UNIT-II

ELECTRICAL MACHINES → DC MACHINES, AC MACHINES

DC GENERATOR:

* A DC Generator is an electrical machine which converts mechanical energy into electrical energy.

MECHANICAL ENERGY → DC GENERATOR → ELECTRICAL ENERGY.

* This energy conversion is based on the principle of Electromagnetic induction.

⇒ According to Faraday's law of electromagnetic induction, whenever a conductor is moved in a magnetic field, e.m.f is produced in the conductor.

* When an external load is connected to the conductor, a current flows through the load. Thus the mechanical energy is converted into electrical energy.

CONSTRUCTION OF DC GENERATOR:

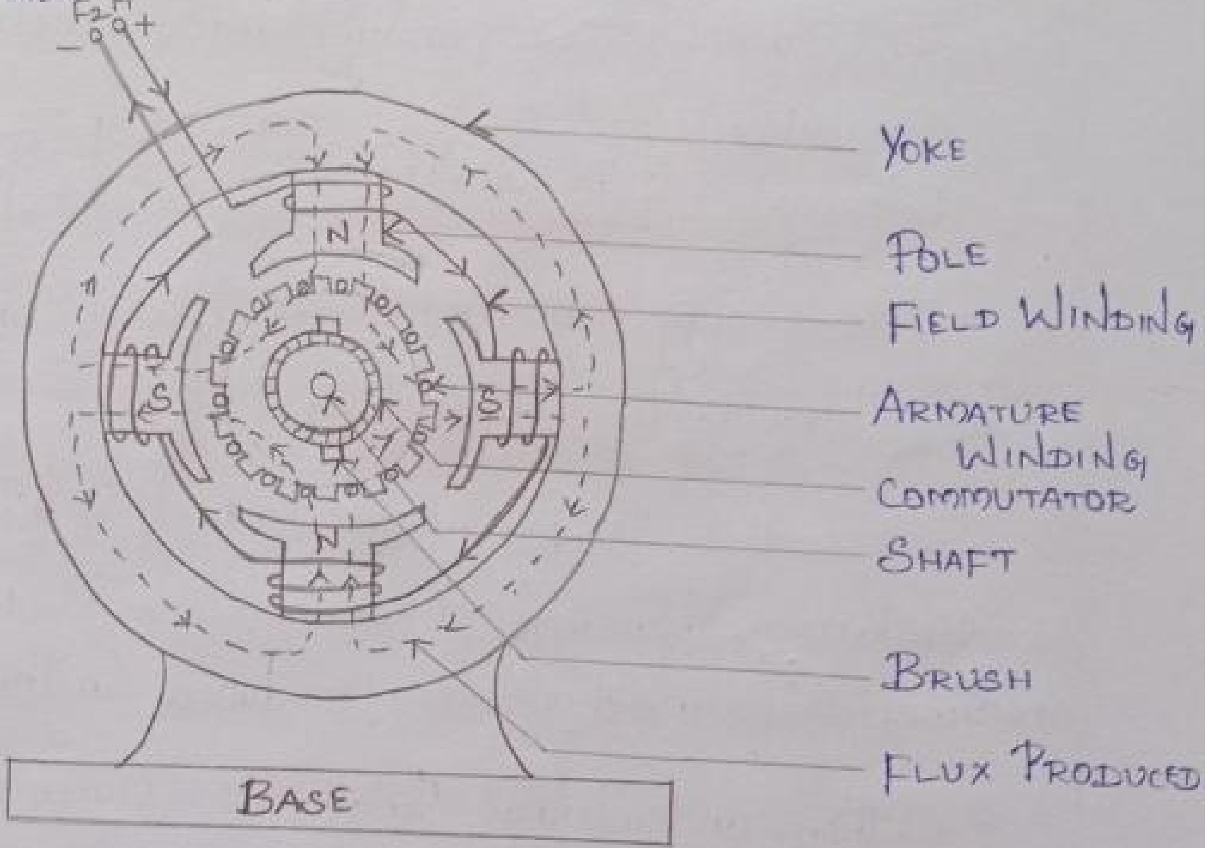
The major parts are given below:

1. Magnetic frame or Yoke
2. Poles, interpoles
3. Field Windings
4. Armature Windings
5. Commutator
6. Brushes and Bearings

② MAGNETIC FRAME OR YOKE:

* It acts a as Protecting Cover for the whole machine and Provides mechanical Support for the Poles.

* The magnetic material used to Construct yoke is Cast iron. It Carries the magnetic flux Produced by the Poles.



POLES:

* Each Poles is divided into two parts, Pole Core & Pole Shoe.

* Pole Core is one which Carries field Windings which is used to Produce flux.

* Pole Shoe is of large area behind the armature Core to Produce larger induced EMF by dividing larger flux to armature Core.

INTERPOLES:

* Interpoles are fixed between main Poles and its Size is also Small when Compared with the main Poles.

③

* They are used to have the Sparkless Commutation.

FIELD WINDINGS:

* The field windings are wounded over the Pole Core with a definite direction.

* When the Current is made to Pass in it, it acts as electromagnet and Produces flux.

* As it helps to Produce magnetic field it is named as field windings (or) Excitation windings

ARMATURE WINDINGS:

* Armature windings are the interconnection of the armature Conductors, Placed in Slots.

* When armature is rotated, the flux Produced gets Cut by armature Conductors and emf gets induced in them.

* The armature windings is made up of Conducting material namely Copper.

COMMUTATOR:

* The Commutator is used to Convert internally developed alternating emf To unidirectional (DC) emf.

* It also Collects the Current from the armature Conductors and then it Converts into DC.

BRUSHES and BEARINGS:

* Brushes are Stationary and resting on the Surface of Commutators.

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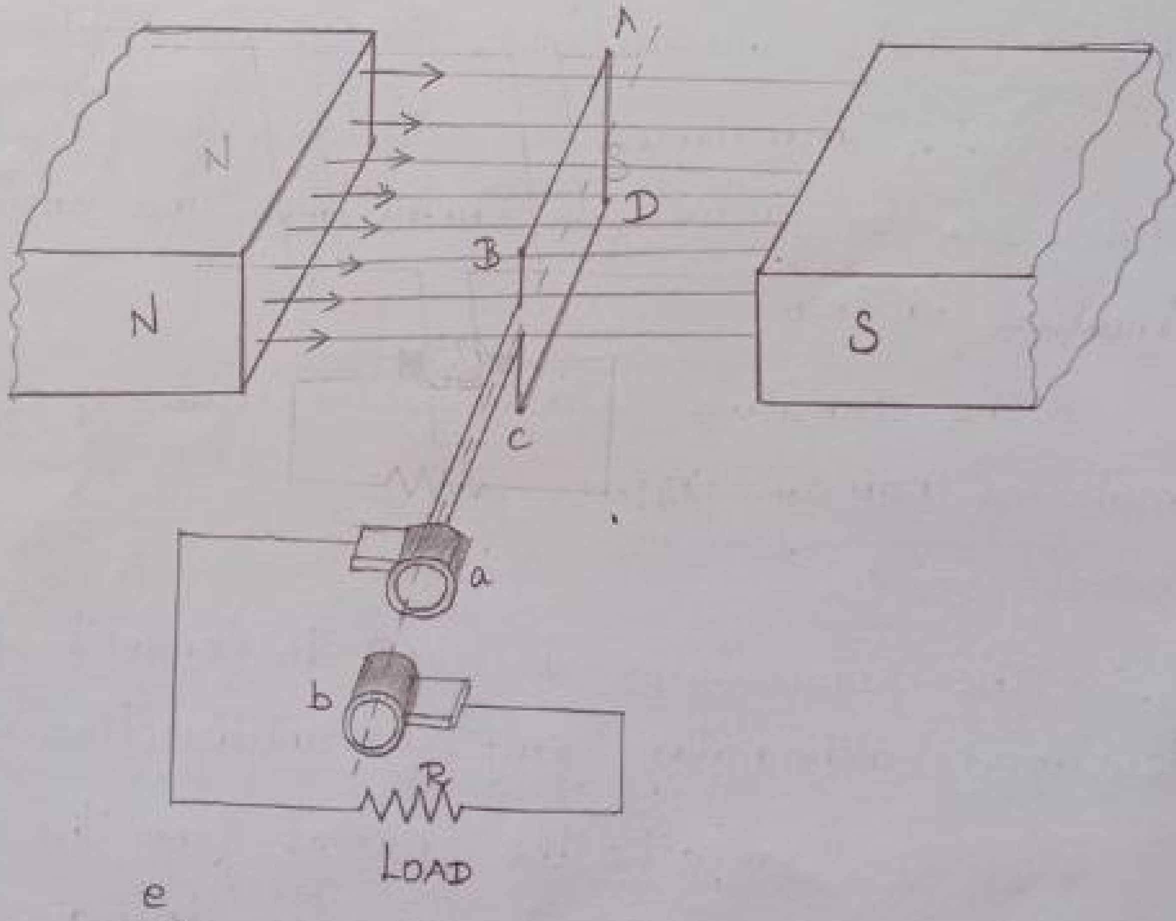
* It Collects the Current from the Commutator and gives to the external Circuits.

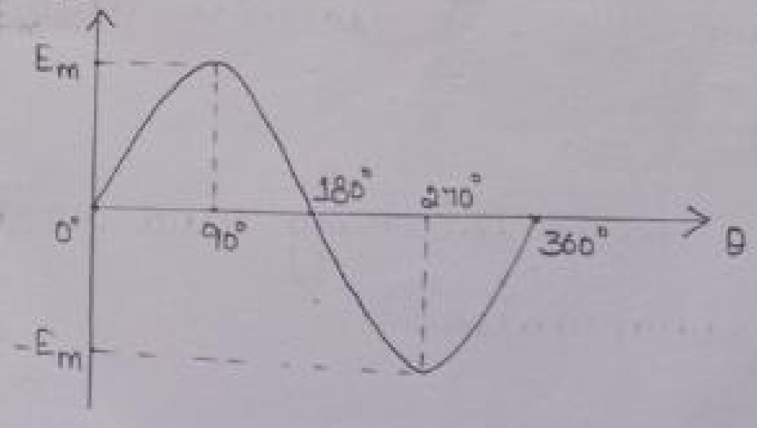
* Brushes are made up of Soft material like Carbon.

* Ball Bearings are usually used as they are more reliable and they are used for quieter operation

OPERATION (OR) WORKING OF DC GENERATOR:

The generator works on the Principle of faradays law of electromagnetic induction.





(5) Let us Consider a Single turn Coil ABCD rotated on a Shaft within a uniform magnetic field. It is rotated in an anticlockwise direction.

When the Coil Sides AB and CD are moving Parallel to the magnetic field, the flux lines are not being Cut and no emf is induced in the Coil.

When the Coil Sides AB and CD are Perpendicular to the magnetic field, the flux lines are Cut by the Conductor and emf is induced in the Coil.

When $\theta = 90^\circ$, the Coil Sides are moving at right angles to the flux lines. The flux lines are Cut at the maximum rate and the emf induced is maximum.

When $\theta = 180^\circ$, the Coil Sides are again moving Parallel to the flux lines [AB and CD have exchanged Positions] and the emf induced is Zero once again.

When $\theta = 270^\circ$, the Coil Sides again move at right angles to the flux lines but with the Opposite direction. So emf induced is maximum in the Opposite direction.

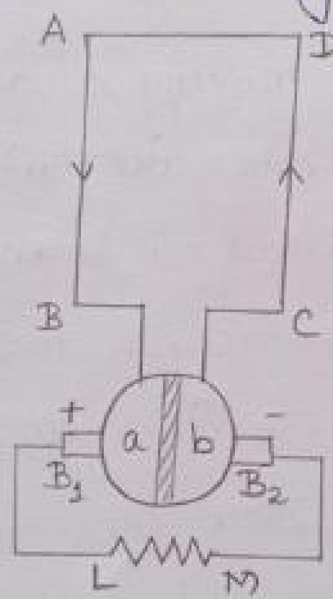
When $\theta = 360^\circ$. The Coil Sides once again move Parallel to the magnetic field making the induced emf equal to Zero.

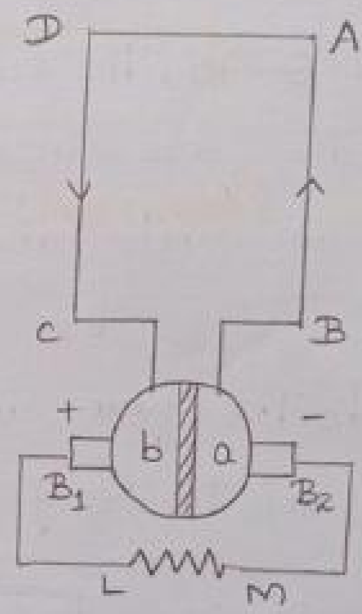
If the rotation of the Coil is Continued, the changes in the emf are again repeated.

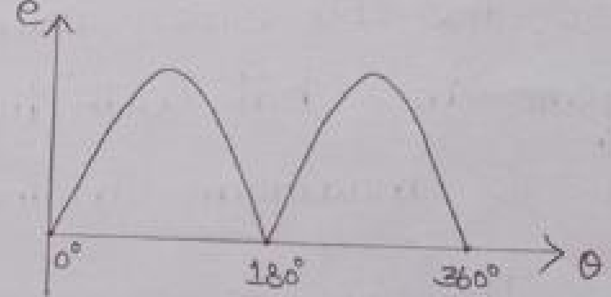
The Current flowing in the external resistance from D C Generator is made unidirectional by replacing the Slip rings by a Split ring (commutator).

The ring is Split into two equal Segments a and b and the Segments are insulated from each other and also from the Shaft.

The Coil Side AB is always attached to the Segment a & likewise CD to b. The brushes B_1 and B_2 touch the Segments a and b to Collect the Current.







During the first half revolution, Current flows along ABLMCB through Brush B_1 which is Positive and into B_2 (negative brush).

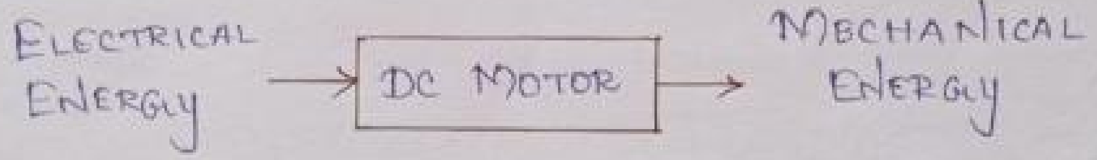
After half a Cycle AB and CD have exchanged Positions along with the Segments a and b, and Current now flows through DCLMBA. B_1 is now in

Contact with b. (B_1 Continues to be Positive).

For each half revolution, the Positions of Segments a and b also reverse. Hence the Current in the load is always unidirectional. In a Generator the Split-rings are Called Commutator.

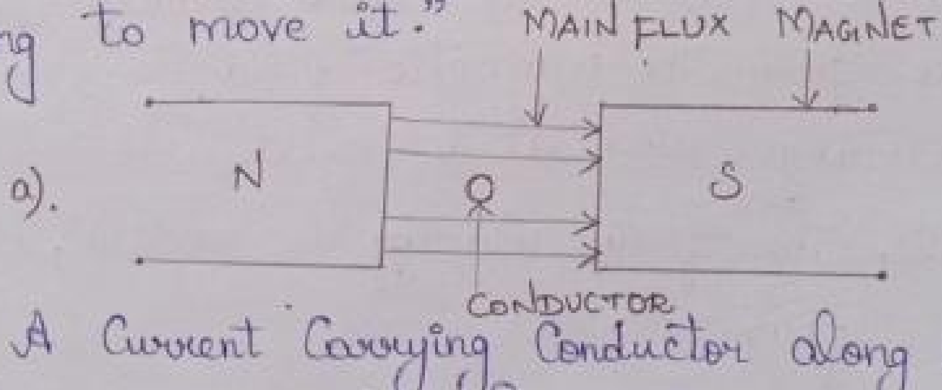
DC Motor:

A DC motor is an electrical machine which Converts electrical energy into mechanical energy.

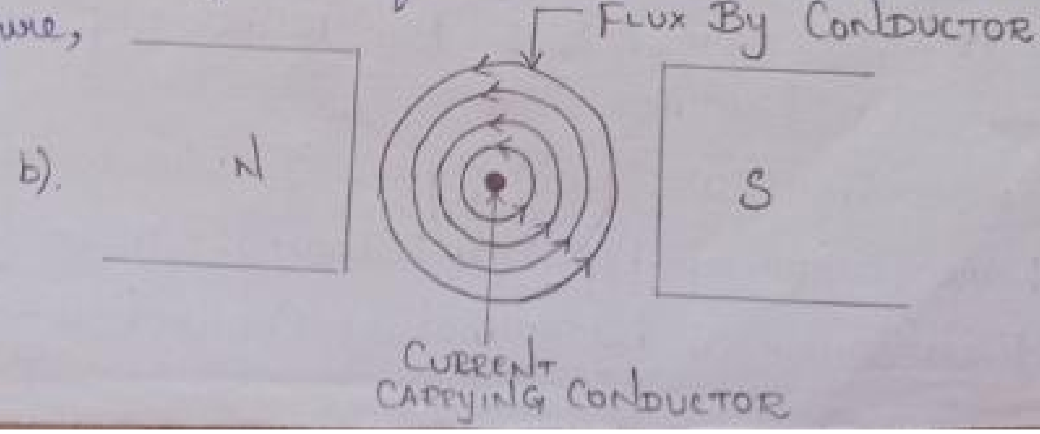


Principle Of Operation:

The basic Principle of Operation of DC motor is that "Whenever a Current Carrying Conductor is placed in a magnetic field, it experiences a force tending to move it."



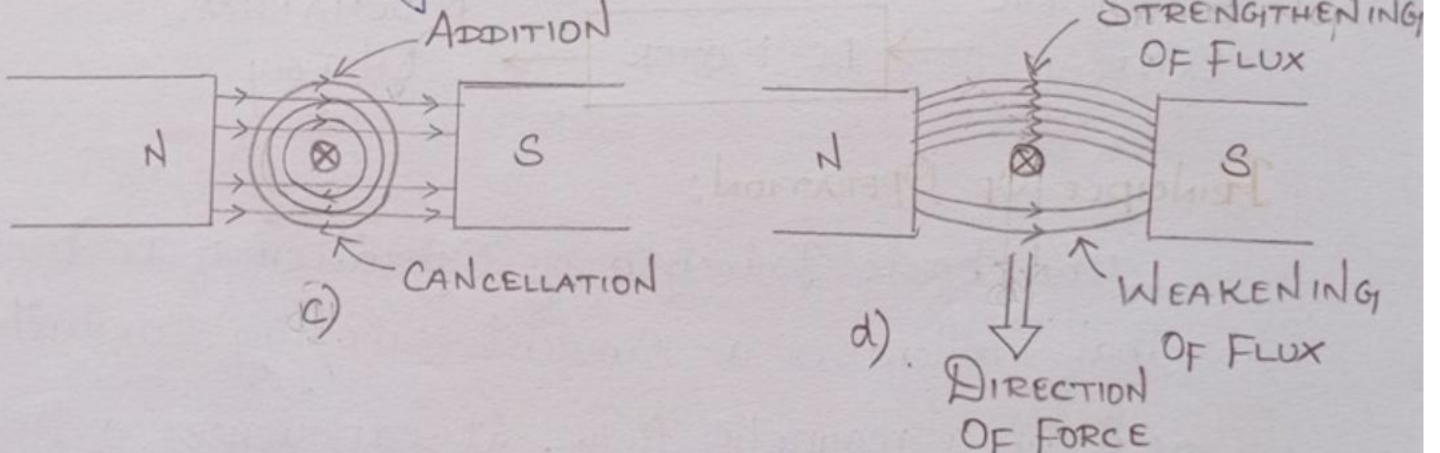
A Current Carrying Conductor along with the direction of the flux loops around it is shown in figure,



(8) In the DC motor, the field windings Produces magnetic field and armature Conductors Plays a role of Current Carrying Conductor experience the force.

The Conductors are Placed in the slots the individual force experienced by the Conductor Produces the twisting (or) turning force in armature Called torque.

So the armature experiences the torque and Starts rotating.



Now let's Consider the Single Conductor placed in the magnetic field. The magnetic field is Produced by the field windings when it is excited.

When the field winding is excited, it Produces the magnetic flux.

When this flux gets induced in the armature Conductors, Produces EMF. Due to this EMF, the armature Conductor too Produces flux.

Now there are two fluxes Produced and they are,

(i). Flux Produced by field Windings - main flux.

(ii). Flux Produced by armature Conductors - armature flux.

(9) When there are both fluxes, at the one side of Conductor the fluxes are in Same direction and in Other Side the fluxes are in Opposite direction.

When the fluxes are in Same direction it gets added and Strengthened and when the fluxes are in Opposite direction the fluxes gets Cancelled and Weakened.

The Strengthened flux Creates a Pressure and moves the Conductors to Weakened Side (low flux density Side).

Thus the Same Process happens in all the Conductors, as a result it Produces the twisting force and the armature Starts rotating.

EMF EQUATIONS OF DC MACHINE :

Let,
- P - number of Poles in DC machine
- ϕ - flux Produced by Pole (Wb)
- N - Speed of armature (RPM)
- Z - Total number of armature Conductors
- A - Number of Parallel Paths of Conductors

$A = P$ (Lap Winding)

$A = 2$ (Wave Winding)

Avg Value of emf, $e = \frac{d\phi}{dt}$

$d\phi$ - change in flux $= P\phi$

(10) dt - change in time $= \frac{60}{N}$

So, $e = \frac{P\phi}{60/N} = \frac{P\phi N}{60}$ (emf induced in one Conductor)

DC machine has Z Conductors and A Parallel Paths of Conductor.

So multiply "e" with $\frac{Z}{A}$

Total EMF, $E = \frac{P\phi N Z}{60 A}$ Volts

In Case of Lap Winding, A=P

So, $E = \frac{\cancel{P}\phi NZ}{60\cancel{P}} = \frac{\phi NZ}{60}$ Volts

In Case of Wave winding, A=2

So, $E = \frac{P\phi NZ}{60 \times 2} = \frac{P\phi NZ}{120}$ Volts

TORQUE EQUATION OF DC MACHINE:

Turning or twisting force in a axis is known as Torque.

Let us Consider a whel of Radius 'R', rotates in Speed "N" of force "F".

The angular Velocity of the wheel } $\omega = \frac{2\pi N}{60}$ (rad/Sec)

Torque, $T = F \times R$ (N-m)

Workdone, $W = F \times$ distance moved

$$W = F \times 2\pi R$$

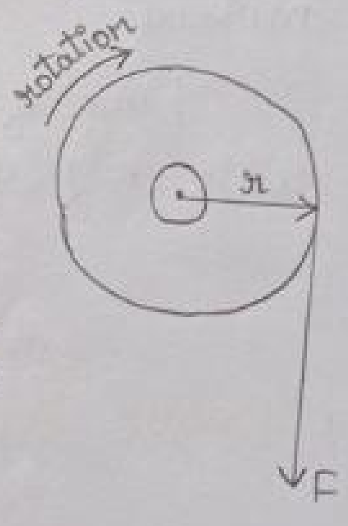
Power developed, $P = \frac{\text{Workdone}}{\text{Time}} = \frac{F \times 2\pi R}{60/N} = \frac{(F \times R)(2\pi N)}{60}$

$$P = T \times \omega \text{ (Watts)}$$

The torque developed by a DC motor is obtained by looking at the electrical Power Supplied to it and mechanical Power Produced by it. It is also Called armature torque. The gross mechanical Power developed in the armature is $E_b I_a$. Then,

Power in armature = Armature torque $\times \omega$

$$E_b I_a = T_a \times \frac{2\pi N}{60}$$



W.K.T, $E_b = \frac{\phi P N Z}{60A}$

$$\frac{P\phi N Z}{60A} \times I_a = T_a \times \frac{2\pi N}{60}$$

$$\frac{P\phi Z}{A} \times I_a = T_a \times 2\pi$$

$$T_a = \frac{1}{2\pi} \frac{P\phi Z}{A} \times I_a$$

$$\boxed{T_a = 0.159 \frac{P\phi Z}{A} \times I_a} \text{ (N-m)}$$

APPLICATIONS OF DC MOTOR:

Series Motor: → Lathe & Drills
→ Boring mills & Shapers
→ Spinning and weaving machines.

(12) Shunt Motor: → Electric traction
→ Cranes & Elevators
→ Air Compressor & Vacuum cleaner
→ Hair drier
→ Sewing machine.

Compound Motor: → Presses Shears
→ Reciprocating machine.

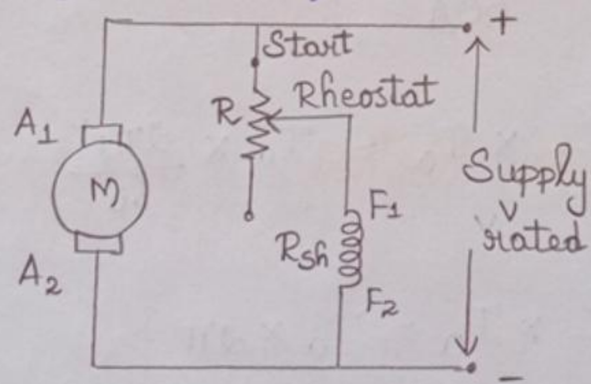
SPEED CONTROL OF DC MOTOR

1. SPEED CONTROL OF DC SHUNT MOTOR

(a). Flux Control Method:

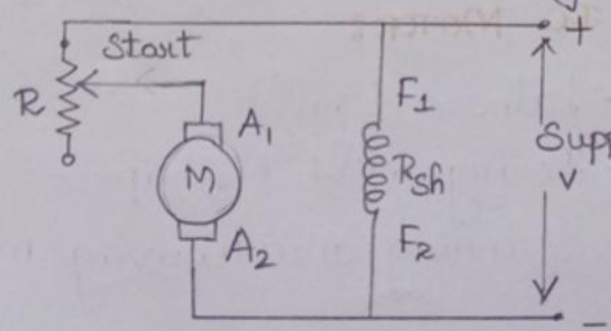
W.K.T, $N \propto \frac{1}{\phi}$. By Varying the flux, the motor speed can be changed and hence it is known as flux control method.

Flux of DC motor can be changed by changing I_{sh} with help of shunt field rheostat.



(b). Armature Voltage Control Method:

By Varying the Voltage across the armature by using the rheostat connected in series with armature, the speed of motor can be changed.



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2. Speed Control Of DC Series Motor:

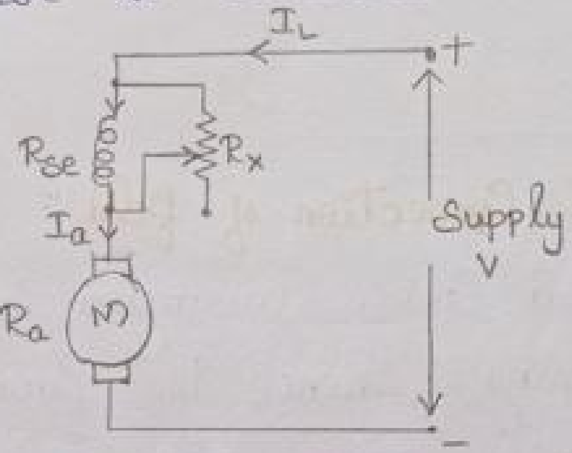
(a). Flux Control Method:

(i). Field Diverter Method

In this method, Variable resistance R_x is Connected Parallel with Series field winding.

By adjusting the Value R_x, any amount of Current Can be diverted through the diverter. Hence the Current through the field winding Can be adjusted.

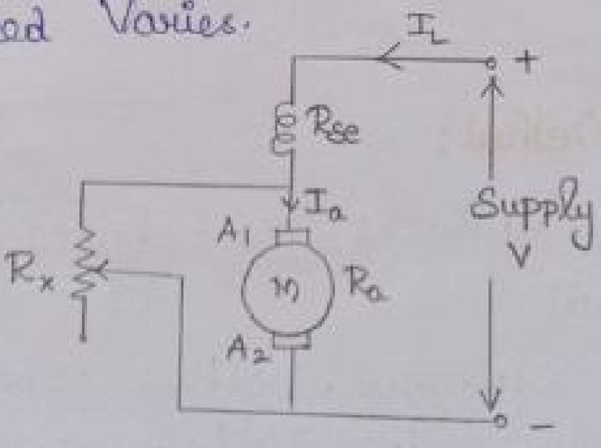
Due to this, flux is Controlled and the Speed of the motor is Controlled.



(ii). Armature Diverter Method

Here the resistance is Connected Parallel with the armature.

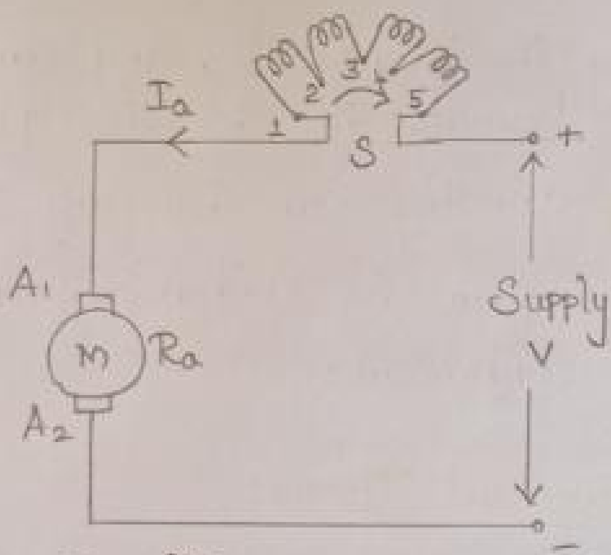
Any amount of armature Current Can be diverted through the diverter. Due to this armature Current reduces, Speed Varies.



(iii) Tapped Field Control

Here the flux changes are achieved by changing the number of turns of field windings. And the field windings are provided with the taps.

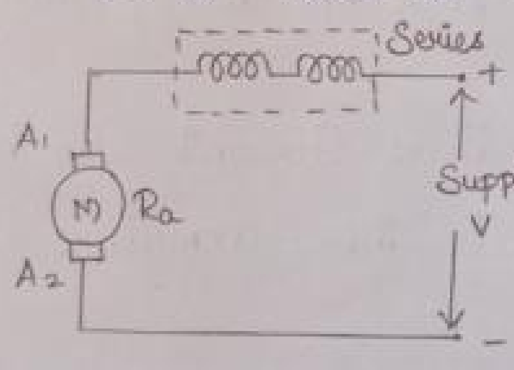
Selector Switch S is used to select the number of turns.

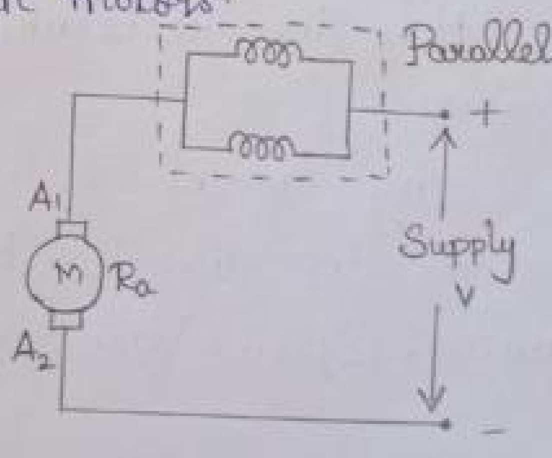


(iv) Series Parallel Connection of field

If the field coil is arranged in Series or Parallel, mmf produced changes, hence the flux changes, hence the speed is varied and controlled.

It is used in fan motors.

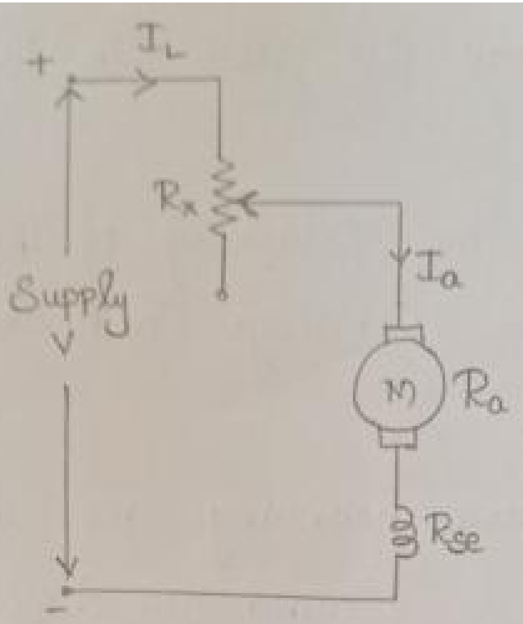




(b). Rheostatic Method:

Here the variable resistance is inserted with the motor circuit.

Due to resistance, voltage drop across resistance occurs, this reduces the voltage across armature as $N \propto V_a$, so speed decreases.



INDUCTION MOTOR

→ 1ϕ Induction Motor

→ 3ϕ Induction Motor

SINGLE PHASE INDUCTION MOTOR:

An induction motor is an AC motor that Operates on the Principle of Electromagnetic Induction.

Construction of Single phase Induction Motor

Two main Parts, a). Stator which is Stationary
b). Rotor which rotates.

a). STATOR:

The Stator has a laminated type of Construction made up of Stampings which is of 0.4 to 0.5 mm thick.

The Stampings are Slotted on its Periphery to Carry the Stator Windings and the Stampings are insulated from each other which Keep the iron loss minimum.

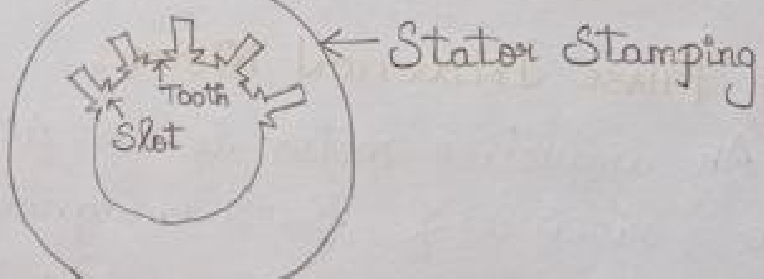
Number of Stampings are Stamped together to build the Stator Core. The material Selected for Stamping is Silicon Steel.

(16) The builded Core is fitted in the fabricated Steel frame.

The Slots on the Periphery of the Stator Core Carries three Phase Windings Connected either in Star or delta.

The three phase Windings are Called Stator Windings and it is Wound for definite number of Poles.

The Speed of the motor depends on the number of Poles.



b) Rotor:

The rotor is placed inside the Stator and the rotor is also laminated and it is made up of Cast iron.

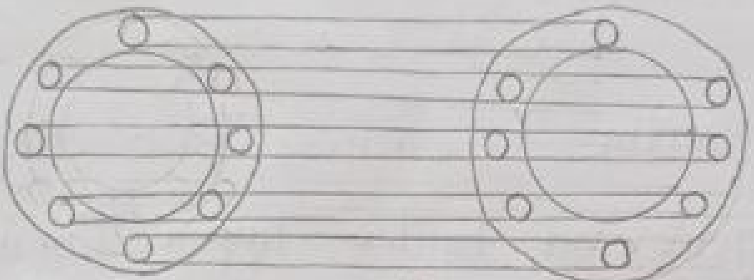
It is Cylindrical with Slots on the Periphery. The rotor Conductors are placed in the rotor Slots.

Squirrel Cage rotor:

The rotor is Cylindrical and Slotted on its Periphery.

The rotor Consists of Copper bars Called rotor Conductors and the bars are shorted at both ends by end rings (Copper rings).

Due to Connections of end rings the rotor is said to be Short Circuited rotor. So due to this no external resistance Can be Connected. The resistance of the rotor is less.



Operation of Single phase Induction Motor:

In a Single phase induction motor, 1 ϕ AC Supply is given to the Stator Winding.

The Stator Winding Carries an alternating Current which Produces the flux. This flux is Called main flux.

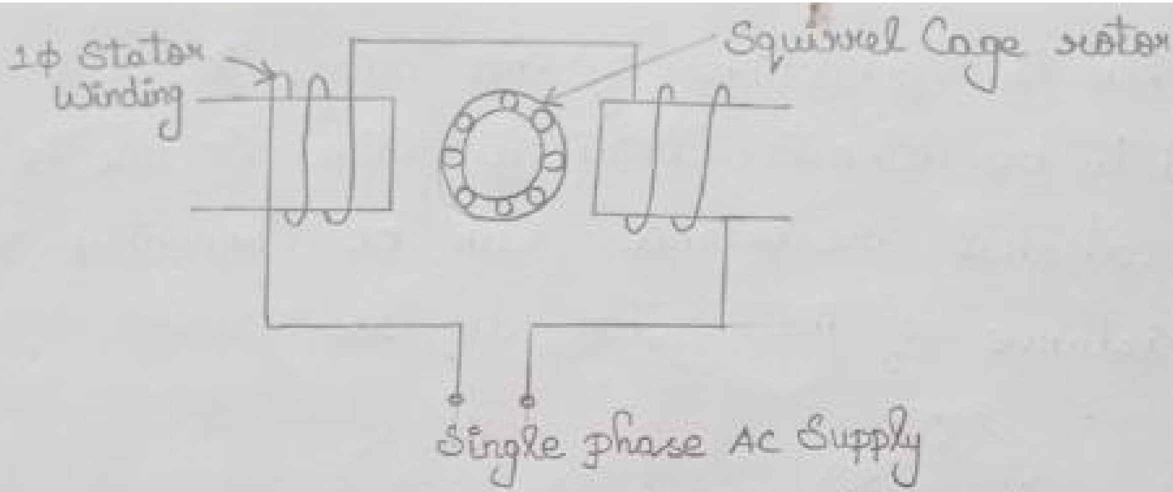
This flux links with the rotor Conductors and due to induction Principle emf get induced in the rotor.

The induced emf drives Current through the rotor, as rotor Circuit is closed Circuit.

This rotor Current Produces another flux Called rotor flux required for the motoring action.

The Second flux is Produced according to the induction Principle due to induced emf, hence the motor is Called induction motor.

(18)

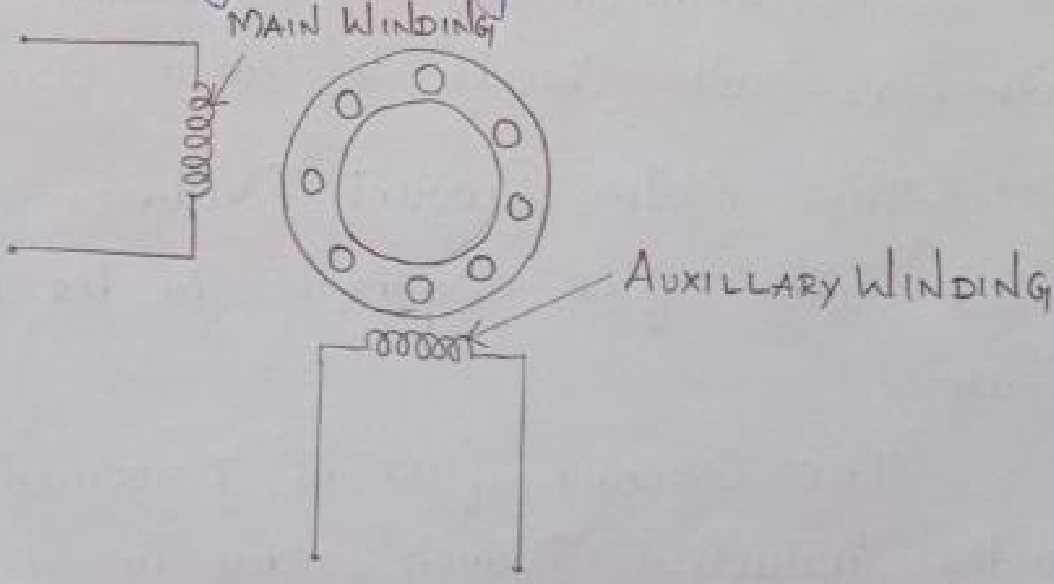


Here the rotor experiences two different forces.

Force experienced by the upper Conductor of the rotor will be directed towards download direction and the force experienced by the lower Conductor of the rotor will be directed towards upward direction.

Hence two Sets of forces will Cancel and the rotor will experience no torque. So the rotor does not rotate.

So to Produce rotation, additional winding Called auxillary winding is Connected.



Now the motor has two windings and they are main winding and auxillary winding.

When the windings are energized, fluxes are Produced.

Flux of main winding and the auxillary winding have 90° phase difference. Thus generates torque and rotor starts to rotate.

APPLICATIONS OF 1ϕ INDUCTION MOTOR:

Pumps

Compressors

Fan

Mixers

Drilling machines.

THREE PHASE INDUCTION MOTOR:

Construction of Three Phase Induction Motor:

The induction motor consists of two main parts,

(i). Stator which is stationary, holds 3 windings.

(ii). Rotor which rotates.

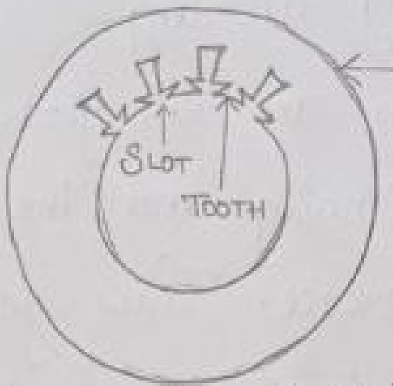
STATOR:

The stator has a laminated type of construction made up of stampings which are 0.4 to 0.5 mm thick.

The stampings are slotted on its periphery to carry the stator windings.

Number of stampings are stamped together to build the stator core and the stator core

(20) is fitted in the fabricated steel frame.



The slots on the periphery of the stator core carries three phase windings connected either in star or delta.

The three phase windings are called stator windings and it is wound for definite number of poles.

The speed of the motor depends on the number of poles.

ROTOR:

The rotor is placed inside the stator and the rotor is also laminated. The rotor conductors are placed in the rotor slots.

There are two types of rotor, (i). Squirrel Cage rotor
(ii) Slip ring or Wound rotor.

(i) Squirrel Cage rotor:

This type of rotor is made up of cylindrical laminated core with slots to carry the rotor conductors.

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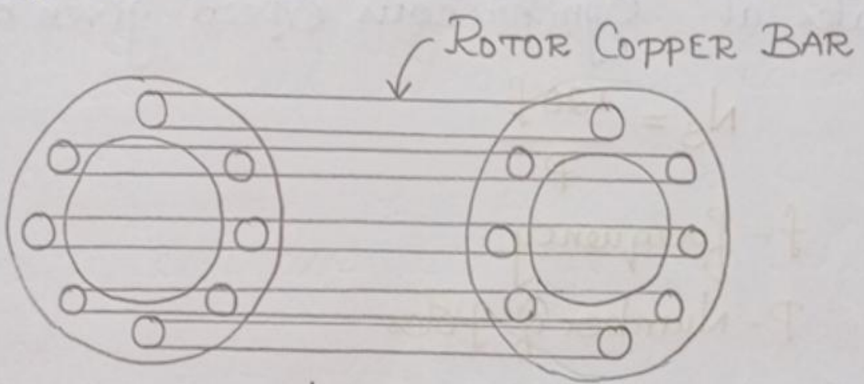
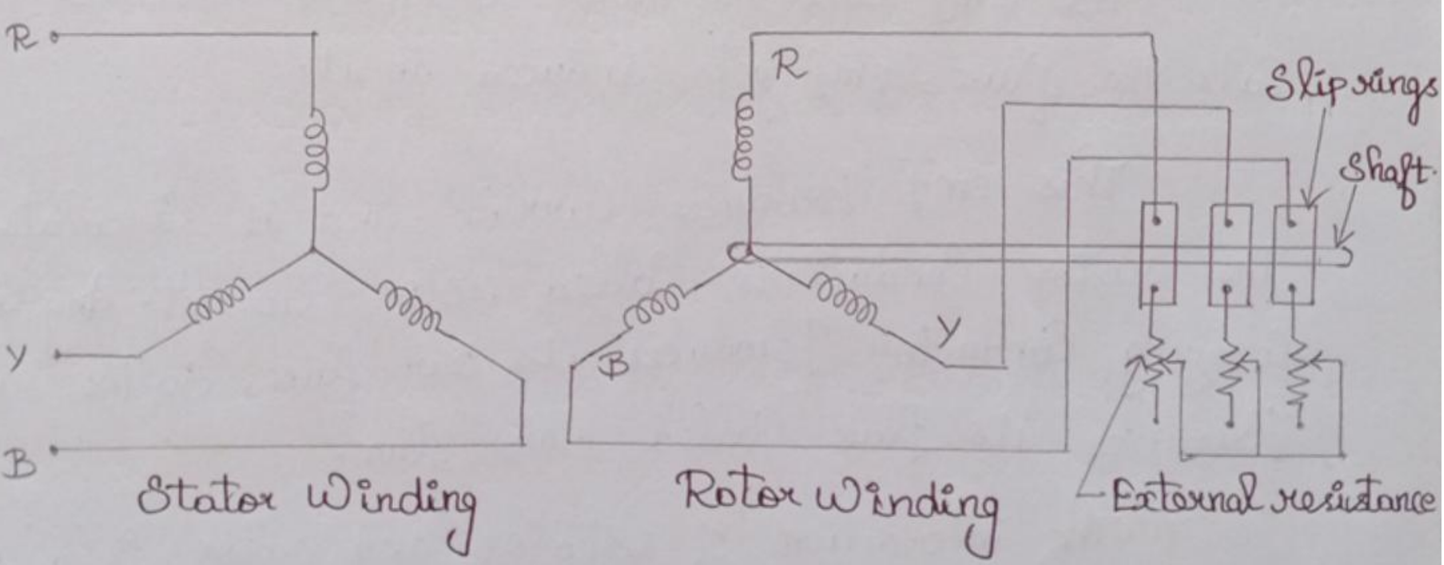
This rotor Consists of Copper bars placed in the Slots and the bars are Shorted at the each ends with the help of Copper rings Called end rings.

Due to Connections of end rings the rotor is Said to be Short Circuited rotor.



(ii) Slip ring or Wound rotor:

In this type of rotor, rotor Windings are Similar to the Stator Windings. The rotor Windings may be Star or delta Connected, distributed Windings.



The external resistance Can be added With the help of brushes and Slip rings.

By Varying it, the motors Speed and torque Can be Controlled.

Operation of Three phase Induction Motor:

Three-phase Supply is given to the Stator Winding. Due to this, Current flows through the Stator Winding. This Current is Called Stator Current.

It Produces a rotating magnetic field in the Space between Stator and rotor. This magnetic field rotates at Synchronous Speed given by, N_s

$$N_S = \frac{120f}{P}$$

f - frequency

P - Number of Poles

This rotating field Produces an effect of rotating Poles around a rotor. The Stator rmf is rotating. So there exists a relative motion between the rmf and the rotor Conductors.

The rmf Cuts the rotor Conductors. Whenever Conductor Cuts the flux, emf gets induced in it.

This emf Produces Current and it Circulates in the rotor Conductors Called rotor Current. Any Current Carrying Conductor Produces its own flux, so the rotor Produces its flux Called rotor flux.

The interaction of Stator and rotor field develops torque. Then the rotor rotates in the Same direction as the rotating magnetic field.

When the rotor is at Standstill, the frequency of rotor is equal to the Supply frequency.

(23) As the rotor Speed Picks up, the frequency of rotor emf and the magnitude of rotor emf decreases.

The rotor tries to Catch up with the rotating magnetic field. However, the rotor Cannot really Catch up and rotate at the Speed Slightly less than Synchronous Speed.

Let us Consider, if the rotor Speed is equal to Stator Speed ($N_r = N_s$), the magnetic field never Cuts the loop thus there will not be any induced emf and Current. Hence no torque.

Therefore, in an induction motor, the rotor Speed is always less than the Synchronous Speed. ($N_r < N_s$). So this machine is Called as Asynchronous motor.

The difference b/w Synchronous Speed and rotor Speed is Called Slip Speed.

$$\text{Slip, } S = \frac{N_s - N_r}{N_s}$$

$$\% \text{ Slip} = \frac{N_s - N_r}{N_s} \times 100.$$

Applications of Three phase Induction Motor:

Lifts
Cranes
Hoists
Large Capacity exhaust fans
Driving lathe machines
Crushers
Oil extracting mills.

Synchronous Machine

An AC generator is an electrical machine which Converts mechanical energy into electrical energy (AC).

Construction of AC Generator (or) Alternator (or) Synchronous Generator / Synchronous Motor:

1). Stator Frame:

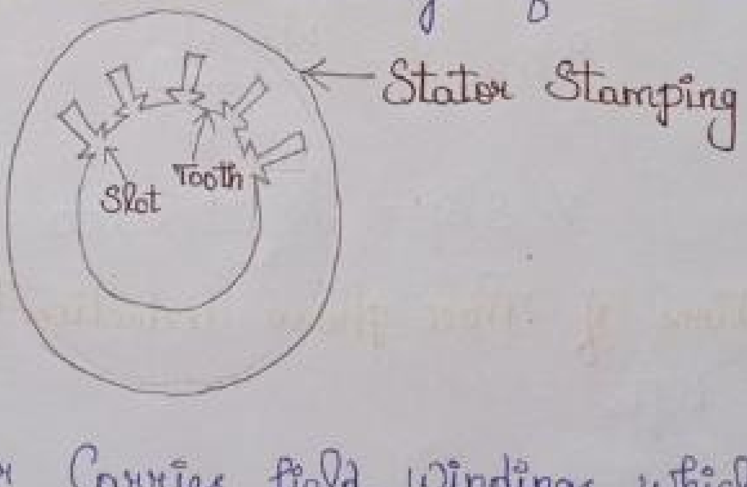
The Stator frame (i.e) Yoke is used for holding the armature Stampings and Windings.

Ventilation is Provided by giving air Spaces.

2). Stator Core:

It is the Stationary Part of the machine and it is made up of Steel laminations having Slot on its inner Periphery.

The Core is laminated to reduce the eddy Current loss. Three phase Windings is placed in these Slots and Serves as the armature windings of the alternator.



3) Rotor:

The rotor Carries field windings which are Supplied with the direct Current through two Slip rings by a Separate DC Source.

Two types of rotor used in alternators and they are,

a). Salient Pole Type

b). Smooth Cylindrical type.

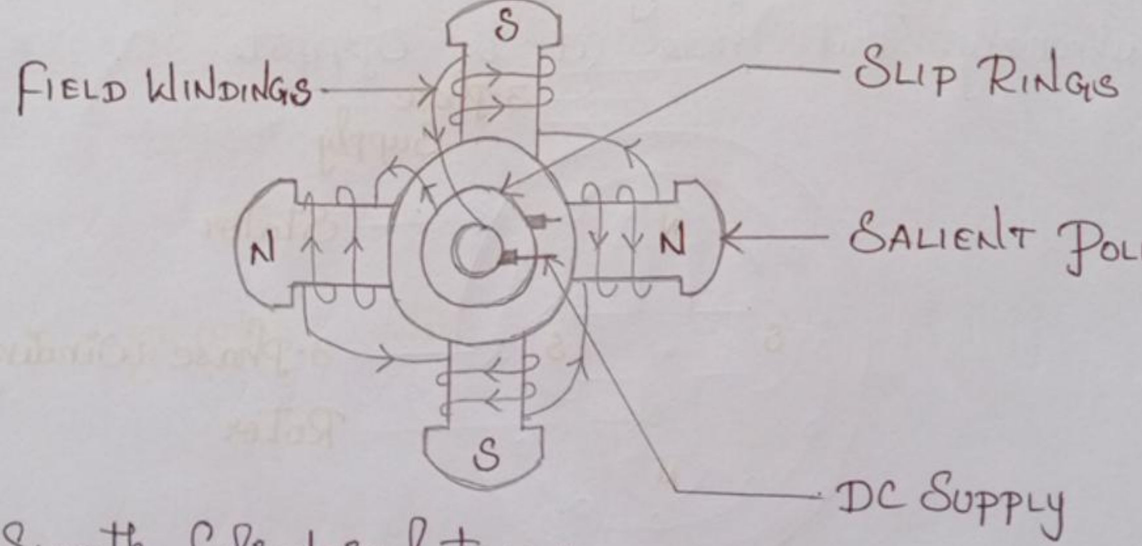
a). Salient Pole type:

The rotor of this type is used in Slow and moderate Speed alternators.

It Cannot be used in high Speed because the mechanical Strength is low. And also the Salient Pole rotor Cannot be used in high Speed alternator.

The field Coil are placed on the Pole Pieces and Connected in Series.

The ends of the field windings are Connected to a DC Source through Slip ring Carrying brushes mounted on the Shaft.

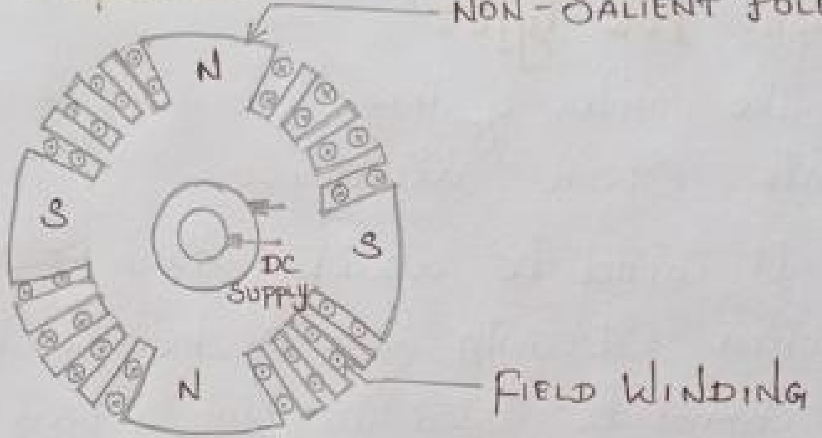


b). Smooth Cylindrical type:

The rotor of this type is used in Very high Speed alternator which is driven by Steam turbine.

This rotor has number of Slots at the Outer Periphery for housing of the field Coils.

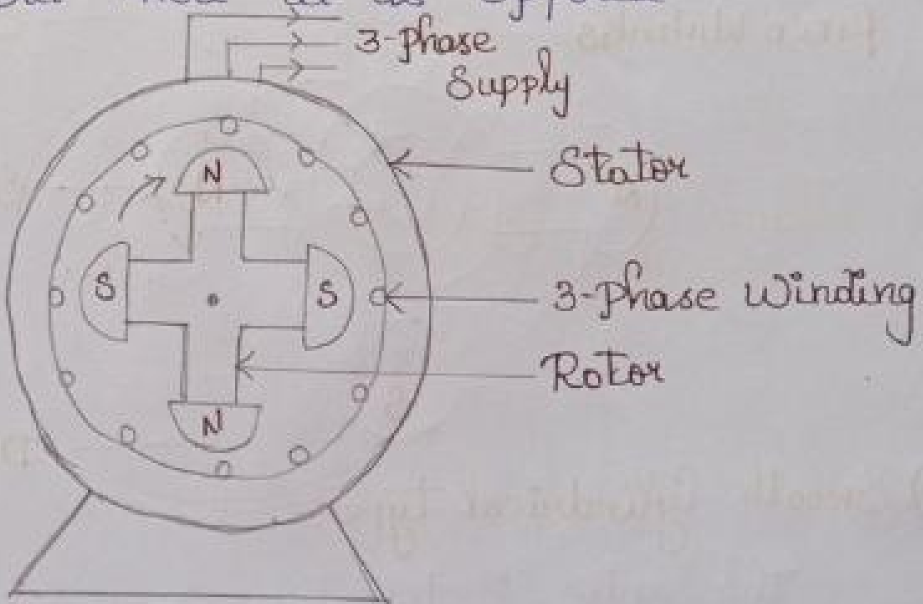
And this rotor is used in 2 Pole and 4 Pole turbo generator running at 3600 rpm.



Working of AC Generator (or) Alternator.

The alternator works on the Principle of electromagnetic induction as a DC generator.

In this Case of DC generator the armature Conductors are rotating and the field System is Stationary. But here it is Opposite.



The armature winding is wounded on the Stationary element Called Stator and the field windings on the rotating element Called rotor.

The field windings which is wounded on the rotor slots are energized by the DC supply which is generated by DC generator (125 to 600V), placed in the same shaft of rotor.

When energized, it starts to produce the magnetic flux of N-pole and S-pole.

The rotor is made to rotate by external source, when the moving flux interacts with the stationary conductors, the emf gets induced.

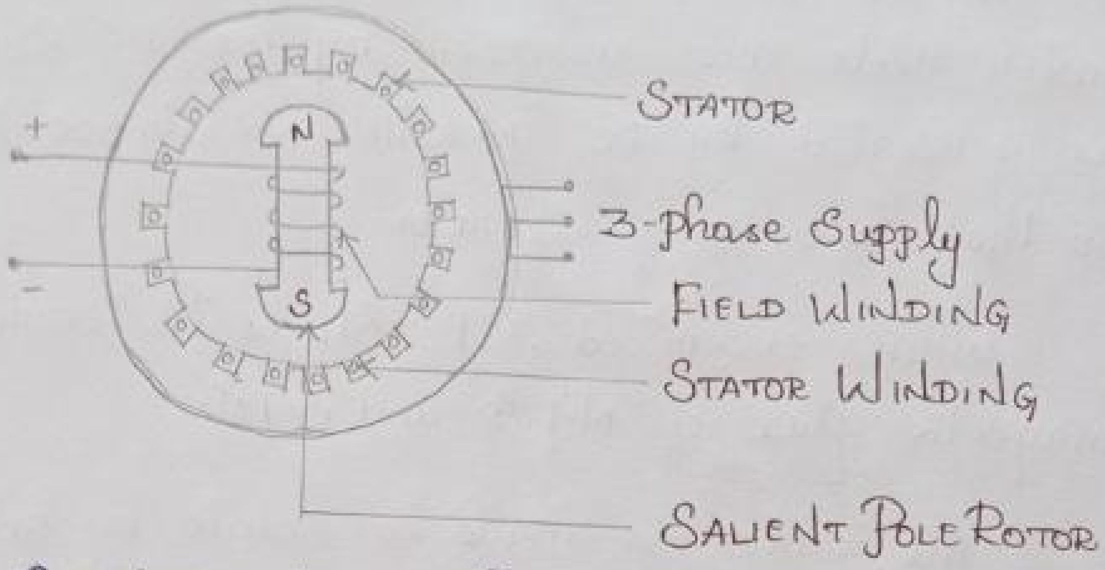
Here in this alternator, there is no brushes, slip rings and commutator because the armature windings are stationary.

Direction of the current will vary according to the N and S pole.

Working of Synchronous Motor:

A Synchronous Motor is the device which converts electrical energy into mechanical energy.

Synchronous Motor works on the Principle of magnetic locking. When two unlike poles are brought near, if the magnets are strong, there exists a tremendous force of attraction between those two poles, in this condition the magnets are said to be magnetically locked.



Consider a three Phase Synchronous motor, whose Stator is wound on the Poles.

The two magnetic fields are Produced in the Synchronous motor by exciting both the windings where Stator with three phase winding and rotor with the DC Supply.

When three phase winding is excited by three Phase AC Supply, flux will be Produced which is rotating at a Synchronous Speed and this magnetic field is Called rotating magnetic field.

$$\text{Synchronous Speed, } N_s = \frac{120f}{P}$$

Let us assume the Stator Poles are N_1 and S_1. Now the field winding of the rotor is excited by DC Supply. So that the rotor also Produces two Poles N_2 and S_2

Now one magnet is rotating at N_s having Poles N_1 and S_1. While the rotor is Stationary having Poles N_2 and S_2.

If Somehow the unlike poles N_1 and S_2 (or) S_1 and N_2 are brought near each other, the magnetic locking will be established between Stator and rotor poles.

As the Stator poles are rotating, due to interlocking, the rotor Starts to rotate at a Synchronous Speed.

Applications of Synchronous Motor:

→ Textile and Paper Industry

→ Fans, blowers, Centrifugal Pumps, etc.,

→ Generating Stations and Substations.

STEPPER MOTOR:

Stepper motor is a electromechanical device that move in discrete Steps. It is also known as Step motor or Stepping motor.

Construction of Stepper Motor:

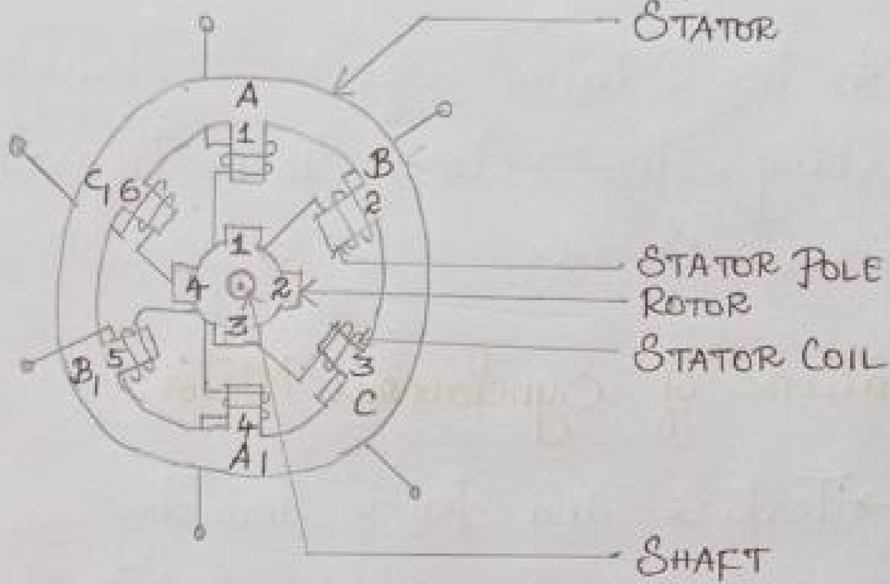
Type of Stator & rotor - Salient pole type.

Stator has Concentrated Windings. Rotor has no Windings. Rotor is a ferromagnetic material.

Number of Poles in the Stator and rotor is different, which gives (i). Self-Starting Capability.
(ii). Ability of bidirectional rotation.

Usually the number of Poles of Stators is even in number. When the Stator has 6 Poles, the rotor has 4 Poles.

Poles are Wounded With Coil and the Opposite pole Windings are Connected where the flux Produced gets added.



Coil A and A' are Connected, B and B', C and C' are Connected in Series to form a phase Windings.

This Phase Windings is Connected to DC Source With help of Semiconductor Switch S_1, S_2 and S_3.

Working of Stepper Motor:

Stepper Motor working on the Principle of Variable reluctance motor.

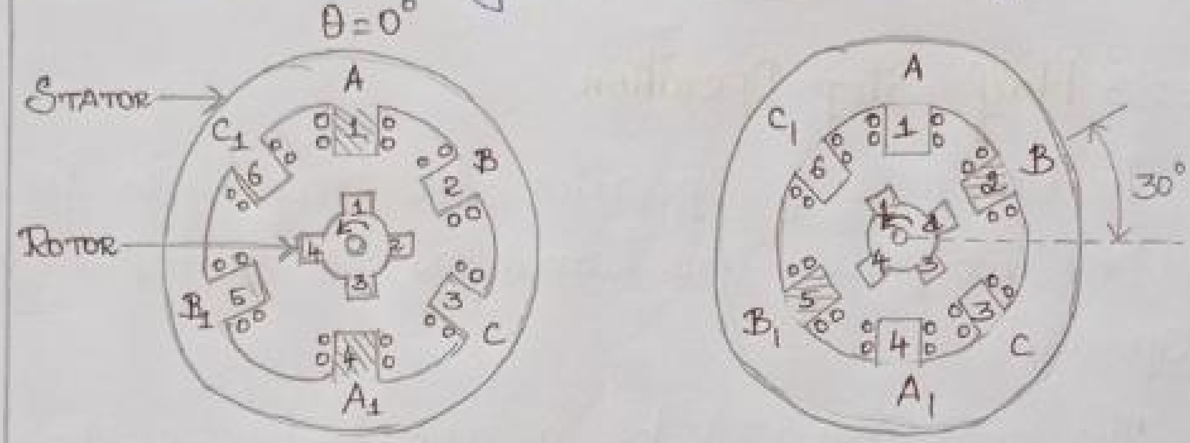
Mode 1: One Phase ON Operation

Here only one Phase is energized at a time.

First, the Switch S_1 is Closed and the Phase A gets energized. Now the rotor Poles 1 and 3 get aligned with the Stator Poles A and A'.

Now Switch S_1 is Opened and Switch S_2 is closed. So the phase B is energized, the rotor Poles 2 and 4 aligns with Stator Poles B and B'.

Then the Switch S_2 is Opened and Switch S_3 is closed. The angular displacement of rotor is 30°.



MODE 2: Two Phase ON Operation

Here two phases are energized at a time.

Now phase A and B are energized, So that the rotor gets aligned between the two Phases. The angular displacement of rotor is 15°.

Now phase B and C are energized, So that the rotor gets aligned between the two Phases. The angular displacement of rotor is 15°.

The total displacement is 15° + 15° = 30°

Then the Phase C and A are energized and the energization Process Continues.

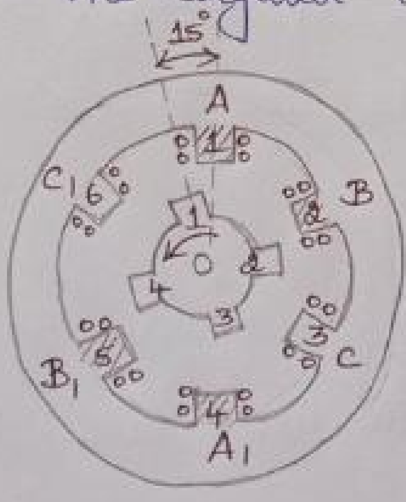
MODE: 3 Half Step Operation

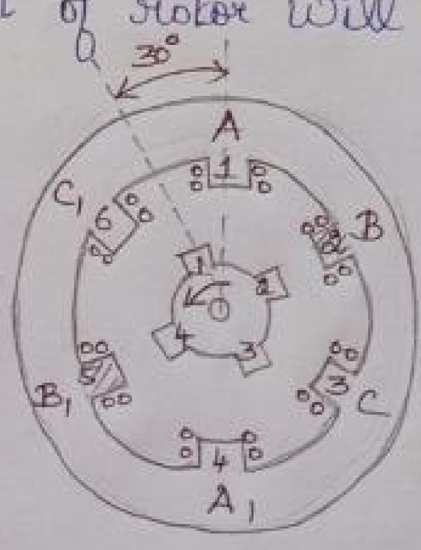
In this mode of Operation, one phase is ON for a while and two phases are turned ON for later Part in the Operation.

The excitation will be a, a+b, b, b+c, c etc.,

The technique of Shifting excitation from one Phase to another is known as half Step.

The angular displacement of rotor will be 15° and 30°.





MODE:4 Miow Stepping Operation

In this mode, the Step angle of the motor will be Very Small So that it is known as miow Stepping

It uses two phases at a time, but the two Currents will be unequal.

The Current is phase A is Constant and Current flow through B phase Windings is increased in Very Small increments until the maximum Current is reached.

The micro Stepping Provides Smooth low Speed Operation.

The Step angle will be 1/2, 1/5, 1/10, 1/16 or 1/32.

Applications of Stepper Motor:

- Commercial, Industrial and medical applications
- Watches and clocks
- Robotics
- Spacecrafts

BRUSHLESS DC MOTOR:

PMBLDC motor is DC motor which has Permanent magnet as a rotor.

Construction:

Stator:

The Stator is made up of Silicon Steel Stampings with Poles/Slots.

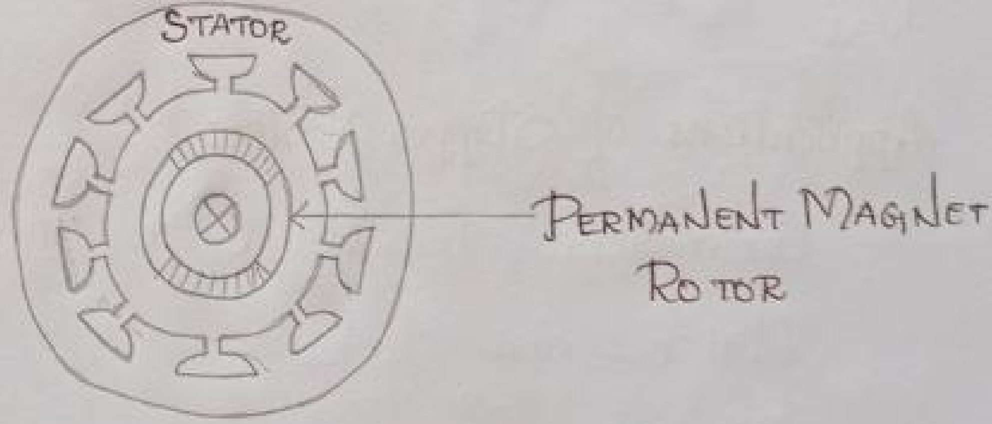
The Windings are placed in the Slots. Windings in Opposite Slots/Poles of Stator are Connected to form a Phase or Set.

Now the Windings are Connected with DC Supply through a Power electronic Switching Circuit.

Rotor:

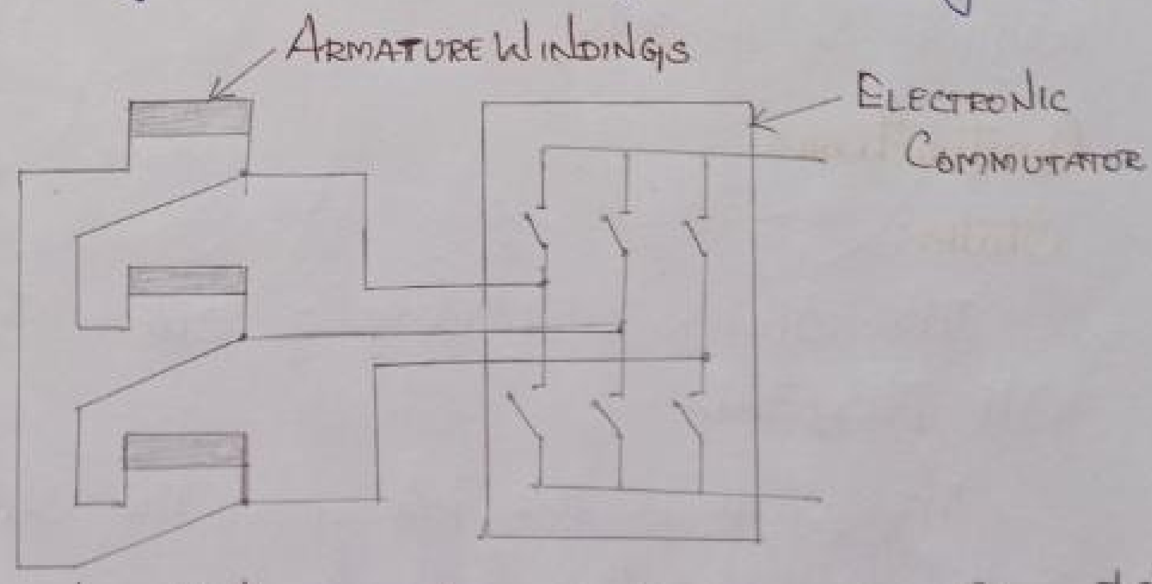
The rotor is Permanent magnet.

The rotor Shaft Carries a rotor Position Sensor which Provides information about the Position of Shaft.



Working:

The Working of the PMBLDC is based on the function between the Permanent magnet (rotor magnet) and electromagnet (Stator Windings when energized).



Connection between rotor Windings and the Commutator.

The DC Supply is given to first Set of Opposite Windings of the PMBLDC motor at one instant.

So the Windings becomes a electromagnet and Pulls the rotor (Permanent magnet) and aligns with it.

Then the first Set of armature Windings is de-energized and the Second Set of armature Winding is energized.

Again the rotor gets aligned with Second Set of armature Winding.

Then the third Set of armature Winding is energized and the Same Process is repeated Continuously till it gets energized.

Applications of PMBLDC Motor:

Automotive applications

Textile Industries

Computer & robotics

Fans and mixers etc.,

TRANSFORMER:

Construction and Operation of Transformer:

A Transformer is a Static device that transfers electrical energy from one Circuit to another Circuit Without change in frequency.

Its Construction is Simple as there are no moving Parts. The main Components are,

1. Magnetic Core:

The transformer Core is made up of good magnetic material like Silicon Steel and it is laminated.

Thickness of Stampings Varies from 0.35mm to 0.5mm

Laminations are insulated with each other by Coating then with a thin Coat of Varnish.

After arranging the laminations, it is bolted.

There are two types of transformer Cores, a). Core type & b). Shell type.

a). CORE TYPE TRANSFORMER:

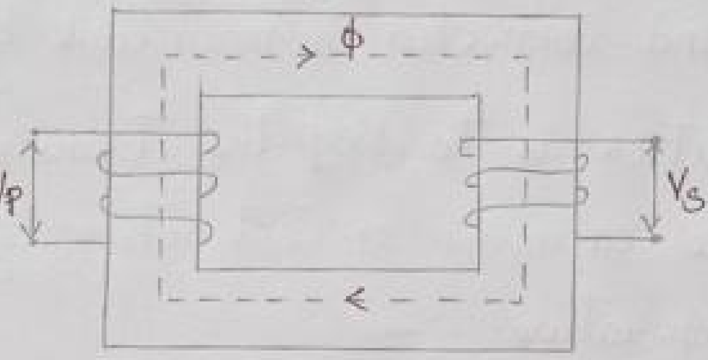
Here the Core is made up of two L type Stampings

The Coil used here is usually Cylindrical type and Wounded.

For transformer of higher rating Stepped Core with Circular Cylindrical Coils are used.

For Transformer of Smaller ratings, rectangular Coils with Core of Square or rectangular Cross Section are used.

Insulating Cylinders are used to Separate Windings from the Core and from each other.



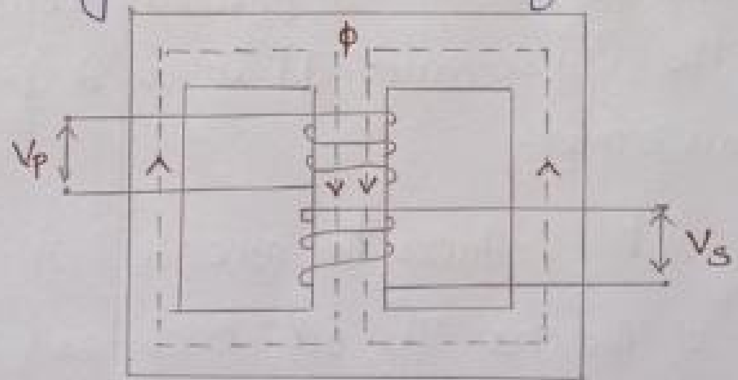
Shell type transformer:

Here the Core is made up of E and I Stampings, and it has three limbs.

It has two Parallel Paths from magnetic flux.

The Coil which is used here is multilayer disc type and are wounded in the form of Pancakes.

Each layer is insulated from each other.



2. WINDINGS:

There are two Windings in transformer and they are Primary and Secondary Windings.

3. INSULATION:

Paper is still used as the insulation.

For Power transformer, enameled Copper with Paper insulation is used.

4. EXPANSION TANK OR CONSERVATOR:-

Small auxiliary oil tank may be mounted above the transformer and connected to main tank by a pipe.

Its function is to keep the transformer tank full of oil despite expansion or contraction of the coil with change in temperature.

A small pipe connection between the gas space in the expansion tank, and the cover of the transformer tank permits the gas above the oil in the transformer to pass into the expansion tank.

So that the transformer tank will be completely filled with oil.

5. BUCHHOLZ RELAY:

The Buchholz relay is placed between the main tank and the conservator. It is used for the protection of the transformer.

The fault induces the arc which increases the temperature of the gas. The oil becomes evaporated and moves upwards.

The Buchholz relay detects the failure and gives the alarm to the personnel. The transformer is disconnected from the main supply for maintenance.

6. BREATHER:

The simplest method to prevent the entry of the moisture inside the transformer tank is to provide chamber known as breather.

Breather is filled with drying agent such as Calcium Chloride or Silica gel.

Silica gel or Calcium chloride absorbs moisture and allows dry air to enter the transformer tank.

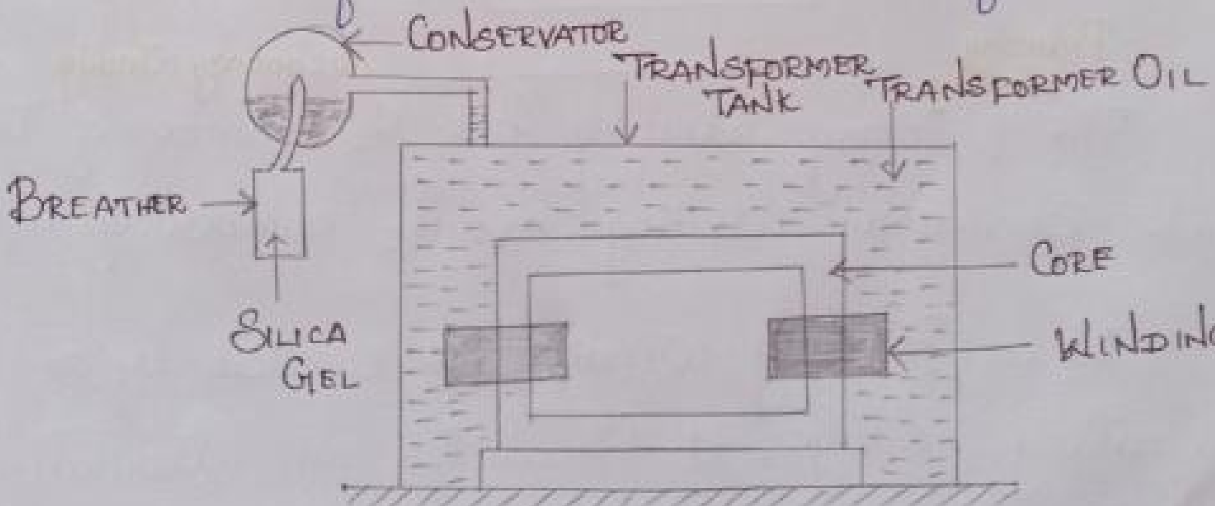
7. Bushings:

Connection from transformer windings is brought out by the means of bushings.

Porcelain Insulator can be used upto a voltage of 33KV. Above 33KV, oil filled type of bushings are used and the bushings are fixed on the transformer tank.

8. COOLING SYSTEM:

The various cooling systems used in transformer are oil immersed natural cooled transformer, oil immersed forced air cooled transformer, oil immersed water cooled transformer, oil immersed forced oil cooled transformer, air blast transformer.



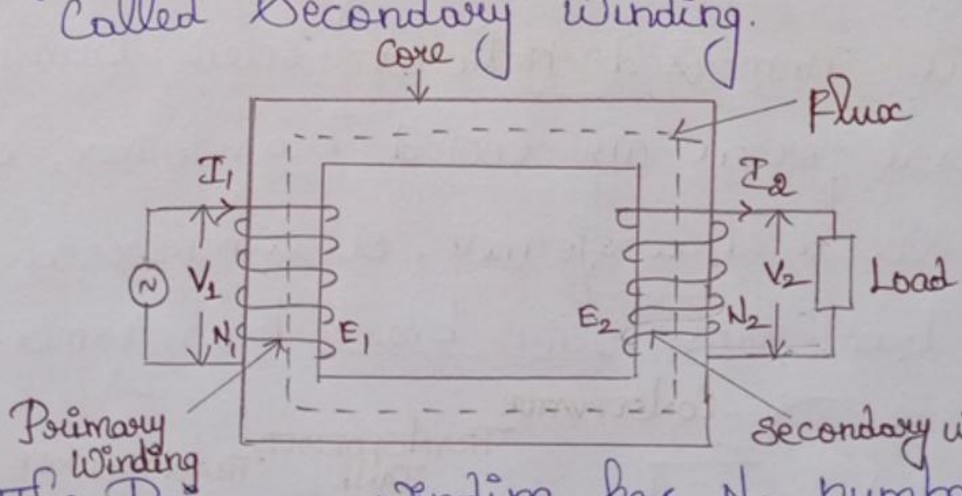
Operation of Transformer:-

The transformer works on the Principle of mutual induction and it States that, when two Coils are inductively Coupled and if there is Current in one Coil, EMF gets induced in the other Coil.

This EMF Can drive Current, when Closed Path is Provided to it.

There are two Coils which are electrically Separated but linked through a magnetic Circuit.

one of the two Coils is Connected to a Source of alternating Voltage, it is Called Primary Winding and the other winding is Connected to load, it is Called Secondary winding.



The Primary winding has N_1 number of turns while Secondary winding has N_2 number of turns.

When Primary winding is excited by an alternating Voltage, it Circulates an alternating Current.

This Current Produces an alternating flux which Completes its Path through Common magnetic Core.

Alternating flux links with the Secondary Winding According to faradays law of electromagnetic induction, mutually induced EMF gets developed in the Secondary Winding.

And if the load is Connected to the Secondary Winding, this EMF drives a Current through it.

Applications of Transformer:

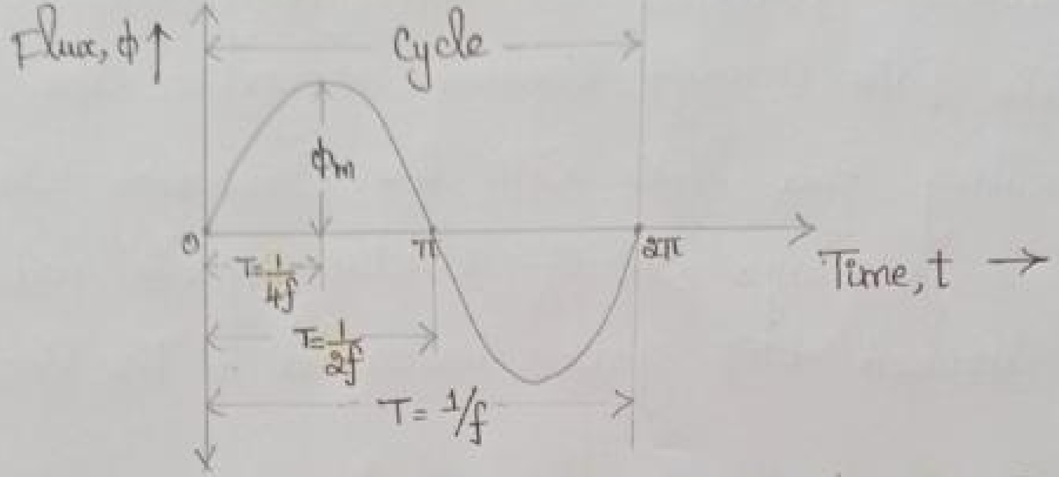
Industrial Machineries
Manufacturing Industry
Control Circuits
Electrical Appliances etc.,

EMF EQUATION OF TRANSFORMER:

The derivation of the EMF equation of the transformer is Shown below.

Let,

ϕ = The flux Per turn in weber
ϕ_m = maximum Value of flux.
N_1 = number of turns in Primary Winding
N_2 = number of turns in Secondary Winding
f = frequency in Hz
E_1 = Primary induced EMF
E_2 = Secondary induced EMF



As shown in above figure - flux increases from its zero value to maximum value ϕ_m in one quarter of the cycle (i-e), in 1/4 second.

Average rate of change of flux $= \frac{d\phi}{dt}$

$$\frac{d\phi}{dt} = \frac{\phi_m}{1/4f} = 4f\phi_m$$

Now rate of change of flux per turn means induced EMF in Volts.

Average EMF per turn $= 4f\phi_m$ Volt.

If flux ϕ_m varies sinusoidally, then RMS value of induced EMF is obtained by multiplying the average value with form factor.

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}} = 1.11$$

RMS Value of EMF $= 1.11 \times 4f\phi_m$

$$\boxed{E = 4.44 f\phi_m} \text{ Volt}$$

RMS Value of EMF in Primary Winding, $\boxed{E_1 = 4.44 f\phi_m N_1}$ Volt

RMS Value of EMF in Secondary Winding, $\boxed{E_2 = 4.44 f\phi_m N_2}$ Volt

(43) ALL DAY EFFICIENCY OF TRANSFORMER:

Transformer Efficiency, $\eta = \frac{\text{Output Power}}{\text{input Power}}$

$$\eta = \frac{\text{Output Power}}{\text{Output Power} + \text{losses}}$$

$$\eta = \frac{\text{Output Power}}{\text{Output Power} + \text{iron losses} + \text{Copper losses}}$$

Output Power = $V_2 I_2 \cos\phi$

where, V_2 = Secondary terminal Voltage on load

I_2 = Secondary Current on load

$\cos\phi$ = Power factor of load.

Transformer efficiency, $\eta = \frac{n V_2 I_2 \cos\phi}{n V_2 I_2 \cos\phi + P_i + n^2 P_{cu}}$

At, Full load, $n = 1$

Half load, $n = 1/2$

The Condition for maximum efficiency is given by,

$$= \text{Full load KVA} * \sqrt{\frac{\text{Iron loss}}{\text{Full load Copper loss}}}$$

The Commercial efficiency of a Transformer is defined as the ratio of the Output Power to the input Power.

$$\%\ \text{efficiency} = \frac{\text{Output Power}}{\text{input Power}} \times 100$$

The Performance of Such transformer is judged on the basis of Energy Consumption during the whole day. This is known as all day (or energy efficiency.

The ratio of Output in kWh to input in kWh of a transformer Over a 24 hrs Period is known as all day efficiency.

$$\eta_{all\text{-}day} = \frac{\text{kWh Output in 24 hours}}{\text{kWh input in 24 hours}}$$

⇒ A transformer with 40 turns on the high Voltage winding is to be used to step down the Voltage from 240V to 120V. Find the number of turns in the low Voltage winding.

Given: High Voltage Winding turns, $N_1 = 40$

Primary Voltage, $V_1 = 240\,V$

Secondary Voltage, $V_2 = 120\,V$

Solutions:

Transformer turns ratio, $K = \frac{V_2}{V_1} = \frac{N_2}{N_1}$

$$N_2 = \frac{V_2}{V_1} \times N_1$$

$$= \frac{120}{240} \times 40 = 20 \text{ turns.}$$