SYNCHRONOUS MOTOR

PrincipleofWorkingof3-PhaseSynchronousMotor

Synchronous motor works on the principle of the magnetic locking. When two unlike poles are brought near each other, if the magnets are strong, there exists a tremendous force of attraction between those two poles. In such condition the two magnets are said to be magnetically locked.

If now one of the two magnets is rotated, the other also rotates in the same direction, with the same speed due to the force of attraction i.e. due to magnetic locking condition. The principle is shown schematically in the Fig

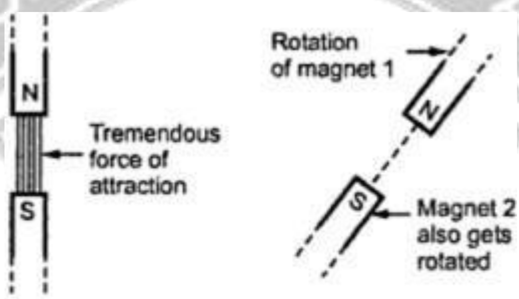

Figure2.1Principleofmagneticlocking

So to have the magnetic locking condition, there must exist two unlike poles and magnetic axes of two must be brought very close to each other. Let us see the application of this principle in case of synchronous motor.

Consider a three phase synchronous motor, whose stator is wound for 2 poles. The two magnetic fields are produced in the synchronous motor by exciting both the windings, stator and rotorwith three phasea.c. supplyand d.c. supplyrespectively. Whenthreephase winding is excited by a three phase a.c supply the the flux produced by the three phase winding is always of rotating type, which is alreadydiscussed in the previous post. Such a magnetic flux rotates in space at a speed called synchronous speed. This magnetic field is called rotating magnetic field. The rotating magnetic field creates the effect similar to the physical rotationof magnets in space with a synchronous speed. So stator of the synchronous motor produces one magnet which is as good as rotating in space with the synchronous speed. The synchronous speed of a stator rotating magnetic field depends on the supply frequency andthe numberof poles for which stator winding is wound. if the frequency ofthe a.c. supplyis f Hz and stator is wound for P number of poles, then the speed of the rotating magnetic field is synchronous given by,

$$N_s=120f/P \text{r.p.m.}$$

In this case, as stator is wound for say 2 poles, with 50 Hz supply, the speed of the rotating magnetic field will be 3000 r.p.m. This effect is similar to the physical rotation oftwo poles with a speed of N_s r.p.m. For simplicity of understanding let us assume that the stator poles are N_1 and S_1 which are rotating at a speed of N_s. The direction of rotation of rotating magnetic field is say clockwise.

When the field winding on rotor is excited by a d.c. supply, it also produces two poles, assuming rotor construction to be two pole, salient type. Let these poles be $N_2$and S_2.

Nowone magnetisrotating at$N_s$having polesN_1andS_1 whileat startrotorisstationary i.e. second magnet is stationary having poles N_2 and S_2. If somehow the unlike poles N_1 and S_2 or S_1 and N_2 are brought near each other, the magnetic locking may get established between stator and rotor poles. As stator poles are rotating due to magnetic locking rotor will alsorotateinthesamedirectionasthatofstatorpolesi.e.inthedirectionofrotatingmagnetic field, with the same speed i.e N_s.Hence synchronous motor rotatesatone and onlyone speedi.e.synchronousspeed.Butthisalldependsonexistenceof magnetic locking between stator and rotor poles. Practically it is not possible for stator poles to pull the rotor poles from their stationary position into magnetic locking condition. hence synchronous motors are not self starting.

WhysynchronousMotorIsNotSelfStarting

Consider the rotating magnetic field as equivalent to physical rotation of two stator poles N_1 and S_1.

Consider an instant when two poles are at such a position where stator magnetic axis is vertical, along A-B as shown in the Fig.

At thisinstant, rotorpoles arearbitrarilypositioned as shown in theFig.

At this instant, rotor is stationary and unlike poles will try to attract each other. Due to this rotor will be subjected to an instantaneous torque in anticlockwise direction as shown in the Fig.

Now stator poles are rotating very fast i.e. at a speed N_s r.p.m. Due to inertia, before rotor hardlyrotates in the direction of anticlockwise torque, to whichit is subjected, 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. This is shown in the Fig.

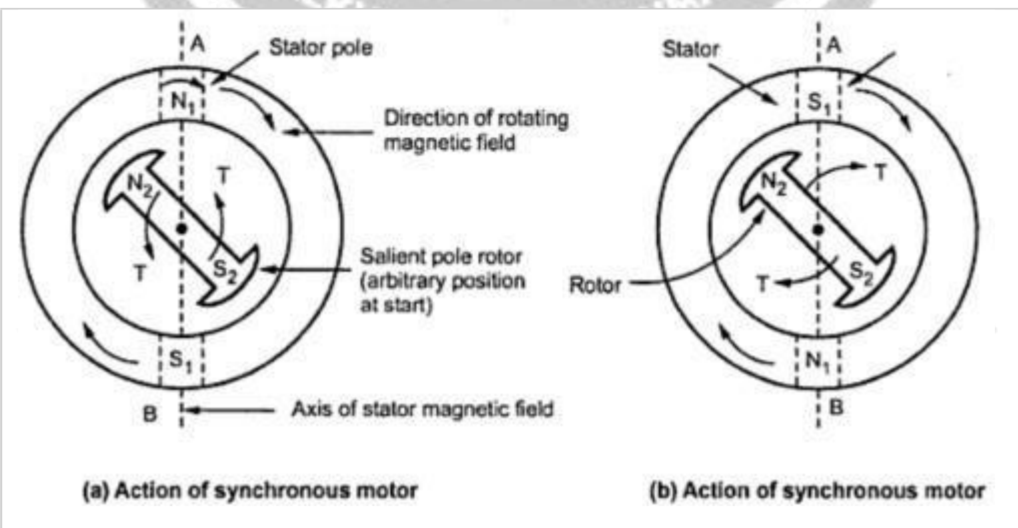

Figure2.2Actionof SynchronousMotor

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 : As a result, the average torque exerted on the rotor is zero. And hence the synchronous motor is not self starting.

Note : The question is obvious that will happen if by chance the rotor position is in such a way that the unlike rotor and stator poles are facing each other ? But owing to the largeinertia of the rotor, the rotor fails to rotate along with the stator poles. Hence again the difference of position of magnetic axes gets created and rotor gets subjected to quickly reversingtorque.This isbecausethespeedwith whichrotatingmagnetic fieldis rotatingisso high that it is unable to rotate the rotor from its initial position, due to the inertia of the rotor. So under any case, whatever may be the starting position of the rotor, synchronous motor is not self starting.

ProceduretoStartaSynchronousMotor

Now suppose the rotor is rotated by some external means at a speed almost equal to synchronous speed. And then the rotor is excited to produce its poles. At a certain instant now, the stator and rotor unlike poles will face each other such that their magnetic axes are near each other. Then the force of attraction between the two, pulls both of them into the magnetic lockingcondition.

Once magnetic locking is established, the rotor and stator poles continue to occupy the same relative positions. Due to this, rotor continuously experiences a unidirectional torque in the direction of therotatingmagnetic field. Hence rotorrotates atsynchronous speed and said to be in synchronism with rotating magnetic field.

The external device used to rotate rotor near synchronous speed can be removed once synchronism is established. The rotor then continues its rotation at N_s due to magnetic locking. This is the reason why synchronous motor runs only at synchronous speed and does notrotateatanyspeedother thanthesynchronous.ThisoperationisshownintheFig

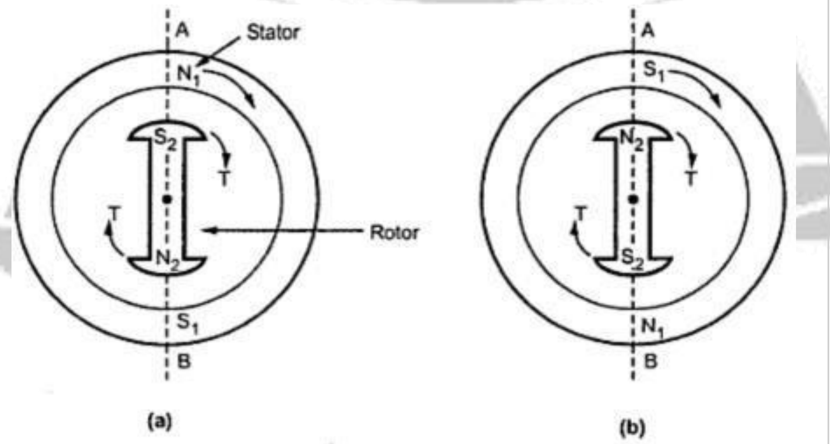

Figure2.3.Unidirectionaltorque experiencedbyrotor

1(a)and(b).It is necessary to keep field winding i.e. rotor excited from d.c. supply to maintain the magnetic locking, as long as motor is operating.

Soa generalprocedure tostart asynchronous motorcan bestatedas :

1. Give a three a.c. supply to a three phase winding. This will produce rotating magneticfield rotating at synchronous speed N_s r.p.m.

2. Then drive the rotor bysome externalmeans like diesel engine in the direction ofrotating magnetic field, at a speed very near or equal to synchronous speed.

3. Switch on the d.c. supply given to the rotor which will produce rotor poles. now there are twp fields one is rotating magnetic field produced by stator while the other is produced by rotor which is physically rotated almost at the same speed as that of rotating magnetic field.

4. At a particular instant, both the fields get magnetically locked. The stator field pulls rotor field into synchronism. Then the external device used to rotate rotor can be removed. But rotor will continue to rotate at the same speed as that of rotating magnetic field i.e. N_s due to magnetic locking.

Key Point : So the essence of the discussion is that to start the synchronous motor, it needs some device to rotate the rotor at a speed very near or equal to the synchronous speed.