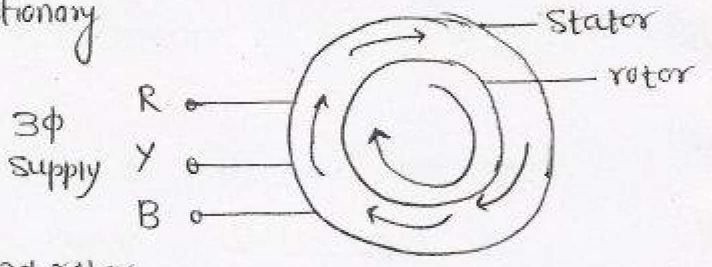
# Principle of operation of 3$\phi$ Induction Motor:—

— 3$\phi$ IM Consists of a Stator/armature winding which is Stationary and a rotor or field winding which rotates.




— Both the Stator and rotor windings are 3$\phi$ windings.

Figure 1

Depending on the rotor winding, the induction motors are Classified into two categories:

(1) Slip ring or wound rotor motor

(2) Squirrel Cage rotor motor

— The 3$\phi$ Stator winding of IM is Connected to the 3$\phi$ ac supply as Shown in figure 1.

— Due to a.c. voltage applied, Current starts flowing in the stator Conductors.

— Due to the 3$\phi$ stator current a rotating magnetic field of constant amplitude and rotating at a Constant speed is setup in the air gap between Stator and rotor.

— The rotating magnetic field rotates at a speed called as synchronous speed. ($N_s$)

$$N_s = \frac{120f}{P}$$

f - Stator Supply frequency

P - No. of poles

## Frequency of rotor voltage and current :-

The frequency of current and voltage in the Stator must be same as the supply frequency is given by

$$f = \frac{PN_s}{120} \quad -(1) \quad \left( \because N_s = \frac{120f}{P} \right)$$

The frequency in the rotor winding is variable and depends on the difference between the synchronous speed and the rotor speed. Hence the rotor frequency depends upon slip.

The rotor frequency is given by

$$f_r = \frac{P(N_s - N_r)}{120} \quad -(2)$$

Divide eqn (2) by (1)

$$\frac{f_r}{f} = \frac{N_s - N_r}{N_s}$$

$$\frac{f_r}{f} = S \quad \left( \because S = \frac{N_s - N_r}{N_s} \right)$$

$$\Rightarrow \boxed{f_r = Sf}$$

i.e. rotor current frequency = Slip * supply freq

Qus) A 3φ, 6 pole, 50Hz, IM has a Slip of 1% at no load, and 3% at full load. Determine (i) synchronous speed (ii) no load speed (iii) frequency of rotor current at full load speed (iv) frequency of rotor current at full Standstill (v) frequency of rotor current at full load.

$N_s = \frac{120f}{P} = 1000 rpm$ $\quad N_0 = N_s(1 - S_0) = 990 rpm$

$N_{fl} = N_s(1 - S_{fl}) = 970 rpm \cdot f_r = Sf = 50Hz, \; f_r' = S_{fl}f =$

The rotor winding is still stationary. So the rotating magnetic field cuts the stationary rotor conductors and induces an emf in the rotor winding.

- The rotor induced voltage gives rise to rotor current. The direction of rotor current is such that it will oppose the very cause that produces the current. And the cause behind ~~the~~ producing the rotor current is the relative velocity b/w the rotating field and the rotor.
- So the rotor current will flow in such a direction that the rotor will experience a force that accelerates it in the same direction as that of rotating magnetic field as shown in figure 1.
- At no load ideally, the rotor should rotate at the same speed as that of rotating magnetic field i.e. $N_s$. But practically it rotates at slightly less speed than $N_s$ due to friction and windage.
- Let us consider for a moment that if rotor is rotating at synchronous speed. Under this condition, there would be cutting of flux by the rotor conductors, and there would be no generated voltage and hence no torque. The rotor speed is slightly less than the synchronous speed.
- When the IM is loaded mechanically, its speed (N) decreases to produce the required amount of torque.

The reduction in the motor speed (N) will stop as the torque produced by the motor (T) is exactly equal to the load torque ($T_L$). The percentage difference b/w synchronous speed ($N_s$) and actual speed ($N_r$) is known as slip.

$$S = \frac{N_s - N_r}{N_s}$$

However, the difference between the synchronous speed and the actual rotor speed is called the slip speed.

Slip speed – expressed the speed of rotor relative to the field.

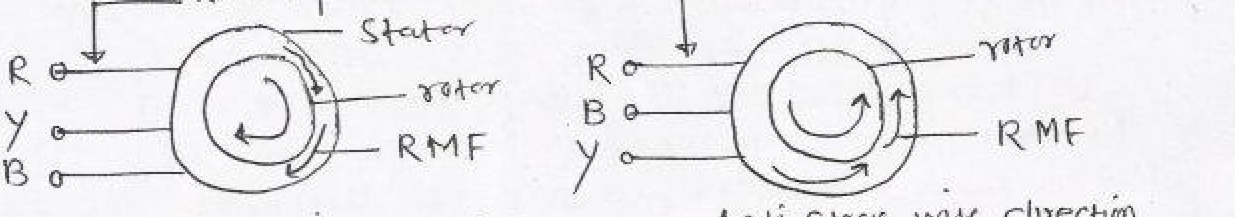
Slip speed $= N_s - N_r$

The slip at full load varies from about 5% for small motor to about 2% for large motors.

— Direction of rotation:—

As rotor always rotates in the same direction as that of the rotating magnetic field, the only way to reverse the direction of rotation of motor is to reverse the direction of rotating field.

– To do so the phase sequence has to be changed by interchanging any two phases as shown in fig 2(b).




Clock wise rotation
Fig 2(a)

Anti clock wise direction