Three Phase Induction Motor

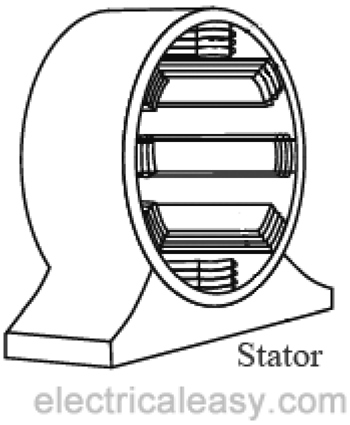
An electrical motor is an electromechanical device which converts electrical energy into mechanical energy. In the case of three phase AC (Alternating Current) operation, the most widely used motor is a **3 phase induction motor**, as this type of motor does not require an additional starting device. These types of motors are known as self-starting induction motors.
Principle: The motor which works on the principle of electromagnetic induction is known as the induction motor. The electromagnetic induction is the phenomenon in which the electromotive force induces across the electrical conductor when it is placed in a rotating magnetic field.

Construction of A 3 Phase Induction Motor

Just like any other motor, a **3-phase induction motor** also consists of a stator and a rotor. Basically, there are two types of 3 phase IM - 1. **Squirrel cage induction motor** and 2. **Phase Wound induction motor (slip-ring induction motor)**. Both types have similar constructed rotor, but they differ in construction of rotor. This is explained further.

Stator

The stator of a 3 phase IM (Induction Motor) is made up with number of stampings, and these stampings are slotted to receive the stator winding. The stator is wound with a 3-phase winding which is fed from a 3-phase supply. It is wound for a defined number of poles, and the number of poles is determined from the required speed. For greater speed, lesser number of poles is used and vice versa. When stator windings are supplied with 3 phase ac supply, they produce alternating flux which revolves with synchronous speed. The synchronous speed is inversely proportional to number of poles ($N_s = 120f / P$). This revolving or rotating magnetic flux induces current in rotor windings according to Faraday's law of mutual induction.



Rotor

The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft. The rotors of the three phase induction motor are further classified as:

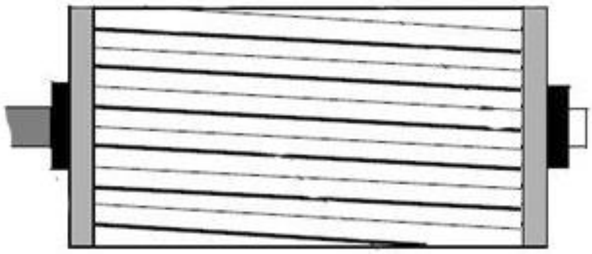
1. Squirrel Cage Rotor
2. Slip Ring Rotor or Wound Rotor or Phase Wound Rotor

Depending upon the type of rotor used the three-phase induction motor is classified as:

1. Squirrel Cage Induction Motor
2. Slip Ring Induction Motor or Wound Rotor Induction Motor or Phase Wound Induction Motor

As described earlier, **rotor of a 3-phase induction motor** can be of either two types, **squirrel cage rotor** and **phase wound rotor** (or simply - wound rotor).

Squirrel Cage Rotor



Squirrel Cage Rotor

electricaleasy.com

Most of the induction motors (up to 90%) are of squirrel cage type. **Squirrel cage type rotor** has very simple and almost indestructible construction. This type of rotor consists of a cylindrical laminated core, having parallel slots on it. These parallel slots carry rotor conductors. In this type of rotor, heavy bars of copper, aluminium or alloys are used as rotor conductors instead of wires. Rotor slots are slightly skewed to achieve following advantages -

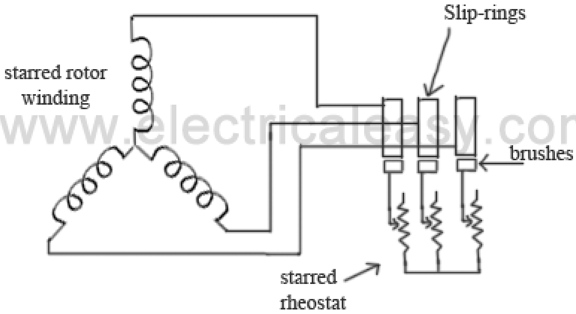
1. it reduces locking tendency of the rotor, i.e. the tendency of rotor teeth to remain under stator teeth due to magnetic attraction.

2. increases the effective transformation ratio between stator and rotor

3. increases rotor resistance due to increased length of the rotor conductor

The rotor bars are brazed or electrically welded to short circuiting end rings at both ends. Thus, this rotor construction looks like a squirrel cage and hence we call it. The rotor bars are permanently short circuited; hence it is not possible to add any external resistance to armature circuit.

Phase Wound Rotor



Phase wound rotor connections

Phase wound rotor is wound with 3 phase, double layer, distributed winding. The number of poles of rotor are kept same to the number of poles of the stator. The rotor is always wound 3 phases even if the stator is wound two phases.
The three-phase rotor winding is internally star connected. The other three terminals of the winding are taken out via three insulated sleep rings mounted on the shaft and the brushes resting on them. These three brushes are connected to an external star connected rheostat. This arrangement is done to introduce

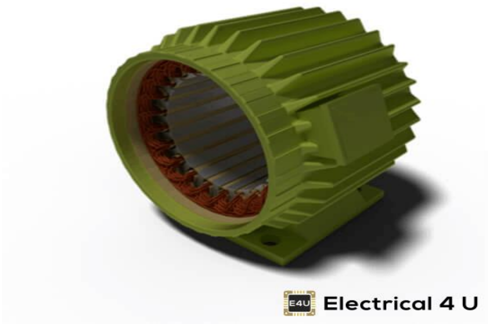
an external resistance in rotor circuit for starting purposes and for changing the speed / torque characteristics.
When motor is running at its rated speed, slip rings are automatically short circuited by means of a metal collar and brushes are lifted above the slip rings to minimize the frictional losses.

To get a good understanding of the working principle of a three-phase induction motor, it’s essential to understand how these motors are constructed. A 3-phase induction motor consists of two major parts:

- A stator
- A rotor

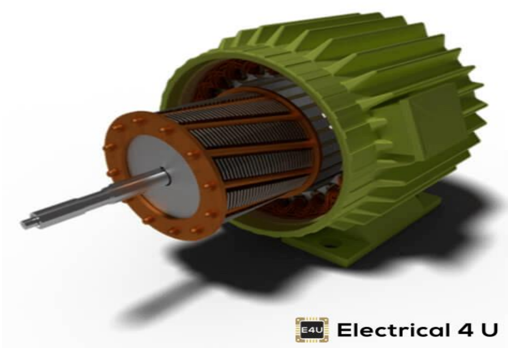
Stator of 3 Phase Induction Motor

The **stator** of three phase induction motor is made up of numbers of slots to construct a 3-phase winding circuit which we connect with 3 phase AC source. We arrange the three-phase winding in such a manner in the slots that they produce one rotating magnetic field when we switch on the three-phase AC supply source.



Rotor of 3 Phase Induction Motor

The **rotor** of three phase induction motor consists of a cylindrical laminated core with parallel slots that can carry conductors. The conductors are heavy copper or aluminium bars fitted in each slot and short-circuited by the end rings. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed because this arrangement reduces magnetic humming noise and can avoid stalling of the motor.



Working of Three Phase Induction Motor

Production of Rotating Magnetic Field

The stator of the motor consists of overlapping winding offset by an electrical angle of 120°. When we connect the primary winding, or the stator to a 3 phase AC source, it establishes rotating magnetic field which rotates at the synchronous speed.

Secrets Behind the Rotation:

According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit. As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, an emf is induced in the rotor copper bar and due to this emf a current flows through the rotor conductor.

Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation; hence as per Lenz's law, the rotor will rotate in the same direction to reduce the cause, i.e., the relative velocity.

Thus, from the **working principle of three phase induction motor**, it may be observed that the rotor speed should not reach the synchronous speed produced by the stator. If the speeds become equal, there would be no such relative speed, so no emf induced in the rotor, and no current would be flowing, and therefore no torque would be generated. Consequently, the rotor cannot reach the synchronous speed. The difference between the stator (synchronous speed) and rotor speeds is called the slip. The rotation of the magnetic field in an induction motor has the advantage that no electrical connections need to be made to the rotor.

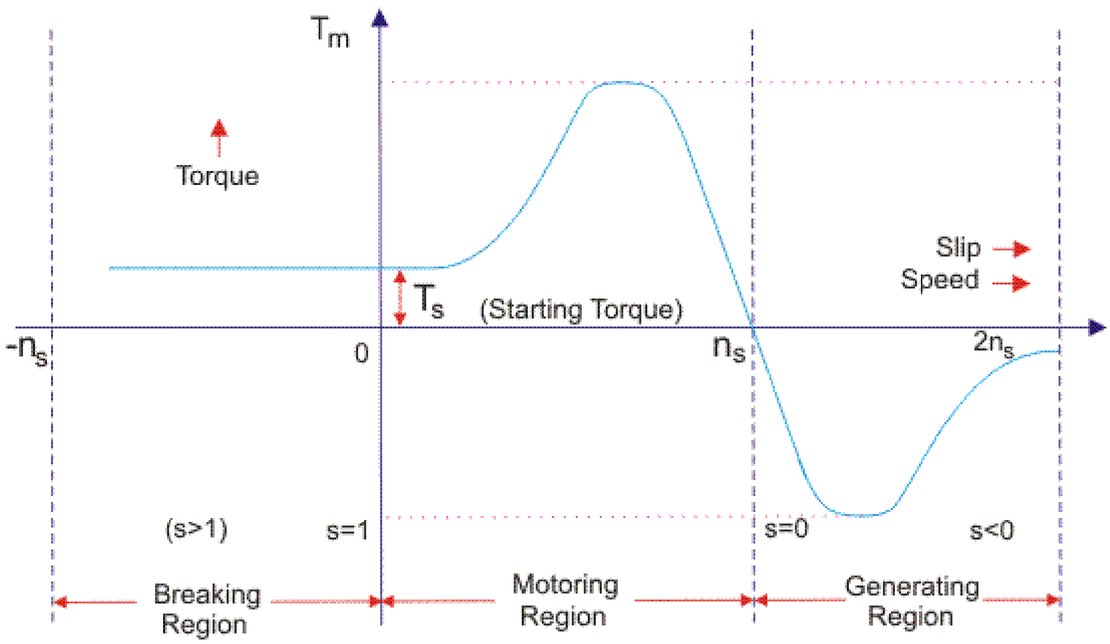
Thus, the **three-phase induction motor** is:

- Self-starting.
- Less armature reaction and brush sparking because of the absence of commutators and brushes that may cause sparks.
- Robust in construction.
- Economical.
- Easier to maintain.

Torque-Slip Characteristic

The torque slip curve for an induction motor gives us the information about the variation of torque with the slip. The slip is defined as the ratio of difference of synchronous speed and actual rotor speed to the synchronous speed of the machine. The variation of slip can be obtained with the variation of speed that is when speed varies the slip will also vary and the torque corresponding to that speed will also vary.

The curve can be described in three modes of operation-



Torque Slip Curve for Three Phase Induction Motor

The torque-slip characteristic curve can be divided roughly into three regions:

- Low slip region
- Medium slip region
- High slip region

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. That is, more is the slip, more will be the torque produced and vice-versa. 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. Actually, in this case, 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. So, as far as possible, induction generators are generally avoided.

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.

If load which the motor drives accelerates the motor in the same direction as the motor is rotating, the speed of the motor may increase more than synchronous speed. In this case, it acts as an induction generator which supplies electrical energy to the mains which tends to slow down the motor to its synchronous speed, in this case the motor stops. This type of breaking principle is called dynamic or regenerative breaking.

Applications of Three Phase Induction Motor

- Lifts
- Cranes
- Hoists
- Large capacity exhaust fans
- Driving lathe machines
- Crushers
- Oil extracting mills
- Textile etc.

Advantages

- They have very simple and rugged (almost unbreakable) construction
- they are very reliable and having low cost
- they have high efficiency and good power factor
- minimum maintenance required
- **3 phase induction motor is self-starting** hence extra starting motor, or any special starting arrangement is not required

Disadvantages

- speed decreases with increase in load, just like a DC shunt motor
- if speed is to be varied, we have sacrifice some of its efficiency