W01

AC Synchronous Motor

Motor Structure

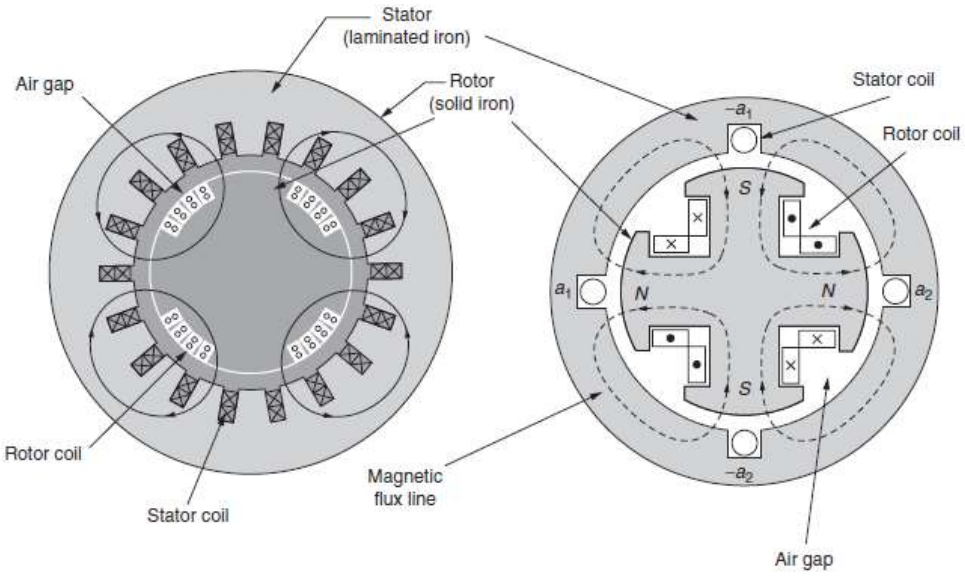
Rotor and Stator Windings

Definition

Synchronous Motors – Convert electrical power into mechanical power. They operate at a constant speed

Construction of Sychronous Motors

like any other motor, it consists of a stator and a rotor.



Cylindirical Rotor | Salient Rotor

DC supply is given to the rotor winding via slip-rings. The direct current excites the rotor winding and creates electromagnetic poles. In some cases permanent magnets can also be used.

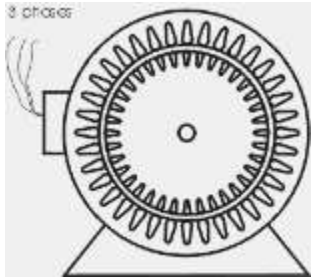
Stator Configuration

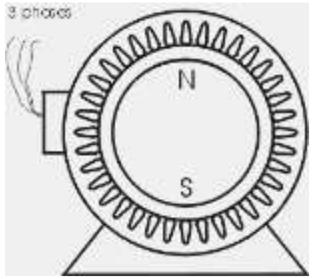
The stator core is constructed with thin silicon lamination and insulated by a surface coating, to minimize the losses.

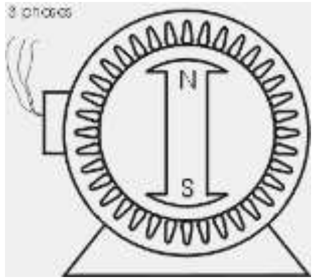
The stator has axial slots inside, in which three phase stator winding is placed.

The stator is wound with a three phase winding for a specific number of poles equal to the rotor poles.

Rotors rotate to align themselves with opposite stator poles







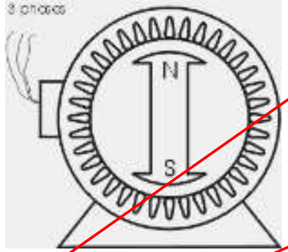
For rotation magnetic poles in stator coils should rotate

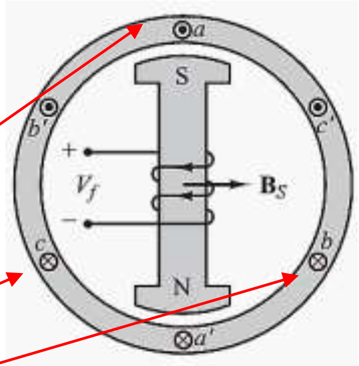
Working Of Synchronous Motor

Rotating magnetic field

Stator Supply

The stator is wound for the similar number of poles as that of rotor, and fed with three phase AC supply. The 3 phase AC supply produces rotating magnetic field in stator.

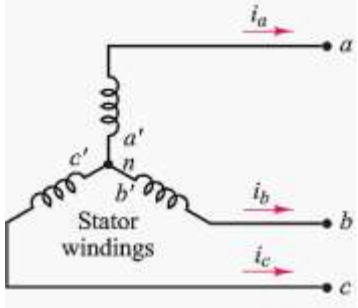




Generation of a rotating magnetic field

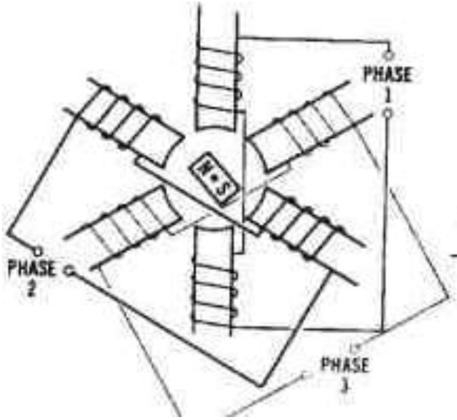
Generation of a rotating magnetic field causes the rotor to turn at a speed that depends on the speed of rotation of the magnetic field.

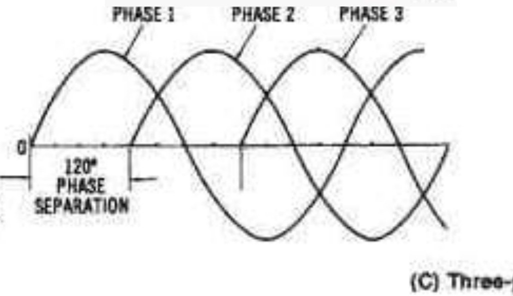
The three phase stator windings are displaced from each other by 120°

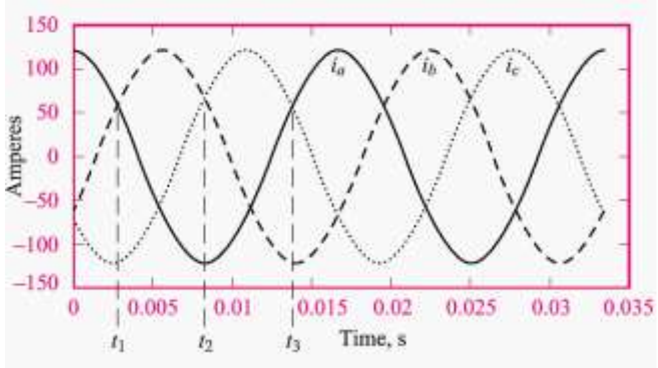


Consider the stator shown in Figure 1, which supports windings a-a', b-b' and c-c'.

The coils are geometrically spaced 120◦ apart, and a three-phase voltage is applied to the coils. The currents generated by a three-phase source are also spaced by 120◦







$$v_a = A\cos(\omega_e t)$$

$$v_b = A\cos\left(\omega_e t - \frac{2\pi}{3}\right)$$

$$v_c = A\cos\left(\omega_e t + \frac{2\pi}{3}\right)$$

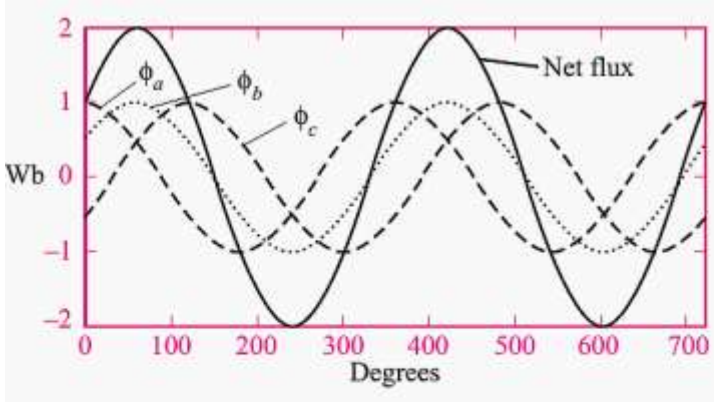
where ωe is the frequency of the AC supply, or line frequency. The coils in each winding are arranged in such a way that the flux distribution generated by any one winding is approximately sinusoidal.

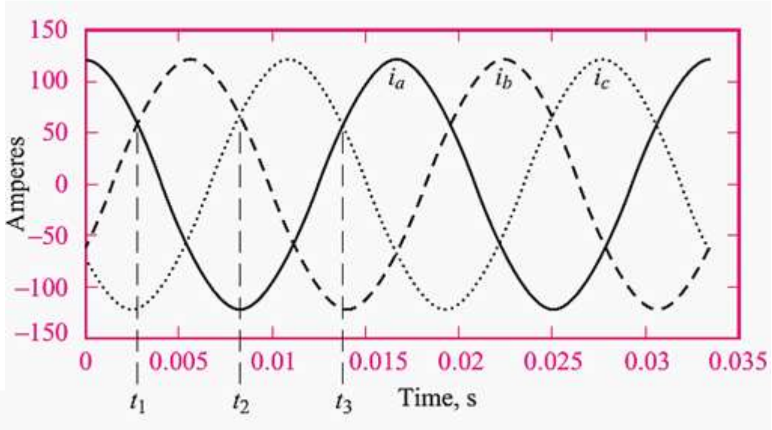
Working Of Synchronous Motor

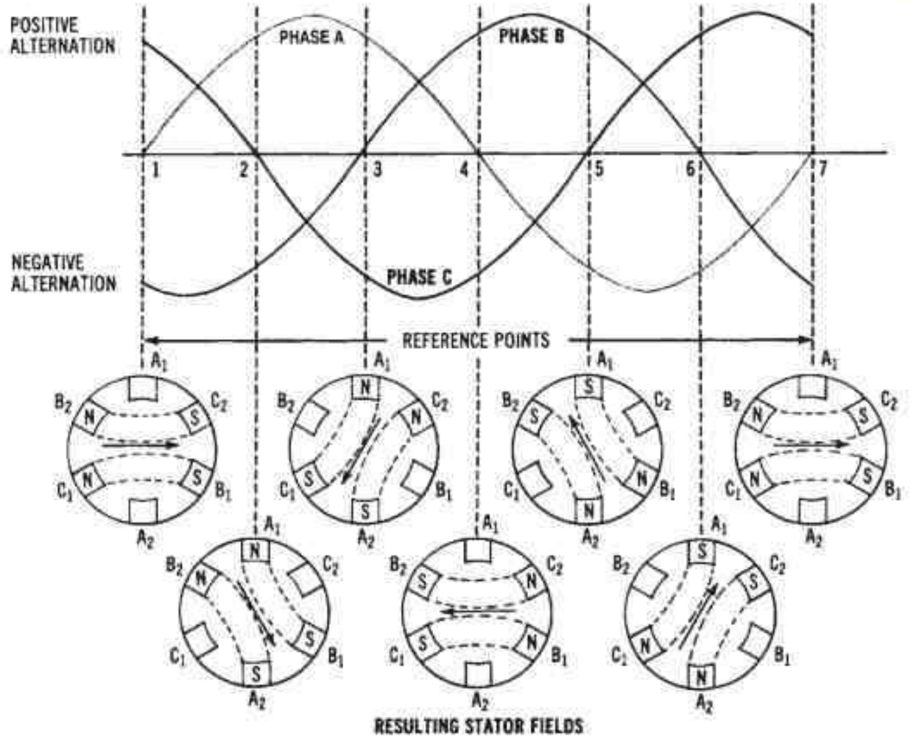
Rotating magnetic field

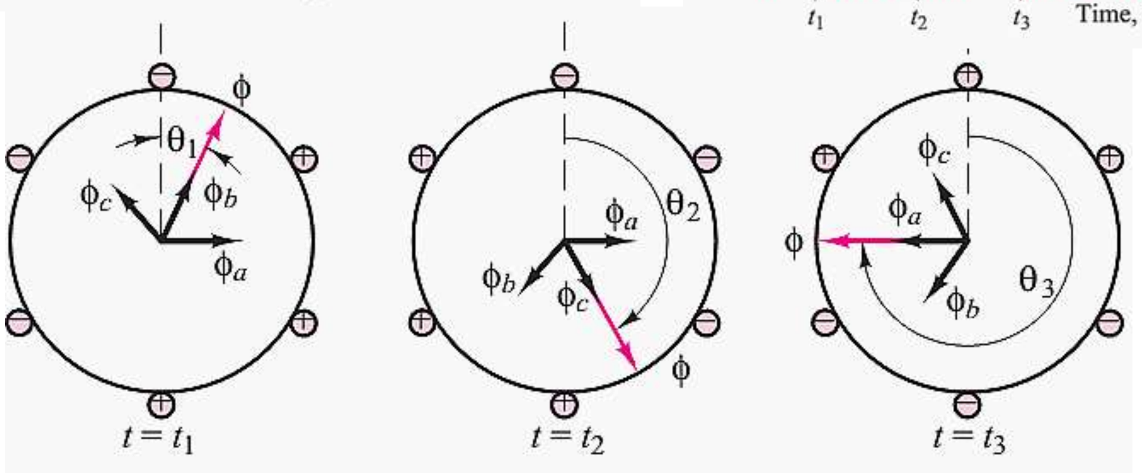
Generation of a rotating magnetic field

Since the coils are spaced 120◦ apart, the flux distribution resulting from the sum of the contributions of the three windings is the sum of the fluxes due to the separate windings









Thus, the flux in a three-phase machine rotates in space according to the vector diagram and the flux is constant in amplitude. A stationary observer on the machine's stator would see a sinusoidally varying flux distribution

Working Of Synchronous Motor

Rotating magnetic field

Developing a Rotating Magnetic Field in Stator Coil

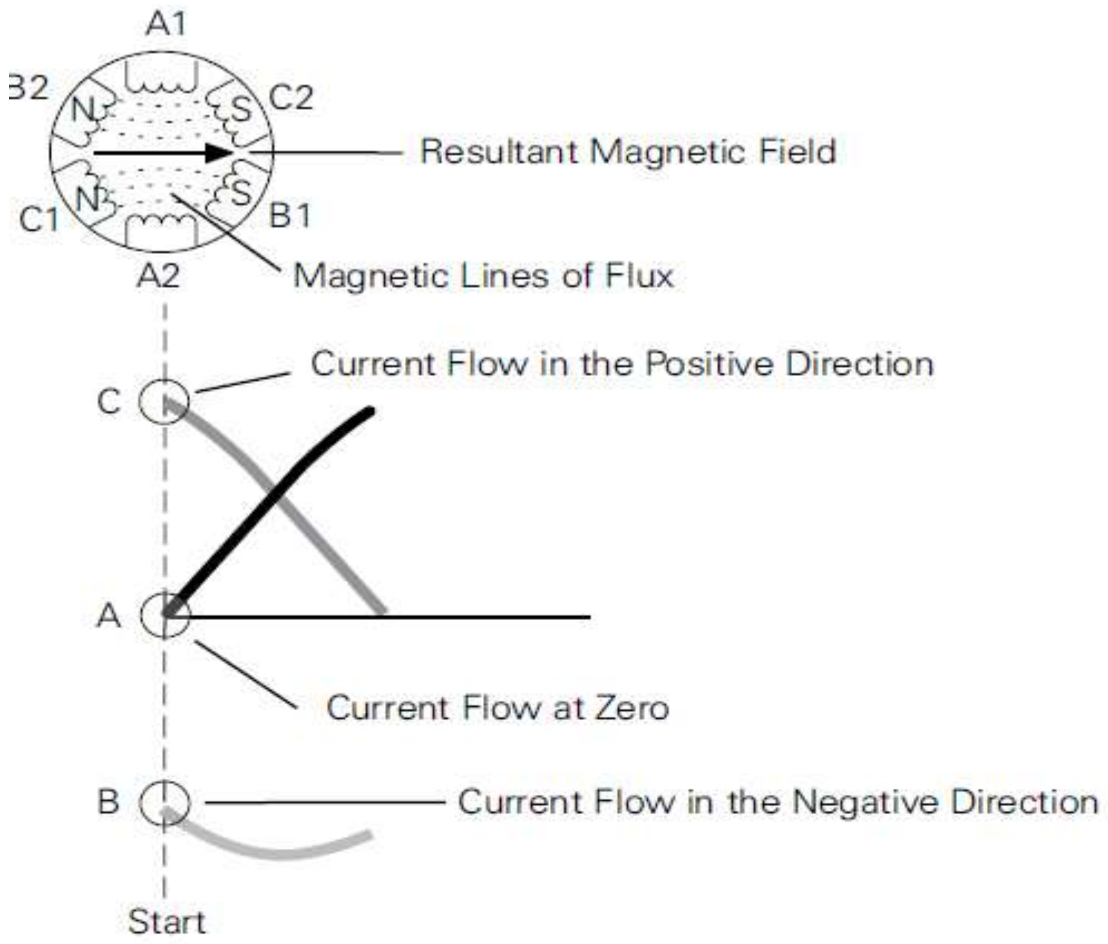
t=0

A has no current flow and its associated coils have no magnetic field. Phase B has current flow in the negative direction and phase C has current flow in the positive direction.

Based on stator winding configuration, B1 and C2 are south poles and B2 and C1 are north poles.

Magnetic lines of flux leave the B2 north pole and enter the nearest south pole, C2.

Magnetic lines of flux also leave the C1 north pole and enter the nearest south pole, B1.
The vector sum of the magnetic fields is indicated by the arrow.



Working Of Synchronous Motor

Rotating magnetic field

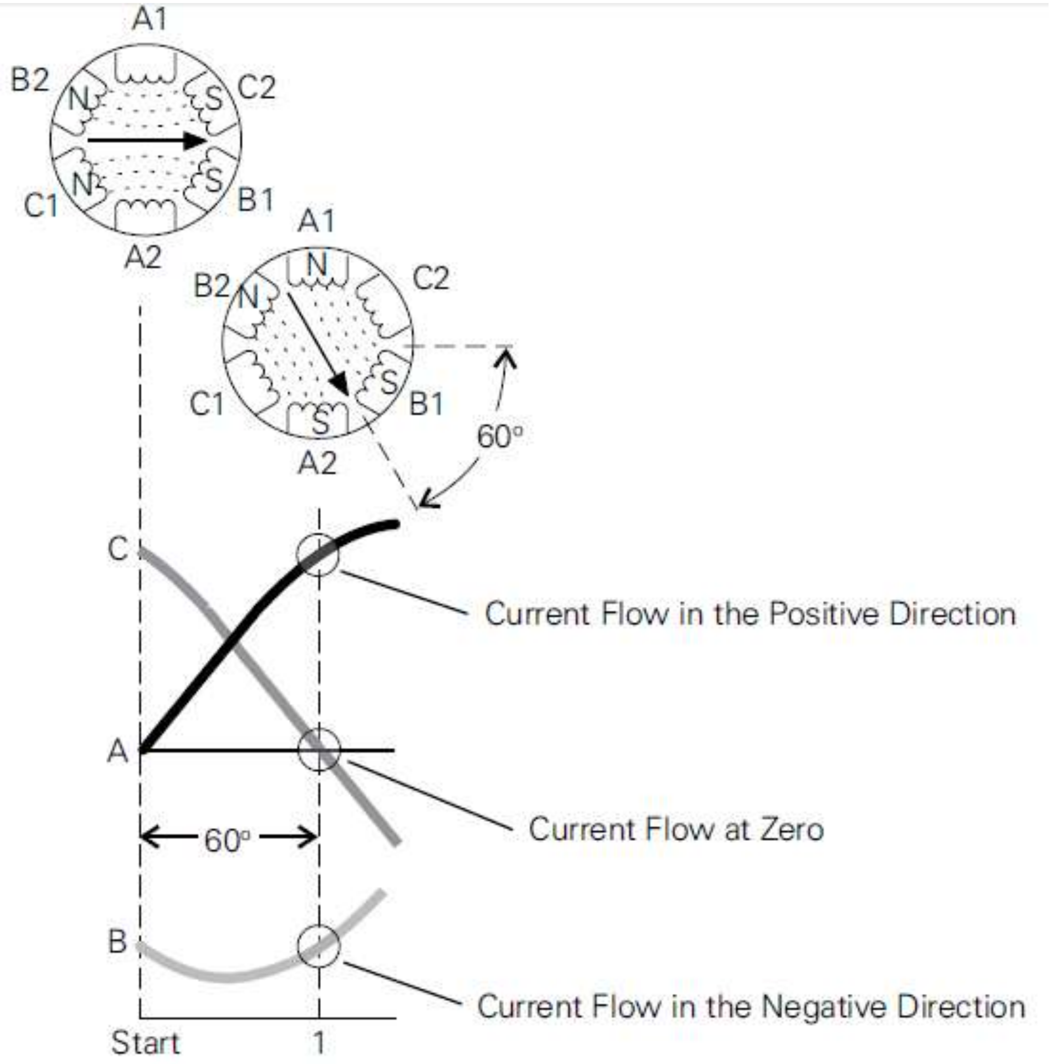
Developing a Rotating Magnetic Field in Stator Coil

$t=t_1$

The following chart shows the progress of the magnetic field vector as each phase has advanced 60°.

Note that at time 1 phase C has no current flow and no magnetic field is developed in C1 and C2. Phase A has current flow in the positive direction and phase B has current flow in the negative direction.

windings A1 and B2 are north poles and windings A2 and B1 are south poles. The resultant magnetic field vector has rotated 60° in the clockwise direction

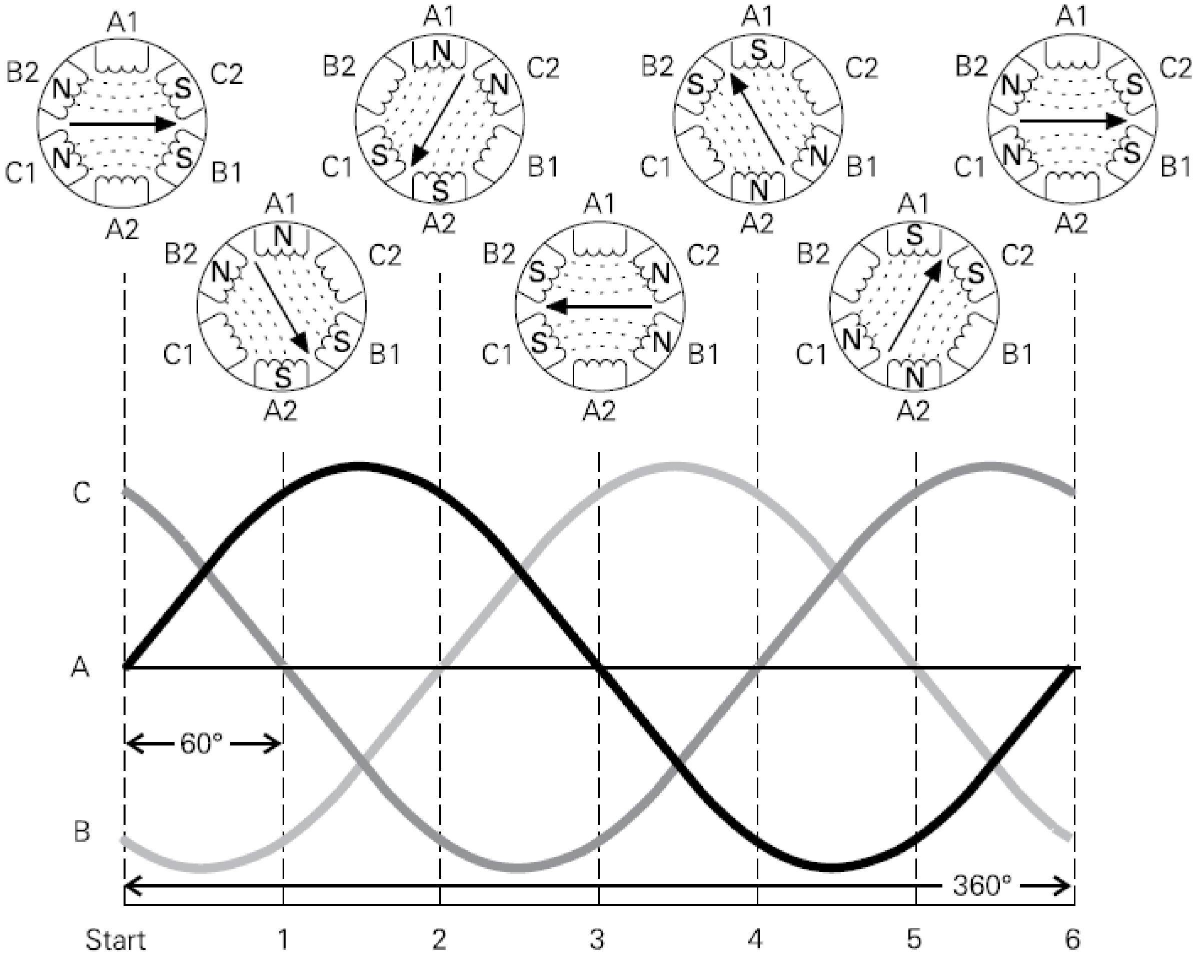


Working Of Synchronous Motor

Rotating magnetic field

Developing a Rotating Magnetic Field in Stator Coil

At the end of six such time intervals (it takes one period of applied AC voltage), the magnetic field will have rotated one full revolution or 360°.

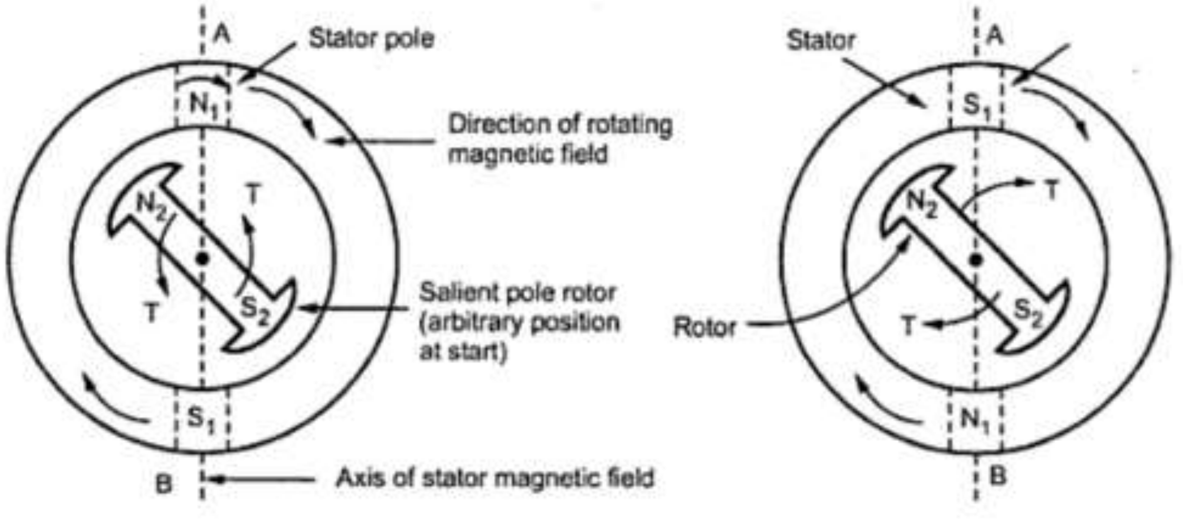


This process repeats 50 times a second for a 50 Hz power source.

Working Of Synchronous Motor

Motor Action

When DC supply is given to stationary rotor unlike poles will try to attract each other. Because of this action rotor will be subjected to an instantaneous torque in anticlockwise direction.As we connected power supply to stator, stator poles will rotate at speed of Ns r.p.m.



(a) Action of synchronous motor

(b) Action of synchronous motor

Due to inertia of rotor it is unable to rotate in the direction of anticlockwise torque, to which is driving force or stator rotating field. Just in that instant the stator poles change their positions. Consider an instant half a period latter where stator poles are exactly reversed but due to inertia rotor is unable to rotate from its initial position.Shown in figure (b).

At this instant, due to the unlike poles trying to attract each other, the rotor will be subjected to a torque in clockwise direction. This will tend to rotate rotor in the direction of rotating magnetic field.But before this happen, stator poles again change their position reversing the direction of the torque exerted on the rotor.

Key Point : Hence the average torque on the rotor is zero.So synchronous motor will not start it self

But, if the rotor is rotated upto the synchronous speed of the stator by means of an external force (in the direction of revolving field of the stator), and the rotor field is excited near the synchronous speed, the poles of stator will keep attracting the opposite poles of the rotor by this means the stator and rotor will get locked with each other, and the rotor will rotate at the synchronous speed.

Working Of Synchronous Motor

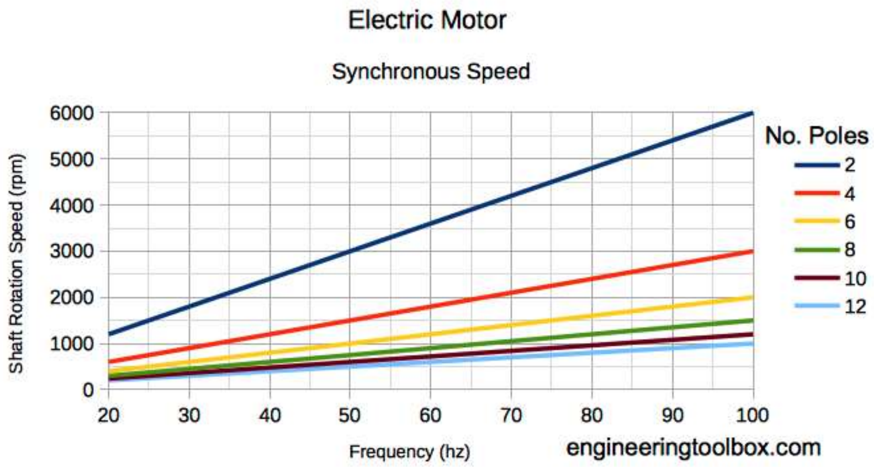
Motor Action

Synchronous speed

The speed of the rotating stator field is called the synchronous speed. The frequency of the power supply and the number of poles of the machine determine the synchronous speed.

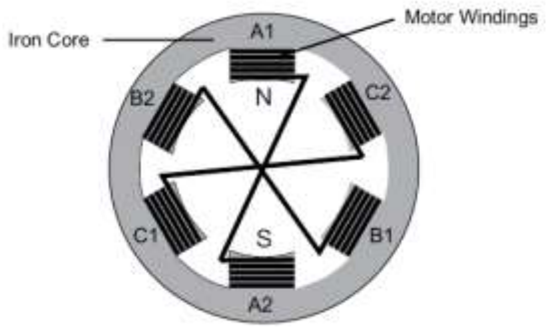
$$n_s = \frac{120 f_{AC}}{p}$$

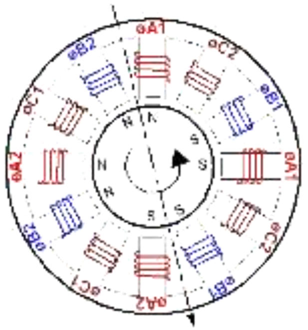
Synchronous speed is equal to 120 times the frequenc (f$_{AC}$), divided by the number of motor poles (p).



Synchronous motor will run either at synchronous speed or will not run at all.

Effect of poles per phase to rotation speed





No. Poles	Synchronous Speed (no Load)	
	60 hz	50 hz
2 Pole	3600	3000
4 Pole	1800	1500
6 Pole	1200	1000
8 Pole	900	750

A synchronous motor is one in which the rotor turns at the same speed as the rotating magnetic field in the stator. Step motors, dc brushless, variable reluctance motors, switched reluctance and hysteresis motors, and dc brush motors all typically operate as synchronous motors