Chapter 4
Synchronous Machines

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Synchronous Machine

- Synchronous machines are AC machine that have a field circuit supplied by an external DC source.
  - DC **field winding** on the rotor,
  - AC **armature winding** on the stator
- Origin of name: syn = equal, chronos = time
- Synchronous machines are called '***synchronous***' because their mechanical shaft speed is directly related to the power system's line frequency.

Synchronous Machine

Construction

- Energy is stored in the inductance
- As the rotor moves, there is a change in the energy stored
- Either energy is extracted from the magnetic field (and becomes mechanical energy – motor)
- Or energy is stored in the magnetic field and eventually flows into the electrical circuit that powers the stator – generator

Synchronous Machine

- DC field windings are mounted on the (rotating) rotor - which is thus a rotating electromagnet
- AC windings are mounted on the (stationary) stator resulting in three-phase AC stator voltages and currents

- The main part in the synchronous machines are
  1. **Rotor**
  2. **Stator**

Synchronous Machine

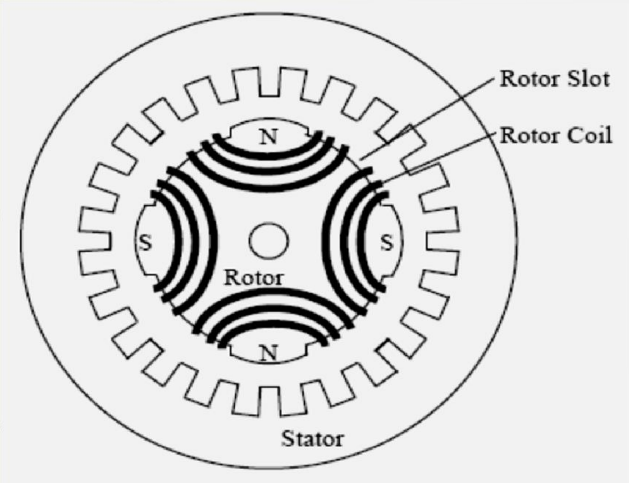
Rotor

There are two types of rotors used in synchronous machines:

1. **Cylindrical (or round) rotors**
2. **Salient pole rotors**

- Machines with cylindrical rotors are typically found in higher speed higher power applications such as turbo-generators. Using 2 or 4 poles, these machines rotate at 3600 or 1800 rpm (with 60hz systems).
- Salient pole machines are typically found in large (many MW), low mechanical speed applications, including hydro-generators, or smaller higher speed machines (up to 1-2 MW).
- Salient pole rotors are less expensive than round rotors.

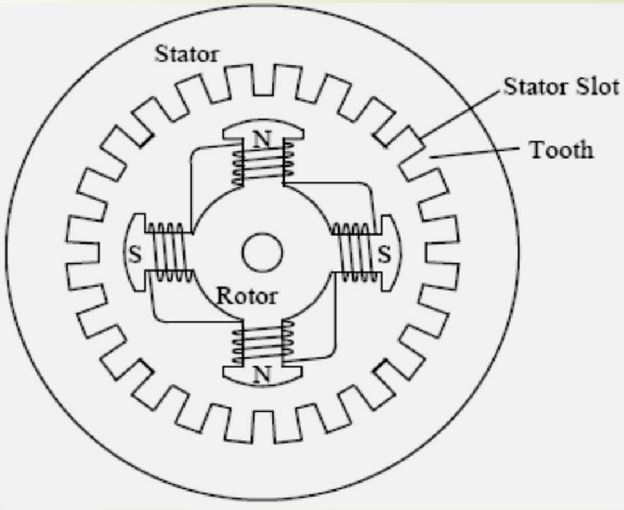
Synchronous Machine



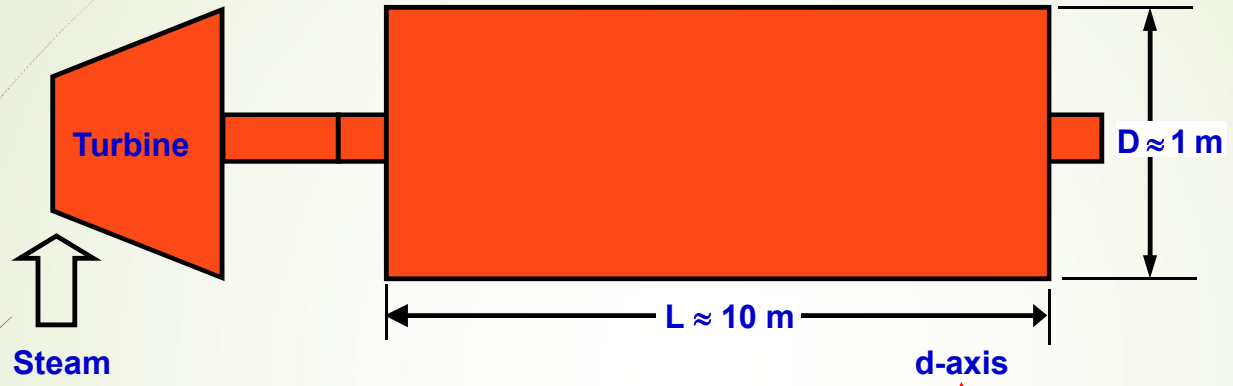
Construction-Rotor

1. Cylindrical (or round) rotor

2. Salient-pole rotor



Synchronous Machine – Cylindrical rotor

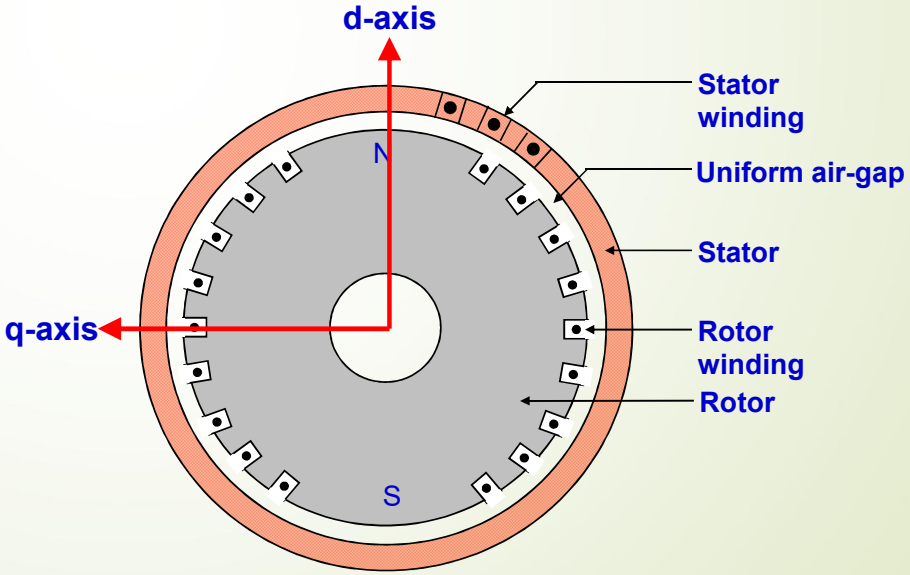


High speed

3600 r/min Þ 2-pole

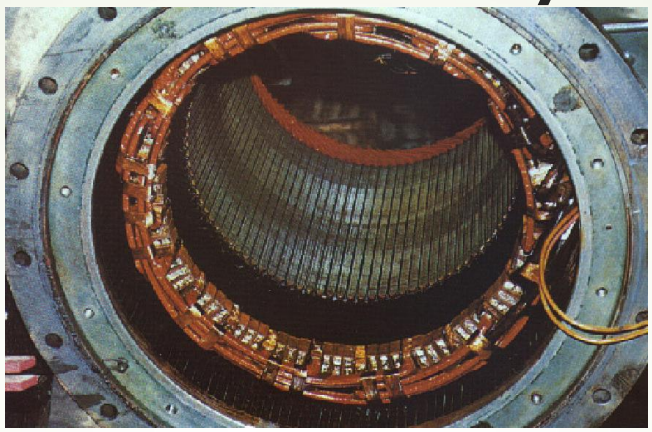
1800 r/min Þ 4-pole

- Direct-conductor cooling (using hydrogen or water as coolant)
- Rating up to 2000 MVA

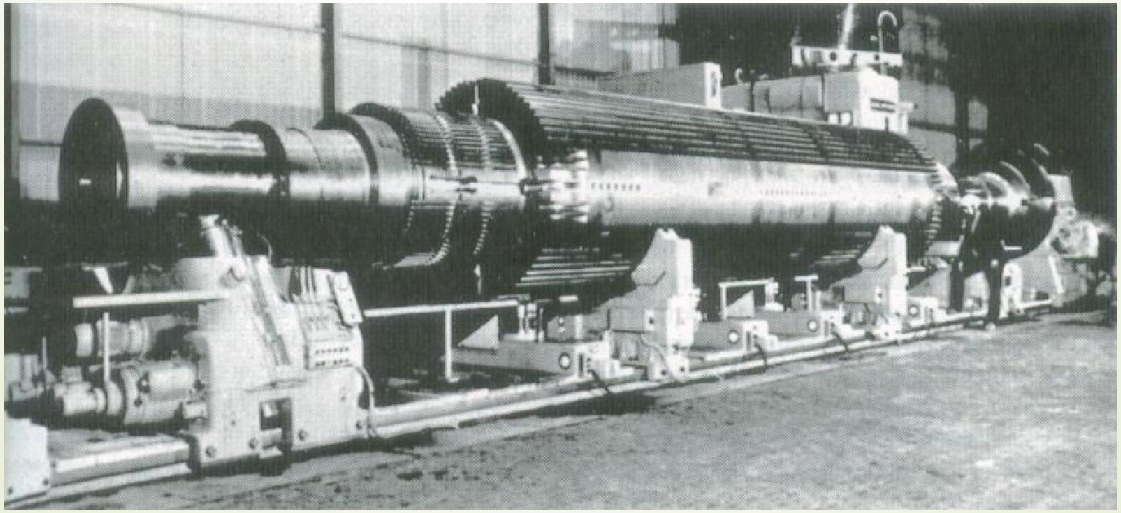


Turbo-generator

Synchronous Machine – Cylindrical rotor



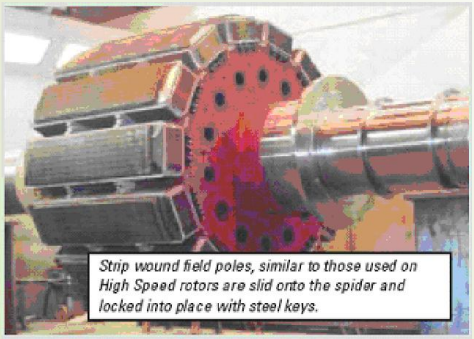
Stator

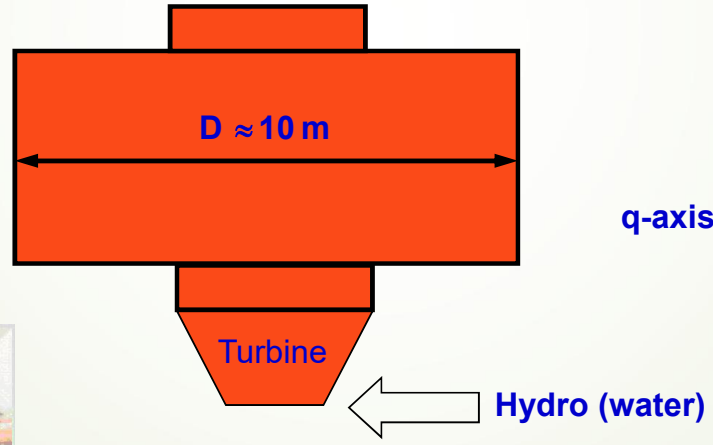


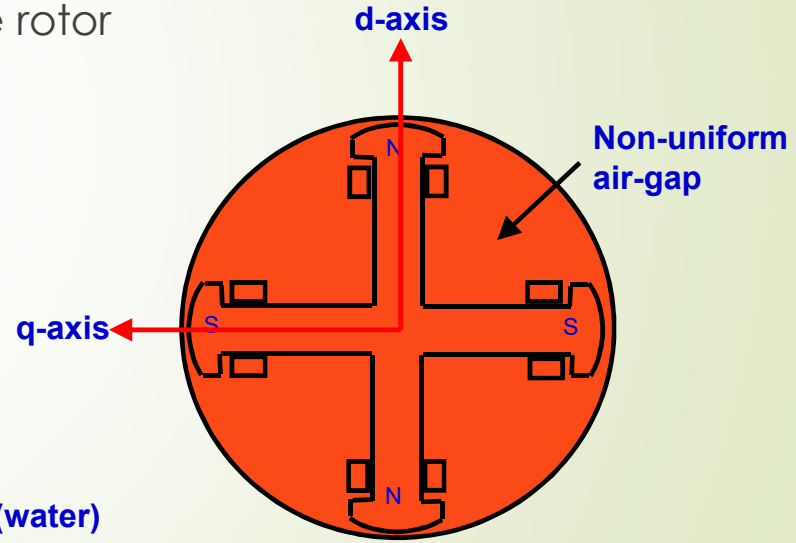
Cylindrical rotor

Synchronous Machine – Salient Pole

- Most hydraulic turbines have to turn at low speeds (between 50 and 300 r/min)
- A large number of poles are required on the rotor

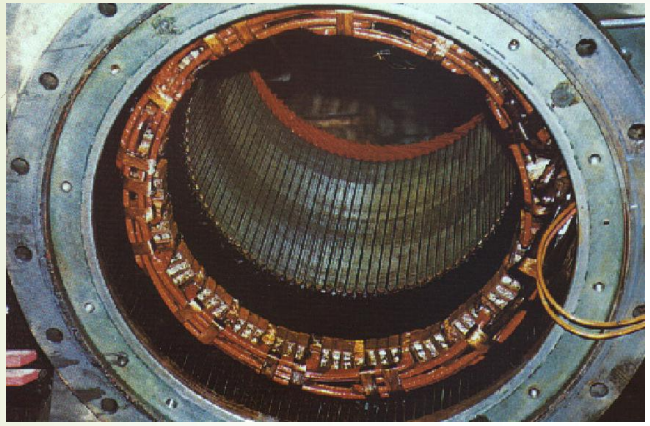




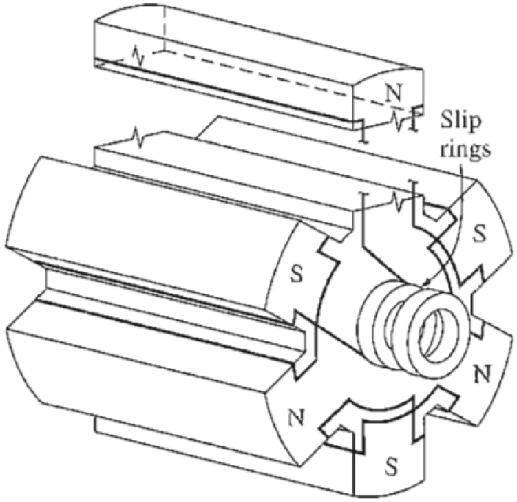


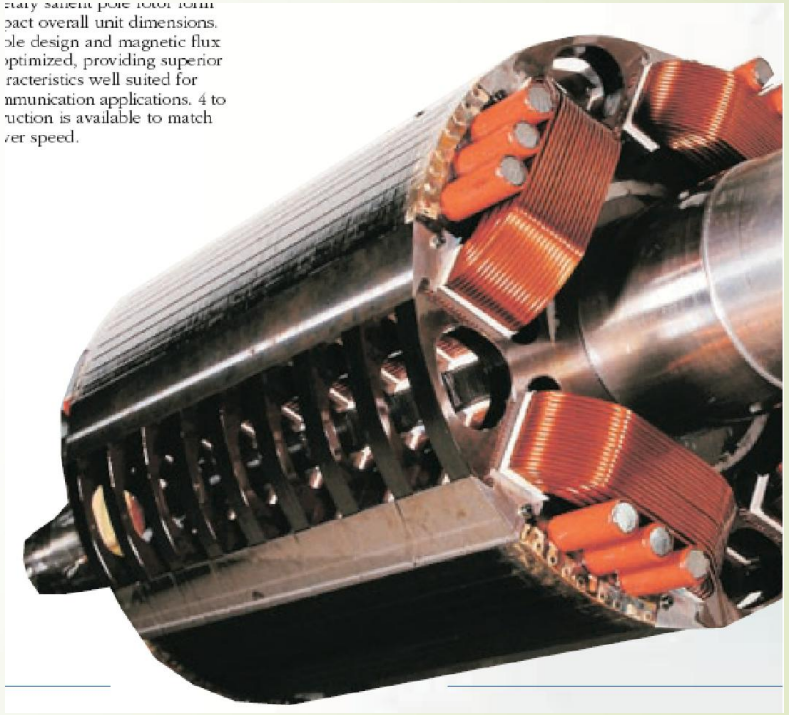
Hydro-generator

Synchronous Machine – Salient Pole



Stator





Salient-pole rotor

Synchronous Machine – Salient Pole

- Synchronous machine rotors are simply rotating electromagnets built to have as many poles as are produced by the stator windings.
- DC currents flowing in the field coils surrounding each pole magnetize the rotor poles.
- The magnetic field produced by the rotor poles locks in with a rotating stator field, so that the shaft and the stator field rotate in synchronism.
- Salient poles are too weak mechanically and develop too much wind resistance and noise to be used in large, high-speed generators driven by steam or gas turbines. For these big machines, the rotor must be a solid, cylindrical steel forging to provide the necessary strength.

Synchronous Machine – Salient Pole

- Axial slots are cut in the surface of the cylinder to accommodate the field windings.
- Since the rotor poles have constant polarity they must be supplied with direct current.
- This current may be provided by an external dc generator or by a rectifier.
  - In this case the leads from the field winding are connected to insulated rings mounted concentrically on the shaft.
  - Stationary contacts called brushes ride on these slip rings to carry current to the rotating field windings from the dc supply.
  - The brushes are made of a carbon compound to provide a good contact with low mechanical friction.
  - An external dc generator used to provide current is called a " brushless exciter ".