

Unit - 4 Electrical Machines

generator

In electrical machines which converts mechanical energy into Electrical energy is known as generator.

The classification of generator are

Generator

DC Generator

Separately excited

Self excited

Series

Shunt (parallel)

Compound

Longshunt

Short shunt

AC Generator

Synchronous Generator

Induction Generator

Motor:

In electrical machines which converts Electrical energy into Mechanical energy is known as Motor.

The classification of motor are

Motor

D.C Motor

Separately excited

Self excited

Series

Shunt (parallel)

Compound

AC Motor

Synchronous motor

Induction motor

Longshunt

shortshunt

Slip: It is defined as ratio of difference b/w Synchronous Speed and rotar Speed to Synchronous Speed.

The mathematical expression slip is

$$S = \frac{N_s - N_r}{N_s}$$

where

N_s = Synchronous Speed

N_r = Rotar Speed.

The percentage of slip is given as

$$\% S = \frac{N_s - N_r}{N_s} \times 100$$

To determine the Rotar Speed based on the above equation is given as

$$\% S = \frac{N_s - N_r}{N_s} \times 100$$

$$N_s S = N_s - N_r$$

$$N_r = N_s - N_s S$$

$$N_r = N_s (1-S) RPM$$

Synchronous Speed:

It is defined as the Speed which magnetic field rotates is known as synchronous speed. It is denoted by N_s .

$$N_s = \frac{120f}{P} RPM$$

RPM = Revolution per Minuter

Where P = No. of poles

f = frequency

Rotar frequency

It is defined as the product of slip and actual frequency is known as Rotar frequency. It is denoted by f_r

$$f_r = S \times f - Hz$$

Q) Three phase induction motor has four poles is connected 400 V, 50 Hz Supply and percentage of slip is 6% and calculate the Nr.
Given data

3-Ø Induction motor

$$\text{No. of poles} = 4$$

$$\text{Voltage } V = 400 \text{ V}$$

$$\text{frequency} = 50 \text{ Hz}$$

$$\therefore \text{Slip} = 6\%$$

$$= 0.06$$

$$Nr = ?$$

$$Nr = N_s(1-S)$$

$$N_s = \frac{120 \times f}{P} \text{ rpm}$$

$$= \frac{120 \times 50}{4}$$

$$N_s = 1500 \text{ RPM}$$

$$Nr = N_s(1-S)$$

$$Nr = 1500 (1-0.06)$$

$$Nr = 1410 \text{ rpm}$$

Q) Three phase induction motor 50 Hz and full load rotar speed 960 RPM calculate the

No. of poles

ii) Slip frequency and consider synchronous speed 1000 rpm.

Given data

$$\text{frequency} = 50 \text{ Hz}$$

$$\text{Rotar Speed} = 960$$

$$\text{Synchronous Speed} = 1000$$

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

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

$$P = \frac{120 \times 50}{1000}$$

$$P = 6$$

$$S = \frac{N_s - N_r}{N_s}$$

$$= \frac{1000 - 960}{1000}$$

$$S = 0.04$$

$$fr = S \times f$$

$$= 0.04 \times 50$$

$$fr = 2 \text{ Hz}$$

Q) 3-Ø induction motor, 400V, 50Hz which has 6 poles as rotar frequency, 2 Hz calculate the slip and Rotar Speed.

Given data

$$\text{Voltage } V = 400$$

$$\text{frequency} = 50 \text{ Hz}$$

$$\text{Rotar frequency} = 2 \text{ Hz}$$

base speed

$$fr = S \times f$$

$$S = \frac{fr}{f} = \frac{2}{50} = 0.04$$

$$S = \frac{N_S - N_r}{N_S}$$

$$\Rightarrow \frac{120f}{P} \\ = \frac{120 \times 50}{6}$$

$$N_S = 1000$$

$$N_r = N_S (1-S) \\ = 1000 (1-0.04)$$

$$N_O = 960 \text{ RPM}$$

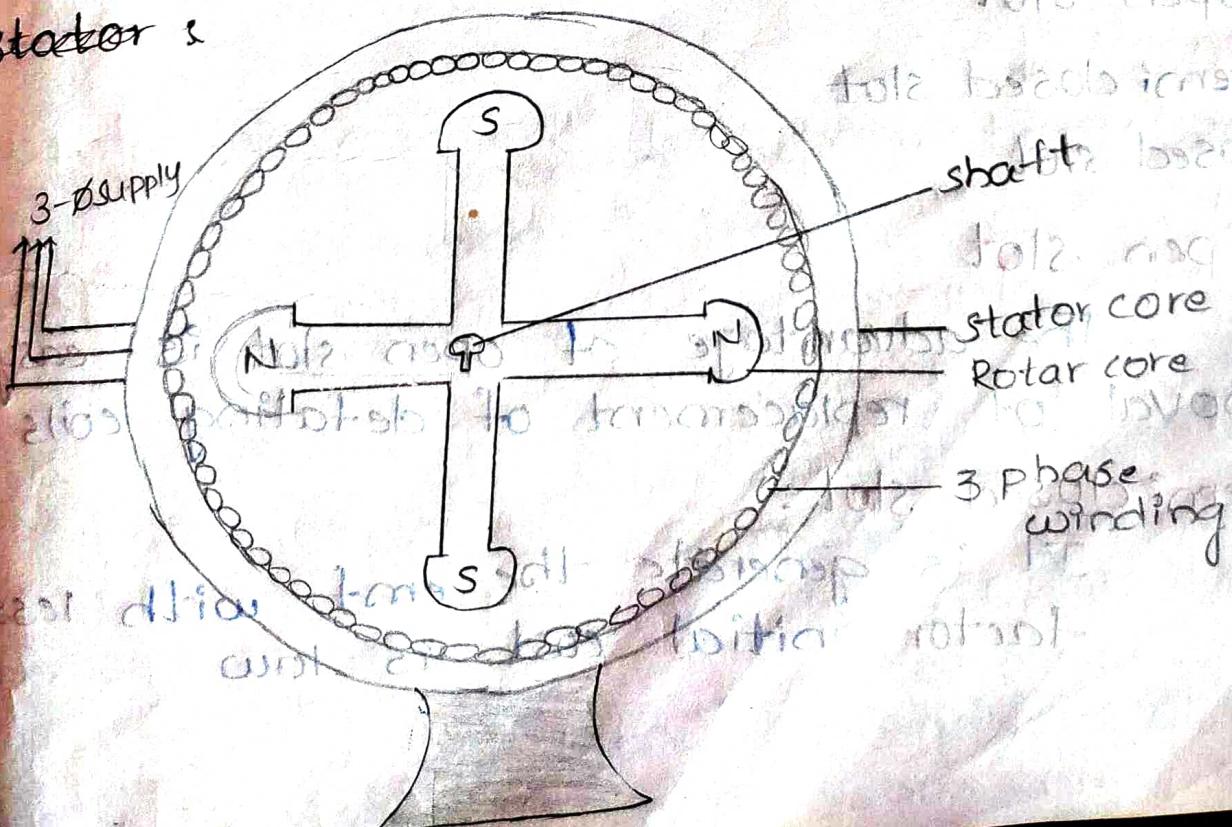
Construction of Synchronous Machines (or) Alternator
 Synchronous machines is double excited energy conversion device since it is field winding is connected to dc supply and Armature winding deliver the Ac power.

Synchronous machines reduce the Iron losses and alternators consisting of two parts.

i) Stator [Armature winding]

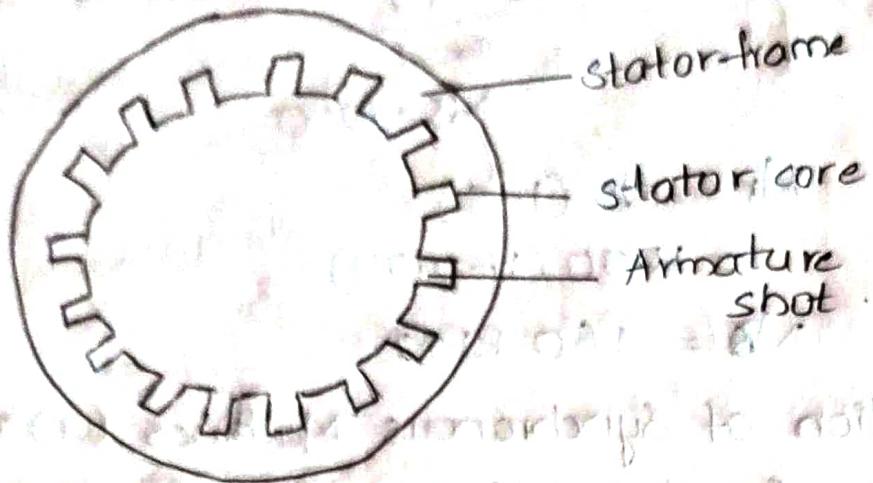
ii) Rotor [field winding]

Stator :



Stator:

Stator is the stationary part and cylindrical structure as shown in fig.



The stator carries Armature winding and this type of stator by using low rating material iron and cast iron used and high rating material 4% of Silicon steel is used which is build up of lamination 0.5mm which are insulated each other reduce the Eddy currents losses.

⇒ The stator core classified into 3 types

- i) Open slot
- ii) Semi closed slot
- iii) Closed slot

i) Open slot

The advantage of open slot is easy removal or replacement of detating coils

ii) Semi closed slot:

It is generate the emf with less factor initial cost is low

Re

ii) closed slot: It is air gap is uniform.

rotar:

Rotar is a Rotating part and it carries field winding and produce the magnetic flux.

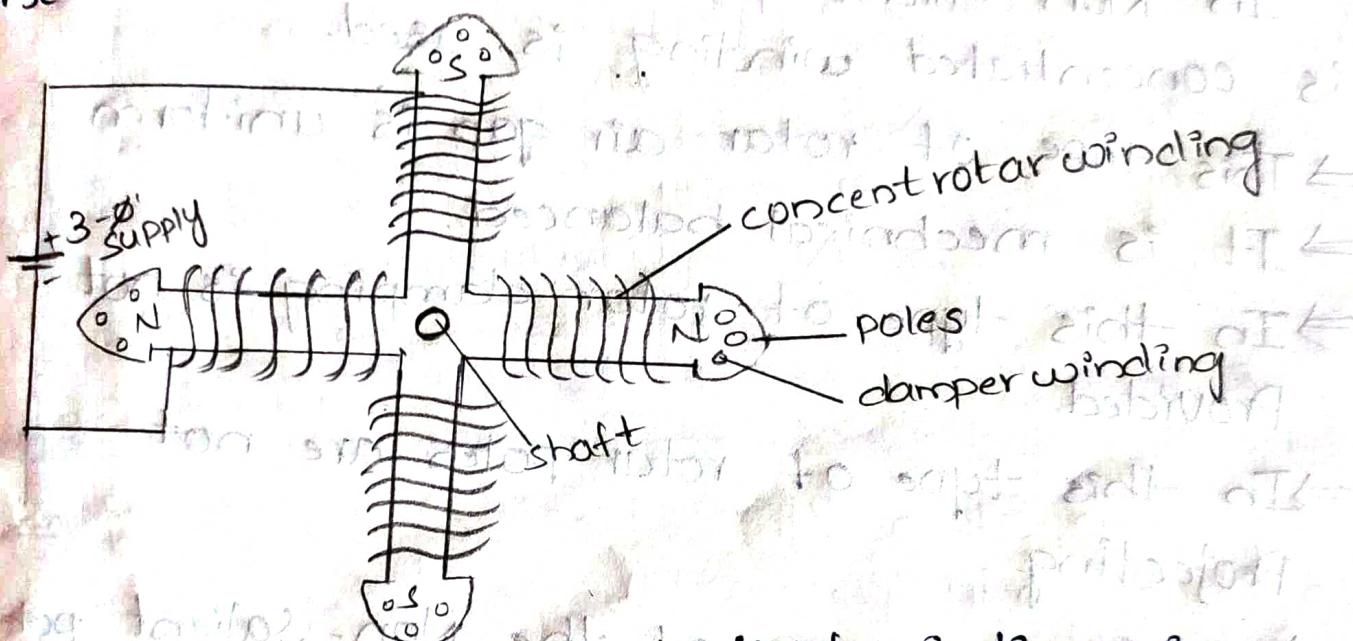
→ The rotar is classified into two types:

i) Salient pole rotar (or) Non-cylindrical rotar

ii) Non Salient pole rotar (or) cylindrical rotar.

i) Salient pole rotar:

The Salient pole rotar as shown in fig.



In salient pole rotar of field winding is concentrated winding is used.

→ This type of rotar area gap is non uniform.

→ It is not mechanical balanced.

→ In this type of rotar damping is provided.

→ In this type of rotar poles are projecting.

→ The speed range of the Salient pole rotar is 50 - 1000 RPM.

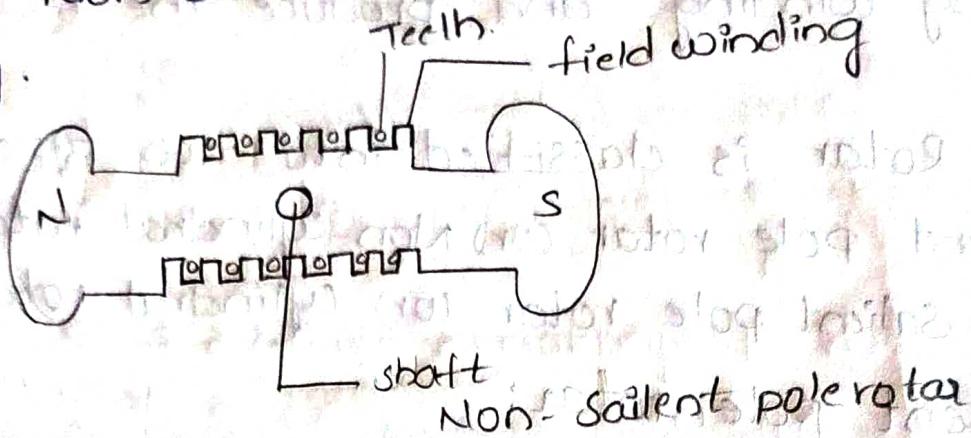
→ In this type of rotar larger diameter and smaller axial length.

→ It is used in water turbines and IE engines.

Non salient pole rotar.

In Non salient pole rotar as shown

in fig.



In Non Salient pole rotar of field winding is concentrated winding is used.

→ This type of rotar air gap is uniform

→ It is mechanical balanced.

→ In this type of rotar damping is not provided.

→ In this type of rotar poles are not projecting.

→ The Speed range of the Non-Salient pole rotar is 1500 - 3000 RPM.

→ In this type of rotar Smaller diameter and larger axial length.

Note:

Damper winding is used in preventing hunting in alternator to provide starting torque of electrical motors and shaft is used in transformation of power [They receiving dc power and deliver the Ac power]

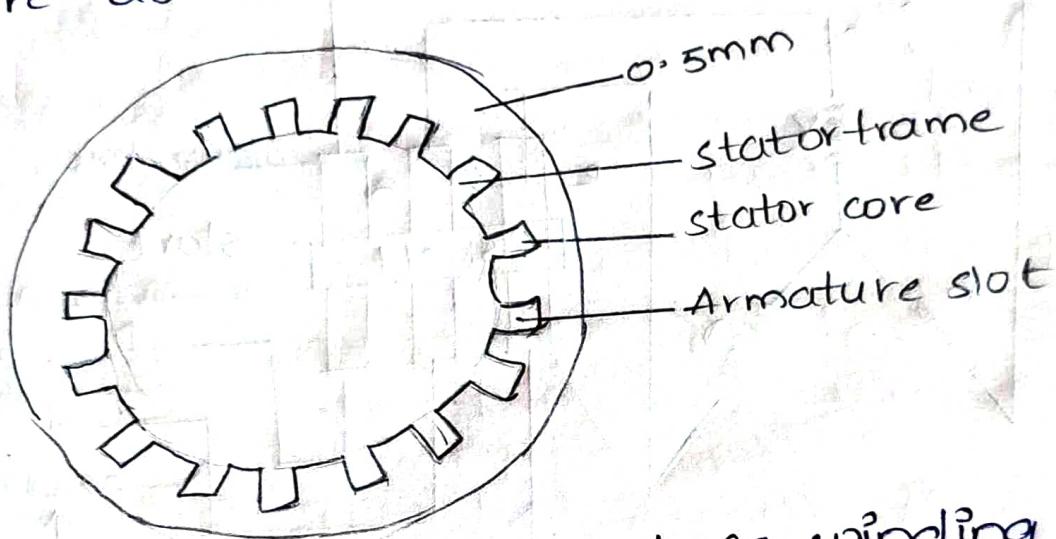
Construction of 3 phase Induction motor.

The 3-phase Induction motor is self starting device and consists consisting of two parts

- i) Stator
- ii) Rotor

Stator:

The stator is stationary part and cylindrical structure as shown in fig



The stator carries 3-phase winding & 3 phase supply is connected and this type of stator 4% of silicon steel is used

The stator is definite no of poles depends upon speed of the motor. If the no. of poles increases and speed of motor the increases.

The thickness of the lamination 0.5mm is used which are insulated by reducing Eddy current losses

possible motor loss well at low power rating as indicated

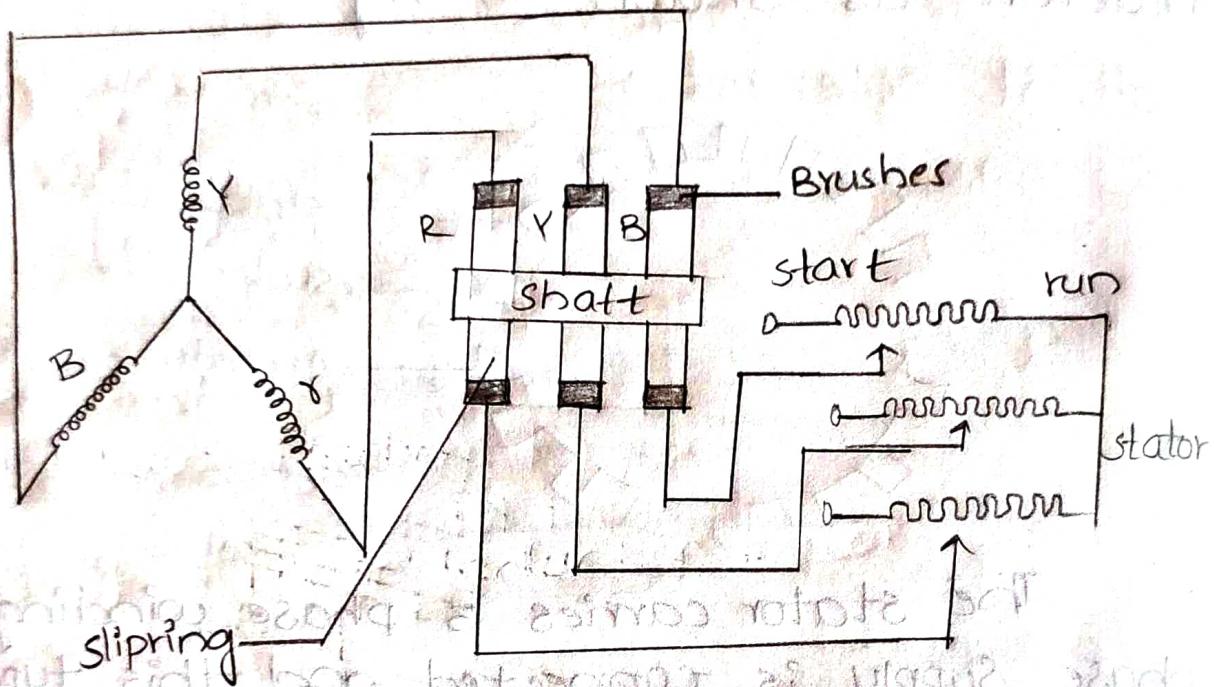
Rotar is a rotating part and classified into two types

- i) slip ring rotar
- ii) squirrel cage rotar

i) Slip ring rotar:

The slip ring rotar as shown in

fig



In this type of Rotar consisting of 3 phase supply similar to the stator.

⇒ In this type of rotar external resistance will be added.

⇒ It is complex Construction and high cost
In this type of rotar maintenance cost is more

⇒ It is low efficiency and low power-factor

⇒ In this type of rotar slip ring and brushes are present

It is high starting torque is applied.
In this type of rotar copper losses is high due to external resistance.

In this type of rotar is used in lift and cranes.

Speed control is possible.

Advantages

i) Speed is constant

ii) Low starting current

iii) High starting torque

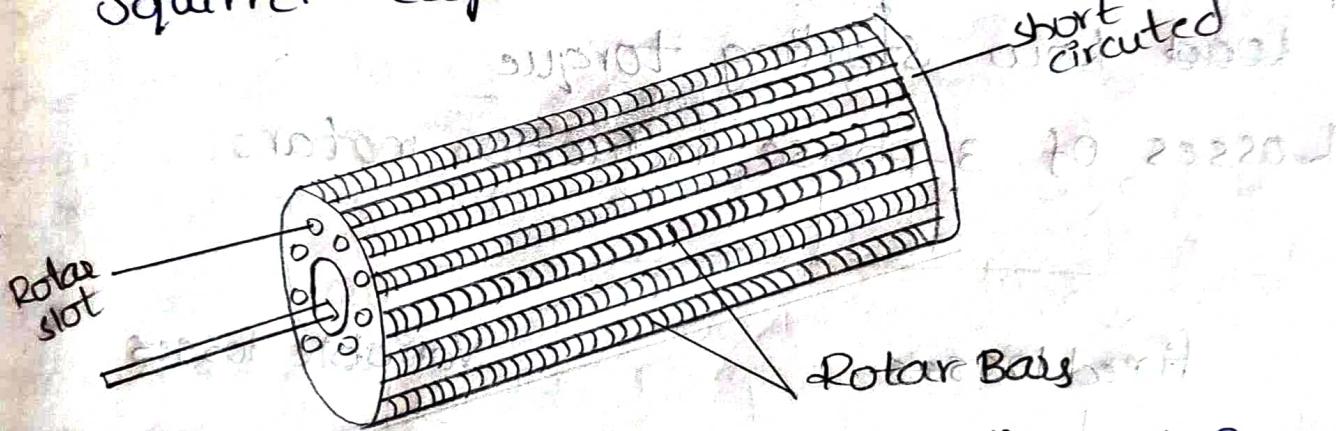
Disadvantages

i) Low efficiency

ii) Low power factor.

Squirrel cage rotar:

Squirrel cage rotar as shown in fig.



In this type of rotar consisting of Bars which are short circuited with the help of Endings

In this type of rotar external resistance can't be added

It is complex construction is low cost

In this type of rotar maintenance cost is high.

- It is high efficiency and high power factor.
- In this type of motor slipping and brushes are absent.
- It is low starting torque ~~can't~~ can't be obtained.
- In this type of motor copper losses is low due to external resistance.
- In this type of motor is used in fans and refrigerators.
- Speed control is not possible.

Advantages:

Low cost

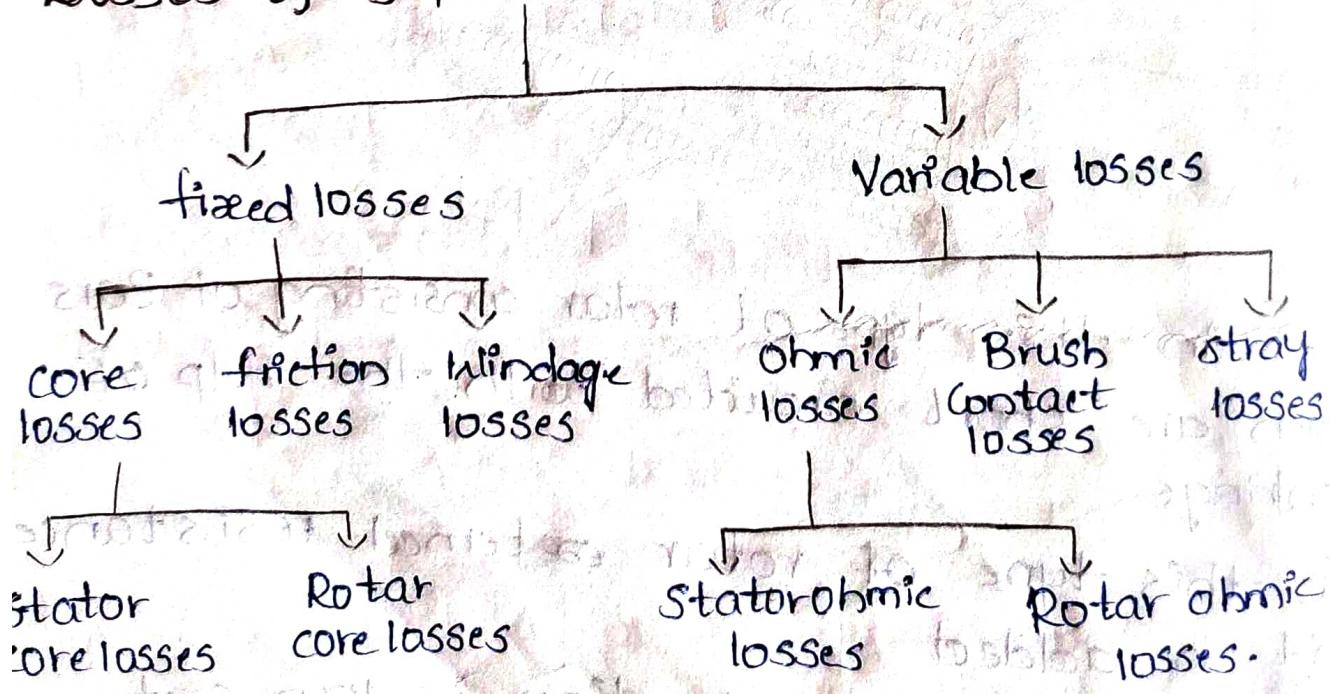
More efficiency

High overload capacity

Disadvantages:

Low starting torque

Losses of 3-phase Induction motor:



- The losses occurs whenever the motor remains constant for any speed and voltage is known as fixed losses.

→ The fixed losses occurs speed of the motor changes very slightly and compare to the speed of the induction motor. The frequency value will be decrease.

→ The core losses also divided into stator core losses and rotor core losses and friction and windage losses are constant.

→ The no load test of three phase induction motor determine the fixed losses.

fixed losses

Variable losses

→ The losses occurs whenever the motor load increases and the losses also increases is known as Variable losses.

→ The ohmic losses known as I^2R losses.

→ The ohmic losses occurs resistance of the stator and rotor winding and generate the heat in increasing temperature.

→ Load test of 3-phase induction motor (or) back rotor test of 3-phase induction motor determine the variable losses.

Efficiency of 3-phase induction motor:
It is defined as the ratio of mechanical energy output to electrical energy input is known as efficiency of 3-phase induction motor.

The mathematical expression of the 3-phase induction motor is given as

$$\% \eta = \frac{\text{Mechanical energy output (Rotor)}}{\text{Electrical energy input (stator)}} \times 100$$

Let consider

$P_{shaft} = \text{rotor output power}$ of induction motor

$P_{statorcore} = \text{stator core losses}$

$P_{rotorcore} = \text{rotor core losses}$

$P_{friction} = \text{friction losses} + \text{windage losses}$

$P_{ohmic} = \text{stator ohmic losses}$

$P_{I^2R \text{ stator}} = \text{stator ohmic losses}$

$P_{I^2R \text{ rotor}} = \text{rotor ohmic losses}$

$P_{stray} = \text{stray losses}$

$P_{additional} = \text{brush contact losses} + \text{stray losses}$

$$P_c = P_{statorcore} + P_{rotorcore} + P_{friction}$$

$$P_{I^2R} = P_{I^2R \text{ stator}} + P_{I^2R \text{ rotor}} + P_{stray}$$

$$\eta = \frac{P_{out}}{P_{input}}$$

$$P_{out} = \text{Input} - \text{Total losses}$$

$$P_{in} = \text{O/p} + \text{Total losses}$$

$$\text{Total losses} = P_c + P_{I^2R}$$

The efficiency of 3-phase induction motor

is given as

$$\% \eta = \frac{P_{shaft}}{P_{shaft} + (P_c + P_{I^2R})} \times 100$$

- Q) 3-phase induction motor 6 poles 440V and 50Hz the rotor input power 60 kilowatts it is observed that the rotor emf 90 complete cycle per minute calculate the

- i) Slip
- ii) Rotar Speed
- iii) Rotar copper losses for phase
- iv) Mechanical Power develop
- v) Rotar resistance per phase with current $IR = 60 \text{ Amp}$
- vi) Given data

3- ϕ induction motor

No. of poles = 6

Voltage $V = 440 \text{ V}$

frequency = 50 Hz

Rotar Input power = 60 KW

Rotar emf = 90 cycle/minute

$$\text{i)} S = ?$$

$$\text{ii)} N_r = ?$$

$$\text{iii)} \text{Rotar cu per phase} = ?$$

$$\text{iv)} P_m = ?$$

$$\text{v)} R_r = ?$$

$$f_r = \frac{90}{60}$$

$$\boxed{f_r = 1.5 \text{ Hz}}$$

$$\text{i)} f_r = S \times f$$

$$S = \frac{f_r}{f} +$$

$$= \frac{1.5}{30}$$

$$\boxed{S = 0.03}$$

$$\text{i)} \boxed{N_r = N_s(1-S)\text{rpm}}$$

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

$$= \frac{120(50)}{6}$$

$$\boxed{N_s = 1000 \text{ rpm}}$$

$$N_r = 1000(1-0.03)$$

$$N_r = 970 \text{ rpm}$$

ii) Rotar copper per phase = $\frac{\text{Rotar S/p power} \times \text{s/p}}{3}$

$$= \frac{60 \times 10^3 \times 0.03}{3}$$

$$\boxed{\text{Rotar copper losses per phase} = 600 \text{ W}}$$

iii) Mechanical power develop

$$P_M = P_{in} (1-s)$$

$$P_M = 60 \cdot (1-0.03)$$

$$\boxed{P_M = 58.2 \text{ KW}}$$

v) Rotar copper losses per phase

$$I^2 R_r$$

$$600 = (60)^2 \times R_r$$

$$600 = 3600 \times R_r$$

$$R_r = \frac{600}{3600}$$

$$\boxed{R_r = 0.16 \Omega}$$

Q) 3-Ø induction motor 50 Hz, 600V & voltage and 4 poles rotar input power 75 Kilowatt it is observed the rotar emf 120 complete cycle per min. calculate the

i) Slip

ii) Rotar Speed

iii) Rotar copper losses

iv) Mechanical power develop

v) Rotar resistance with $IR = 80 \text{ Amp}$

Given data

3- ϕ induction motor

No. of poles = 4

Voltage $V = 9$

frequency = 50 Hz

Rotar input power = 75 kW

Rotar emf = 120 cycle / minute

$$\text{i) } s = ?$$

$$\text{ii) } N_r = ?$$

$$\text{iii) Rotar current per losses} = ?$$

$$\text{iv) } P_m = ?$$

$$\text{v) } R_r = ?$$

$$f_r = \frac{120}{4}$$

$$\boxed{f_r = 20 \text{ Hz}}$$

$$\text{i) } f_r = s \times f_t$$

$$s = \frac{f_r}{f}$$

$$= \frac{2}{50}$$

$$\boxed{s = 0.04}$$

$$\text{ii) } N_r = N_s(1-s)$$

$$N_s = \frac{120f}{P_p}$$

$$= \frac{120(50)}{4}$$

$$= \frac{6000}{4}$$

$$N_r = 1500$$

$$N_r = N_s(1-s)$$

$$= 1500(1-0.04)$$

$$\boxed{N_r = 1440 \text{ rpm}}$$

$$\text{iii) Rotar copper losses} = \text{Rotar I}^2 \times \text{Rr} \times \text{S}^2$$

$$= 75 \times 10^3 \times 0.04$$

$$\boxed{\text{Rotar copper losses} = 3000 \text{W}}$$

iv) Mechanical power

$$P_M = P_{in} (1 - S)$$

$$= 75 (1 - 0.04)$$

$$\boxed{P_M = 72 \text{ kW}}$$

$$\text{v) Rotar copper losses} = I_R^2 \times R_r$$

$$= (80)^2 \times R_r$$

$$3000 = 6400 \times R_r$$

$$R_r = \frac{3000}{6400}$$

$$\boxed{R_r = 0.46 \Omega}$$

$$\frac{0.01}{0.5} = 0.02$$

$$S^2 + 0.02^2 = 1.1$$

Q) 3-Ø induction motor 50Hz the line voltage 500V and 6 poles gives an output power 37.3 kW at 955 rpm the power factor 0.86 frictional and windage losses 1.492 kW the stator losses approximately 1.5 kW determine the line current, efficiency and rotar copper losses this motor.

Given data

3-Ø induction motor

frequency $f = 50 \text{ Hz}$

Line Voltage $V_L = 500 \text{ V}$

No. of poles = 6

Rotar output = 37.3 kW

$N_r = 955 \text{ rpm}$

$\cos \phi = 0.86$

$$\text{i) } S = \frac{N_s - N_r}{N_s}$$

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

$$S = \frac{1000}{1000}$$

$$\boxed{S = 0.04}$$

Rotar copper

Mech

Rotar

Rot

Rotar

=

Rotar

Rotar

Rotar

Rotar

$$\Rightarrow \% \eta = \boxed{1}$$

- stator in

stator in

iii) $\% \eta$

$$\text{iii) Rotar copper losses} = \text{Rotar I}^2 \times \text{Rr}$$

$$= 75 \times 10^3 \times 0.04$$

Rotar copper losses = 3000W

iv) Mechanical power

$$P_M = P_{in} (1 - s)$$

$$= 75 (1 - 0.04)$$

P_M = 72 kW

v) Rotar copper losses = I_R² × R_r

$$= (80)^2 \times R_r$$

$$3000 = 6400 \times R_r$$

$$R_r = \frac{3000}{6400}$$

R_r = 0.46 Ω

Q) 3-Φ induction motor 50Hz the line voltage 500V and 6 poles gives an output power 37.3 kW at 955 rpm the power factor 0.86 frictional and windage losses 1.492 kW the stator losses approximately 1.5 kW. determine the line current, efficiency and rotar copper losses this motor.

Given data

3-Φ induction motor

frequency f = 50Hz

Line voltage V_L = 500V

No. of poles = 6

Rotar out put = 37.3 kW

N_r = 955 rpm

COS Φ = 0.86

frictional and windage losses = 1.492 kW

- Stator losses = 1.5 KW

$$\therefore S = \frac{N_s - N_r}{N_s}$$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6}$$

$$N_s = 1000 \text{ rpm}$$

$$S = \frac{1000 - 955}{1000}$$

$$S = 0.04$$

rotor copper losses = Rotar I/p power \times Slip

Mechanical power

$$\frac{\text{Rotar output power}}{\text{Rotar input power}} = \frac{N_r}{N_s}$$

$$\text{Rotar I/p} = \frac{\text{Rotar O/p} \times N_s}{N_r}$$

$$= \frac{37.3 \times 10^3 \times 1000}{955}$$

$$\text{Rotar I/p} = 39057.5 \text{ W}$$

$$\boxed{\text{Rotar I/p} = 39.05 \text{ KW}}$$

$$\text{Rotar copper losses} = 39.05 \times 10^3 \times 0.04$$

$$= 1562 \text{ KW}$$

$$\boxed{\text{Rotar copper losses} = 1.562 \text{ KW}}$$

$$\% \eta = \frac{\text{Mechanical energy output power}}{\text{electrical energy input power}} \times 100$$

- stator input power = Rotar input power + stator losses

$$= 39.05 + 1.5$$

$$\boxed{\text{stator input power} = 40.55 \text{ KW}}$$

$$\% \eta = \frac{37.3}{40.55} \times 100$$

$$\boxed{\% \eta = 91.98 \%}$$

$\Rightarrow I_L = ?$

Stator input power = $\sqrt{3} V_L I_L \cos\phi$

$$40.55 \times 10^3 \sqrt{3} \times 500 \times I_L \times 0.86$$

$$I_L = \frac{40.55 \times 10^3}{\sqrt{3} \times 500 \times 0.86}$$

$$I_L = 54.44 A$$

Q) 3-Ø induction motor 50 Hz, 600 V line voltage and 6 poles the rotar output power 47.5 kW at 800 RPM. The power factor 0.45 the frictional and windage losses 1.7 kW and stationary losses 1.75 kW approximately. Determine the line current efficiency rotar copper losses of the motor.

Given data

3-Ø induction motor

frequency = 50 Hz

line voltage = 600 V

No. of poles = 6

rotar output power = 47.5 kW

$N_r = 800 \text{ RPM}$

$\cos\phi = 0.45$

frictional and windage losses = 1.7 kW

$$\%s = \frac{N_s - N_r}{N_s}$$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6}$$

$$N_s = 1000 \text{ rpm}$$

$$1.8 P_{IP} = \rho d$$

$$S = \frac{1000 - 800}{1000} = \frac{200}{1000}$$

$$S = 0.2$$

rotor copper losses = Rotor I/p power \times slip
Mechanical power

$$\frac{\text{Rotor o/p power}}{\text{Rotor I/p power}} \times \frac{N_r}{N_s}$$

$$\text{Rotor I/p} = \frac{\text{rotor o/p} \times N_s}{N_r}$$

$$= \frac{47.5 \times 1000 \times 10^3}{800}$$

$$= 59375 \text{ W}$$

$$= 59.37 \text{ kW}$$

$$\text{Rotor copper losses} = 59.37 \times 10^3 \times 0.2$$

$$= 11874 \text{ W}$$

$$= 11.874 \text{ kW}$$

$$\eta = \frac{\text{mechanical energy o/p power}}{\text{electrical energy I/p power}} \times 100$$

$$\text{stator I/p power} = \text{Rotor I/p power} + \text{stator losses}$$

$$= 59.37 + 1.7$$

$$= 61.07$$

$$\eta = \frac{47.5}{61.07} \times 100$$

$$= 77.7\%$$

$$\Omega_L = ?$$

$$\text{stator I/p power} = \sqrt{3} \times \Omega_L \cos \theta$$

$$61.07 \times 10^3 = \sqrt{3} \times 600 \times \Omega_L \times 0.45$$

$$\Omega_L = \frac{61.07 \times 10^3}{\sqrt{3} \times 600 \times 0.45}$$

$$\Omega = 130.70 \text{ A}$$

Construction of Single phase Induction Motor

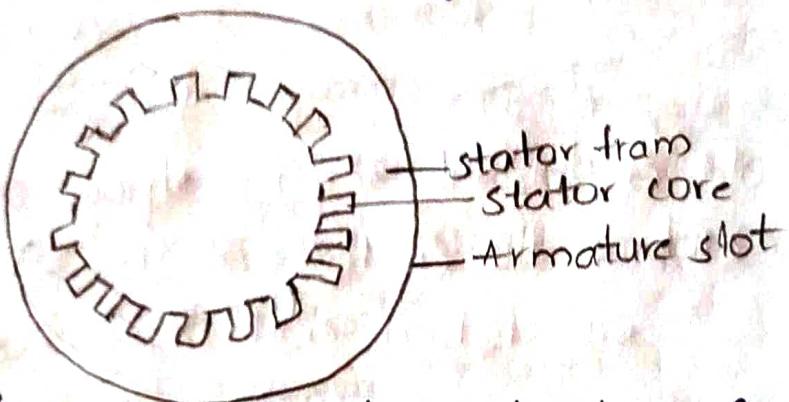
⇒ The single phase induction motor is not self starting device and it consisting of two parts

i) Stator

ii) Rotor

i) Stator

Stator is a stationary device and cylindrical structure as shown in fig.



The stator carries 1-Ø Supply two connected and which are insulated by laminated lamination of 41% of silicon steel is used in this material and thickness of the lamination from 0.036 - 0.06 cm and reduce the Eddy current losses.

Rotor:

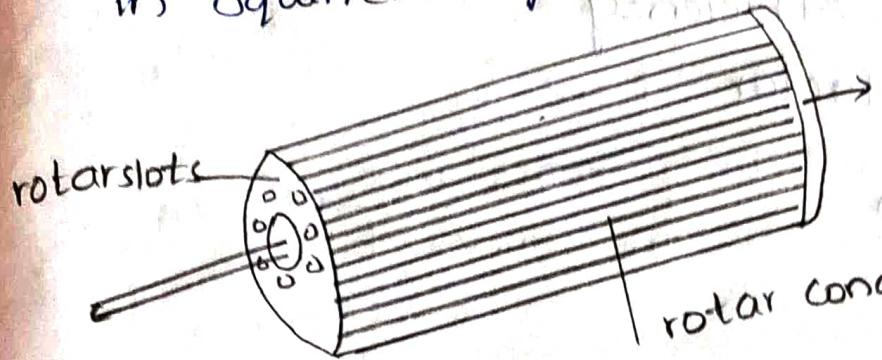
Rotor is a rotating part and in classification rotor are

i) Squirrel cage rotor

ii) Slip ring rotor

Squirrel cage rotar

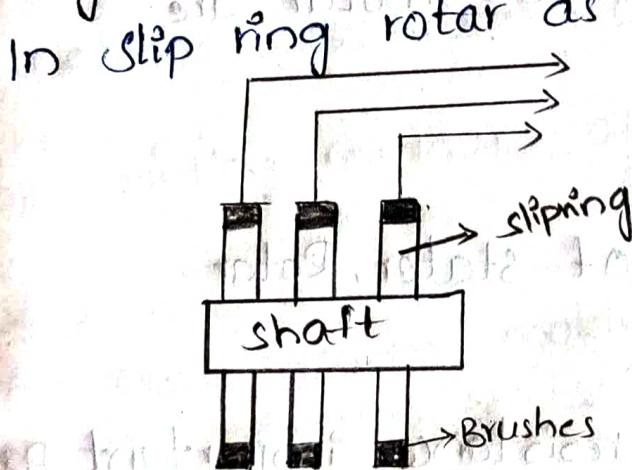
In squirrel cage rotar as shown in fig



In type of rotar consisting of rotor slots to the lamination of the silicon steel is used and rotor slots connected which carries the rotor bars and rotor conductors connected to end rings it reduce the copper losses due to low power factor.

Slip ring rotar

In slip ring rotar as shown in fig



In this type of rotar consisting of slip rings are connected rotor and shaft.

⇒ The slip rings connected to the shaft in parallel connection and reduce the copper losses and high power factor.

Advantages:

- i) Most economical
- ii) easy to repair

Disadvantages

- i) Reduce the efficiency
- ii) Low power factor

Application

- i) fans
- ii) Refrigerator
- iii) Vacuum cleaners
- iv) Printing machines
- v) Washing machines
- vi) Mixes, grinders

factors of Single phase Induction Motor

The classification of factors of Single phase induction motor are

- i) Rotar resistance
- ii) Air gap length
- iii) physical structure of stator, Rotar
- iv) Rotar resistance

The rotar resistance important parameters of performance of $1-\phi$ induction motor which are determine with help of area of cross section of the material.

If the rotar resistance increases and the torque will be maximum.

If the rotar resistance increases decrease the starting current and efficiency and percentage

of

voltage regulation is increases.

Air gap length:

Reduction of the air gap length it causes more losses and reduce the over load capacity.

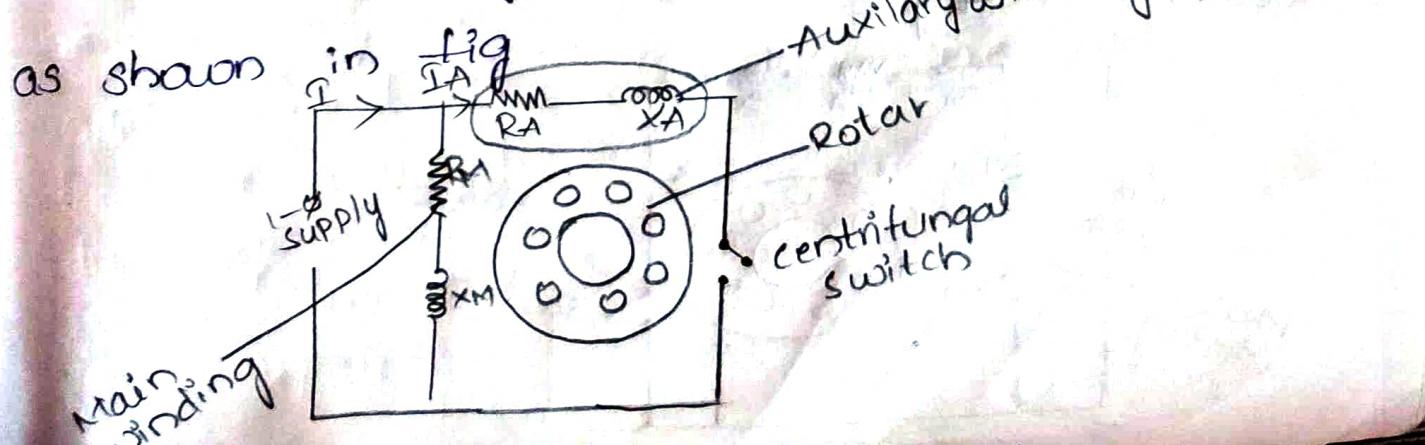
The air gap length completely depends upon power factor and no. of poles. physical structure of stator, Rotar.

These parameters very important role of working of single phase induction motor the maximum torque will be produced reduce the intergal slot winding and increase the air gap length.

Starting methods / classification of 1- ϕ induction motor.

The starting methods of 1- ϕ induction motor.

- i) Split phase induction motor
- ii) capacitor start induction motor
- iii) capacitor run induction motor
- iv) Two value capacitor induction motor
- v) Split phase induction motor:
In type of motor in the circuit



In this type of induction motor connected in single phase supply and flow of current divided into auxiliary and main winding current. In auxiliary winding resistance, reactance and centrifugal switch are connected in series and parallel with main winding.

⇒ In this type of motor has low efficiency, low power factor and slow starting torque.

⇒ Start characteristic of split phase induction motor:-

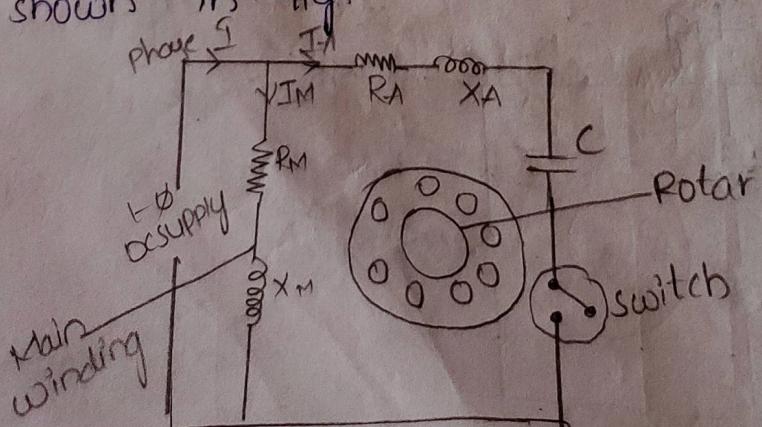
- i) The starting torque of the motor 100-250%.
 - ii) Break down torque of the motor upto 300%.
 - iii) The efficiency of motor 55-65%.
 - iv) The power factor of the induction motor 0.5-0.65.
- v) The power rating induction motor range from $\frac{1}{2}$ HP - 1 HP

Applications:

- i) Washing machines
- ii) Mixers, grinders

Capacitor start induction motor.

In this type of motor in the circuit as shown in fig.



In this type of resistance, reactor is series with main winding in this type of motor. In this type of motor and low power characteristic of motor.

- i) The starting torque 250-400%.
- ii) Breakdown torque.
- iii) The efficiency.
- iv) The power factor 0.5-0.65%.
- v) The power from $\frac{1}{8}$ HP.

Applications:

- i) Motor pump.
- ii) Air compressor.

Capacitor start

as shown

In type of induction motor connected in single phase supply and flow of current divided into auxiliary and main winding current.

- In auxiliary winding resistance, reactance and centrifugal switch are connected in series and parallel with main winding.
- In this type of motor has low efficiency, low power factor and slow starting torque.

Start characteristic of Split phase induction motor:-

i) The starting torque of the motor 100-250%.

ii) Break down torque of the motor upto 300%.

iii) The efficiency of motor 55-65%.

iv) The power factor of the induction motor

0.5-0.65

v) The power rating induction motor range from $\frac{1}{2}$ HP - 1 HP

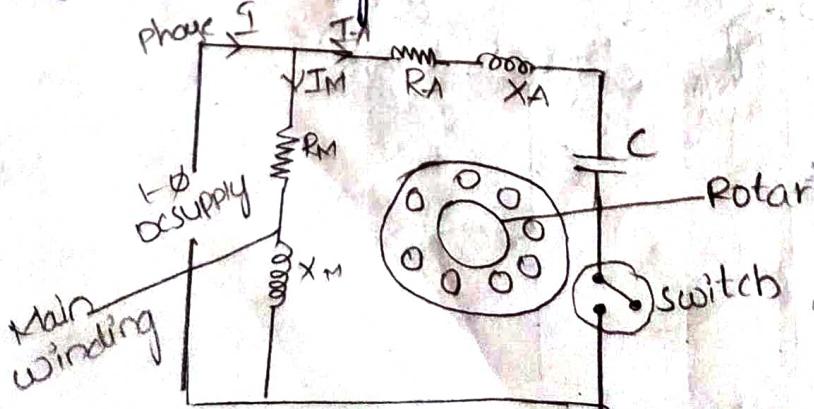
Applications:

i) Washing machines

ii) Mixers, grinders

Capacitor start induction motor.

In this type of motor in the circuit as shown in fig.



In this type of motor auxiliary winding resistance, reactance and capacitor connected in series with centrifugal switch and parallel with main winding.

In this type of motor also low efficiency and low power factor.

Characteristic of capacitor start induction motor.

The starting torque of the induction motor 250-400%.

Breakdown torque of the motor upto 350%.

The efficiency of motor 55-65%.

The power factor of the induction motor.

0.5-0.65%.

The power rating of induction motor range

from 1/8 HP - 1 HP

Applications:

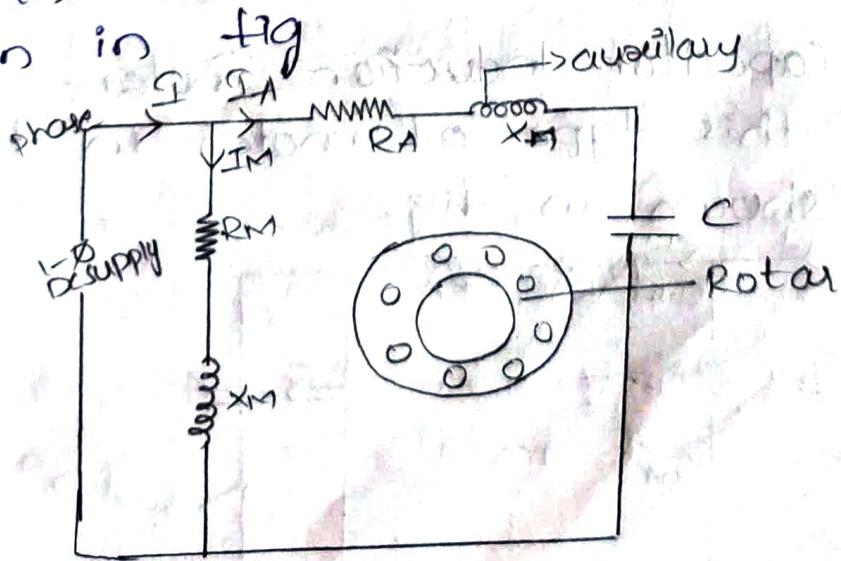
Motor pump

Air compression

Capacitor run induction motor.

In this type of motor in the circuit

as shown in fig



In this type of motor is auxiliary resistance, reactance and capacitance are connected in series in the circuit no centrifugal switch is required and parallel with main winding.

In this type of motor high starting torque, high power-factor and high efficiency.

characteristic capacitor run induction motor:

i) The starting torque of the induction motor $50 - 100\%$

ii) Break down torque of the motor upto $50 - 60\%$
250

iii) Efficiency of the motor $60 - 70\%$

iv) The power factor of the induction motor $0.75 - 0.9$

v) The power rating induction motor range from $1/8 \text{ HP} - 1 \text{ HP}$

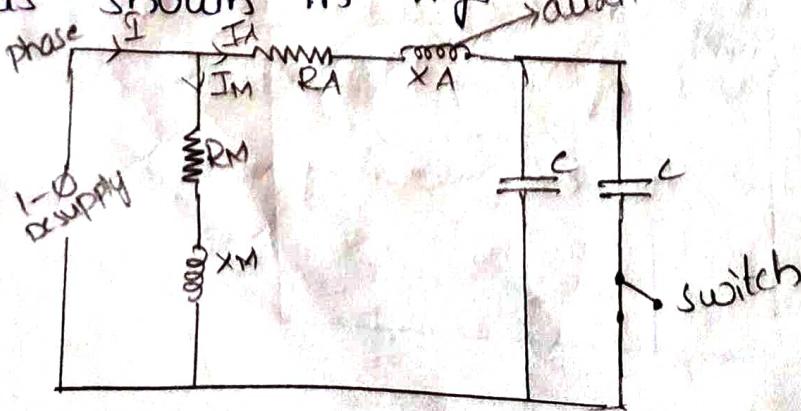
Applications:

i) fans

ii) voltage regulator.

Two value capacitor induction motor:

In this type of motor in the circuit as shown in fig.



In this type of motor is auxiliary winding resistance, reactance and capacitance in series connection

CR is permanent circuit are parallel

with CS where CS = short time capacitor in the circuit and parallel with main winding.

In this type of motor high starting torque, high power factor and high efficiency.

characteristic of two value capacitor induction motor are:

- i) The starting torque of the induction motor 200-300 %
- ii) Breakdown torque of the motor upto 250 %
- iii) The power efficiency of the induction motor 60-70 %
- iv) The power factor of the induction motor 0.75-0.9

The power rating of induction motor range from $\frac{1}{8}$ HP - 1 HP

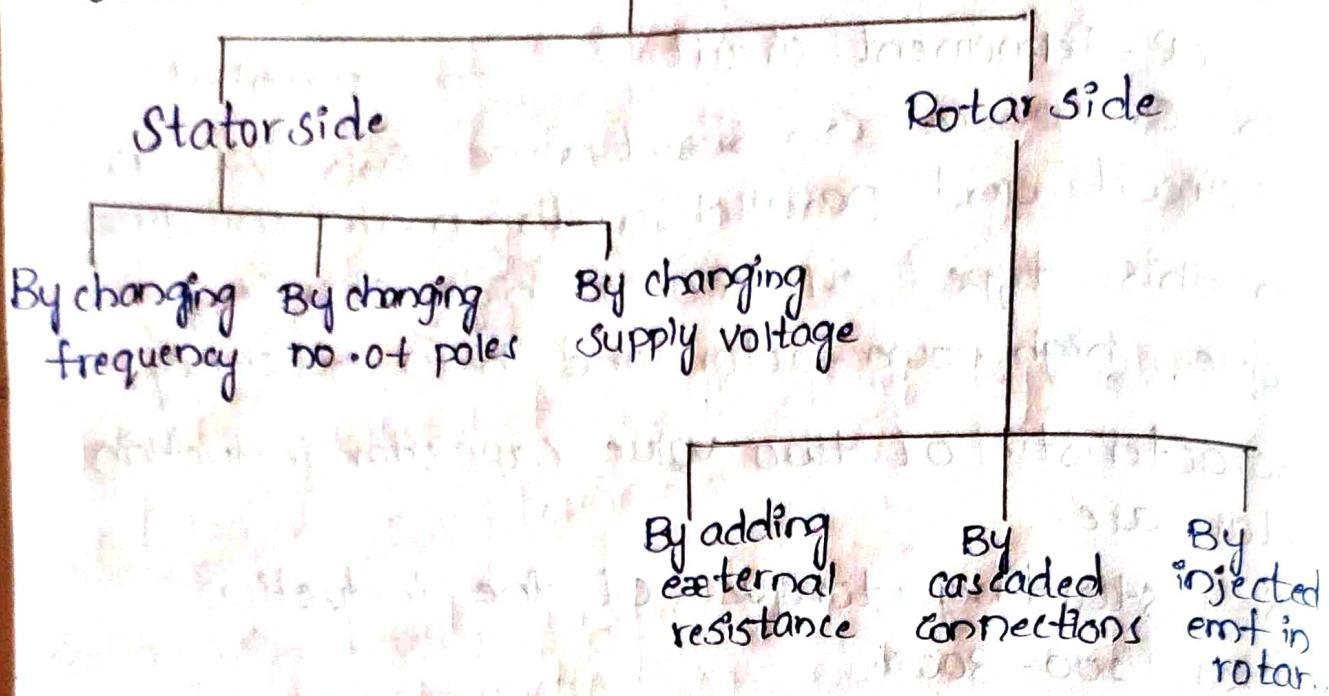
Applications:

- i) Refrigerator
- ii) Air condition compression.

All motor applications of small size and low power are suitable for household and office use. Small size motor can be used for various applications like washing machine, fan, pump etc.

Speed controlled Methods of 3-phase Induction Motor

Motar:



The Various factors of Speed controlled motor are 3-Ø induction motor

→ Speed controlled By changing frequency :

- i) In the Speed controlled method the Speed is directly proportional to Supply frequency. If the Supply frequency changes the speed of the motor changes simultaneously.
- ii) In Speed Control method the Supply Voltage is constant the frequency value decreases and flux increases.
If the flux increases reduce the iron losses and efficiency.
- iii) If the frequency increases the flux value will be decreases and reduce the maximum torque

Speed controlled method by changing no. of poles:
it is suitable for only squirrel cage induction motor because squirrel cage rotor is automatically developed no. of poles equal to poles of the stator winding.

Suppose motor has two winding for 6 poles and 4 poles and $50 + 1\frac{2}{3}$ supply the synchronous speed will be $1000 - 1500$ RPM respectively and for slip value 5% the rotor speed will be 950 and 1425 RPM respectively.

By changing no. of poles increases and the rotor and synchronous speed will be decreases.

In the Speed controlled method it is not possible. In the speed controlled methods by changing supply voltage:

In this method of speed controlled is constant frequency and varied the supply voltage which is produced by induction motor which is directly proportional to square of rotor induced emf

This rotor induced emf is directly proportional to supply voltage

TRUE

$E_2 \propto V$

iii) the torque is directly proportional to square of the supply voltage is given as

$$T \propto S V^2$$

from based on the above eq supply voltage decreases and the torque value also decreases.

Speed controlled method of by adding external resistance.

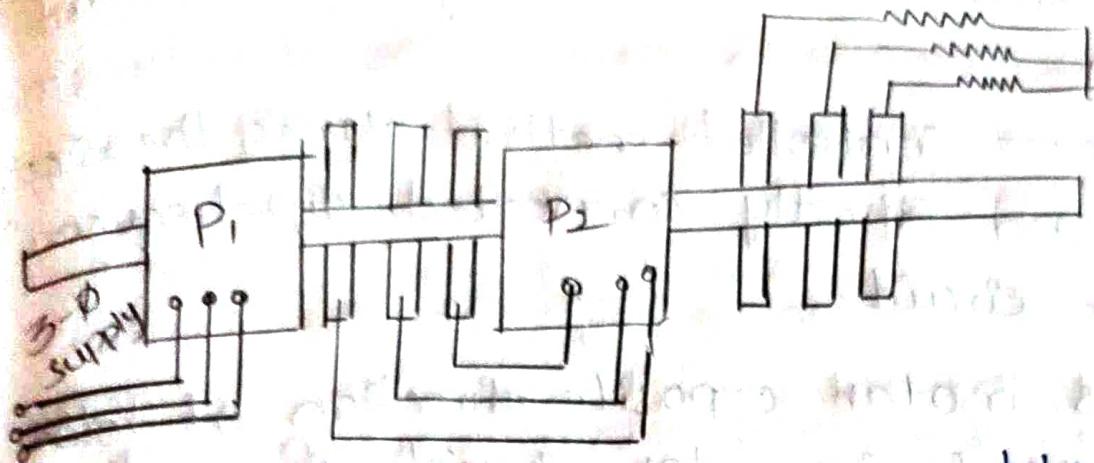
i) In the speed controlled method suitable for slip ring induction motor and the speed controlled method similar to speed controlled method of Dc shunt motor.

ii) In the speed control method speed is valued by adding external resistance in rotor circuit the starting torque will be increases it causes more losses.

iii) In the speed control method frequency and supply voltage is constant and the speed of the motor continuously decreases.

Speed controlled method by cascaded connection

i) If the speed controlled method basically arrangements of both motor connected signal shaft then they are motor run same side of the rotor



for P_1 motor can be run separately from the synchronous speed will be

$$N_s = \frac{120f}{P_1}$$

for P_2 motor can be run separately from the synchronous speed will be

$$N_s = \frac{120f}{P_2}$$

Basically consisting of both motors connected in cascaded connection and the synchronous speed is

$$N_s = \frac{120f}{P_1+P_2}$$

It is consisting of both motors connected in different mode based on the no. of poles the synchronous speed is given as

$$N_s = \frac{120f}{P_1-P_2} \text{ (or) } N_s = \frac{120f}{P_2-P_1}$$

In the speed control method torque and speed of the shaft will be increases and the frequency and the synchronous speed decreases.

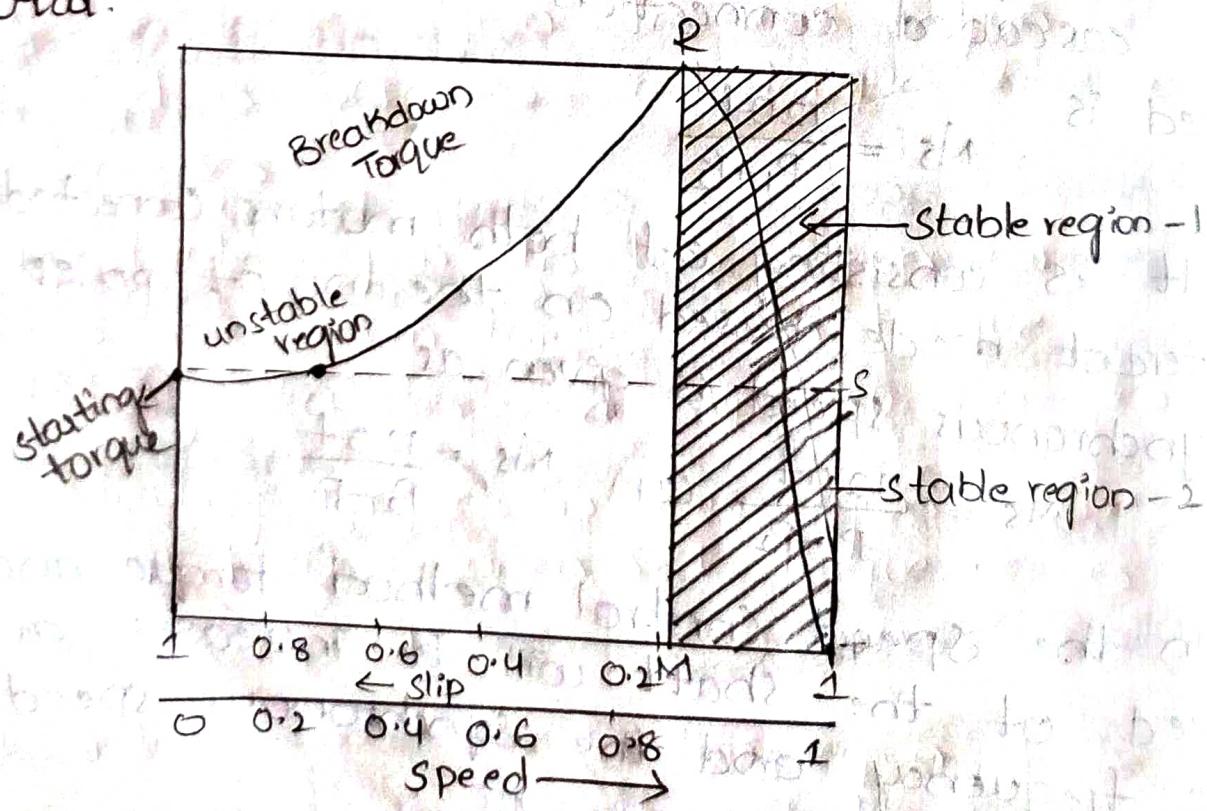
Speed Controlled method by injected emf in rotor.

In speed controlled method varies the supply voltage and directly connected slip frequency in rotor circuit.

In this motor opposite direction of rotor induced emf in rotor circuit the voltage resistance will be increases and the speed of the motor decreases.

In injected emf of rotor connected in motor the total resistance decreases and speed of the motor increases.

~~Ans~~ In this method speed control is possible by Torque-Slip characteristic of 3-phase induction motor.



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Torque Slip characteristic of 3-φ induction motor is given as

$$T \propto \frac{SE_2^2 R_2}{(R_2)^2 + (Sx_2)^2}$$

$$T = \frac{KSE_2^2 R_2}{(R_2)^2 + (Sx_2)^2}$$

where

K = Rotar constant

S = Slip

E_2 = Rotar induced emf

R_2 = Rotar resistance

x_2 = Rotar reactance

for case 1: No load condition

In no load condition of 3-φ induction

motor is rotar speed will be equal to zero

[$N_r=0$] Based on the above condition the

slip is given as

$$S = \frac{N_s - N_r}{N_s}$$

$$S = \frac{N_s - 0}{N_s}$$

$$\boxed{S = 1}$$

when $S=1$ torque reaches starting point

is known as starting torque.

for case 2: Increasing load condition.

In Increasing load condition of 3-φ

induction motor torque is inversely proportional to slip

$$\boxed{T \propto \frac{1}{S}}$$

In this condition if the load is increased

torque and speed will be decreases and

slip is increases.

for case 3 : Maximum torque condition

The maximum torque condition of 3-Ø induction motor is torque is directly proportional to slip $T \propto S$

Based on the above eqn if the increasing load and the rotor and slip also increases the torque reaches max torque is known as breakdown torque for case 4 : Different nodes of 3-Ø induction motor

3-Ø induction motor

consisting of four different nodes are follows

i) PQ - Unstable region

ii) ST - Stable region

iii) OP - Starting Torque

iv) MR - Maximum torque

i) PQ - Unstable region : In this region if the load is increases and torque value will be decreases.

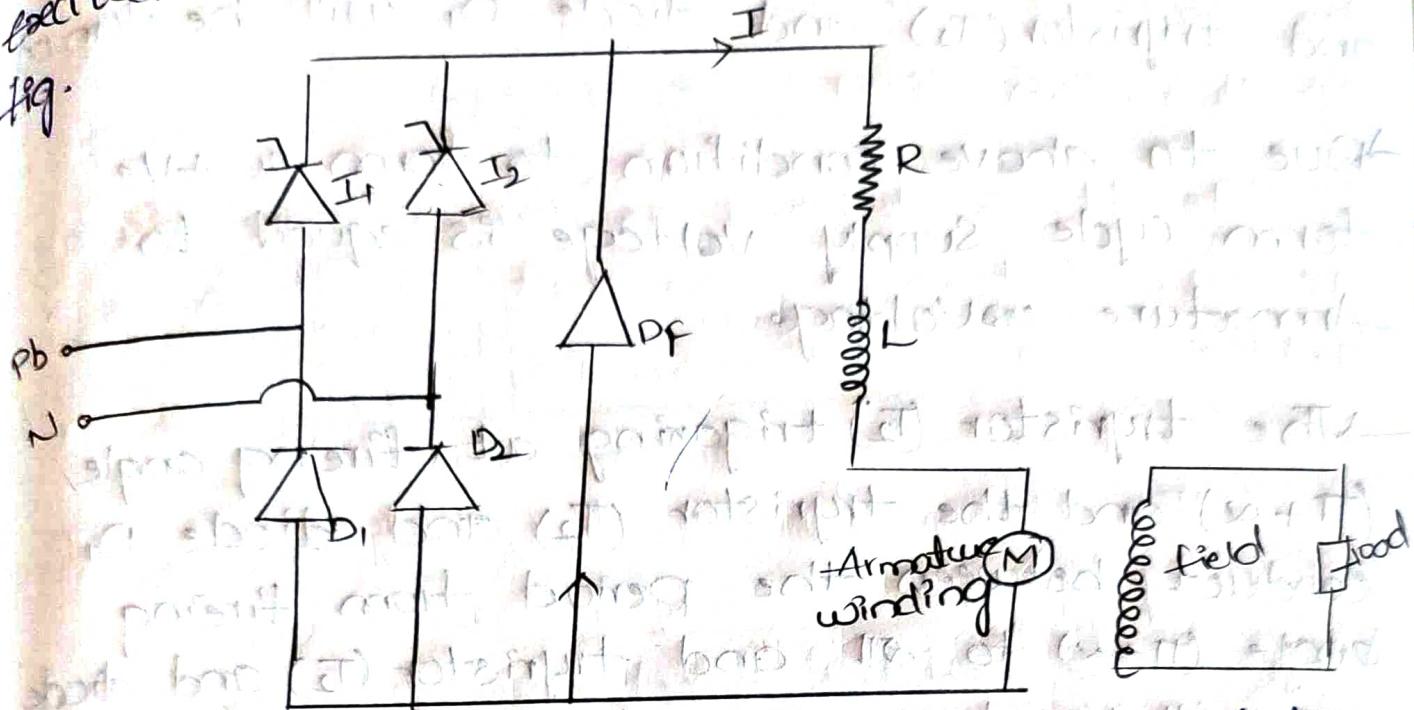
ii) ST - stable region : In this region torque reaches maximum torque then torque continuously decreases and slip also decreases

iii) OP - Starting Torque : In this region whenever the applied load when $S=1$ torque reaches the starting point

iv) MR - Maximum Torque : In this region if the load is increases torque and slip also increases

Speed control method of Separately excited 1-phase D.C motor:

Speed control method of Separately excited 1-Φ D.C motor in the circuit showing fig.



In Speed control method of Separately excited single phase simi converter are controlled by Armature Voltage or varying freeing angle (α) and depending upon circuit parameters and operation

- In the Speed control method the armature current can be continuous or discontinuous mode.
- The effect of Amature current in discontinuous mode are given as
 - i) Poor regulation
 - ii) The power factor of the armature current will be increased

Hence by using 1-Φ dc motor the continuous armature current can be operated

→ The Thyristor (T_1) trigating at firing angle α and the thyristor (T_1) and diode D_2 conduct between the period from firing α to π and the thyristor (T_1) diode D_2 will be turn on and thyristor (T_1) and diode D_1 will be turn on and thyristor (T_1) and diode D_1

→ Due to above condition to form a +ve form cycle supply voltage is equal to Armature ~~voltage~~

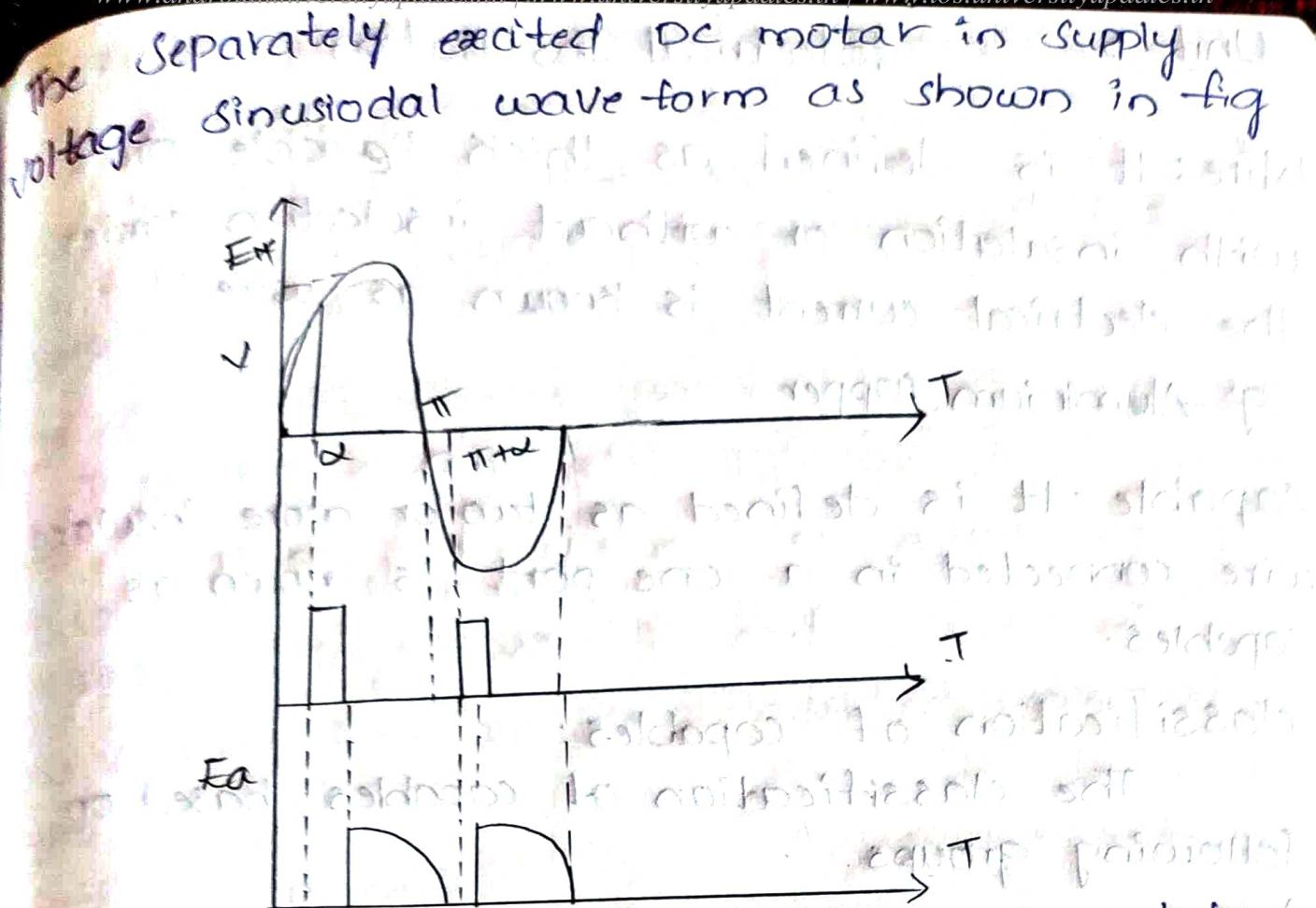
→ The thyristor (T_2) trigating at firing angle $(\pi + \alpha)$ and the thyristor (T_2) and diode D_1 conduct between the period from firing angle $(\pi + \alpha)$ to $\alpha\pi$ and thyristor (T_2) and diode (D_1) will be turn on and thyristor (T_2) and diode (D_2) will be turn on

Due above condition to form a -ve of cycle supply voltage reverse to +ve of cycle.

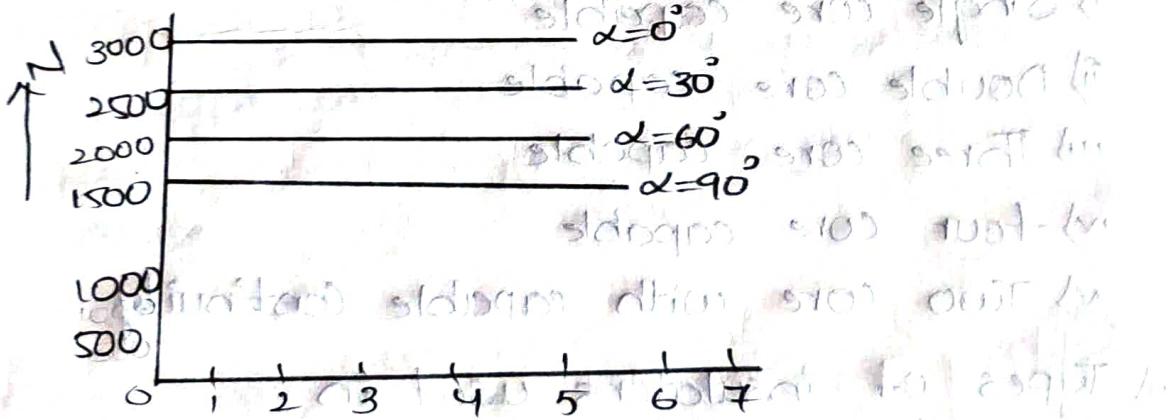
→ The purpose of freewheeling Diode ~~is~~ used in circuit control the armature voltage in -ve of cycle and freewheeling diode and passing to the reverse direction of Armature Current and the armature Voltage will be zero.

→ The Average armature Voltage is given as

$$E_a = \frac{E_m (1 + \cos \alpha)}{\pi}$$



Torque Speed characteristic Separately excited d.c. motor. In this method, the torque is directly proportional to torque increase speed also increases.



As the load angle increases, the speed decreases proportionally. The speed is inversely proportional to the load angle.