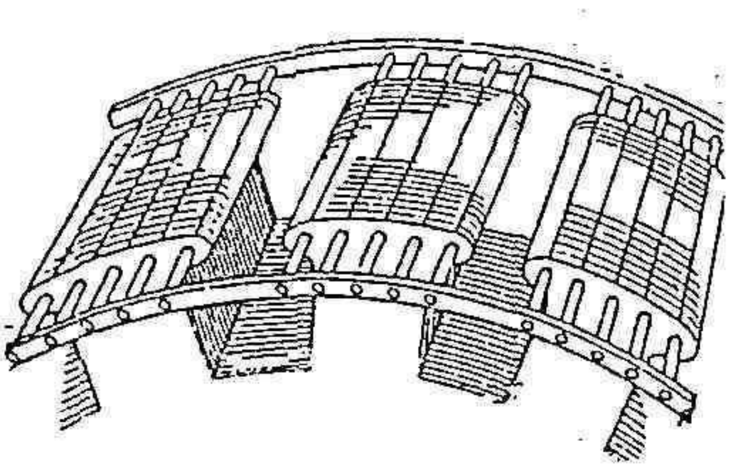


- Rotor of hydraulic unit

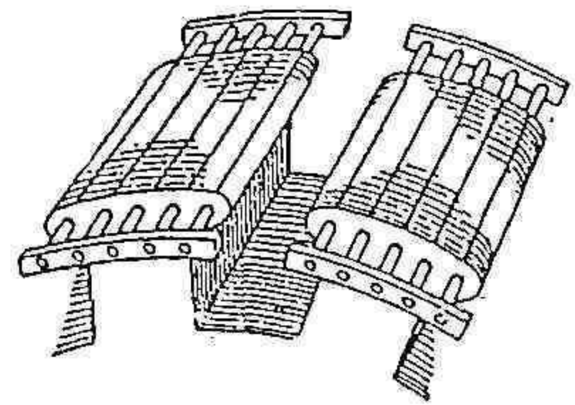
- Normally have damper windings or amortisseurs
  - non-magnetic material (usually copper) rods embedded in pole face
  - connected to end rings to form short-circuited windings
- Damper windings may be either continuous or non-continuous
- Space harmonics of the armature mmf contribute to surface eddy current therefore, pole faces are usually laminated

- Salient pole rotor construction

Salient pole rotor construction

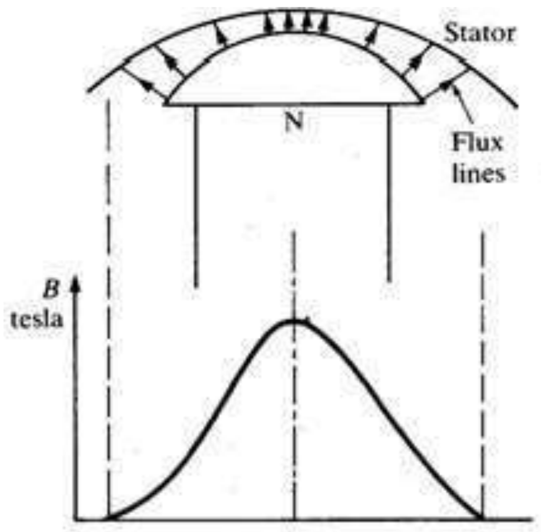


(a) Continuous damper



(b) Non-continuous damper

- **Salient Pole**
- Difference between pole face curvature and stator creates non-linear variation in flux across pole face



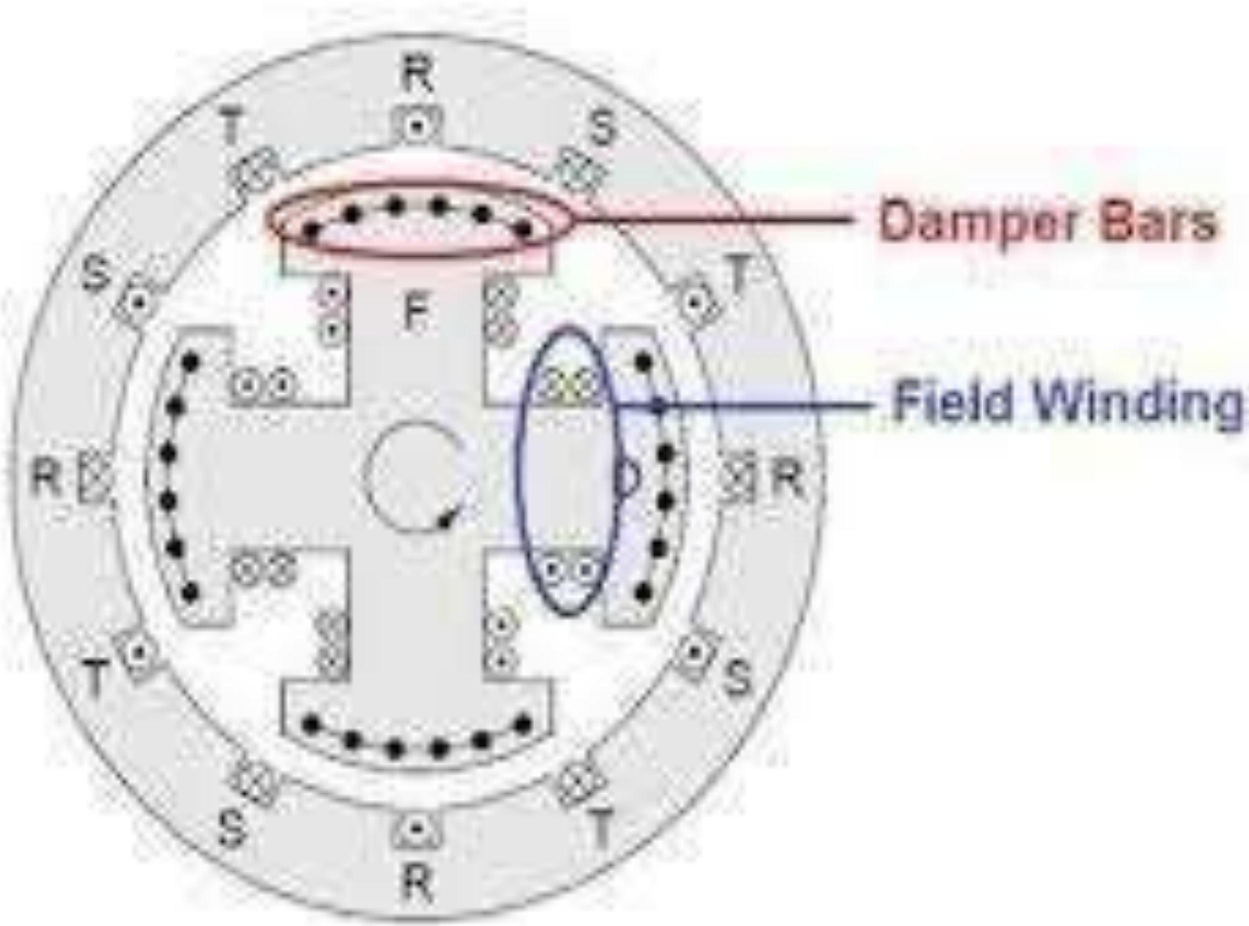
- Non-linear variation in flux across pole face produces sinusoidal change in the induced EMF

ROTOR

- Rotor of water wheel generator consists of salient poles. Poles are built with thin silicon steel laminations of 0.5mm to 0.8 mm thickness to reduce eddy current laminations. The laminations are clamped by heavy end plates and secured by studs or rivets. Generally rectangular or round pole constructions are used for such type of alternators. However the round poles have the advantages over rectangular poles.
-

DAMPER WINDING

Damper windings are provided in the pole faces of salient pole alternators. Damper windings are nothing but the copper or aluminum bars housed in the slots of the pole faces. The ends of the damper bars are short circuited at the ends by short circuiting rings similar to end rings as in the case of squirrel cage rotors.



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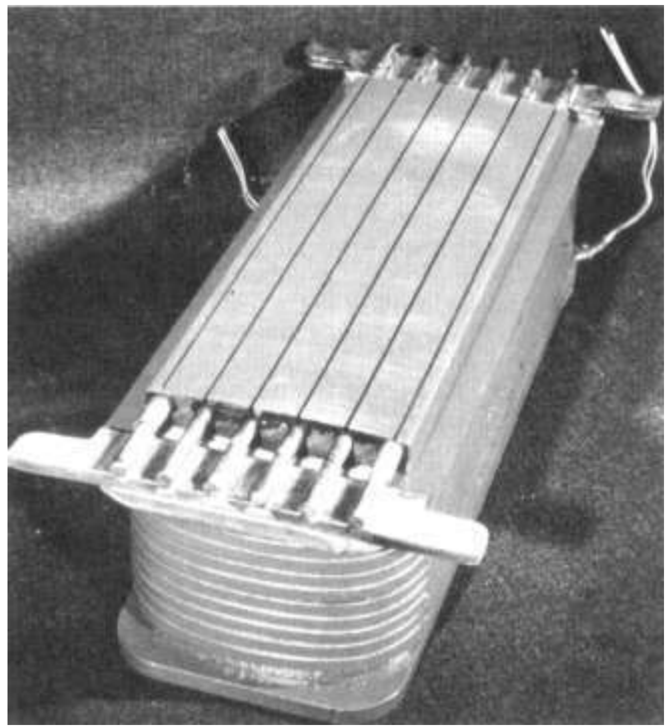
Damper Bars
Field Winding

A synchronous rotor with 8 salient poles



- Two common approaches are used to supply a DC current to the field circuits on the rotating rotor:
- Supply the DC power from an external DC source to the rotor by means of slip rings and brushes;
- Supply the DC power from a special DC power source mounted directly on the shaft of the machine.

Slip rings are metal rings completely encircling the shaft of a machine but insulated from it. One end of a DC rotor winding p rings on the machin shes connected to D supplying DC s the position or spe

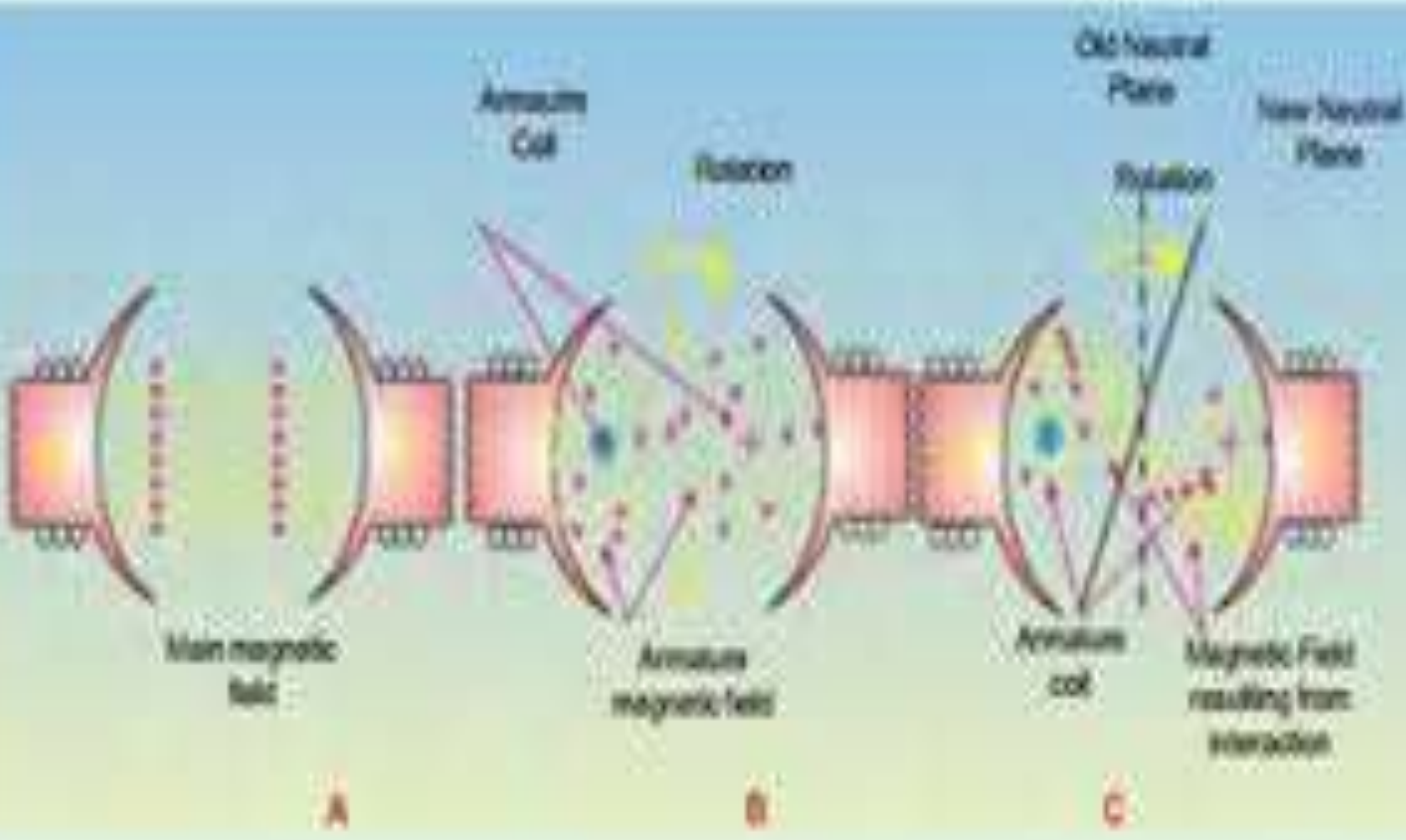
Armature reaction

- **Armature reaction** in a DC machine. In a DC machine, the main field is produced by field coils. In both the generating and motoring modes, the **armature** carries current and a magnetic field is established, which is called the **armature** flux.
- The effect of **armature** flux on the main field is called the **armature reaction.**

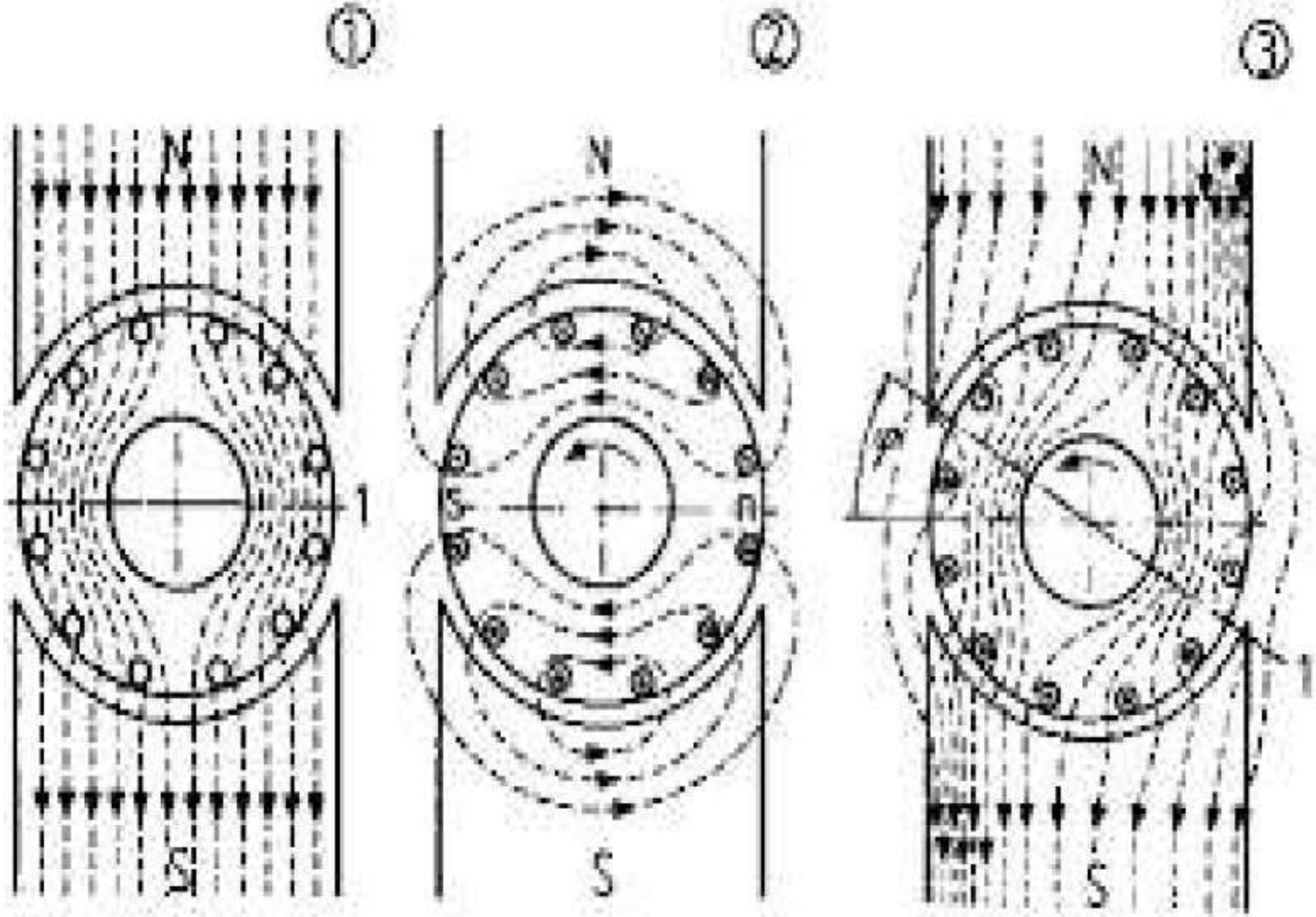
EFFECTS OF ARMATURE REACTION

- The armature reaction will reduce the generated EMF due to *decrease in value of flux per pole*.
- The iron losses in the teeth and pole shoes are determined by the maximum value of flux density at which they work. Due to distortion in main field flux the maximum density at load increases above no load. Thus *more iron losses* are observed on load than no load.
- Due to this process the maximum value of gap flux density increases. This will increase the maximum voltage between adjacent commutator segments at load. If this voltage exceeds beyond 30V the *sparking may take place* between adjacent commutator segments.

- The armature reaction *shifts brush axis from GNA*. Thus flux density in the interpolar axis is not zero but having some value. Thus there will be an induced emf in the coil undergoing commutation which will try to maintain the current in original direction. This will *make commutation difficult* and will cause delayed commutation.



Armature reaction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METHOD TO REDUCE ARMATURE REACTION

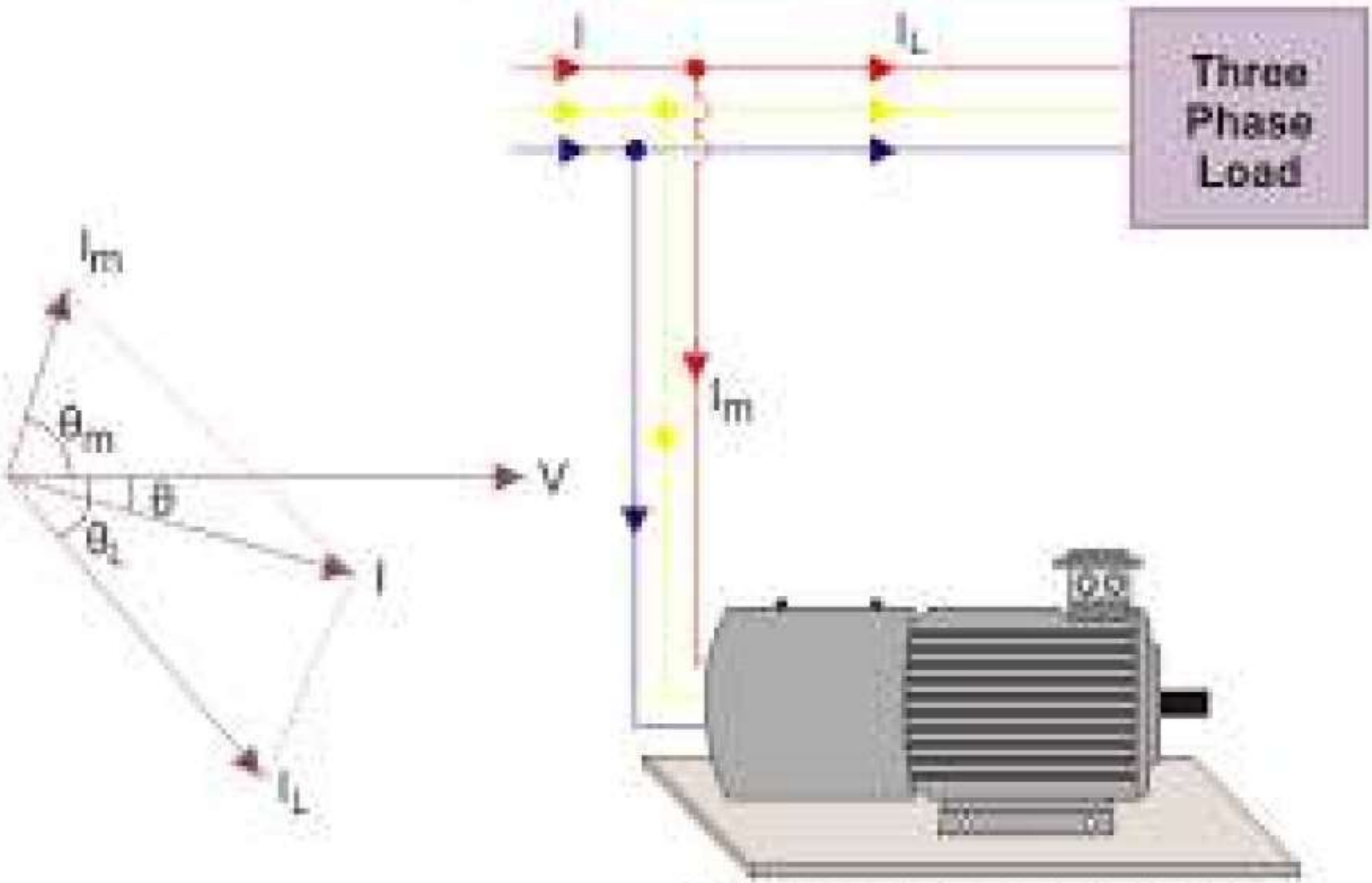
- The following methods are used in order to reduce the effect of armature reaction.
- The armature reaction causes the distortion in main field flux.
  This can be reduced if the reluctance of the path of the cross-magnetising field is increased.
  The armature teeth and air gap at pole tips offer reluctance to armature flux.
  Thus by increasing length of air gap, the armature reaction effect is reduced.

- If reluctance at pole tips is increased it will reduce distorting effect of armature reaction. By using special construction in which leading and trailing pole tip portions of laminations are alternately omitted.
- The effect of armature reaction can be neutralized by use of compensating winding. It is always placed in series with armature winding.
  The armature ampere conductors under pole shoe must be equal to compensating winding ampere conductors which will compensate armature mmf perfectly.

- The armature reaction causes shifting the magnetic neutral axis.
  Therefore there will be some flux density at brush axis which produces emf in the coil undergoing commutation.
  This will lead to delayed commutation.
  Thus the armature reaction at brush axis must be neutralized.
  This requires another equal and opposite mmf to that of armature mmf.
  This can be applied by interpoles which are placed at geometric neutral axis at midway between the main poles

synchronous condenser

- A **synchronous condenser** is an over excited **synchronous** motor, which draws leading currents from the system and hence compensates for lagging VARs.
- It is used as a reactive power compensator in some systems for power factor correction purposes.



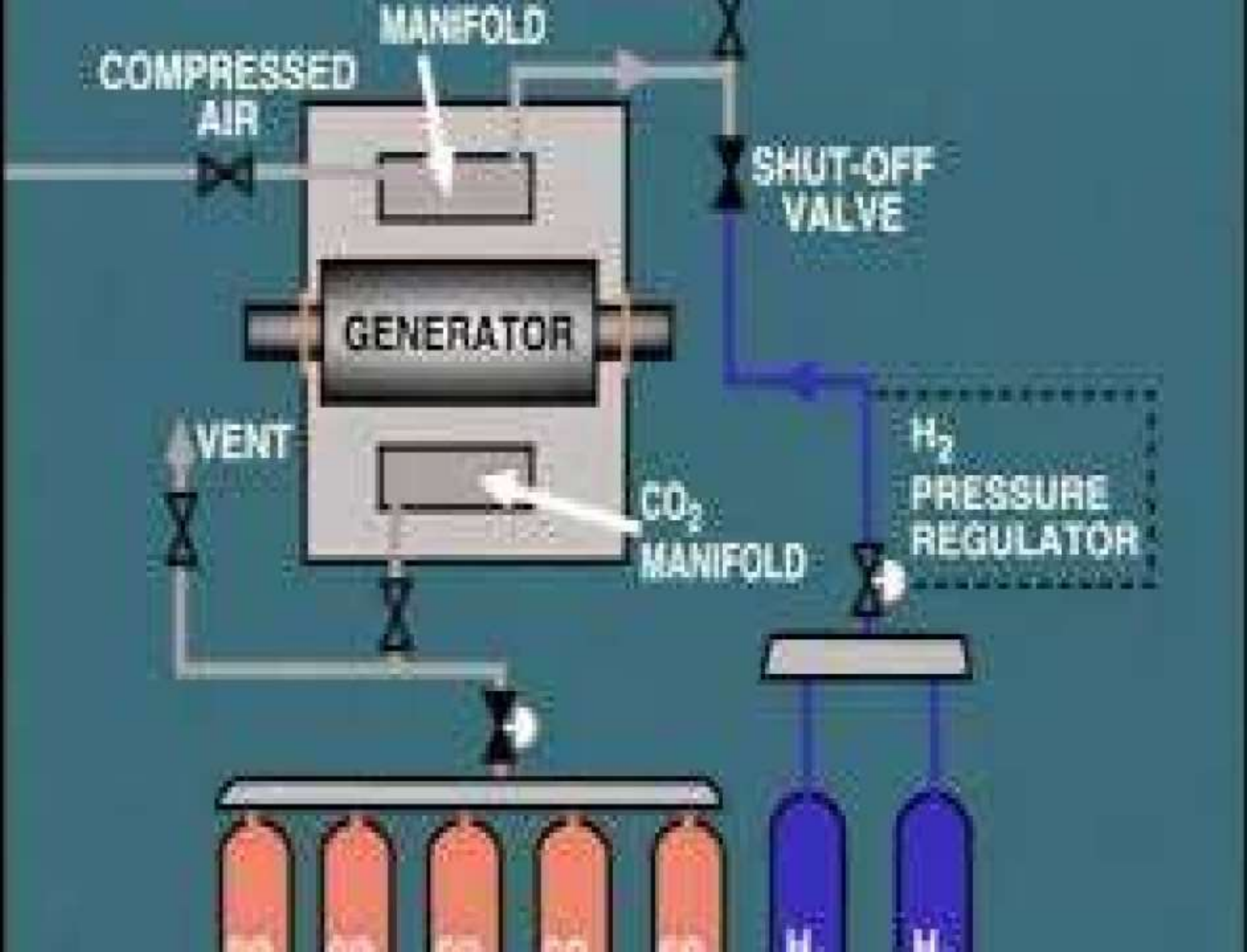
Three Phase Synchronous Motor

Cooling of Synchronous Machine

- **Cooling** of a **Synchronous** Generator is very essential. ... In the forced air **cooling** system, air is forced into the alternator so that a greater quantity of air is passed over the surface and a large amount of heat is removed.

Hydrogen Cooling

- **Hydrogen Cooling** or you can say hydrogen gas is used as a cooling medium in the generator casing because of its superior cooling properties.
- Certain mixtures of hydrogen and air are explosive. The explosion may take place with a range of 6 percent hydrogen and 94 percent air up to 71 percent hydrogen and 29 percent air. When there is more than 71 percent hydrogen, the mixture is not combustible.
- In practice 9:1 ratio of hydrogen to air is used in very large turbo alternators.



MANIFOLD
COMPRESSED AIR
SHUT-OFF VALVE
GENERATOR
VENT
CO_2 MANIFOLD
H_2 PRESSURE REGULATOR

APPLICATIONS

- Synchronous motors are used in generating stations and in substations connected to the busbars to improve the power factor. For this purpose they are run without mechanical load on them and in over-excited condition.
- These machines when over excited delivers the reactive power to grid and helps to improve the power factor of the system. The reactive power delivered by the synchronous motors can be adjusted by varying the field excitation of the motor. These motors used for power factor correction applications can also be termed as "synchronous condensers".

- Advantage of synchronous condensers compared to shunt capacitors is that shunt capacitors generate constant reactive power whereas on the other hand synchronous condensers can able to deliver different reactive power levels by varying the excitation of machine.

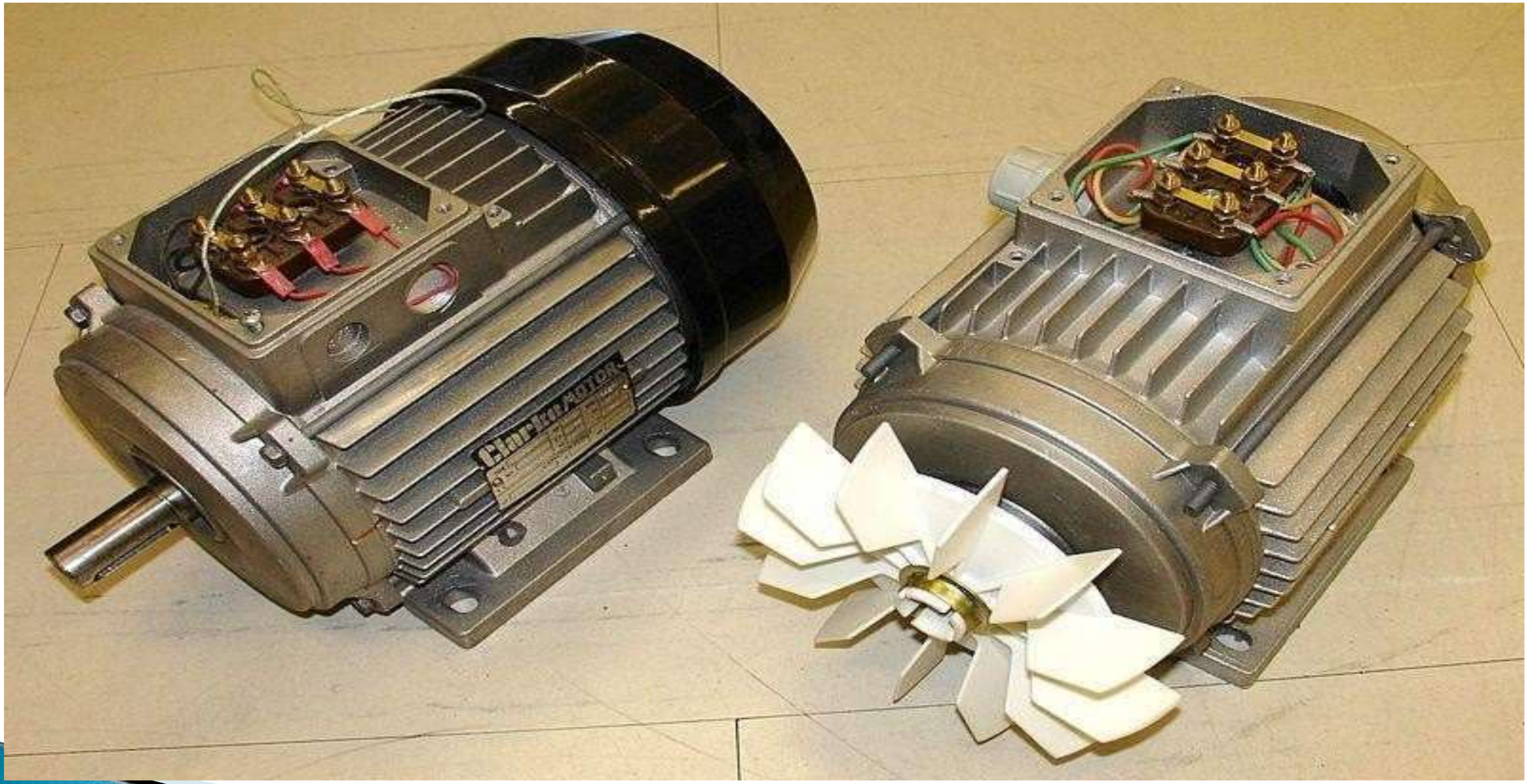
- Because of the higher efficiency compared to induction motors they can be employed for loads which require constant speeds. Some of the typical applications of high speed synchronous motors are such drives as fans, blowers, dc generators, line shafts, centrifugal pumps, compressors, reciprocating pumps, rubber and paper mills

Three phase induction motor

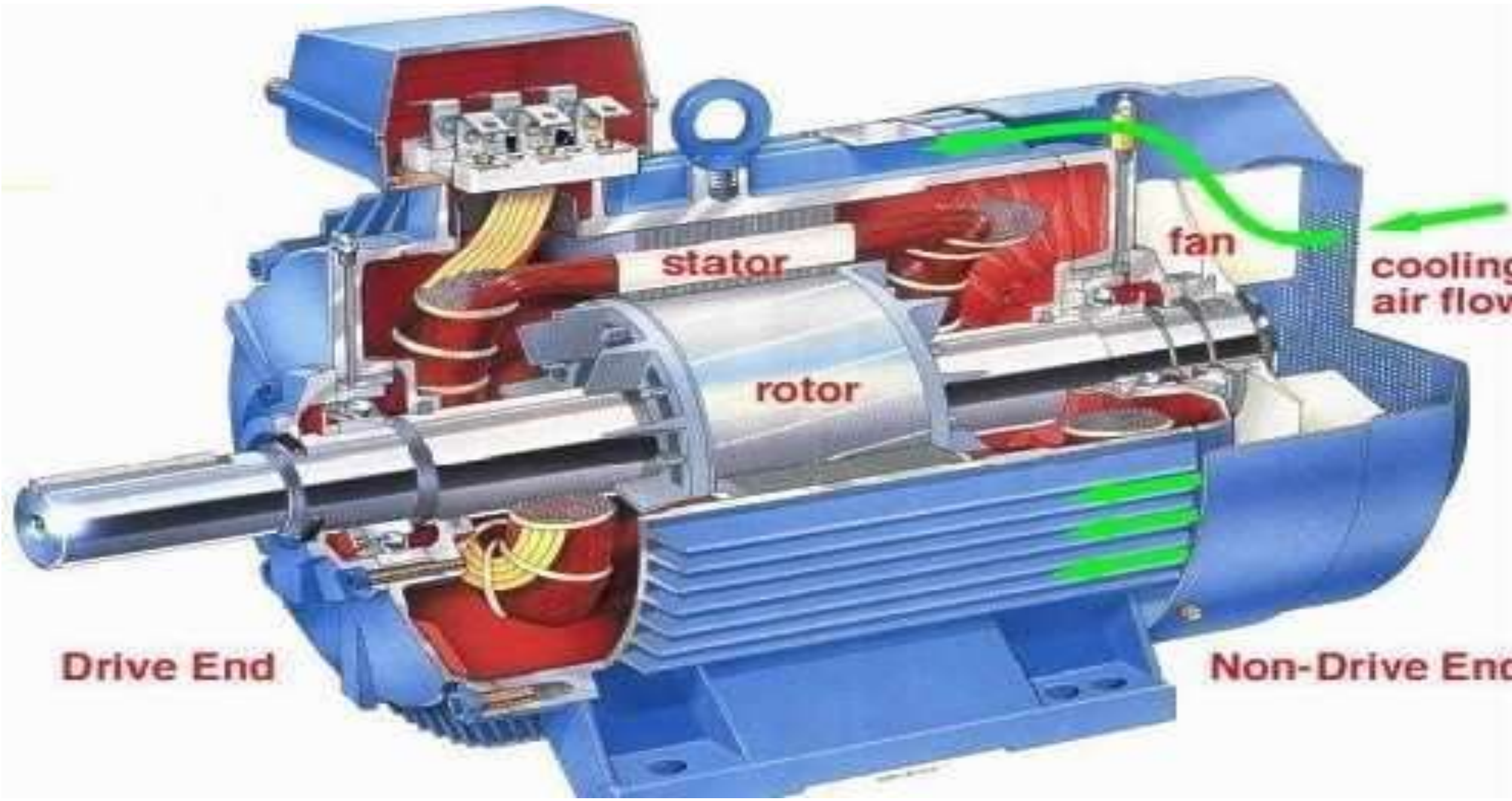
- An **induction motor** or **asynchronous motor** is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.
- An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type.

Image of 3-Phase Induction

Terminals of 3-phase Induction Motor

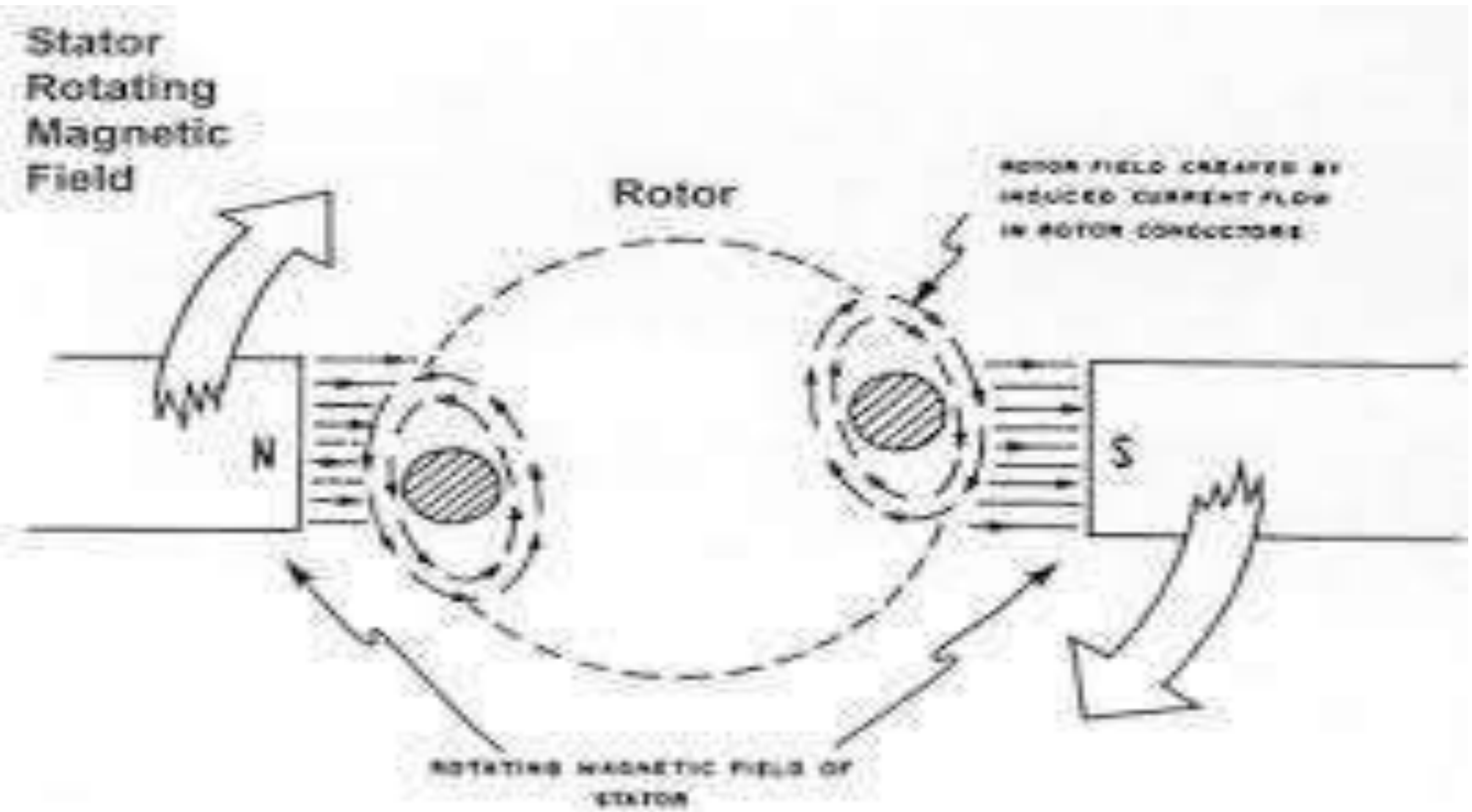


Cut view of 3-phase I.M



Working principle

- Basic **working principle** of an **Induction Motor**.
  In a DC **motor**, supply is needed to be given for the stator winding as well as the rotor winding.
- But in an **induction motor** only the stator winding is fed with an **AC** supply. Alternating flux is produced around the stator winding due to **AC** supply.

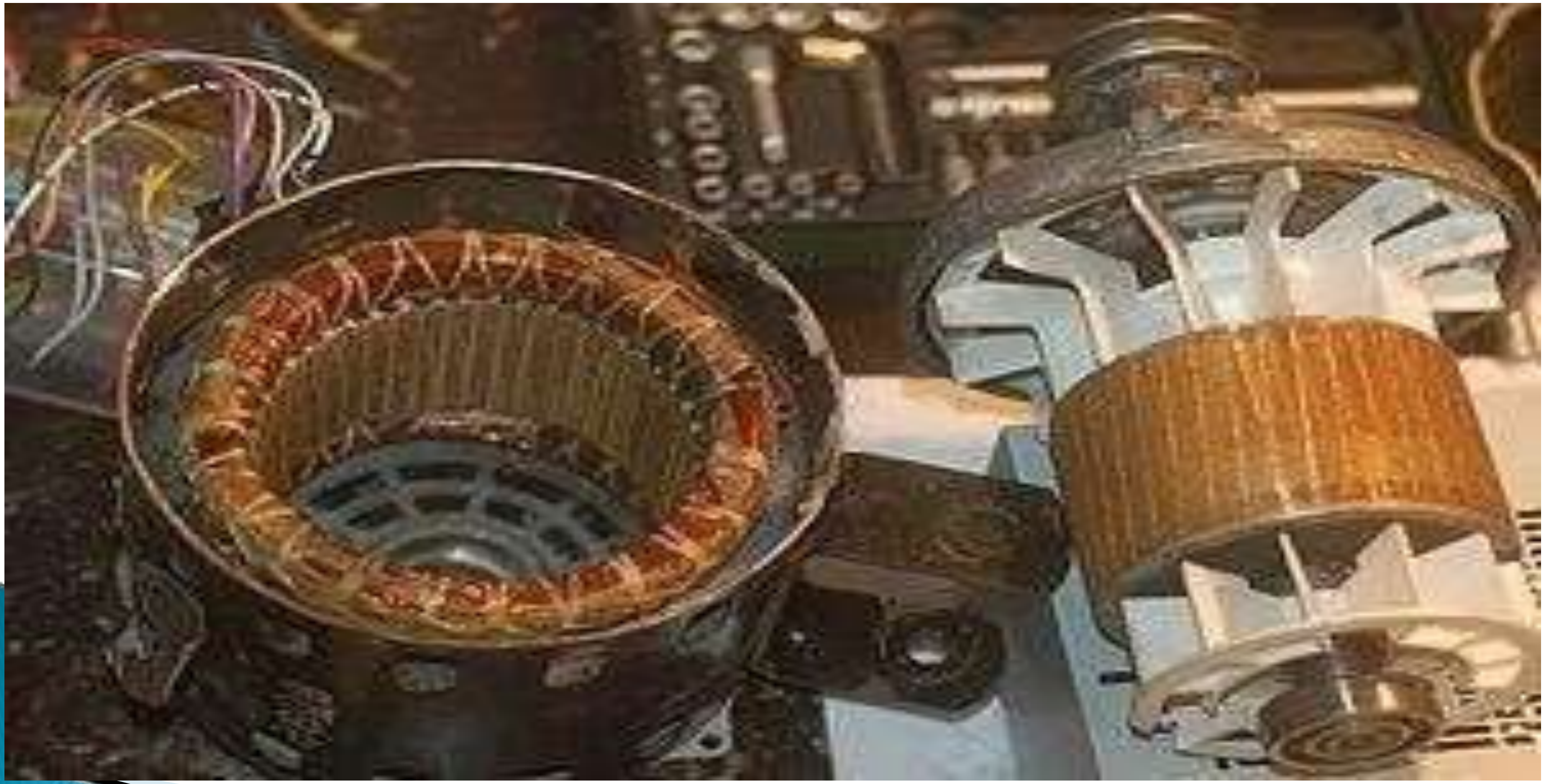

Stator
Rotating
Magnetic
Field
Rotor
ROTOR FIELD CREATED BY
INDUCED CURRENT FLOW
IN ROTOR CONDUCTORS
N
S
ROTATING MAGNETIC FIELD OF
STATOR

Constructional features

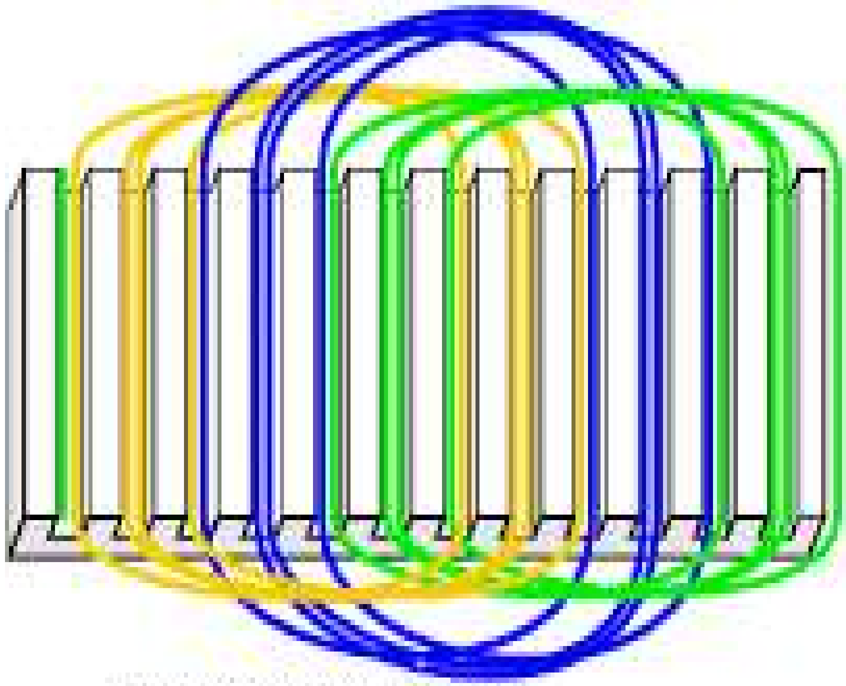
- Frame
- Stator
- Stator Winding
- Rotor
- Rotor Winding
- Cooling Fan
- Bearings Frame:
- Frame provides mechanical support to the stator and rotor. It is made from casting materials.
- Stator:
- It is stationary part of induction motor. It consists stator winding
- It is housed on the motor frame.


Basics of
3-phase Induction Motor

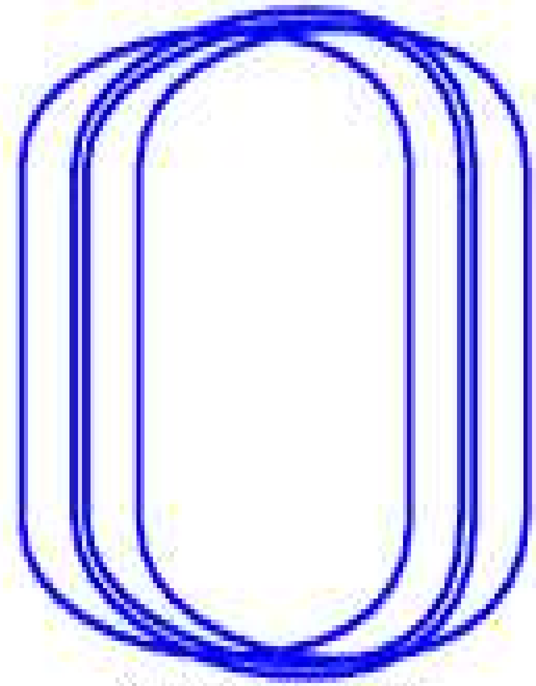
Rotor and Stator



Winding

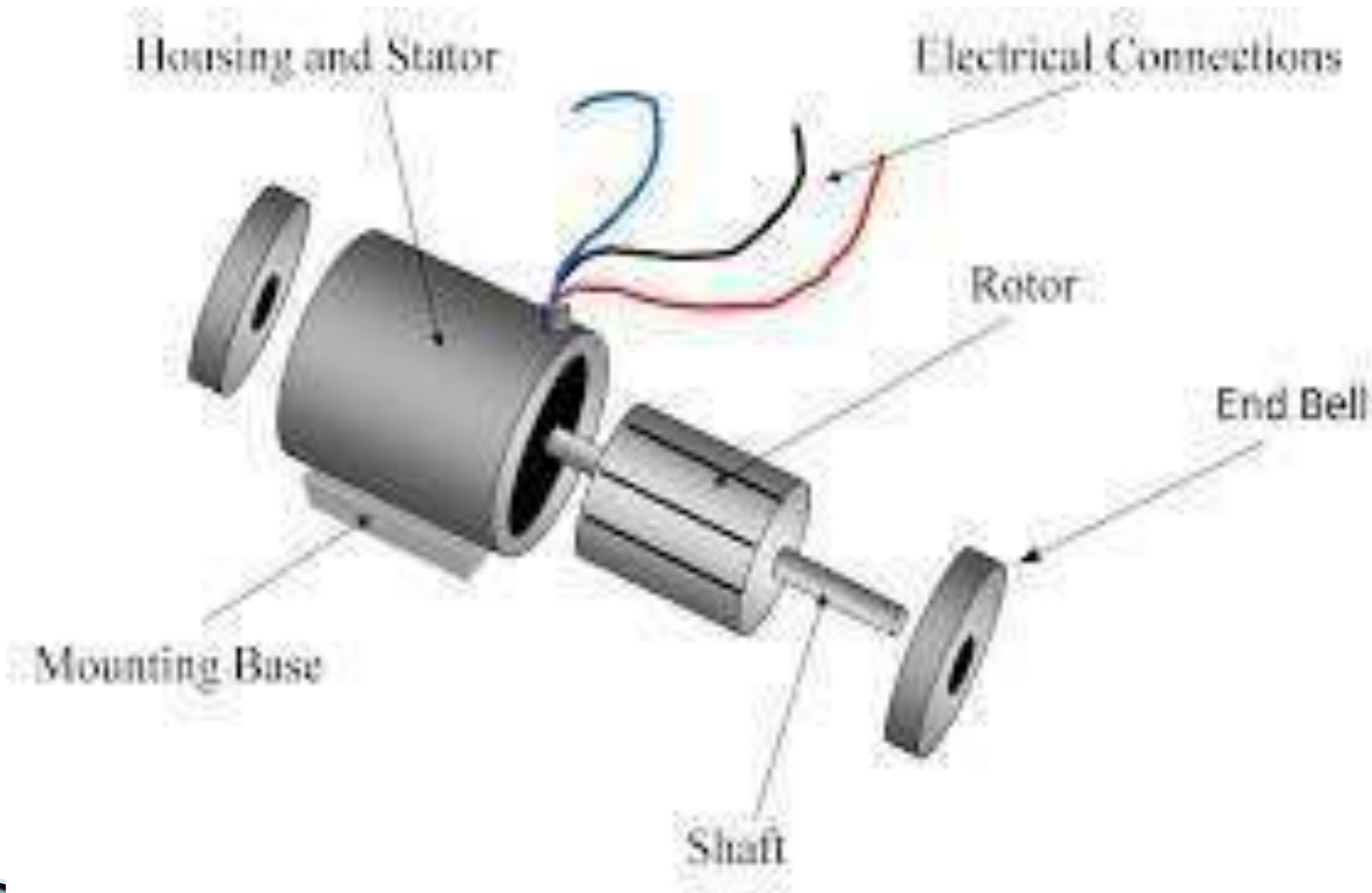


3-ϕ distributed winding



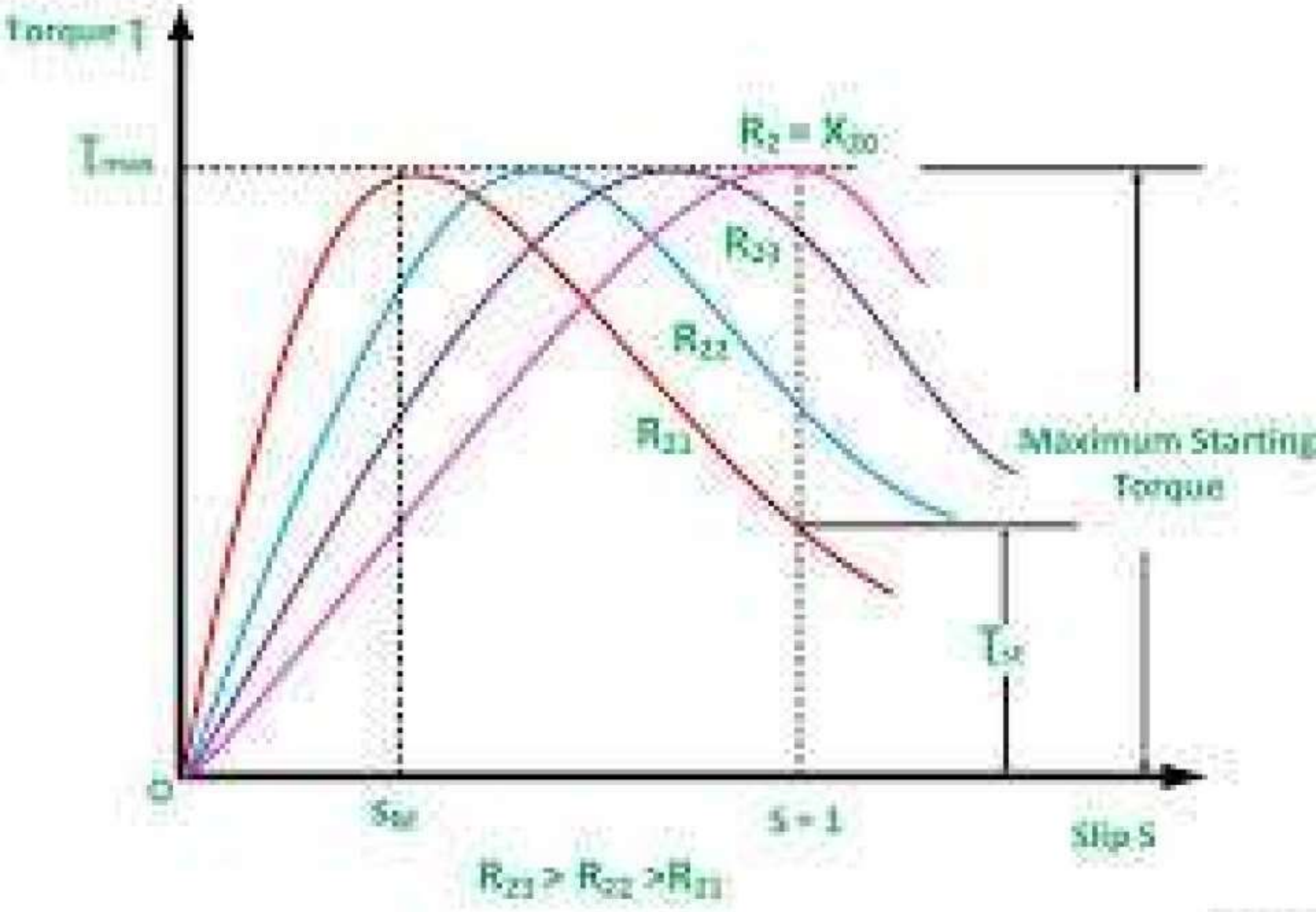
Single phase belt

Shaft


Housing and Stator
Electrical Connections
Rotor
End Bell
Mounting Base
Shaft

Speed torque char. Of indution motor

- It can be observed that the maximum torque is independent of rotor resistance. However, the slip at which the maximum torque occurs changes with rotor resistance. When the rotor resistance is increased, so is the slip for maximum torque, and the stable operating slip range of the motor increases. Typical characteristics of an induction motor for different values of rotor resistance are shown in Fig. 1.22. From the figure it is seen that the starting torque can be increased by increasing the rotor resistance. The maximum torque occurs at starting if the rotor resistance is increased to a value.



Torque T
T_{max}
$R_2 = X_{20}$
R_{23}
R_{22}
R_{21}
Maximum Starting
Torque
T_{st}
O
S_M
S = 1
Slip S
$R_{23} > R_{22} > R_{21}$

SINGLE PHASE INDUCTION MOTOR

Single phase induction machine is the most frequently used motor for refrigerators, washing machines, clocks, drills, compressors, pumps.

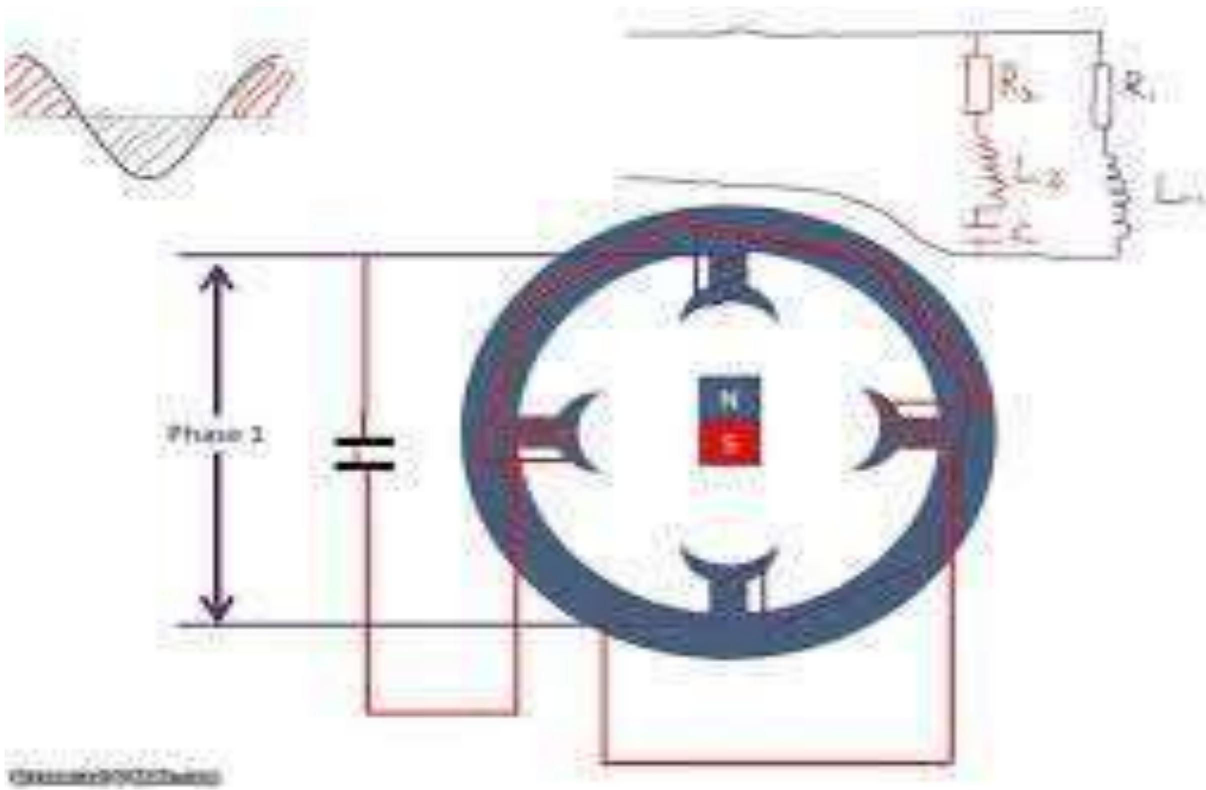
Construction

- Construction of Single Phase induction motor are stator and rotor.
- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly, One is the main and the other is the auxiliary winding or starting winding

STATOR AND ROTOR

Working

- A **Single Phase Induction Motor** consists of a **single phase** winding which is mounted on the stator of the **motor** and a cage winding placed on the rotor. A pulsating magnetic field is produced, when the stator winding of the **single-phase induction motor** shown below is energized by a **single phase** supply.


Phase 1
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Types of Single Phase Induction Motor

- **Split Phase Capacitor Start Run Shaded Pole**
- **Split phase induction motor.**
- **Capacitor start inductor motor.**
- **Capacitor start capacitor run induction motor**(two value **capacitor** method).
- Permanent **split capacitor** (PSC) motor .
- Shaded pole induction motor.

- THANK YOU

INTRODUCTION OF PLC

- **PLC (Programmable Logic Control) :**

Programmable logic controllers (PLCs) have been an integral part of factory automation and industrial process control for decades. PLCs control a wide array of applications from simple lighting functions to environmental systems to chemical processing plants. These systems perform many functions, providing a variety of analog and digital input and output interfaces; signal processing; data conversion; and various communication protocols. All of the PLC's components and functions are centered around the controller, which is programmed for a specific task.

- **Advantages of PLC**

1. **Flexibility**: One single Programmable Logic Controller can easily run many machines.
2. **Correcting Errors**: In old days, with wired relay-type panels, any program alterations required time for rewiring of panels and devices. With PLC control any change in circuit design or sequence is as simple as retyping the logic. Correcting errors in PLC is extremely short and cost effective.
3. **Space Efficient:** Today's Programmable Logic Control memory is getting bigger and bigger this means that we can generate more and more contacts, coils, timers, sequencers, counters and so on. We can have thousands of contact timers and counters in a single PLC. Imagine what it would be like to have so many things in one panel.
4. **Low Cost:** Prices of Programmable Logic Controllers vary from few hundreds to few thousands. This is nothing compared to the prices of the contact and coils and timers that you would pay to match the same things. Add to that the installation cost, the shipping cost and so on.
5. **Testing:** A Programmable Logic Control program can be tested and evaluated in a lab. The program can be tested, validated and corrected saving very valuable time.
6. **Visual observation:** When running a PLC program a visual operation can be seen on the screen. Hence troubleshooting a circuit is really quick, easy and simple.

- **Disadvantages of PLC**

1. There's too much work required in connecting wires.
2. There’s difficulty with changes or replacements.
3. It's always difficult to find errors; And require skilful work force.
4. When a problem occurs, hold-up time is indefinite, usually long.

- **Application of PLC**

1. Application of PLC in Glass Industry

From the year 1980 the Programmable-logic controllers are in use in the glass industry, and they are assembled bit by bit. PLCs are used mainly in every procedure and workshop for controlling the material ratio, processing of flat glasses, etc.

2. Applications of PLC in Cement Industry

Along with the best-quality raw materials, the accurate data regarding process variables, especially during mixing processes within the kiln, ensures that the output provided should be of the best possible quality.

3. Production machine
   Controls and monitor automatic production machines like – packaging machines at high efficiency rates.

4. Conveyor System

   Control all sequential operations, alarms and safety logics

5. IC Engine Monitoring

   Acquires and analysis the data recorded from the sensor located at the internet combustion engine.

6. Paint Spraying

   Control the printing sequence in auto manufacturing.

7. Loading and unloading of alloy

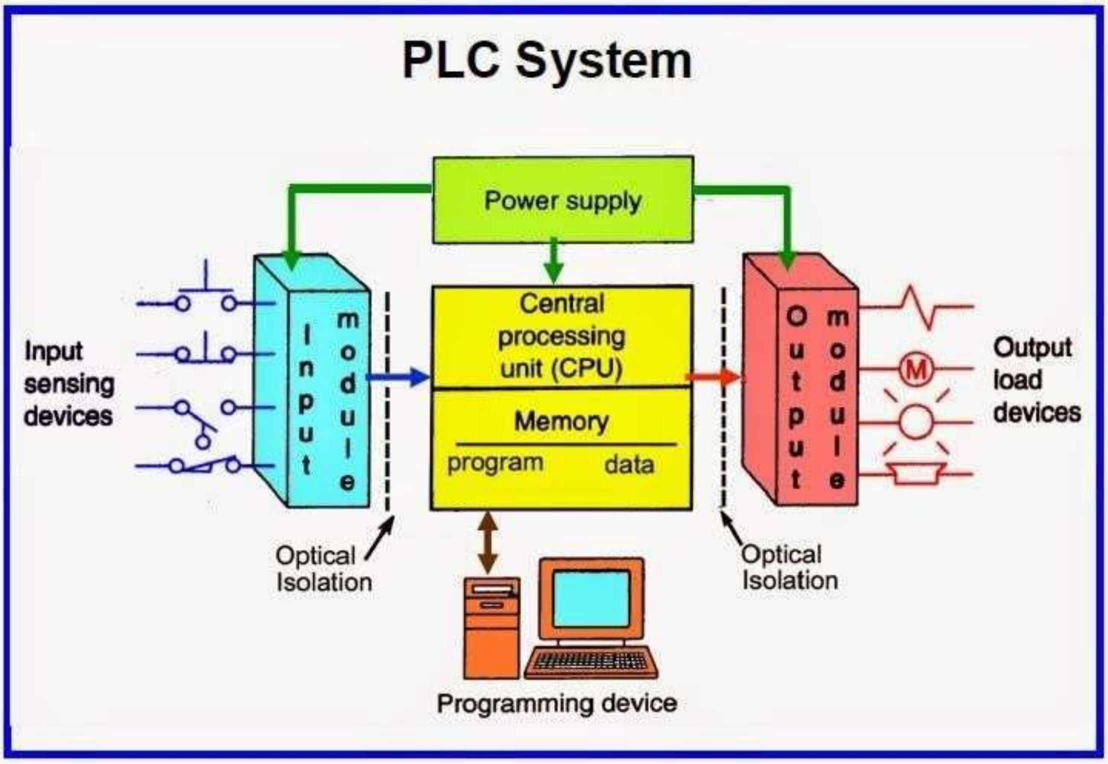
   Control and Monitors the quantity of coil, iron core and limestone to be melted.

8. Power plant system

   Monitor and control burning rates, temperature generated sequencing of valves and analog controller jet valves.

- **Basic Operation of PLC**

  A PLC is a centralised digital computer used for automation of electromechanical process.



The basic parts of PLC architecture are:

1. **Input module**
2. **Output scan**
3. **CPU (Central Processing Unit)**
4. **Memory**
5. **Power supply**
6. **Monitoring**
7. **Display**
8. **Rachas or chasis**

Input Module: Input devices, such as switches, can be manipulated to give the open and closed contact conditions and the corresponding LED on the input module observed. It should be illuminated when the input is closed and not illuminated when it is open. Failure of an LED to illuminate could be because the input device is not correctly operating, there are incorrect wiring connections to the input module, the input device is not correctly powered, or the LED or input module is defective. For output devices that can be safely started, push buttons might have been installed so that each output could be tested.

Output Module: Output modules convert control signals from the CPU into digital or analog values that can be used to control various **output** devices. The programming device is used to enter or change the **PLCs** program or to monitor or change stored values.

CPU: The processor unit or central processing unit (CPU) is the unit containing the microprocessor. This unit interprets the input signals and carries out the control actions according to the program stored in its memory, communicating the decisions as action signals to the outputs.

Memory: The memory unit is where the program containing the control actions to be exercised by the microprocessor is stored and where the data is stored from the input for processing and for the output.

Two types of memory

1. **Program memory (user memory)**
2. **Storage memory (data memory)**

Power supply: The power supply unit is needed to convert the mains AC voltage to the low DC voltage (5 V) necessary for the processor and the circuits in the input and output interface modules

PLC Operation:

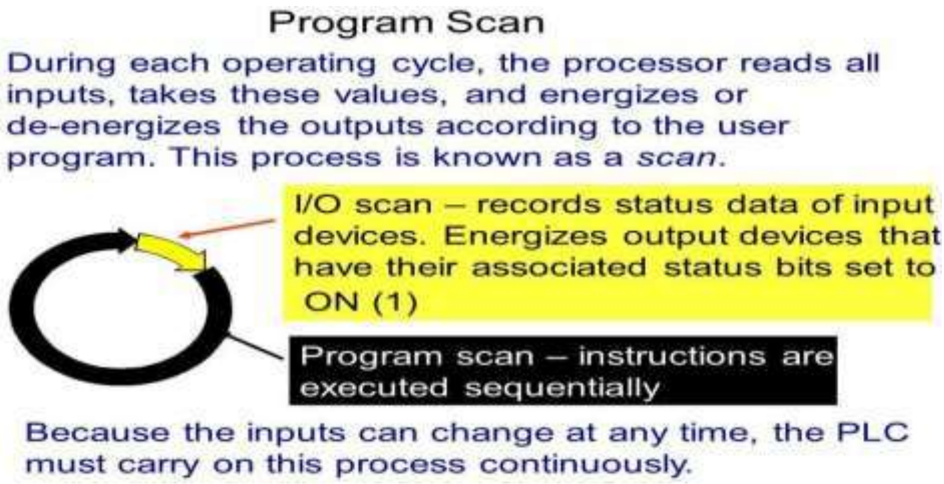
When the PLC id power On , the processor checks for memory , input output device before the actual start of execution of user program . During PLC operation CPU read the input status, execute the user ladder program stored in system memory and output the data to output device and repeat the same program again and again. This processing technique is called PLC scanning.

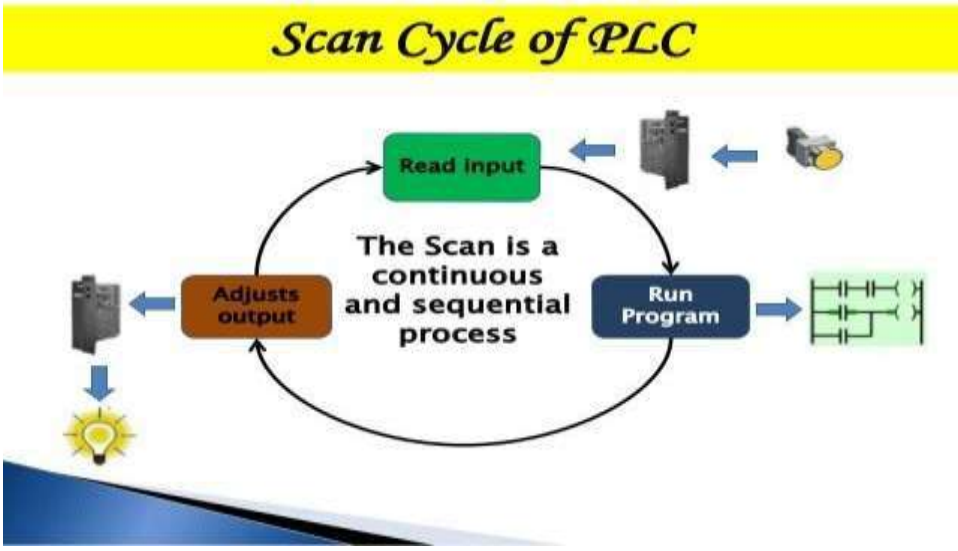
PLC scanning operation is divided into three parts :

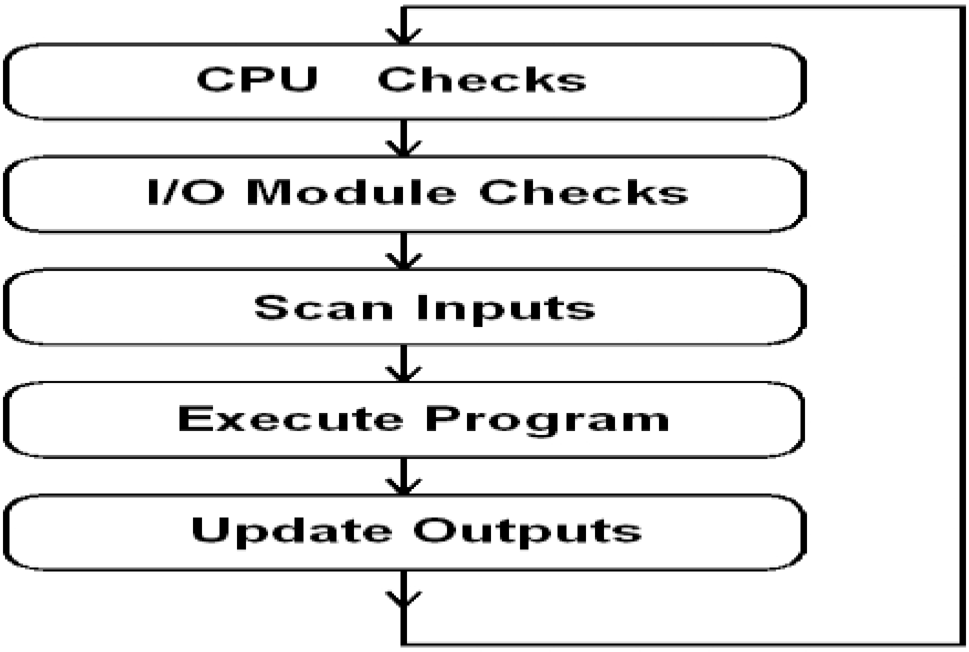
A) Input scan

B) Output scan

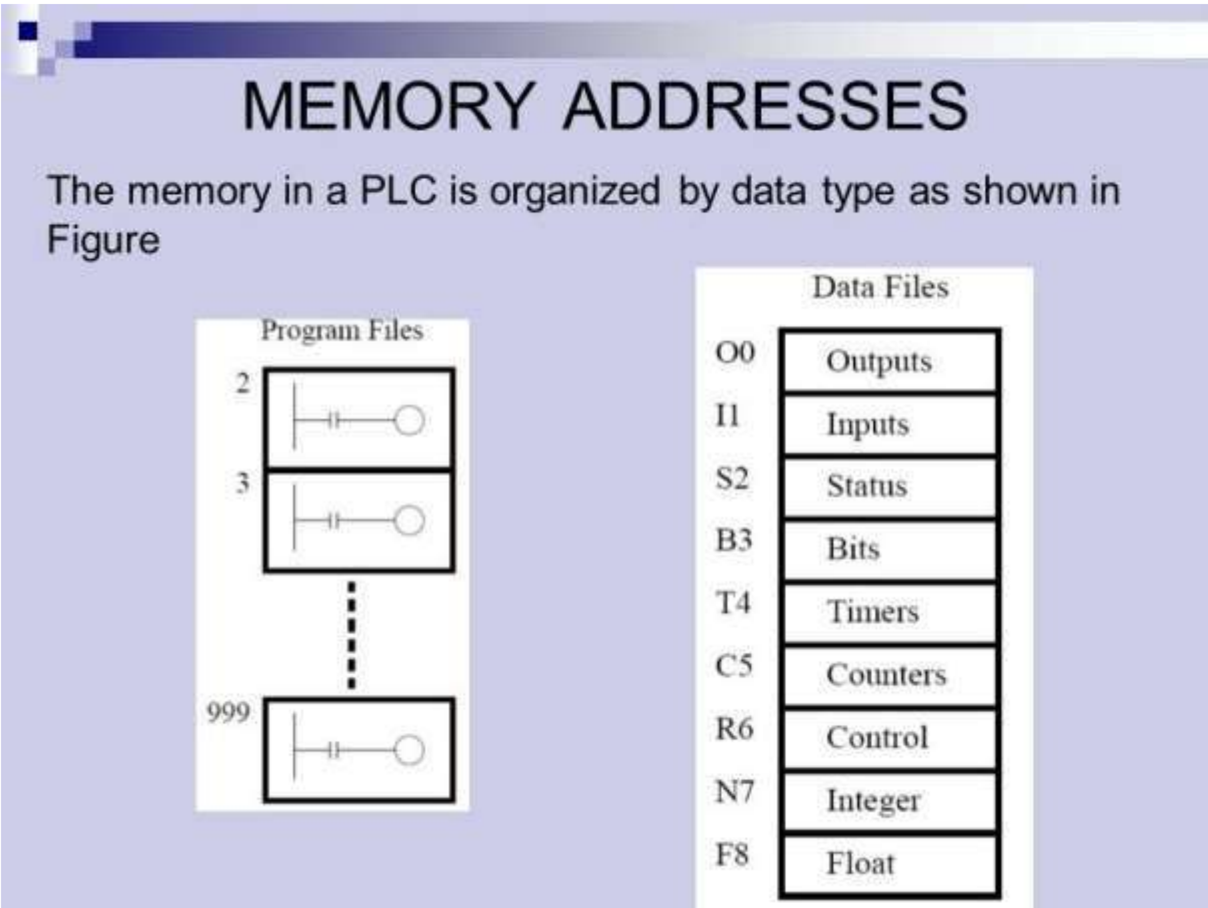
c) Program scan







- **Data File memory**



Output image status bit: This file store the status of discrete output terminals .during program scan, this data is updated and at the end of program scan, It is transferred to real world outputs.

Input Image status file: This file store the status of input terminal of the controller.

Status file: This file is store controller operation status**, error** codes, arithmetic status bits etc. this file is useful for troubleshooting controller and program operation.

Bit file: This file is used for internal relay logic storage.

Timer File: This file stores the timer status bits, present value and accumulated value of each timer .Each timer uses three word memory.

Counter file: This file is stores the counter status bit, preset value and accumulated value of each counter. Each counter uses three word memory.

Control file: This file stores the length, pointer, position and status bits for instruction such as shift register and sequencer.

Integer data file: This file stores numeric value or bit information.

Floating point file : Some PLC can also uses floating point values .This file is used to solve numeric values in floating point notation.

User defined file: This memory area can be used by a user for any of the above types of file. Some PLC can work with string data values which are also defined in this area.

- **Input/output Modules :**

The input output modules works as an interface between the processor and the real world devices like a switches, lamps, Contractor etc. attached to the PLC.

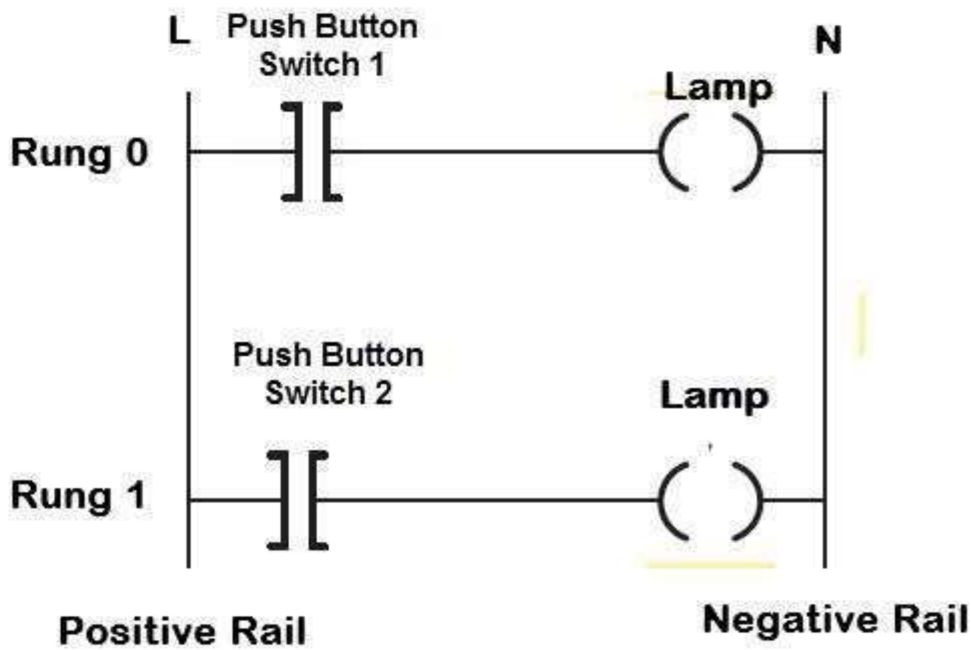
The input output, modules can be divided into three categories:

1. Discrete input /output modules
2. Analog input/output modules
3. Register modules

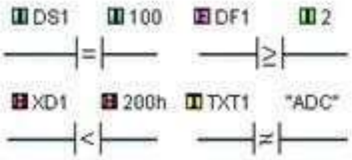
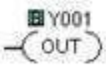
- **Sourcing and sinking input output**

The terms sourcing and sinking are used to describe the way in which DC devices are connected to a PLC. With sourcing, using the conventional current flow direction as from positive to negative, an input device receives current from the input module, that is, the input module is the source of the current. With sinking, using the conventional current flow direction, an input device supplies current to the input module, that is, the input module is the sink for the current. If the current flows from the output module to an output load, the output module is referred to as sourcing .If the current flows to the output module from an output load, the output module is referred to as sinking.

- **Ladder diagram:** Ladder logic diagram are normally use in PLC to write program instruction ladder languages uses input and output symbols and is a graphic base language. The ladder diagram represents program steps using Input and Output symbols like in a electrical relay diagram.

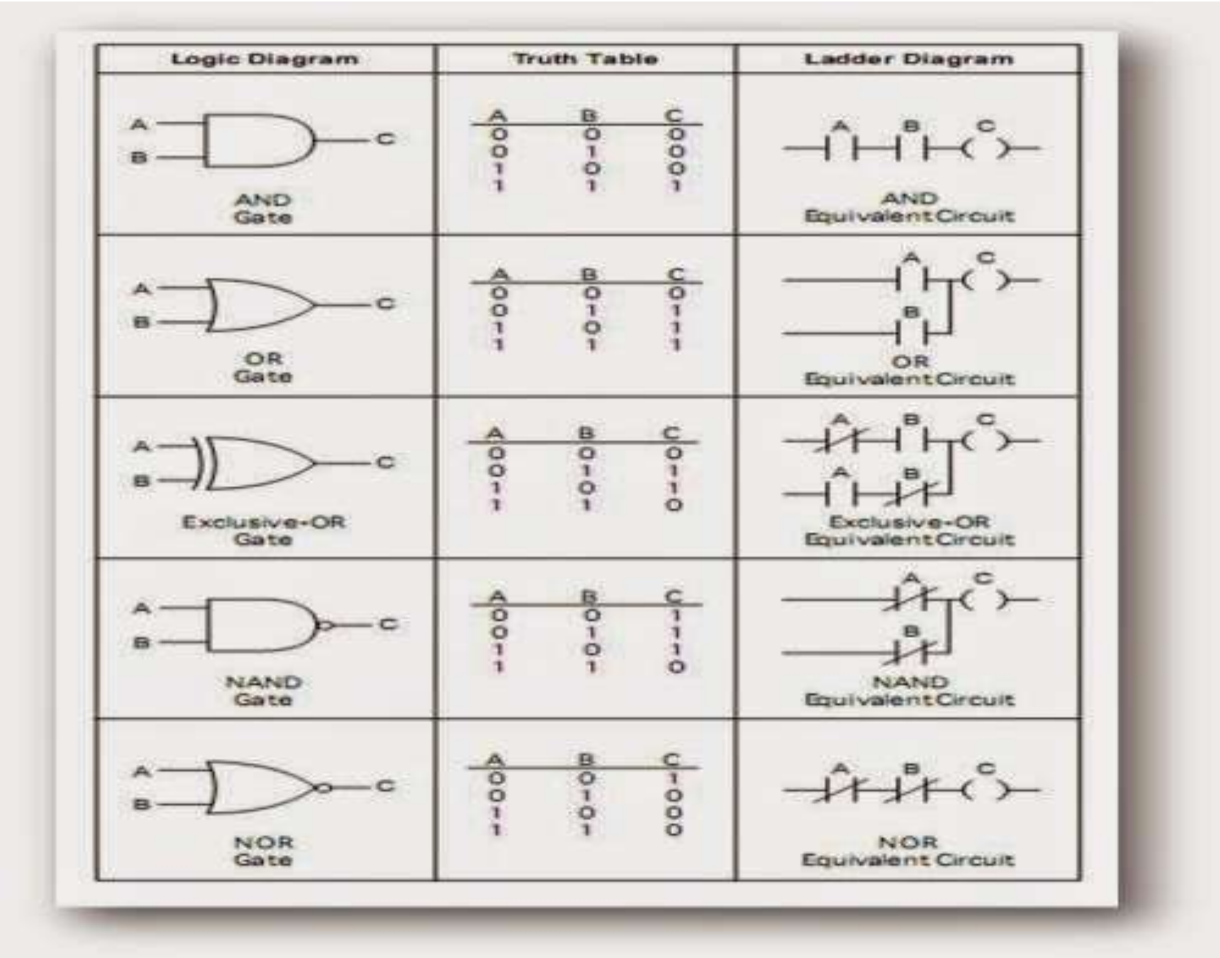


- **Bit instruction**

CLICK PLC Instruction Set			
Ladder Symbol	**Title**	**Type**	**Description**
	Normally Open Contact	Bit Instruction	The Normally Open Contact mimics the behavior of a physical contact and changes in response to the status of a Bit Memory Address. The Normally Open Contact is ON when the related bit is ON.
	Normally Closed Contact	Bit Instruction	The Normally Closed Contact mimics the behavior of a physical contact and changes in response to the status of a Bit Memory Address. The Normally Closed Contact is ON when the related bit is OFF.
	Edge Contact	Bit Instruction	The Edge Contact turns ON when the related bit transitions from OFF to ON (Rising Edge) or ON to OFF (Falling Edge).
	Compare Contact	Word Instruction	The Compare instruction uses a Mathematical Operator as a basis for comparison of two data values. When the data values satisfy the selected mathematical relationship (>, <, =, etc.) the Compare Contact turns ON.
	Out Coil	Bit Instruction	An Out instruction turns ON its associated Bit Memory when the status of the rung is true. The Out instruction turns OFF its associated Bit Memory when the status of the rung is false.
	Set Coil	Bit Instruction	The Set instruction turns ON the associated Bit Memory when the status of the rung is true. The Bit Memory stays on after the rung becomes false.

- **Ladder diagram for Boolean Logic of input:** In process control application output condition may depend upon logic combination (AND, OR, XOR, NAND, NOR) of inputs these logic combination can be easily made in ladder diagram.

AND Combination: The ‘AND’ command is used to perform the logic and instruction on each bit of the value in source A with each bit of the value of source B, storing the output logic in the destination.



OR Combination: For logical ‘OR’ combination of two or more inputs are put in parallel to each other. The rung condition will be TRUE if any one of the input is true if the inputs are false then only the rung condition will be false.

NOR Combination: For logical ‘NOR’ combination, normally closed contacts of inputs are put in series. The rung condition will be TRUE only if all the input is true are FALSE (0). If any of the inputs are TRUE, then only the rung condition will be FALSE.

Timer: PLC timers are instructions that provide the same functions as on-delay and off-delay mechanical and electronic timing relays. A PLC timer provides a preset delay to the control actions.

	D15	D14	D13	D7
Word 0	EN	TT	DN	INTERNAL USE
Word 1	PRESET VALUE (PRE)			
Word 2	ACCUMULATED VALUE			

Timer Address Format

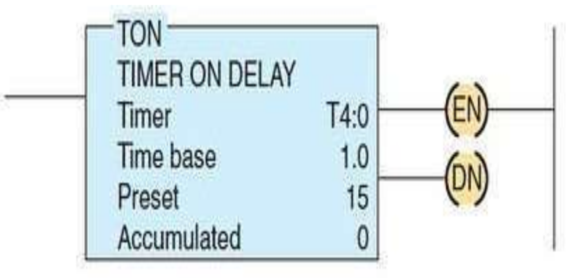
In general, there are three types of PLC timer delays, ON-delay timer, OFF-delay timer and retentive timer on.

The terms represented in the timer block in the PLC are a Preset value which means the delay period of the timer, an Accumulated value which is the current delay of the timer.

A timer begins the counting on time-based intervals and continues until the accumulated value equals the preset value. When the accumulated value equals the preset time the output will be energized. Then the timer sets the output.

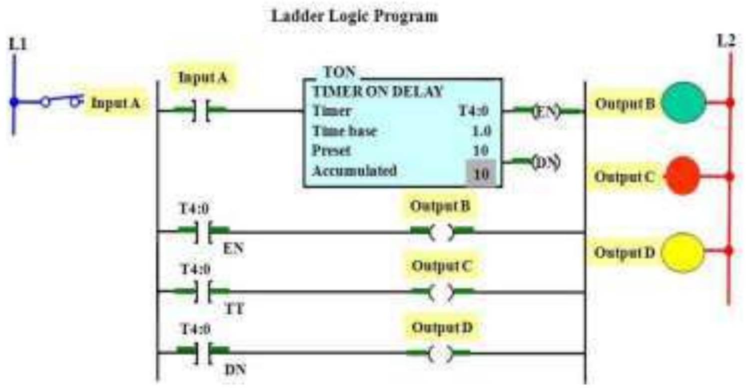
TON timer or ON delay timer

An ON delay timer is used where we need a time delay before the time delay before an instruction becomes true.



TON Instruction Symbol

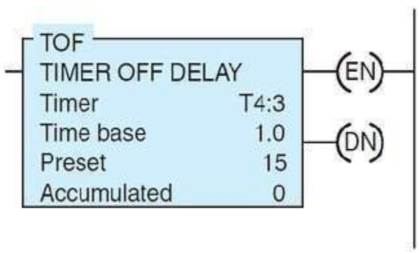
On-Delay Timer Program



- The timer starts operating when the rung condition becomes true. The timer delay starts counting when the rung condition starts to accumulate.
- When the Preset value becomes equal to the accumulated value, the output is made true.
- The timed output becomes true sometime after the timer rung becomes true; hence, the timer is said to have an on-delay.
- The length of the delay can be adjusted by setting the preset value.

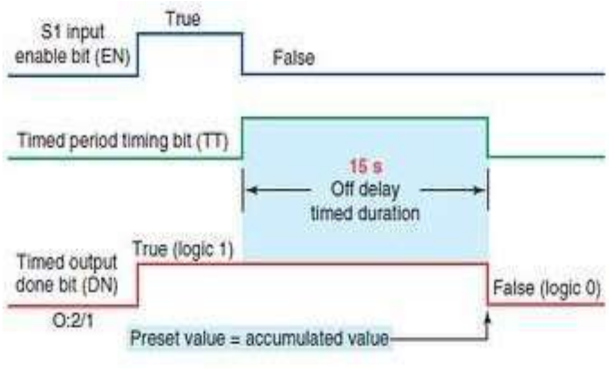
TOFF Timer or OFF delay timer:

A TOFF timer will keep the output energized for a preset time after the rung signal has gone false.



TOF Instruction Symbol

The TOFF timer will have all the contents as in the TON timer, with the similar function.



OFF delay timer

When the rung timer is true, the output will be true without any delay. When the rung signal becomes false the timer starts operating.

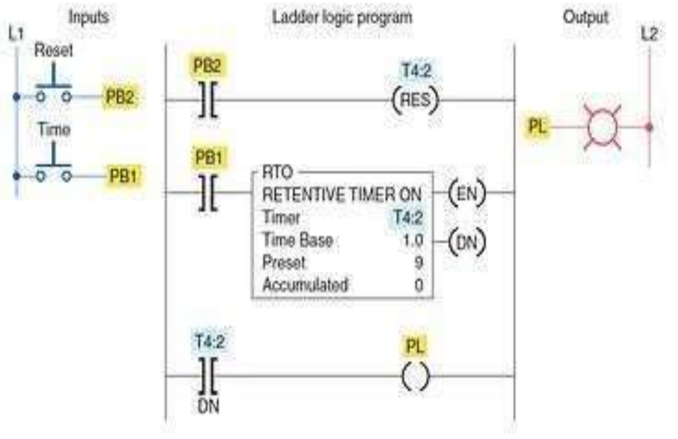
- The timer starts accumulating times when the rung condition becomes true, until the accumulated value becomes equal to the Preset value.
- The output turns off when the output will turn false when the accumulated value equals the preset value.

Retentive timer:

A retentive timer is used when you want to retain accumulated time value through the power loss or the change in the rung state.

A retentive timer accumulates time whenever the device receives power, and it maintains the current time should power be removed from the device

Loss of power to the timer after reaching its preset value does not affect the state of the contacts. The retentive timer must be intentionally reset with a separate signal for the accumulated time to be reset



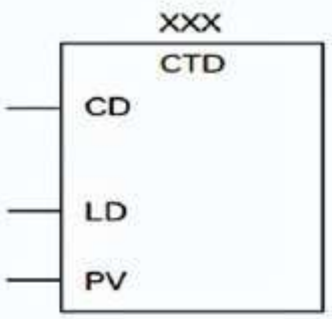
Counter: Counters are PLC instruction that either increment or decrement or decrement the integer value when the input line make True from False. The counter which increment value is known as Up counters and Down counters decrement the integer values on a trigger. Both the Up and Down counter starts counting on one trigger.

The Up-Down counter has two input triggers one for Up counting and other for Down counting.

	D15	D14	D13	D12	D11	D7
Word 0	EN	TT	DN	OV	UN	INTERNAL USE
Word 1	PRESET VALUE (PRE)					
Word 2	ACCUMULATED VALUE					

Counter Address Format

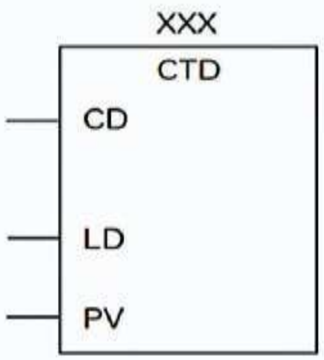
Up counter:



Up counter counts a value from the current value when a signal arrives at the input CU. R is the reset input and PV the preset value. The counter counts up until the count reaches the preset value.

Whenever the input CU value changes from 0 to 1 the counter increment 1 from the preset value. When the input value reaches the preset value the output turns ON. The counter preset value is user defined.

Down counter:



Each time the input CD turns ON the counter decrement one from the preset value. Whenever LD (load) input becomes high then the preset value is reloaded to the counter from the current value.

Whenever the input CD value changes from 0 to 1 the counter decrement 1 from the preset value.

Up/Down counter:

The Up/Down Counter work as both the up counter and the down counter. The up/down counter has input for both the Up counter and Down counter operation CU and CD. And has both the inputs R and LD also.zero and LD load the load the pressed value to the counter ignoring the current counter value.

The two input value has two corresponding output lines for CD and CU.

DCS (Distributed Control System) :

In recent years, the use of smart devices and field buses makes **distributed control system (DCS)** to be prominent in large and complex industrial processes as compared to the former centralized control system. This distribution of control system architecture around the plant has led to produce more efficient ways to improve reliability of control, process quality and plant efficiency.Nowadays, distributed control system has been found in many industrial fields such as chemical plants, oil and gas industries, food processing units, nuclear power plants, water management systems, automobile industries, etc

A ***distributed control system (DCS)*** is a specially designed automated control system that consists of geographically distributed control elements over the plant or control area.
It differs from the centralized control system wherein a single controller at central location handles the control function, but in DCS each process element or machine or group of machines is controlled by a dedicated controller. DCS consists of a large number of local controllers in various sections of plant control area and are connected via a high speed communication network.

In DCS control system, data acquisition and control functions are carried through a number of DCS controllers which are microprocessor based units distributed functionally and geographically over the plant and are situated near area where control or data gathering functions being performed as shown in the figure above. These controllers able to communicate among themselves and also with other controllers like supervisory terminals, operator terminals, historians, etc.

Distributed individual automatic controllers are connected to field devices such as sensors and actuators. These controllers ensure the sharing of gathered data to other hierarchal controllers via different field buses. Different field buses or standard communication protocols are used for establishing the communication between the controllers. Some of these include Profibus, HART, arc net, Modbus, etc.

DCS is most suited for large-scale processing or manufacturing plants wherein a large number of continuous control loops are to be monitored and controlled. The main advantage of dividing control tasks for distributed controllers is that if any part of DCS fails, the plant can continue to operate irrespective of failed section.

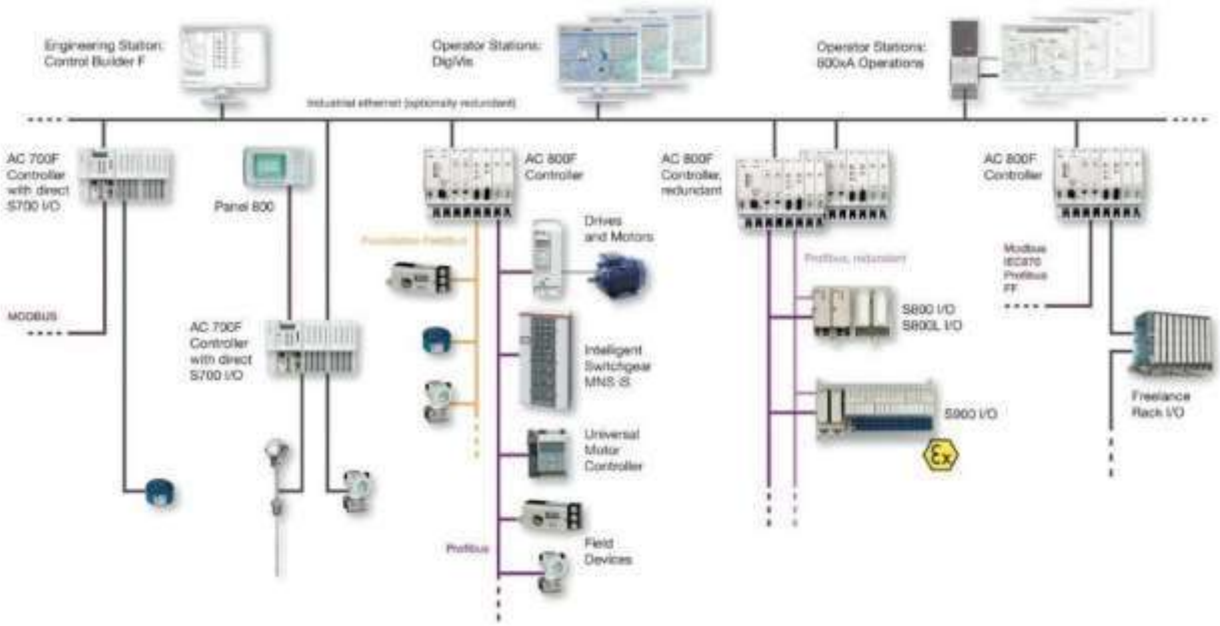
You may also read: What Exactly Is A Smart Grid?

Architecture of Distributed Control System

As the name suggests, DCS has three main qualities. The first one is the distribution of various control functions into relatively small sets of subsystems, which are of semiautonomous, and are interconnected through a high speed communication bus. Some of these functions include data acquisition, data presentation, process control, process supervision, reporting information, storing and retrieval of information.

The second attribute of DCS is the automation of manufacturing process by integrating advanced control strategies. And the third characteristic is the arranging the things as a system. DCS organizes the entire control structure as a single automation system where various subsystems are unified through a proper command structure and information flow.

- These attributes of DCS can be observed in its architecture shown in the diagram below. The basic elements comprised in a DCS include engineering workstation, operating station or HMI, process control unit or local control unit, smart devices, and communication system.

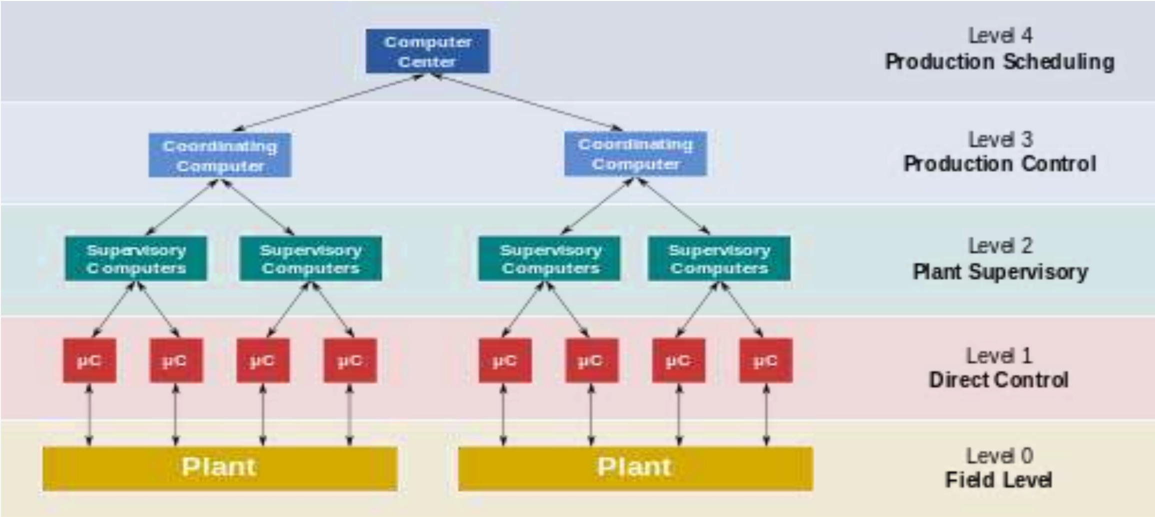


- **DDC (Direct Digital Control):** DDC takes a centralized network-oriented approach. All instrumentation is gathered by various analog and digital converters which use the network to transport these signals to the central controller. The centralized computer then follows all of its production rules (which may incorporate sense points anywhere in the structure) and causes actions to be sent via the same network to valves, actuators, and other HVAC components that can be adjusted.

- **SCADA (Supervisory control and Data Acquisition): Supervisory control and data acquisition** (**SCADA**) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as programmable logic controllers and discrete PID controllers to interface to the process plant or machinery. The operator interfaces which enable monitoring and the issuing of process commands, such as controller set point changes, are handled through the SCADA computer system. However, the real-time control logic or controller calculations are performed by networked modules which connect to the field sensors and actuators.

The SCADA concept was developed as a universal means of remote access to a variety of local control modules, which could be from different manufacturers allowing access through standard automation protocols. In practice, large SCADA systems have grown to become very similar to distributed control systems in function, but using multiple means of interfacing with the plant. They can control large-scale processes that can include multiple sites, and work over large distances as well as small distance.[1] It is one of the most commonly-used types of industrial control systems; however there are concerns about SCADA systems being vulnerable to cyberwarfare/cyberterrorism attacks.

The SCADA concept in control operations.



Functional levels of a manufacturing control operation

The key attribute of a SCADA system is its ability to perform a supervisory operation over a variety of other proprietary devices.

The accompanying diagram is a general model which shows functional manufacturing levels using computerised control.

Referring to the diagram,

- Level 0 contains the field devices such as flow and temperature sensors, and final control elements, such as control valves.
- Level 1 contains the industrialised input/output (I/O) modules, and their associated distributed electronic processors.
- Level 2 contains the supervisory computers, which collate information from processor nodes on the system, and provide the operator control screens.
- Level 3 is the production control level, which does not directly control the process, but is concerned with monitoring production and targets.
- Level 4 is the production scheduling level.

Level 1 contains the programmable logic controllers (PLCs) or remote terminal units (RTUs).

Level 2 contains the SCADA software and computing platform. The SCADA software exists only at this supervisory level as control actions are performed automatically by RTUs or PLCs. SCADA control functions are usually restricted to basic overriding or supervisory level intervention. For example, a PLC may control the flow of cooling water through part of an industrial process to a set point level, but the SCADA system software will allow operators to change the set points for the flow. The SCADA also enables alarm conditions, such as loss of flow or high temperature, to be displayed and recorded. A feedback control loop is directly controlled by the RTU or PLC, but the SCADA software monitors the overall performance of the loop.

Levels 3 and 4 are not strictly process control in the traditional sense, but are where production control and scheduling takes place.

Data acquisition begins at the RTU or PLC level and includes instrumentation readings and equipment status reports that are communicated to level 2 SCADA as required. Data is then compiled and formatted in such a way that a control room operator using the HMI (Human Machine Interface) can make supervisory decisions to adjust or override normal RTU (PLC) controls. Data may also be fed to a historian, often built on a commodity database management system, to allow trending and other analytical auditing.

SCADA systems typically use a *tag database*, which contains data elements called *tags* or *points*, which relate to specific instrumentation or actuators within the process system according to such as the Piping and instrumentation diagram. Data is accumulated against these unique process control equipment tag references.

Examples of use

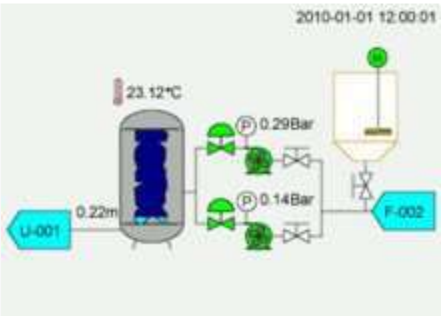
Example of SCADA used in office environment to remotely monitor a process

Both large and small systems can be built using the SCADA concept.
These systems can range from just tens to thousands of control loops, depending on the application. Example processes include industrial, infrastructure, and facility-based processes, as described below:

- Industrial processes include manufacturing, Process control, power generation, fabrication, and refining, and may run in continuous, batch, repetitive, or discrete modes.
- Infrastructure processes may be public or private, and include water treatment and distribution, wastewater collection and treatment, oil and gas pipelines, electric power transmission and distribution, and wind farms.
- Facility processes, including buildings, airports, ships, and space stations. They monitor and control heating, ventilation, and air conditioning systems (HVAC), access, and energy consumption.

However, SCADA systems may have security vulnerabilities, so the systems should be evaluated to identify risks and solutions implemented to mitigate those risks.

SCADA system components



Typical SCADA mimic shown as an animation. For process plant, these are based upon the piping and instrumentation diagram.

A SCADA system usually consists of the following main elements:

Supervisory computers

This is the core of the SCADA system, gathering data on the process and sending control commands to the field connected devices. It refers to the computer and software responsible for communicating with the field connection controllers, which are RTUs and PLCs, and includes the HMI software running on operator workstations. In smaller SCADA systems, the supervisory computer may be composed of a single PC, in which case the HMI is a part of this computer. In larger SCADA systems, the master station may include several HMIs hosted on client computers, multiple servers for data acquisition, distributed software applications, and disaster recovery sites. To increase the integrity of the system the multiple servers will often be configured in a dual-redundant or hot-standby formation providing continuous control and monitoring in the event of a server malfunction or breakdown.

Differentiate between SCADA and DCS

	SCADA	DCS
1.	It is Supervisory Control and Data Acquisition.	It is Distributed Control System.
2.	SCADA is most used for wide area eg. 10 Km and more.	DCS is used for specific wide area within a specific boundary.
3.	SCADA is preferred for applications that are spread such a wide geographic location.	DCS is used to handle operations on a single location.
4.	SCADA is used to control very big plant.	DCS is used to control and monitor small no. of equipment's in a field.
5.	SCADA have more than one DB(Data Base)	DCS have almost one DB(Data Base)
6.	SCADA is expected to separate despite failure of field communications.	DCS operation stations are always connected to its I/O.
7.	SCADA was more for data gathering.	DCS was more for controlled processes
8.	SCADA generally supports storing of data base.	DCS does not support data base.
9.	SCADA is not confined in a factory or industrial.	DCS is more confined in a factory or industrial.
10.	SCADA system is more flexible.	DCS system integrated.

POWER-1

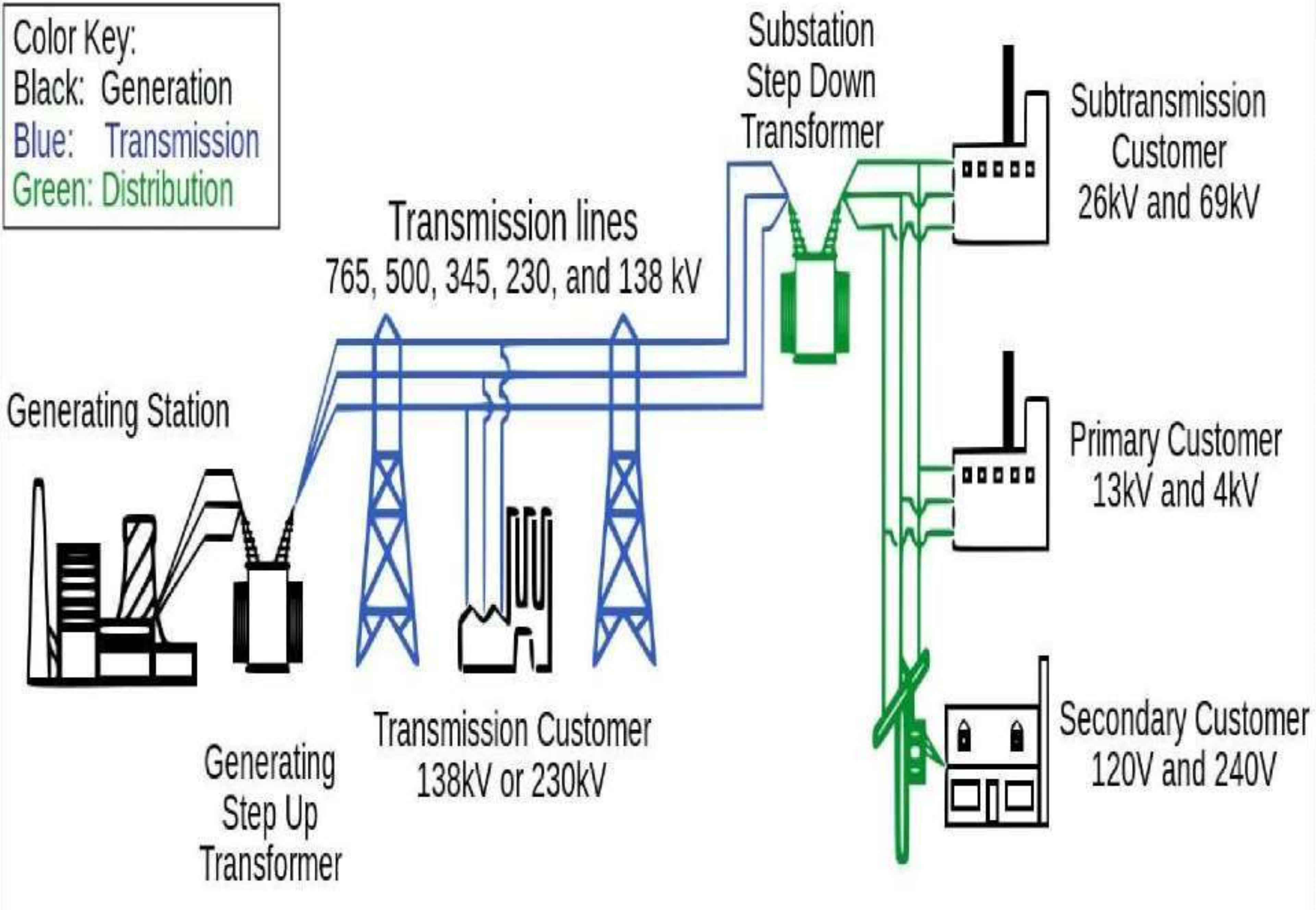
5th Semester

Electrical Engg.

Power System

An **electric power system** is a network of electrical components deployed to Generate, Transmission, and Distribution of **Electric power**.

An example of an **Electric power system** is the **grid** that provides **power** to an extended area


Color Key:
Black: Generation
Blue: Transmission
Green: Distribution
Substation
Step Down
Transformer
Subtransmission
Customer
26kV and 69kV
Transmission lines
765, 500, 345, 230, and 138 kV
Generating Station
Primary Customer
13kV and 4kV
Secondary Customer
120V and 240V
Transmission Customer
138kV or 230kV
Generating
Step Up
Transformer

Sorces of Energy

- Renewable Energy and Non Renewable Energy Sources
- Renewable energy is derived from natural processes that are replenished constantly such as solar, wind, ocean, hydropower, biomass, geothermal resources, and Biofuels and hydrogen.

Non Renewable Energy

- Coal, Oil and Natural gas are the non-renewable sources of energy.
- They are also called fossil fuels as they are products of plants that lived thousands of years ago.
- Fossil fuels are the predominantly used energy sources today.
- India is the third largest producer of coal in the world, with estimated reserves of around 315,148.81 million tonnes of Geological Resources of Coal (as of 1.4.2017).

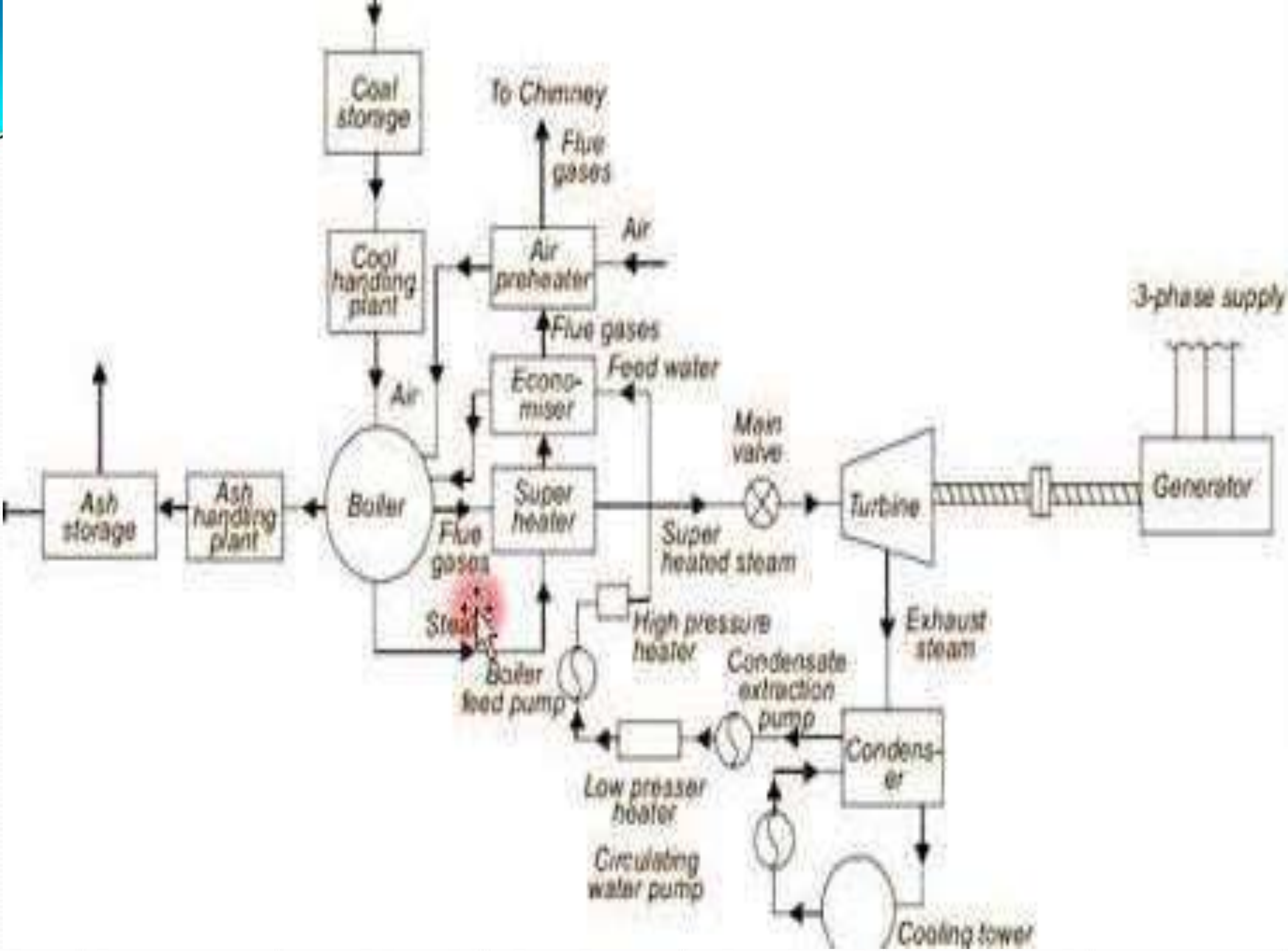
- Coal supplies more than 58% of the country's total primary energy requirements. India consumes about 210 MT of crude oil annually, and more than 70% of it is imported. Burning fossil fuels cause great amount of environmental pollution.

Power Plants

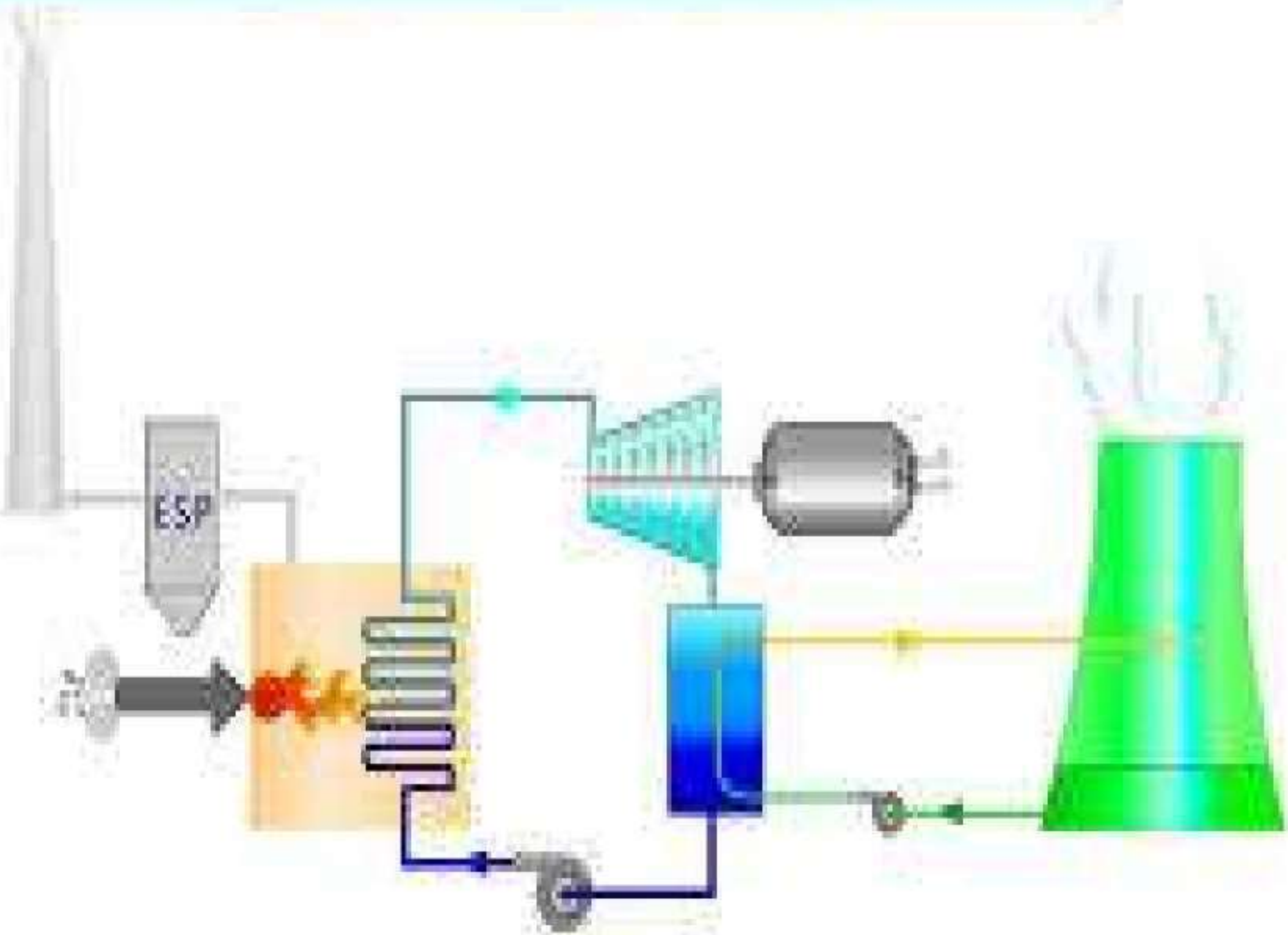
- A power station, also referred to as a power plant or powerhouse and sometimes generating station or generating plant, is an industrial facility for the generation of electric power.
- Most power stations has one or more generators, a rotating machine that converts mechanical power into electrical power.

Thermal Power Plant

- A thermal power station is a power station in which heat energy is converted to electric power.
- In most of the places in the world the turbine is steam-driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator.


Coal storage
To Chimney
Flue gases
Air
Coal handling plant
Air preheater
3-phase supply
Flue gases
Feed water
Air
Econo-miser
Main valve
Ash storage
Ash handling plant
Boiler
Super heater
Turbine
Generator
Flue gases
Super heated steam
Exhaust steam
High pressure heater
Boiler feed pump
Condensate extraction pump
Condens-er
Low presser heater
Circulating water pump
Cooling tower

THERMAL POWER PLANT



Selection of Thermal Power Plant

- **Availability of coal:**

  A thermal plant of 400M, capacity requires nearly 6000 tons of coal every day. Power plant should be located near coal mines.

- **Ash Disposal Facilities:**

Ash comes out in hot condition and handling is difficult.

The ash can be disposed into sea or river.

-

- **Water Availability :**
- Water consumption is more as feed water into boiler, condenser and for ash disposal.
- Water is required for drinking purpose.
- Hence plant should be located near water source.

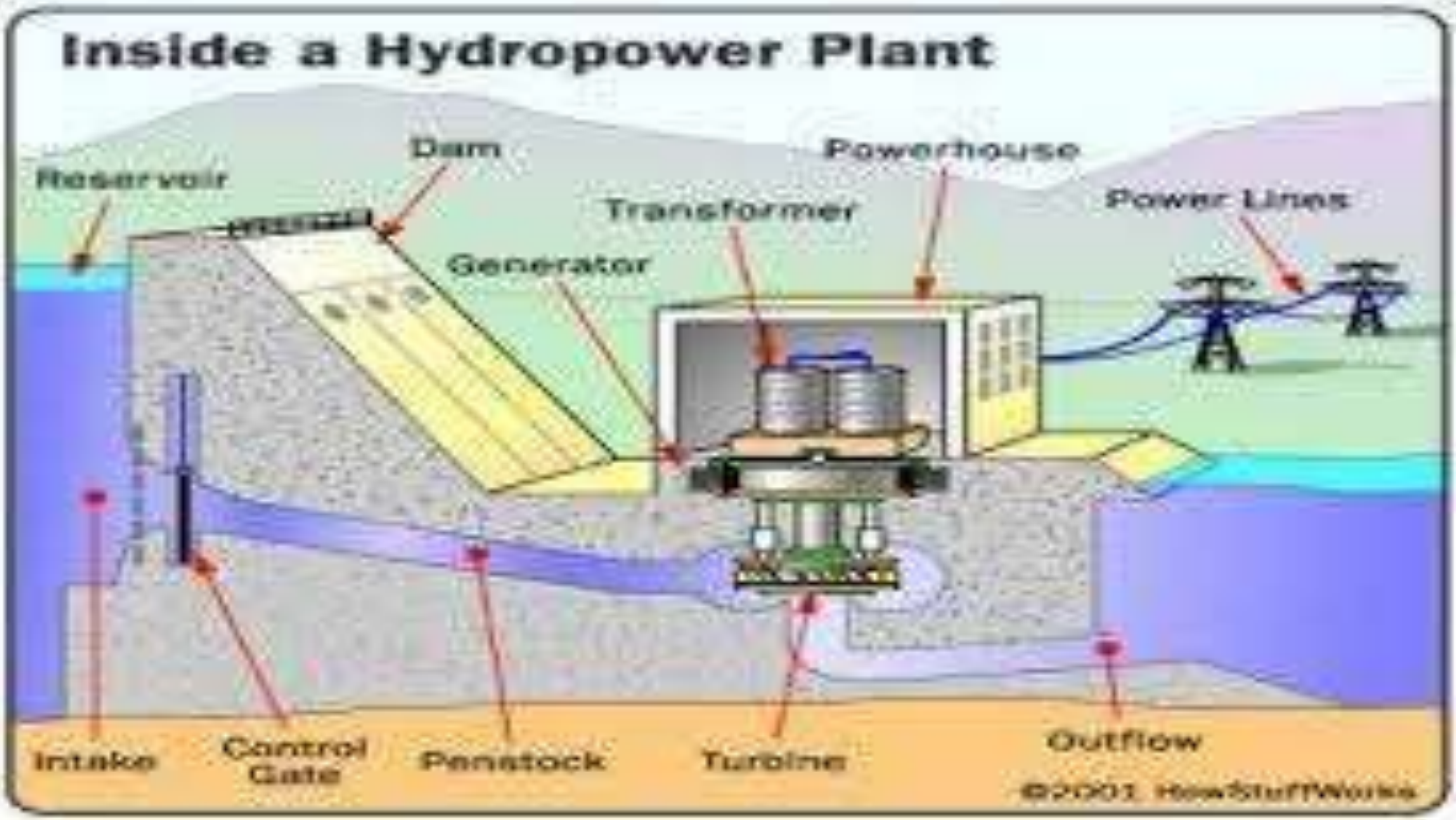
- **Transport Facility :**
- **Public Problems:**
- The plant should be far away from residential area to avoid nuisance from smoke, fly ash and noise.

- **Nature of Land :**
- Many power plants have failed due to weak foundations.
- Land (soil) should have good bearing capacity to withstand dead load of plant.

- **Thermal Pollution:**
- Thermal plants produce 40 million kJ of heat to the environment through condenser water and exhaust gases.
- Thermal pollution of atmosphere can be reduced using the low grade energy exhausted steam.
- **Noise Pollution:**
- The sources of noise in a power plant are turbo alternators, fans and power transformers.

Sound proofing can be done to reduce the noise.

Hydroelectric Power Plant



COMPONENTS OF HYDRO ELECTRIC POWER PLANT:

- **Reservoir :**
- Water is collected during rainy season

- It is stored in the reservoir.
- A dam is built across the river adequate water head.

- **Penstock :**
- It is a passage through which water flows from reservoir to turbine.
- **Surge Tank :**

It is installed along the penstock (between turbine and reservoir)

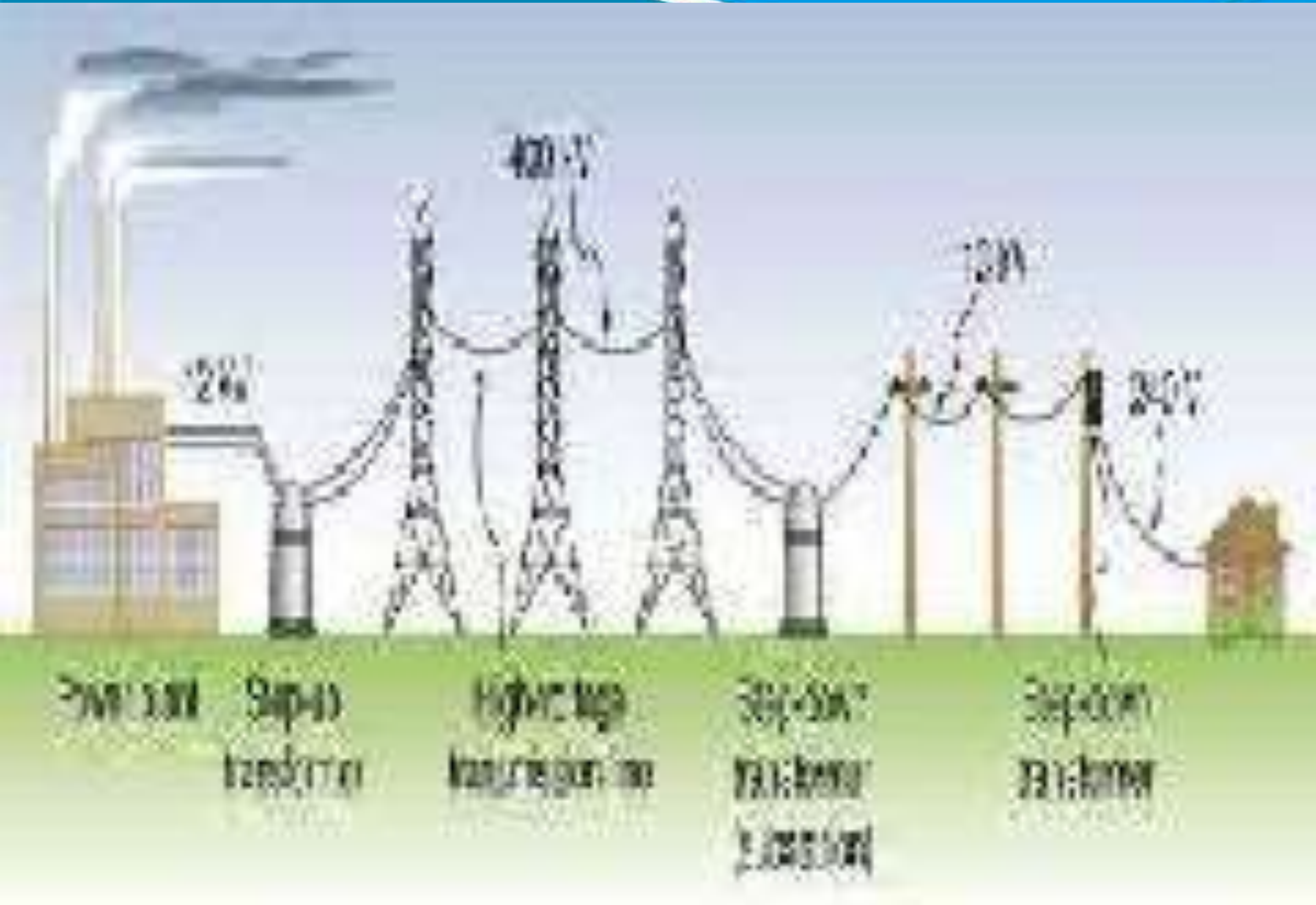
- To control or regulate the sudden water over flow and to protect the penstock from bursting.
- It reduces the pressure and avoids damage to the penstock due to the **water hammer** effect.

- **Water Turbine**:
- Water turbines such as Pelton, Kaplan and Francis are used to convert pressure and kinetic energy of flowing water into mechanical energy.
- **Draft Tube**:
- It is connected to the outlet of the turbine.
- **Tailrace:**
- It refers to the downstream level of water discharged from turbine.

- **Generator** :
- It is a machine used to convert mechanical energy into electrical energy.
- **Step up Transformer**:
- It converts the Alternating Current (AC) into high voltage current suitable for transmission

Transmission of Power

- **Power transmission** is the movement of **energy** from its place of generation to a location where it is applied to perform useful work



The main components of Line

- **The main components of high-voltage electric transmission lines and associated facilities include:**
- Line supports . Transmission towers are the most visible component of the electric transmission system.
- **Conductors** (Transmission lines)
- Insulator

Line Supports

- The **line** supports **used** for **transmissi on** and distribution of electric power are of various **types** including wooden **poles**, steel **poles**, R.C.C. **poles** and lattice steel towers.


alamy stock photo


alamy stock photo

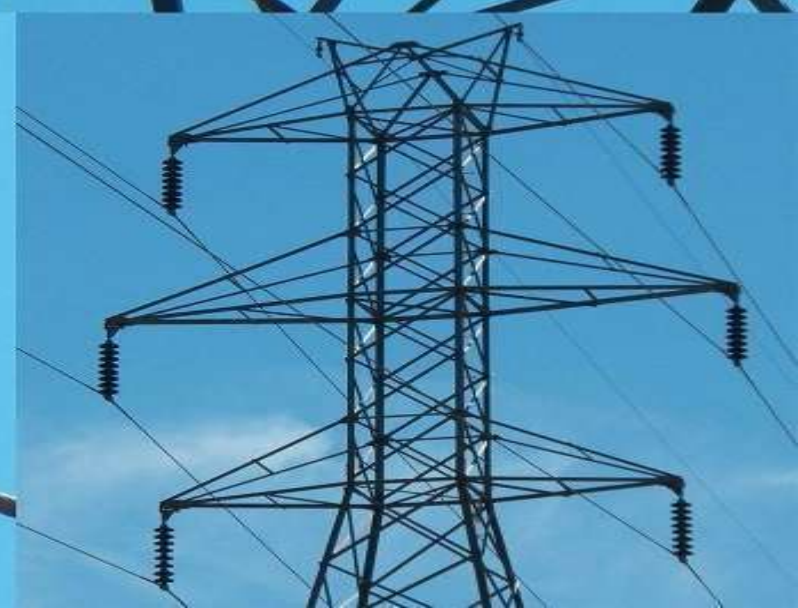
Conductor

- **There are four major types of overhead conductors used for electrical transmission and distribution.**
- AAC - All **Aluminum Conductor**.
- AAAC - All **Aluminum Alloy** Conductor.
- **ACSR - Aluminum Conductor Steel Reinforced**.
- ACAR - **Aluminum Conductor Aluminum**-Alloy Reinforced.

Insulator

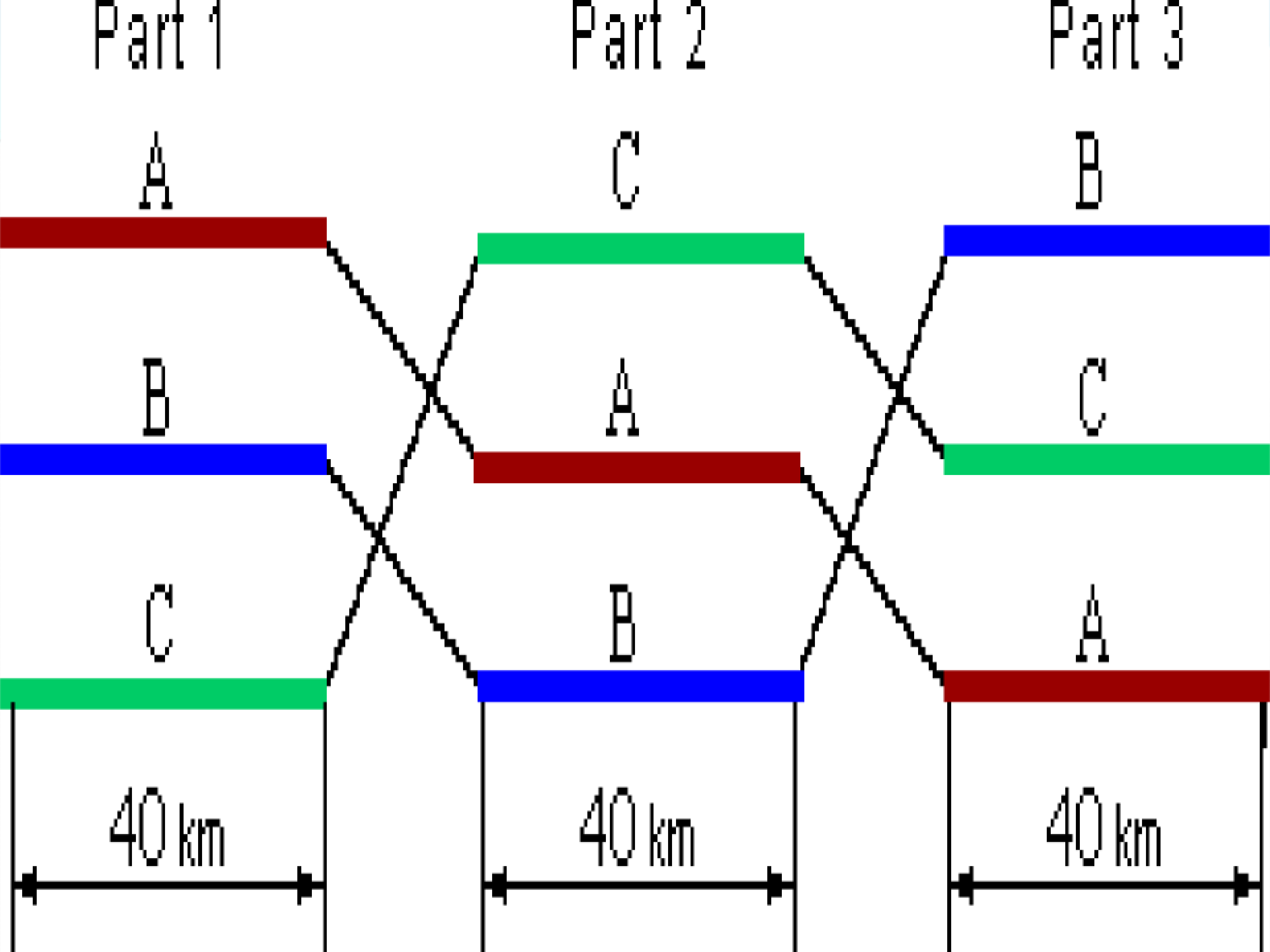
- Insulators are used for providing Mechanical Support and Electrical Isolations. Main types are:
- Pin Type
- Shackle type
- Suspension and Strain Type

Pin Insulator



Transposition

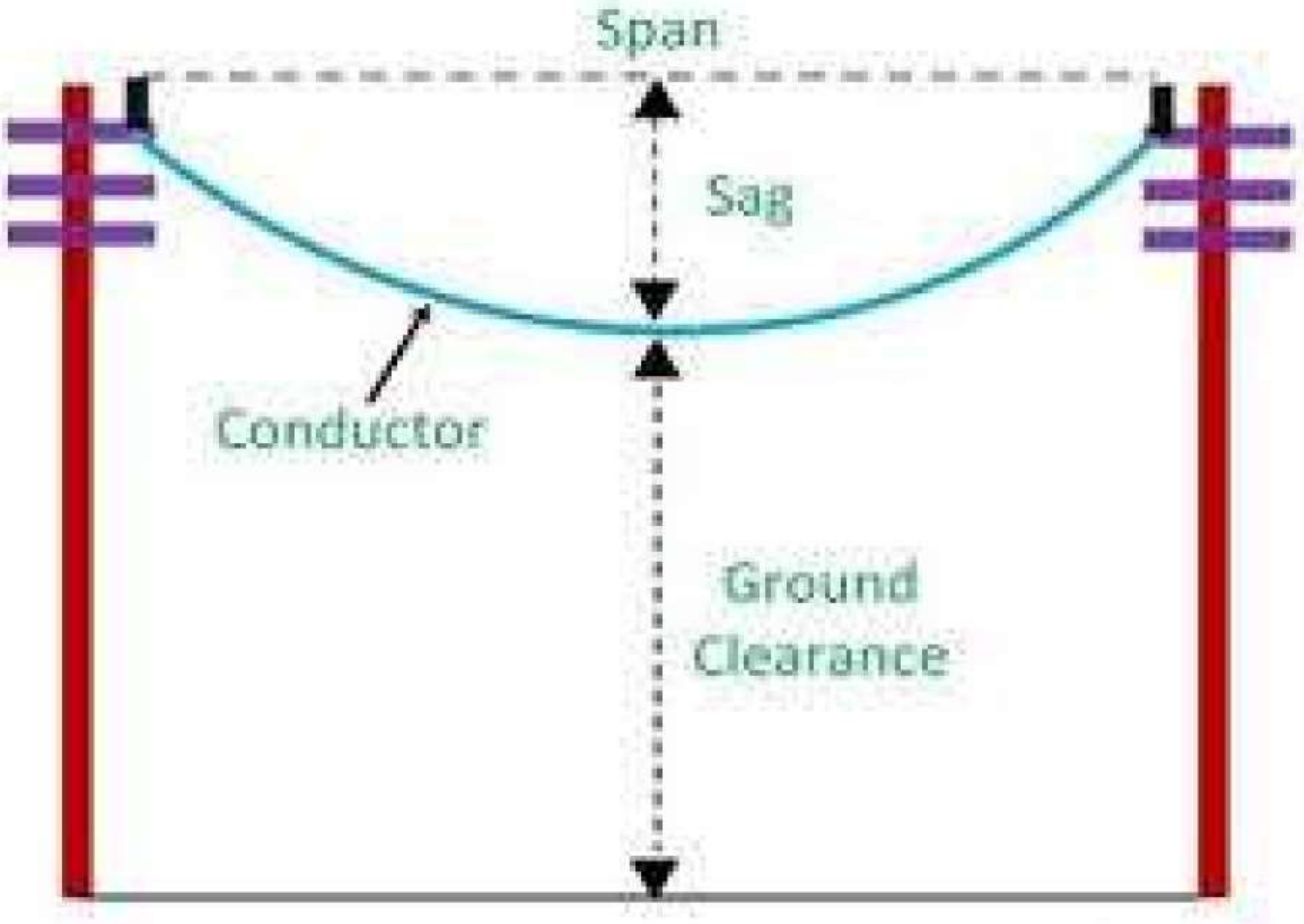
- **Transposition** is the periodic swapping of positions of the conductors of a **transmission line**, in order to reduce crosstalk and otherwise improve **transmission**.
- In telecommunications this applies to balanced pairs whilst in **power transmission lines** three conductors are periodically **transposed**.



Part 1
Part 2
Part 3
A
C
B
B
A
C
C
B
A
40 km
40 km
40 km

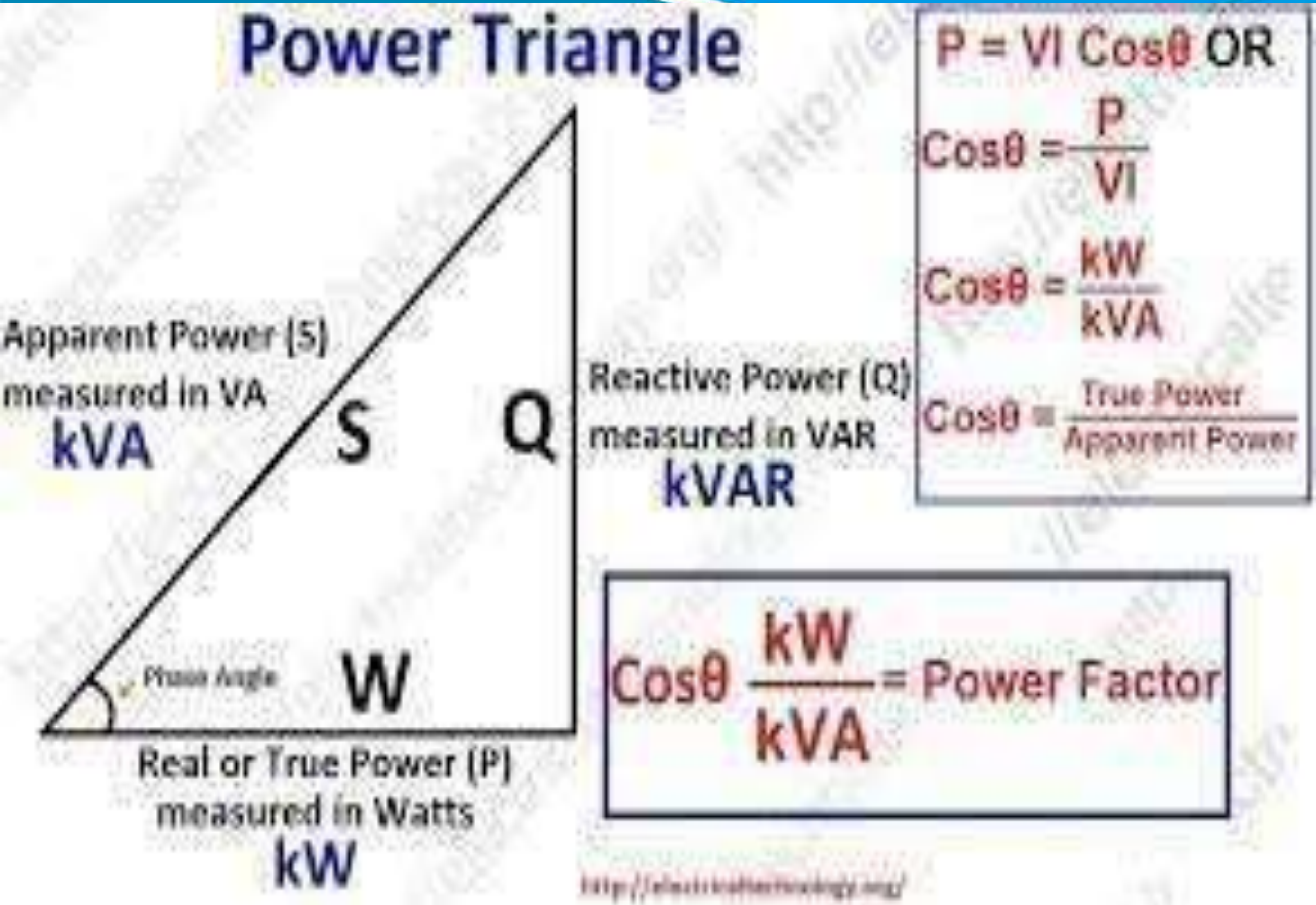
Sag

- **Sag** in overhead **Transmission line** conductor refers to the difference in level between the point of support and the lowest point on the conductor.
- Therefore, in order to have safe tension in the conductor, they are not fully stretched rather a sufficient dip or **Sag** is provided


Span
Sag
Conductor
Ground
Clearance

Power Factor

- In electrical engineering, the **power factor** of an AC electrical **power** system is defined as the ratio of the real **power** flowing to the load to the apparent **power** in the circuit



Power Triangle
Apparent Power (S) measured in VA
kVA
S
Q
Reactive Power (Q) measured in VAR
kVAR
Phase Angle
W
Real or True Power (P) measured in Watts
kW
P = VI Cosθ OR
Cosθ = P / VI
Cosθ = kW / kVA
Cosθ = True Power / Apparent Power
Cosθ kW / kVA = Power Factor

Importance of Power Factor

- **Power Factor** is very important for every power system or company, because it helps in maintaining inductive load. As its values lies in between **0–1**.
- Any system which has a power factor close to 1 is considered as good or excellent system, whereas any system which has a power factor close to 0 (Like 0.2, 0.3, 0.4, 0.5, 0.6) is considered as bad system and that power company have to pay something as a penalty fee. Because whenever power factor is not good or lagging power factor then imposes a severe impact on power supplying side.

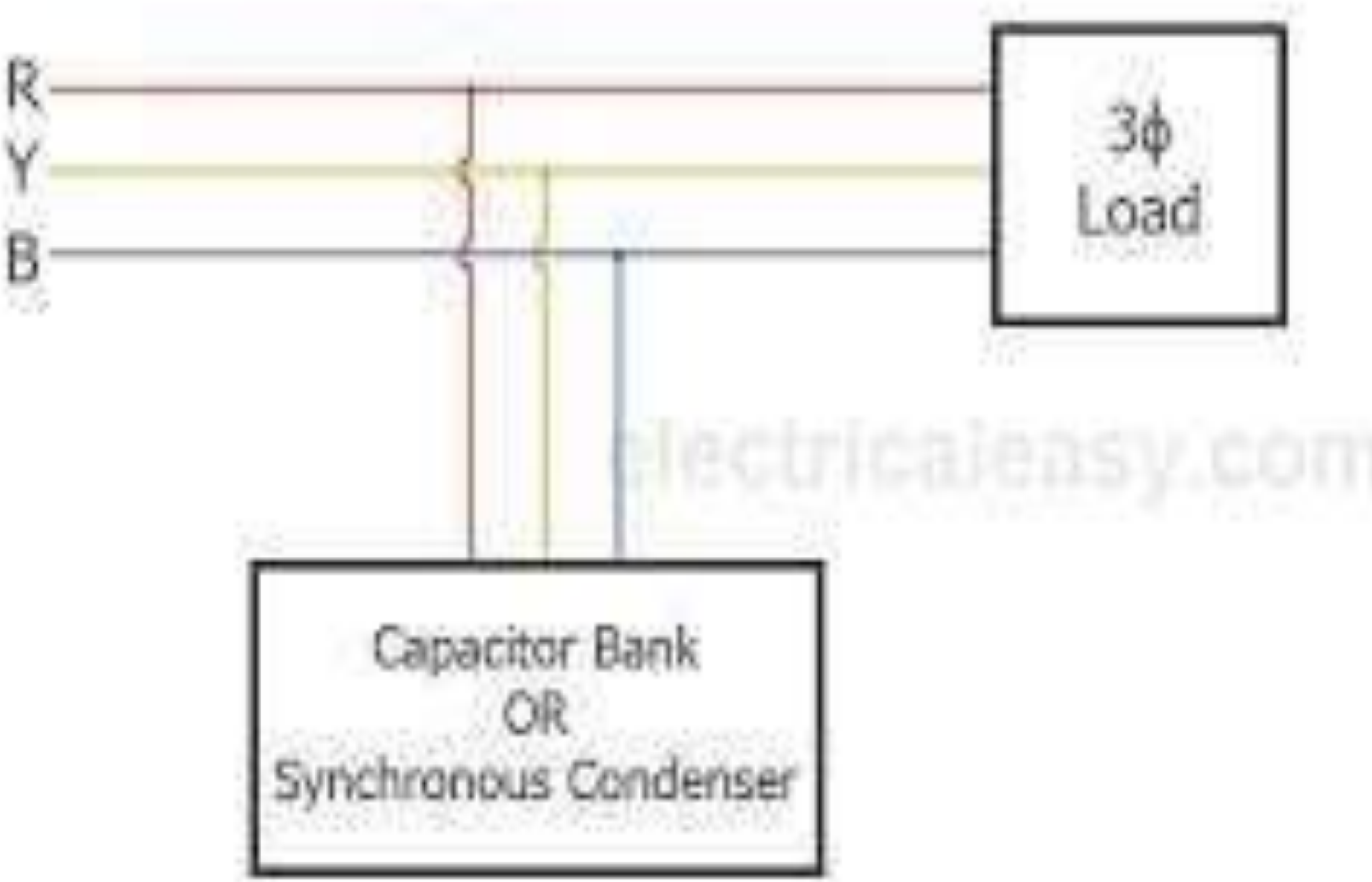
- You can see in above formula that when P.F is low then Apparent power or total power increases, it means Power supplying company has to provide more power to that company which has low P.F & this increases the line current which has a bad impact on the conductors or cables through which power is flowing, conductors becomes hot and heat dissipation will high, which causes a power supplying company to produce more power in order to compensate the power demand, their production cost of power will be increase and equipment cost also increases.
- So it is better to have a good P.F, in order to avoid penalty and other things.

Causes of Low PF

- The main **cause of low** p.f. is Inductive Load. As in pure inductive **circuit**, Current lags 90° from **Voltage**, this large difference of phase angle between current and **voltage causes** zero **power factor**. eg Inductive Loads are like:
- Arc Lamps
- Computer Systems
- Induction motors
- Electric Furnaces

Methods to Improve PF

- Synchronous Condenser: They are 3 phase synchronous motor with no load attached to its shaft. .
- Phase Advancer: This is an **ac** exciter mainly used to **improve pf** of induction motor.
- Capacitors: **Improving power factor** means reducing the phase difference between voltage and current. ...



Power Factor Improvement

Thanks

SOLAR PANEL INSTALLATION AND MAINTENANCE

SEMESTER 5th

Prepared by:- Dr. Neeraj kamboj(Lecturer, Electrical Engg.)
(Govt. Polytechnic, Nanakpur, Panchkula)

LEARNING OUTCOMES:

At the end of the course, the students will be able to:

Check site condition, collect tools and raw material

Install solar panel

Coordinate colleagues at workplace.

Ensure safety at workplace

DETAIL CONTENTS

1. Check site conditions, collect tools and raw materials

1.1. Basics on solar energy and power generation systems

1.2. Use and handling procedure of solar panels

1.3. Energy storage, control and conversion

1.4. Basic electrical system and functioning

1.5. Mechanical equipment and its functioning

1.6. Maintenance procedure of equipment

1.7. Site survey, design and evaluation of various parameters

1.8. Tools involved in installation of system

1.9. Quality and process standards

1.10. Occupational health and safety standards

2. Installation of Solar Panel

2.1 Solar energy system components such as panels, batteries, charge controllers,
inverters

2.2 Significance of volts, amps and watts: series and parallel connection

2.3 Voltage requirement of various equipment

2.4 Panel mounting and inclination and angle of tilt

2.5 Placement of solar panel mounting

2.6 Sunlight and direction assessment

2.7 Site surveying methods and evaluation parameters

2.8 Tools involved in installation of system

3. Coordinate colleagues at work

3.1 Company's policies on incentives, delivery standards, and personnel management

3.2 Importance of the individual's role in the workflow
3.3 Reporting structure
3.4 Communicating effectively
3.5 Building team coordination

4. Safety at workplace

4.1 Maintaining the work area safe and secure
4.2 Handling hazardous material
4.3 Operating hazardous tools and equipment
4.4 Emergency procedures to be followed such as fire accidents, etc.

5. Concept of Solar Tracking System

Chapter-1

Check site condition, collect tools and raw material

Introduction:- The demand for solar electric systems grows, progressive builders are adding solar photovoltaics (PV) as an option for their customers. This overview of solar photovoltaic systems will give the builder a basic understanding of:

- Evaluating a building site for its solar potential
- Common grid-connected PV system configurations and components
- Considerations in selecting components
- Considerations in design and installation of a PV system
- Typical costs and the labor required to install a PV system
- Building and electric code requirements
- Where to find more information

Basic on Solar energy

Solar energy is a powerful source of energy that can be used to heat, cool, and light homes and businesses.

Solar Energy Basics

- Solar Photovoltaic Technology. Converts sunlight directly into electricity to power homes and businesses.
- Passive Solar Technology. Provides light and harnesses heat from the sun to warm our homes and businesses in winter.
- Solar Water Heating.
- Solar Process Heat.
- Concentrating Solar Power.

Power Generation system

Solar energy generation is one of fastest growing and most promising renewable energy sources of power generation worldwide. Nowadays, the electrical energy becomes one of the basic needs in our daily life, which makes increasing demand for it. As a major source of electrical power generation fossil fuels are depleting day by day and also its usage raises serious environmental concerns. These reasons force the development of new energy sources which are renewable and ecologically safe. The renewable energy sources include wind, solar, water, biomass and geothermal energy sources. Out of which, solar energy has the greatest potential in the long term and is predicted to play a major role in coming years. It is the cheapest method of generating electricity compared with other energy sources.

Solar-powered photovoltaic (PV) panels convert the sun's rays into electricity by exciting electrons in silicon cells using the photons of light from the sun. This electricity can then be used to supply renewable energy to your home or business.

Uses and handling procedure of solar panel:-

Uses:-

- As heat for making hot water, heating buildings and cooking.
- To generate electricity with solar cells or heat engines.
- To take the salt away from sea water.
- To use sun rays for drying clothes and towels.
- It is used by plants for the process of photosynthesis.

Handling procedure of Solar panel:-

Solar panels are heavy and awkward to lift and carry. Loading and unloading panels from trucks and onto roofs can cause strains, sprains, muscle pulls and back injuries as well as cumulative trauma that stresses the spine. The panels can also heat up quickly when exposed to sunlight, causing burns if not handled safely.

Safety measures for solar workers:

- Lift each solar panel with at least two people while applying safe lifting techniques.
- Transport solar panels onto and around the work site using mobile carts or forklifts.
- Never climb ladders while carrying solar panels. To get solar panels onto rooftops, use properly inspected cranes, hoists or ladder-based winch systems.
- Once unpackaged, cover panels with an opaque sheet to prevent heat buildup.
- Always wear gloves when handling panels.

Energy storage:-

One way solar power storage can be accomplished is by using a battery bank to store the electricity generated by the PV solar power system. A battery solar power storage system is used in a grid-tied PV system with battery backup and stand-alone PV systems.

The major components of a battery solar power system are...

Charge Controller: Prevents the battery bank from overcharging by interrupting the flow of electricity from the PV panels when the battery bank is full.

Battery Bank: A group of batteries wired together. The batteries are similar to car batteries, but designed specifically to endure the type of charging and discharging they'll need to handle in a solar power system.

System Meter: Measures and displays your solar PV systems performance and status.

Main DC Disconnect: A DC rated breaker between the batteries and the inverter. Allows the inverter to be quickly disconnected from the battery bank for service.

- **Lighting control** - turns attached light on and off based on dusk and dawn. Many controllers are configurable, allowing settings for a few hours or all night, or somewhere in between.
- **Display**- may show voltage of battery bank, state of charge, amps coming in from solar panel.

Conversion process:-

Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a nonmechanical device usually made from silicon alloys.
Solar-powered photovoltaic (PV) panels convert the sun's rays into electricity by exciting electrons in silicon cells using the photons of light from the sun. This electricity can then be used to supply renewable energy to your home or business.

Control of Solar power

A solar charge controller manages the power going into the battery bank from the solar array. It ensures that the deep cycle batteries are not overcharged during the day, and that the power doesn't run backwards to the solar panels overnight and drain the batteries.

Types of controller:-

1. Pulse width modulation solar charge controller.
2. Maximum Power Point Tracking solar charge controller

The key features of solar charge controller:-

- **Multistage charging of battery bank:** -changes the amount of power set to the batteries based on its charge level, for healthier batteries.
- **Low voltage disconnect**- turns off attached load when battery is low and turns it back on when the battery is charged back up.

CONVERSION PROCESS

Basic electrical system and functioning

Components of A Residential Solar Electric System

- Solar Panels. Solar panels are the most noticeable component of a residential solar electric system. ...
- Solar Array Mounting Racks. ...
- Array DC Disconnect. ...
- Inverter. ...
- Battery Pack. ...
- Power Meter, Utility Meter, Kilowatt Meter. ...
- Backup Generator. ...
- Charge Controller.

Function of Solar Power:-

A solar power panel is able to function using the solar energy which is derived from the sun. ... The solar panels installed on the rooftops absorb sun's light (photons) from the sun. 2. The silicon and the conductors in the panel convert the sunlight into Direct Current (DC) electricity which then flow into the inverter.

It is important to understand exactly how solar panels work, and how they can be used to produce electricity for the average home.

1. The solar panels installed on the rooftops absorb sun's light (photons) from the sun.
2. The silicon and the conductors in the panel convert the sunlight into Direct Current (DC) electricity which then flow into the inverter.

3. The inverter then converts DC to AC (alternating current) electrical power which you can use at your home.
4. Excess electricity that is not used by you can be fed back to the grid.
5. When your solar panels produce less power than what is required by you at home, you can always buy electricity from the utility.

Mechanical Equipment

- Stringer machine for photovoltaic cells;
- Layup station;
- Automatic station with conveyor belts for manual bussing or Automatic Bussing Machine;
- Electroluminescence Test;
- Laminator with buffers;
- Automatic framing machine;
- Automatic silicone dispenser;
- Eva and backsheet cutting machine;

Maintenance procedure of equipment

- The timely and regular cleaning of solar cells and PV panels.
- Regular maintenance of all thermal-based components.
- Servicing of HT side equipment on an annual basis.
- Diagnosis and tests pertaining to low solar power production.
- Testing and upkeep of circuits.

Site Survey:-

What exactly is a Site Survey?

A Site Survey is done to collect information about various aspects such as local conditions, physical details of the site (including the roof), and the consumer's power consumption needs. Some of the information collected is:

- Local climatic conditions.
- Physical details of the site (including the roof).
- The consumer's power consumption needs.
- Shading on the roof and so on.

Site surveys are often done manually by skilled manpower, on the basis of which a 3D model of the site is prepared, which is used for the system design. A site survey consists of an inspection of the area of installation of solar panels to see if the proposed site is suitable. As a solar installer, when checking a potential site, you will primarily check for whether the roof will be able to support the extra load of the solar system, and if during peak hours there is no shade obstructing the panels.

The main objectives of a site survey are:

1. Ensure a site is free from shade due to obstacles such as water tanks, AC units, staircase, etc.
2. Clear access for maintenance at the site
3. Appropriate orientation to the sun
4. Obtain dimensions of the roof structure
5. Aesthetics of the installation
6. The energy consumption of the consumers.

Basic information about the site/location:

Address/Plant Name: For identification

Latitude and Longitude: For obtaining the satellite image of the site

Details person at the plant (Name, Designation, E-Mail ID and Mob No): For contact details

Information regarding the Electrical Energy Sources:

Sanctioned load from the grid (kVA): Since state policy does not permit more than the specified amount, and varies for different states

Connected Load

Installed capacity & voltage of transformers

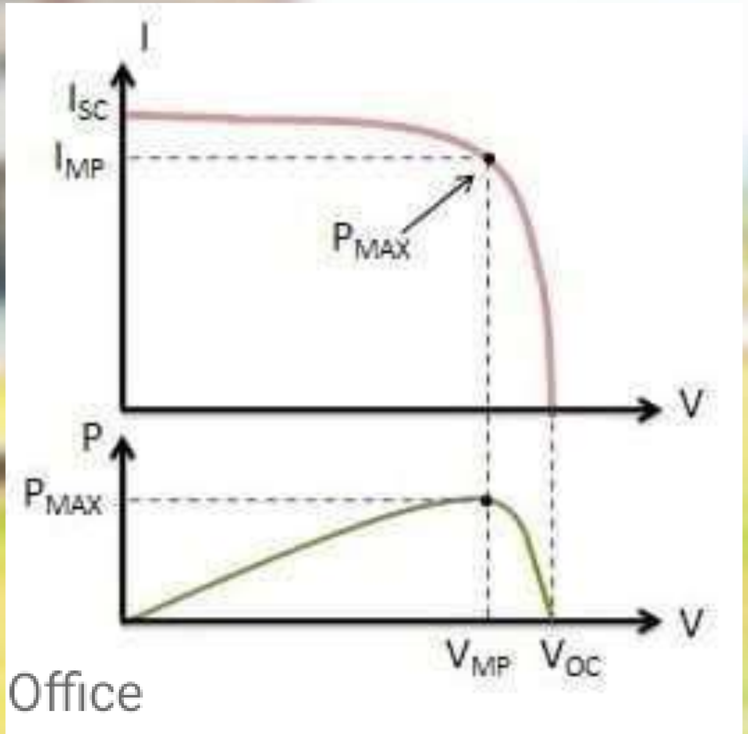
Actual connected load (KVA)

Power Units consumption per Month / Day

Average Unit Cost – Grid

Important Parameters in Solar Panel Installations

- **Maximum Power (Pmax)** Pmax is the highest power output of a solar panel under standard test conditions (STC). ...
- **Voltage at Maximum Power (Vmp)** The Vmp is the voltage generated by the solar panel when the power output is highest. ...
- **Current at Maximum Power (Imp)**



Tools involved in installation of system

Site Assessment Tools

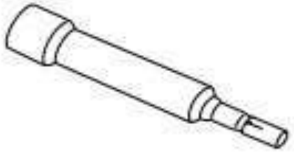
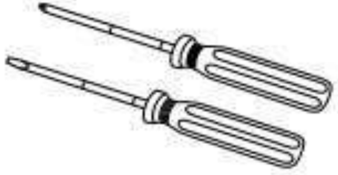
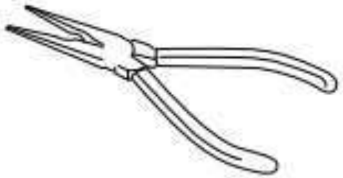
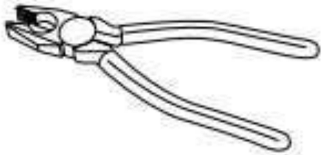
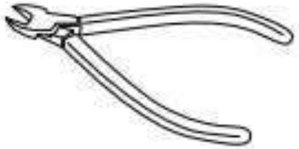
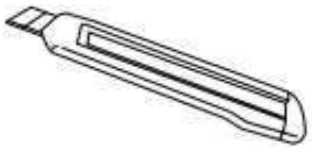
1. 50-100 ft. tape measure
2. Solar Pathfinder (evaluates the solar energy potential at a site)
3. Compass (not needed if you're using a Solar Pathfinder)
4. Maps (reference for location latitude and magnetic declination)
5. Digital camera

Additional Tools to Consider (especially for multiple installations)

1. DC clamp-on ammeter
2. Reciprocating saw / Jig saw
3. Right angle drill
4. Conduit bender
5. Large crimpers
6. Magnetic wristband for holding bits and parts
7. C-clamp

Basic Tools Needed for Installation

1. Angle finder
2. Torpedo level
3. Fish tape
4. Chalk line
5. Cordless drill (14.4V or greater), multiple batteries
6. Unibit and multiple drill bits (wood, metal, masonry)
7. Hole saw
8. Hole punch
9. Torque wrench with deep sockets
10. Nut drivers (most common PV sizes are 7/16”, ½”, 9/16”)
11. Hacksaw
12. Tape measure
13. Blanket, cardboard or black plastic to keep modules from going “live” during installation
14. Heavy duty extension cords

Tools	Cordless drill 	Socket drivers 8 mm & 13 mm 	Phillips driver bits 	Drill 	Screw driver set 
	Needle nose pliers 	Line man's pliers 	Wire cutters 	Hammer 	Chisel 
	Crimping tool 	Knife 	Tape measure 	Extension cord 	Chalk line 


Gloves & safety helmet
Rope
Tool belt
Ladders
Safety Harness
Safety glasses
Air mask
Ratchet Wrench
13 mm
8 mm
Measurement
Compass
Calculator
Solar insolation meter
Digital multimeter

Quality and process standards

The quality of photovoltaic solar panels is an important factor to consider for any solar plant project on the roof or on the ground.

The qualities are following:-

a. The guarantee
b. Price
c. Manufacture, Solar panel technology
d. Efficiency of the solar panel
e. The by Pass box and the cables:
f. The frame of the solar panel:
g. Temperature coefficient

A high temperature coefficient is a sign of a lower quality solar panel. A reasonable number is around 0.5%, also the best solar panels down to 0.3% while 0.7% indicates a poor coefficient in terms of performance and thus a photovoltaic equipment not very reliable.

Standards generally used in photovoltaic modules:

IEC 61215 (crystalline silicon performance), 61646 (thin film performance) and 61730 (all modules, safety)

ISO 9488 Solar energy—Vocabulary.

UL 1703 from Underwriters Laboratories

UL 1741 from Underwriters Laboratories

UL 2703 from Underwriters Laboratories

CE mark

Electrical Safety Tester (EST) Series (EST-460, EST-22V, EST-22H, EST-110).

Safety measures for solar workers:

- Lift each solar panel with at least two people while applying safe lifting techniques.
- Transport solar panels onto and around the work site using mobile carts or forklifts.
- Never climb ladders while carrying solar panels. To get solar panels onto rooftops, use properly inspected cranes, hoists or ladder-based winch systems.
- Once unpackaged, cover panels with an opaque sheet to prevent heat buildup.
- Always wear gloves when handling panels.

CHAPTER- 2

INSTALLATION OF SOLAR PANEL

Solar energy system components:-

The four major components of a solar energy system are the panels, inverter(s), racking and solar battery storage unit(s) (if desired).

- **Panels**

Solar panels are the most visible element of your system, which is why you're likely the most familiar with it. The way that solar panels work is that the panels generate DC electricity as sunlight, or solar irradiation, stimulates electrons to move though solar cells that are in-built into the solar panels.

Technology – Polycrystalline or Monocrystalline Panels?

Monocrystalline panels consist of singular large crystals, are darker in colour, even in aesthetic consistancy and, as a result of the production process, the corners of cells are usually missing.

Polycrystalline panels consist of multiple smaller crystals, can be light or dark blue in colour and have variation in texture where some patches are lighter than others.

■ Inverters

Inverters are a crucial part of any solar energy system. Their purpose is to convert the DC electricity that the solar panels produce into 240V AC electricity, which is what powers everything in your home. The inverter is a hardworking piece of equipment that works constantly throughout the lifetime of your system – so it tends to be the piece most likely to have faults.

■ Racking

The third main component of a solar energy system is the racking/ mounting. This is what securely attaches your panels to your roof. Racking / mounting will not be a decision you need to lose sleep over. Any reputable solar provider will use quality racking equipment from brands like Radiant or Sunlock, which are Australian made

■ Batteries

Batteries are used to store energy generated during the day to be used throughout the night when the system is no longer generating power. Battery technology is quickly developing into a more feasible option for those who primarily use their energy in the evenings. We have installed battery systems for major clients such as PCYC Queensland and schools like Bundaberg Christian College, who operate sporting facilities and boarding colleges that require energy throughout the night.

- Charge controller

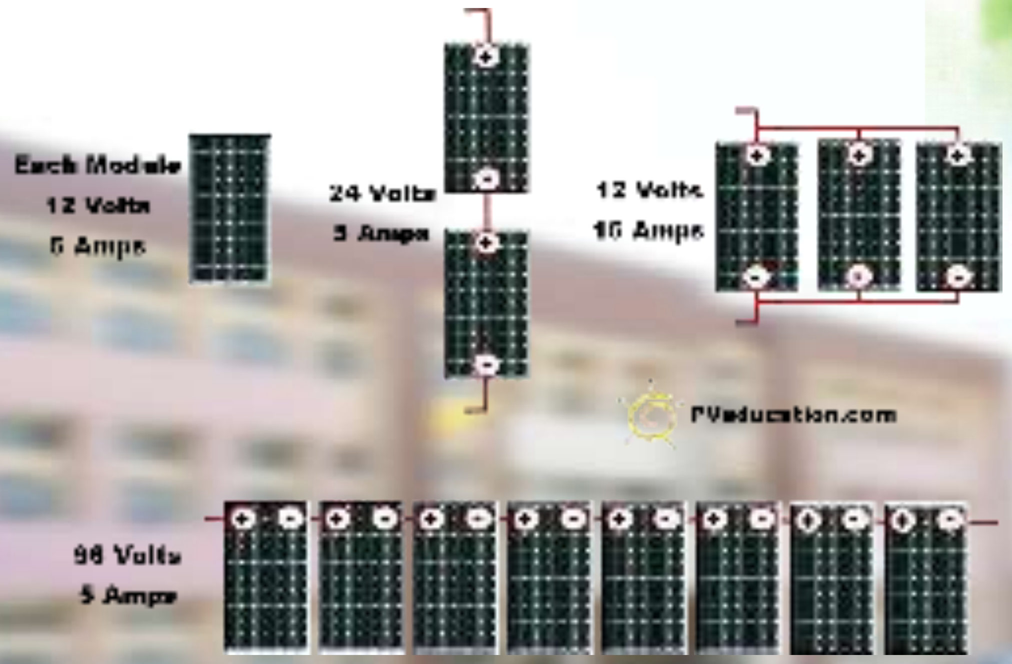
A charge controller is an important component in a battery based solar system and are not used in straight grid tie systems. The primary role is to manage charging the battery bank, prevent it from overcharging and many control the rate of the current and voltage at which it charges.

Series and Parallel Connection in Solar system

The following image is a great example of series and parallel wiring.

Series Wiring:

Series wiring is when the voltage of a solar array is increased by wiring the positive of one solar module to the negative of another solar module. This is similar to installing batteries in a flashlight. As you slide the batteries into the flashlight tube the voltage increases

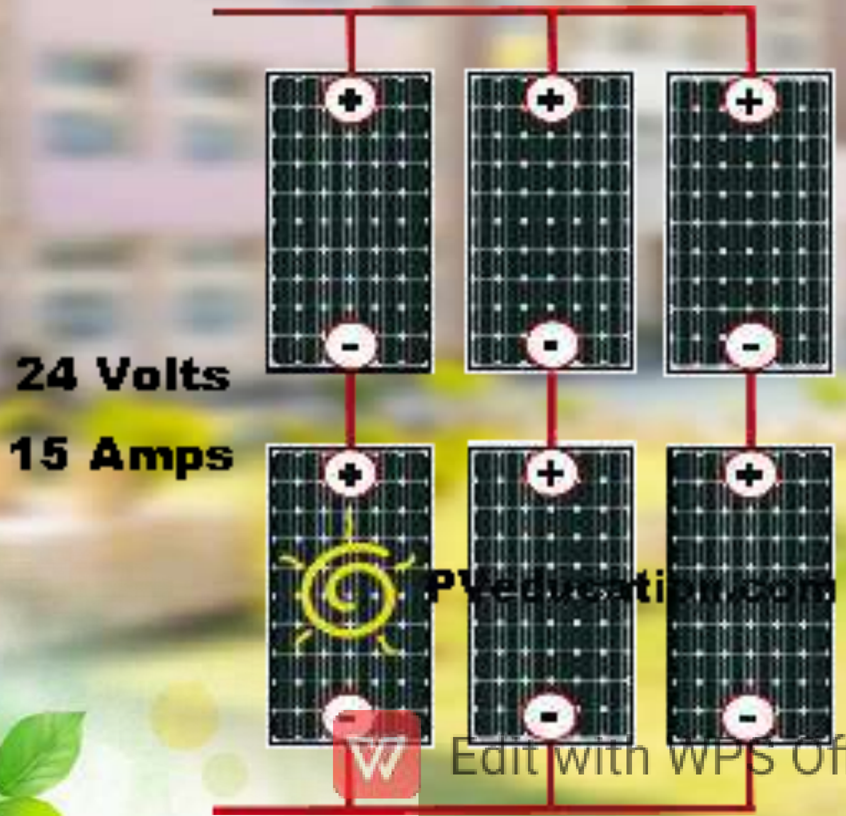


Parallel Wiring:

Parallel wiring increases the current (amps) output of a solar array while keeping the voltage the same. Parallel wiring is when the positives of multiple modules are connected together and all the negatives for the same modules are connected together.

Series Parallel Combination:

Here is an example of what is found in most large solar systems, a series and parallel wiring combination.



Pole mounting

Photovoltaic mounting systems (also called solar module racking) are used to fix solar panels on surfaces like roofs, building facades, or the ground. These mounting systems generally enable retrofitting of solar panels on roofs or as part of the structure of the building (called BIPV).

Angle of tilt for Solar Panel: -

The "tilt angle" or "elevation angle" describes the vertical angle of your solar panels. "Azimuth angle" is their horizontal facing in relation to the Equator. Solar panels should face directly into the sun to optimize their output.

The optimum tilt angle is calculated by adding 15 degrees to your latitude during winter, and subtracting 15 degrees from your latitude during summer. For instance, if your latitude is 34°, the optimum tilt angle for your solar panels during winter will be 34 + 15 = 49°.

Placement of solar panel mounting

The most optimum direction to face your solar panels is somewhere between south and west. It is at this location that your panels will receive the maximum sunlight throughout the day.

If your roof does not face the right direction, then surface mounted panels or pole mounted panels may be your best bet.

Site Surveying Method

- Roof Orientation and Shading Analysis- Helpful in in identifying the suitable location for Solar Panel installation.
- Roofing Details – Study the roofing details to install the right solar PV system.
- Load Analysis – Helpful to understand the energy needs of the building.

Evaluation parameters for Solar system:-

The following are the parameters you should evaluate on:

- Grade – Solar panels come in Grades A, B & C (Grade A being the highest quality)
- Tier of the manufacturer – Organizations such as BNEF have come up with ranking of the solar panel manufacturer, classifying them into one of three Tiers (Tier 1 being the highest)
- Efficiency – Solar panels have efficiencies ranging from 13%-24%
- Performance under low light conditions – Some solar panels can generate higher amounts of electricity than other panels with the same
- Temperature coefficient – Solar panels with lower temperature coefficient (and higher temperature tolerance) lose less of their efficiency at higher temperatures
- Warranties available – Solar panels come with performance warranties, which range from Standard to Linear
- Presence of anti-PID features – Solar panels also come with features to tackle PID or Potential Induced Degradation, a characteristic that can cause significant harm to the panel within the first few years of installation.

Chapter-4

SAFETY AT WORK PLACE

INTRODUCTION- The Occupational Safety and Health Administration (OSHA) requires employers to implement safety training and protection for their employees. Many solar installation companies have taken OSHA's requirements a step farther, creating manuals of their own that detail the specific measures they require to manage solar energy safely.

<u>Maintaining the work area safe and secure:-</u>

Every Worksite Presents Different Risks

No two worksites are the same. Before a solar installation begins, it's essential for the installer to visit the site, identify the safety risks and develop specific plans for addressing them. Plans should include:

- Equipment to be used for safe lifting and handling of solar panels
- Type and size of ladders and scaffolding if needed
- Fall protection for rooftop work
- Personal protective equipment for each installer

All equipment needed for the job should be inspected and verified to be in good working order before being brought to the worksite.

Lifting and Handling Solar Panels

Solar panels are heavy and awkward to lift and carry. Loading and unloading panels from trucks and onto roofs can cause strains, sprains, muscle pulls and back injuries as well as cumulative trauma that stresses the spine. The panels can also heat up quickly when exposed to sunlight, causing burns if not handled safely.

Safety measures for solar workers:

Lift each solar panel with at least two people while applying safe lifting techniques.

Transport solar panels onto and around the work site using mobile carts or forklifts.

Never climb ladders while carrying solar panels. To get solar panels onto rooftops, use properly inspected cranes, hoists or ladder-based winch systems.

Once unpackaged, cover panels with an opaque sheet to prevent heat buildup.

Always wear gloves when handling panels.

Ladder Safety

Solar construction often involves working on roofs and from ladders. Choosing the right ladder and using it properly are essential.

Safety measures for solar workers:

Select the ladder that best suits the need for access – whether a stepladder, straight ladder or extension ladder. Straight or extension ladders should extend a minimum of three feet above the rung that the worker will stand upon.

Select the right ladder material. Aluminum and metal ladders are the most commonly used today and may have their place on the job, but they're a serious hazard near power lines or electrical work. Use a fiberglass ladder with non-conductive side rails near power sources.

Trips and Falls

Trips and falls are a common hazard of all construction jobs, including solar. They can happen anywhere on the jobsite, especially off roofs or ladders. Rooftop solar installations are especially hazardous because the work space diminishes as more panels are installed, increasing the risk of falls.

Safety measures for solar workers:

Keep all work areas dry and clear of obstructions.

For fall distances of six feet or more, take one of three protective measures: install guardrails around ledges, sunroofs or skylights; use safety nets; or provide each employee with a body harness that is anchored to the rooftop to arrest a potential fall.

Cover holes on rooftops, including skylights, and on ground-level work surfaces

Solar Electrical Safety

Solar electric (photovoltaic or PV) systems include several components that conduct electricity: the PV solar array, an inverter that converts the panel's direct current to alternating current, and other essential system parts. When any of these components are "live" with electricity generated by the sun's energy, they can cause injuries associated with electric shock and arc-flash. Even low-light conditions can create sufficient voltage to cause injury.

Safety measures for solar workers:

Cover the solar array with an opaque sheet to "turn off" the sun's light.

Treat the wiring coming from a solar PV array with the same caution as a utility power line. Use a meter or circuit test device to ensure that all circuits are de-energized before working on them.

Lock out the power on systems that can be locked out. Tag all circuits you're working on at points where that equipment or circuit can be energized.

What are the hazards of solar power?

Hazards and Controls

Workers in the solar energy industry are potentially exposed to a variety of serious hazards, such as arc flashes (which include arc flash burn and blast hazards), electric shock, falls, and thermal burn hazards that can cause injury and death.

Handling hazardous material

Hazardous Waste or Not?

Solar panel waste can include heavy metals such as silver, lead, arsenic and cadmium that – at certain levels – may be classified as hazardous waste.

Solar panels may be considered a waste when:

- A generator decides to discard unused solar panels: and
- Used solar panels are disconnected/removed from service and will not be reused.

It is important to remember that some types and brands of solar panels are hazardous waste
while other are not.

The following are some panels that do or may contain toxic material.

- CDTe solar panels may be a hazardous due to cadmium.
- Gallium arsenide (GaAs) panels may be hazardous due to arsenic.
- Some older silicon solar panels may be hazardous waste for hexavalent chromium coatings.
- Newer, thin-film solar panels contain CIS/CIGS and may be hazardous due to copper and/or selenium.

Site Risk & Hazard Assessment

Hazards & How They Can Be Prevented

Hazard	Description	How to Prevent Injury
Exposure	• Sun damage • Symptoms of dehydration • Heat stroke	• *Wear a hat and long-sleeved clothes* • *Drink plenty of fluids, never alcohol* • *Take regular breaks in the shade*
Injury	• Falling from roof or ladder • Cut finger with sharp edge of metal and metal slivers • Bump head on the low beams and PV frame • Back strain by lifting and carrying heavy equipment • Burn caused by contacting hot metal	• *Wear comfortable shoes* • *Have a partner to hold the ladder and assist with handling equipment* • *Wear gloves* • *Wear a safety helmet*

Insects, Snakes	• Spiders and insects often move in and inhabit junction boxes and other enclosures.	--
Electrical Shock	• The human body acts like a resistor and allows current to pass. • The value of resistance varies with condition. (**Wet:** 1,000 Ω – **Dry:** 100,000 Ω) • The amount of current that will flow is determined by Voltage and Resistance in the current pass. • Current greater than 20mA may give a serious damage to the body.	• *Always check the voltage between any conductor and any other wires, and to ground.* • *Do not touch conductive part by wet hand*

Chapter - 5 SOLAR TRACKING SYSTEM

Introduction :-Trackers direct solar panels or modules toward the sun. These devices change their orientation throughout the day to follow the sun's path to maximize energy capture.... Because these trackers follow the sun vertically and horizontally they help obtain maximum solar energy generation.

What are solar trackers?

A solar tracking system maximizes your solar system's electricity production by moving your panels to follow the sun throughout the day, which optimizes the angle at which your panels receive solar radiation. Solar trackers are typically used for ground-mounted solar panels and large, free-standing solar installations like solar trees.

When solar panels are exposed to sunlight, the angle at which the sun's rays meet the surface of the solar panel (known as the "angle of incidence") determines how well the panel can convert the incoming light into electricity. The narrower the angle of incidence, the more energy a photovoltaic panel can produce. Solar trackers help to minimize this angle by working to orient panels so that light strikes them perpendicular to their surface.

There are two types of solar tracking systems:

- single-axis
- dual-axis.

A single-axis tracker moves your panels on one axis of movement, usually aligned with north and south. These setups allow your panels to arc from east to west and track the sun as it rises and sets.

- Single-axis trackers are nearly 32.17% efficient compared to a fixed solar tracker mount panel.

  These trackers follow the Sun from East to West, providing consistent power output all day long.

  The trackers generate 15-16% higher annual power as compared to a static station of the same installed capacity.

Disadvantages:-

- Energy output is lower by single-axis tracker during sunny conditions compared to dual-axis trackers
- Limited technological upgrade.
- Solar trackers are slightly more expensive than their stationary counterparts, due to the more complex technology and moving parts necessary for their operation. This is usually around a $0.08 – $0.10/ W increase depending on the size and location of the project.

Find the right solar setup for your property

Whether you want a ground-mounted solar array with solar trackers or a rooftop system, it is always important to compare your options before moving forward. On the EnergySage Solar Marketplace, you can solicit quotes for both ground-mounted and rooftop solar projects from qualified, pre-vetted installers in your area. If you are interested in a tracking system, simply leave a note on your profile that you would like quotes including solar trackers.

Reading a Solar Panel Name Plate

Maximum Power means it can deliver maximum 100 Watts electricity.

Maximum Voltage means its maximum output voltage is 18.0V.

Open Circuit Voltage means the voltage without load.

Maximum Current means the maximum output current.

Short Circuit Current means the current of short circuit of solar panel.

Maximum System Voltage means that, when we connect solar panel in series then

Maximum Voltage Limit is 1000V.

100W Photovoltaic Solar Panel	
Part #:	SOL-100W-00
Maximum Power (Pmax):	100 Watts
Open Circuit Voltage (Voc):	22.10 Volts
Short Circuit Current (Isc):	5.91 Amps
Max Power Voltage (Vpm):	18.00 Volts
Max Power Current (Imp):	5.56 Amps
Max System Voltage:	1000 VDC
Dimensions:	40.2" x 26.4" x 1.4" [1020mm x 670mm x 35mm]
Weight:	17.6 lbs [8kg]
Max Series Fuse Rating:	15 Amps
Nom Operating Cell Temp:	25°C [+/-2°]

Figure 6: The picture above shows an extract of a name plate of a solar panel

Safety Management

Clothes: Wear proper clothes for on-site work and ambient environment (Long-sleeved clothes, Hat, Shoes etc.)

Safety Equipment: Prepare safety equipment (Gloves, Protective glasses, Safety helmet, Appropriate ladder, insulated tools, Proper measuring equipment etc.)

Work Plan: Check specification and diagram of PV system. Make work plan which reflect results of the risk assessment and inform the workers about work plan in advance.

Work at Site: Confirm risks and safety measures before starting work. Conduct work complying with work plan.

When dealing with any electrical installations it is better SAFE than SORRY.


Thank you!