THREE PHASE INDUCTION MOTOR

Introduction:

The most common type of a.c. motor being used for various industrial applications are the induction motors. Three phase induction motors are widely used for industrial applications such as lifts, cranes, pumps, lathes, exhaust fans etc.
It has following main advantages:

- Very simple and rugged construction
- Low cost
- It has sufficiently high efficiency and reasonably good power factor
- Minimum maintenance, very reliable
- Self starting

Construction:

An induction motor consists essentially of two parts:

1. **Stator**
2. **Rotor**

The rotor is placed inside the stator and is supported on both sides by two-end shields. Energy is supplied to the windings through electromagnetic Induction and hence such machines are called induction motors.

1. Stator

As the name suggests, it is a stationary part of the motor. Stator consists of three phase windings, which are placed in the slots of a laminated steel core which is enclosed and supported by a cast iron or steel frame as shown in figure 1. It is wound for definite number of poles. These windings are insulated from each other and separated in space by 120^0 electrical. These windings are either connected permanently in star or in delta internally or all the six terminals are brought out to the terminal box. The operator can connect the machine in star or delta as per requirement. When the stator is enegised from a three phase supply it produces a rotating magnetic field in the stator core.

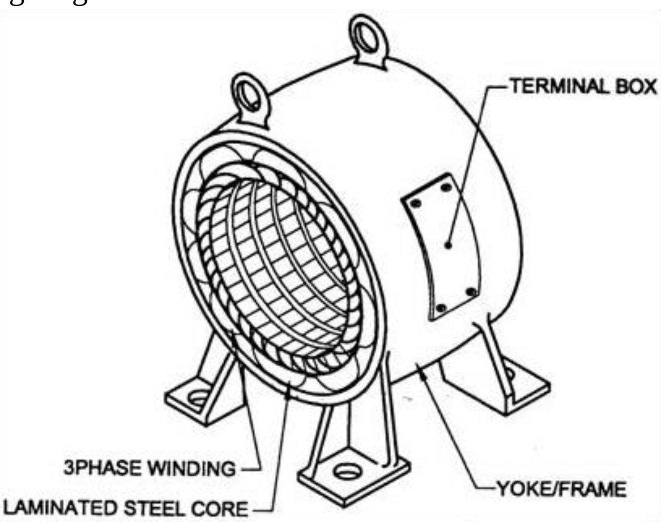

Figure 1: Stator

2. Rotor

Induction motors are classified according to the rotor they have. There are two types of Rotors -

a) **Squirrel cage rotor**
b) **Slip ring or Phase wound rotor**

a) Squirrel cage rotor:

Almost 90% of induction motors are squirrel cage type because of its simple and most rugged construction. It consists of cylindrical laminated core with number of parallel slots as shown in figure 2. One rotor bar is placed in each slot. Rotor conductors are heavy bars of copper, aluminum or alloys and all the bars are permanently short-circuited by two end rings. This gives us a Squirrel cage like construction. As the rotor conductors are permanently short circuited, it is not possible to add an external resistance in the rotor circuit.
The rotor slots are skewed at a certain angle. This is useful in two ways.

1. It helps to reduce magnetic noise (hum)
2. It helps in reducing the locking tendency of the rotor with the stator.

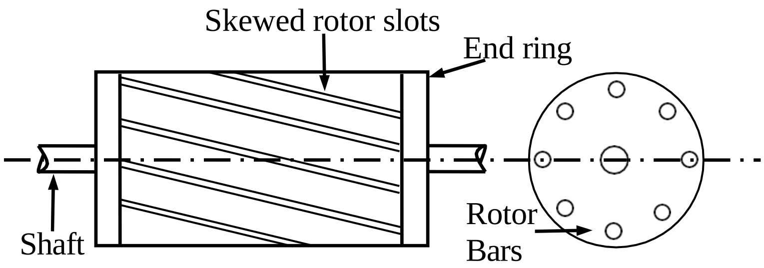

Figure 2: Squirrel cage rotor

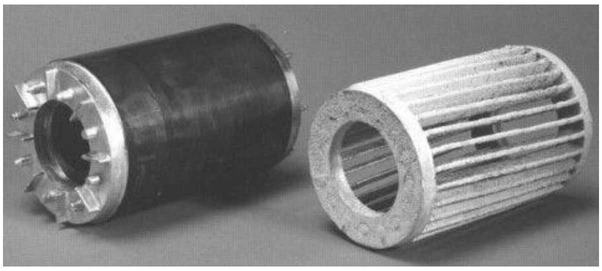

Figure 3: Photographic view of Squirrel cage type rotor

b) Slip ring or Phase wound rotor:

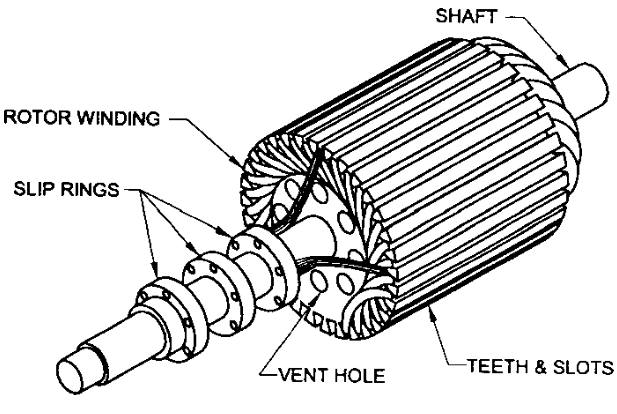

Figure 4: Slip-ring or phase wound type rotor

In this type, the rotor winding is made on the insulated rotor slots with copper conductors similar to the stator winding as shown in figure 4. The rotor is wound for the same number of poles as that of the stator. The windings are internally connected in star. The other three winding terminals are brought out and connected to three insulated slip rings mounted on the

shaft with brushes resting on them. Additional resistance can be inserted in the rotor circuit for increasing starting torque of the motor as shown in figure 5.
When running under normal conditions, the slip rings are short circuited by a metal collar and the brushes are lifted from the slip-rings to reduce the frictional losses and wear.

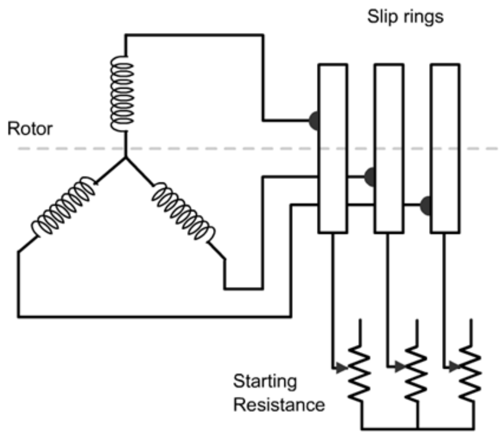

Figure 5: Circuit for slip-ring type rotor

The graphic shown in figure 6 shows the structural details of an induction motor. It consists of -

1. Frame
2. Stator and rotor core
3. Stator windings.
4. Shafts and Bearings.
6. Fan

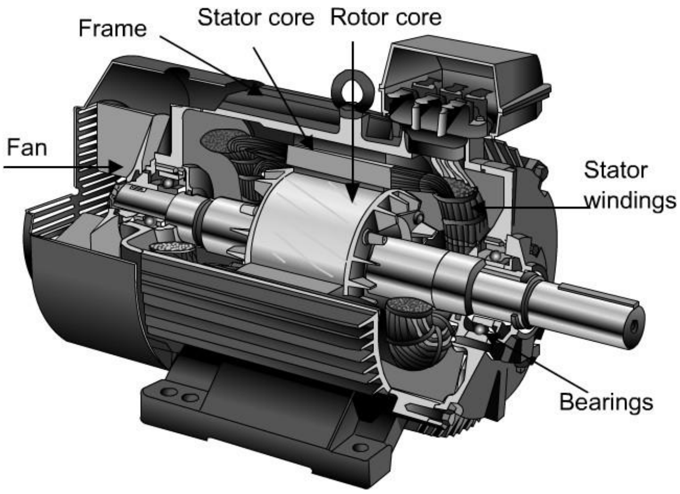

Figure 6: Structural details of an induction motor

Synchronous speed N_s:

When the stator is connected to a three-phase supply, a rotating magnetic field of constant magnitude is produced. The speed at which the stator magnetic field rotates is known as synchronous speed Ns. It is given by $\boxed{N_s = \frac{120 f}{P}}$

Where

f = Supply frequency in H_z and

P = the number of stator poles.

Working Principle of a three phase induction motor:

When the stator is connected to 3 phase supply, a rotating magnetic field of constant magnitude is produced. Let us assume that the stator field is rotating clockwise. Initially the rotor is stationary. Thus, the relative motion of the rotor with respect to the stator is anticlockwise as shown in figure 10(a). Due to this relative motion an e.m.f. is induced in rotor conductors according to Faraday's laws of electromagnetic induction. The direction of induced e.m.f. is given by Fleming's Right-hand rule. It is found to be outwards as shown in figure 10(b). It is the case of current carrying conductor placed in the magnetic field. So each conductor will experience a mechanical force. The direction of force can be determined by applying Fleming's left-hand rule. It is found that the rotor conductors experience a force tending to rotate them in the same direction as that of stator flux as shown in figure 10(c).

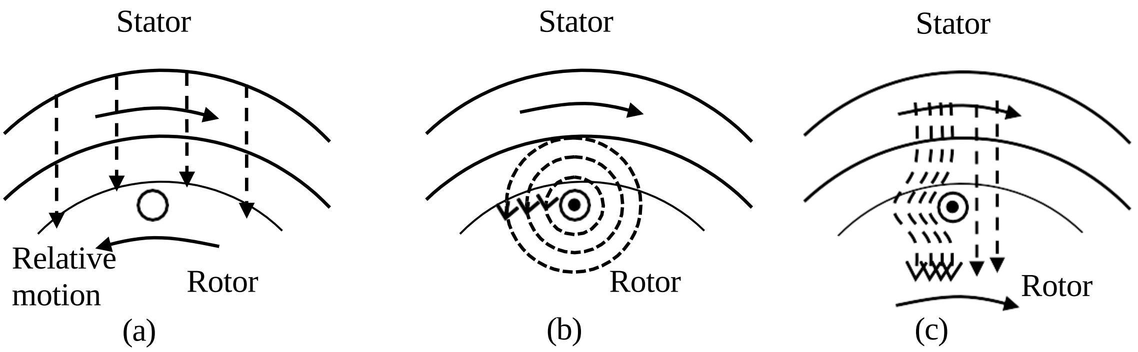

Figure 10: Working principle of three phase induction motor

This principle of operation can also be explained by Lenz's law. According to Lenz's law the direction of induced current is such that it opposes the cause producing it. Here the cause for induced current is the relative speed between rotor and stator field. Hence to reduce the relative speed, the rotor starts to rotate in the same direction as that of the stator flux.

Slip (s):

In practice, the rotor speed N is always less than synchronous speed Ns. If N = N_s then the relative speed will be zero. Hence no rotor emf, no rotor current and so no torque to maintain rotation. Thus N is always less than N_s. The difference in speeds (N_s – N) is known as slip speed.

The difference between the synchronous speed Ns and the actual speed N of the rotor is known as slip (s). It is expressed as % of Ns. Thus

$$\boxed{\%\text{ slip } s = \frac{N_s - N}{N_s} \times 100}$$