BASIC ELECTRICAL & ELECTRONICS ENGINEERING (20A02101T)

PREPARED BY

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VEMU IT

UNIT – 1
DC & AC CIRCUITS

Voltage:-

It is defined as work done per unit charge.

$$V = \frac{W}{Q}$$

Where V is the voltage (or) potential difference, W is the work done, Q is the charge.

Current:-

It is defined as flow of charge per unit time.

(or)

Current is defined as the rate of flow of electrons in a conductor. It is measured by the number of electrons that flow in unit time.

$$I = \frac{\text{Charge}}{\text{Time}} = \frac{Q}{t}$$

Where I is the current, Q is the charge of electrons, t is the time.

Work:-

When a force is applied to a body causing it to move, and if a displacement, d is caused in the direction of the force, then

Work done = Force × Distance

$$W = F \times D$$

If force is in Newtons and d is in meters, then work done is expressed in Newton–meter which is called Joules.

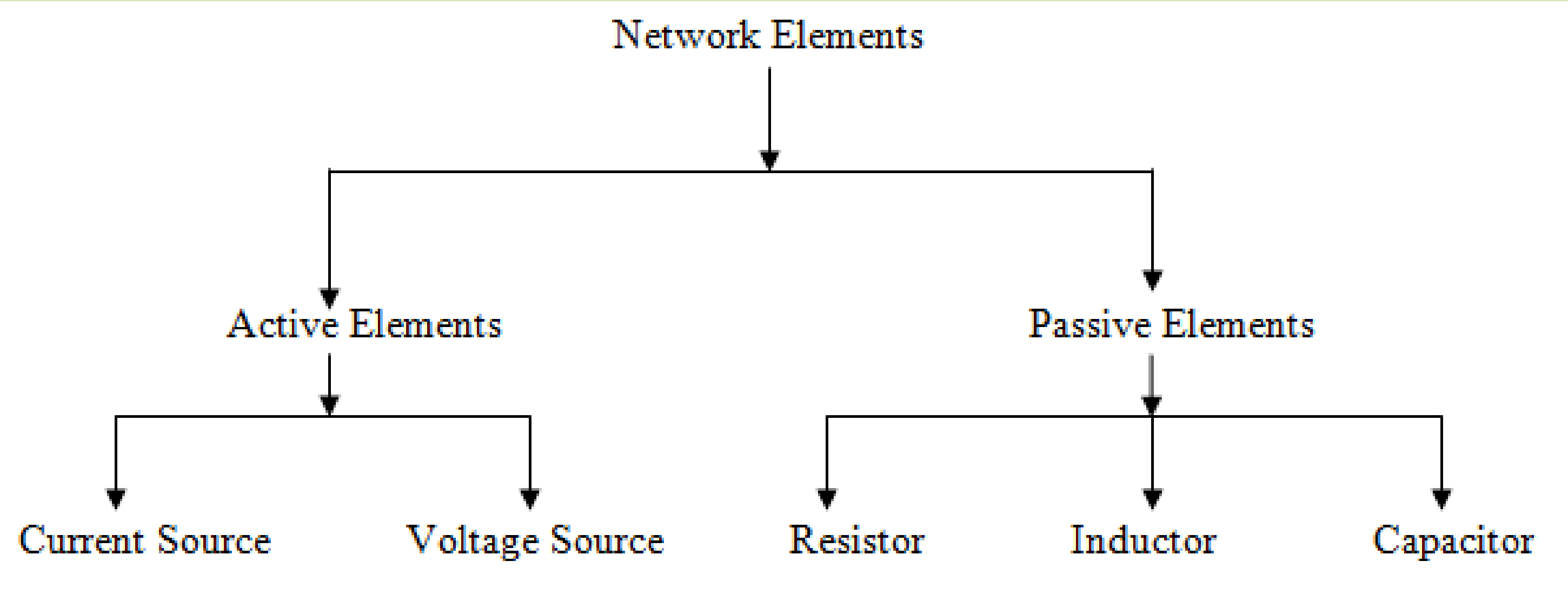
Power:-

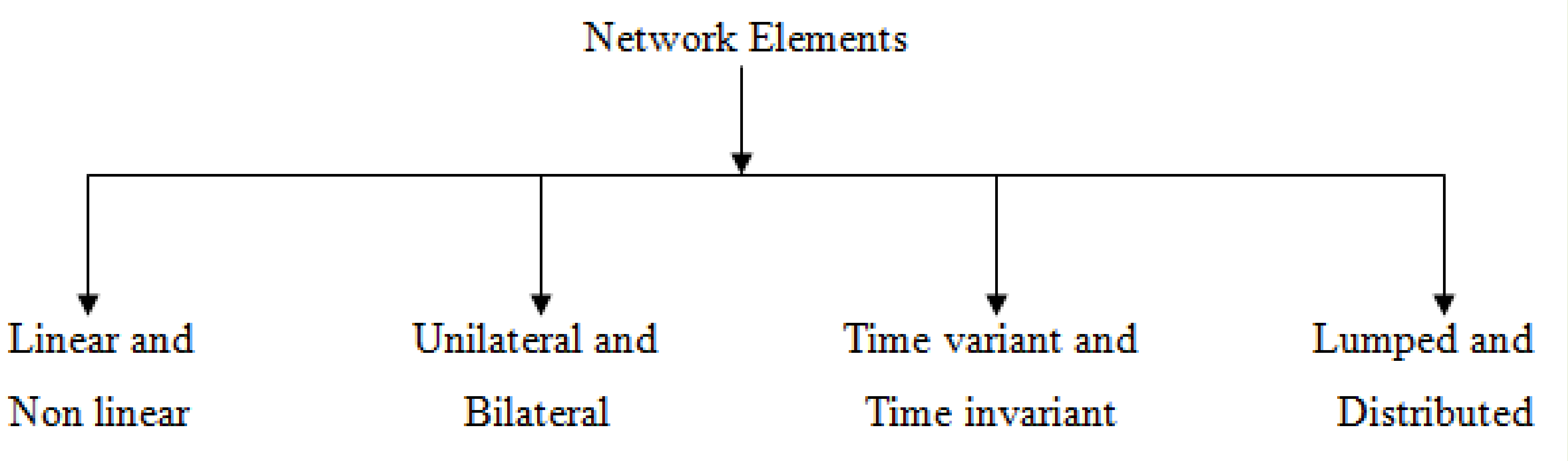
Power is the rate at which work is done, i.e., rate of doing work.

$$\text{Power (P)} = \frac{\text{Work done}}{\text{time}}$$

The unit of power is Joules/second which is also called Watt. When the amount of power is more, it is expressed in Kilowatt, i.e., kW.

CLASSIFICATION OF NETWORK ELEMENTS:-





While discussing network theorems, laws, and electrical and electronic circuits, one often comes across the following terms.

i) Circuit: A conducting path through which an electric current either flows or is intended to flow is called a circuit.

ii) Electric network: A combination of various circuit elements, connected in any manner, is called an electric network.

iii) Linear circuit: The circuit whose parameters are constant, i.e., they do not change with application of voltage or current is called a linear circuit.

iv) Non linear circuit: The circuit whose parameters change with the application of voltage or current is called a non linear circuit.

v) Circuit parameters: The various elements of an electric circuit are called its parameters, like resistance, inductance, and capacitance.

vi) Bilateral circuit: A bilateral circuit is one whose properties or characteristics are the same in either direction. E.g., transmission line.

vii) Unilateral circuit: A unilateral circuit is one whose properties or characteristics change with the direction of its operation. E.g., diode rectifier.

viii) Active network: An active network is one which contains one or more sources of EMF.

ix) Passive network: A passive network is one which does not contain any source of EMF.

x) Node: A node is a junction in a circuit where two or more circuit elements are connected together.

xi) Branch: The part of a network which lies between two junctions is called a branch.

xii) Loop: A loop is a closed path in a network formed by a number of connected branches.

xiii) Mesh: Any path which contains no other paths within it is called a mesh. Thus, a loop contains meshes but a mesh does not contain a loop.

xiv) Lumped circuit: The circuits in which circuit elements can be represented mutually independent and not interconnected.

Electrical circuit elements (R, L, C):-

Resistors, inductors, and capacitors are the three basic circuit parameters or circuit components of any electrical network.

Resistor (or) resistance (R):-

The property of a material to restrict the flow of electrons is called resistance.

(or)

Electrical resistance is the opposition to the flow of electrons in a given material.

(or)

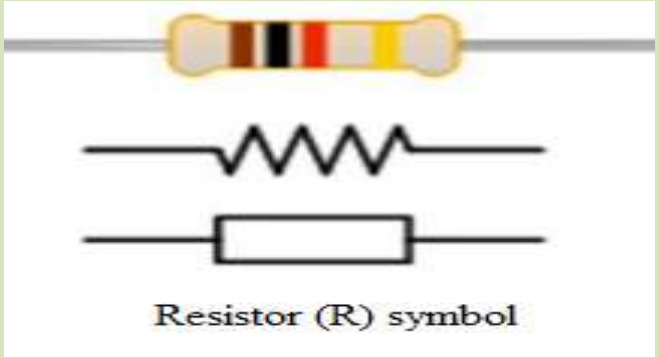
Resistance is the property of a material due to which it opposes the flow of electric current through it.

(or)

The opposition to flow of electrons is called electrical resistance (R).

(or)

Resistance may also be defined as “the property of the electric circuit which opposes the flow of current”.



The unit of resistance is **ohm** and is represented by the symbol **Ω**. The resistance of a conductor depends on the following factors:

(i) It is directly proportional to its length.

(ii) It is inversely proportional to the area of cross section of the conductor.

(iii) It depends on the nature of the material.

(iv) It also depends on the temperature of the conductor.

Inductor:-

If the energy is stored in magnetic field, the element is inductor.

The unit of inductor is Henry, denoted by H and circuit symbol is shown in figure.

The inductance of a coil is defined as the ratio of flux linkage to the current flowing through the coil.

$$L = \frac{N\emptyset}{i}$$

Where N is the number of turns, ϕ is the flux, I is the current.

$$Li = N\emptyset$$

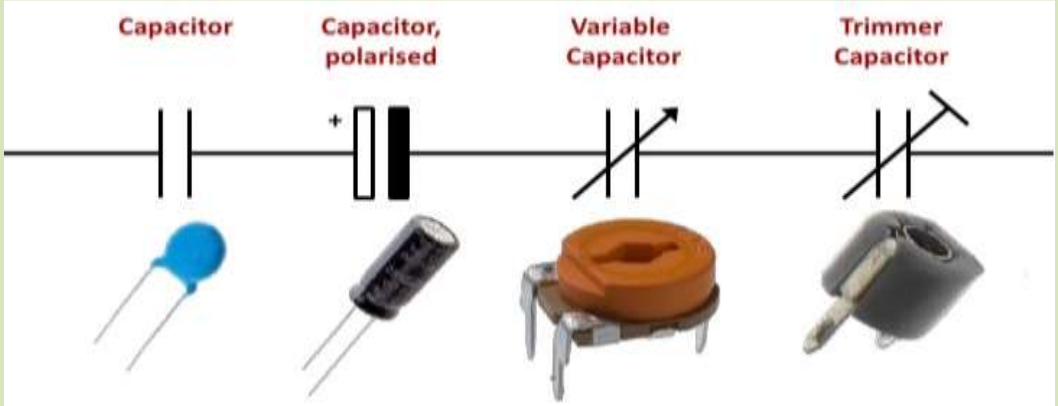
$$L\frac{di}{dt} = N\frac{d\emptyset}{dt}$$

$$V = L\frac{di}{dt}$$

Capacitor:-

If the energy is stored in an electric filed, the element is capacitor.

The unit of capacitor is Farad, denoted by F and circuit symbol is shown in figure.



Charge on a capacitor, $q \propto V$,

$$q = CV$$

$$\frac{dq}{dt} = C\frac{dV}{dt}$$

$$I = C\frac{dV}{dt}$$

$$V = \frac{1}{C}\int i\, dt$$

KIRCHHOFF LAWS:-

Two laws given by Gustav Robert Kirchhoff (1824–1887) are very useful in writing network equations.

These laws are known as Kirchhoff's current law (KCL) and Kirchhoff's voltage law (KVL).

The first law deals with flow of current and is popularly known as Kirchhoff's current law (KCL) while the second one deals with voltage drop in a closed circuit and is known as Kirchhoff's voltage laws (KVL).

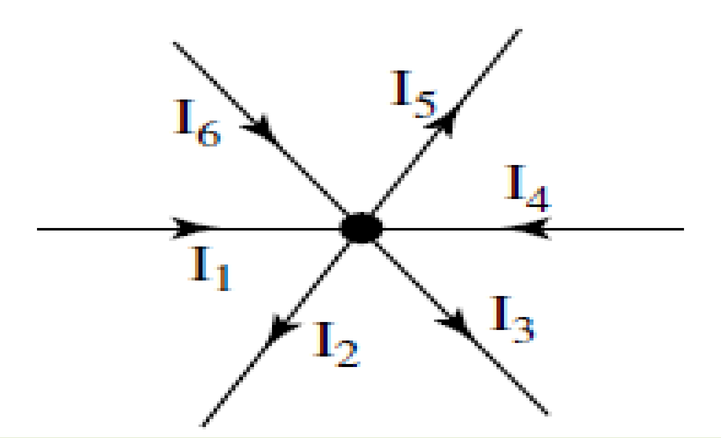
1) Kirchhoff's Current Law (KCL):

This law states that the algebraic sum of currents meeting at a junction or a node in a circuit is zero.

(or)

The sum of current flowing towards a junction or a node is equal to the sum of currents flowing out of the junction.

The current entering the junction has been taken as positive while the currents leaving the junction have been taken as negative.



$$I_1 + I_6 + I_4 - I_5 - I_3 - I_2 = 0$$

$$I_1 + I_6 + I_4 = I_5 + I_3 + I_2$$

2) Kirchhoff's Voltage Law (KVL):

KVL states that at any instant of time the algebraic sum of voltages in a closed loop is zero.

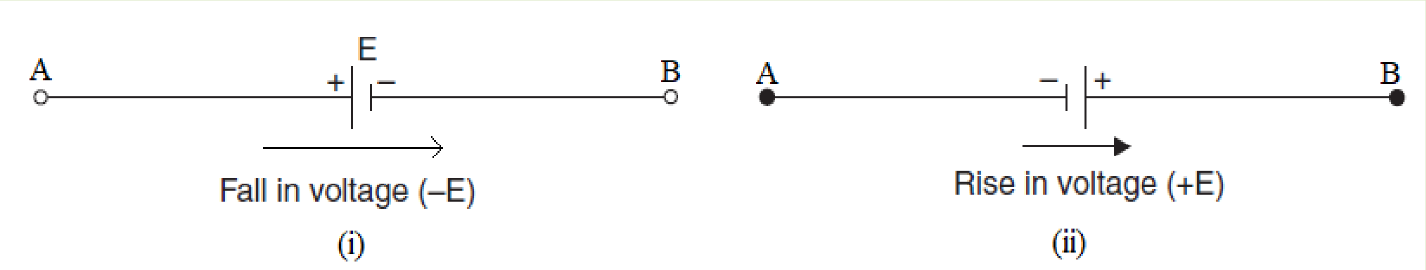
(or)

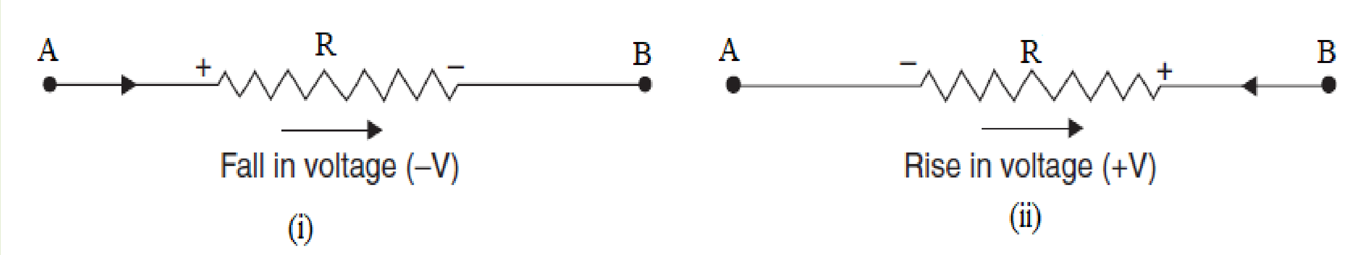
The sum of the e.m.fs (rises of potential) around any closed loop of a circuit equals the sum of the potential drops in that loop.

(or)

In any network, the algebraic sum of the voltage drops across the circuit elements of any closed path is equal to the algebraic sum of the e.m.fs in the path.

A rise in potential can be assumed to be positive while a fall in potential can be considered negative.





SERIES–PARALLEL CIRCUITS:-

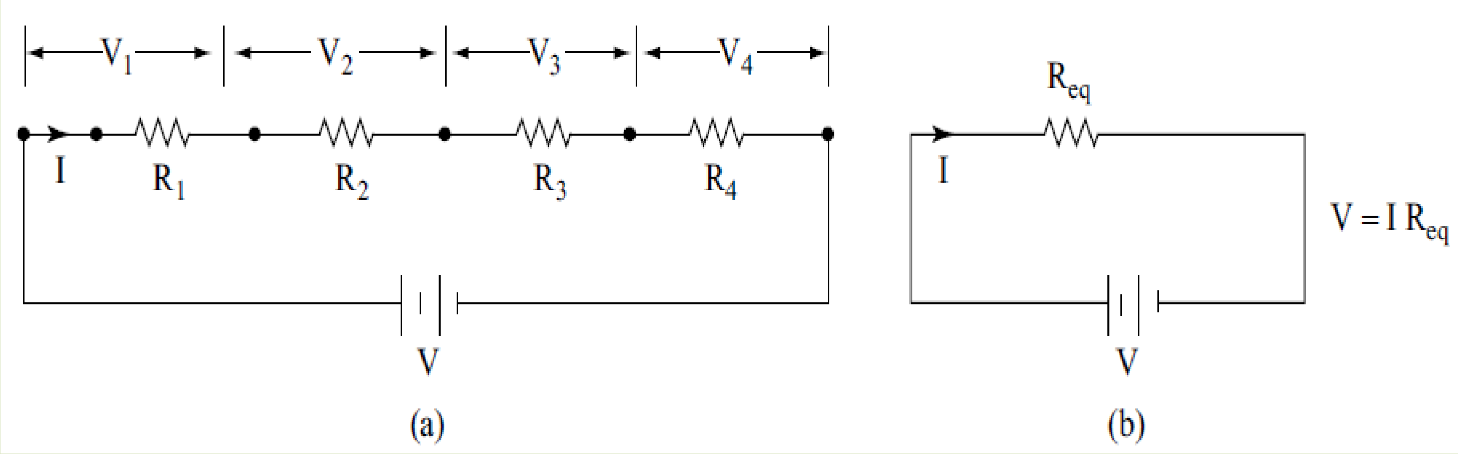
Resistances, capacitances, and inductances are often connected in series, in parallel, or a combination of series and parallel.

We need to calculate the division of voltage and currents in such circuits

1) Series Circuits:

When a number of resistances are connected end to end across a source of supply, there will be only one path for the current to flow as shown in Figure.

The circuit is called a series circuit.



$$IR_{eq} = IR_1 + IR_2 + IR_3 + IR_4$$

$$R_{eq} = R_1 + R_2 + R_3 + R_4$$

Assuming R_{eq} as equal to R, $R = R_1 + R_2 + R_3 + R_4$

2) Parallel Circuits:

When a number of resistors are connected in such a way that both the ends of individual resistors are connected together and two terminals are brought out for connection to other parts of a circuit, then the resistors are called connected in parallel as shown in Fig.

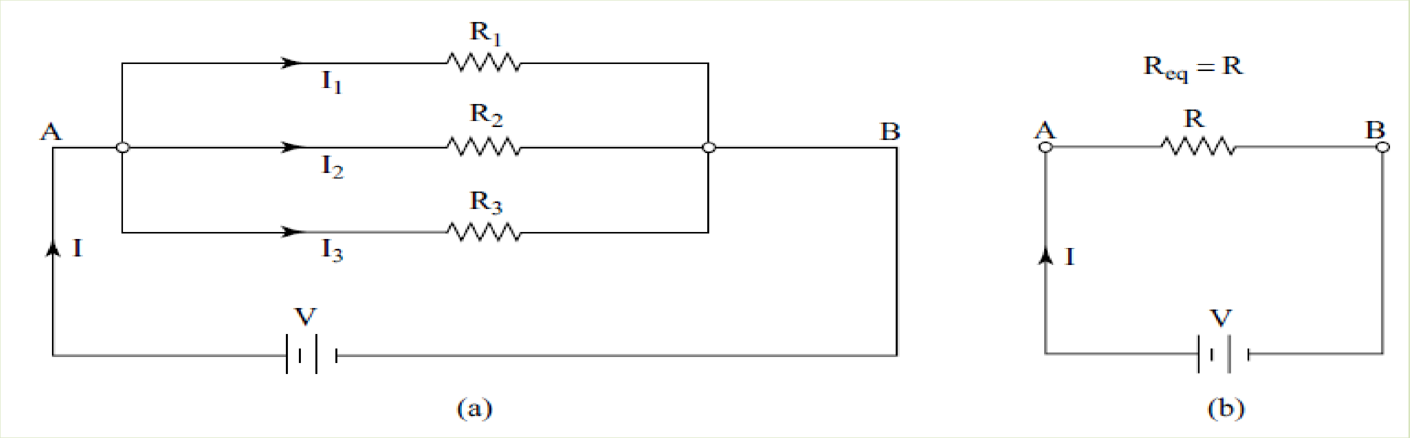
Voltage V is connected across the three resistors R_1, R_2, R_3 connected in parallel.

The total current drawn from the battery is I.

This current gets divided into I_1, I_2, I_3 such that $I = I_1 + I_2 + I_3$.

As voltage V is appearing across each of these three resistors, applying Ohm's law we write

$$I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

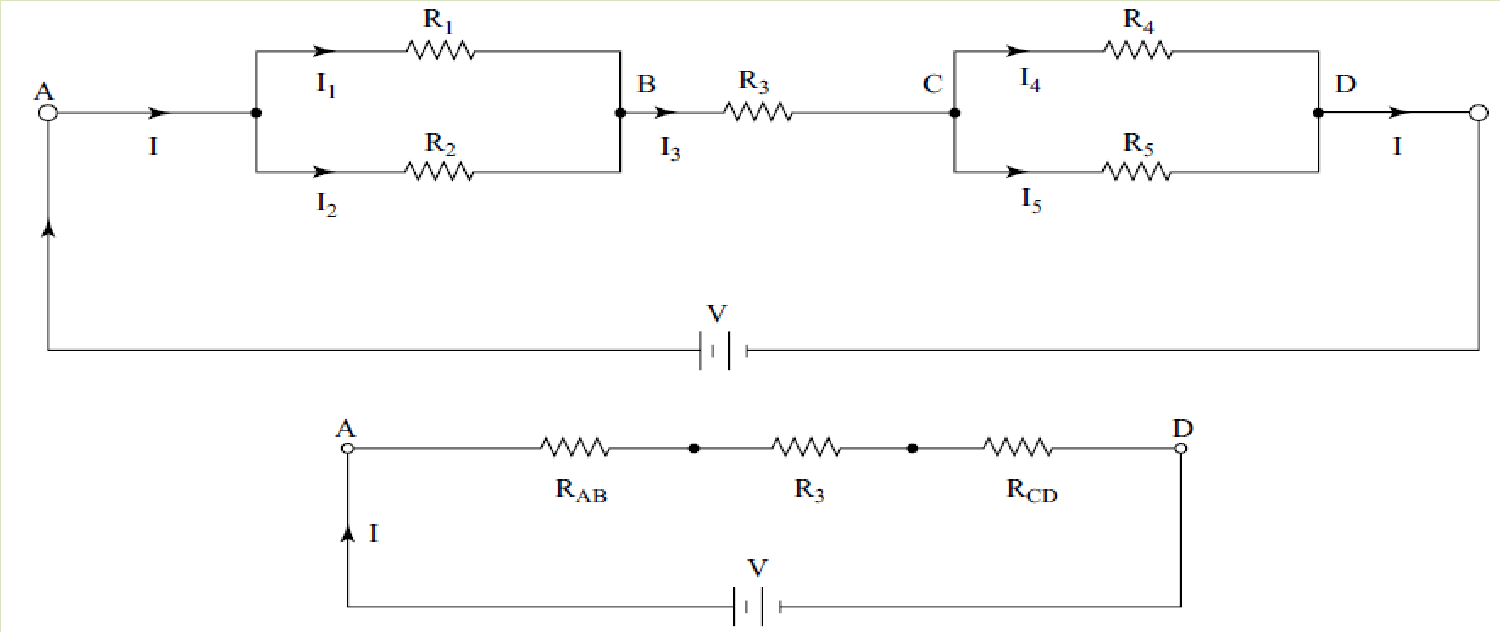


3) Series–Parallel Circuits

Figure shows a number of resistors connected in series–parallel combinations.

Here, two parallel branches and one resistance, all connected in series have been shown.

To determine the equivalent resistance across the end terminals of the entire circuit, we first calculate the equivalent resistance of parallel branches and then put them in series along with any individual resistance already connected in series.



$$R = \frac{R_1 R_2}{R_1 + R_2} + R_3 + \frac{R_4 R_5}{R_4 + R_5}$$

SUPERPOSITION THEOREM:-

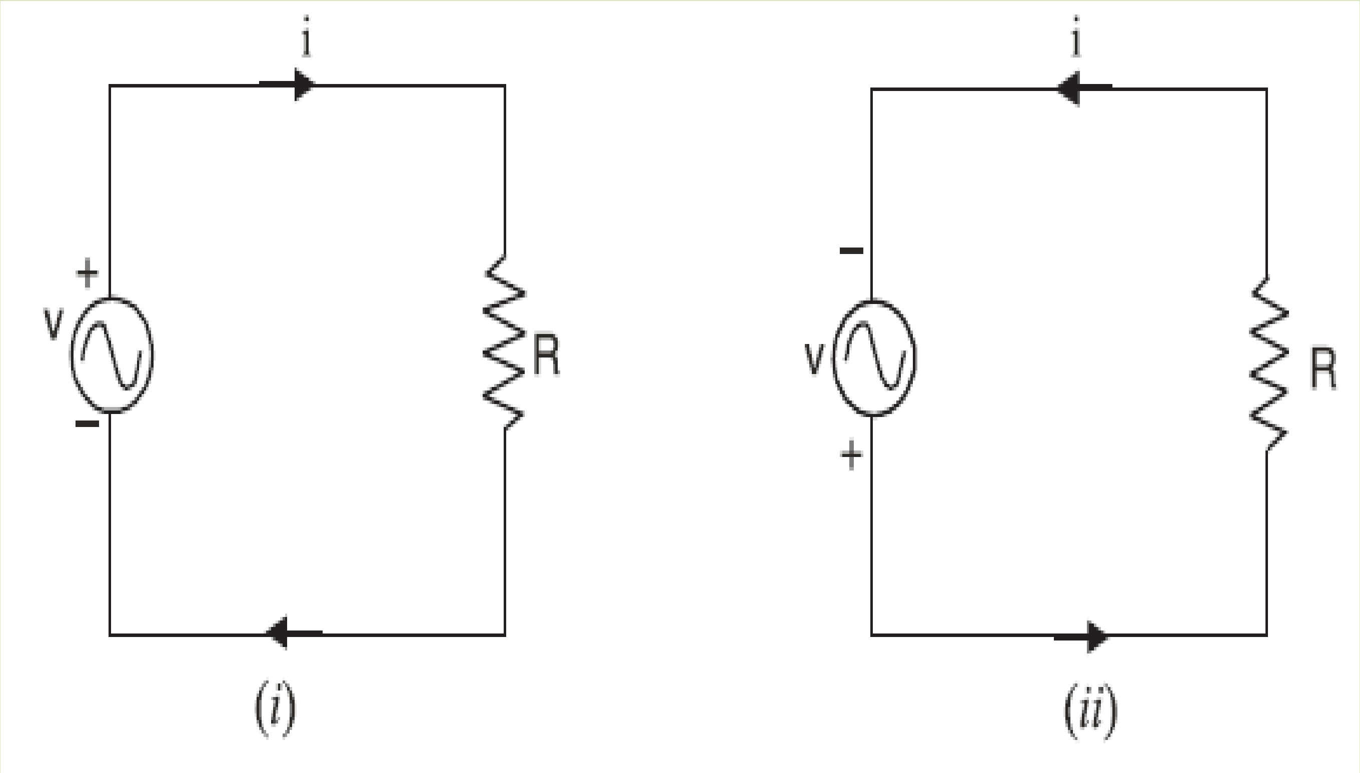
The superposition theorem states that in a linear network containing more than one source, the current flowing in any branch is the algebraic sum of currents that would have been produced by each source taken separately, with all the other sources replaced by their respective internal resistances.

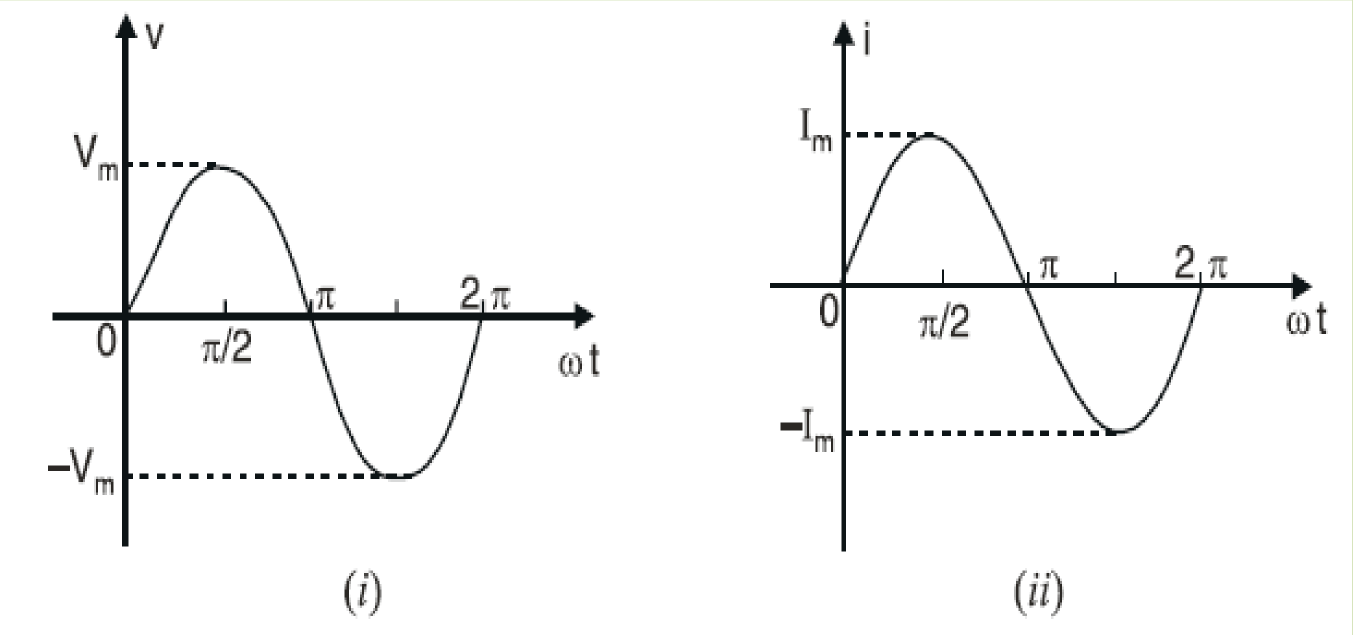
In case the internal resistance of a source is not provided, the voltage sources will be short circuited and current sources will be open circuited.

REPRESENTATION OF SINUSOIDAL WAVEFORMS:-

A voltage which changes its polarity at regular intervals of time is called an **alternating voltage**.

When an alternating voltage is applied in a circuit, the current flows first in one direction and then in the opposite direction; the direction of current at any instant depends upon the polarity of the voltage.





$$v = V_m \sin \omega t$$

where, v = Instantaneous value of alternating voltage

Vm = Max. value of alternating voltage

ω = Angular velocity of the coil

VALUES OF ALTERNATING VOLTAGE AND CURRENT:-

In a d.c. system, the voltage and current are constant so that there is no problem of specifying their magnitudes.

However, an alternating voltage or current varies from instant to instant.

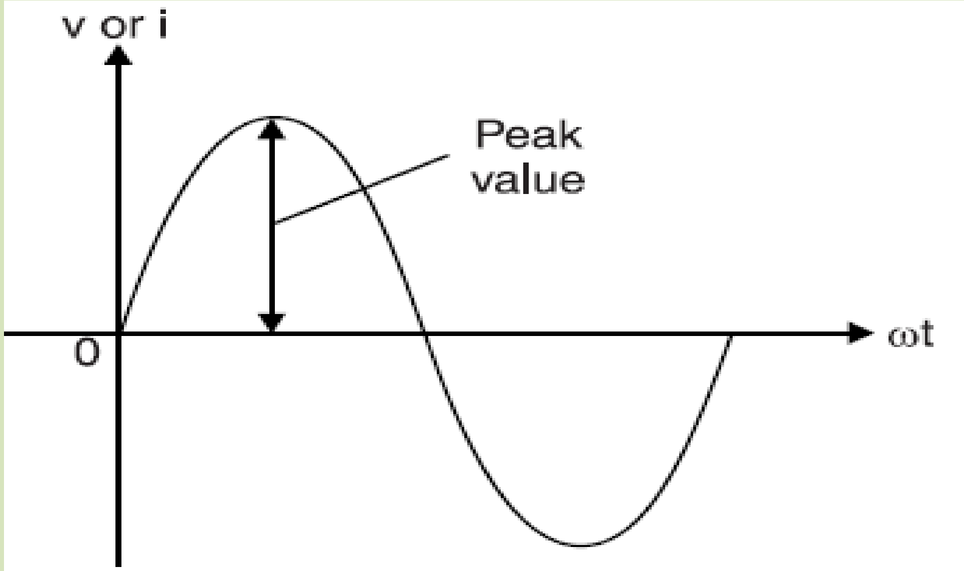
A natural question arises how to express the magnitude of an alternating voltage or current.

There are three ways of expressing it, namely;

(i) Peak value

(ii) Average value or mean value

(iii) R.M.S. value or effective value



(i) Peak Value:

It is the maximum value attained by an alternating quantity.

The peak or maximum value of an alternating voltage or current is represented by Vm or Im.

The knowledge of peak value is important in case of testing materials. However, peak value is not used to specify the magnitude of alternating voltage or current.

Instead, we generally use r.m.s. values to specify alternating voltages and currents.

(ii) Average Value:

The average value of a waveform is the average of all its values over a period of time.

(iii) RMS Value (or) Effective Value:

The **effective (or) r.m.s. value** of an alternating current is that steady current which when flowing through a given resistance for a given time produces the same amount of heat as produced by the alternating current when flowing through the same resistance for the same time.

PHASE DIFFERENCE:-

When two alternating quantities of the same frequency have different zero points, they are said to have a **phase difference.**

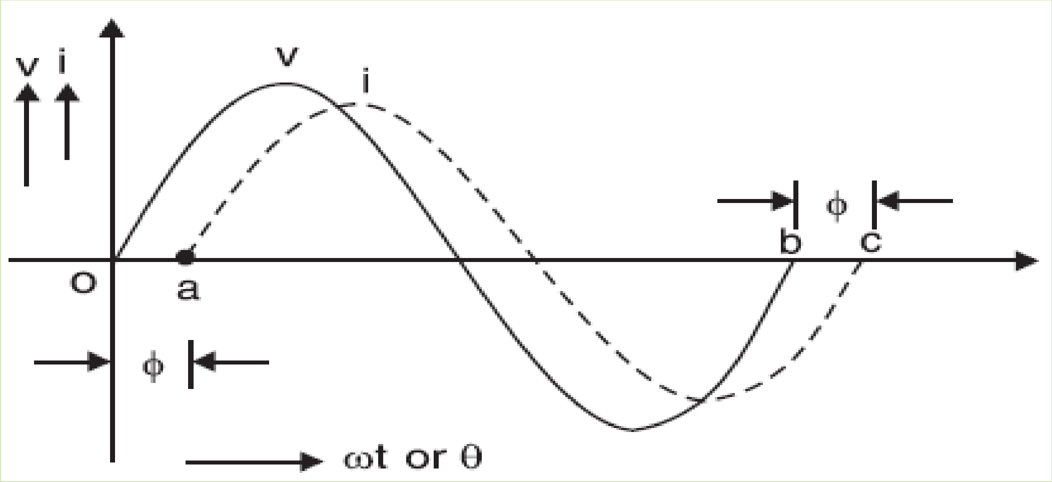
When an alternating voltage is applied to a circuit, an alternating current of the same frequency flows through the circuit.

In most of practical circuits, for reasons we will discuss later, voltage and current have different phases.

In other words, they do not pass through a particular point, say zero point, in the same direction at the same instant.

Thus voltage may be passing through its zero point while the current has passed or it is yet to pass through its zero point in the same direction.

We say that voltage and current have a phase difference.

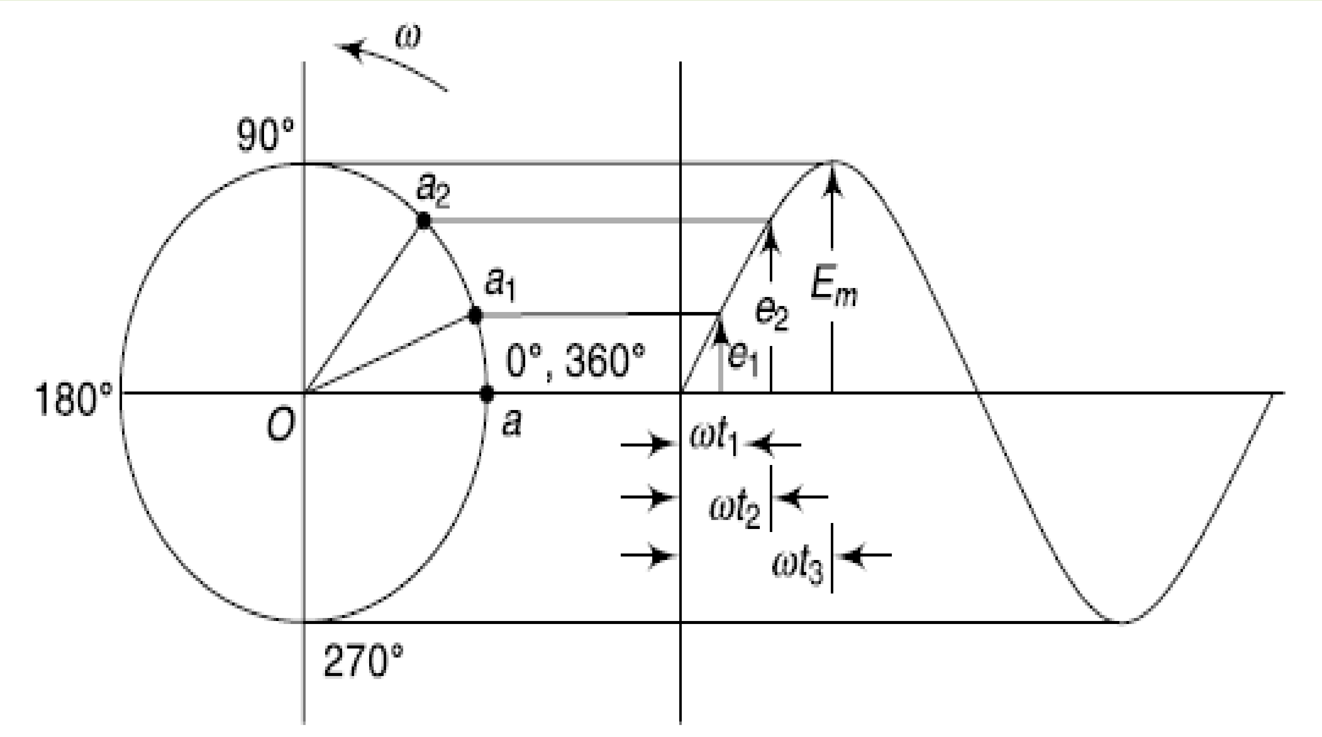


PHASOR REPRESENTATION OF AN ALTERNATING QUANTITY:-

Alternating quantities have varying magnitude and direction.

So they are represented by a rotating vector.

A phasor is a vector rotating at a constant angular velocity.



ANALYSIS OF SINGLE-PHASE AC CIRCUITS CONSISTING OF RL - RC - RLC SERIES CIRCUITS:-

The relationship of applied voltage and current in an ac circuit involving only a resistance, an inductance, and a capacitance.

When a resistance is connected across an ac supply we call it a purely resistive circuit.

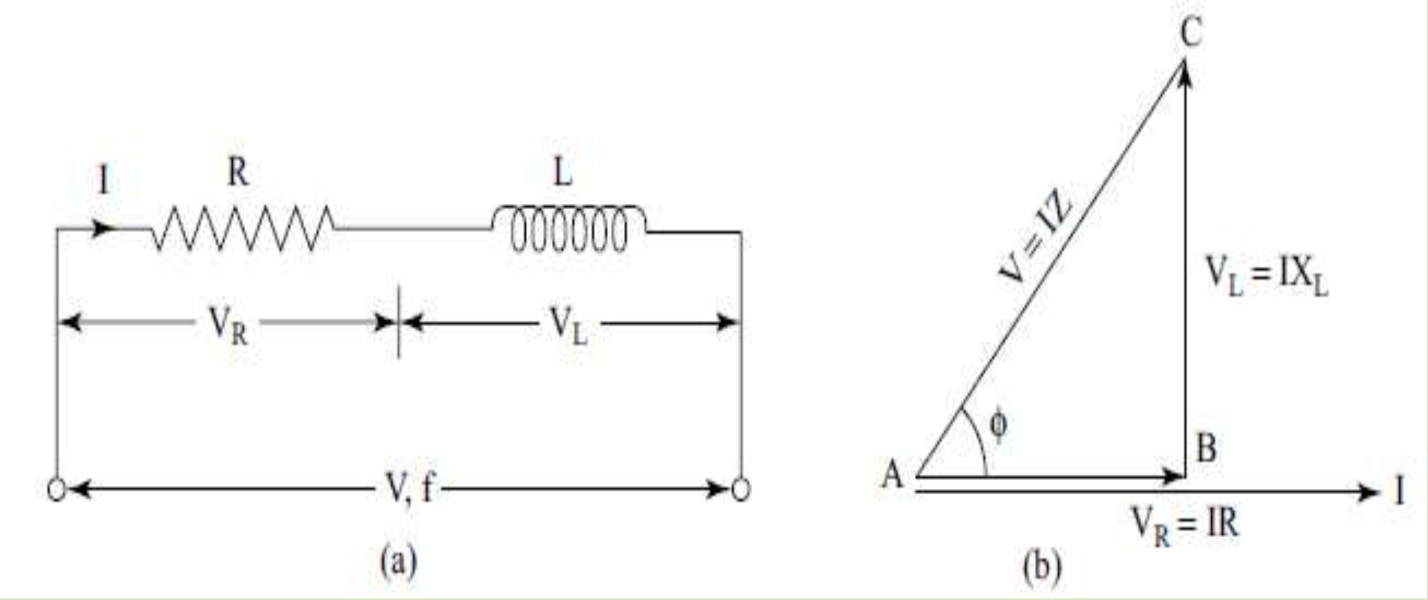
Similarly an inductance coil connected across an ac supply is called a purely inductive circuit and a capacitance connected across an ac supply is called a purely capacitive circuit.

1) **<u>RL SERIES CIRCUITS:-</u>**

Let us consider a resistance element and an inductor connected in series as shown in Fig (a). A voltage (V) of frequency (f) is applied across the whole circuit.

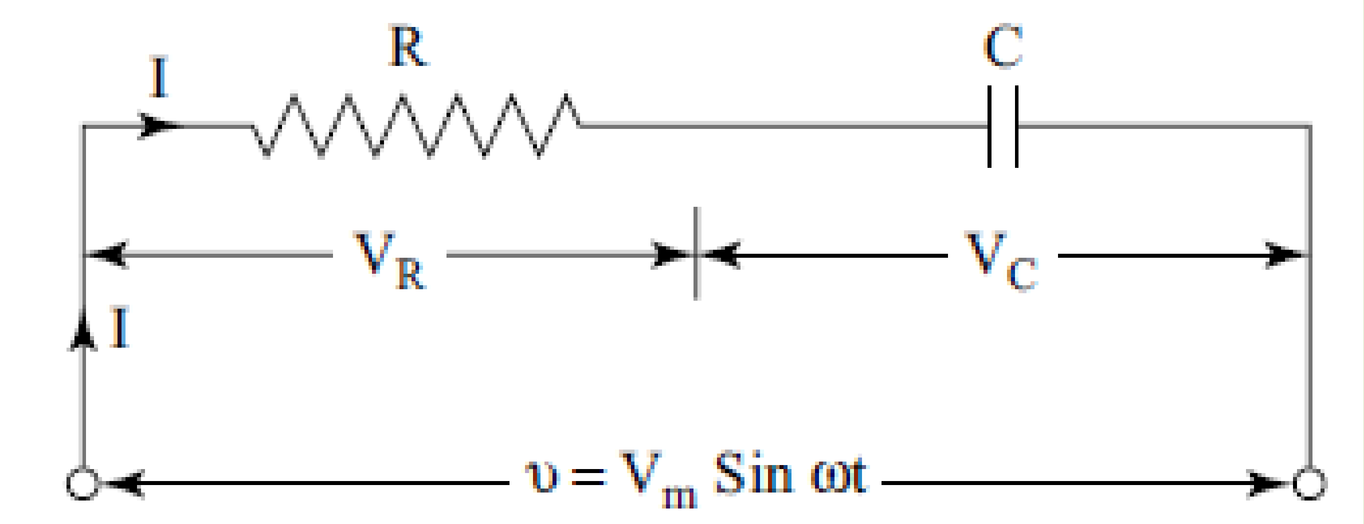
The voltage drop across the resistance is V_R and across the inductor is V_L.

Current flowing through the circuit is I.



2) <u>RC SERIES CIRCUITS:-</u>

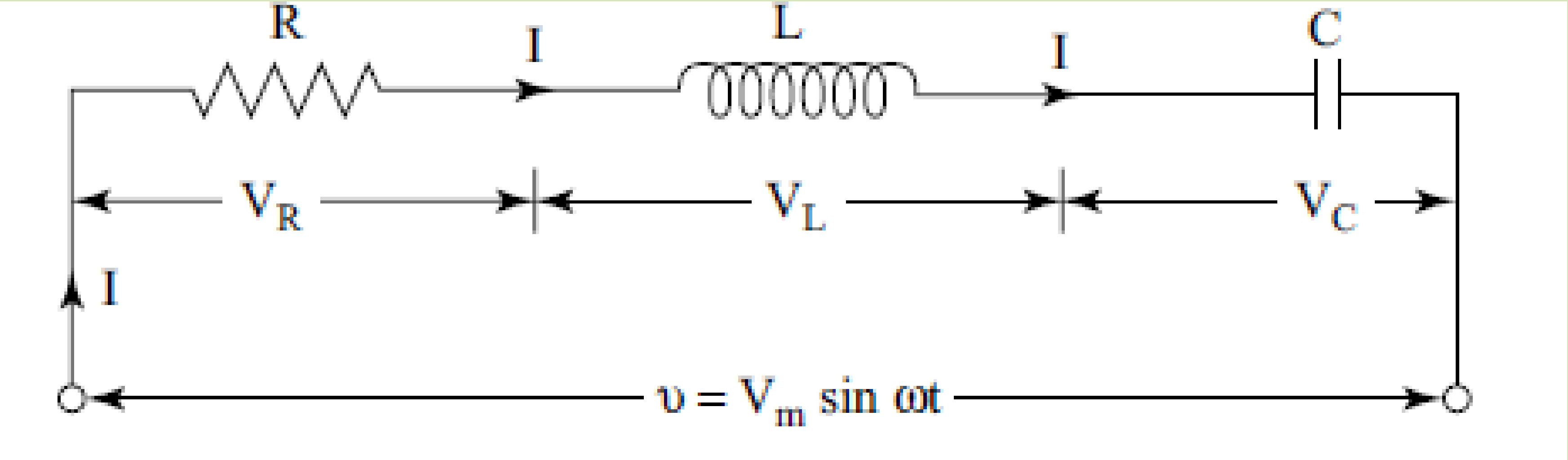
Consider a circuit consisting of a resistance R and connected in series with a capacitor C across an ac supply of frequency f as shown in Figure.



3) **<u>RLC SERIES CIRCUITS:-</u>**

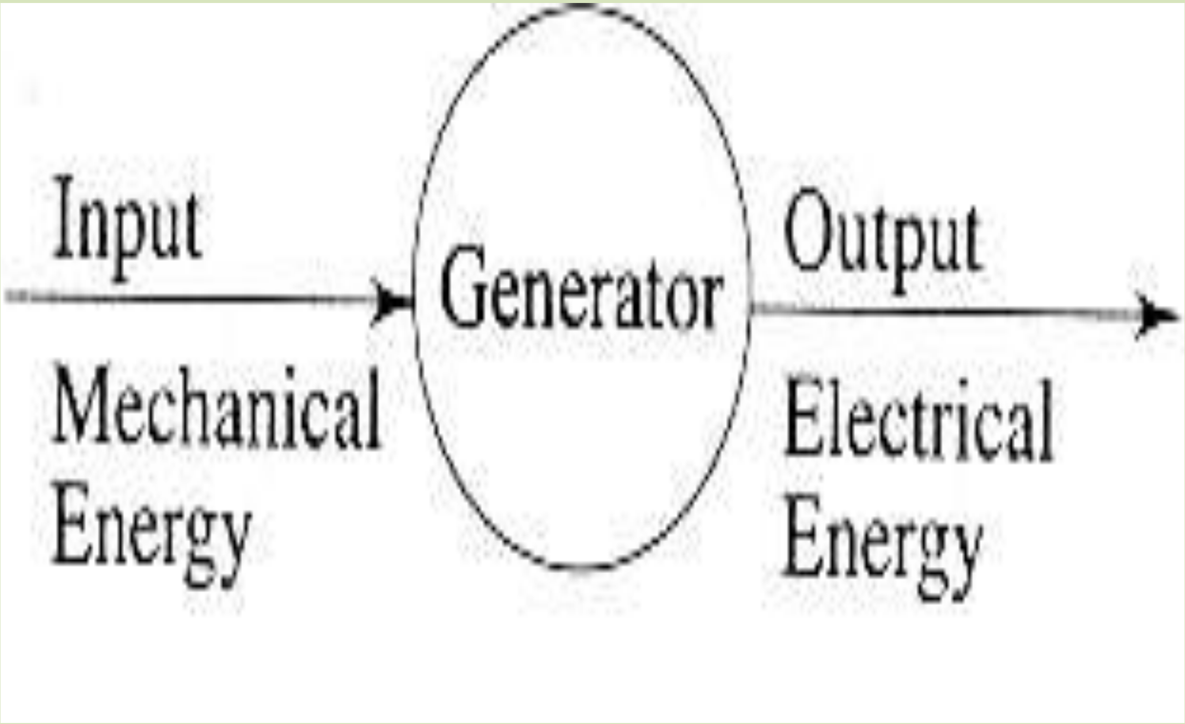
Consider a circuit consisting of resistance R, inductance L, and capacitance C connected in series with each other across an ac supply.

The circuit has been shown in Figure.



UNIT – 2
DC & AC MACHINES

DC Generator



D.C. GENERATORS PRINCIPLE OF OPERATION

- DC generator converts mechanical energy into electrical energy. when a conductor move in a magnetic field in such a way conductors cuts across a magnetic flux of lines and e.m.f. produces in a generator and it is defined by faradays law of electromagnetic induction e.m.f. causes current to flow if the conductor circuit is closed.

First Law :

Whenever the magnetic flux linked with a circuit changes, an e.m.f. is always induced in it.

or

Whenever a conductor cuts magnetic flux, an e.m.f. is induced in that conductor.

Second Law :

The magnitude of the induced e.m.f. is equal to the rate of change of flux linkages.

The following are the basic requirements to be satisfied for generation of E.M.F

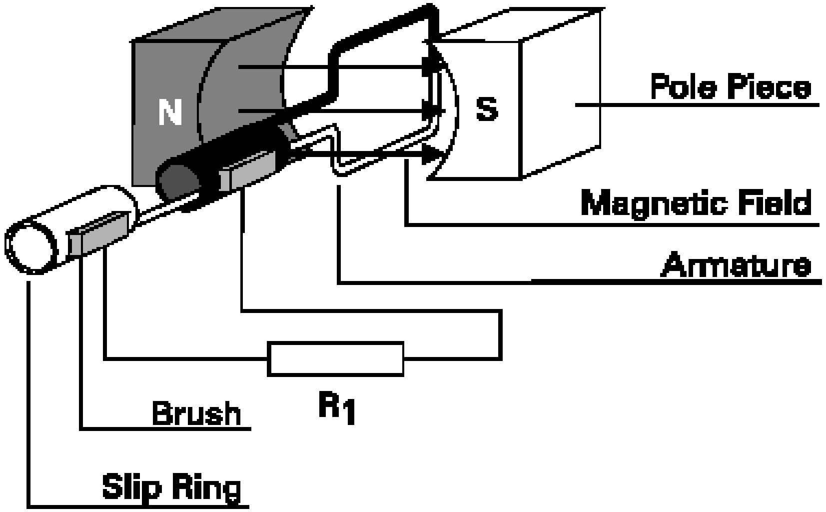
1.A uniform Magnetic field (Flux)
2.A System of conductors
3.Relative motion between the magnetic field and conductors

- **Magnetic field :-**
  Permanent Magnet
  (or)
  Electro Magnet (practical)
- **Conductor :- Copper (or) Aluminum bars placed in slots cut around the periphery of cylindrical rotor**
- **Relative motion:-**
  By Prime Mover
  Turbine
  I.C Engine (Internal combustion)

Working Operation of Generators

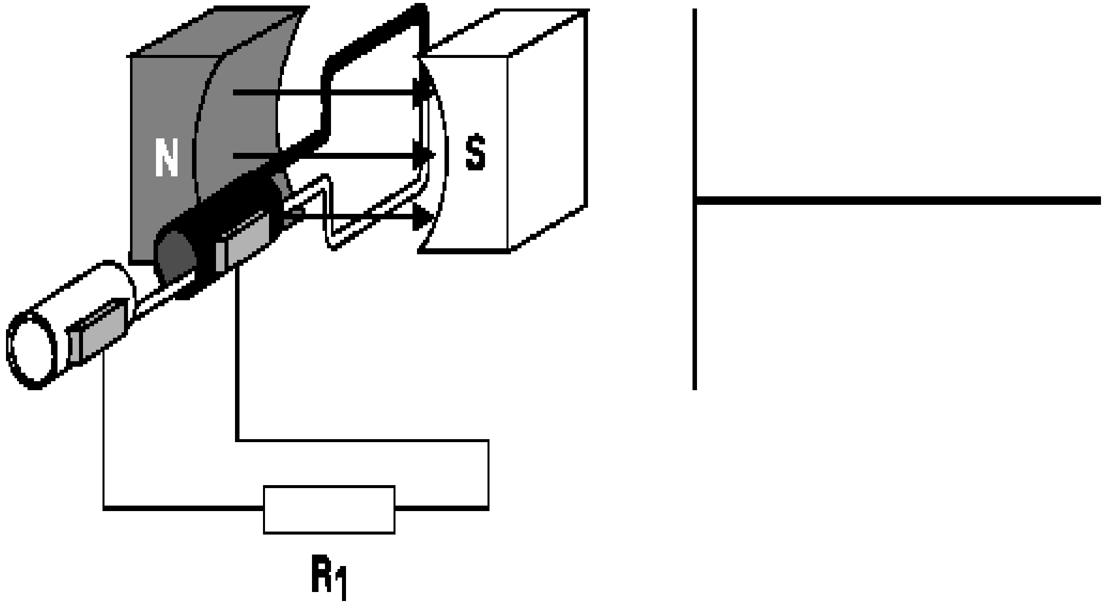
Basic generator

A basic generator consists of a magnetic field, an armature, slip rings, brushes and a resistive load. The magnetic field is usually an electromagnet. An armature is any number of conductive wires wound in loops which rotates through the magnetic field. For simplicity, one loop is shown. When a conductor is moved through a magnetic field, a voltage is induced in the conductor. As the armature rotates through the magnetic field, a voltage is generated in the armature which causes current to flow. Slip rings are attached to the armature and rotate with it. Carbon brushes ride against the slip rings to conduct current from the armature to a resistive load.



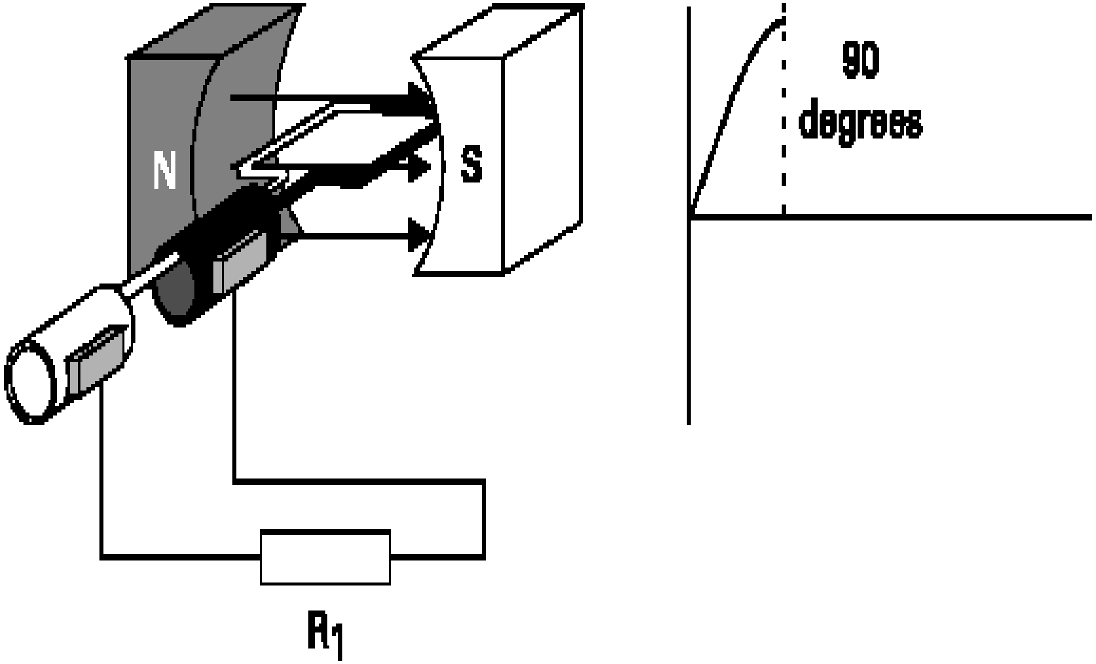
Basic generator operation

An armature rotates through the magnetic field. At an initial position of zero degrees, the armature conductors are moving parallel to the magnetic field and not cutting through any magnetic lines of flux. No voltage is induced.



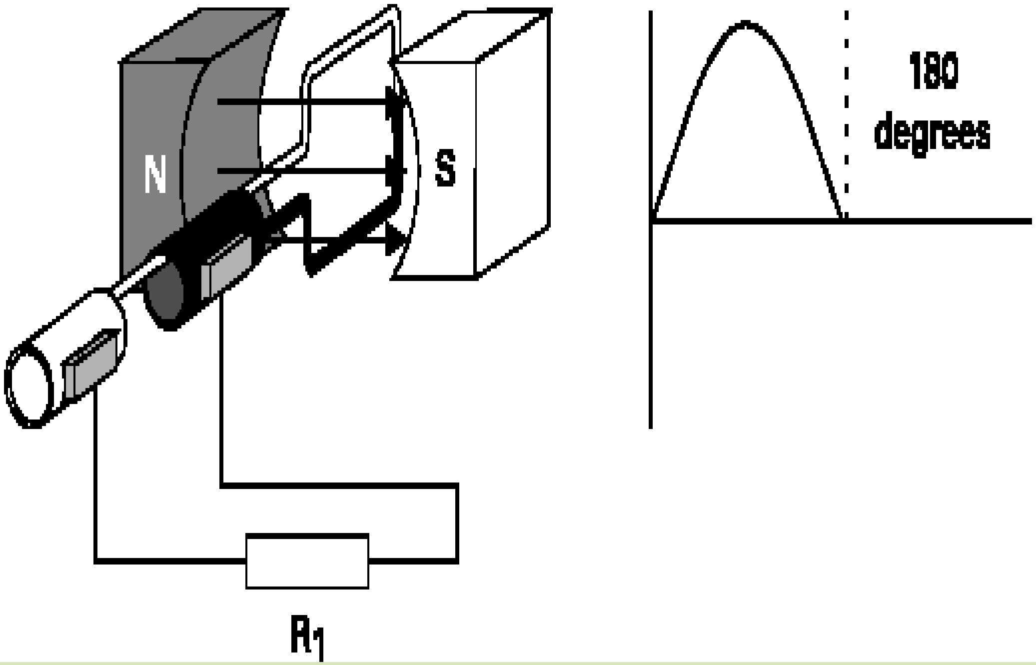
Generator operation from zero to 90 degrees

The armature rotates from zero to 90 degrees. The conductors cut through more and more lines of flux, building up to a maximum induced voltage in the positive direction.



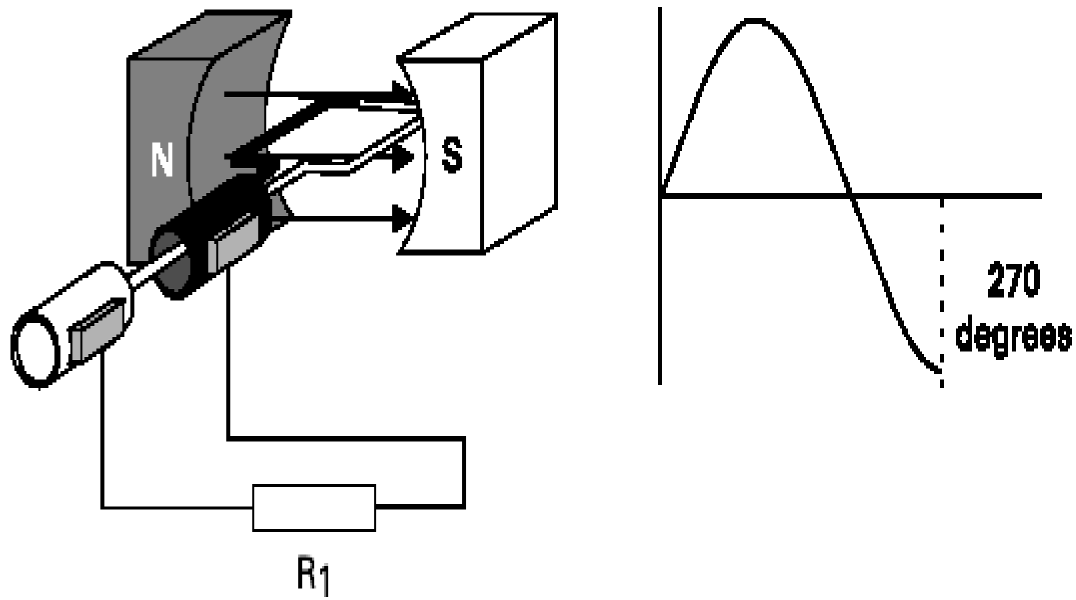
Generator operation from 90 to 180 degrees

The armature continues to rotate from 90 to 180 degrees, cutting less lines of flux. The induced voltage decreases from a maximum positive value to zero.



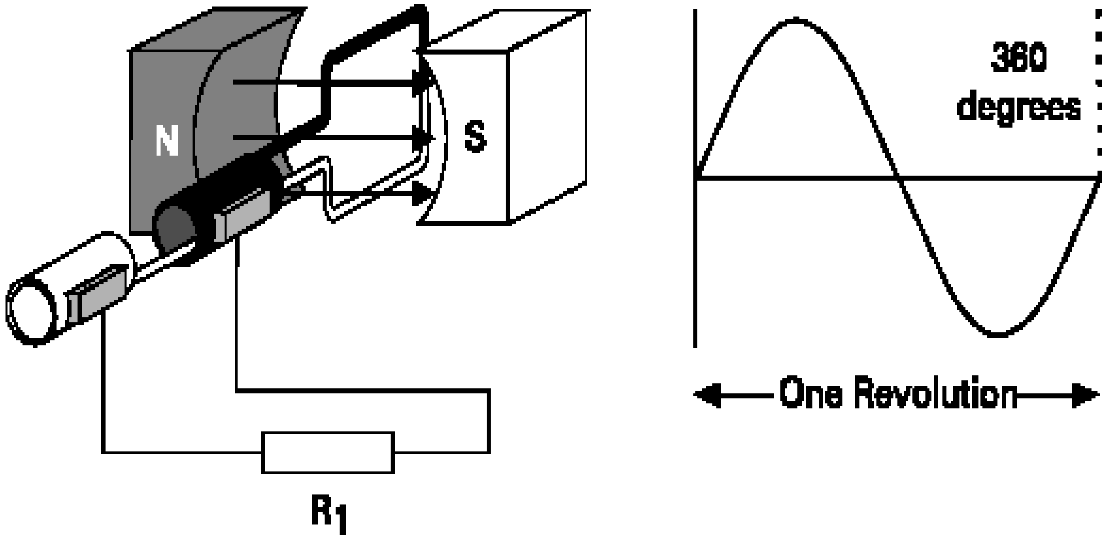
Generator operation from 180 to 270 degrees

The armature continues to rotate from 180 degrees to 270 degrees. The conductors cut more and more lines of flux, but in the opposite direction. Voltage is induced in the negative direction building up to a maximum at 270 degrees.



Generator operation from 270 to 360 degrees

The armature continues to rotate from 270 to 360 degrees. Induced voltage decreases from a maximum negative value to zero. This completes one cycle. The armature will continue to rotate at a constant speed. The cycle will continuously repeat as long as the armature rotates.



Generated EMF or EMF Equation of a generator

Let Φ = flux/pole in Weber

Z =Total number of armature conductors

=No. of slot × No. of conductors/slot

P= No. of generator poles

A =No. of parallel paths in armature

N= Armature rotation in revolutions per minute (r. p. m)

E= e.m.f induced in any parallel path in armature

Average e.m.f generated/conductor = $\frac{d\Phi}{dt}$ volt

Now, flux cut/conductor in one revolution $d\Phi = \Phi P$ wb

No. of revolutions/sec=N/ 60

$\therefore$ Time for one revolution , dt= 60 /N sec

According to Faraday's Law of electro magnetic induction

E.M.F generated/conductor = $\frac{d\Phi}{dt} = \frac{\Phi PN}{60}$ volts

No. of conductors (in series) in one parallel path= Z / A

$\therefore$ E.M.F generated/path= $\frac{\Phi PN}{60} \times \frac{Z}{A}$ Volts

$\therefore$ Generate E.M.F, $E_g = \frac{\Phi Z N}{60} \times \frac{P}{A}$ Volts

For

i) Wave winding A = 2

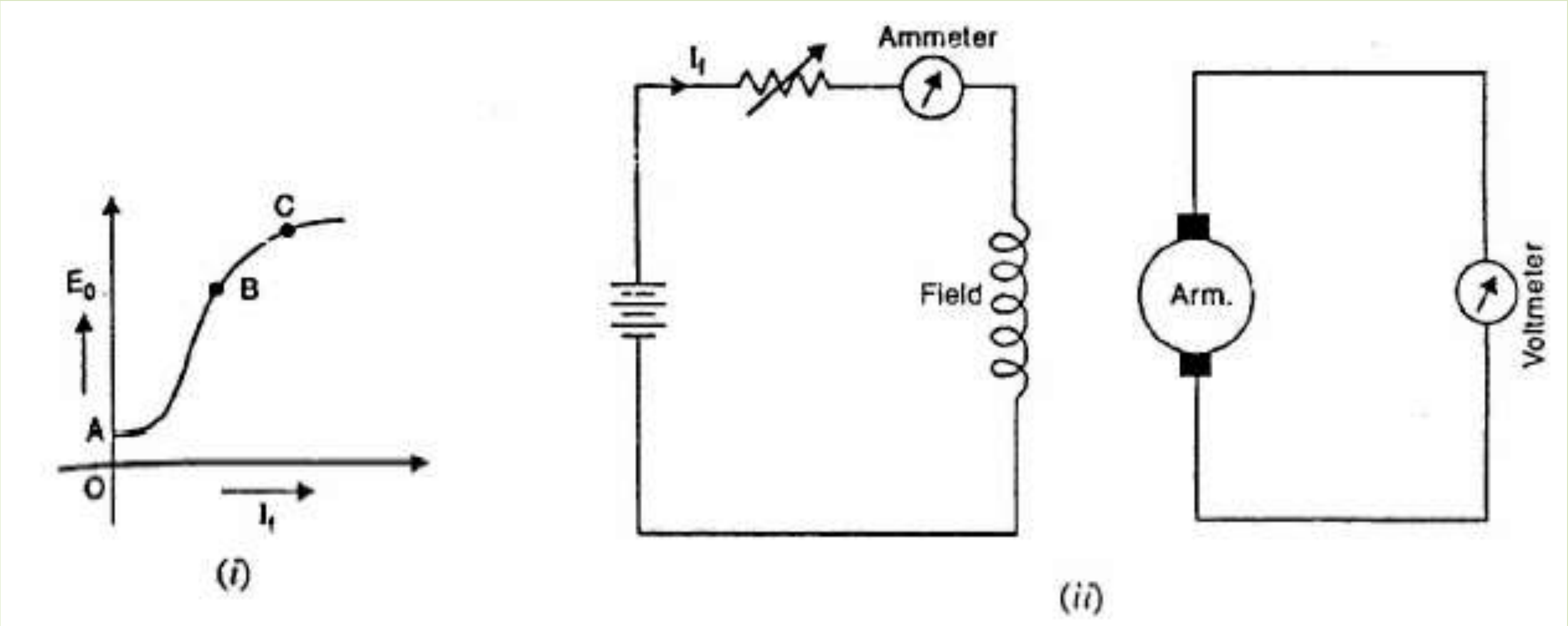
ii) Lap winding A = P

D.C. Generator Characteristics

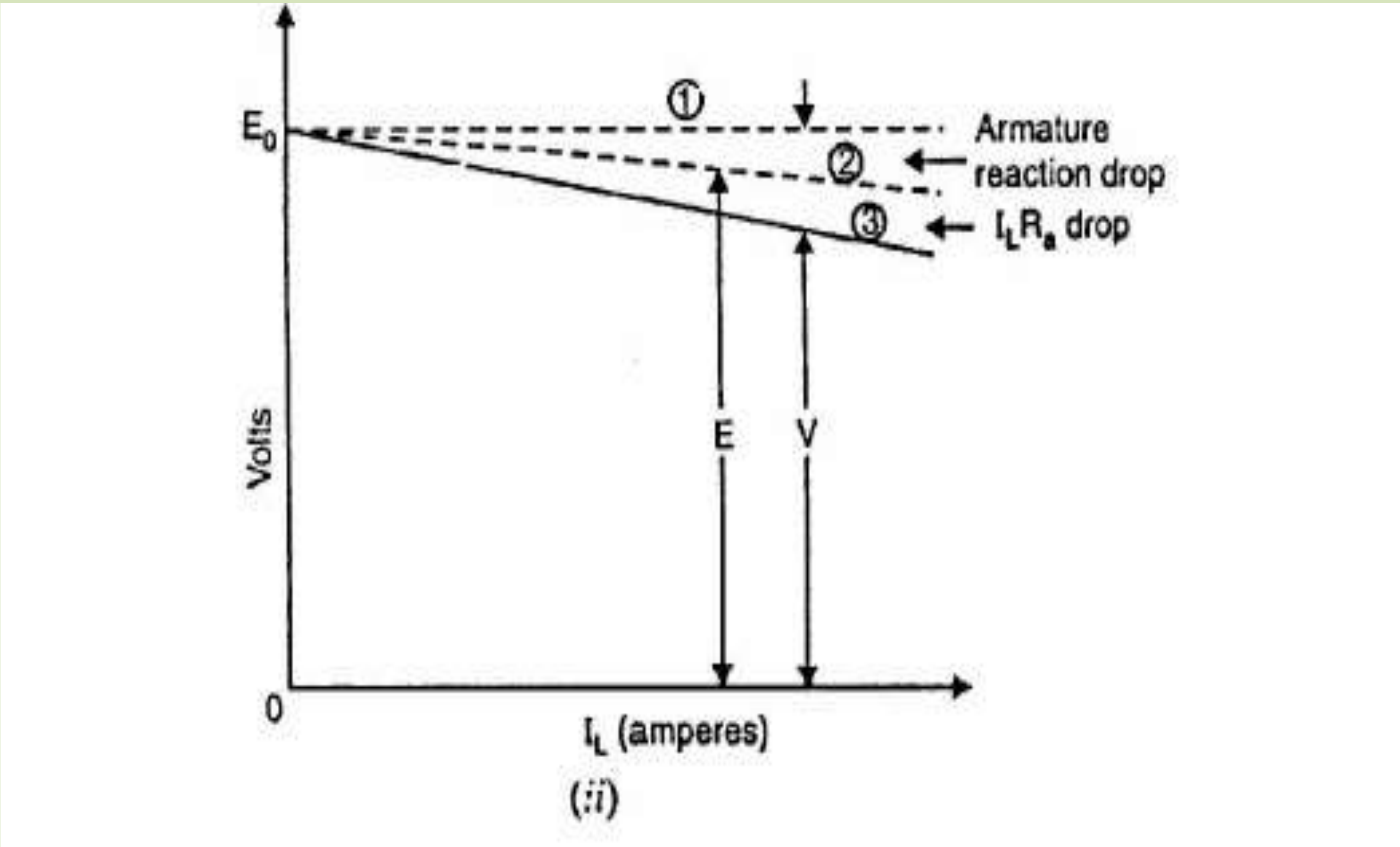
The following are the three most important characteristics in a D.C. generator:

1. Open Circuit Characteristics (E_o/I_F)
2. Internal Characteristics (E/I_a)
3. External Characteristics (V/I_a)

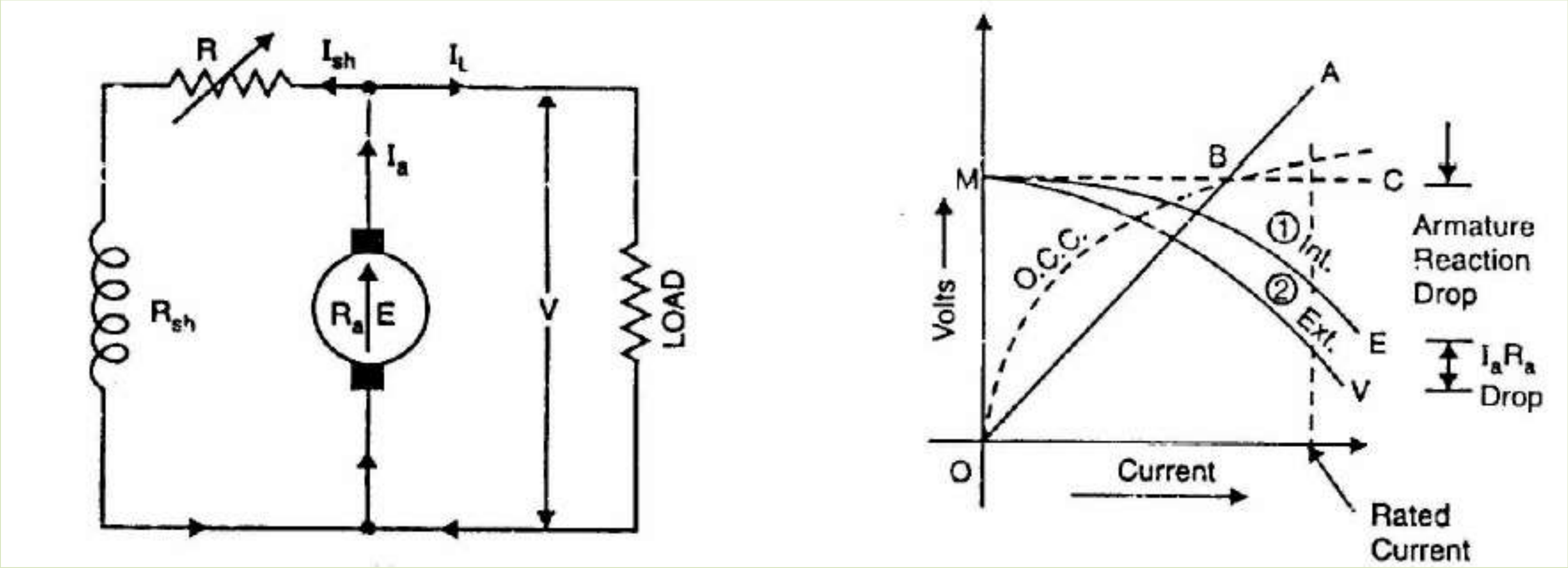
Open circuit characteristics of Separately Excited D.C. Generator

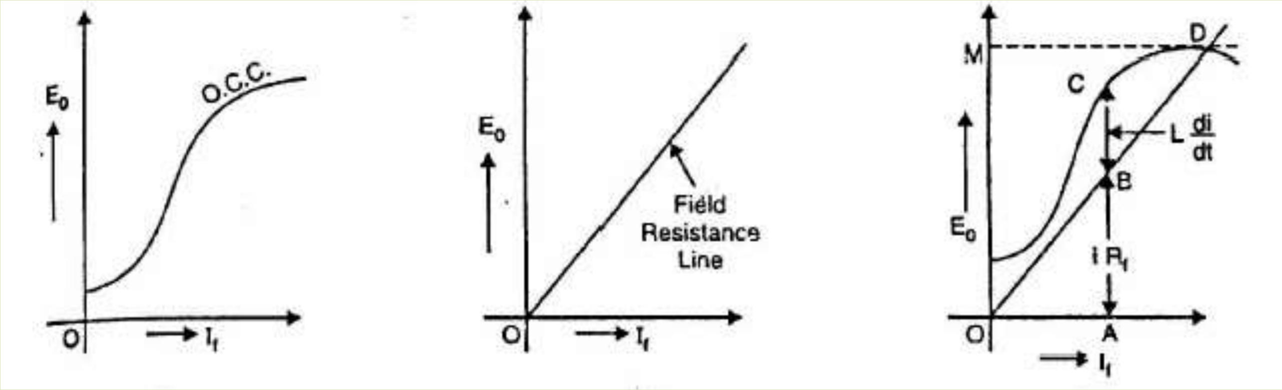


Internal and External Characteristics

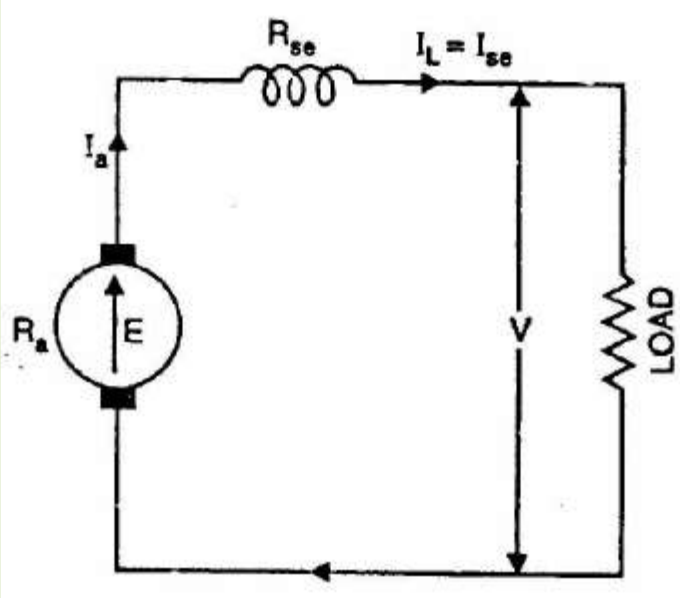


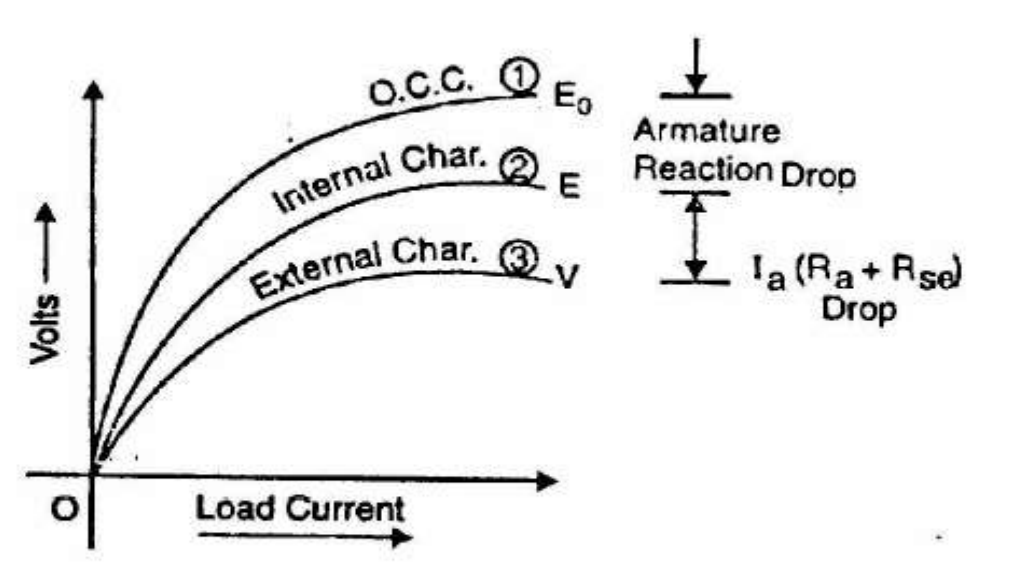
Characteristics of Shunt Generator



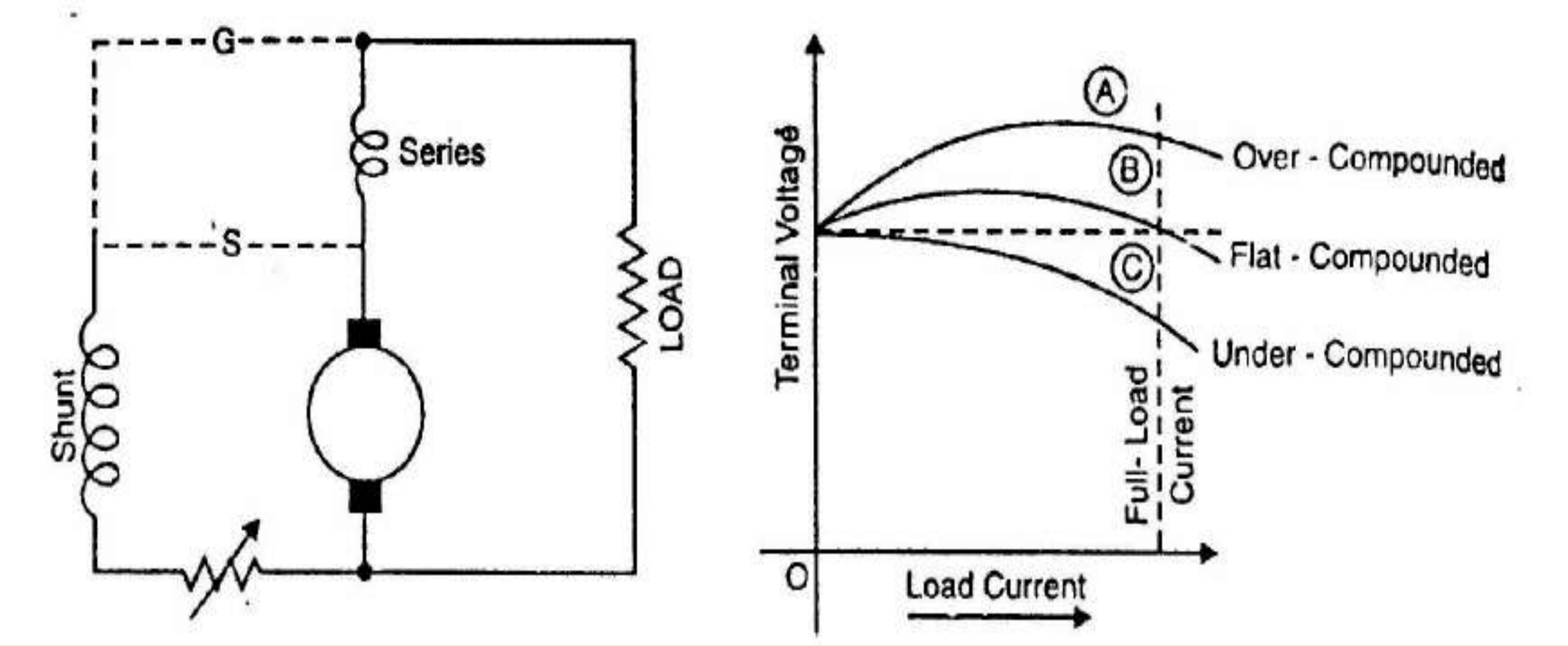


Characteristics of Series Generator

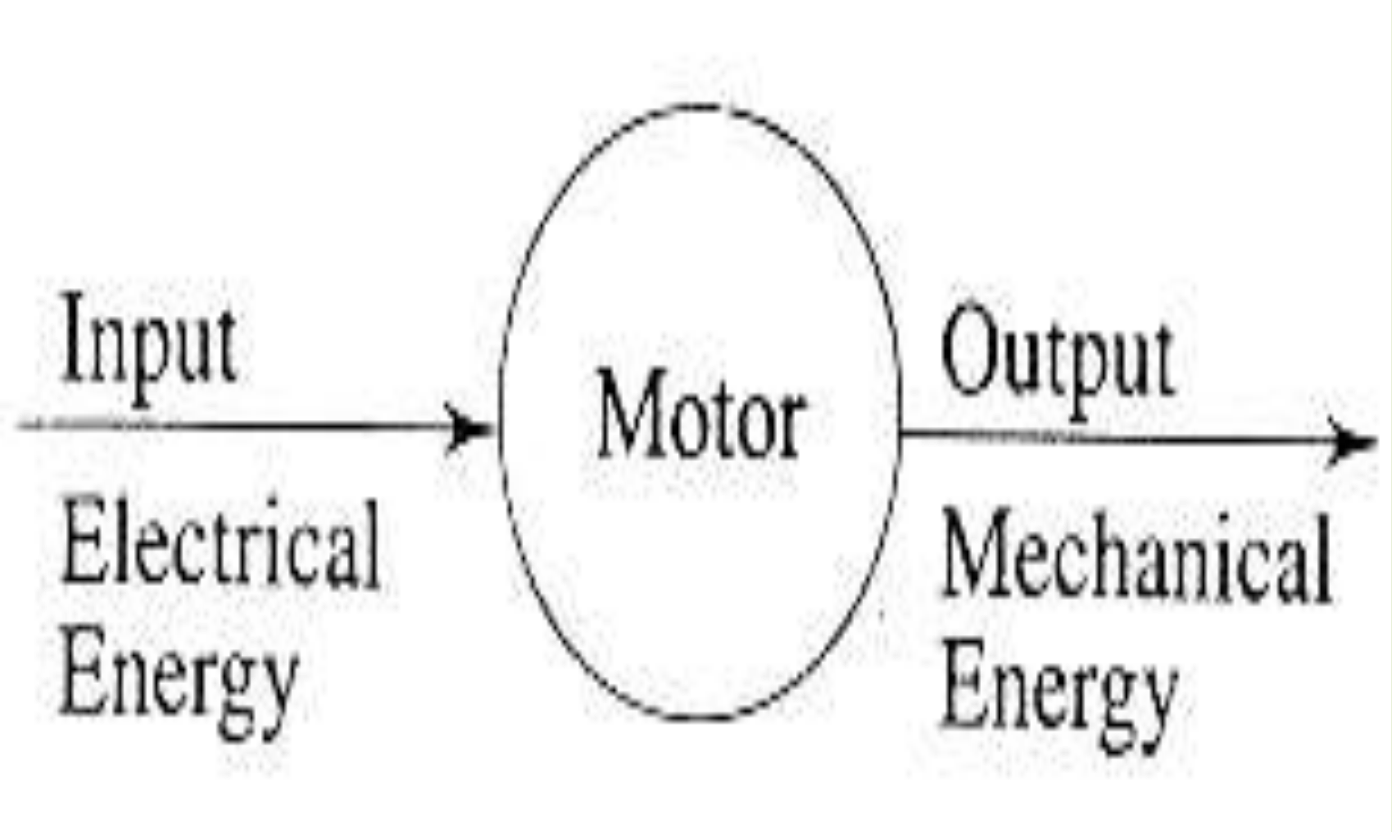




Compound Generator Characteristics



DC motor

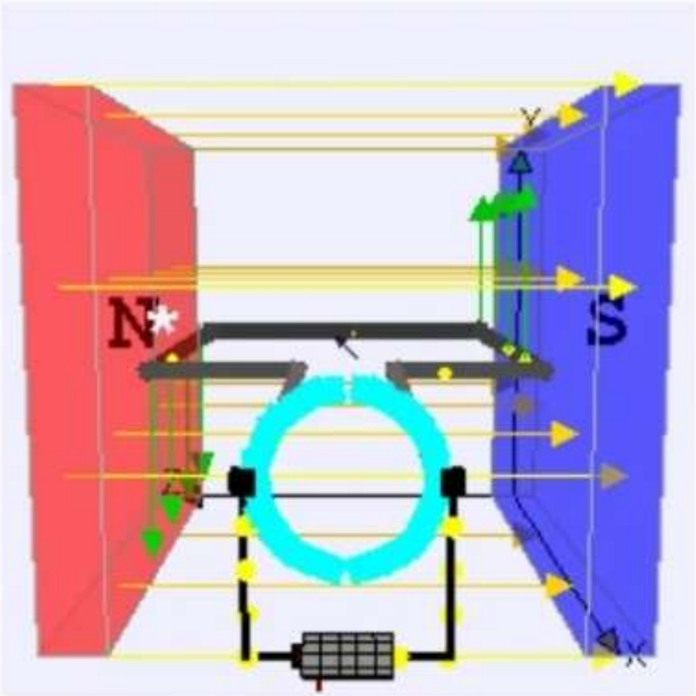


DC MOTOR

- A DC motor or Direct Current Motor converts electrical energy into mechanical energy.
- A direct current (DC) motor is a fairly simple electric motor that uses electricity and a magnetic field to produce torque, which turns the rotor and hence give mechanical work.

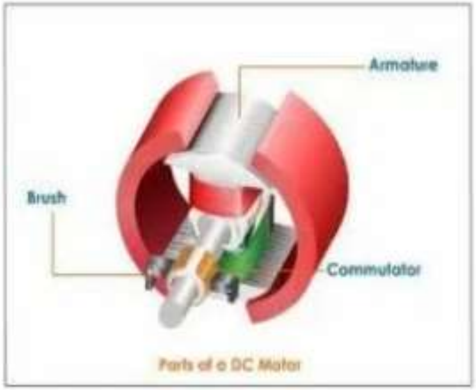
PRINCIPLE OF DC MOTORS

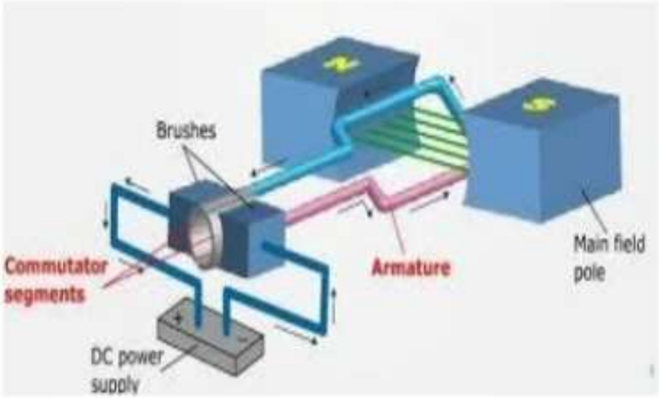
- In any electric motor, operation is based on simple electromagnetism.
- When a current-carrying conductor is placed in an external magnetic field, it will experience a force i.e. Lorentz force.
- Due to this force torque is produced which rotates the rotor of motor and hence a motor runs.



Principle of operation of DC Motor:

When current carrying conductor is placed in a magnetic field it experience a force.





Characteristics of DC Shunt Motor:

To study the performance of the DC shunt Motor various types of characteristics are to be studied.

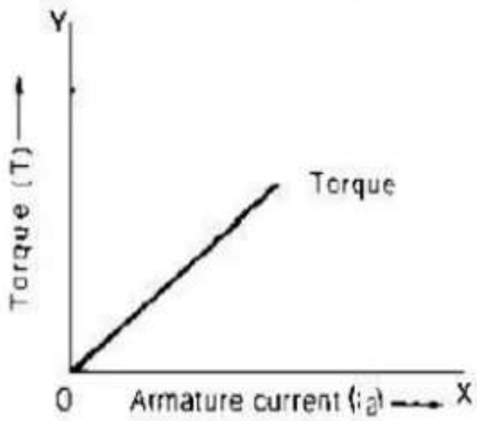
1. Torque Vs Armature current characteristics.
2. Speed Vs Armature current characteristics.
3. Speed Vs Torque characteristics.

Torque Vs Armature current characteristics of DC Shunt motor

This characteristic gives us information that, how torque of machine will vary with armature current, which depends upon load on the motor.

$$T \propto Ia$$

Thus,



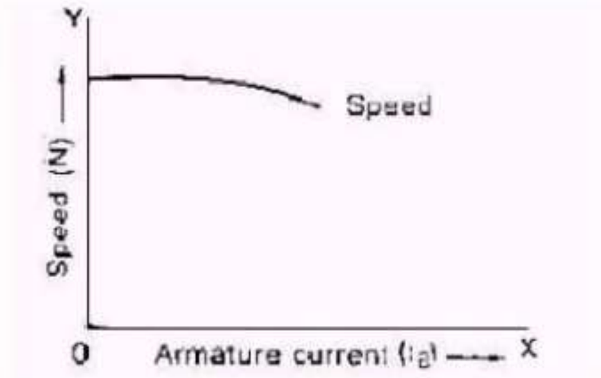
Speed Vs Armature current characteristics of DC Shunt Motor

The back emf of dc motor is $Eb = \frac{N\emptyset ZP}{A60} = V - IaRa$

Therefore $N = \frac{(V - I_a R_a)\ 60\ A}{\phi PZ} = \frac{K(V - I_a R_a)}{\phi}$

where K = 60A/ ZP and it is constant. In dc shunt motor, when supply voltage V is kept constant the shunt field current and hence flux per pole will also be constant.

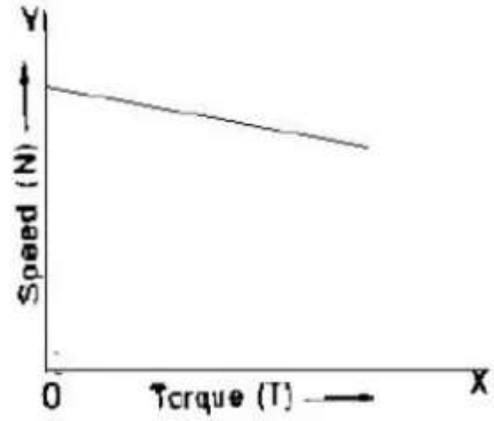
$\therefore N \propto V - Ia\,Ra$



- Therefore shunt motor is considered as constant speed motor.

Speed Vs Torque characteristics of DC Shunt motor

- From the above two characteristics of dc shunt motor, the torque developed and speed at various armature currents of dc shunt motor may be noted.
- If these values are plotted, the graph representing the variation of speed with torque developed is obtained.
- This curve resembles the speed Vs current characteristics as the torque is directly proportional to the armature current.



Torque Vs Armature current characteristics of DC Series motor

- Torque developed in any dc motor is

$$T \propto \emptyset Ia$$

- In case of a D.C. series motor, as field current is equal to armature current, and for small value of I_a

$$\emptyset \propto I_a$$

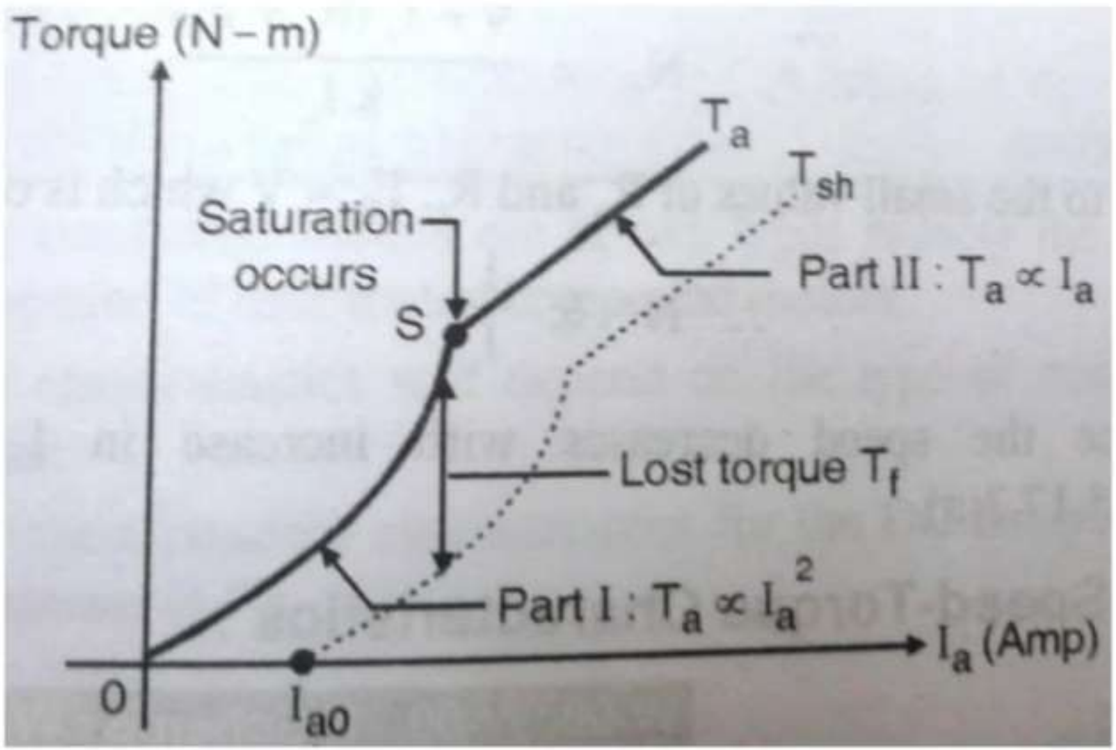
- Therefore the torque in the dc series motor for small value of I_a

$$T \propto Ia^2$$

- When I_a is large the $\emptyset$ remains the constant due to saturation, thus torque is directly proportional to armature current for large value of I_a

$$T \propto I_a$$

- Thus Torque Vs Armature current characteristics begin to raise parabolically at low value of armature current and when saturation is reached it become a straight line as shown below.



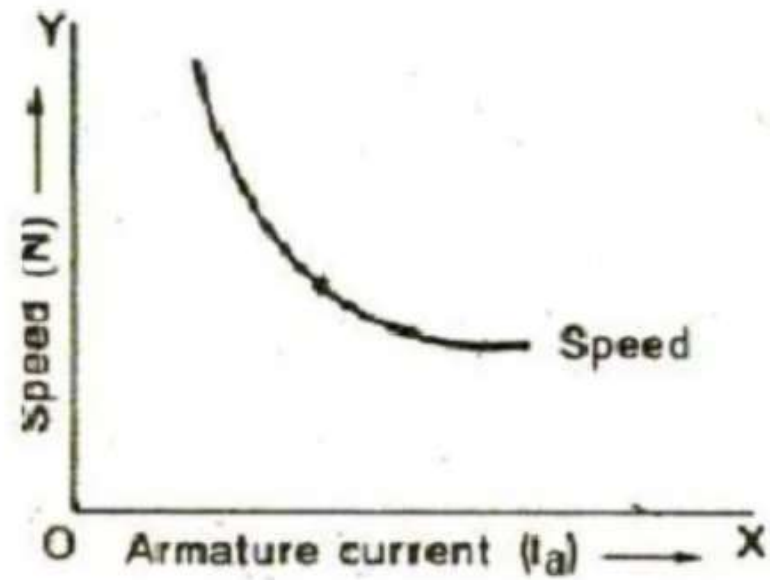
Speed Vs Armature current characteristics of DC Series Motor

Consider the following equation:

$$N = \frac{K(V - IaRa)}{\emptyset}$$

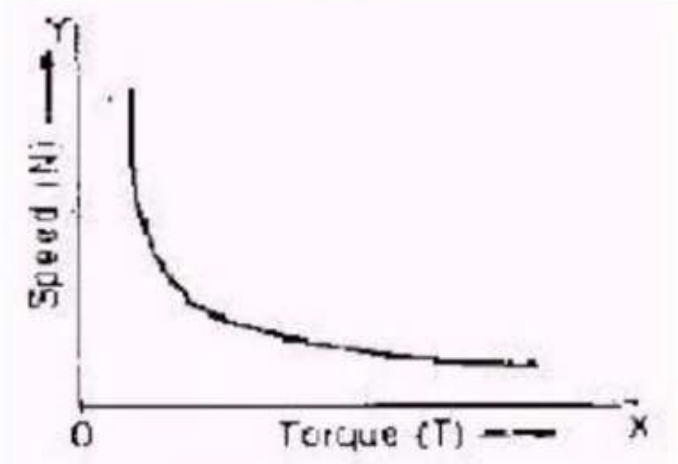
When supply voltage V is kept constant, speed of the motor will be inversely proportional to flux. In dc series motor field exciting current is equal to armature current which is nothing but a load current. Therefore at light load when saturation is not attained, flux will be proportional to the armature current and hence speed will be inversely proportional to armature current. Hence speed and armature current characteristics is hyperbolic curve upto saturation.

- As the load increases the armature current increases and field gets saturated, once the field gets saturated flux will become constant irrespective of increases in the armature current. Therefore at heavy load the speed of the dc series motor remains constant.
- This type of dc series motor has high starting torque.



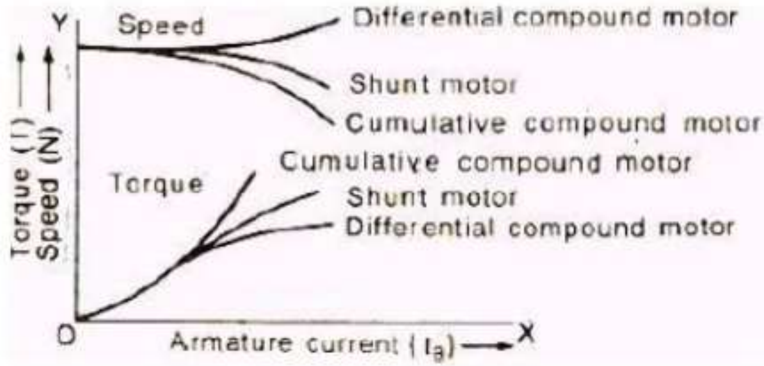
Speed Vs Torque characteristics of DC Series motor

- The Speed Vs Torque characteristics of dc series motor will be similar to the Speed Vs Armature current characteristics it will be rectangular hyperbola, as shown in the fig.

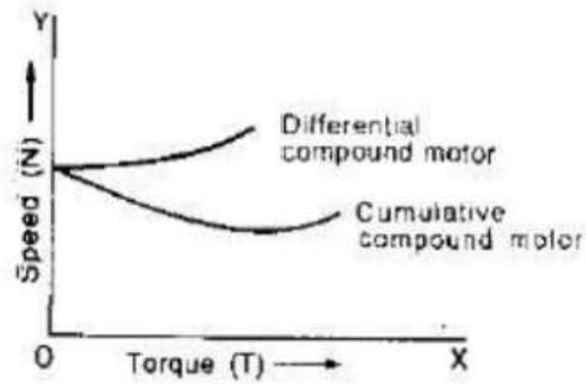


- In dc compound motors both shunt and series field acting simultaneously.
- In cumulative compound motor series field assist the shunt field.
- In such motors when armature current increases the field flux increases.
- So for given armature current the torque developed will be greater and speed lower when compared to a dc shun motor.
- In differential compound motor series field opposes the shunt field, therefore when armature current decreases the field flux decreases, so for given armature current the torque developed will be lower and speed greater when compare to the dc shunt motor.

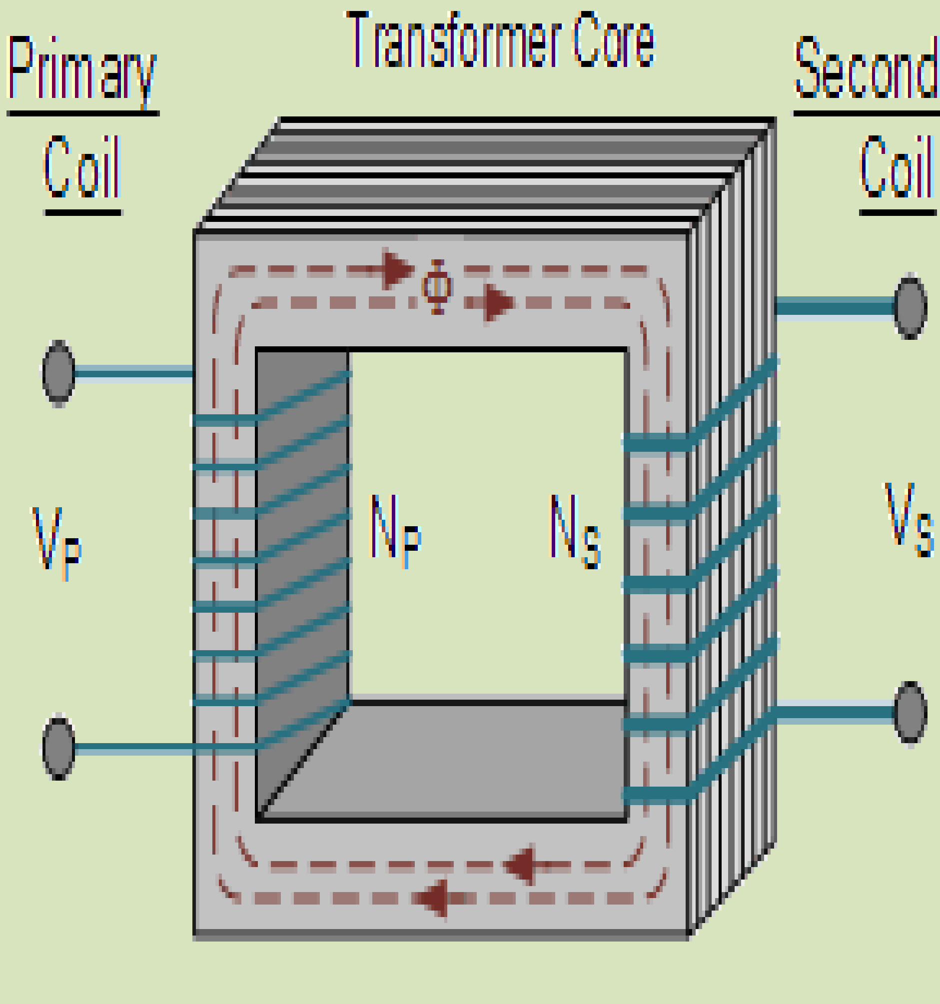
Torque Vs Armature current and Speed Vs Armature current characteristics of dc compound motors



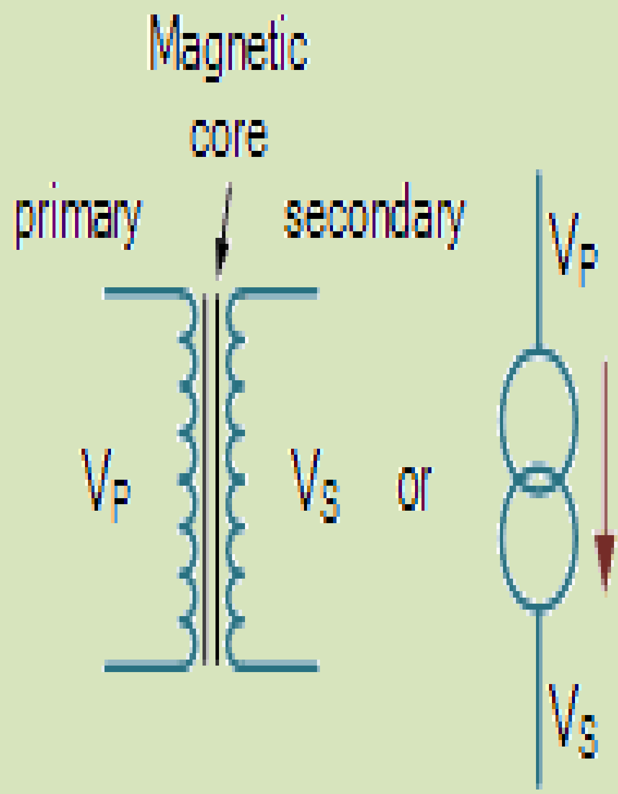
Speed Vs Torque characteristics are compared with that of shunt motor.



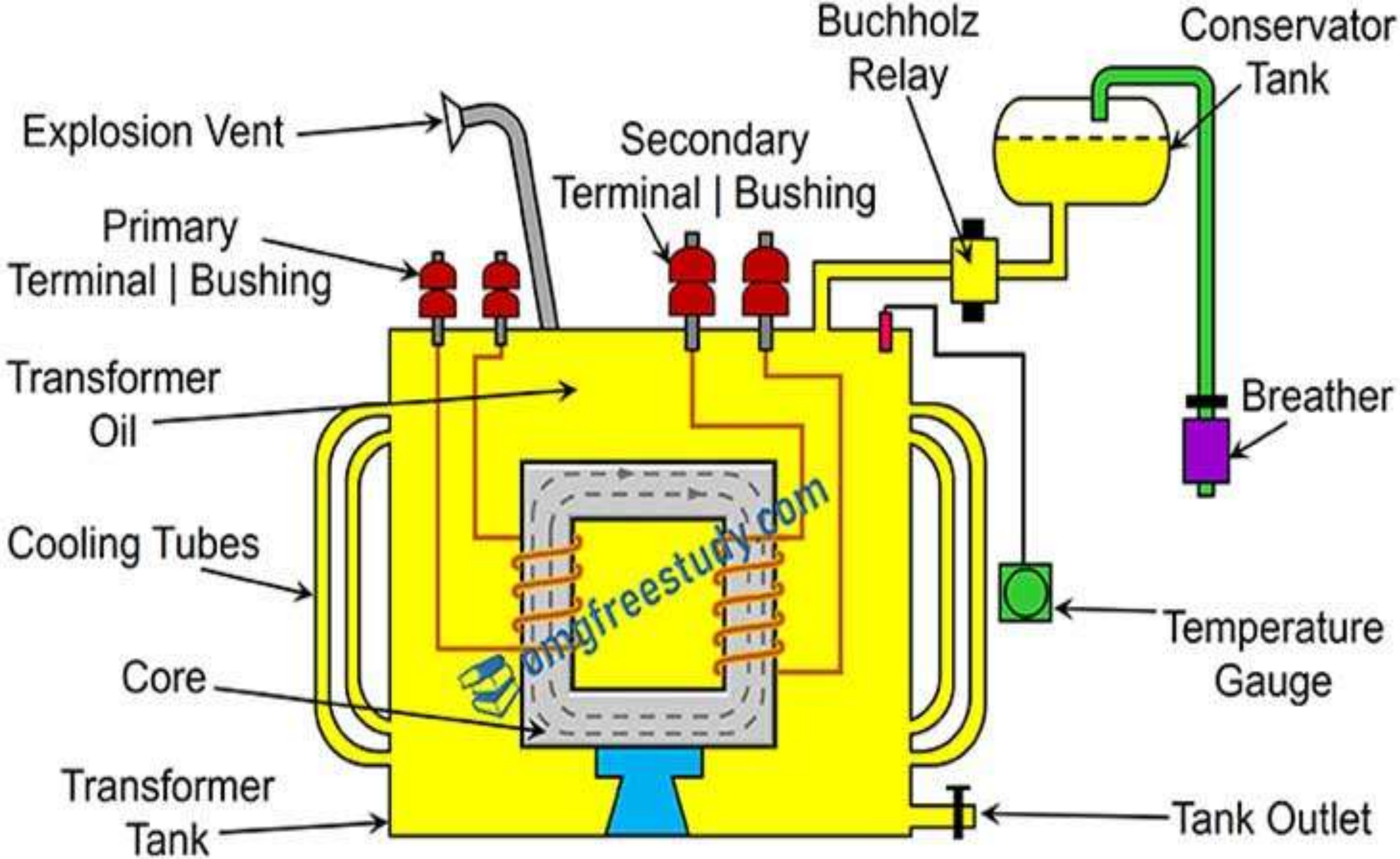
TRANSFORMER



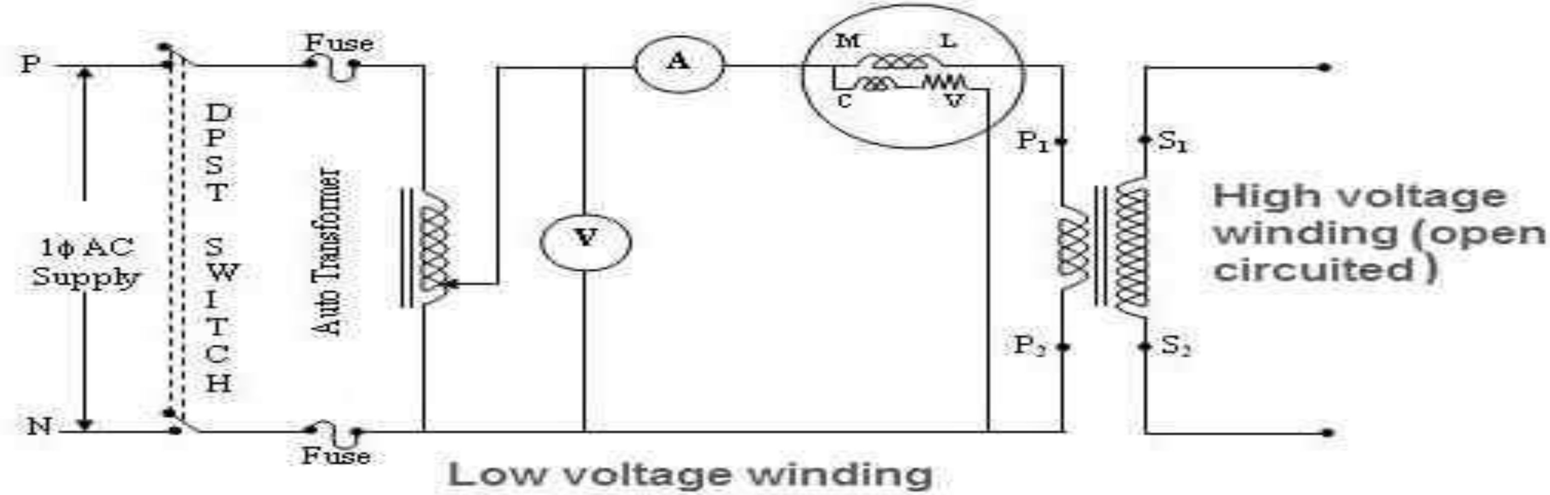
Transformer Construction



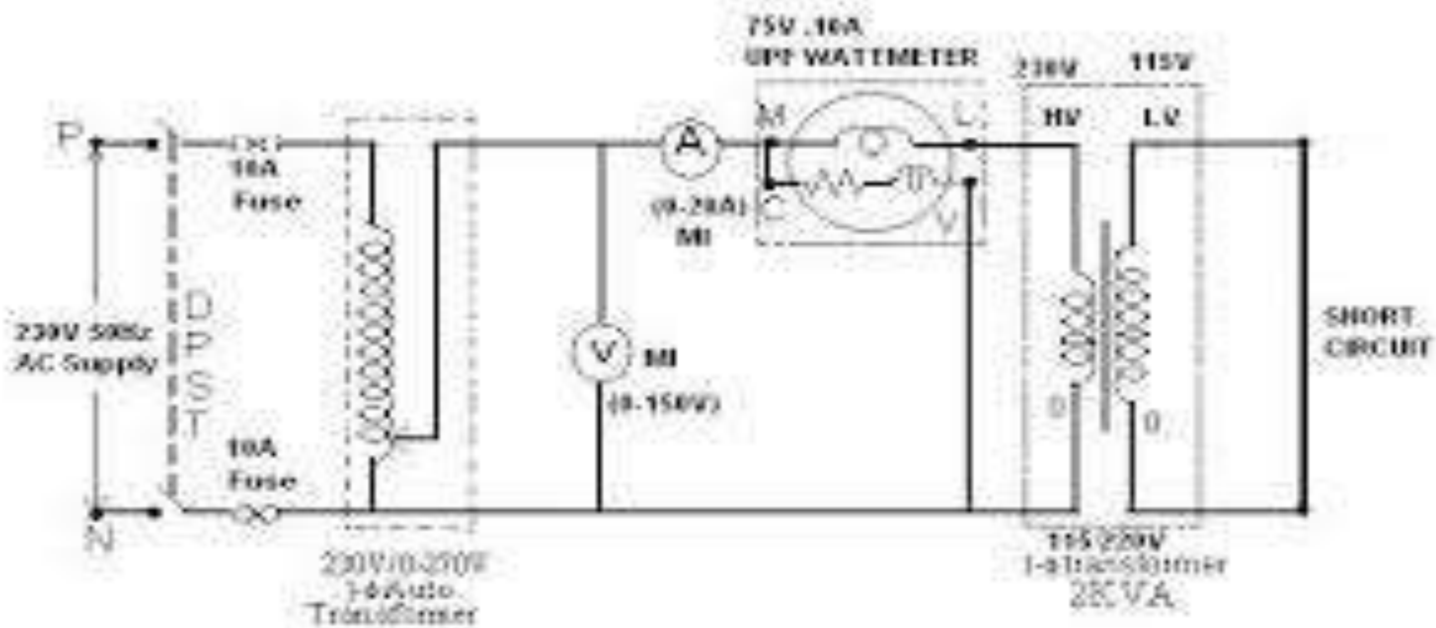
Transformer Symbols



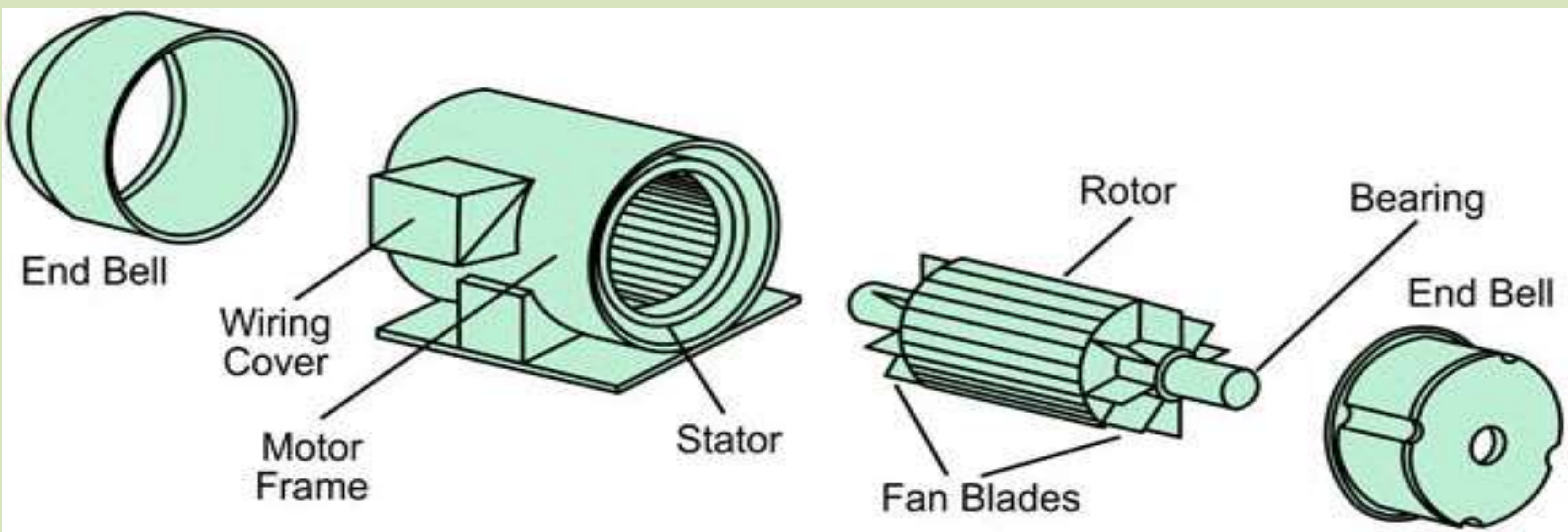
Construction of Transformer

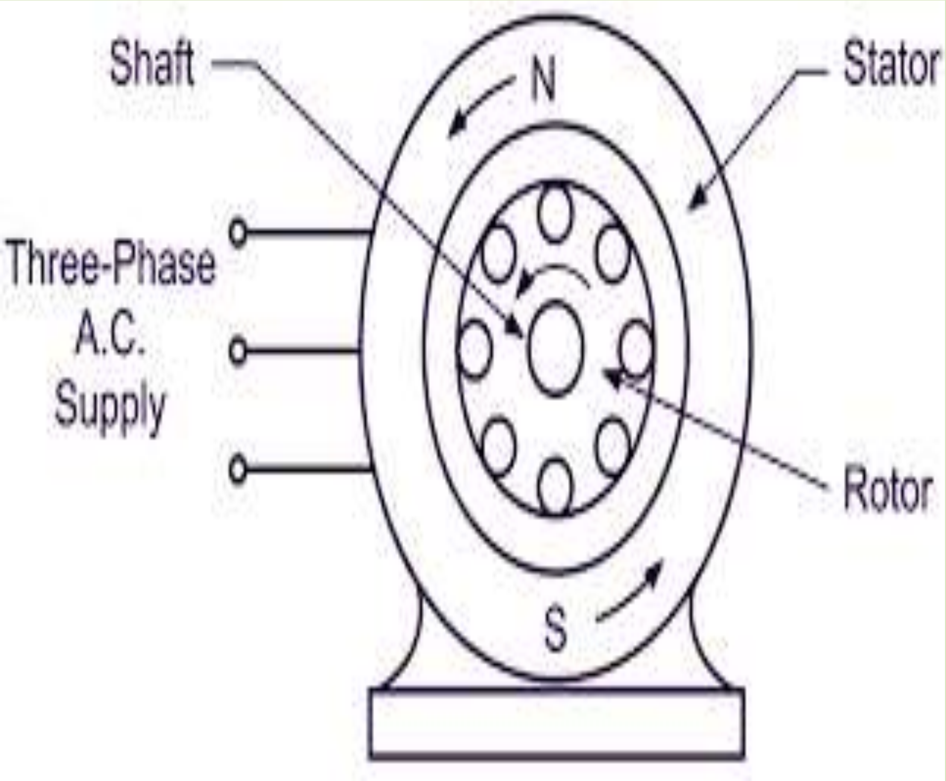


Open Circuit Test of a Transformer

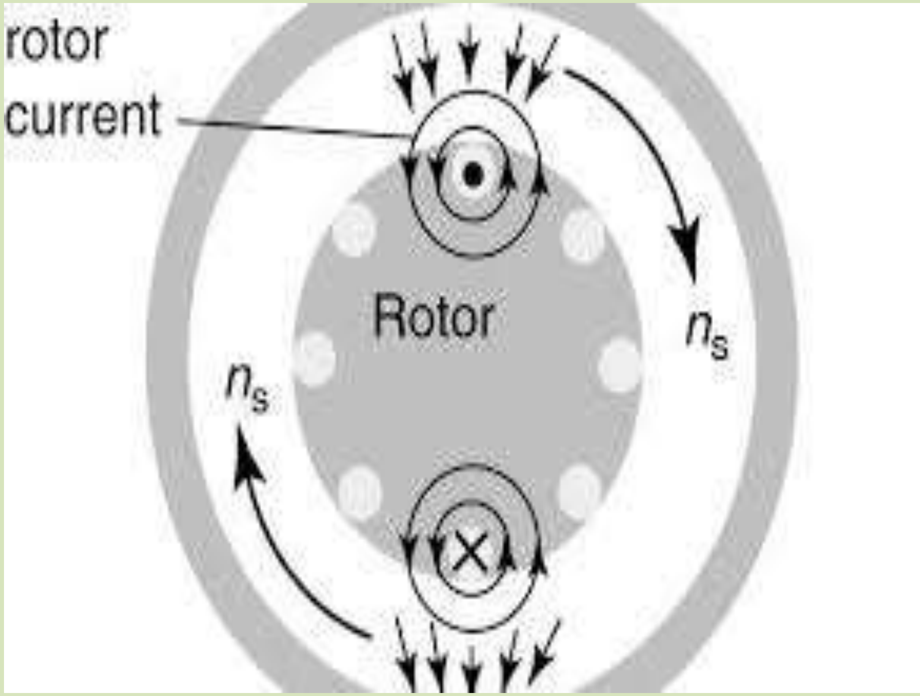


INDUCTION MOTOR





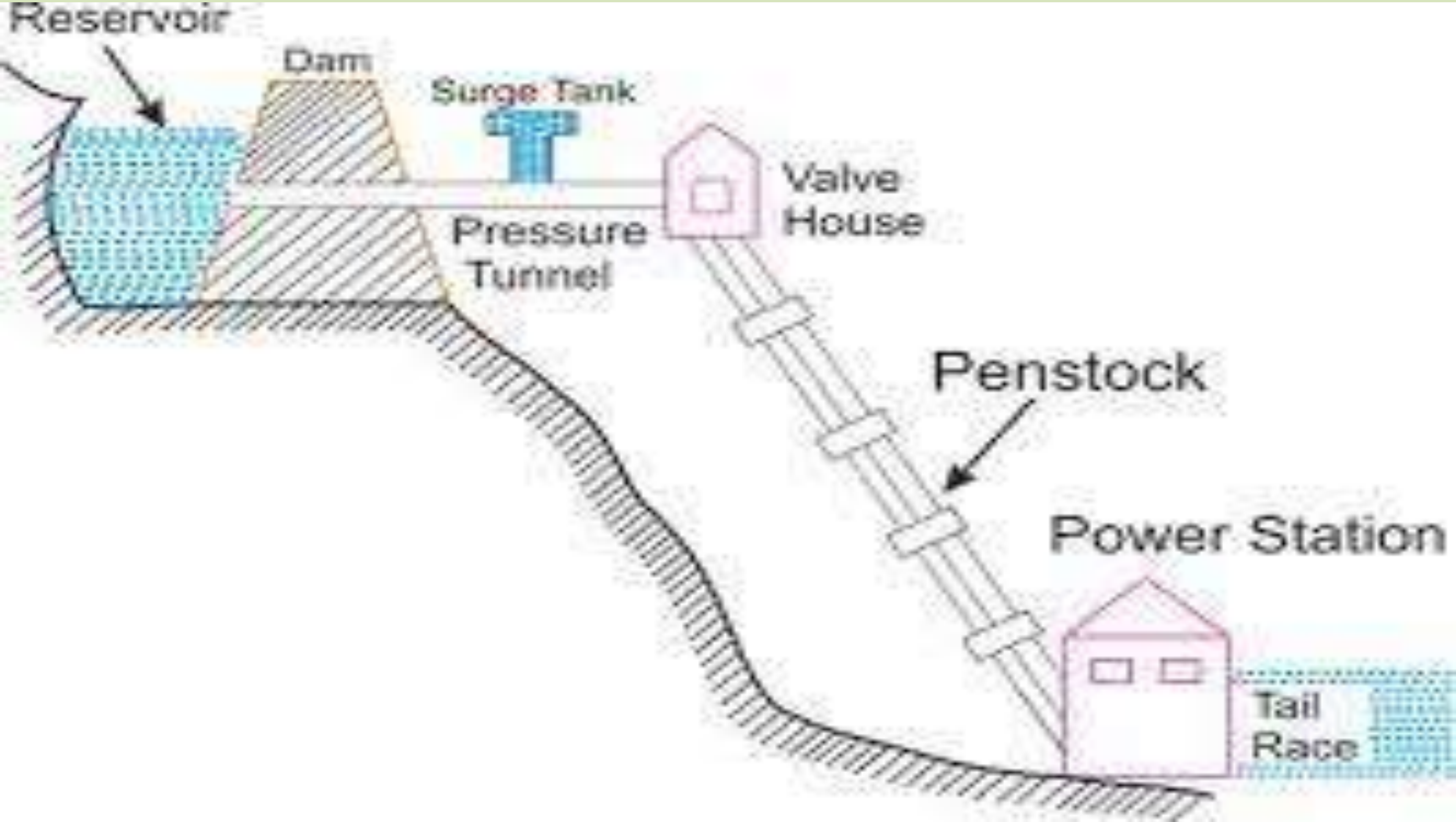
Shaft
Stator
N
Three-Phase
A.C.
Supply
Rotor
S



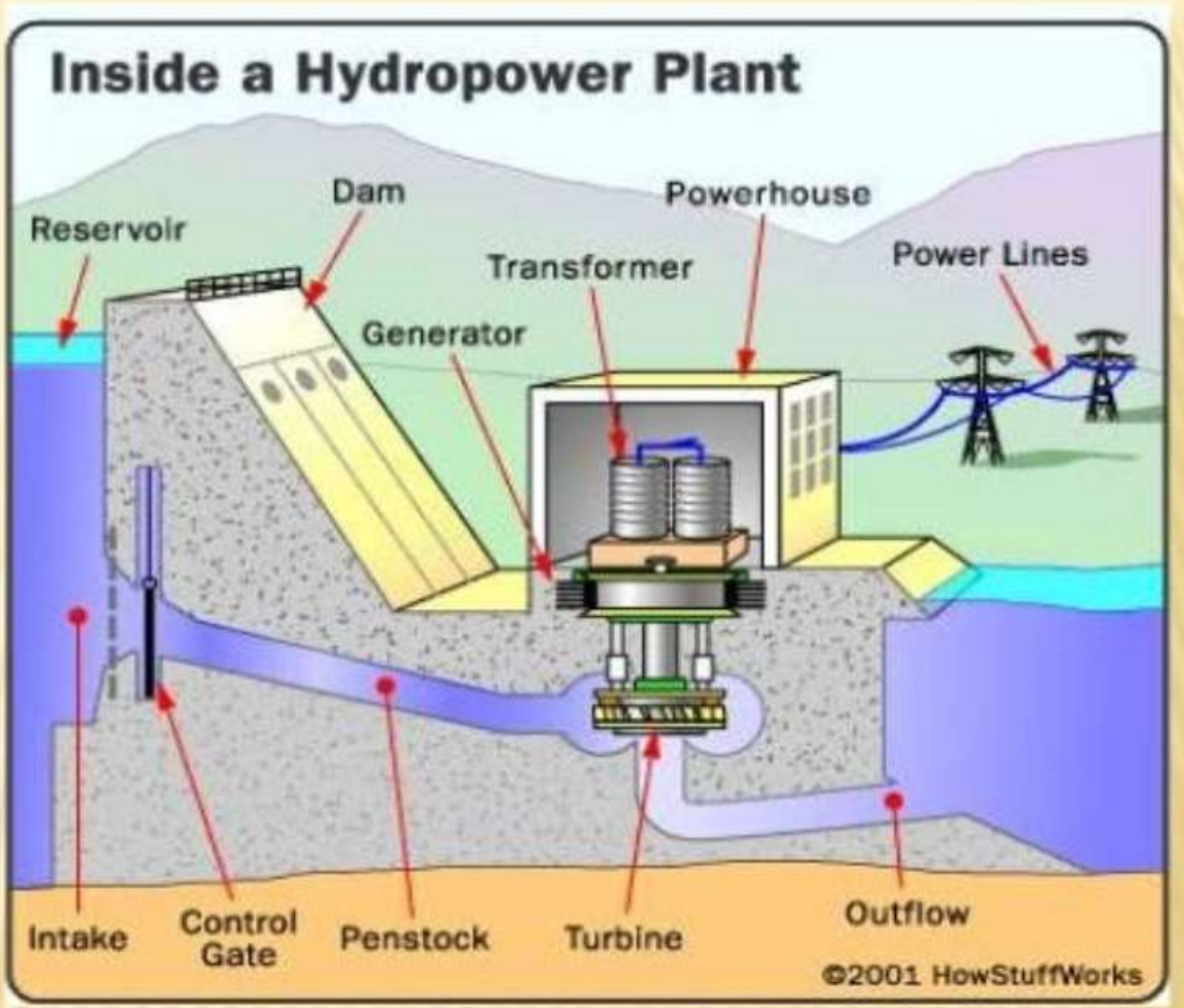
rotor
current
Rotor
n_s
n_s

UNIT – 3
BASICS OF POWER SYSTEMS

HYDRO POWER PLANT



1. Dam and Reservoir
2. Spillway
3. Fore bay
4. Surge tank
5. Penstock
6. Turbine
7. Power house
8. Draft tube



COMPONENTS

DAM AND RESERVOIR

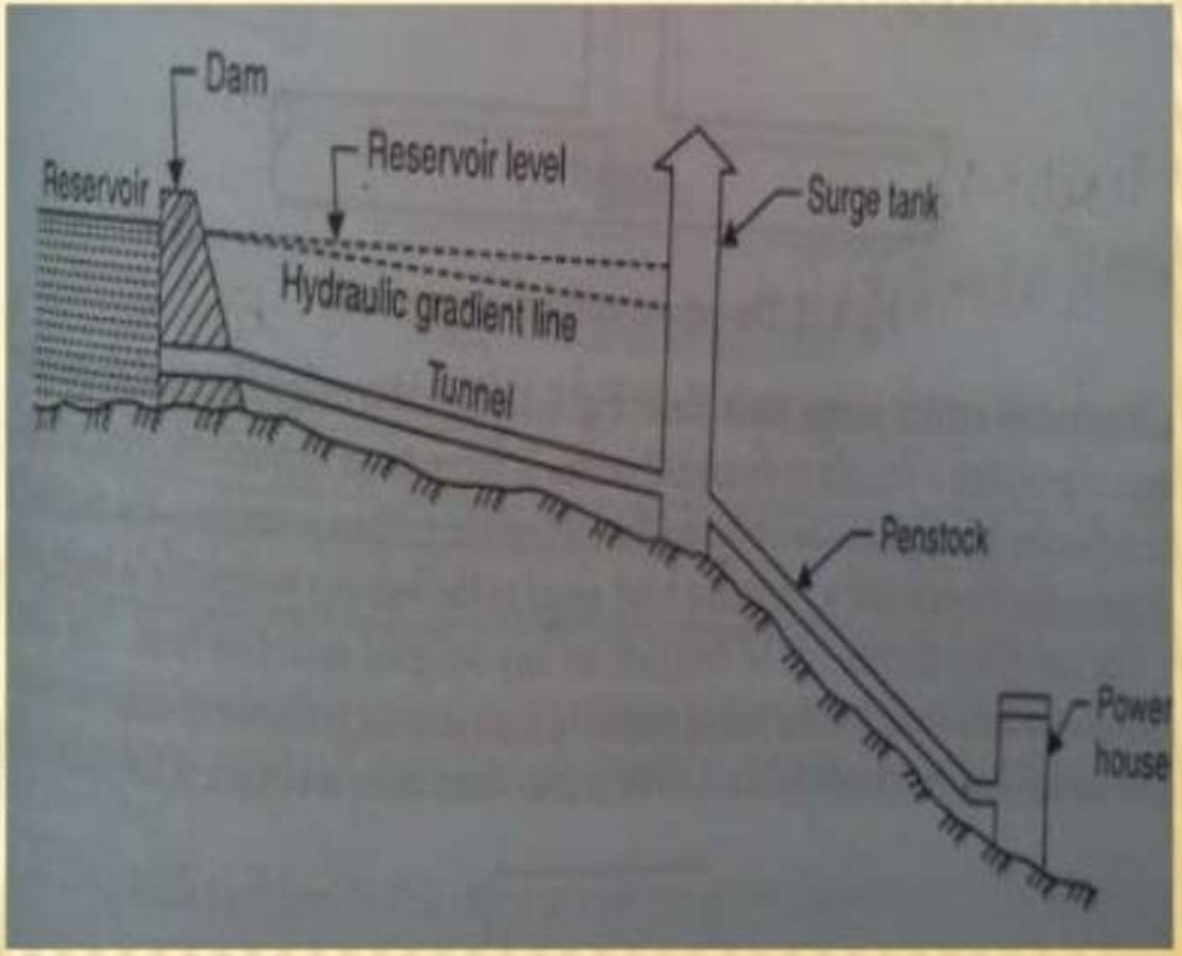
An open-air storage area usually formed by masonry or earthwork where water is collected and kept in quantity so that it may be drawn off for use.

- The water reservoir is the place behind the dam where water is stored.
- The water in the reservoir is located higher than the rest of the dam structure.
- The height of water in the reservoir decides how much potential energy the water
- The higher the height of water, the more its potential energy.
- The high position of water in the reservoir also enables it to move downwards effortlessly.

Spillway is constructed to act as a safety valve. It discharge the overflow water to the down stream side when the reservoir is full. These are generally constructed of concrete and provided with water *discharge* opening.

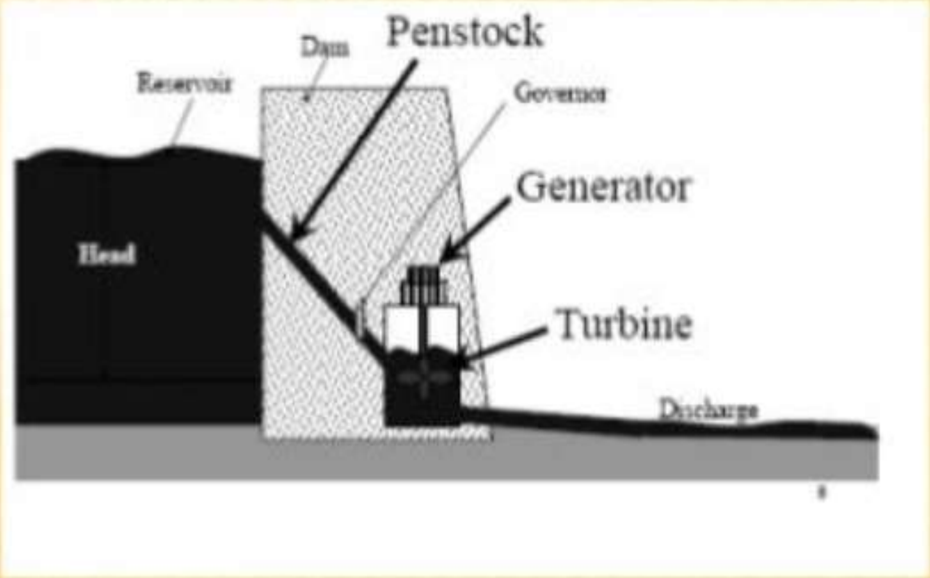
SPILLWAY

- Surge tank acts as a temporary reservoir.
- It helps in stabilizing the velocity and pressure in penstock and thereby saves penstock from getting damaged.
- It serve as supply tank to the turbine in case of increased load conditions, and storage tank in case of low load conditions.



SURGE TANK

The penstock is the long pipe or the shaft that carries the water flowing from the reservoir towards the power generation unit, comprised of the turbines and generator. The water in the penstock possesses kinetic energy due to its motion and potential energy due to its height.



PENSTOCK

POWER HOUSE

A power house usually contains following components:

- Hydraulic turbines
- Electric generators
- Governors
- Water circulation pumps
- Air ducts
- Switch board and instruments
- Storage batteries
- Cranes

WORKING

- Initially the water of the river is in Catchments Area.
- From catchments area the water flows to the dam.
- At the dam the water gets accumulated . Thus the potential energy of the water increases due to the height of the dam .
- When the gates of the dam are opened then the water moves with high Kinetic Energy into the penstock.
- Through the penstock water goes to the turbine house.
- Since the penstock makes water to flow from high altitude to low altitude, Thus the Kinetic Energy of the water is again raised.

ADVANTAGE

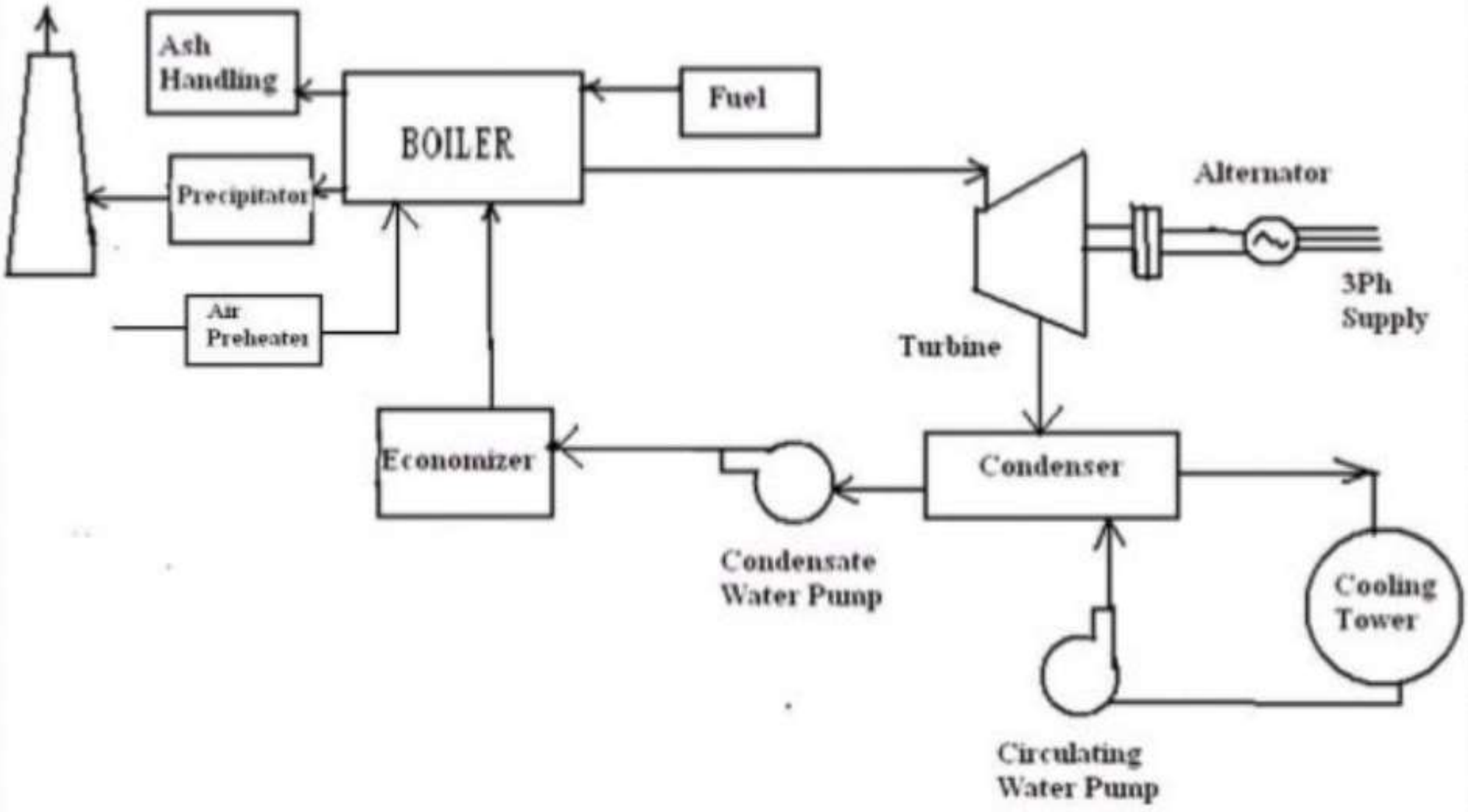
- No fuel charges.
- Less supervising staff is required.
- Maintenance & operation charges are very low.
- Running cost of the plant is low.
- The plant efficiency does not changes with age.
- It takes few minutes to run & synchronize the plant.
- No fuel transportation is required.
- No ash & flue gas problem & does not pollute the atmosphere.
- These plants are used for flood control & irrigation purpose.
- Long life in comparison with the Thermal & Nuclear Power Plant.

DISADVANTAGE

- The initial cost of the power plant is very high.
- Takes long time for construction of the dam.
- Generally, Such plant's are located in hilly area's far away from load center & thus they require long transmission lines & losses in them will be more.
- Power generation by hydro power plant is only dependent on natural phenomenon of rain. Therefore at the time of drought or summer session the Hydro Power Plant will not work.

THERMAL POWER PLANT

GENERAL LAYOUT OF THERMAL POWER PLANT



INTRODUCTION

- A Thermal Power Plant converts the heat energy of coal into electrical energy. Coal is burnt in a boiler which converts water into steam. The expansion of steam in turbine produces mechanical power which drives the alternator coupled to the turbine.Thermal Power Plants contribute maximum to the generation of Power for any country.

- Thermal Power Plants constitute 75.43% of the total installed captive and non-captive power generation in India.

- In thermal generating stations coal, oil, natural gas etc. are employed as primary sources of energy.

WORKING PRINCIPLE

- Firstly the water is taken into the boiler from a water source. The boiler is heated with the help of coal.
- The increase in temperature helps in the transformation of water into steam. The steam generated in the boiler is sent through a steam turbine.
- The turbine has blades that rotate when high velocity steam flows across them. This rotation of turbine blades is used to generate electricity.
- A generator is connected to the steam turbine. When the turbine turns, electricity is generated and given as output by the generator, which is then supplied to the consumers through high-voltage power lines.

MAIN EQUIPMENTS

- Coal handling plant
- Pulverizing plant
- Boiler
- Turbine
- Condenser
- Cooling towers and ponds
- Feed water heater
- Economizer
- Air preheater

COAL HANDLING PLANT

- Coal is transported to power station by rail or road and stored in coal storage plant and then pulverized.
- The function of coal handling plant is automatic feeding of coal to the boiler furnace.
- A thermal power plant burns enormous amounts of coal.
- A 200MW plant may require around 2000 tons of coal daily.

PULVERIZING PLANT

- In modern thermal power plant, coal is pulverized i.e. ground to dust like size and carried to the furnace in a stream of hot air. Pulverizing is a means of exposing a large surface area to the action of oxygen and consequently helping combustion.
- Pulverizing process consists 3 stages classified as:

1. Feeding
2. Drying
3. Grinding

BOILER

The function of boiler is to generate steam at desired pressure and temperature by transferring heat produced by burning of fuel in a furnace to change water into steam.

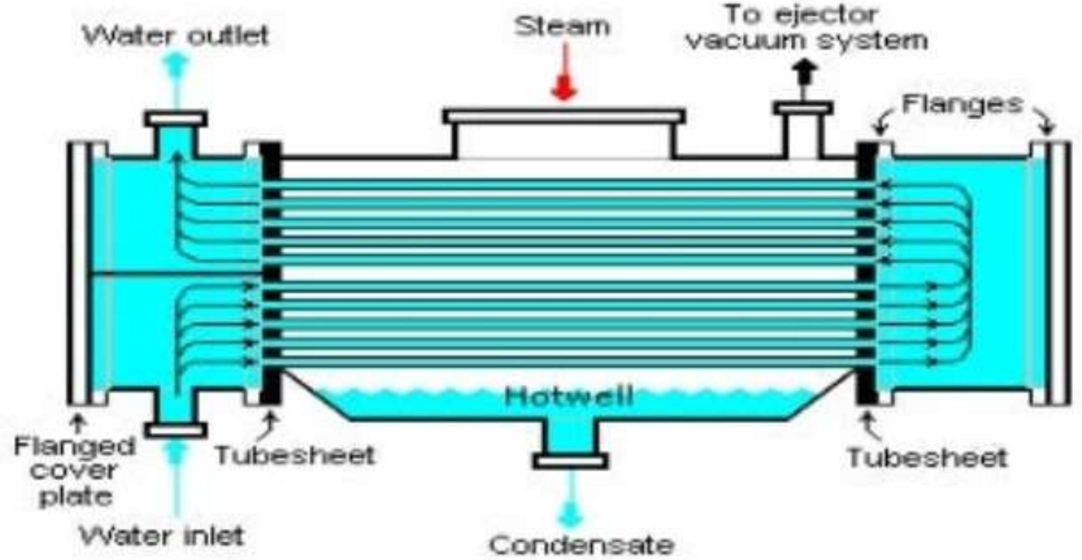
TURBINE

In thermal power plants generally 3 turbines are used to increases the efficiency.

- High pressure turbine
- Intermediate pressure turbine
- Low pressure turbine

CONDENSER

The surface condenser is a shell and tube heat exchanger where cooling water flows through tubes and exhaust steam fed into the shell surrounds the tubes. as a result, steam condense outside the tubes.



COOLING TOWERS AND PONDS

- A condenser needs huge quantity of water to condense the steam.
- Most plants use cooled cooling system where warm water coming from condenser is cooled and reused.
- Cooling tower is a steel or concrete hyperbolic structure with the height of 150m.

FEED WATER HEATER

- Feed water heating improves overall plant efficiency.
- Thermal stresses due to cold water entering the boiler drum are avoided.
- Quality of steam produced by the boiler is increased.

ECONOMIZER

- Flue gases coming out of the boiler carry lot of heat. An economizer extracts a part of this heat from flue gases and uses it for heating feed water.

- Saving coal consumption and higher boiler efficiency.

AIR PREHEATER

- The function of air preheaters is to preheat the air before entering to the furnace by utilizing some of the energy left in the flue gases before exhausting them to the atmosphere.

- After flue gases leave economizer, some further heat can be extracted from them and used to heat incoming heat. Cooling of flue gases by 20 degree centigrade increases the plant efficiency by 1%.

ADVANTAGES:

- The fuel used is quite cheap.
- Less initial cost as compare to other generating stations.
- It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of plant by rail or roads.

DISADVANTAGES:

- It pollutes the atmosphere due to producing large amount of smoke and fumes.
- Higher maintenance cost and operational cost.
- Huge requirement of water.

NUCLEAR POWER PLANT

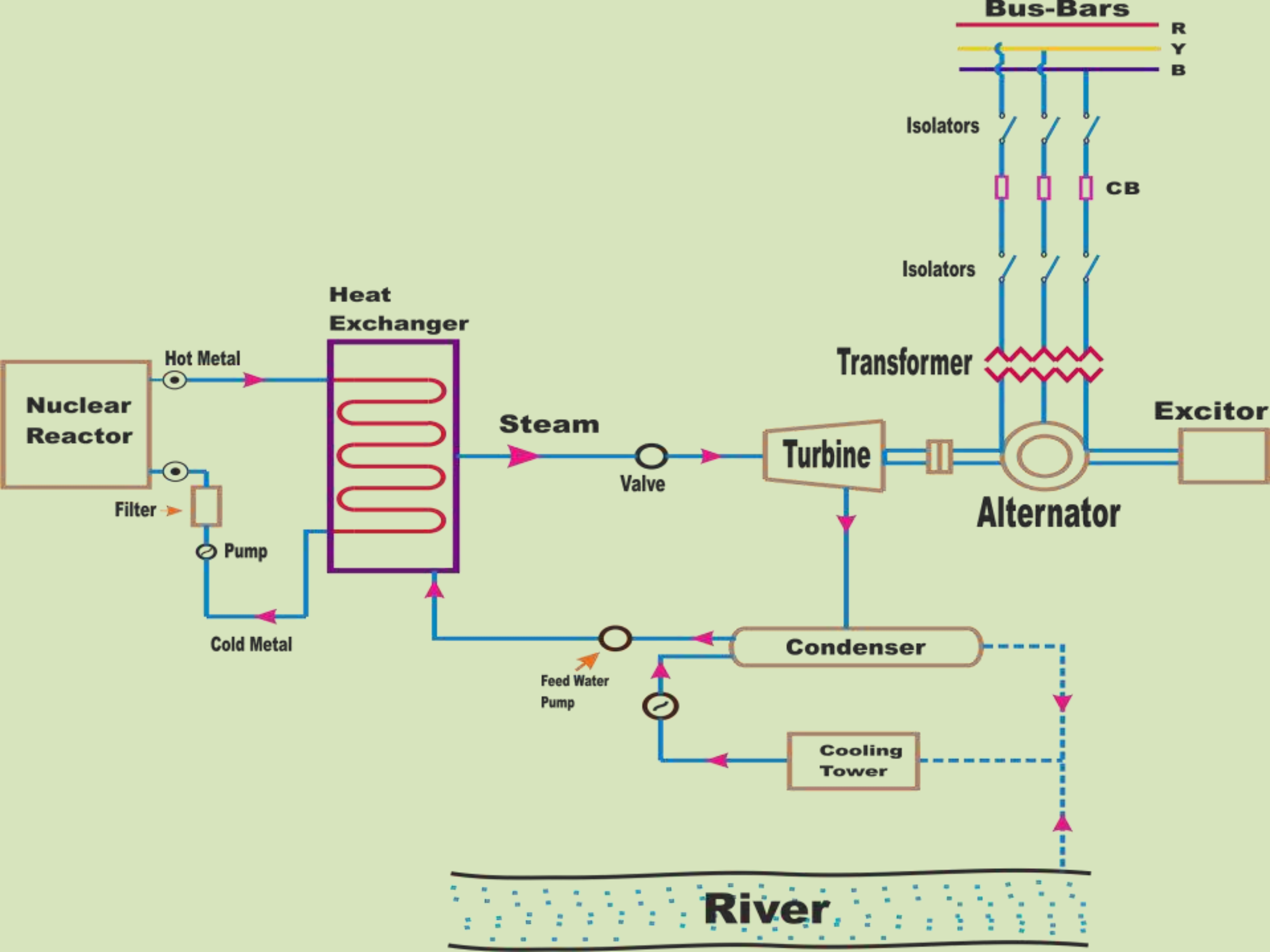
Nuclear (Atomic) Power Plant

❑ Working principle :

- A nuclear power plant works in a similar way as a thermal power plant. The difference between the two is in the fuel they use to heat the water in the boiler(steam generator).

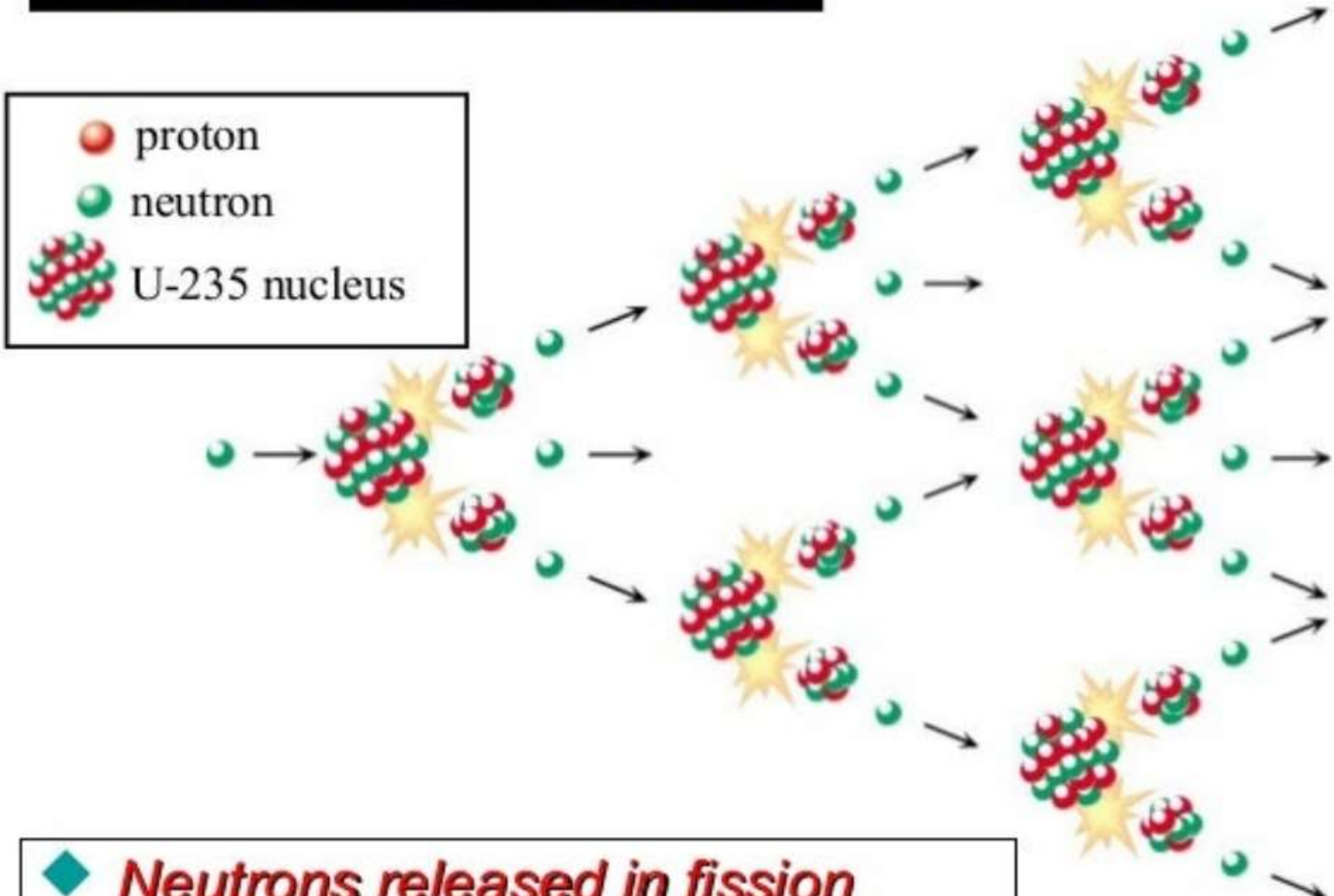
- Inside a nuclear power station, energy is released by nuclear fission in the core of the reactor.

- 1 kg of Uranium U^{235} can produce as much energy as the burning of 4500 tonnes of high grade variety of coal or 2000 tonnes of oil.



Bus-Bars
R
Y
B
Isolators
CB
Isolators
Heat
Exchanger
Transformer
Hot Metal
Nuclear
Reactor
Steam
Excitor
Turbine
Valve
Alternator
Filter
Pump
Cold Metal
Condenser
Feed Water
Pump
Cooling
Tower
River

Nuclear chain reaction



- ***Neutrons released in fission*** trigger the fissions of other nuclei

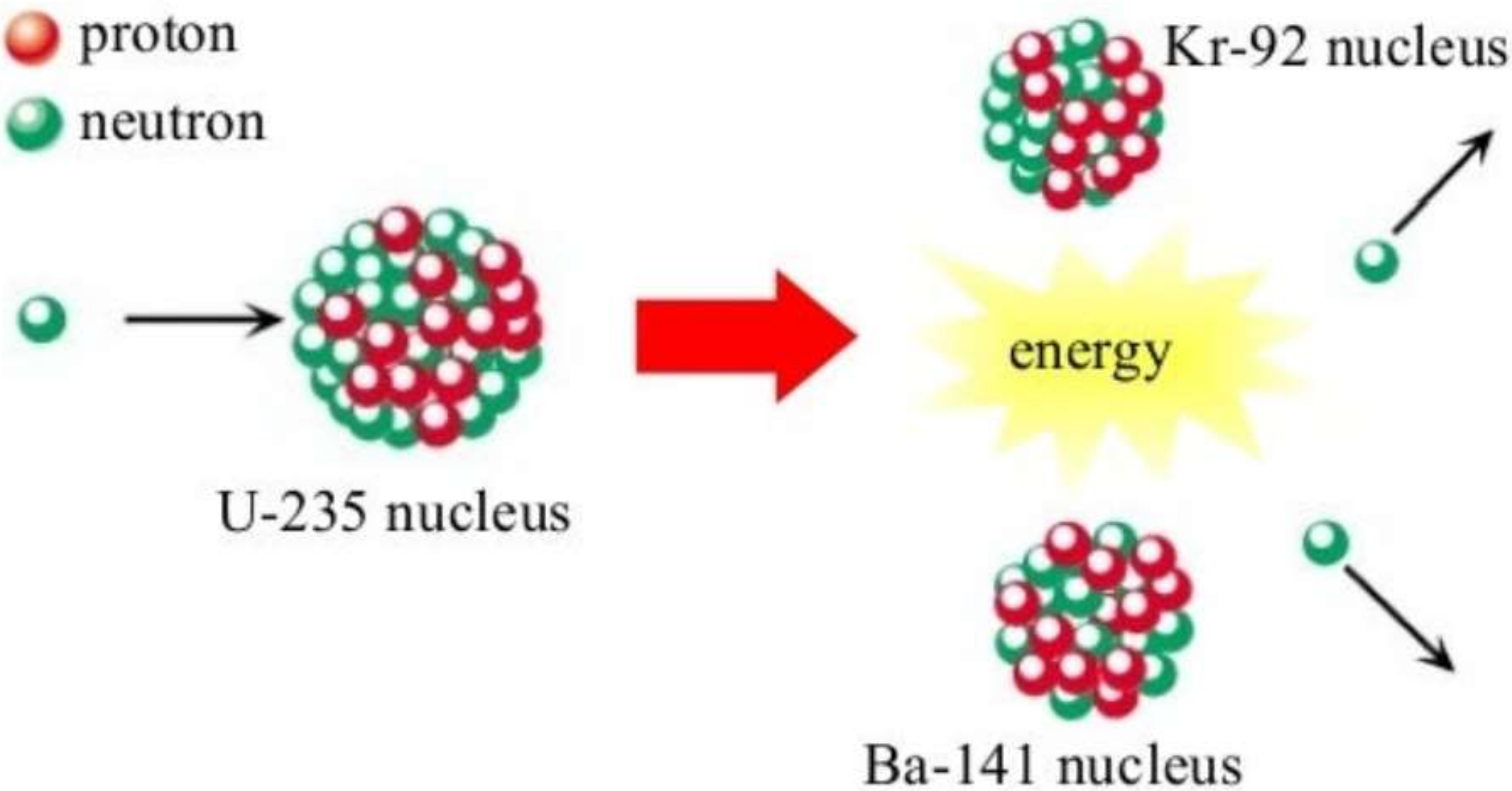
Nuclear (Atomic) Power Plant…

Chain Reaction…

- Uranium exists as an isotope in the form of U^{235} which is unstable.
- When the nucleus of an atom of Uranium is split, the neutrons released hit other atoms and split them in turn. More energy is released each time another atom splits. This is called a chain reaction.

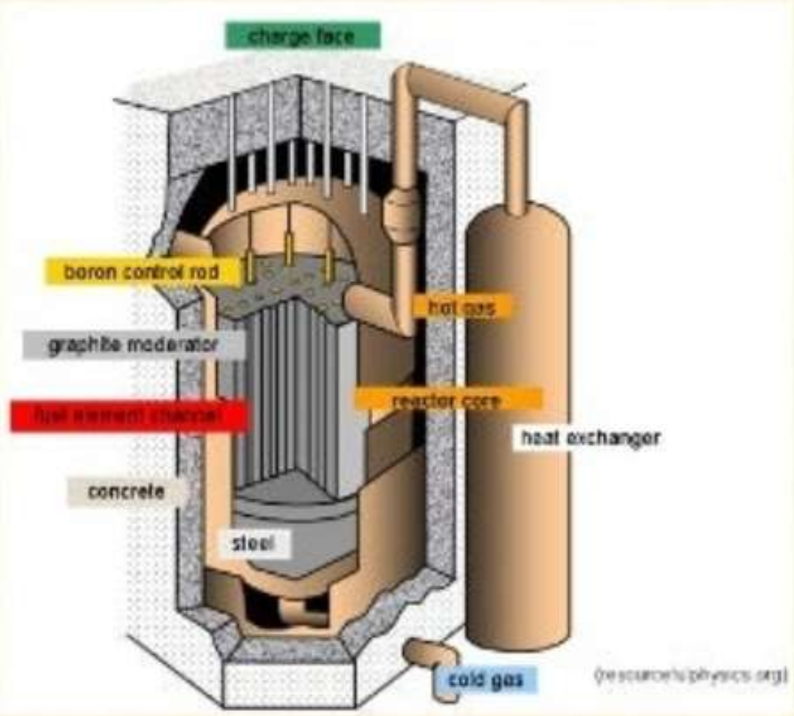
Nuclear fission…

- Nuclear fission: **heavy nuclei split into two smaller parts** in order to become more stable



Nuclear (Atomic) Power Plant…

- Principal parts of a nuclear reactor:



Core : Here the nuclear fission process takes place.

Moderator : This reduces the speed of fast moving neutrons. Most moderators are graphite, water or heavy water.

Nuclear (Atomic) Power Plant…

- Principal parts of a nuclear reactor…

Control rods :

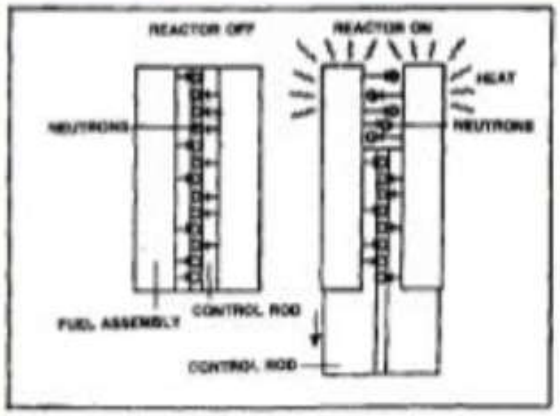


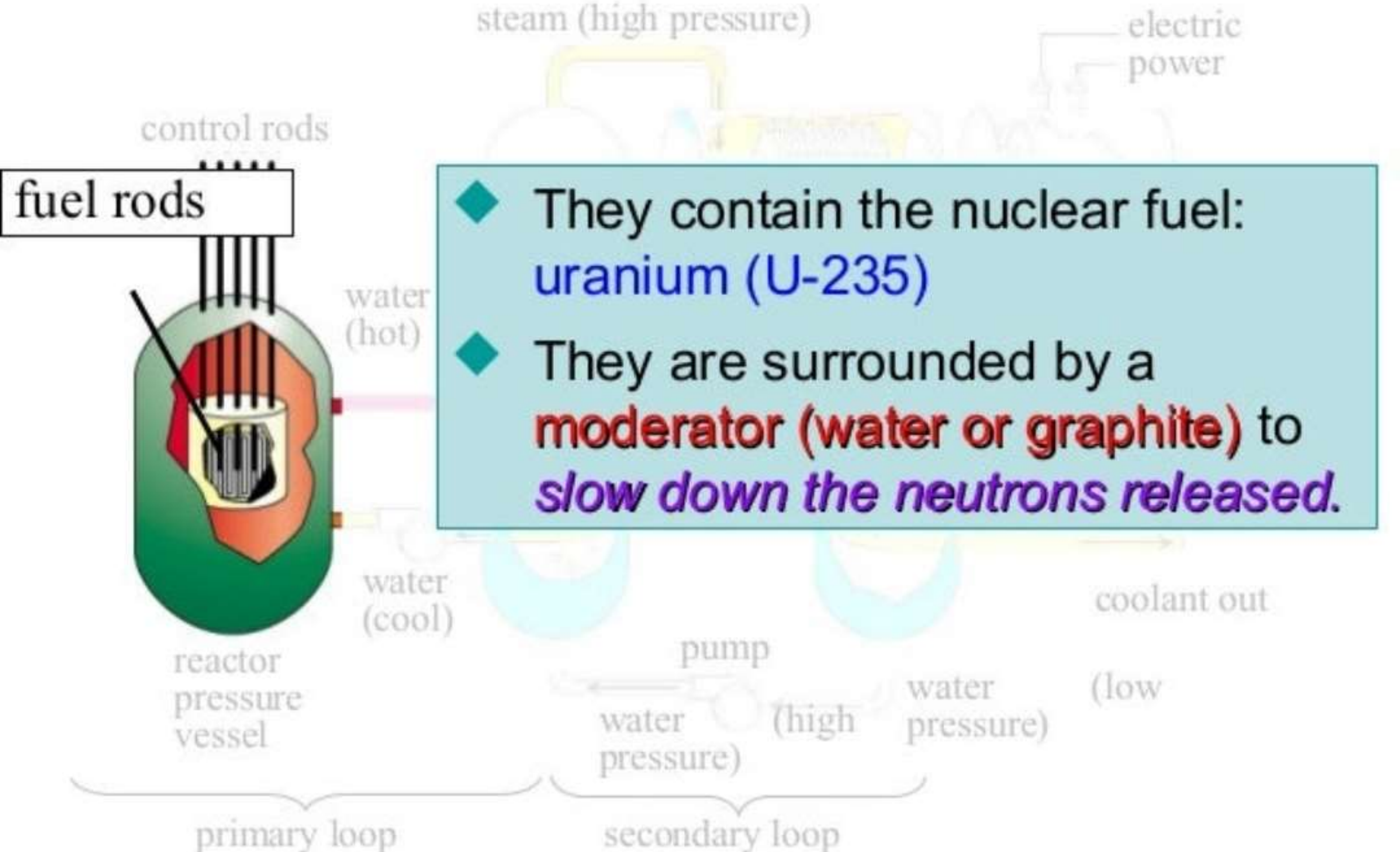
Fig. 3.8: CONTROL RODS

Control rods limit the number of fuel atoms that can split. They are made of boron or cadmium which absorbs neutrons

Coolant : They carry the intense heat generated. Water is used as a coolant, some reactors use liquid sodium as a coolant.

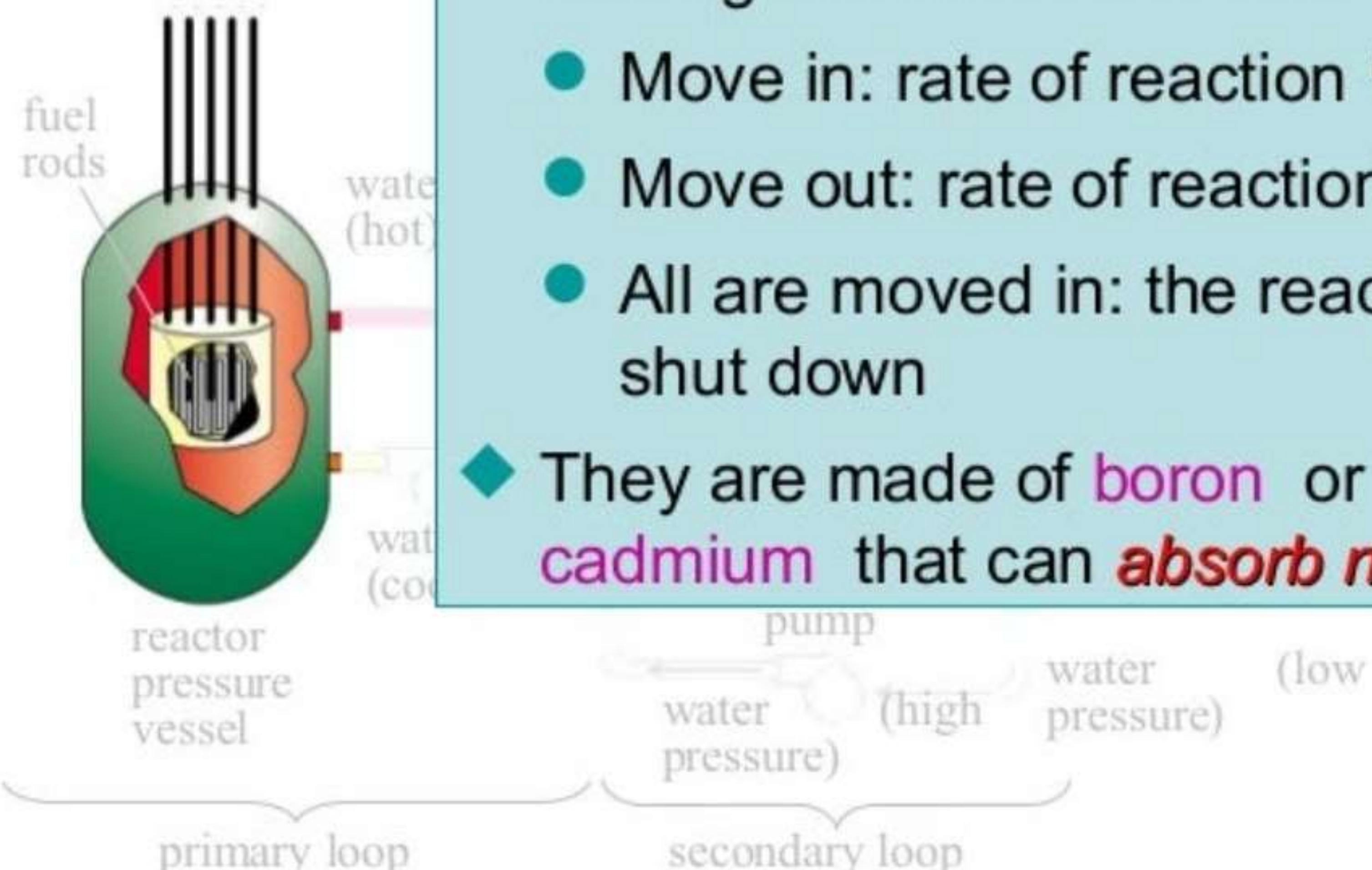
Fuel : The fuel used for nuclear fission is U235 isotope.

Radiation shield : To protect the people working from radiation and
(thermal shielding) radiation fragments.

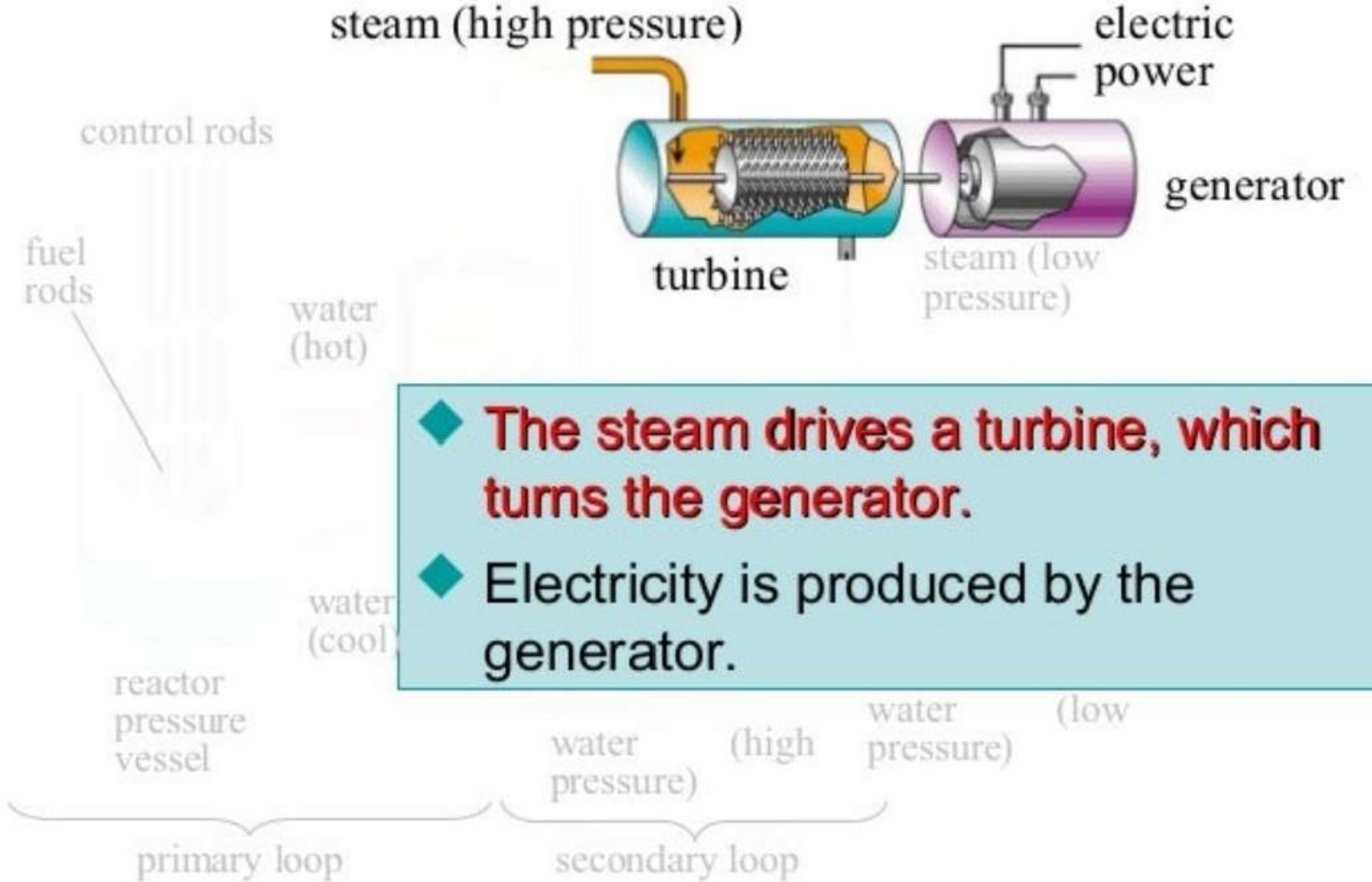


- They contain the nuclear fuel: uranium (U-235)
- They are surrounded by a moderator (water or graphite) to *slow down the neutrons released.*

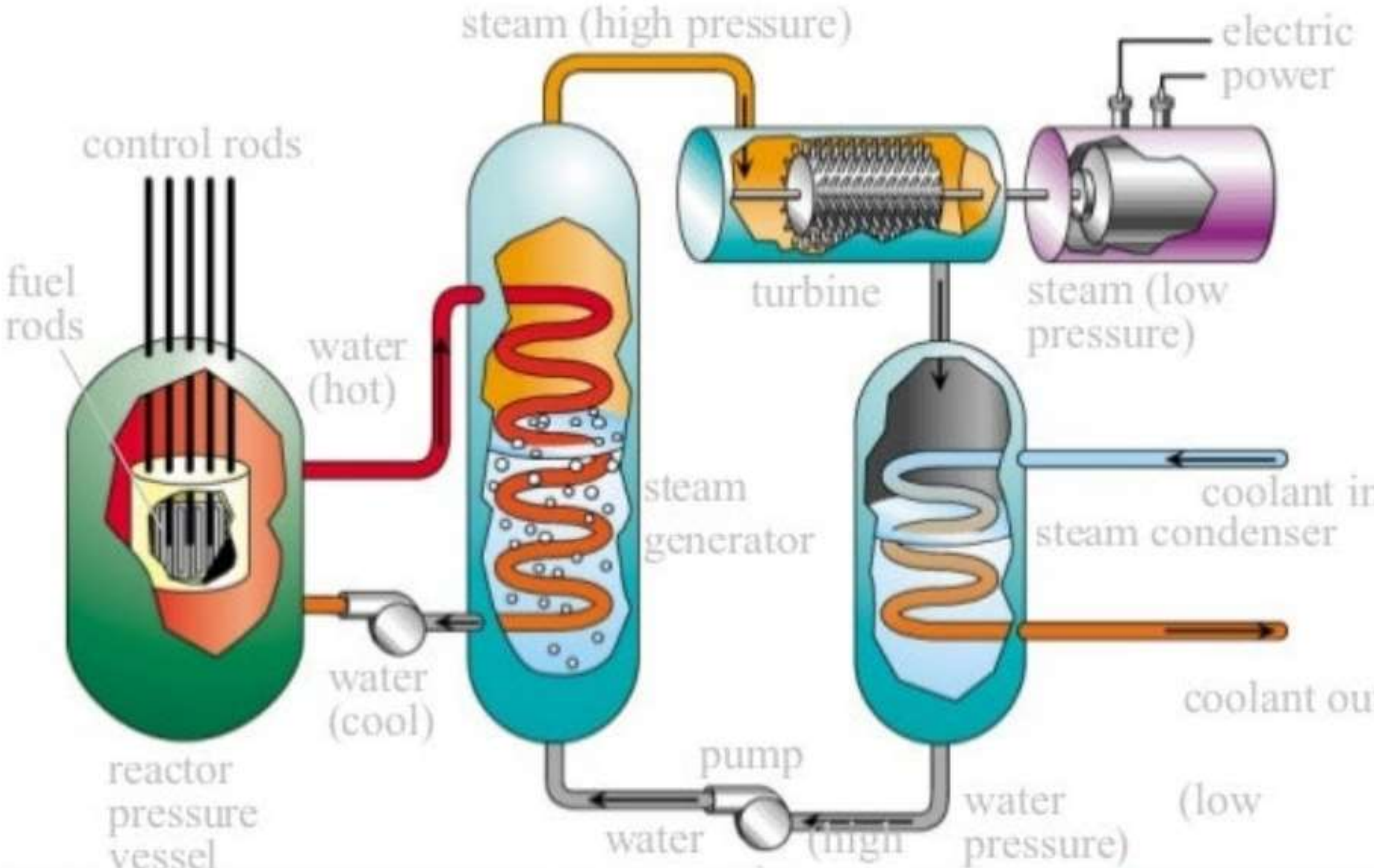
control rods



- They control the rate of reaction by moving in and out of the reactor.
  - Move in: rate of reaction ↓
  - Move out: rate of reaction ↑
  - All are moved in: the reactor is shut down
- They are made of boron or cadmium that can ***absorb neutrons.***



- **The steam drives a turbine, which turns the generator.**
- Electricity is produced by the generator.



- ***Two separate water systems*** are used to avoid radioactive substances to reach the turbine.

Nuclear (Atomic) Power Plant…

❑ Advantages of Nuclear power plant:

- Space required is less when compared with other power plants.
- Nuclear power plant is the only source which can meet the increasing demand of electricity at a reasonable cost.
- A nuclear power plant uses much less fuel than a fossil-fuel plant.
  1 metric tonne of uranium fuel = 3 million metric tonnes of coal = 12 million barrels of oil.

❑ Disadvantages of Nuclear power plant:

- Radioactive wastes must be disposed carefully, otherwise it will adversely affect the health of workers and the environment as a whole.
- Maintenance cost of the plant is high.

Solar Power Plant

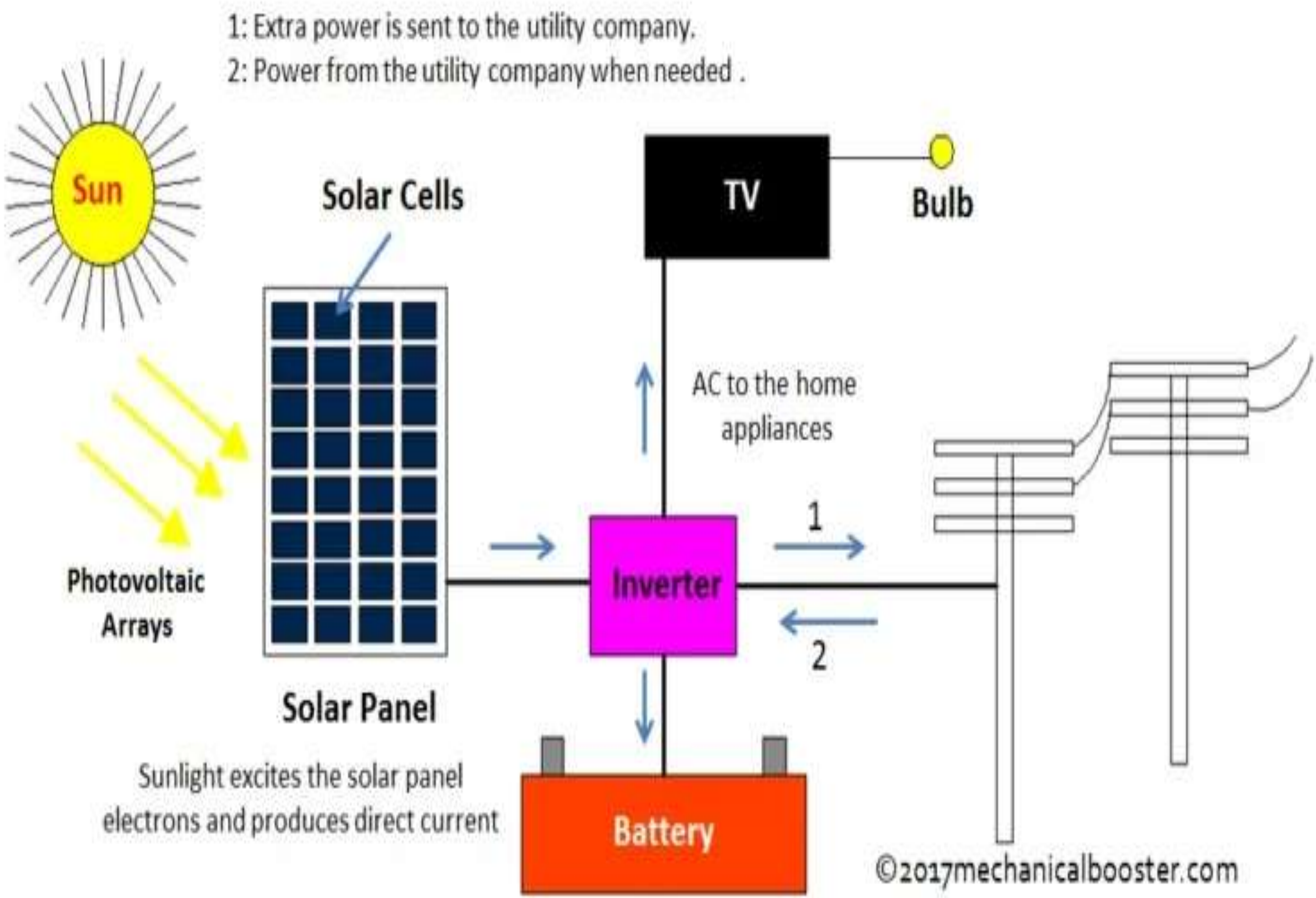
Solar Energy System

Introduction

It is the best alternative source for power generation. There are two ways, to generate electrical energy from sunlight.

We can create electricity directly by using photovoltaic (PV) cell.

The photovoltaic cell is made up of silicon. Many cells are connected in series or parallel to make a solar panel.



Working of Solar Power Plant

1. Solar Panels

It is the heart of the solar power plant. Solar panels consists a number of solar cells. We have got around 35 solar cells in one panel. The energy produced by each solar cell is very small, but combining the energy of 35 of them we have got enough energy to charge a 12 volt battery.

2. Solar Cells

It is the energy generating unit, made up of p-type and n-type silicon semiconductor. It's the heart of solar power plant.

3. Battery

Batteries are used to produce the power back or store the excess energy produced during day, to be supplied during night.

4. D.C. to A.C. Converter (Inverter)

Solar panels produce direct current which is required to be converted into alternating current to be supplied to homes or power grid.

Working of Solar Power Plant

As sunlight falls over a solar cells, a large number of photons strike the p-type region of silicon. Electron and hole pair will get separated after absorbing the energy of photon. The electron travels from p-type region to n-type region due to the action of electric field at p-n junction. So this, current starts flowing in the circuit for individual solar cell. We combine the current of all the solar cells of a solar panel, to get a significant output.

Solar power plant have a large number of solar panels connected to each other to get a large voltage output. The electrical energy coming from the combined effort of solar panels is stored in the Lithium ion batteries to be supplied at night time, when there is no sunlight.

Advantages:

1. The transmission cost is zero for a stand-alone solar system.
2. Solar electricity generation system is environment-friendly.
3. The maintenance cost is low.
4. It is an ideal source for remote locations that cannot link to the grid.

Disadvantages:

1. Initial expenses are high.
2. Require large area for bulk production.
3. Solar electricity generation system is weather-dependent.
4. Solar energy storage (battery) is costly.

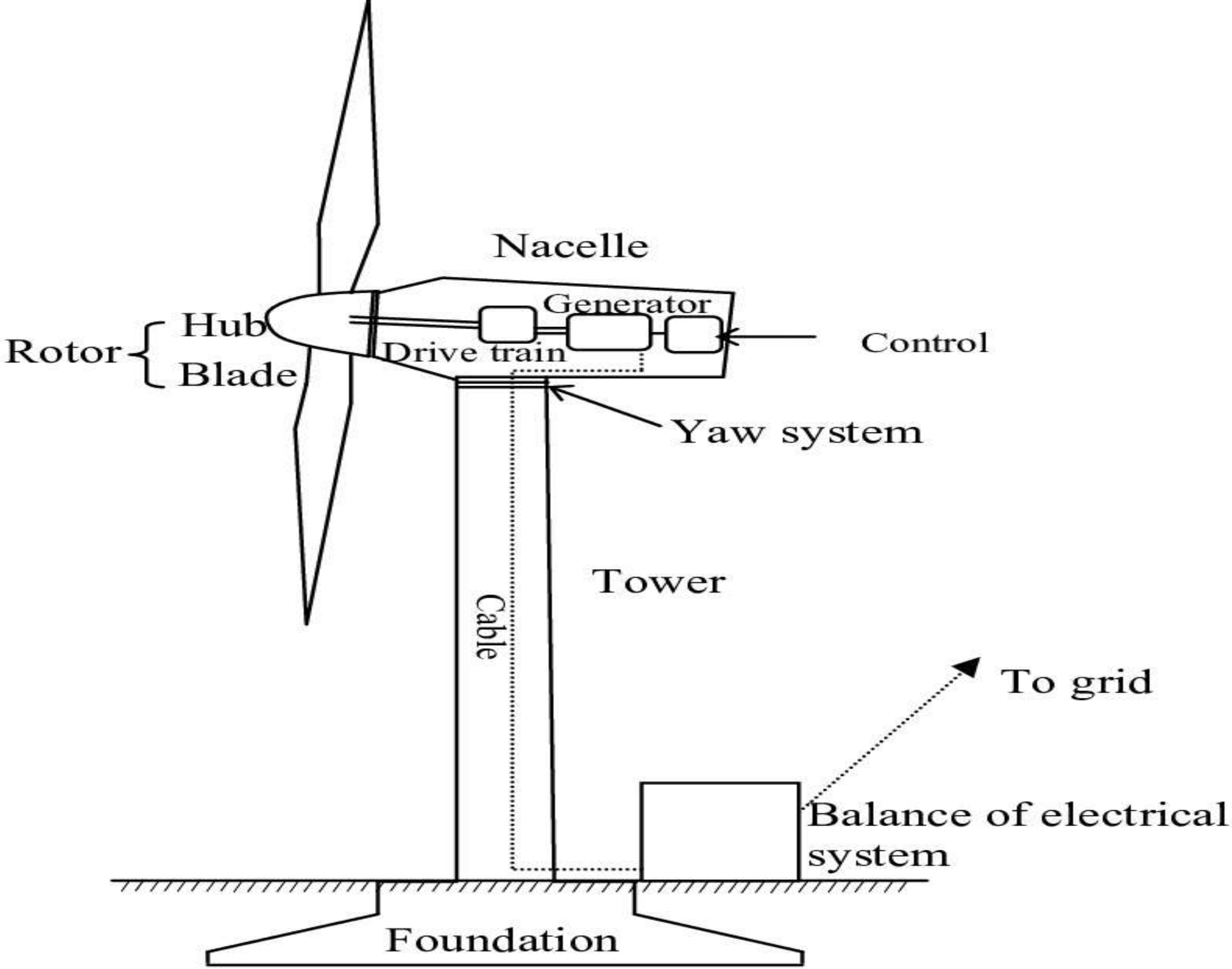
Wind Power Plant

Wind Energy System

Wind turbines are used to convert wind energy into electrical energy. Wind flows due to temperature changes in the atmosphere. Wind turbines turn wind energy into kinetic energy. The rotating kinetic energy rotates the induction generator, and that generator converts kinetic energy into electrical energy.

Working of Wind Turbine

When the wind strikes the rotor blades, blades start rotating. The turbine rotor is connected to a high-speed gearbox. Gearbox transforms the rotor rotation from low speed to high speed. The high-speed shaft from the gearbox is coupled with the rotor of the generator and hence the electrical generator runs at a higher speed. An exciter is needed to give the required excitation to the magnetic coil of the generator field system so that it can generate the required electricity. The generated voltage at output terminals of the alternator is proportional to both the speed and field flux of the alternator.


Nacelle
Generator
Hub
Rotor
Blade
Drive train
Control
Yaw system
Tower
Cable
To grid
Balance of electrical system
Foundation

Advantages:

1. Wind energy is an unlimited, free and clean source of energy.
2. The operating cost is almost zero.
3. A wind electricity generating system can generate power in a remote location.

Disadvantages:

1. It cannot produce the same amount of electricity at all time.
2. It needs a big open area.
3. It makes noise.
4. The construction process of a wind turbine is expensive.
5. It gives lower electricity output.
6. It poses threats from flying birds.

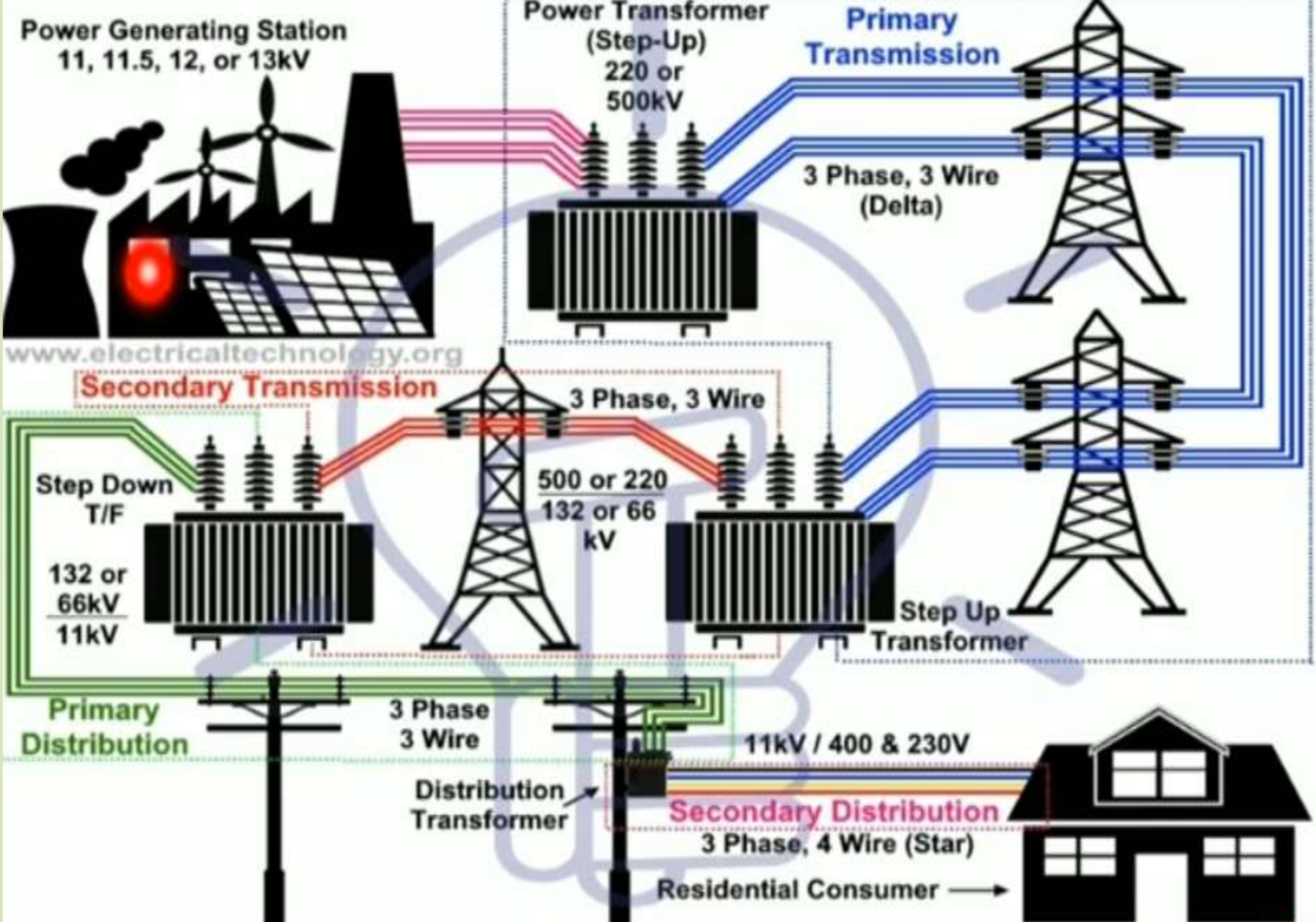
Electrical Supply system

- The conveyance of electric power from a power station to consumers' premises is known as electric supply system.

- Electric supply system consist of three principle components:
  1)Power station
  2)Transmission lines
  3)Distribution system

- The electric supply system can be broadly classified into:
  1)DC or AC system
  2)Overhead or underground system

Typical AC Supply Scheme



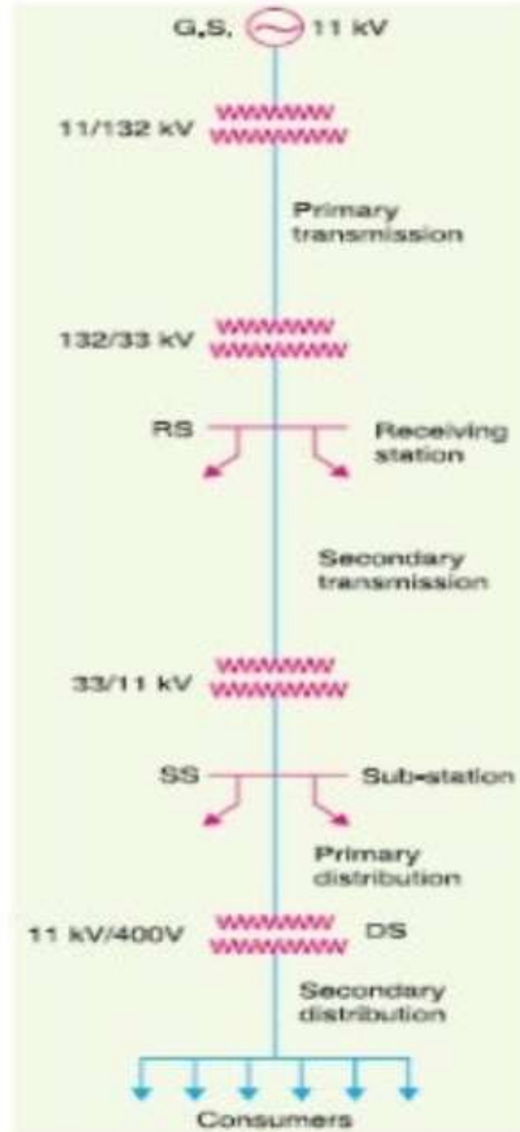
Typical AC Power Supply System (Generation, Transmission and Distribution)

Typical AC power supply scheme

Different blocks of typical ac power supply scheme are as per following::

1)Generating Station:

- In generating station power is produced by three phase alternators operating in parallel.
- the usual generation voltage is 11 kV.
- For economy in the transmission of electric power, the generation voltage is stepped up to 132 kV or more at generating station with the help of three phase transformer.



2)Primary transmission:

- The electric power at 132 kV is transmitted by 3-phase,3 wire overhead system to the out skirts of the city.

3)Secondary transmission:

- At the receiving station the voltage is reduced to 33kV by step down transformer.

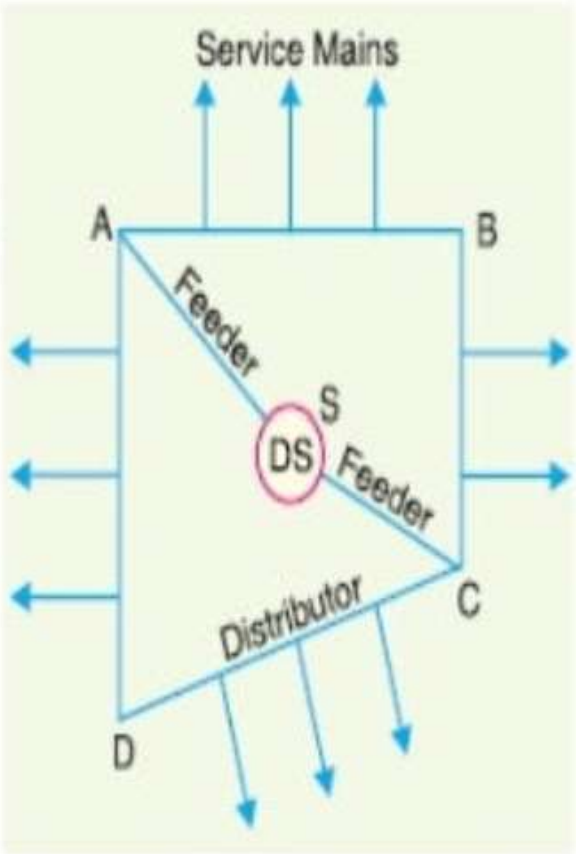
4)Primary distribution:

- At the substation voltage is reduced 33kV to 11kV. The 11kV line run along important road sides to city. This forms the primary distribution.

5)Secondary distribution:

- The electric power form primary distribution line is delivered to distribution substation. The substation is located near the consumers location and step down the voltage to 400V, 3-phase ,4-wire for secondary distribution.

- The voltage between any two phases is 400V and between any phase and neutral is 230V.



AC transmission

Advantages:

- The power can be generated at high voltages.
- The maintenance of AC substation is easy and cheaper.
- The AC voltage can be steeped up or stepped down by transformers.

Disadvantages:

- Requires more copper than DC.
- Due to skin effect in the AC system the effective resistance of line is increased.
- AC line has capacitance therefore there is continuous loss of power due to charging current even when the line is open.