EE8401 - Electrical Machines - II

Starting and speed control Methods of 3φ Induction Motor

UNIT - IV

1. Explain the starters (any two) used for squirrel cage induction motor.

Ans: The Starters used for squirrel cage I.M are

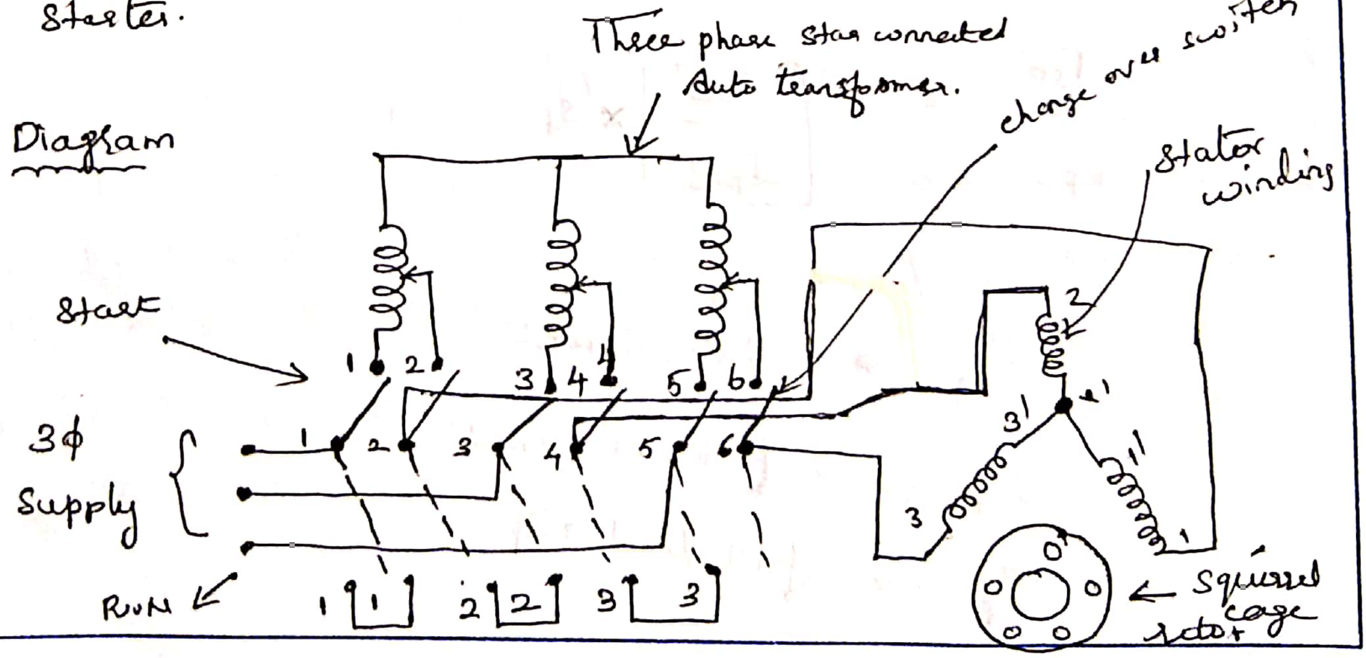
1. Stator resistance starter
2. Auto transformer "
3. Star Delta "
4. Direct on line "

Auto transformer Starter.

Introduction:

A Three phase star connected auto transformer can be used to reduce the voltage applied to the stator. Such a starter is called an autotransformer starter.

Diagram



Description:-

→ It consists of a suitable change over switch.

→ when switch in start position the stator winding is supplied with reduced voltage. This can be controlled by tappings in autotransformer.

→ when motor gathers 80% of the normal speed the change over switch is thrown to run position

→ The motor starts rotating with normal speed.

Relation between T_{st} and $T_{F.L}$

Let x → be the fractional percentage tappings

I_{sc} → starting motor current at rated voltage

I_{st} → starting motor current with starter.

$$I_{st} = x I_{sc}$$

$$T_{st} \propto I_{st}^2 , \qquad T_{FL} \propto \frac{[I_{F.L}]^2}{s_f}$$

$$\frac{T_{st}}{T_{FL}} = x^2 \left[\frac{I_{sc}}{I_{F.L}}\right]^2 \times s_f .$$

I_{sc} → starting current

I_{FL} → full load current

s_f → full load slip

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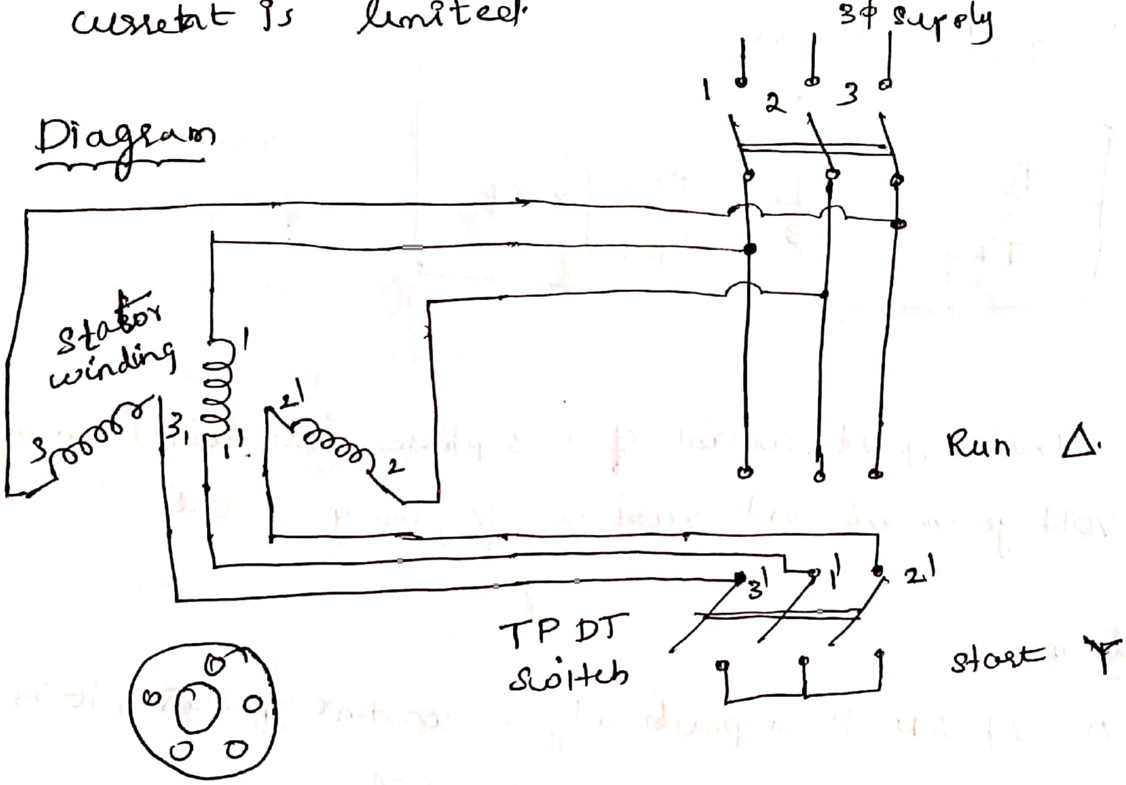
(ii) ## Star-Delta Starter

Introduction

This is the cheapest of all starters commonly used for the induction motors. It uses TPDT switch. The switch connects the stator winding in star at start. The voltage gets reduced by $1/\sqrt{3}$, so the starting current is limited.

Diagram



Operation

When the switch is thrown on other side, windings get connected in delta, the motor get normal rated voltage and gathers sufficient speed.

It is the cheapest of all starter. The operation of the switch is automatic by using relays.

Advantages:

→ cheaper of all

→ maintenance free operation

Limitations:

→ Suitable for delta connected motor

→ voltage changes $1/\sqrt{3}$ cannot be changed.

Ratio of T_{st} to T_{FL}

$$\frac{T_{st}}{T_{FL}} = \frac{1}{3}\left[\frac{I_{sc}}{I_{F.L}}\right]^2 \times S_f$$

4) Explain the speed control of a 3 phase induction motor using voltage control and variable frequency control.

Introduction:

A 3ϕ I.M is a practically a constant motor, it is very difficult to acheive smooth speed control.

If control is achieved by some method, the performance of Induction motor gets affected in terms of power factor & efficiency.

WKT, $N = N_s(1-s)$

So speed can be changed by changing its synchronous speed or slip.

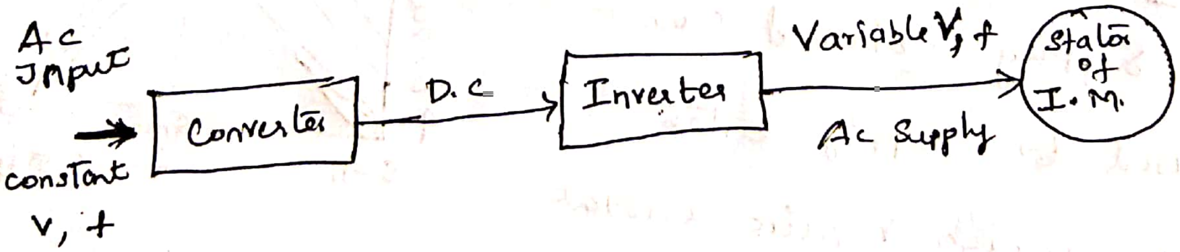
Torque equation $T \propto \frac{S E_2^2 R_2}{R_2^2 + (S X_2)^2}$

So, the parameters like R_2 E_2 are changed to keep the torque constant for constant load condition motor reacts by change in its slip.

Methods of speed control:-

1. From stator side
   - → supply frequency control or called V/f control ✓
   - → supply voltage control ✓
   - → controlling no. of stator poles to control Ns.
   - → Adding reheostats in a stator circuits
2. From Rotor side
   - → Adding External Resistance in the rotor circuit
   - → cascade control
   - → Injecting slip frequency voltage in to a rotor circuit

Supply frequency control or V/f control:



The synchronous speed of Induction Motor is given by $N_s = \frac{120f}{P}$ → frequency, P → poles.

→ Thus by controlling the supply frequency, speed can be controlled

But the Expression of air gap is given by

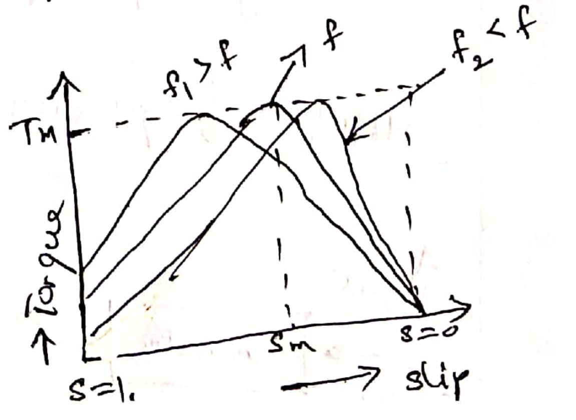
$$\phi_g = \frac{1}{4.44 K_1 T_{ph_1}} \left(\frac{V}{F}\right)$$

→ If the frequency is changed, the air gap flux gets affected results in saturation of stator and rotor cores. So to keep air gap flux constant, frequency changes, V, also changes. so as to keep V/f ratio constant.

→ The normal supply with constant V, f is this supplied to the converter. The converter converts the supply in to dc. again this dc. was given to the inverter.

→ The Inverter is a device which converts d.c. supply to variable voltage and frequency of ac supply

→ By selecting proper Frequency V/f maintaining constant smooth speed control is possible



Dis Advantages

→ The Supply obtained cannot be used to supply other devices which require constant voltage.

→ costly. Method.

(ii) Supply Voltage control

Torque equation of Induction Motor is given

by $T \propto \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$

rotor induced emf E_2 at stand still is proportional

to applied voltage

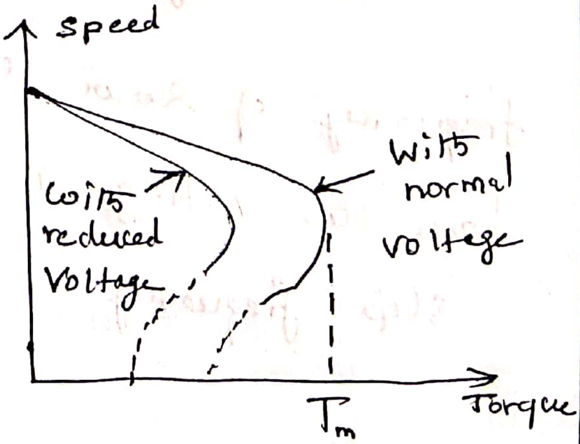
$E_2 \propto V$.

For low slip region $(sX_2)^2 << R_2$ → can be neglected

$T \propto \frac{sV^2 R_2}{R_2^2} \propto sV^2$ for constant R_2

If supply voltage is reduced below rated value, the torque produced decreases. But to supply the same load it is necessary to develop same torque produced remains same hence the value of the slip increases

slip increases means motor reacts by running at lower speed to decrease in supply voltage.

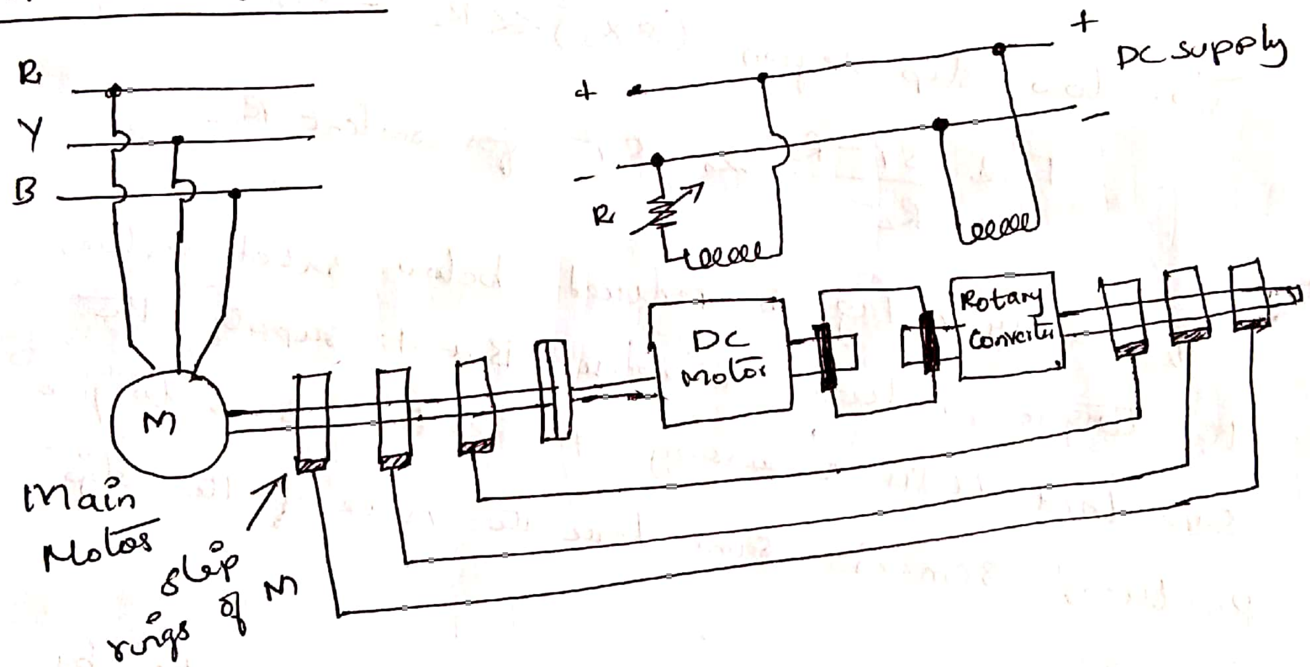


3. Injecting slip frequency Emf in to Rotor circuit

Two Methods Available for This Principle

1. Kramer System
2. Scherbius System.

Kramer System



Principle

A voltage is injected in the rotor circuit. The frequency of rotor circuit is at slip frequency & hence the voltage is to be injected must be at a slip frequency

Description:-

It consists of main motor M, the speed of which is to be controlled, and other are dc motor and a rotary converter.

The d.c side of the rotary converter feeds a dc shunt motor commutator which is connected to the shaft of the main motor. A seperated dc supply is given to excite the field winding of both the machine

Working:-

The speed is controlled by varying the field of the d.c. motor with the rheostat R. when 'R' changes, the back emf of motor changes and thus the dc voltage at the commutator changes

This changes the d.c voltages on the d.c side of a rotary converter. and so the voltage on ac sides also changes. This ac voltage is given to slip ring of main motor. which produces the required speed control.

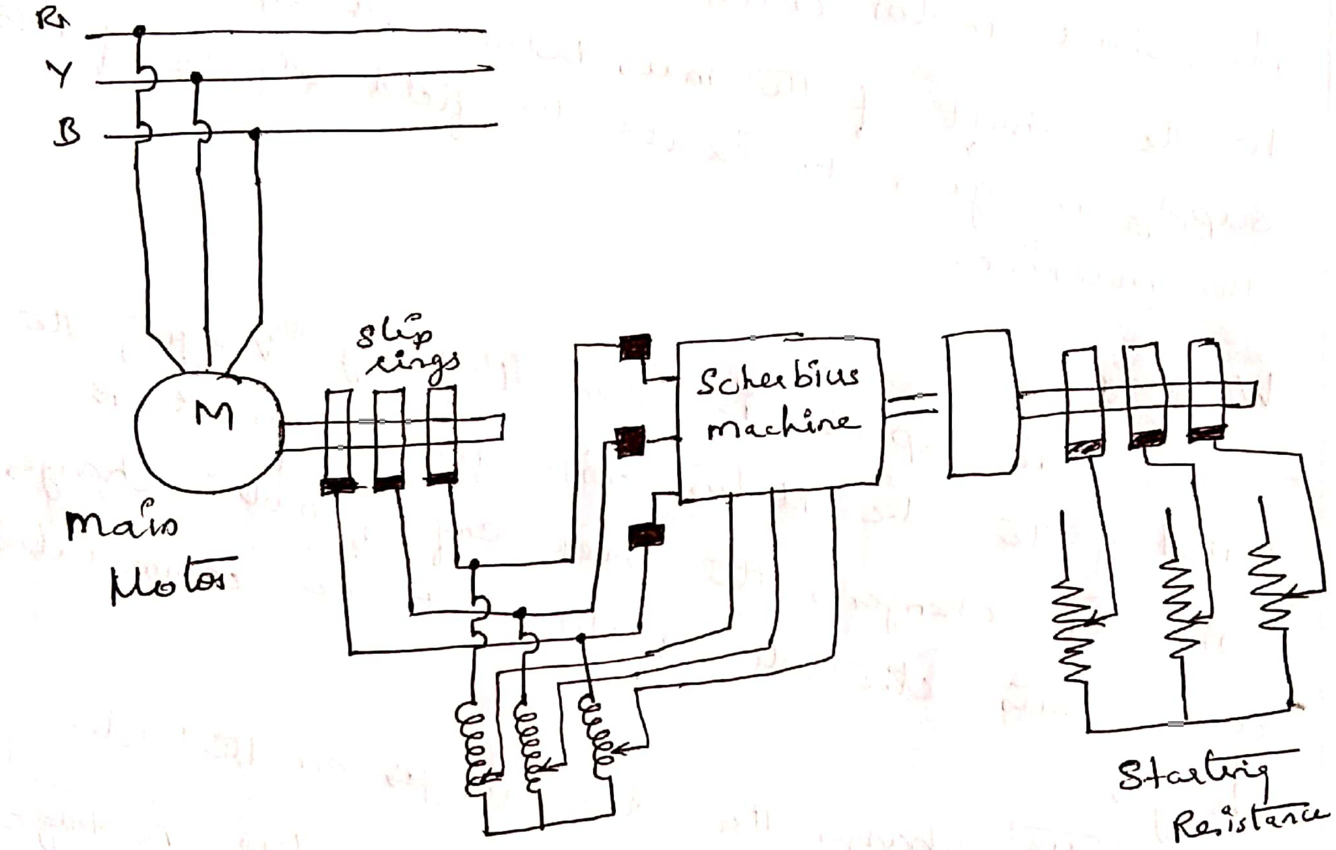
Advantages

* Smooth speed control is possible in wide range
* power factor improvement is also possible

Application

Very large Motor above 4000 kW such as steel rolling mills use this speed control.

(ii) Scherbius System :



Operation :-

This method needs an auxilliary 3 ϕ or 6 ϕ ac commutator machine which is called Scherbius machine. The machine is excited at slip frequency from the rotor of a main motor. through a regulating transformer.

The taps on the regulating transformer can be varied, This ~~volt~~ changes the voltage developed in the rotor of Scherbius machine, which is injected in to the rotor of main motor. This controls the speed of the main motor.

Advantage:

It is also used to control speed of large induction Motor

Disadvantage:-

It is used only for slip ring Induction Motor

4.(i) Describe in detail the slip power recovery scheme of three phase induction motor.

Slip Power recovery Scheme:-

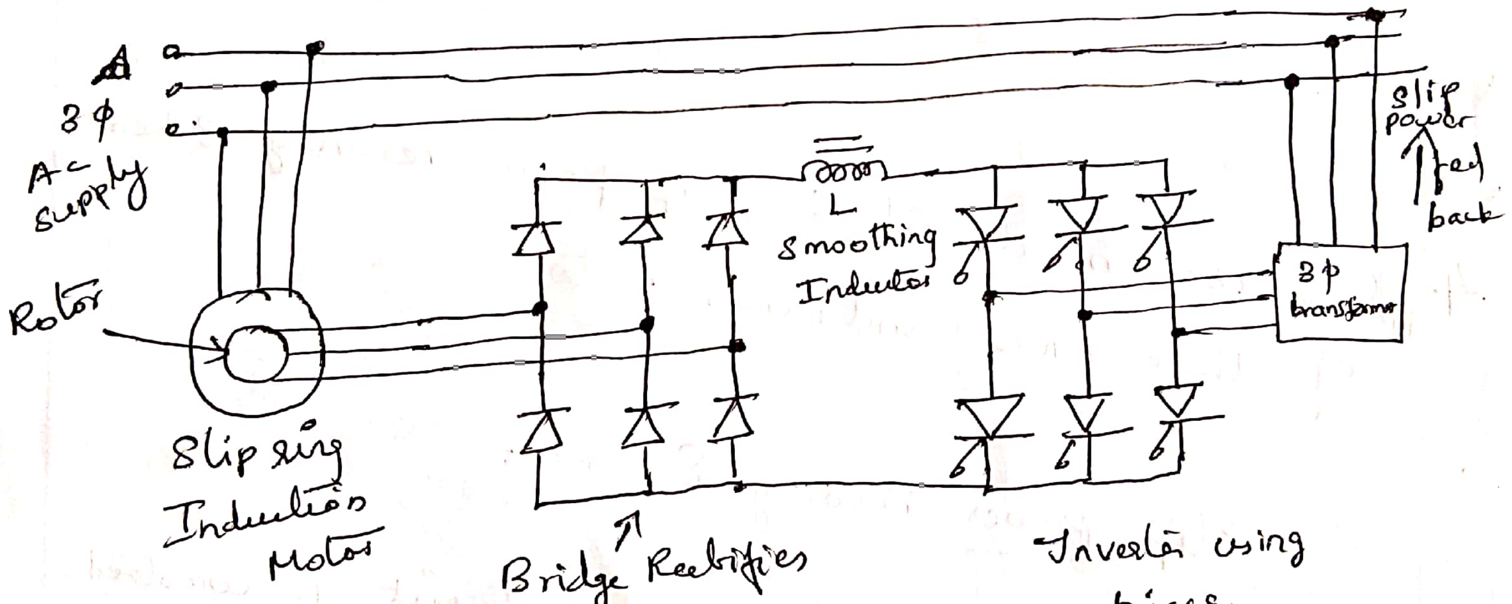
Def: The slip power in the rotor circuit is wasted as I^2R losses in the rotor resistance speed control. It is possible to recover the slip power from the rotor and fed back to the supply using static devices. This is called ~~static~~ slip power recovery scheme

In this method the rotor ac slip power is converted to d.c using bridge rectifier using diodes.

The rectified current is smoothed by using a smoothing inductor L. This dc output is given as a input to a line commutated inverter using triacs.

This inverter converts dc power to the ac power, a three phase transformer is used at the output of an transformer is fed back to the d.c supply.

This method offers speed control below the synchronous speed.



Advantages:-

→ high efficiency.
→ Low cost

Application

Used in large fan and pump drives which require speed control in narrow range.

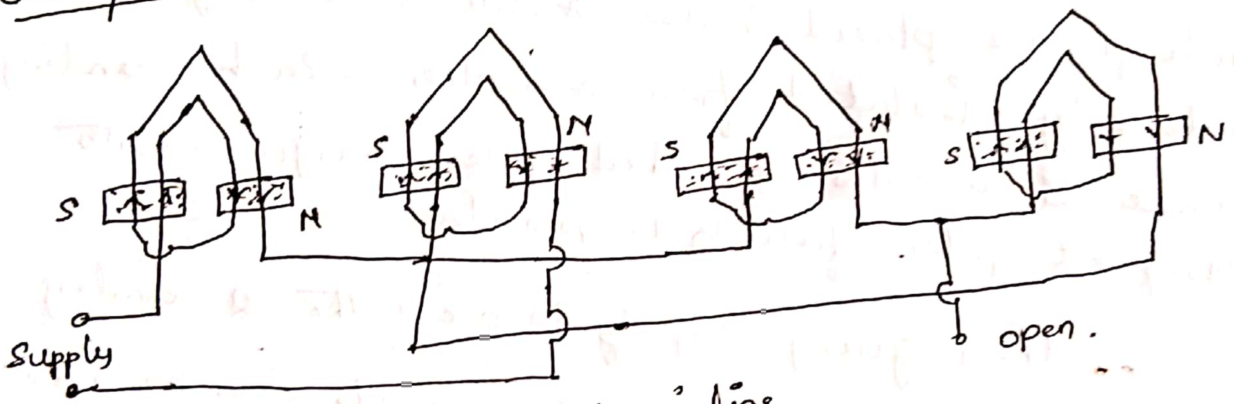
4(iii) Explain the pole changing method of controlling the speed of induction motor.

Controlling Number of poles:

The stator poles can be changed by foll. methods

1. Consequent poles method
2. Multiple stator winding method
3. Pole amplitude modulation method.

Consequent poles method



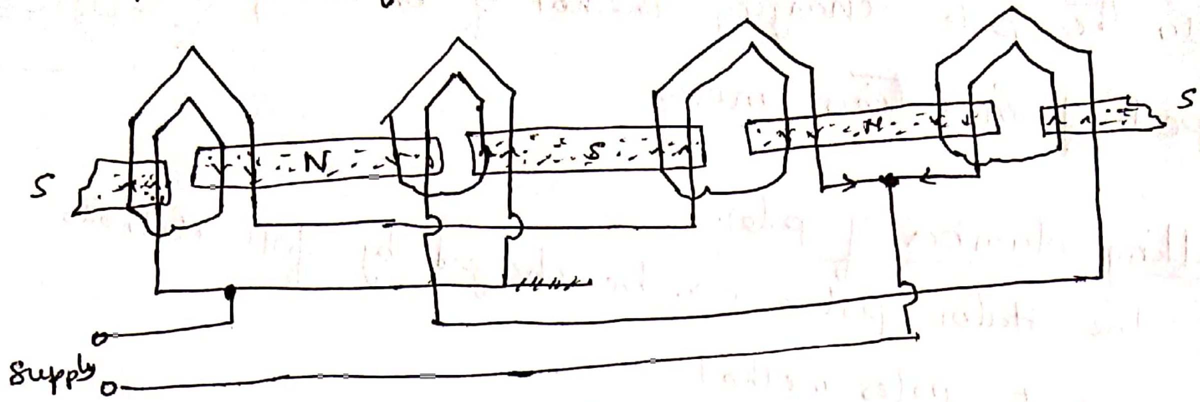
8 pole winding

In this method connections of the stator winding are changed with the help of simple switching. Due to this, the number of stator poles get changed in the ratio 2:1

Consider the pole formation due to single phase of a three phase winding. It can be seen that current in all the part of stator coil is flowing in one direction only. Due to this 8 poles get formed.

Now if the two terminals to which supply was given earlier are joined together and supply is given between this common point and the open third terminal

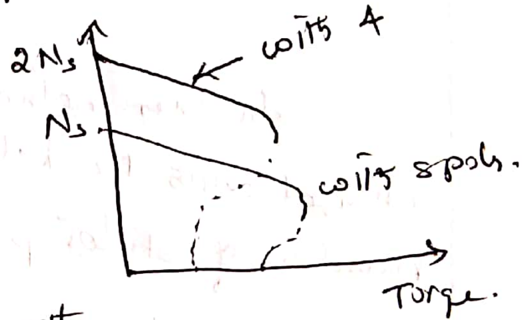
The poles are formed as shown.



Multiple stator winding

In this method instead of one winding, two seperate stator windings are placed in the stator core. The windings are placed in the stator slots only but are windings are placed in the stator slots only but are electrically isolated from each other. Each winding is divided in to coils to which pole changing with consequent poles, facility is provided.

Thus giving supply to one of the 2 winding + using switching arrangement two speeds can be achieved.



Pole Amplitude Modulation Method

* The basic disadvantages of other Method which is non availability of smooth speed control is eliminated by this method.
* The ratio of two speeds in this method, need not be necessarily 2:1.
* The basic principle of this Method is the modulation of two sinusoidally varying mmf waves with different number of poles.

DACE Cultivating Technology

Electric Braking of an Induction Motor.

5. Discuss the Electric braking Method used in 3ϕ Induction Motor?

Braking Methods:

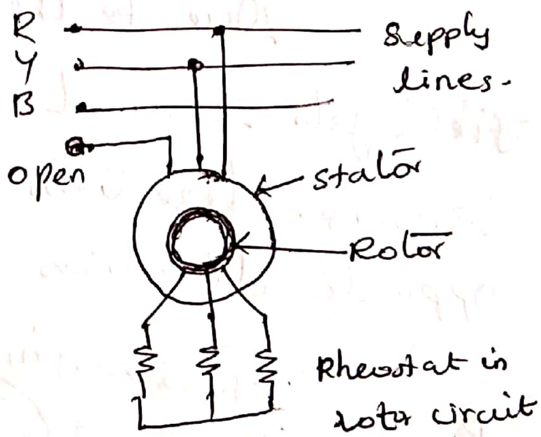
1. Dynamic or Rheostatic Braking.
2. plugging or counter current Braking.
3. D.C. Dynamic Braking
4. Regenerative Braking.

(1) Rheostatic Braking

In Rheostatic braking one supply line of R, Y, Br B is disconnected from the supply. Depending upon the condition of the disconnected line, it is of two types

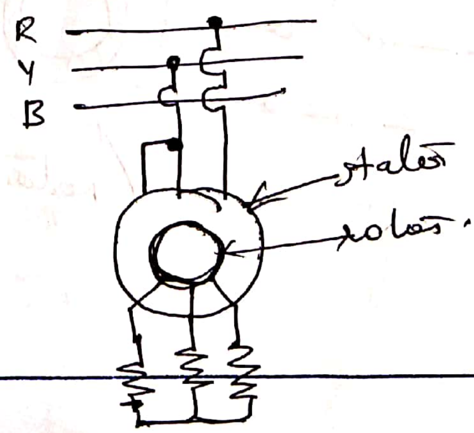
(i) Two lead connection

In this method, the disconnected line is kept open, called two lead connections.



(ii) Three lead connections

In this method, the disconnected line is connected directly to the other line of the machine.



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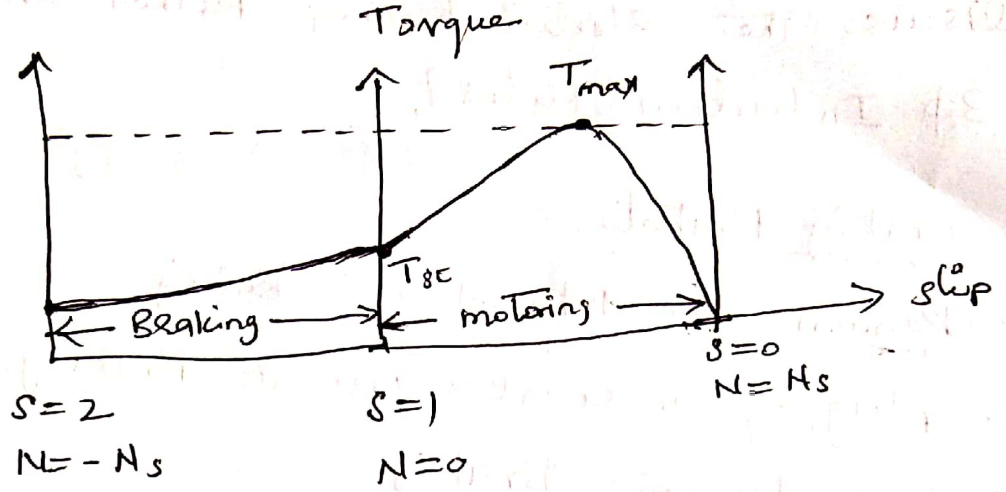
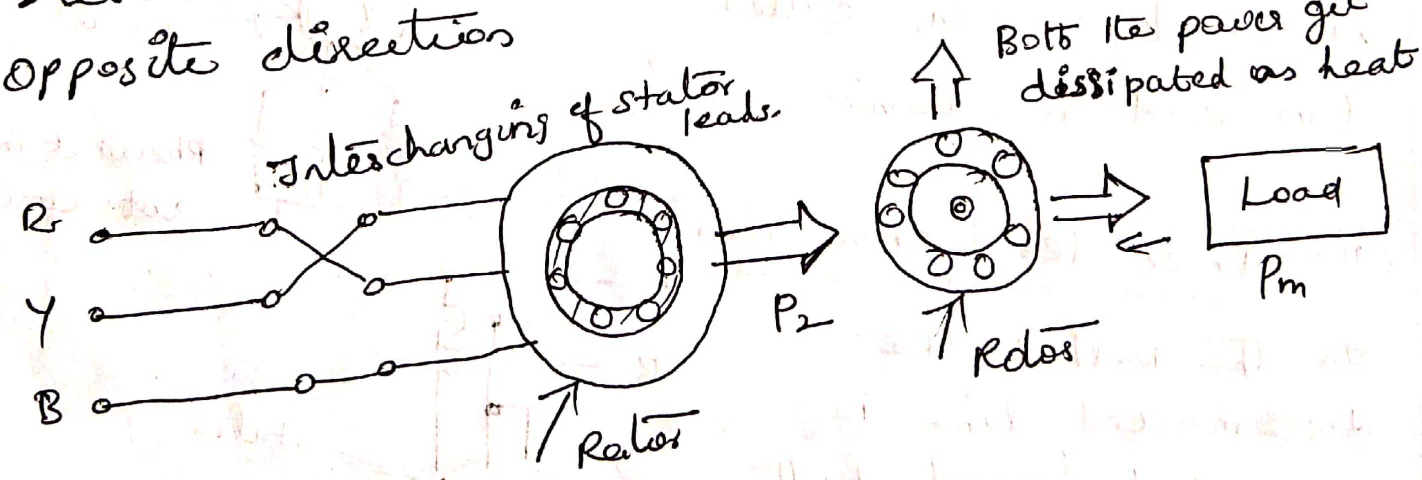
The torque slip characteristics of motoring and braking operation is shown.



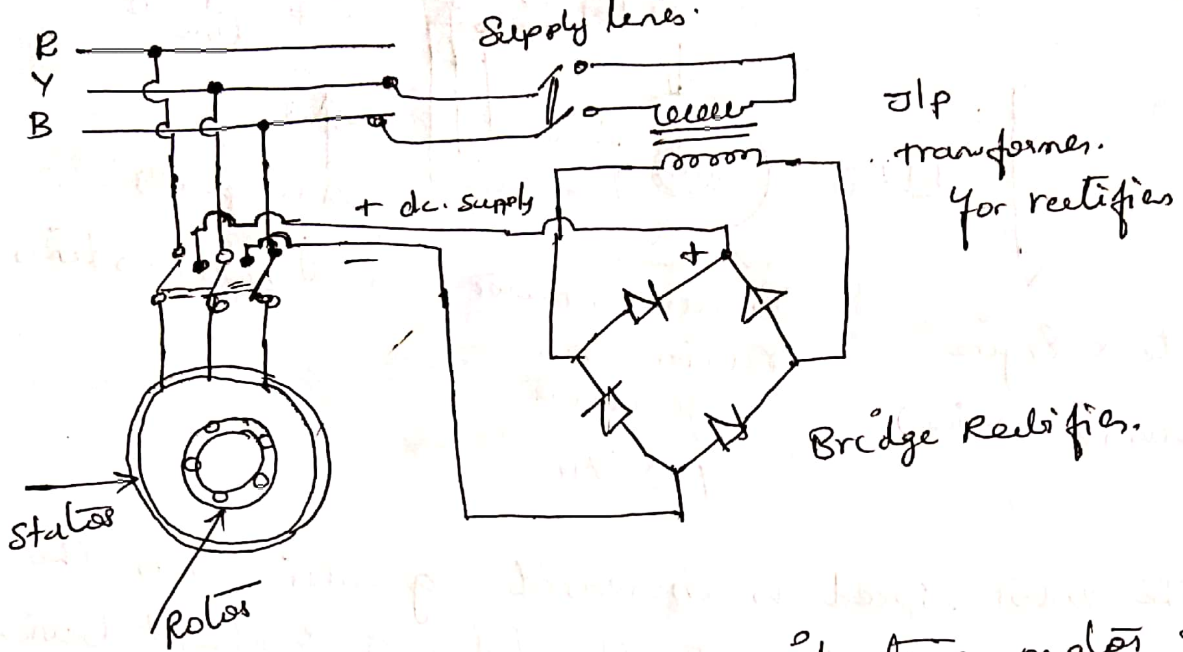
(iii) Plugging

The reversal of direction of rotation of motor is the main principle in plugging of motor. The Induction Motor can be stopped by interchanging any two stator leads.

Due to this direction of rotation of magnetic field gets reversed suddenly & torque produced in reverse direction and motor tries to rotate in opposite direction.



(3) DC Dynamic Braking



A quick stopping of an induction motor and its high inertia load can be achieved by connecting stator terminals to a d.c. supply.

Any two stator terminals can be connected to a d.c supply and third terminal may be kept open or may be connected directly to the other stator terminals. This is called d.c dynamic braking.

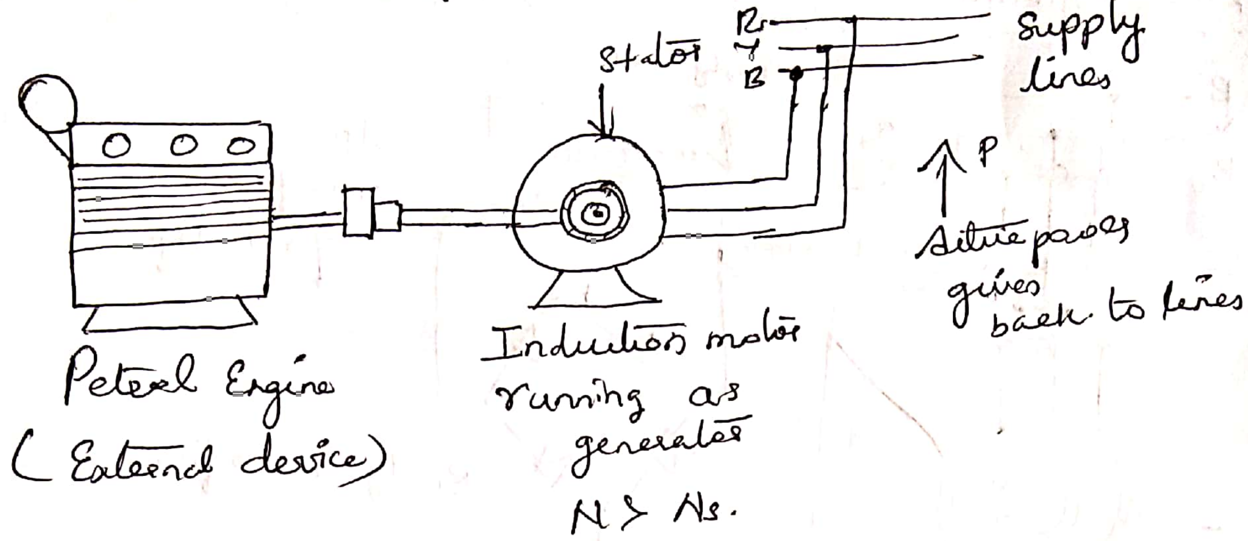
When all the kinetic Energy gets dissipated as heat in the rotor, the induction motor comes to rest.

Advantages

The heat produced is less when compared to plugging.

Quick stopping of motor is possible.

Regenerative Braking

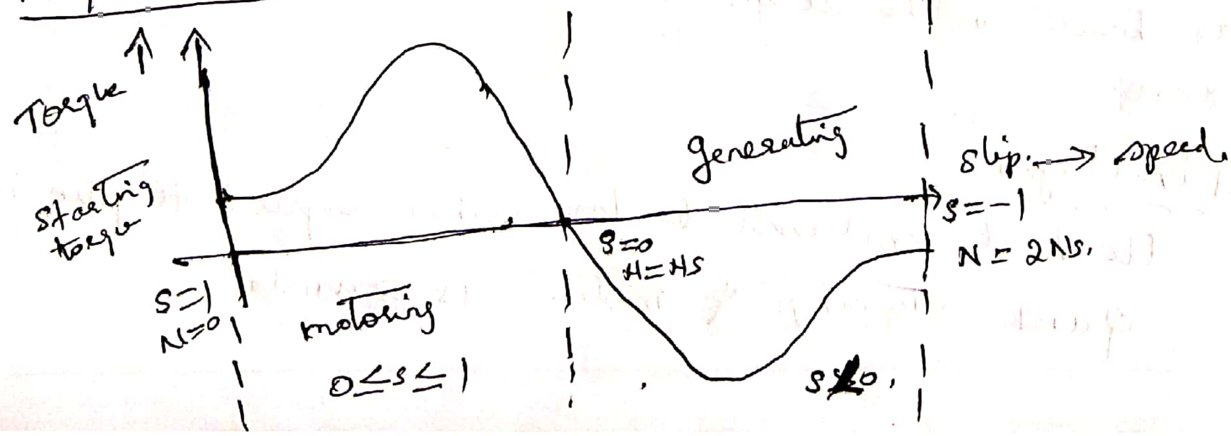


If the rotor speed is increased greater than the synchronous speed with the help of External device, it acts as an Induction generator. It converts the Input Mechanical Energy to an Electrical energy gives back to supply.

It delivers active power to the 3 phase line. The power flow reverses hence the rotor current & emf also reverses. So the rotor produces torque in opposite direction to acheive the braking.

This is called regenerative braking.

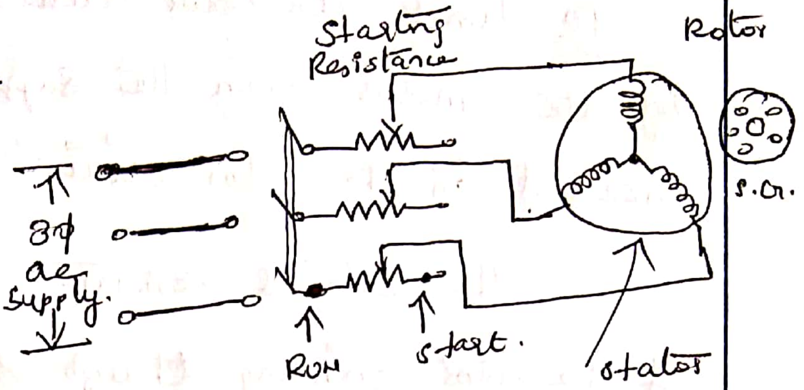
Torque - slip characteristics



6 Starters used for 3φ Induction Motors.

question ① Ans. 4. ① + ②

(3) Stator resistance starter



To apply reduced voltage to the stator of the induction motor, three resistances are added in series with each phase of the stator winding. Due to this large voltage gets dropped across the resistance & hence reduced voltage is applied to the stator.

When the motor starts running, the resistances are gradually cut off from the stator circuit. Motor runs with normal speed.

Advantage

Starter is simple in construction and cheap.
used for both star + delta connected stator

Disadvantage

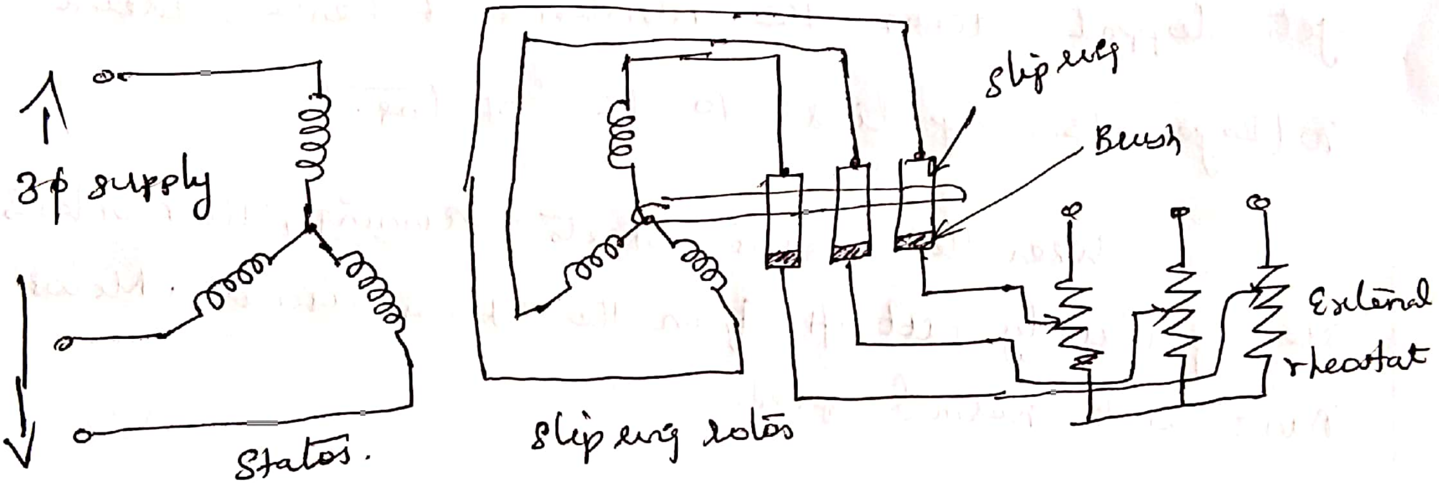
Large power losses due to resistances.
Starting torque reduces due to reduced voltage

$$\frac{T_{st}}{T_{FL}} = x^2 \left[\frac{I_{sc}}{I_{FL}}\right]^2 S_f.$$

Rotor Resistance Starter

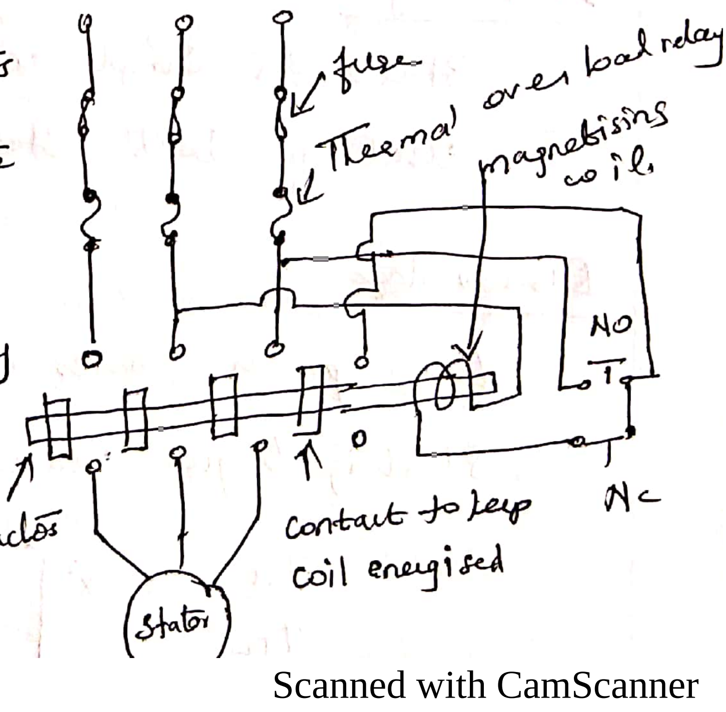
To limit the rotor current, the current drawn by the motor from the supply, the resistance can be inserted in the rotor circuit at start.

The External resistance is inserted in each phase of the rotor winding through slip ring and brush assembly. Initially maximum resistance is in the circuit. As motor gathers speed, the resistance is gradually cut off.



Direct on line Stater (DOL)

In case of small capacity motor having rating less than 5 h.P. the starting current is not very high and such motors can withstand such starting current without any starter.



There is no need to reduce applied voltage, to control the starting current. Such motors use a type of starter which is used to connect stator directly to the supply lines without any reduction of voltage.

The NO contact is normally open and NC is normally closed. At start, NO is pushed for fraction of second due to which coil gets energised and attracts the contactor. So stator directly gets supply.

Under load condition the current increases excessive heat produced, Thermal relays get opened due to high temperature protecting the motor from overload conditions.

7) Determine approximately the starting torque of an induction motor in terms of full load torque when started by i) star delta starter and ii) Auto-starter with 50% tapping. The short circuit current of the motor at normal supply is 5 times the full load current and the full load slip is 4%.

Solution: $I_{sc} = 5 I_{fl}$. $s_f = 4\% = 0.04$

(i) Star – delta starter:

$$\frac{T_{st}}{T_{FL}} = \frac{1}{3}\left[\frac{I_{sc}}{I_{FL}}\right]^2 \cdot s_f \Rightarrow \frac{1}{3}(5)^2 \times 0.04$$

$$= 0.333$$

$$\boxed{T_{st} = 33.33\% \text{ of } T_{FL}}$$

(ii) Auto - starter with 50% tapping

$k = 0.5, \quad k^2 = 0.25$

$$\frac{T_{st}}{T_{FL}} = k^2\left[\frac{I_{sc}}{I_{FL}}\right]^2 s_f = 0.25 \times 25 \times 0.04$$

$$= 0.25$$

$$\boxed{T_{st} = 25\% \text{ of } T_{FL}}$$
