Synchronous Motor Working Principle

Electrical motor in general is an electro-mechanical device that converts energy from electrical domain to mechanical domain. Based on the type of input we have classified it into single phase and 3 phase motors. Among 3 phase induction motors and synchronous motors are more widely used. When a 3 phase electric conductors are placed in a certain geometrical positions (In certain angle from one another) there is an electrical field generate. Now the rotating magnetic field rotates at a certain speed, that speed is called synchronous speed. Now if an electromagnet is present in this rotating magnetic field, the electromagnet is magnetically locked with this rotating magnetic field and rotates with same speed of rotating field.

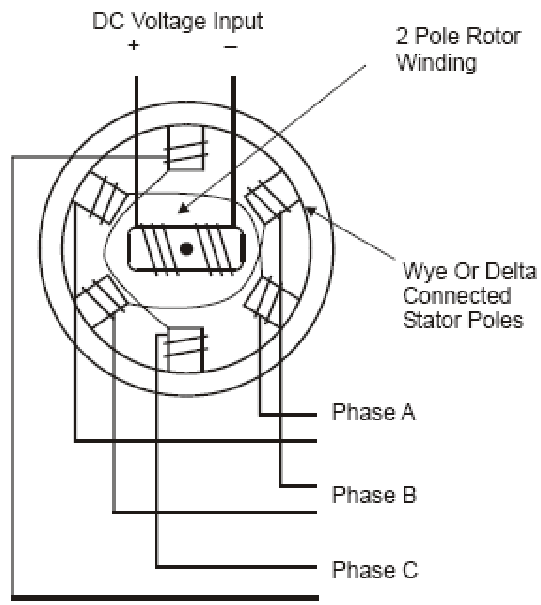
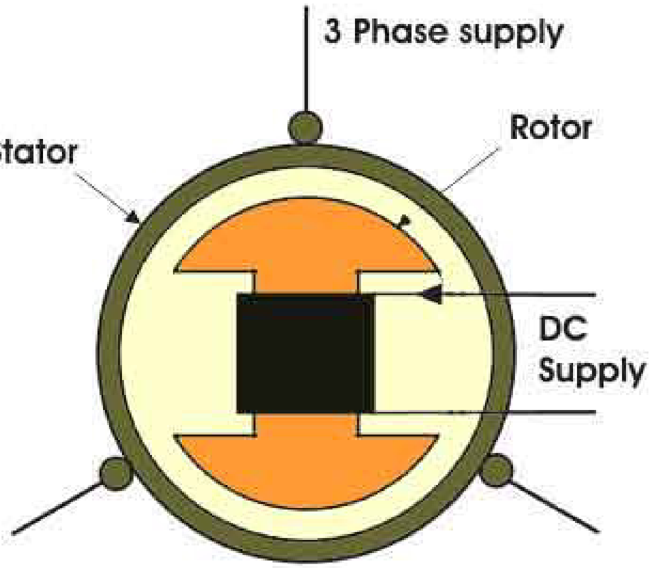


Figure 3-41. AC synchronous motor diagram

Synchronous motors is called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there or in other words it's in synchronism with the supply frequency. Synchronous speed is given defined by the number of pole pairs and the supply frequency. I.e. a motor running at 50Hz and using only one pole pair per phase would run at 60 x 50 = 3000rpm. A motor running at 60Hz and using 2 pole pairs per phase would run at (60 x 60) / 2 = 1800rpm



Synchronous Motor

Normally it's construction is almost similar to that of a 3 phase induction motor, except the fact that the rotor is given dc supply, the reason of which is explained later. Now, let us first go through the basic construction of this type of motor

From the above picture, it is clear that how this type of motors are designed. The stator is given is given three phase supply and the rotor is given dc supply.

Main Features of Synchronous Motors

Synchronous motors are inherently not self starting. They require some external means to bring their speed close to synchronous speed to before they are synchronized.

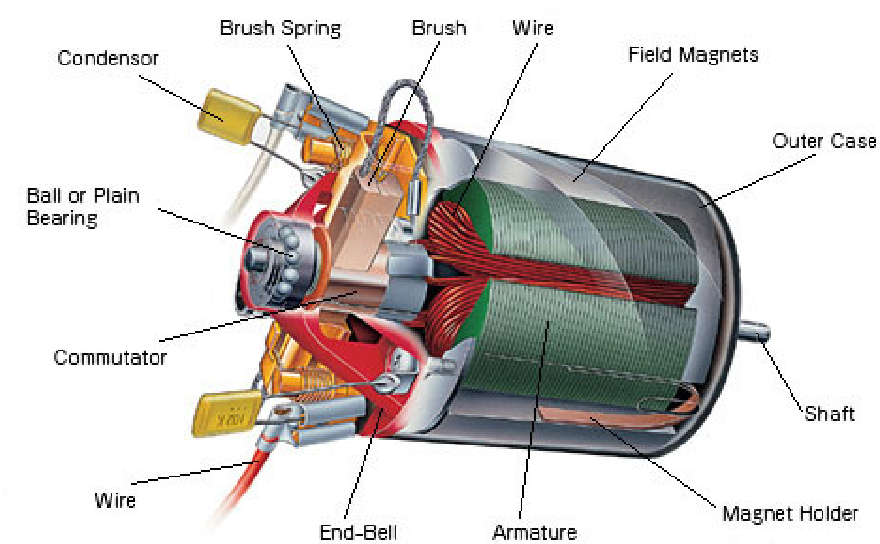
The speed of operation of is in synchronism with the supply frequency and hence for constant supply frequency they behave as constant speed motor irrespective of load condition

This motor has the unique characteristics of operating under any electrical power factor. This makes it being used in electrical power factor improvement.

Principle of Operation Synchronous Motor

Synchronous motor is a doubly excited machine i.e two electrical inputs are provided to it. It's stator winding which consists of a 3 phase winding is provided with 3 phase supply and rotor is provided with DC supply. The 3 phase stator winding carrying 3 phase currents produces 3 phase rotating magnetic flux. The rotor carrying DC supply also produces a constant flux. Considering the frequency to be 50 Hz, from the above relation we can see that the 3 phase rotating flux rotates about 3000 revolution in 1 min or 50 revolutions in 1 sec. At a particular instant rotor and stator poles might be of same polarity (N-N or S-S) causing repulsive force on rotor and the very next second it will be N-S causing attractive force. But due to inertia of the rotor, it is unable to rotate in any direction due to attractive or repulsive force and remain in standstill condition. Hence it is not self starting.

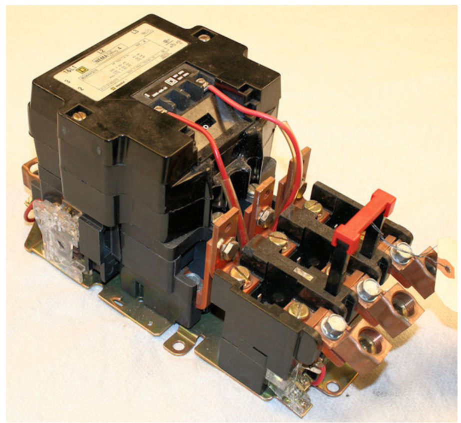
To overcome this inertia, rotor is initially fed some mechanical input which rotates it in same direction as magnetic field to a speed very close to synchronous speed. After some time magnetic locking occurs and the synchronous motor rotates in synchronism with the frequency.



Methods of Starting of Synchronous Motor

Synchronous motors are mechanically coupled with another motor. It could be either 3 phase induction motor or DC shunt motor. DC excitation is not fed initially. It is rotated at speed very close to its synchronous speed and after that DC excitation is given. After some time when magnetic locking takes place supply to the external motor is cut off.

Damper winding : In case, synchronous motor is of salient pole type, additional winding is placed in rotor pole face. Initially when rotor is standstill, relative speed between damper winding and rotating air gap flux in large and an emf is induced in it which produces the required starting torque. As speed approaches synchronous speed , emf and torque is reduced and finally when magnetic locking takes place, torque also reduces to zero. Hence in this case synchronous is first run as three phase induction motor using additional winding and finally it is synchronized with the frequency.



Application of Synchronous Motor

Synchronous motor having no load connected to its shaft is used for power factor improvement. Owing to its characteristics to behave at any electrical power factor, it is used in power system in situations where static capacitors are expensive.

Synchronous motor finds application where operating speed is less (around 500 rpm) and high power is required. For power requirement from 35 kW to 2500 KW, the size, weight and cost of the corresponding three phase induction motor is very high. Hence these motors are preferably used. Ex- Reciprocating pump, compressor, rolling mills etc.

Synchronous Motor Excitation

Prior to understanding this synchronous motor excitation, it should be remembered that any electromagnetic device must draw a magnetizing current from the ac source to produce the required working flux. This current lags by almost 90° to the supply voltage. In other words, the function of this magnetizing current or lagging VA drawn by the electromagnetic device is to set up the flux in the magnetic circuit of the device.

The synchronous motor is doubly fed electrical motor i.e it converts electrical energy to mechanical energy via magnetic circuit. Hence it comes under electromagnetic device. It receives 3 phase ac electrical supply to its armature winding and DC supply is provided to rotor winding.

Synchronous motor excitation refers to the DC supply given to rotor which is used to produce the required magnetic flux.One of the major and unique characteristics of this motor is that it can be operated at any electrical power factor leading, lagging or unity and this feature is based on the excitation of the synchronous motor.

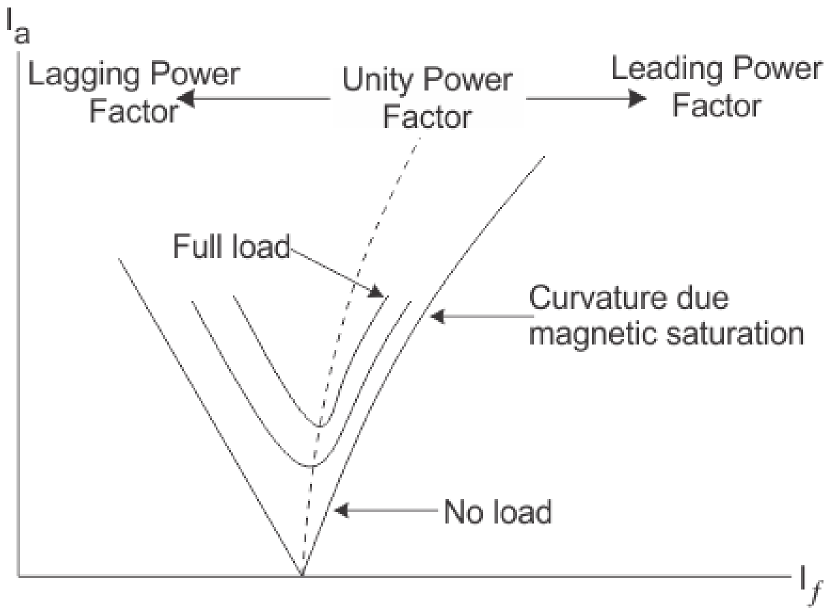
When the synchronous motor is working at a constant applied voltage V, the resultant air gap flux as demanded by V remains substantially constant. This resultant air gap flux is established by the co operation of both AC supply of armature winding and DC supply of rotor winding.

CASE 1: When the field current is sufficient enough to produce the air gap flux, as demanded by the constant supply voltage V, then the magnetizing current or lagging reactive VA required from ac source is zero and the motor operate at unity power factor. The field current, which causes this unity power factor is called normal excitation or normal field current.

CASE 2: If the field current is not sufficient enough to produce the required air gap flux as demanded by V, additional magnetizing current or lagging reactive VA is drawn from the AC source. This magnetizing current produces the deficient flux (constant flux- flux set up by dc supply rotor winding). Hence in this case the motor is said to operate under lagging power factor and the is said to be under excited.

CASE 3: If the field current is more than the normal field current, motor is said to be over excited. This excess field current produces excess flux (flux set up by DC supply rotor winding – resultant air gap flux) must be neutralized by the armature winding. Hence the armature winding draws leading reactive VA or demagnetizing current leading voltage by almost 90o from the AC source. Hence in this case the motor operate under leading power factor.

Conclusion: An overexcited synchronous motor operate at leading power factor, under-excited synchronous motor operate at lagging power factor and normal excited synchronous motor operate at unity power factor.



V curves for a synchronous motor with variable excitation