3-Phase Induction Motor

A *3-phase induction motor* is an electromechanical energy conversion device which converts 3-phase input electrical power into output mechanical power.

A 3-phase induction motor consists of a stator and a rotor. The stator carries a *3-phase stator winding* while the rotor carries a short-circuited winding called *rotor winding*. The stator winding is supplied from a 3-phase supply. The rotor winding drives its voltage and power from the stator winding through *electromagnetic induction* and hence the name.

Construction of **Three Phase Induction Motor**

A 3-phase induction motor has two main parts –

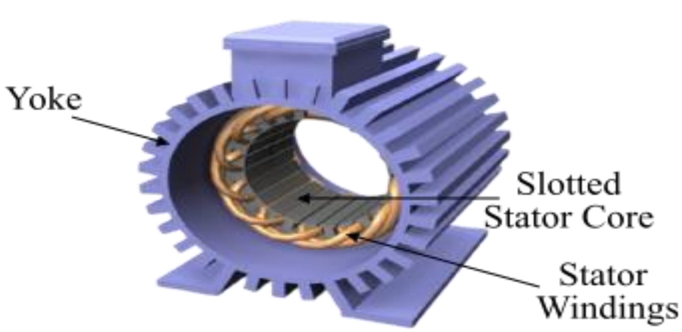
- Stator
- Rotor

The rotor and stator are separated by a small air gap ranges from 0.5 mm to 4 mm depending on the power rating of the motor.

Stator of Three Phase Induction Motor

The stator is the stationary part of the motor. It consists of a steel frame which encloses a hollow cylindrical core. The core of the three phase induction motor is made up of thin laminations of silicon steel to reduce the eddy current and hysteresis losses.

A number of equally spaced slots are provided on the inner periphery of the laminated core as shown in the figure. The insulated conductors are placed in these stator slots and are connected in a suitable manner to form a balanced 3-phase star or delta connected stator winding.



The 3-phase stator windings are wound for a definite number of poles depending upon the requirement of speed, i.e., greater the number of poles, lesser is the speed of the motor and *vice-versa*.

When a balanced 3-phase supply is fed to the stator winding a rotating magnetic field (RMF) of constant magnitude is produced and this RMF induces currents in the rotor circuit by electromagnetic induction.

Rotor of Three Phase Induction Motor

The rotor of an induction motor is a hollow cylindrical laminated core, having slots on its outer periphery. The rotor windings are placed in these rotor slots.

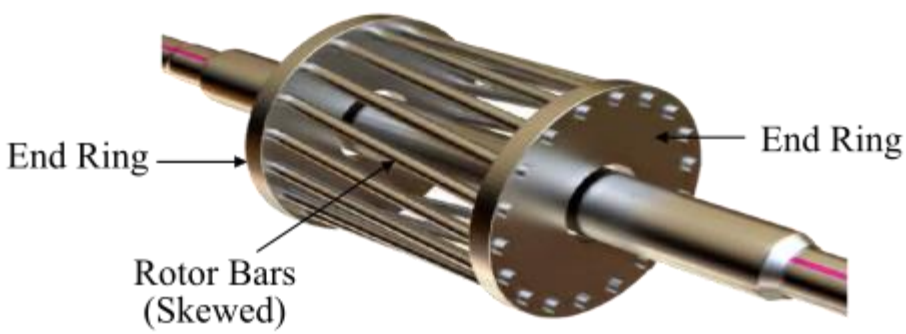
Depending upon the winding arrangement, the rotor of a 3-phase induction motor is of two types −

- Squirrel Cage Type Rotor
- Wound Type or Slip-Ring Type Rotor

Squirrel Cage Type Rotor

The squirrel cage rotor consists of a cylindrical laminated core having slots on its outer periphery which are nearly parallel to the shaft axis or *skewed*. An uninsulated copper or aluminium bar (rotor conductor) is placed in each slot.

At each end of the rotor, the rotor bar conductors are short-circuited by heavy end rings of the same material (see the figure). This forms a permanently short circuited winding which is indestructible. This entire arrangement resembles a cage which was once commonly used for keeping squirrels and hence the name.



This rotor is not connected electrically to the supply but has currents induced in it by the electromagnetic induction from the stator.

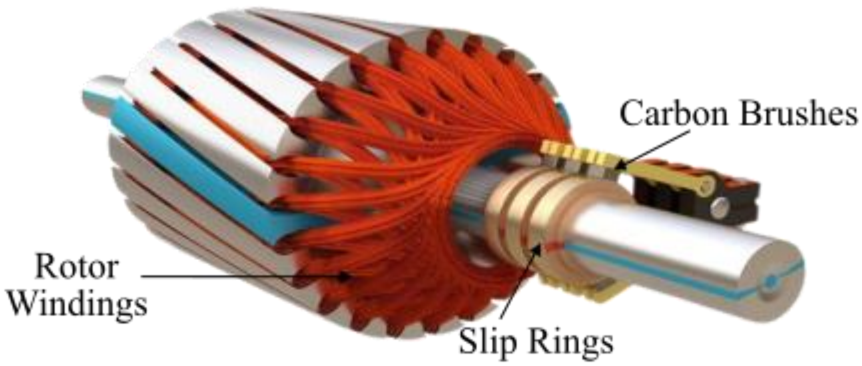
Those 3-phase induction motors which employed squirrel cage rotor are known as *squirrel cage induction motors*. Most of the 3-phase induction motors in the industries use squirrel cage rotor because it has simple and robust construction enabling it to operate in the most adverse environment. Although, it suffers from a disadvantage of low starting torque.

The *skewing* of squirrel cage rotor conductors offers following advantages −

- The noise is reduced during operation.
- More uniform torque is produced.
- The *cogging* or *magnetic* locking tendency of the rotor is reduced. During cogging, the rotor and stator teeth locked with each other due to magnetic action.

Wound Rotor or Slip Ring Rotor

The slip ring rotor consists of a laminated cylindrical armature core. The slots are provided on the outer periphery and insulated conductors are put in the slots. The rotor conductors are connected to form a 3-phase double layer distributed winding similar to the stator winding. The rotor windings are connected in star fashion (see the figure).



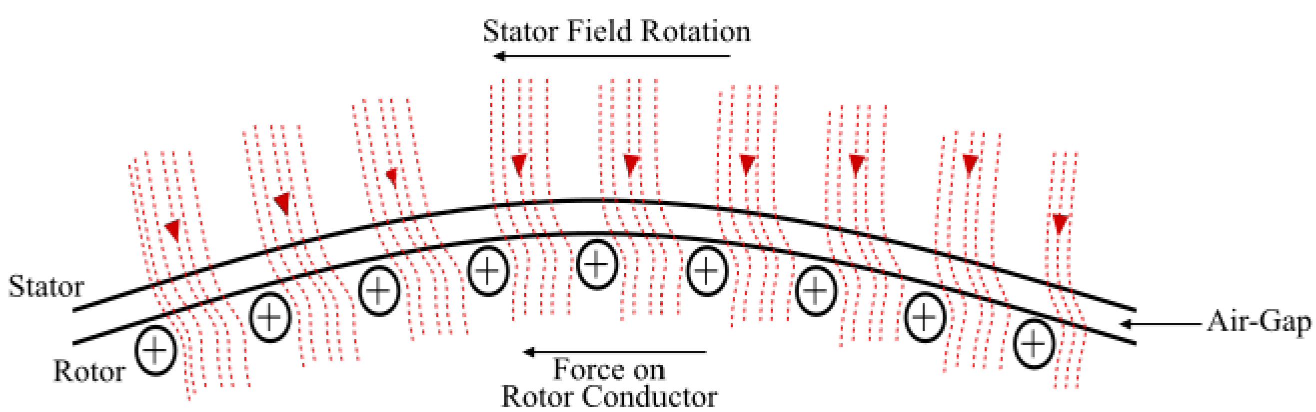
The open ends of the star circuit are taken outside the rotor and connected to three insulated slip rings. The slip rings are mounted on the rotor shaft with brushes resting on them. The brushes are connected to three variable resistors which are also connected in star. Here, the slip rings and brushes are used to provide a mean for connecting external resistors in the rotor circuit.

The external resistors enable the variation of each rotor phase resistance to serve following two purposes −

- To increase the starting torque and reduce the starting current from the supply.
- To control the speed of the motor.

Working Principle of a 3-Phase Induction Motor

The working principle of a 3-phase induction motor can be explained by considering a portion of it as follows−



- When the 3-phase stator winding is fed from a balanced 3-phase supply, a rotating magnetic field (RMF) is produced in the motor. This RMF rotates around the stator at *synchronous speed* which is given by,

SynchronousSpeed,NS=120f/P

- The RMF passes through the air gap and cuts the rotor conductors, which as yet are stationary. Due to the relative motion between the RMF and the stationary rotor conductors, EMFs are induced in the rotor conductors. As the rotor circuit is closed with short-circuit so currents start flowing in the rotor conductors.
- Since the current carrying rotor conductors are placed in the magnetic field produced by the stator winding. As a result, the rotor conductors experience mechanical force. The sum of the mechanical forces on all the rotor conductors produce a torque which moves the rotor in the same direction as the rotating magnetic field. Hence, in such a way the three phase input electric power is converted into output mechanical power in a 3-phase induction motor.
- Also, *according to Lenz's law*, the rotor should move in the direction of the stator field, i.e., the direction of rotor currents would be such that they tend to oppose the cause producing them. Here, the cause producing the rotor currents is the relative speed between the RMF and the rotor conductors. Thus to reduce this relative speed, the rotor starts running in the same direction as that of the RMF.

Advantages of Three Phase Induction Motor

Following are the chief advantages of a 3-phase induction motor −

- It has simple and rugged construction.
- It requires less maintenance.
- It has high efficiency and good power factor.
- It is less expensive.
- It has self-starting torque.

Disadvantages of Three Phase Induction Motor

The disadvantages of a 3-phase induction motor are given as follows −

- The 3-phase induction motors are constant speed motors; hence their speed control is very difficult.
- 3-phase induction motors have poor starting torque and high inrush currents (about 4 to 8 times of the rated current).
- They always operate under lagging power factor and during light loads, they operate at very worst power factor (about 0.3 to 0.5 lagging).