SUBJECT : Electric Machine - II

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Assignment: 1

Question # 1

Write Introduction, Advantages, Disadvantages, Construction of Three Phase Induction Motor.

INDUCTION MOTOR: An induction motor or 3 phase induction motor is an electric motor in which electric current in rotor needed to produce torque is obtain by electromagnetic induction from magnetic field of stator winding.

INTRODUCTION: The induction motor with a wrapped rotor was invented by Nikola Tesla in 1882. Technological development in field has improved to where a 100hp (74.6KW) motor from 1976 takes the same volume as a 7.5hp (5.5KW) motor did in 1897. Currently, most induction motor is the cage rotor motor.

An electric motor convert electric power to mechanical power in its rotor (rotating part). In Dc motor is this power is supplied to armature directly from a Dc source, While in induction motor this power is induced in rotating device.

An induction motor sometimes called a rotating

transformer, because stator is essentialy primary side of transformer and rotor is secondary side. Induction motors are widely used, especially Polyphase induction motors, which are frequently used in industrial drives.
Induction motor now are preffered choice for industrial motors due to their rugged construction, absence of brushes and ability to control speed of motor.

Construction:

Like any other electrical motor, induction motor also have two main parts namely:

i) Rotor ii) Stator

The Rotor is separated from stator by a small air-gap which ranges from 0.4mm to 4mm depending on power of motor.

Stator: Stator is stationary part of induction motor. A stator winding is placed in stator of induction motor and 3-phase supply is given to it. Stator is made up of number of stampings in which different slots are cut to receive 3ϕ winding circuit which is connected to 3phase ac supply. Speed is inversely proportional to number of poles, windings are wound for definite number of poles depending

upon the speed requirements. given by the formula: $N_s = 120f/P$

Stator of three phase Induction motor consist of three main parts following:

(a) **Stator Frame:** Stator frame is outermost part of induction motor. Its main function is to support stator core and field winding.

(b) **Stator Core:** Its main function is to carrying alternating flux. Stator core is laminated to reduce eedy current losses. These laminated types of structered are made up of stamping which is about 0.4 to 0.5 mm thick.

(c) **Field Winding:** The three phase winding is supplied by three phase ac supply. The three Phases of winding are connected in star or delta depend upon method is used. The winding wound on stator of 3ϕ motor is called field winding, when excited. it Produce a rotating magnetic.

∴ **Rotor:** Rotating part of induction motor is called rotor. Rotor is connected to mechanical load through shaft. Rotors consist of cylinderical laminated core with parallel slots that carry conductor bars.

The rotor mounted on a shaft. is a hallow

laminated core having slots on its outer periphery. The winding placed in these slots may be one of following two types.

a) Squirrel Cage (b) Wound

Advantages

There are following advantages of three phase induction motor.

* Working of the motor is independent of Environmental condition.
* Squirrel cage induction motor does not contain Brushes, slip rings and Commutators for while Cost of motor is quite low.
* Due to absence of Brushes, there are no sparks in the motor.
* A 3ϕ induction motor has a high starting torque, good speed regulation and reasonable overload capacity.
* It is a highly efficient machine with full load efficiency varying from 85 to 97 percent.

Disadvantages:

* A single phase induction motor does not have a self starting torque.
* During light load condition, Power factor of motor drops to very low value.

★ Speed control of induction motor is very difficult to attain.

★ Induction motor have high input surge currents, which are referred to as Magnetising Inrush currents.

★ Due to poor starting torque, motor cannot be used for application which require high starting torque.

Application OF Induction Motor:

Some of three phase induction motor application are following:

(a) Wound rotors motors are suitable for load requiring high starting torque.

(b) Use for loads which required a gradual buildup of torque.

(c) Use for loads that requires speed control.

(d) Wound rotors induction motors are used in conveyors, Cranes, Pumps, elevators and Compressors.

(e) The maximum torque is above 200 percent of full load value while full load slip may be as low as 3 percent. The efficiency is about 90%.

Question-2

Write operation Principal of Three phase Induction Motor.

The operation of a 3ϕ-induction motor is based upon application of Faraday Law and the Lorentz force on a conductor. Behaviour can be understood by following steps

⇒ An AC current is applied in stator armature which generate a flux in stator magnetic circuit.

⇒ This flux induces an emf in conducting bars of rotor as they are "cut" by flux while magnet is being moved ($E=BVL$)

⇒ A current flow in rotor circuit due to induced emf, which in term produce a force, ($F=BIL$) can be changed to the torque as output.

In a 3-phase induction motor, three-phases current i_a, i_b and i_c, each of equal magnitude but differing in phase by 120°. Each phase current produce a magnetic flux and 120° phase shift. The summation of three ac fluxes results in a rotating flux, which turns with constant speed and has constant amplitude.

Development of Induced Torque in an Induction motor:

A three phase set of voltage has been applied to stator and three phase set of stator currents is flowing. These currents produces a magnetic field Bs. which is rotating in clockwise direction.

Speed of magnetic field rotation is given by:

$$n_{syc} = \frac{120 f_{se}}{P}$$

where f_{se} = frequency applied in Hertz

P = Number of Poles

This rotating magnetic field Bs Passes over the rotor bars and induced voltage in them.

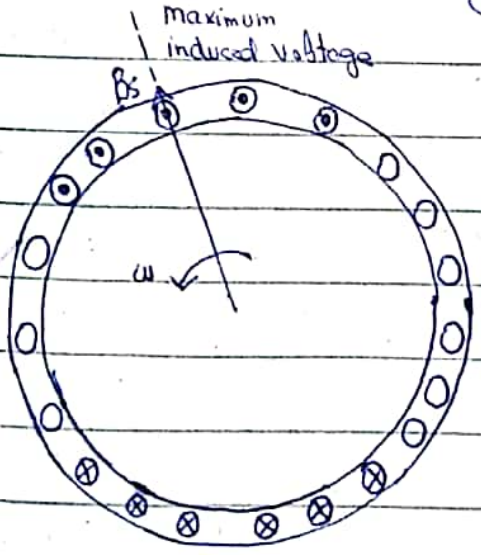
Induced voltage is given by:

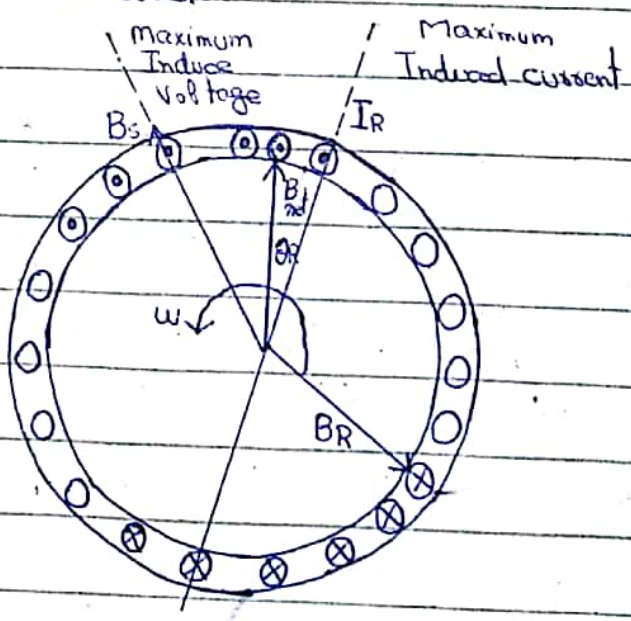
$$e_{ind} = (V \times B).l$$

where V = velocity of bar

B = magnetic flux density vector

l = length of Conductor





It is relative motion of rotor compared to stator magnetic field that produced induced voltage in a rotor bar. The velocity of upper rotors bar relative to magnetic field is to the right. so induced voltage in upper bar is out of page, while induced voltage in lowest bars is into Page.
This result in a current flow out of upper bars and into lower bars.
However, Since ~~motor~~ rotor assembly in inductive, the peak rotor current lags behind peak rotor voltage. The Rotor current flow Produces a rotor magnetic field B_R.
Finally, induce torque in machine is given by.

$$T_{ind} = K B_R \times B_S$$

the resulting torque is counterclockwise.
Since rotor induced torque in counterclockwise, the rotor accelerate in that direction.

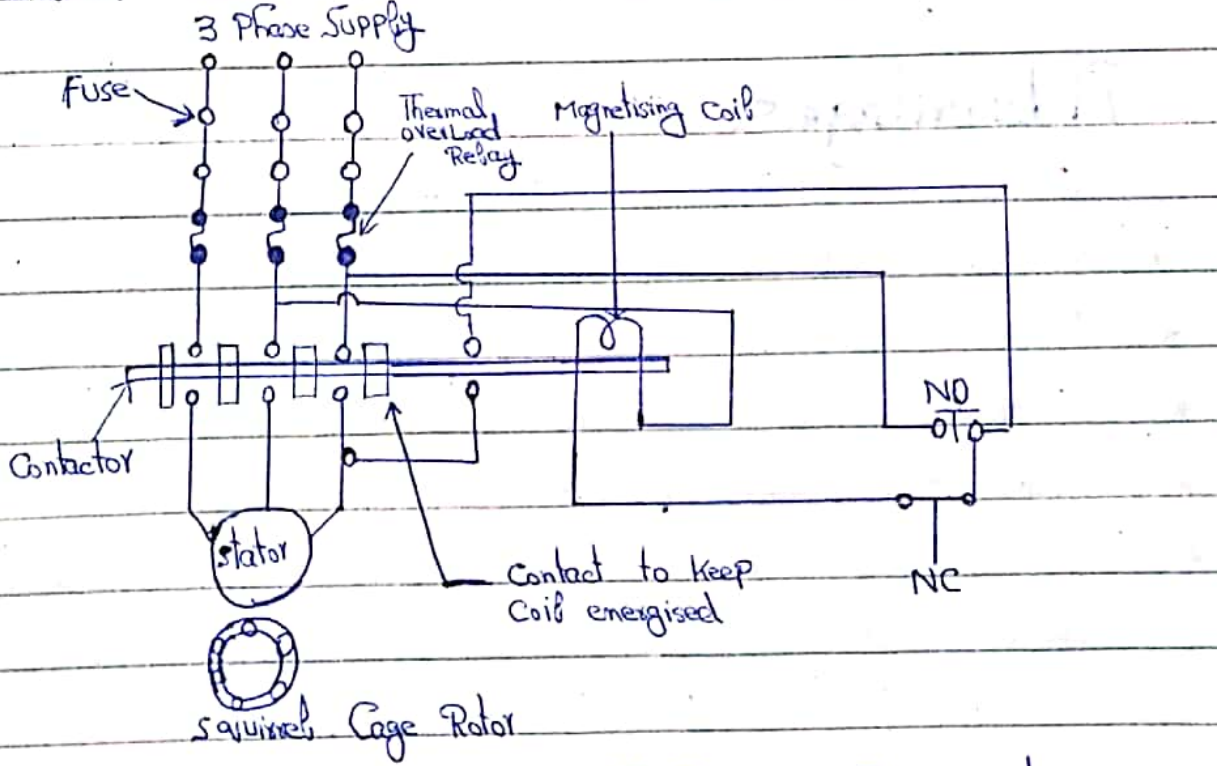
Question-3

Discuss different types of Stator Starter for 3-ϕ induction motor?

(a) Direct On-Line Starter

A DoL starter is a method of starting of a 3 phase induction motor. In DOL starter an induction motor is connected across its 3-phase supply and DoL starters applies full line voltage to motor terminals. Despite this direct direction, no harm is done to the motor.

A wiring diagram of a DoL starter is shown below:



The motor draws a very high inrush current compared to full load current of motor upto 5-8

higher. Value of this large current decreases as motor reaches its rated speed.

DOL Stater Principal:

Working Principal of a DOL starter begins with connection of 3ϕ main with motor. The control circuit is connected to any two phases and energized from them only. When we press start button, current flow through contactor coil and control circuit also. The current energise contactor coil and lead to close contacts and hence 3-phase supply become available to the motor.

If we press stop button, current through contact become discontinued, hence supply to motor will not be available, machine will come to rest.

Advantages:

Advantages of DOL starter include:

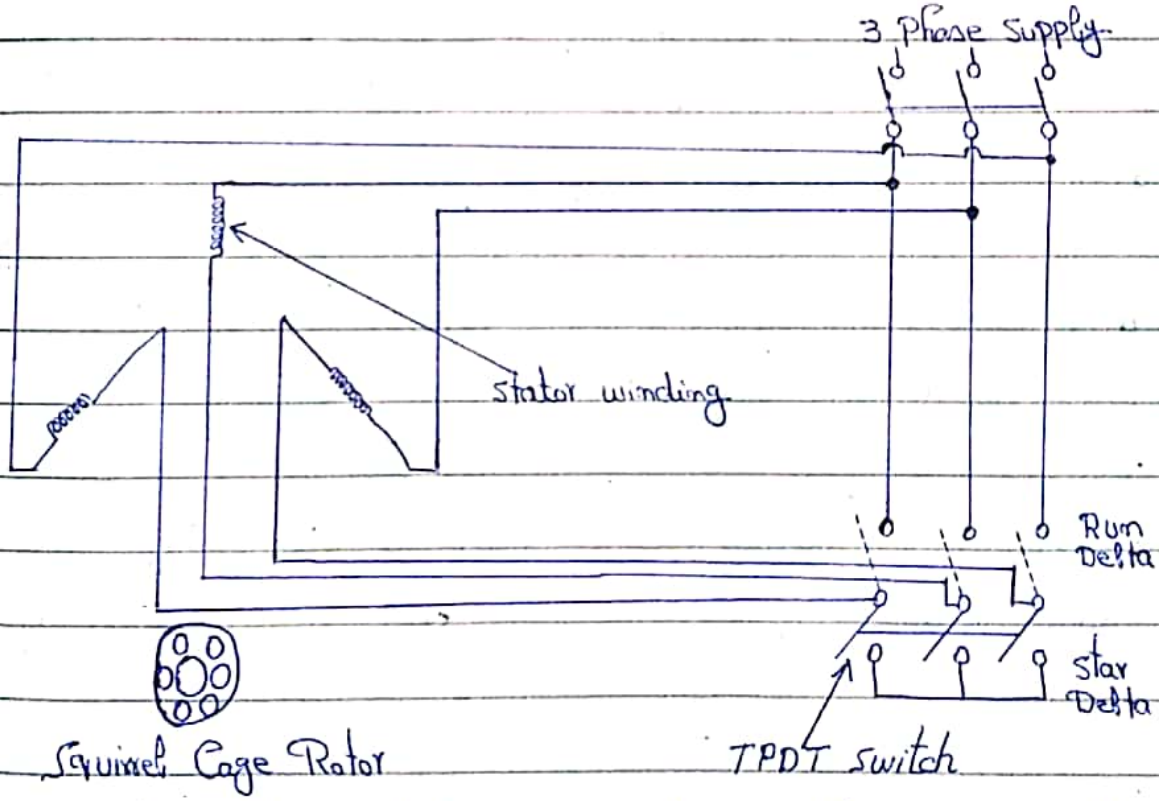
* Simple and most economical starter.
* Motor comfortable to design, operate and control.
* Provides nearly full starting torque at starting.
* Eassy to understand and troubleshoot.
* DOL starter connects the supply to the delta winding of motor.

(b) Star-Delta Starter

A star-Delta starter is a starting method of induction motor. In star-Delta starting an induction motor is connected in through a star connection throughout starting period. Then once motor reaches required speed, the motor is connected in through a delta connection.

Explanation:

A star delta starter will start a motor with a star connected stator winding. When motor reaches about 80% of its full load speed, it will begin to run in a delta connected stator winding.

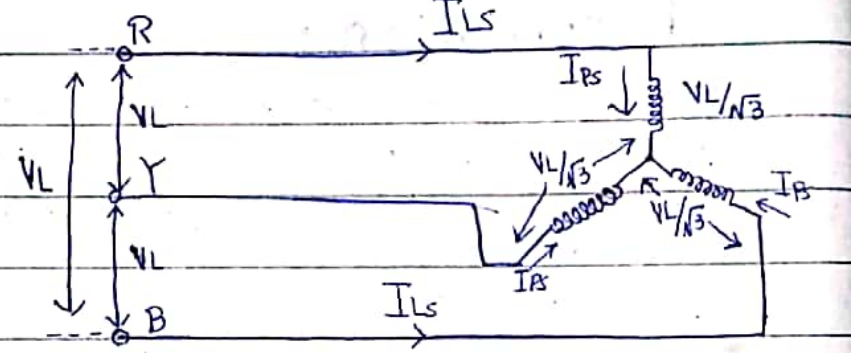


A star-delta starter is a type of reduced voltage starter. We use it to reduce starting current of

motor, without using any external device or appratus. This is a big advantage of a star delta starter as it typically has around 1/3 of inrush current compared to DOL starter.

Starter mainly consist of a TPDP (Tripple Pole Double Throw switch), that changes stator winding from star to delta. Now see how a starter reduces starting current of 3ϕ induction motor.

- As winding is star connected so $I_{PS} = I_{LS}$ Voltage across each phase is $V_L/\sqrt{3}$. Hence winding current per phase is $I_{PS} = V_L/\sqrt{3}Z$



- Here, winding current per phase equal to supply line current $I_{PS} = \frac{V_L}{\sqrt{3}Z} \iff I_{LS} = \frac{V_L}{\sqrt{3}Z}$
- Winding is delta connected supply line currents is root three times of current per phase $I_{LD} = \sqrt{3} I_{PD} \Rightarrow I_{PD} = V_L/Z$
- Comparing supply Line currents drawn by induction motor with star and delta connected winding are $\frac{I_{LD}}{I_{LS}} = \frac{\sqrt{3}V_L/Z}{V_L/\sqrt{3}Z} = 3 \Rightarrow I_{LS} = \frac{1}{3} I_{LD}$

Thus we can say starting current from main in case of star-delta is one-third of direct

switching in delta. Star-delta stater is equivalent to an autotransformer with a 57.7% tapping.

Advantages:

(a) Inexpensive
(b) No heat is produced
(c) Starting current reduced to 1/3 of online current.
(d) Produce high torque per ampere of line current.

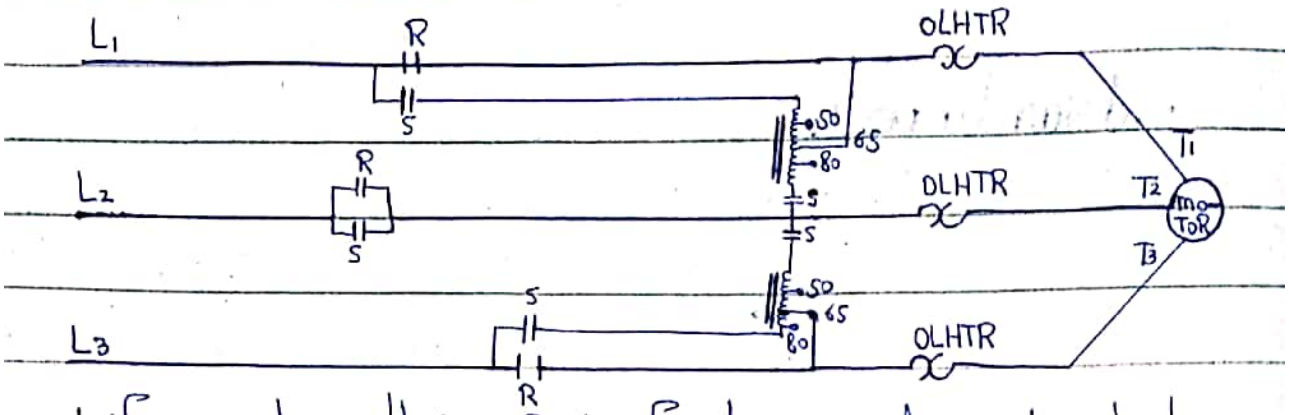
(C) Auto Transformer Starter

Autotransformer starters are used generally with star connected AC squirrel cage motors. ~~As squirrel cage~~ As high voltage AC squirrel cage motors are connected in star to reduce voltage strain on winding insulation. So limit starting current to decrease starting strains on those motors. auto-transformer are used.

Working Principle:

To reduce voltage across motors terminals during starting period, this type starter connected in open delta. In this method only two windings are used as shown in figure.

As the time of starting, a reduced voltage is applied across motor terminals. With lower starting voltage, motor draws less current and develops less torque.



When motor attain 80% of its normal speed, auto-transformer are cut out and full supply voltage is applied to motor. The switch making these changes from start to run may be airbreak to reduce sparking.

- When start button is pressed a circuit its completed to coil of control relay CR. When coil of S contactor energizes, all S contactor change position. The normally closed S connected in series with R coils open to prevent both S and R contactors from being energized at same time.
- When S load contact close, motor is connected to Power line through autotransformer and 65% of supply voltage is applied to motor. When contactor R energized, all R contacts change position.
- When stop button is pressed, Control relay CR de-energized and open all CR contacts. This disconnect all other control components from Power line and circuit returns to its normal speed.

Advantages:

(a) The autotransformer starters limits significantly inrush current.

(b) It is used for large motors.

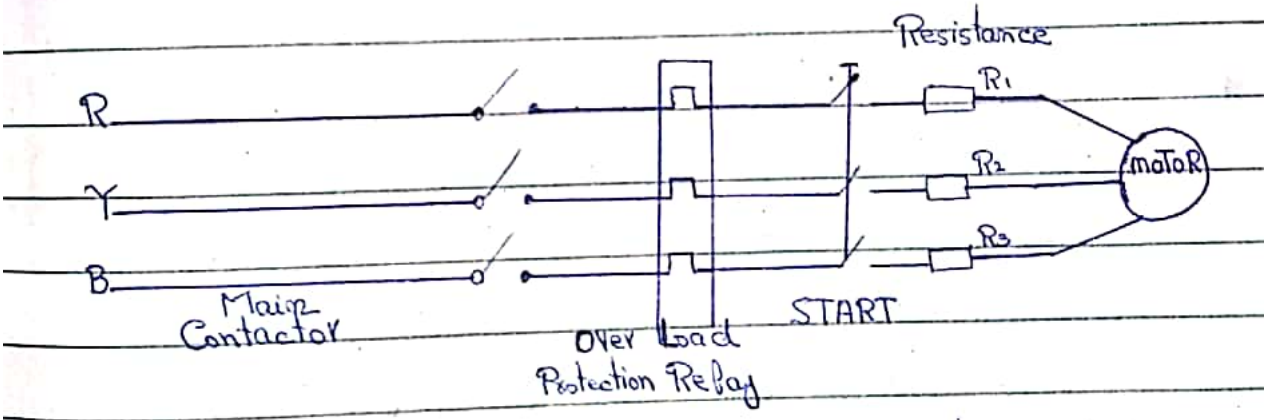
(c) Most effective ratio is between 65-80%.

(d) Highest torque per ampere of supply current.

(e) Motor current larger than supply current.

(d) Rotor Impedance Starter

It consist of 3 resistance connected in series with rotor winding. thus reducing the rotor currents but increasing the torque.



- This starter is used with a wound rotor induction motor. It uses an external resistance phase in rotor circuit.
- High torque is produced at low speeds when extend resistance is at its higher value.

- At start Supply Power is connected to stator through a three Pole contactor and at a same time, an external rotor resistance is added.
- The high resistance limits starting current and allows the motor to start safely against high load.
- Resistors are normally of wire wound type, connected through bushes and slip rings to each rotor phase.
- As motor start, external rotor resistance is gradually cut out of circuit. handler or starter is turned and moves three contacts simultaneously from one fixed contact to the next.
- The three moving contacts are interconnected to form a start point for resistor.
- To ensure that the motor cannot be started until all rotor resistance is in circuit, an interlock is fitted which prevents the contactors from being closed until this condition is fulfilled.

Advantages:

(a) Smooth variation of rotor resistance.
(b) Simplicity of operation using close loop control.
(c) Quick response of time.
(d) Rotor resistance unbalanced can be eliminating using power electronics device.

Conclusion:

Although method of speed controlling of induction motor using technology is efficient, but as we are using Resistance to control speed of motor here also resistive losses occurs which causes unnecessary heating effect on motor and also reduces efficiency in some extents, that is why it cannot be operated for continuous operation.
It is used in intermittent application such as overhead cranes, load fluctuations, etc.

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