Synchronous Motor

→ A synchronous motor is a **doubly-excited machine.**

→ Its **armature winding** is energised from **3-ϕ ac supply**, and its **field winding** is energised from a **d.c. source.**

– A synchronous motor is similar in construction to an alternator. An alternator can be run as synchronous motor, if it is given 3-ϕ ac supply in stator and dc supply in rotor.

– A synchronous motor runs only at synchronous speed and no other speed. So, we cannot change the speed of synchronous ~~speed~~ motor, by changing its excitation, as was the case in DC motor.

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Whereas, an induction motor runs at all speeds, other than synchronous speed.

– A synchronous motor can be made to operate at a wide-range of power-factor, by changing the excitation.

– A synchronous motor is not self-starting. We need to employ different methods to make it self starting.

Operating Principle of Synchronous Motors.

- Synchronous motor is doubly excited machine.
  - ↳ Stator is given 3-phase ac supply in 3-phase distributed windings.
  - ↳ Rotor is given DC supply.

- A rotating magnetic field is created in space, when 3-phase ac supply is given to 3-phase distributed windings.

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  This rotating magnetic field rotates in space at synchronous speed, Ns.

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  This is like, North and South pole of stator rotating at speed Ns.

- The rotor also has its own North and South pole, as it is energised from DC supply.

- Since, the stator poles are rotating at very high speed of Ns, they attract and repel the rotor poles at very fast rate. In one half-cycle, rotor pole is attracted by stator pole and in next half-cycle it is repelled.

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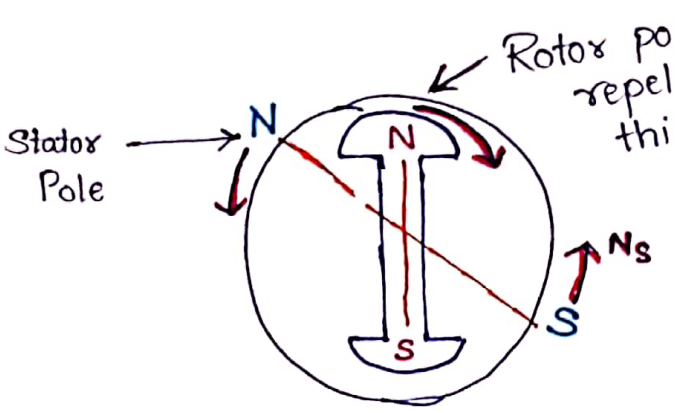
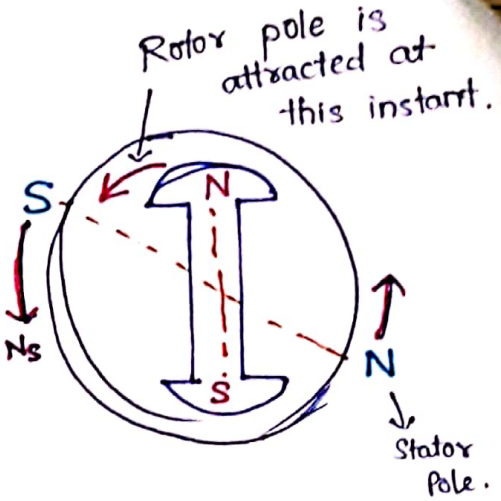
  So, ultimately the rotor is unable to rotate in any direction, because of its high inertia.





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This repulsion and attraction of the rotor pole happens at such a fast pace that the rotor is unable to overcome its inertia and remains stationary.

→ So, we see that a bi-directional torque acts on the rotor, when it is stationary.

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This bi-directional torque acts on the rotor, till there is relative speed between stator field and rotor field. Under stationary condition, relative speed is N_s. So, frequency of reversal of torque is maximum. At any speed below synchronous speed, the relative speed is somewhat smaller, so this torque reversal frequency is slower.

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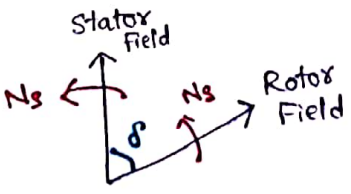
A stable, uni-directional torque will act on rotor, only when relative speed between stator field and rotor field is zero i.e. both stator and rotor field rotate at same speed N_s.



Torque angle → δ
↓
is constant here
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∴ A constant and stable torque occurs.

In case of 3-phase induction motor, a uni-directional torque acts on the rotor, at all speeds below synchronous speed.

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It is so because, the rotor in induction motor is not energised, and it gets attracted by the stator poles. There is no repulsive force, as there is no pole on the rotor. So, for all speeds below synchronous speed, the rotor is attracted by stator field, creating a uni-directional torque.

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If the rotor also attains synchronous speed, then there will be no flux cutting by rotor conductor due to zero relative speed. So, there will be no induced emf, ∴ no rotor current and no torque on the rotor.

Starting methods of synchronous motor.

→ No-Load starting method.

↳(i) Auxiliary motor starting.

↳ Using either DC motor or 3-phase Induction motor as prime-mover, till speed near synchronous speed is not achieved.

→ On-load starting method

↳(i) Damper-winding starting

↳(ii). Variable Voltage and frequency starting (Keepin $\frac{V}{f}$ ratio constant)

→ Auxiliary motor starting.

- First of all 3-phase ac supply is given to 3-phase distributed winding in stator, creating a rotating magnetic field.
- Rotor is not energised initially, i.e. it is not given DC supply initially.
- A DC motor or 3-phase induction motor is connected to shaft of synchronous motor. This auxiliary motor acts as prime-mover for synchronous motor, which takes it to a speed near synchronous speed.
- Once our synchronous motor reaches speed near synchronous motor, the auxiliary motor is decoupled and rotor of synchronous motor is given DC excitation.

- Rotor field is established after getting excitation and it is rotating at speed near synchronous speed, and in same direction as stator field.
- So, the relative speed between stator field and rotor field decreases, as compared to standstill condition. So, the frequency of reversal of torque on rotor also reduces.
- So, the rotor is pulled into synchronism, i.e. its speed becomes Ns. and there is magnetic interlocking between the stator field and rotor field.
- Thus a stable steady state torque is established when the rotor attains synchronous speed.