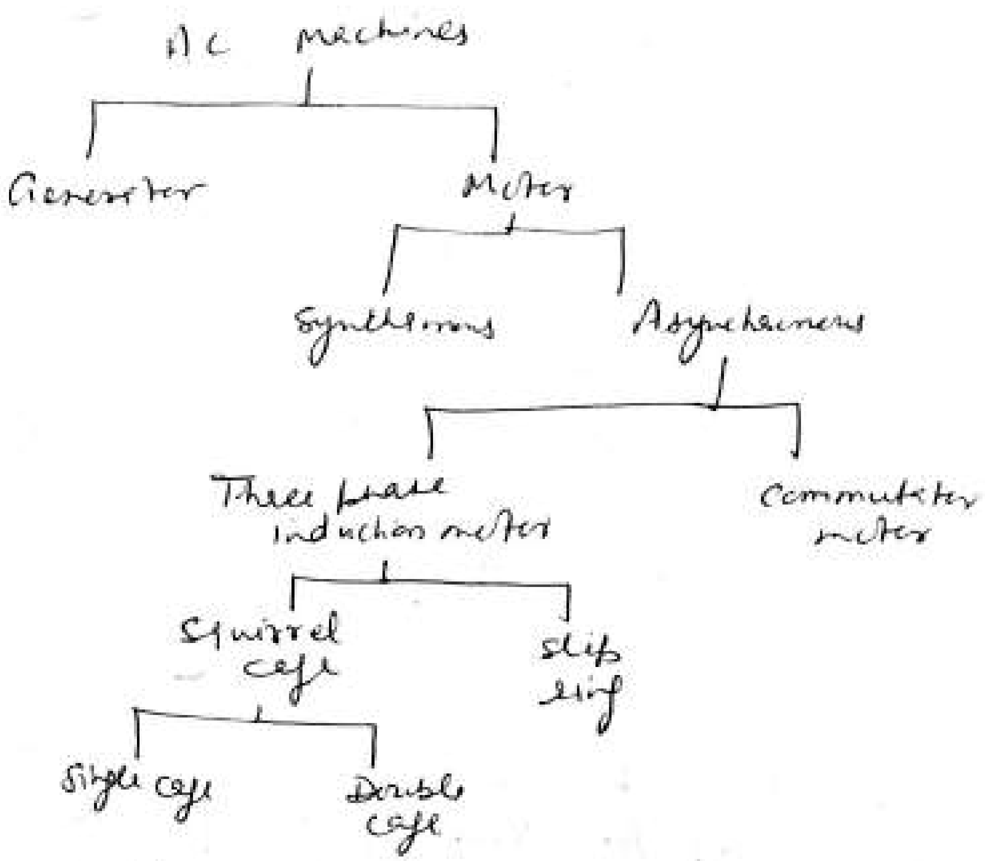
3 phase Induction motor



Three phase induction motor

Three phase induction motor is the most popular type of a.c motor. It is very commonly used for industrial drives since it is cheap, ~~rug~~ robust, efficient and reliable. It has good speed regulation and high starting torque. It require little maintenance. It has a reasonable overload capacity.

__Construction__ :- A three phase induction motor essentially consists of two parts: the __stator__ and the __rotor__.

__Stator__ :- The stator is the stationary part. The stator is built up of high grade alloy steel lamination to reduce eddy current losses. The lamination are slotted ~~on~~ on the inner periphery and are insulated from each other. These lamina are supported in a stator frame of cast iron or fabricated steel plate.

The insulated stator conductor are placed in these slots. The stator conductor are connected to form a three phase windings. The phase winding may be either star or delta connect. The stator winding are also known as primary windings.

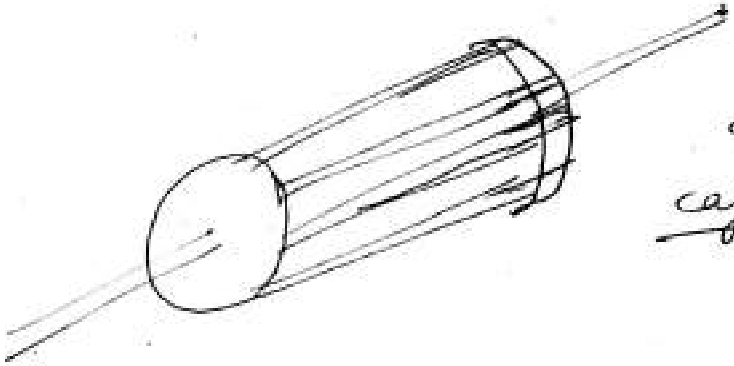
Rotor - The rotor is also built up of thin laminations of the same material as stator. The laminated core is mounted directly on the shaft. These lamination are slotted on their outer periphery to receive the rotor conductors. There are two type of induction motor rotor.

(1) squirrel cage rotor

(2) phase wound or wound rotor. Motor using this type of rotor are also called slip ring motor.

(1) cage rotor :- ~~It consists of a~~ Almost 90% of the induction motor are provided with squirrel cage rotor because of its simple construction. It consists of a cylindrical laminated core with slots nearly parallel to shaft axis. At each end of the rotor, the rotor bar conductors are short circuited by heavy end rings of the same material.

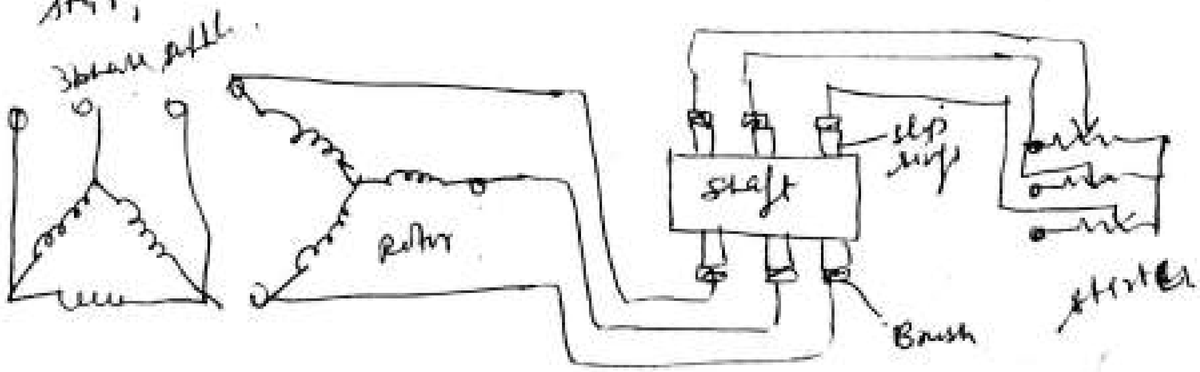
The conductor and the end rings form a cage of the type which was once commonly used for keeping squirrels, hence its name, as shown



~~cage rotor~~

cage Rotor

__wound rotor ~~of~~ or slip ring motor:-__ The wound rotor consists of slotted armature. Insulated conductors are put ~~on~~ in the slots and connected to form a three phase ~~double layer~~ winding similar to the stator windings. The ~~rotor~~ winding are connected in star. The open end of the star are brought out side the rotor and connected to three insulated slip rings. The slip rings are mounted on the shaft with brushes resting on them. The brushes are connected to three variable resister connected in ~~star~~ star,



slip ring Induction Motor

Induction Motor – general Principal

As a general rule, conversion of electric power in to mechanical power takes place in the rotating part of an electric motor.

In dc motor, the electric power is conducted directly to the armature (i.e rotating part) through brushes and commutator. Hence in this sense, a d.c motor can be called a conduction motor.

However in a.c motor, the rotor does not receive electric power by conduction but by induction in exactly the same way as the secondary of a two winding transformer receives its power from the primary. That is why such motors are called induction motor.

In fact, an induction motor can be treated as a rotating transformer i.e one in which primary winding is stationary but the secondary is free to rotate.

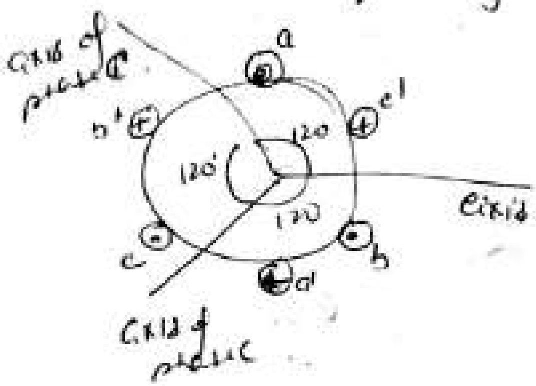
Production of Rotating field → when 3 phase winding displaced in space by 120° are supplied by 3 phase currents displaced in time by 120°, a magnetic flux is produced which rotate in space

Production of Rotating field :-

Now we will show that when stationary coil wound for two or three phases are supplied by ~~two or~~ three phase supply a uniform rotating magnetic flux of constant value is produced.

Analytical method:

consider three identical coils located on ~~axis~~ axis physically at 120° in space. let each coil be supplied from one phase of a balanced 3 phase supply. Each coil will produce an alternating flux along its own axis (whenever a ~~curr~~ conductor carrying current it establishes its ~~own~~ own magnetic flux)



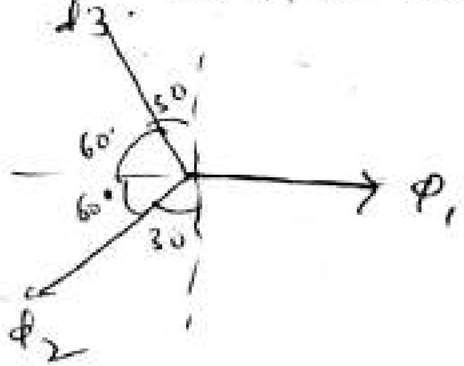
let the instantaneous fluxes be given by.

$$\phi_1 = \phi_m \sin\omega t$$

$$\phi_2 = \phi_m \sin(\omega t - 120)$$

$$\phi_3 = \phi_m \sin(\omega t + 120) \text{ or } \phi_m \sin(\omega t - 240).$$

The resultant flux produced by this system may be determined by resolving the components w.r. to the physical axes as shown in fig.



The resultant horizontal component of flux is given by

$$\phi_h = \phi_1 - \phi_2 \cos 60^\circ - \phi_3 \cos 60^\circ$$

$$= \phi_1 - (\phi_2 + \phi_3) \cos 60^\circ$$

$$= \phi_1 - \frac{1}{2}(\phi_2 + \phi_3)$$

$$= \phi_m \sin\omega t - \frac{1}{2}\left[\phi_m \sin(\omega t - 120^\circ) + \phi_m \sin(\omega t + 120^\circ)\right]$$

$$= \phi_m \sin\omega t - \frac{\phi_m}{2}\left[\sin\omega t \cos 120^\circ - \sin 120^\circ \cos\omega t + \sin\omega t \cos 120^\circ + \cos\omega t \sin 120^\circ\right]$$

$$= \phi_m \sin\omega t - \frac{\phi_m}{2}\left(\sin\omega t\left(\frac{-1}{2}\right) - \frac{\sqrt{3}}{2}\cos\omega t + \sin\omega t\left(-\frac{1}{2}\right) + \cos\omega t \frac{\sqrt{3}}{2}\right)$$

$$\left[\cos 60^\circ = \frac{1}{2},\ \cos 120^\circ = -\frac{1}{2}\right]$$

$$= \phi_m \sin\omega t - \frac{\phi_m}{2} \times 2\sin\omega t\left(-\frac{1}{2}\right)$$

$$\phi_n = \phi_m \sin\omega t + \frac{1}{2}\phi_m \sin\omega t = \frac{3}{2}\phi_m \sin\omega t.$$

Similarly the resultant vertical component of flux is given by

$$\phi_v = 0 - \phi_2 \cos 30^\circ + \phi_3 \cos 30^\circ$$

$$= \cos 30^\circ\left[-\phi_2 + \phi_3\right]$$

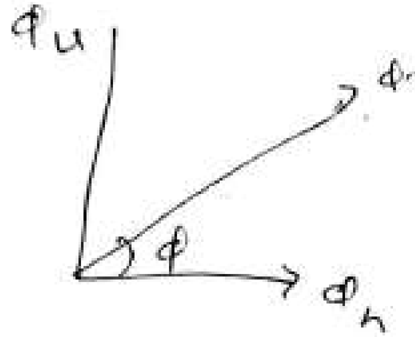
$$= \cos 30^\circ\left[-\phi_m \sin(\omega t - 120^\circ) + \phi_m \sin(\omega t + 120^\circ)\right]$$

$$= \frac{\sqrt{3}}{2}\phi_m\left[-(\sin\omega t \cos 120^\circ - \cos\omega t \sin 120^\circ) + \sin\omega t \cos 120^\circ + \cos\omega t \sin 120^\circ\right]$$

$$= \frac{\sqrt{3}}{2}\phi_m\left[-\sin\omega t \cos 120^\circ + \cos\omega t \sin 120^\circ + \sin\omega t \cos 120^\circ + \cos\omega t \sin 120^\circ\right]$$

$$= \frac{\sqrt{3}}{2}\phi_m\left[2\cos\omega t \frac{\sqrt{3}}{2}\right] \qquad \left[\sin 120^\circ = \frac{\sqrt{3}}{2}\right]$$

$$= \frac{3}{2}\phi_m \cos\omega t$$



— fig ①

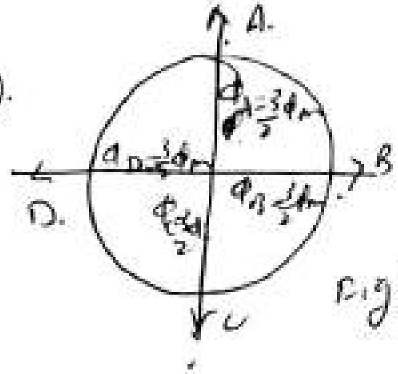


fig ②

The resultant flux

$$\phi_r = \sqrt{\phi_n^2 + \phi_u^2} = \sqrt{\left(\frac{3}{2}\phi_m \sin\omega t\right)^2 + \left(\frac{3}{2}\phi_m \cos\omega t\right)^2}$$

$$= \frac{3}{2}\phi_m \sqrt{\sin^2\omega t + \cos^2\omega t} = \frac{3}{2}\phi_m$$

$$\phi_r = \frac{3}{2}\phi_m \quad \text{— ①}$$

eqn ① shows that resultant flux is independent of time. It is a constant flux of magnitude equal to $\frac{3}{2}$ times the maximum flux per phase.

Also from fig ①

$$\tan\theta = \frac{\phi_u}{\phi_n} = \frac{\frac{3}{2}\phi_m \cos\omega t}{\frac{3}{2}\phi_m \sin\omega t}$$

$$= \frac{\cos\omega t}{\sin\omega t} = \cot\omega t = \tan\left(\frac{\pi}{2} - \omega t\right)$$

$$\theta = \frac{\pi}{2} - \omega t \quad \text{— ②}$$

eqn ② shows that angle θ is dependent on time.

From eqn ② $\theta = 90 - \omega t$.

(a) At $\omega t = 0°$, $\theta = 90°$ corresponding to position A in fig ②

(b) At $\omega t = 90°$, $\theta = 0$ corresponding to position B

(c) At $\omega t = 180°$, $\theta = -90°$ corresponding to position C.

(d) At $\omega t = 270°$, $\theta = -180°$ corresponding to position D.

It is seen that the resultant flux rotates in space in the clockwise dirn with angular velocity of ω radian per second.

Hence we conclude that-

1. the resultant flux is of constant value $= \frac{3}{2}\phi_m$ ie 1.5 times the max value of the flux due to any phase

2. The resultant flux rotates around the stator at synchronous speed given by $N_S = \frac{120f}{P}$ where f is the supply freq. and P is the no of poles on the stator.

Principal of operation: (why Rotor Rotate)

When the stator or primary winding of 3 phase induction motor is connected to 3 phase supply, a rotating field is established which rotate at synchronous speed, The dirn. of rotation of this field will depend upon the phase sequence of the primary currents and therefore will depend upon the order of connection of the primary terminals to the supply. The speed at which the field produced by the primary currents will revolve is called the synchronous speed of the motor. and is given by expression

$$N_S = \frac{120f}{P}$$ where f is the supply freq and P is the no. of poles on stator.

The revolving magnetic field produced by the primary current sweeps across the rotor conductor and thereby induces emf in these conductor, Since the rotor winding is either directly shorted or closed through some external resistance, the emf induced in secondary by a revolving field causes a current to flow in rotor conductors

The setting up of torque causing the rotor to rotate.