

Synchronous motors are widely used in the industry for high precision applications. This video gives illustrative and logical explanation on its working.

Detailed webpage version the video is given below.

## Introduction

As the name suggests Synchronous motors are capable of running at constant speed irrespective of the load acting on them. Unlike induction motors where speed of the motor depends upon the torque acting on them, synchronous motors have got constant speed-torque characteristics.

Synchronous motors have got higher efficiency (electrical to mechanical power conversion ratio) than its counterparts. Its efficiency ranges from 90 – 92%.



Fig.1 Synchronous motors are high efficiency and high accuracy machines

## The Working Principle: RMF – Constant Magnetic field interaction

The constant speed characteristic is achieved by interaction between a constant and rotating magnetic field. Rotor of synchronous motor produces a constant magnetic field and Stator produces a Rotating magnetic field.

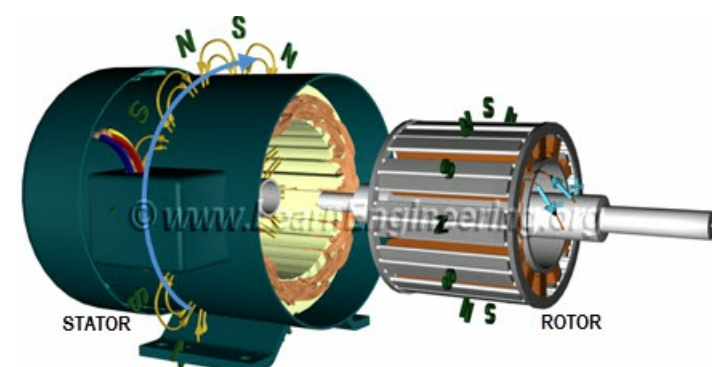


Fig.2 Interaction between a revolving and constant magnetic field helps in achieving constant speed characteristic

## Stator: Revolving Magnetic Field

The field coil of stator is excited by a 3 phase AC supply. This will produce a revolving magnetic field (*RMF*), which rotates at synchronous speed. The way RMF is produced with 3 phase AC excitation is explained in a separate article. RMF produced in a synchronous motor and its direction is marked in Fig.2

## Rotor: Constant Magnetic field

Rotor is excited by a D.C power supply, magnetic field produced around the rotor coil by DC excitation is shown below. It is clear that the rotor acts like a permanent magnet due to such magnetic field. Alternatively rotor can also be made of permanent magnet.

Interaction of Rotor and RMF is interesting. Assume you are giving an initial rotation to the rotor, with same direction of RMF. You can see that opposite poles of RMF and Rotor will attract each other and they will get locked magnetically. This means that rotor will rotate at the same speed of RMF, or rotor will rotate at synchronous speed.

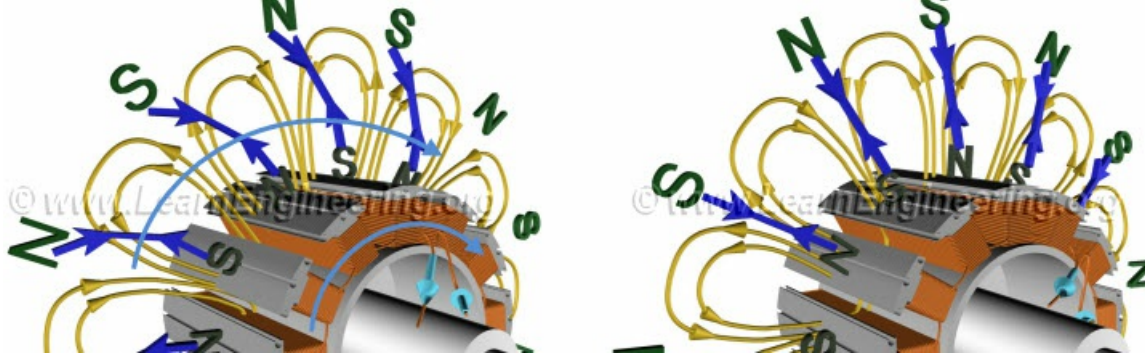


Fig.3 In first figure opposite poles of RMF and Rotor pole get attracted, rotor already rotating: In second figure poles are magnetically locked

### Synchronous Speed

Speed at which RMF rotates or Synchronous speed can easily be derived as follows.

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

It is clear from the relationship that speed of synchronous motor,  $N_s$  (rpm) is directly proportional to frequency of the electricity,  $f$  (Hz).  $P$  represents number of poles of the rotor. This means that if one has got control over frequency of the electricity, speed of synchronous motor can be very accurately controlled. This is the reason why they are suitable for high precision applications.

### Why Synchronous motors are not self starting ?

But if the rotor has got no initial rotation, situation is quite different. North Pole of the Rotor will obviously get attracted by South Pole of RMF, and will start to move in the same direction. But since the rotor has got some inertia, this starting speed will be very low. By this time South pole of RMF will be replaced by a North pole. So it will give repulsive force. This will make the rotor move backward. As a net effect the rotor won't be able to start.

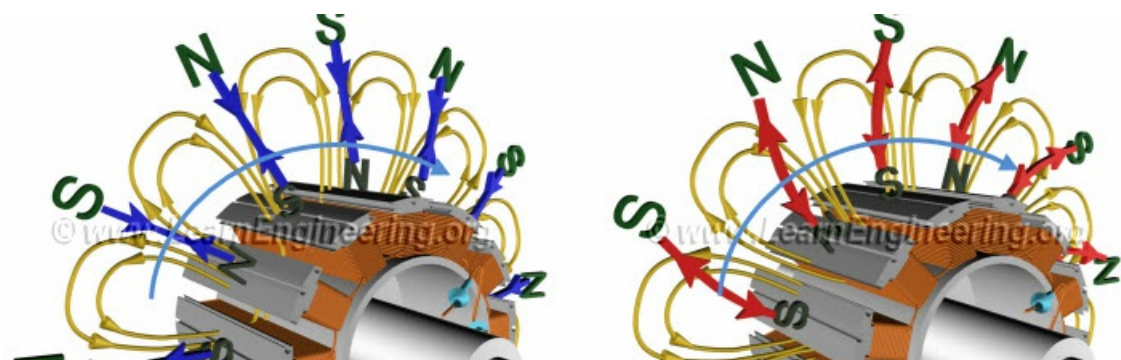


Fig.4 In first figure opposite poles of RMF and rotor get attracted, when the rotor has no initial rotation: In 2nd figure this becomes a repulsive force

So it can be summarized that synchronous motors are not inherently self starting.

### Making Synchronous Motor Self Start – Use of Damper winding

To make synchronous motor self start, a squirrel cage arrangement is cleverly fitted through pole tips. They are also called as damper windings.



Fig.5 Damper winding (squirrel cage) is fitted through poles of the rotor

At the starting rotor field coils are not energized. So with revolving magnetic field, electricity is induced in squirrel cage bars and rotor starts rotating just like an induction motor starts.

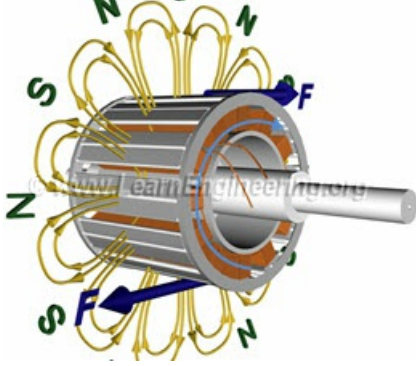


Fig.7 Damper winding helps synchronous motor start just like an induction motor starts

When the rotor has achieved its maximum speed, rotor field coils are energized. So as discussed earlier poles of rotor gets locked with poles of RMF and will start rotating at synchronous speed. When rotor rotates at synchronous speed, relative motion between squirrel cage and RMF is zero. This means zero current and force on squirrel cage bars, thus it will not affect synchronized operation of the motor.

### Synchronous motor out of Synchronism

Synchronous motors will produce constant speed irrespective of motor load only if the load is within the capability of motor. If external torque load is more than torque produced by the motor, it will slip out of synchronism and will come to rest. Low supply voltage and excitation voltage are other reasons of going out of synchronism. It is interesting to note that synchronous motor has got the same constructional features of an alternator.

### Synchronous Condenser

Synchronous motors can also be used to improve overall power factor of the system. When the sole purpose of application is power factor improvement synchronous motors are referred as *synchronous condenser*. In such situation shaft of the motor is not connected to any mechanical load and it spins freely.

Stator: Unlike in [DC machine](#) stator of an alternator is not meant to serve path for magnetic flux. Instead, *the stator is used for holding armature winding*. The stator core is made up of lamination of steel alloys or magnetic iron, to minimize the [eddy current losses](#).

### Why Armature Winding Is Stationary In An Alternator?

- At high voltages, it easier to insulate stationary armature winding, which may be as high as 30 kV or more.
- The high voltage output can be directly taken out from the stationary armature. Whereas, for a rotary armature, there will be large brush contact drop at higher voltages, also the sparking at the brush surface will occur.
- Field exciter winding is placed in rotor, and the low dc voltage can be transferred safely.
- The armature winding can be braced well, so as to prevent deformation caused by the high centrifugal force.

Rotor: There are two types of rotor used in an AC generator / alternator:

#### (i) Salient and (ii) Cylindrical type

1. Salient pole type: Salient pole type rotor is used in low and medium speed alternators. **Construction of AC generator** of salient pole type rotor is shown in the figure above. This type of rotor consists of large number of projected poles (called salient poles), bolted on a magnetic wheel. These poles are also laminated to minimize the eddy current losses. Alternators featuring this type of rotor are large in diameters and short in axial length.
2. Cylindrical type: Cylindrical type rotors are used in high speed alternators, especially in turbo alternators. This type of rotor consists of a smooth and solid steel cylinder having slots along its outer periphery. Field windings are placed in these slots.

The DC supply is given to the rotor winding through the slip rings and brushes arrangement.