POLYPHASE INDUCTION MACHINES

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INDUCTION MOTOR

ADVANTAGES

- It has very simple and rugged construction
- It's cost is low
- It has high efficiency and good power factor
- It needs minimum maintenance
- It has starting torque

CONSTRUCTION

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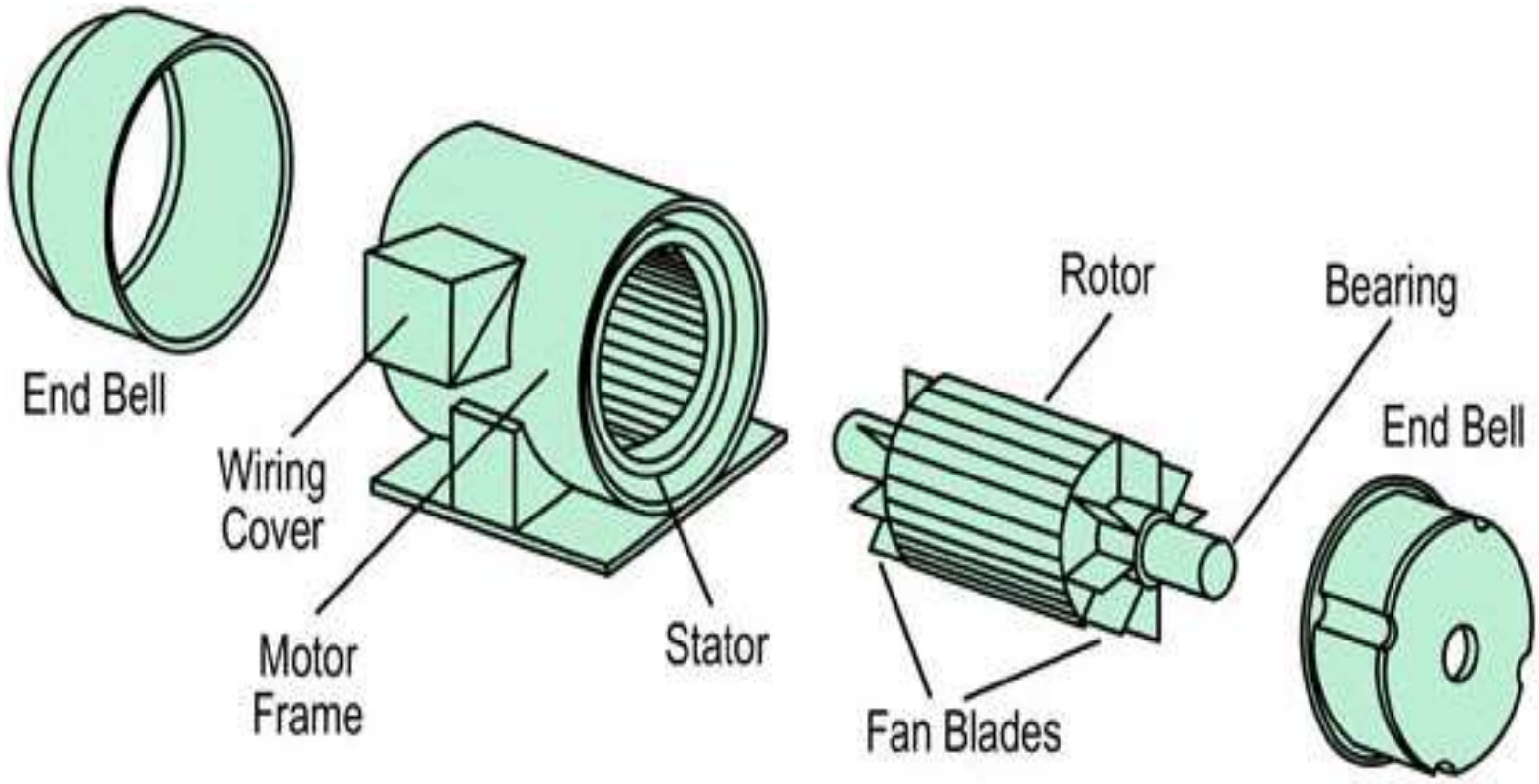


CONSTRUCTION

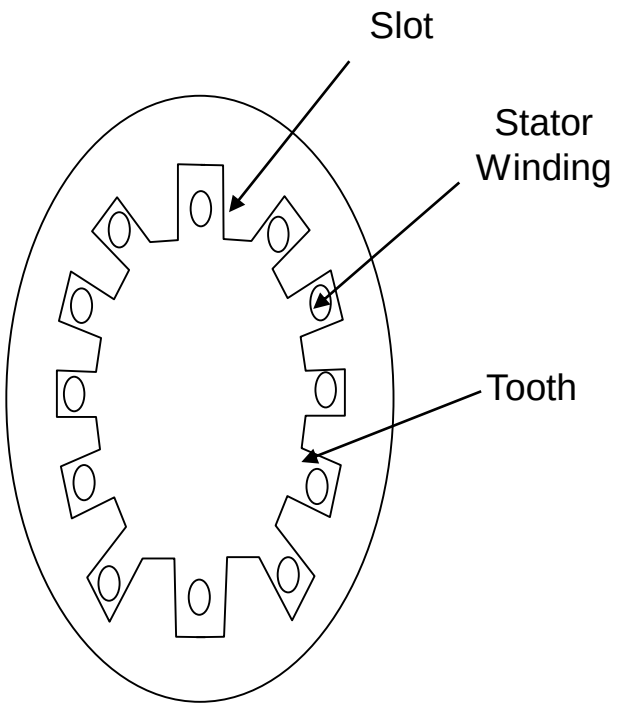
A 3-Phase Induction motor has Main two

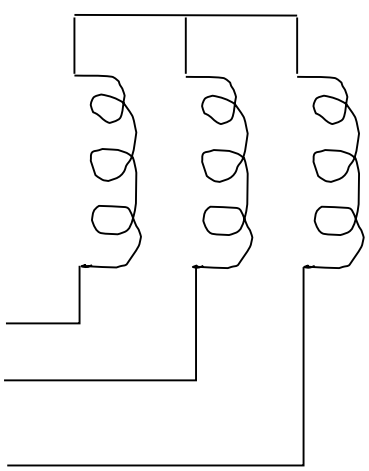
- Stator
- Rotor

Stator:

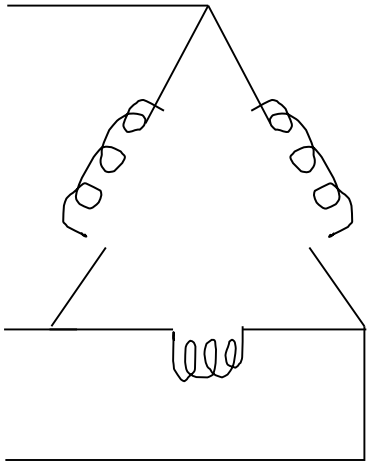
- The stator of an I.M. is the same as that of a synchronous machine.
- It is made from laminated steel with slots in the inner periphery.
- The stator carries a poly-phase winding in these slots. For a 3-ph I.M. the winding is connected in star or delta connection.

- The stator winding of a poly-phase I.M. is almost similar to the armature winding of a poly-phase alternator.





Star



Delta

Rotor

The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.

The rotor of the three phase induction motor are further classified as

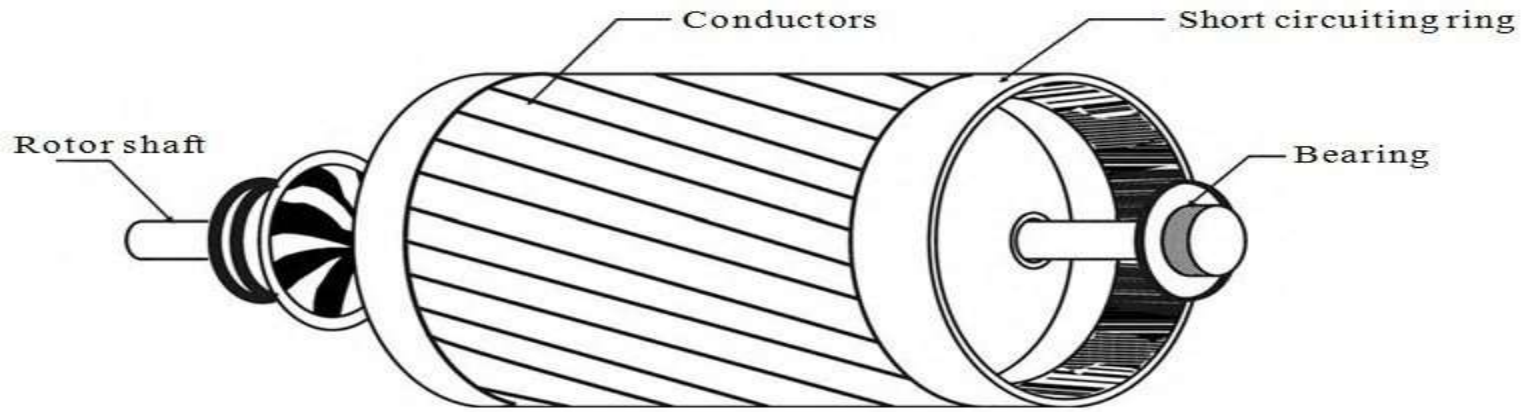
- Squirrel cage rotor
- Slip ring rotor or wound rotor or phase wound rotor.

The other parts of a 3 phase induction motor are:

- Shaft for transmitting the torque to the load. This shaft is made up of steel.
- Bearings for supporting the rotating shaft.
- One of the problems with electrical motor is the production of heat during its rotation. To overcome this problem, we need a fan for cooling.
- For receiving external electrical connection Terminal box is needed.
- There is a small distance between rotor and stator which usually varies from 0.4 mm to 4 mm. Such a distance is called air gap.

Squirrel-Cage Rotor

- The rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor bars. These bars are short-circuited by two end-rings. The rotor slots are not quite parallel to the shaft but are given slight skew.



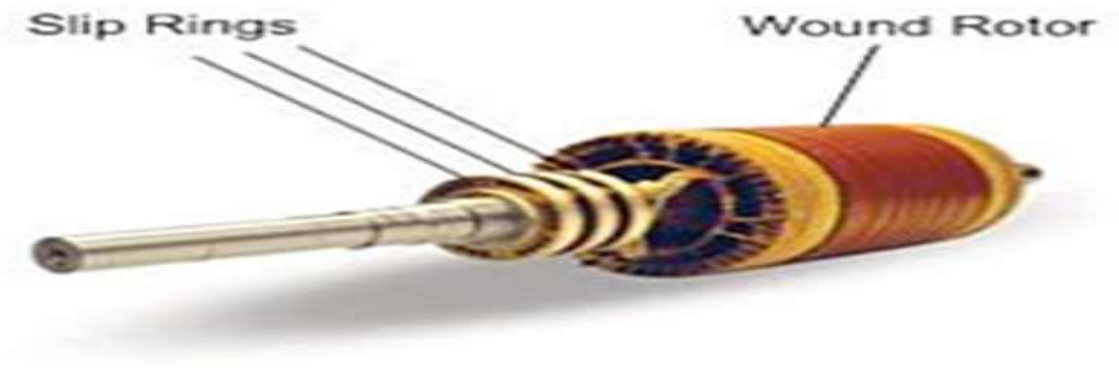
Rotor of Squirrel Cage Induction Motor

Advantages

- The advantages of skewing are:
- It makes the motor run quietly by reducing the magnetic hum.
- It reduces the locking tendency of the rotor. The tendency of the rotor teeth to remain under the stator teeth due to direct magnetic attraction between them.

Wound Rotor

- The rotor core is laminated with skewed slots on its outer periphery. The rotor is provided with 3-ph, double-layer, distributed windings. The rotor is wound to have the same number of poles as for the stator. The 3-ph windings are connected in star formation. The terminals of the rotor star-winding are connected to slip-rings mounted on the shaft.



Advantages

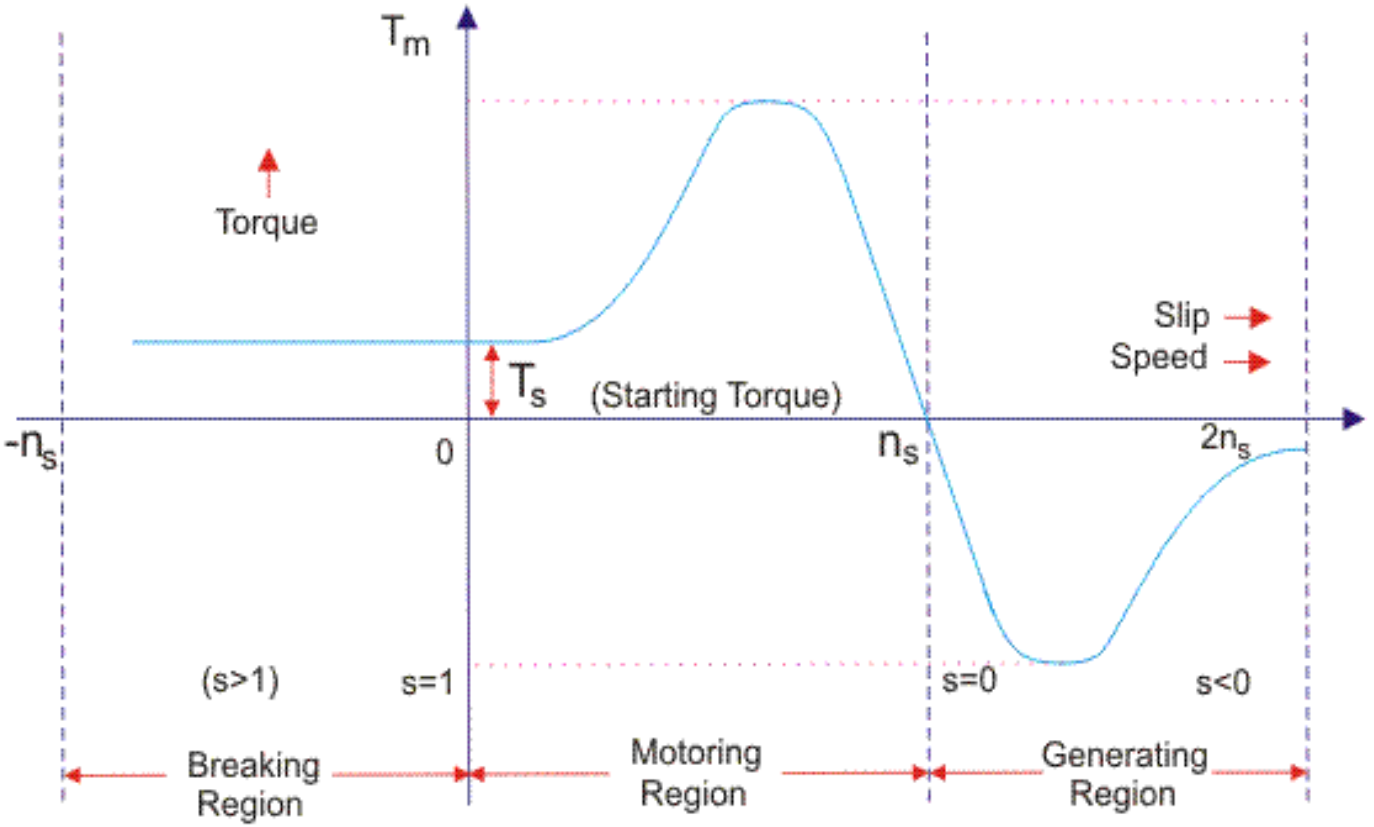
- In a wound rotor induction motor you can start the motor with very low currents or with maximum torque, and still have good efficiency in the load region.
- squirrel cage motor that is much cheaper to produce and don't need the mechanical slipping contacts.
- wound rotor, the rotor windings are shorted through brushes riding on the slip rings.

Low Power Factor Operation of Induction Motor

- Induction Motors finds various applications in industries and household equipments. Such machine requires magnetic fields for its functioning hence, it draws magnetizing current from the source.
- It is typically around 20% to 60% of the full load current of the motor.
- Magnetizing current does not contribute to the work output of motor, as its role is to provide a medium (magnetic field) required in power exchange between stator and rotor through induction principle.

An Induction motors operates at low power factor (approx pf 0.2 to 0.4) during light load or no load condition and at full load (approx pf 0.8 to 0.9). At low load or no load condition

Torque Slip Characteristics of Induction Motor



Torque Slip Curve for Three Phase Induction Motor

Motoring Mode

- In this mode of operation, supply is given to the stator sides and the motor always rotates below the synchronous speed.
- The induction motor torque varies from zero to full load torque as the slip varies.
- The slip varies from zero to one. It is zero at no load and one at standstill. From the curve it is seen that the torque is directly proportional to the slip.
- The linear relationship simplifies the calculation of motor parameter to great extent.

Generating Mode

- In this mode of operation induction motor runs above the synchronous speed and it should be driven by a prime mover.
- The stator winding is connected to a three phase supply in which it supplies electrical energy. the torque and slip both are negative so the motor receives mechanical energy and delivers electrical energy.
- Induction motor is not much used as generator because it requires reactive power for its operation.
- That is, reactive power should be supplied from outside and if it runs below the synchronous speed by any means, it consumes electrical energy rather than giving it at the output.

Braking Mode

- In the Braking mode, the two leads or the polarity of the supply voltage is changed so that the motor starts to rotate in the reverse direction and as a result the motor stops.
- This method of braking is known as plugging. This method is used when it is required to stop the motor within a very short period of time.
- The kinetic energy stored in the revolving load is dissipated as heat. Also, motor is still receiving power from the stator which is also dissipated as heat.
- So as a result of which motor develops enormous heat energy. For this stator is disconnected from the supply before motor enters the braking mode.

Torque Slip Characteristics of Single Phase Induction Motor

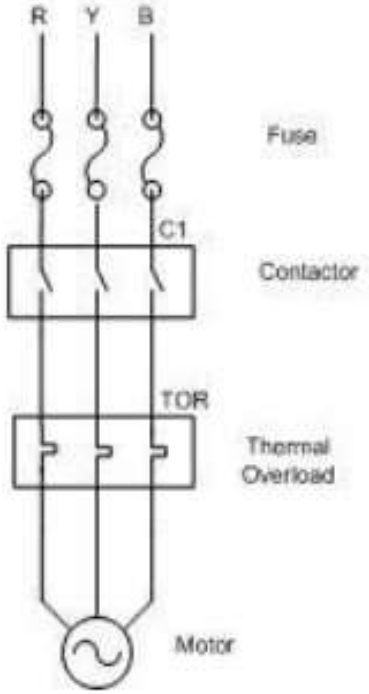
Starting methods of Induction motor

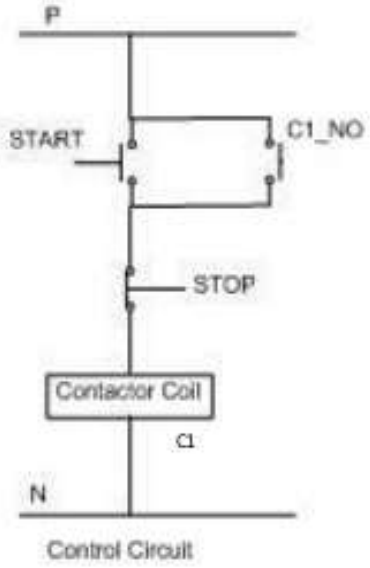
- Direct –On– line (DOL) starters for less than 10 Kw motors.
- Star–Delta starters for large motors. The stator winding is initially connected in a star configuration and later on changed over to a Delta connection, when the motor reaches rated speed.
- Auto transformer.

Direct On Line Starter

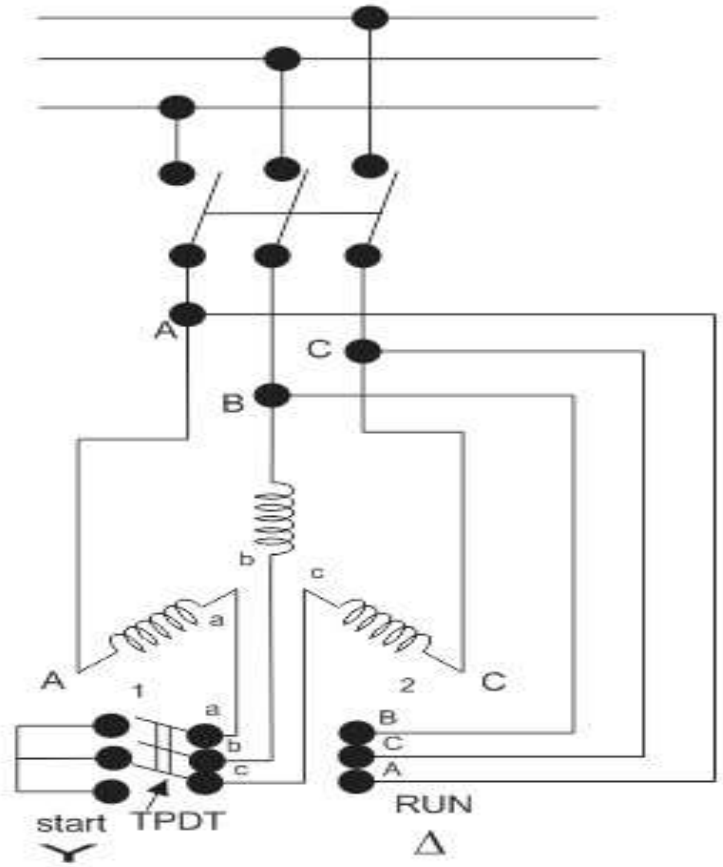
- It is simple and cheap starter for a 3-phase induction motor.
- The contacts close against spring action.
- This method is normally limited to smaller cage induction motors, because starting current can be as high as eight times the full load current of the motor
- An isolator is required to isolate the starter from the supply for maintenance.
- Protection must be provided for the motor. Some of the safety protections are over-current protection, under-voltage protection, short circuit protection, etc. Control circuit voltage is sometimes stepped down through an autotransformer.

1. Direct Online Starter(DOL Starter)





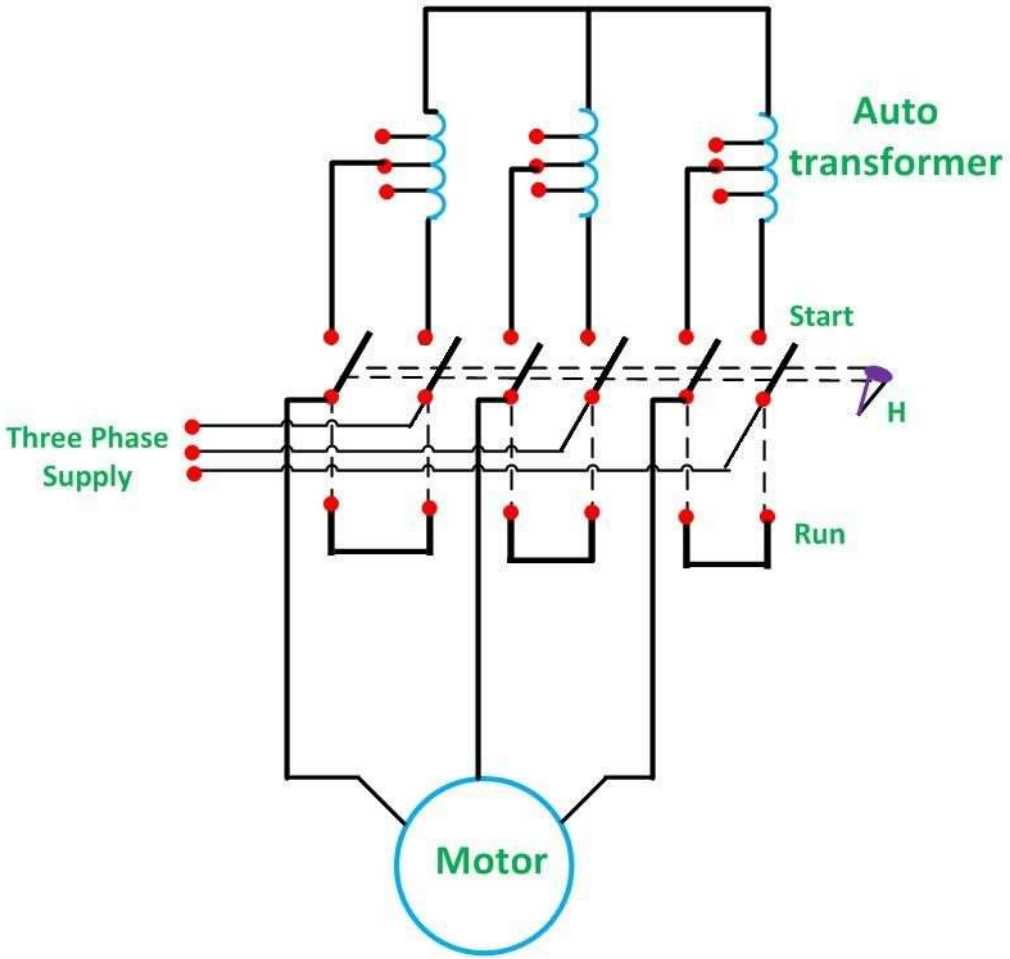
Star-Delta Starter



Star-Delta Starter

- A two-position switch (manual or automatic) is provided through a timing relay.
- Starting in star reduces the starting current.
- When the motor has accelerated up to speed and the current is reduced to its normal value, the starter is moved to run position with the windings now connected in delta.
- More complicated than the DOL starter, a motor with a star-delta starter may not produce sufficient torque to start against full load, so output is reduced in the start position. The motors are thus normally started under a light load condition.
- Switching causes a transient current which may have peak values in excess of those with DOL.

Auto Transformer Starter



Auto Transformer Starter

- Operated by a two position switch i.e. manually / automatically using a timer to change over from start to run position.
- In starting position supply is connected to stator windings through an auto-transformer which reduces applied voltage to 50, 60, and 70% of normal value depending on tapping used.
- Reduced voltage reduces current in motor windings with 50% tapping used motor current is halved and supply current will be half of the motor current. Thus starting current taken from supply will only be 25% of the taken by DOL starter.
- For an induction motor, torque T is developed by V2, thus on 50% tapping, torque at starting is only $(0.5V)^2$ of the obtained by DOL starting. Hence 25% torque is produced.
- Starters used in lager industries, it is larger in size and expensive.
- Switching from start to run positions causing transient current, which can be greater in value than those obtained by DOL starting.

Speed Control of Three Phase Induction Motor

- A three phase induction motor is basically a constant speed motor so it's somewhat difficult to control its speed. The speed control of induction motor is done at the cost of decrease in efficiency and low electrical power factor.
- the speed of three phase induction motor one should know the basic formulas of speed and torque of three phase induction motor as the methods of speed control depends upon these formulas.

Speed Control from Stator Side

V / f Control or Frequency Control

- Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

$$N_s = \frac{120f}{2p}$$

- In three phase induction motor emf is induced by induction similar to that of transformer which is given by

E or V =4.44øK.T.f

Controlling Supply Voltage

- The torque produced by running three phase induction motor is given by

$$T = K \frac{R_2' S \, V_1^{\,2}}{R_2'^{\,2} + \left(S X_2'\right)^2}$$

We know that rotor induced emf $E_2 \propto V$. So, $T \propto sV^2$.

- The speed above the normal value is not possible.
- Large speed change requires a large value of resistance, and if such large value of resistance is added in the circuit, it will cause large copper loss and hence reduction in efficiency.
- Presence of resistance causes more losses.
- This method cannot be used for squirrel cage induction motor.

Injecting Slip Frequency EMF into Rotor Side

- The speed control of three phase induction motor is done by adding resistance in rotor circuit, some part of power called, the slip power is lost as I^2R losses.
- the efficiency of three phase induction motor is reduced by this method of speed control.
- This slip power loss can be recovered and supplied back to improve the overall efficiency of the three-phase induction motor, and this scheme of recovering the power is called slip power recovery scheme and this is done by connecting an external source of emf of slip frequency to the rotor circuit.
- The injected emf can either oppose the rotor induced emf or aids the rotor induced emf.

Continued

- If it opposes the rotor induced emf, the total rotor resistance increases and hence the speed is decreased and if the injected emf aids the main rotor emf the total decreases and hence speed increases.
- Therefore by injecting induced emf in the rotor circuit, the speed can be easily controlled.
- The main advantage of this type of speed control of three phase induction motor is that a wide range of speed control is possible whether it is above normal or below normal speed.

Induction Generator

- Induction machines are sometimes used as a generator. These are known as induction generators or asynchronous generators.

An induction machine will behave as an induction generator when:

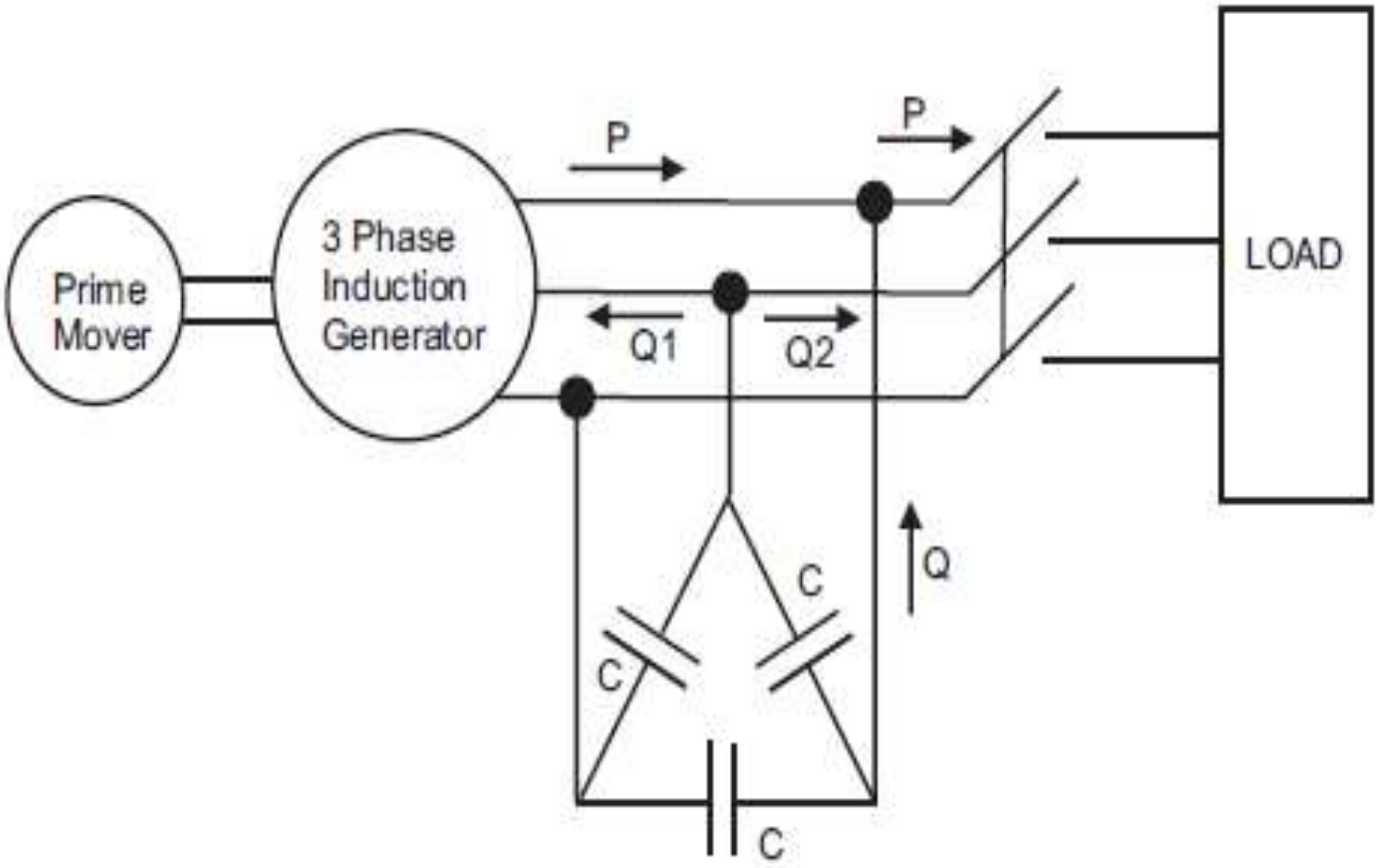
- Slip becomes negative due to this the rotor current and rotor emf attains negative value.
- The prime mover torque becomes opposite to electric torque.

- An induction generator can't work in isolation because it continuously requires reactive power from the supply system. However, we can have a self-excited or isolated induction generation if we use a capacitor bank for reactive power supply instead of an AC supply system. We'll now discuss isolated induction generators in detail.

How induction generators work

- Consider, an AC supply is connected to the stator terminals of an induction machine. Rotating magnetic field produced in the stator pulls the rotor to run behind it (the machine is acting as a motor).
- Now, if the rotor is accelerated to the synchronous speed by means of a prime mover, the slip will be zero and hence the net torque will be zero. The rotor current will become zero when the rotor is running at synchronous speed.
- If the rotor is made to rotate at a speed more than the synchronous speed, the slip becomes negative. A rotor current is generated in the opposite direction, due to the rotor conductors cutting stator magnetic field.
- This generated rotor current produces a rotating magnetic field in the rotor which pushes (forces in opposite way) onto the stator field. This causes a stator voltage which pushes current flowing out of the stator winding against the applied voltage. Thus, the machine is now working as an induction generator (asynchronous generator).

CIRCUIT DIAGRAM OF INDUCTION GENERATOR



Thank You