14. SYNCHRONOUS MOTOR

**CHARACTERISTIC FEATURES:**
1. It runs either at synchronous speed or not at all.
2. It is not self-starting. It has to be run up to synchronous speed by some means.
3. It is capable of being operated under a wide range of power factors.

**The Constructional Details:**
1. **STATOR** – It is stationary part made of silicon steel stampings having slots on inner periphery.
2. **STATOR WINDINGS** – It is a star or delta connected super enamelled copper winding inserted in the stator slots.
3. **ROTOR** – Cylindrical part having poles on the surface. It is also made of silicon steel stampings. There are two types of rotors:
   - Salient pole type
   - Smooth cylindrical shape
4. **ROTOR WINDINGS** – Enamed copper windings is put on the poles and excited by D.C. supply received from exciter.
5. **EXCITER** – It is a small capacity D.C. shunt generator generally mounted on same shaft of that of rotor and when moving generates D.C. supply to be fed to rotor windings.
6. **SLIP RINGS AND BRUSHES** – There are two slip rings made of phosphor bronze fitted on the shaft. Two carbon brushes are kept touching with slip ring.

**Working of Synchronous Motor**
1. When a 3- phase stator winding is fed by 3- phase supply then a magnetic flux of constant magnitude but rotating at synchronous speed is produced.
2. D.C. voltage from exciter is supplied through brushes and slip rings to the rotor. Thus rotor poles are formed as N and S.
3. Suppose the stator poles are at that instant situated at points A and B, the two similar poles N of rotor and Ns of stator as well as S and Ss will repel each other and rotor tends to rotate in the anticlockwise direction as shown in the figure.

4. But half a period later, stator poles having rotated around interchange their position. Ns attracts S and Ss attracts N. Hence, rotor tends to rotate clockwise as shown in (a).

5. Rotor is not subjected to unidirectional torque owing to large inertia. Rotor cannot respond to such quickly reversing torque with the result it remains stationary.

**How the motor can be started?**

- If the rotor poles also shift their positions along with the stator poles, then there will be unidirectional torque. Hence by some mechanical force, rotor is rotated then there is magnetic locking between stator and rotor poles. Even if now mechanical source is taken out, the motor keeps on rotating with the speed=Ns.

DIFFERENT METHODS OF STARTING SYNCHRONOUS MOTOR.

- **Providing Damper Windings** –

  - Damper winding consists of copper bars placed in slots provided on pole faces of salient rotor poles.
  - These copper bars are short circuited with the help of short-circuiting ring on both the ends.
  - This winding is similar to squirrel cage winding.
At starting, field winding is kept unexcited and motor is not loaded. Three phase voltage is applied to stator winding.

The rotating flux is produced which links with short circuited damper winding and induces emf in it as per Faraday’s first law of electromagnetic induction.

Motor starts as a three-phase induction motor.

When it acquires speed near to synchronous speed the D.C. excitation is switched ON and the motor is pulled into synchronism and runs as synchronous motor. This motor is called as Induction start synchronous run motor.

**USE OF PONY MOTOR**

It is a small induction motor which can be geared to the synchronous motor. This induction motor drives the synchronous motor and when the speed is nearly synchronous speed the D.C. excitation is made on to the rotor, the motor pulls up into synchronism at the same time the induction motor is switched off and may be disconnected detaching its gearing.

**EXCITER USED AS A D.C. MOTOR**

Exciter can be run as a D.C. motor. Supply may be separately available. This will drive the synchronous motor up to the required synchronous speed then the exciter is switched ON and the rotor is pulled into synchronism.

**D.C. GENERATOR AS A LOAD OF SYNCHRONOUS MOTOR CAN BE RUN AS D.C. MOTOR**

The (load) D.C. generator is run as a D.C. motor to drive the rotor of synchronous motor, when the rotor of synchronous motor reaches synchronous speed the exciter is switched ON and the rotor is pulled into synchronism. Now the same synchronous motor drives this D.C. generator.

**SYNCHRONOUS MOTOR APPLICATIONS**

- Poly phase synchronous motor finds extensive applications.
- Power factor correction: Over-excited synchronous motor (synchronous condenser) having leading power factor are widely used for improving power factor.
- Constant speed – constant load drives: Driving D.C. generators, rubber mills, textile mills, pumps, ship-propulsion, and compressors.
- Voltage regulation: Because of inductive loads the voltage at the end of long transmission lines varies greatly. As a voltage regulator, synchronous motor is used.
- Single phase fractional H.P synchronous motors are widely used in clocks and stroboscope.
**V-CURVE AND INVERTED V-CURVE**

**V-CURVE**

- V-curves of synchronous motor show how armature current varies with its field current (exciting current) when motor input is constant.
- Armature current is more for low values and high values of excitation (though it is lagging for low excitation and leading for high excitation).
- It has minimum value corresponding to certain excitation.
- Variation of armature current with excitation is known as V-curves because of its shape.

**INVERTED V-CURVE**

- For the same input armature current varies over a wide range and so causes the power factor to vary accordingly.
- Over excited motor runs with leading power factor.
- Under excited motor runs with lagging power factor.
- In between, power factor is unity.
• Variation of power factor with excitation is like inverted V-curve.
• Minimum armature current corresponds to unity power factor.

HUNTING OF SYNCHRONOUS MOTOR:

- When suddenly mechanical load on rotor shaft increases or decreases then it causes rotor oscillations and rotor oscillates about its equilibrium (it falls back or advances) position corresponding to mechanical load. Rotor oscillations are called Hunting or surging or phase swinging.
- Hunting is highly undesirable because if rotor oscillation frequency becomes equal to natural frequency of rotor, mechanical resonance will occur. Amplitude of oscillation will increase to a very high value and there is possibility that rotor may fall out of synchronism.
- For reducing hunting damper windings are provided. Damper windings are copper bars provided on rotor pole shoes and short circuited on both sides.
### COMPARISON BETWEEN SYNCHRONOUS MOTOR AND INDUCTION MOTOR:

<table>
<thead>
<tr>
<th>Synchronous Motor</th>
<th>Induction Motor</th>
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<tbody>
<tr>
<td>1. It runs at the Constant average speed at any load.</td>
<td>1. Speed slightly decreases at higher loads.</td>
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<tr>
<td>2. It can be operated at any desired p.f. unity leading or lagging by changing excitation.</td>
<td>2. It runs at lagging p.f. only.</td>
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<tr>
<td>3. It is not self starting. Either damper winding is provided or it is run first by some means.</td>
<td>3. It is self starting.</td>
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<tr>
<td>4. Changes in the applied voltage do not affect the torque much more.</td>
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<td>5. It requires D.C. excitation for rotor field winding.</td>
<td>5. No D.C. excitation is required.</td>
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<tr>
<td>7. For the same H.P. motor is bulky</td>
<td>7. Comparatively light in weight.</td>
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<td>8. Cost is more.</td>
<td>8. Cost is less.</td>
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<tr>
<td>9. Used for the specific purposes, such as, for cont. speed, improvement of p.f. etc.</td>
<td>9. Used in industries.</td>
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