Day 35

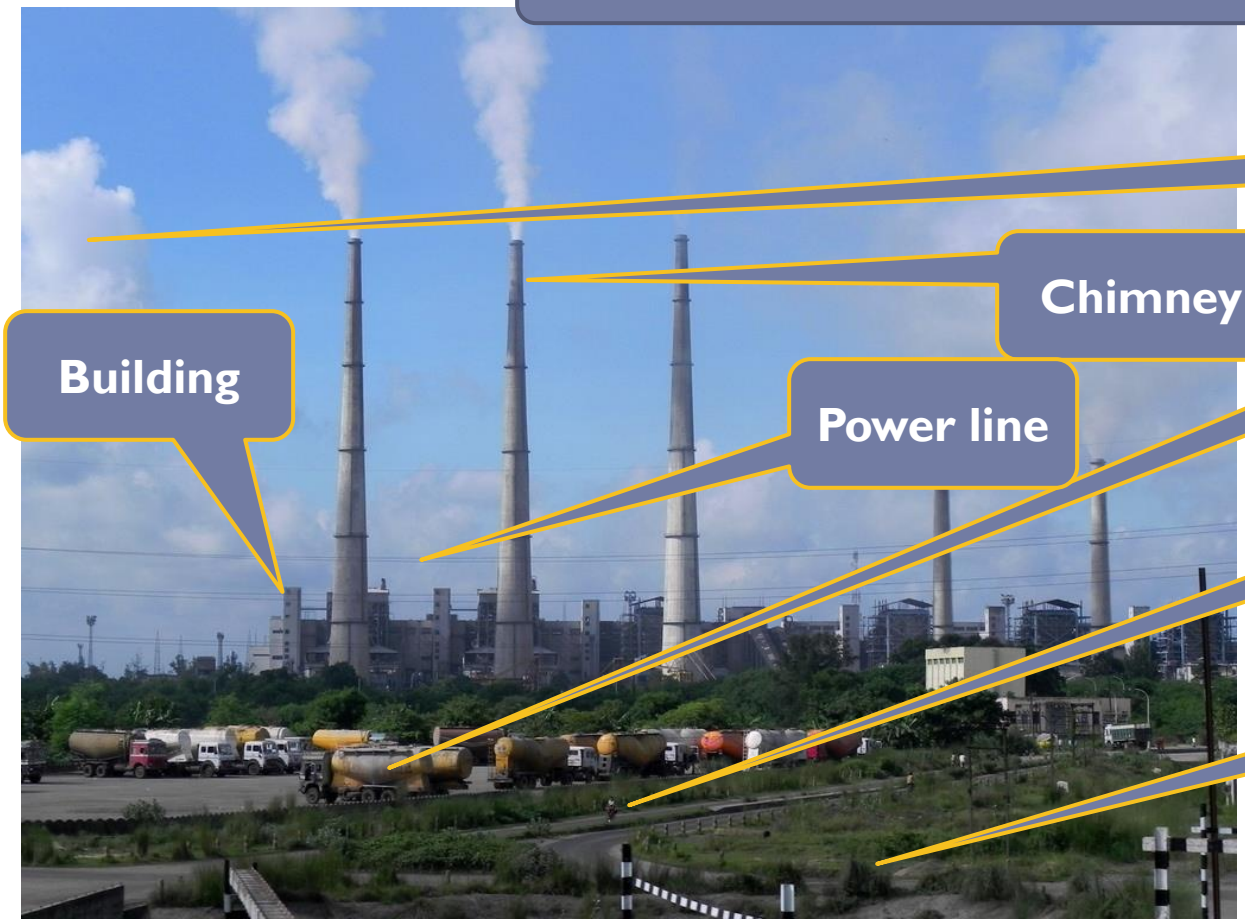
Synchronous Generators or Alternators

ILOs

- Introduction
- Operation
- Construction

Synchronous Generator (Alternator)

What components can you identify of this photo?



Thermal power plant

duce?

- Electricity

C or

- A

1-Ph or 3

- 3-ph

put energy ?

- Mecha

Prime

- Steam turbine

Alternator converts input mechanical energy to output electrical energy

Synchronous Generator (Alternator)

Hydro power plant

What do they produce?

- Electricity

DC or AC?

- AC

1-Ph or 3-ph ?

- 3-ph

Input energy ?

- Mechanical rotation

Prime mover?

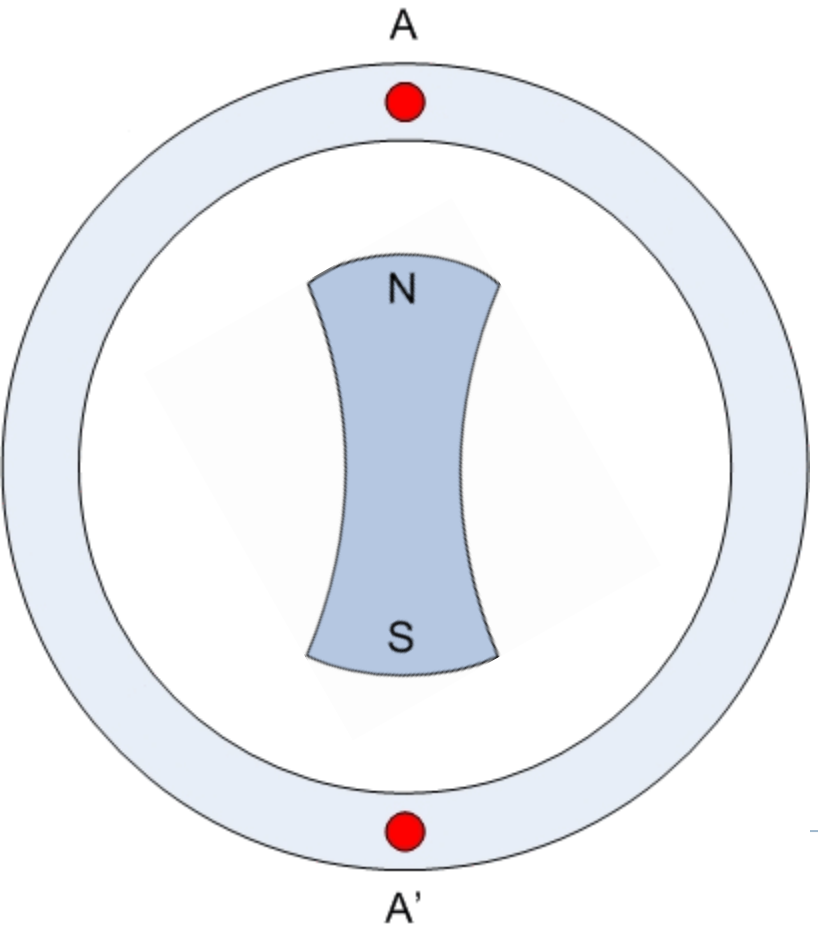
- Water turbine

Alternator converts input mechanical energy to output electrical energy

- **Operation of synchronous generator**

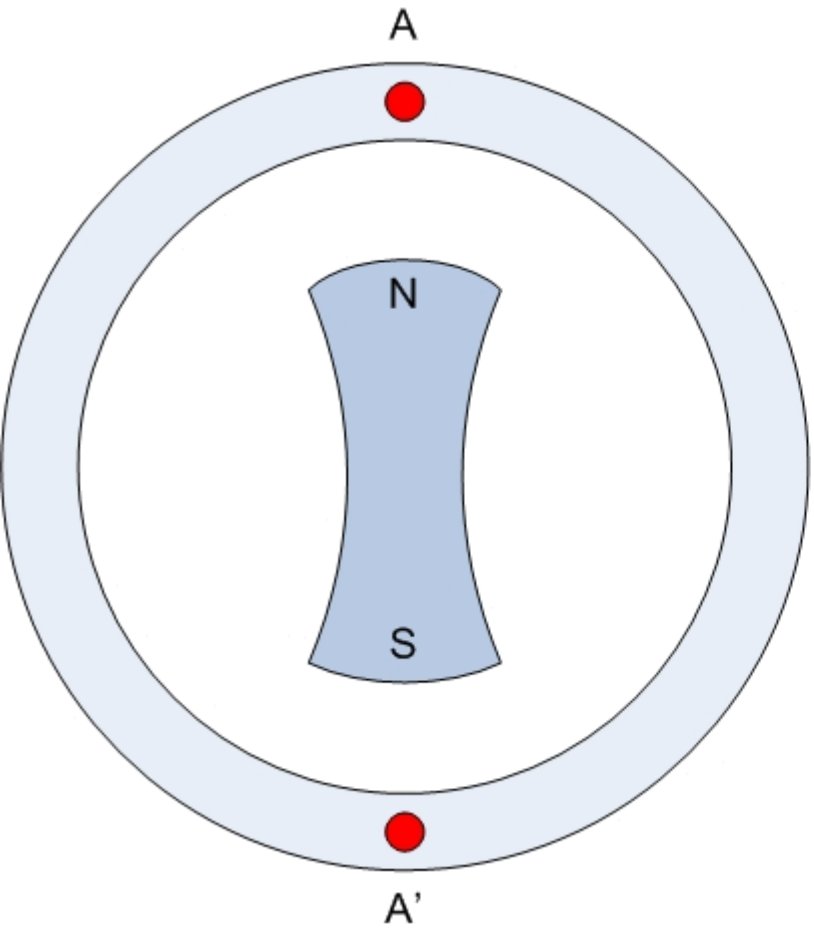
Generation of AC signal in alternator

- One coil in the stator (outer hollow cylindrical static part) A-A'
- Pair of permanent magnets in rotor
- Rotor rotated by external mechanical force (prime mover)



Generation of AC signal in alternator

- EMF is induced in stator coil ($d\phi/dt$)

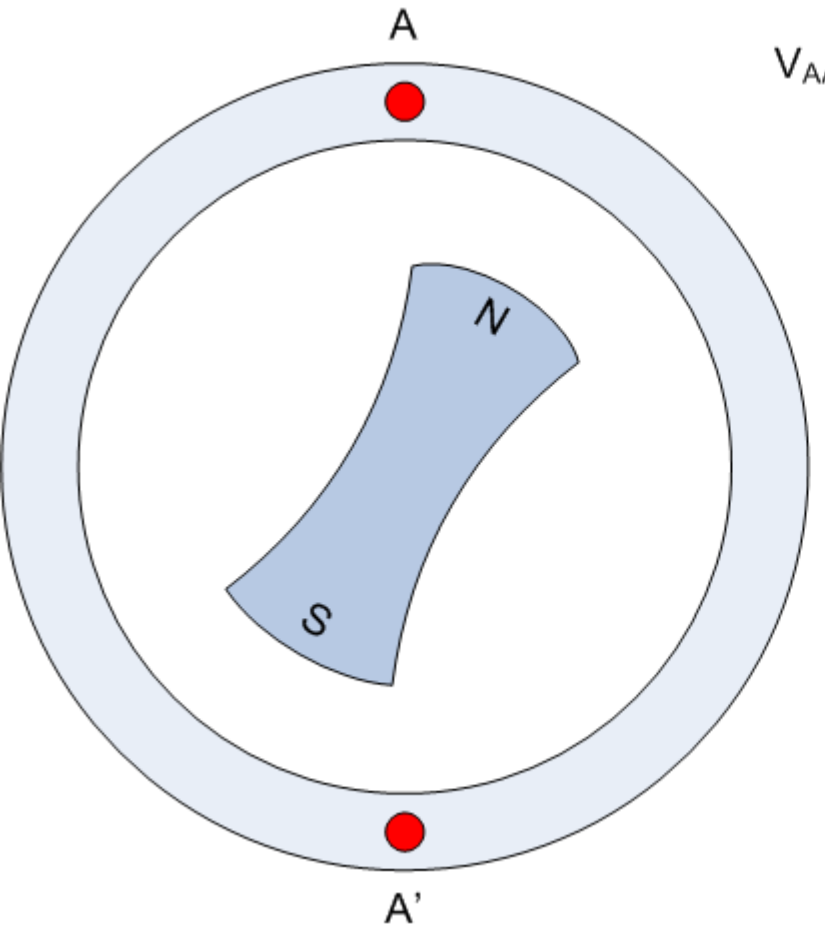


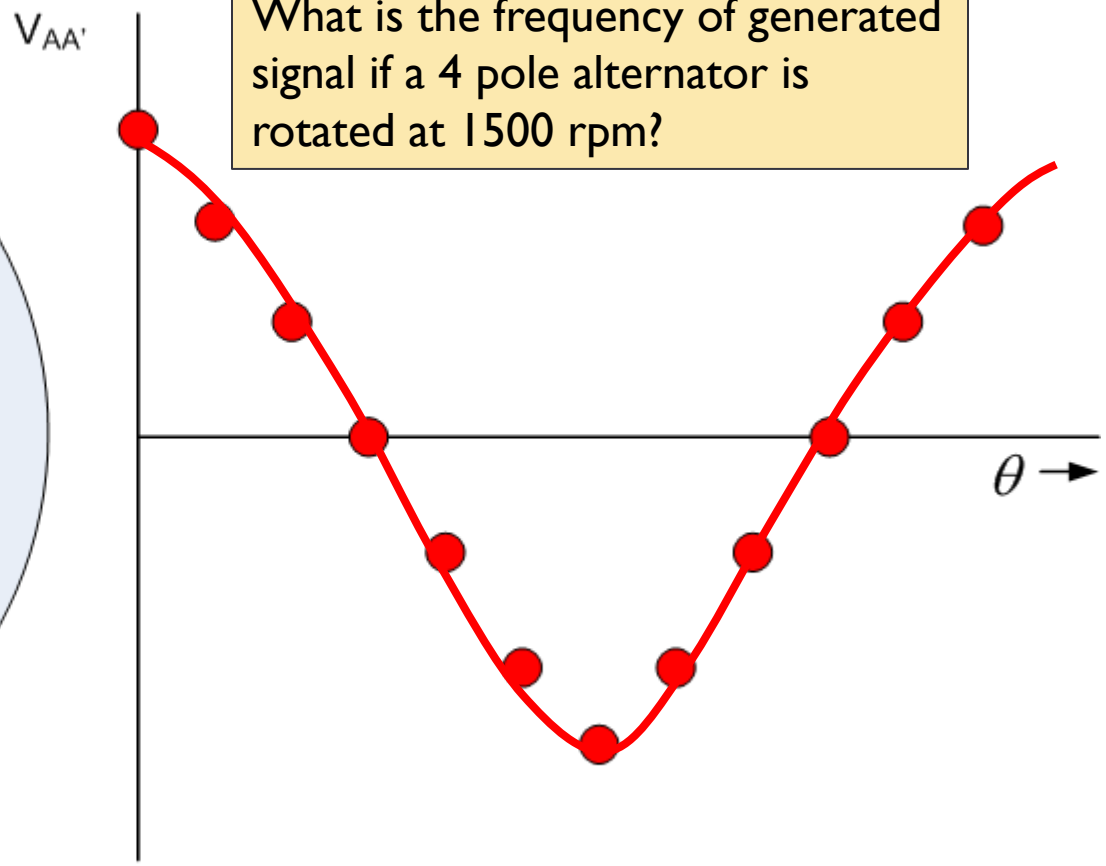
Generation of AC signal in alternator

EMF is sinusoidal $e_A = E_m \sin\theta = E_m \sin\omega t$

$$\omega = 2\pi f$$

$$N_S = \frac{120\,f}{P}$$

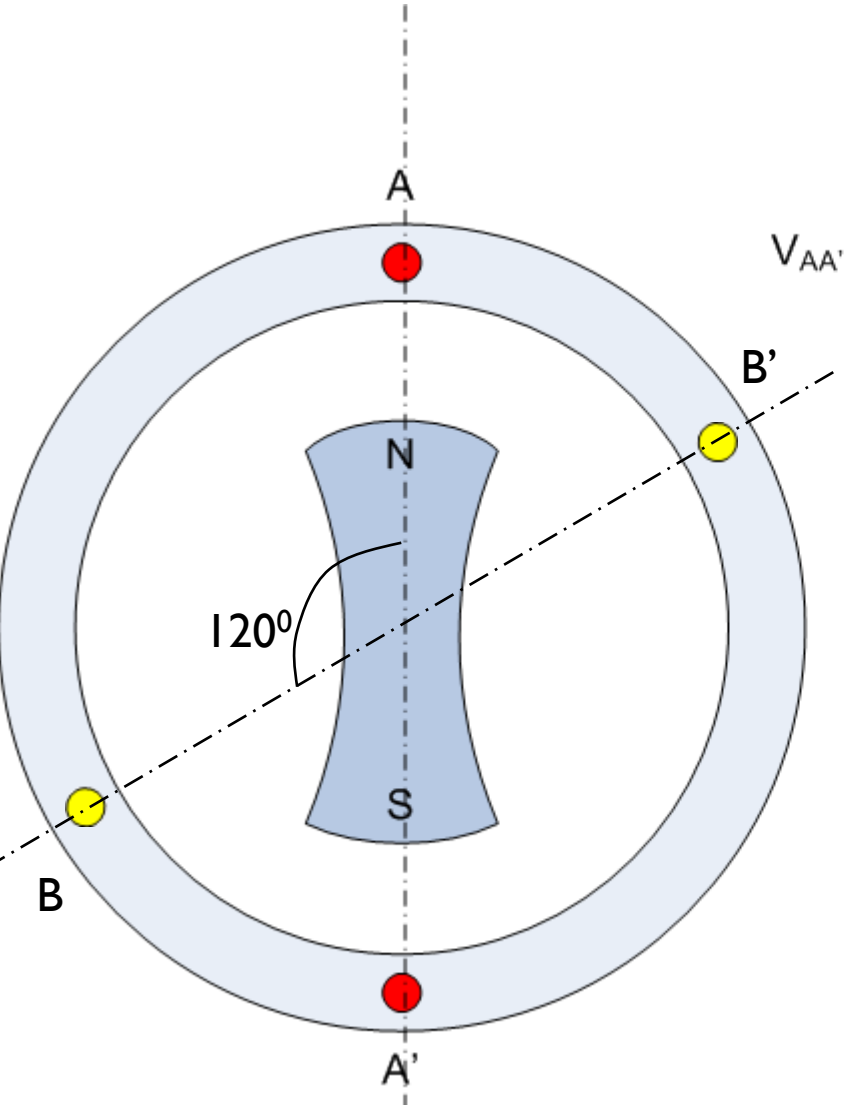


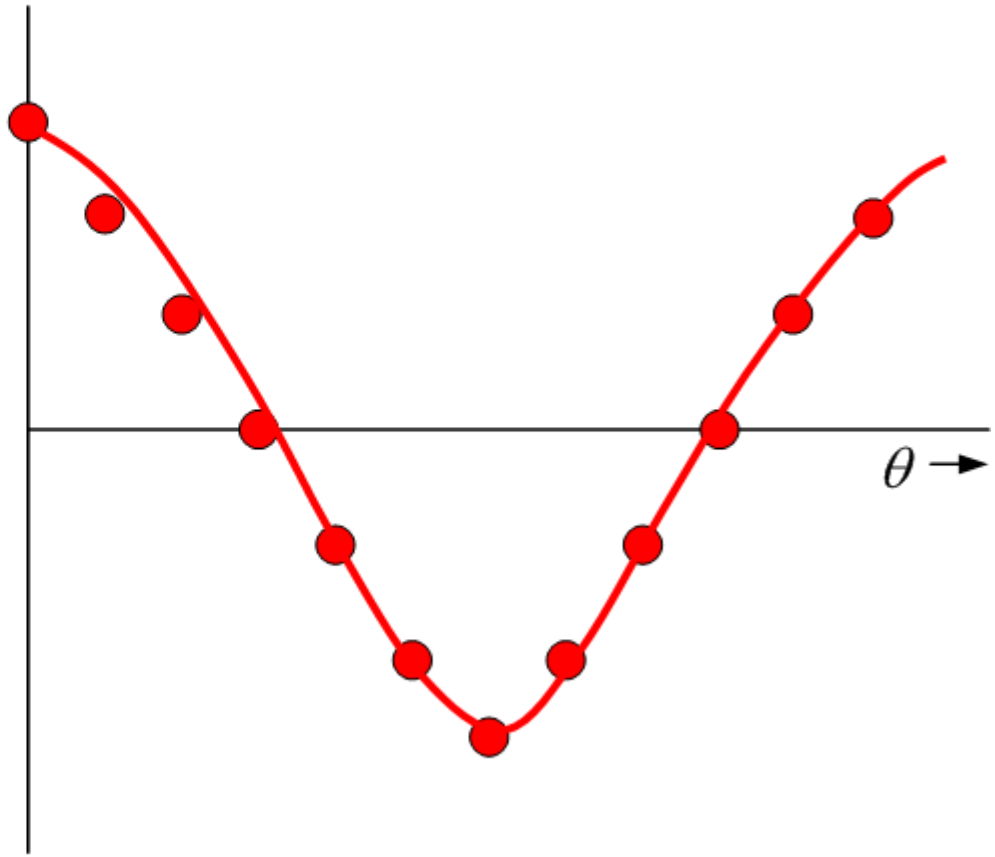


What is the frequency of generated signal if a 4 pole alternator is rotated at 1500 rpm?

Generation of 3-phase AC signal

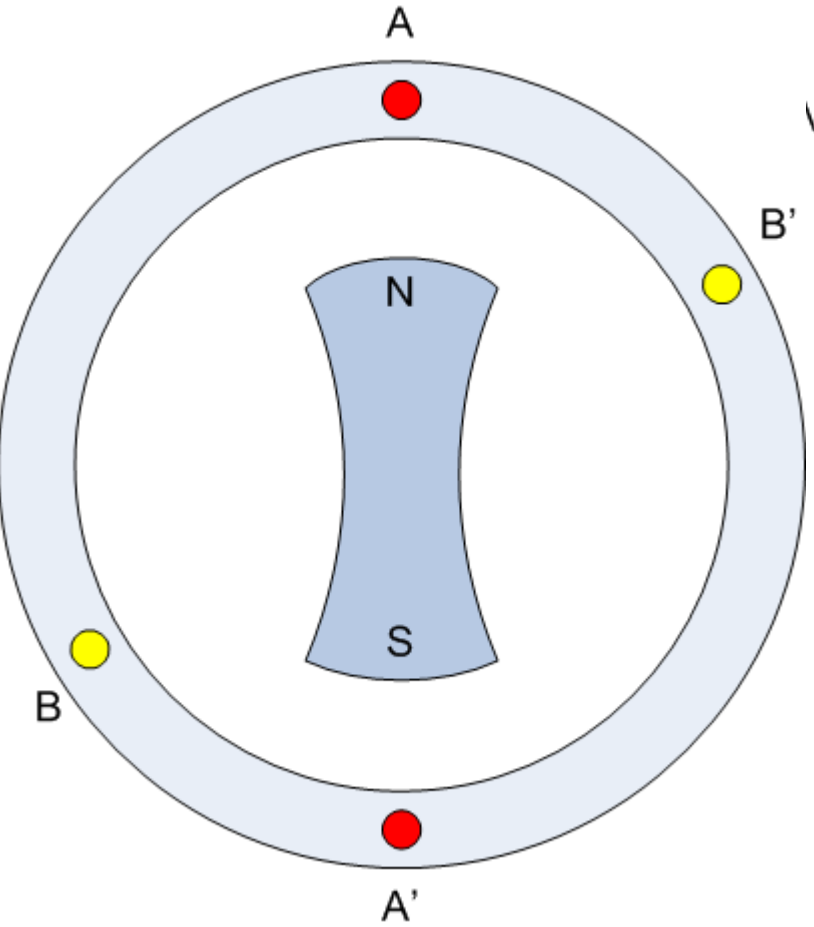
Put a second coil B-B' 120^0 after A-A'

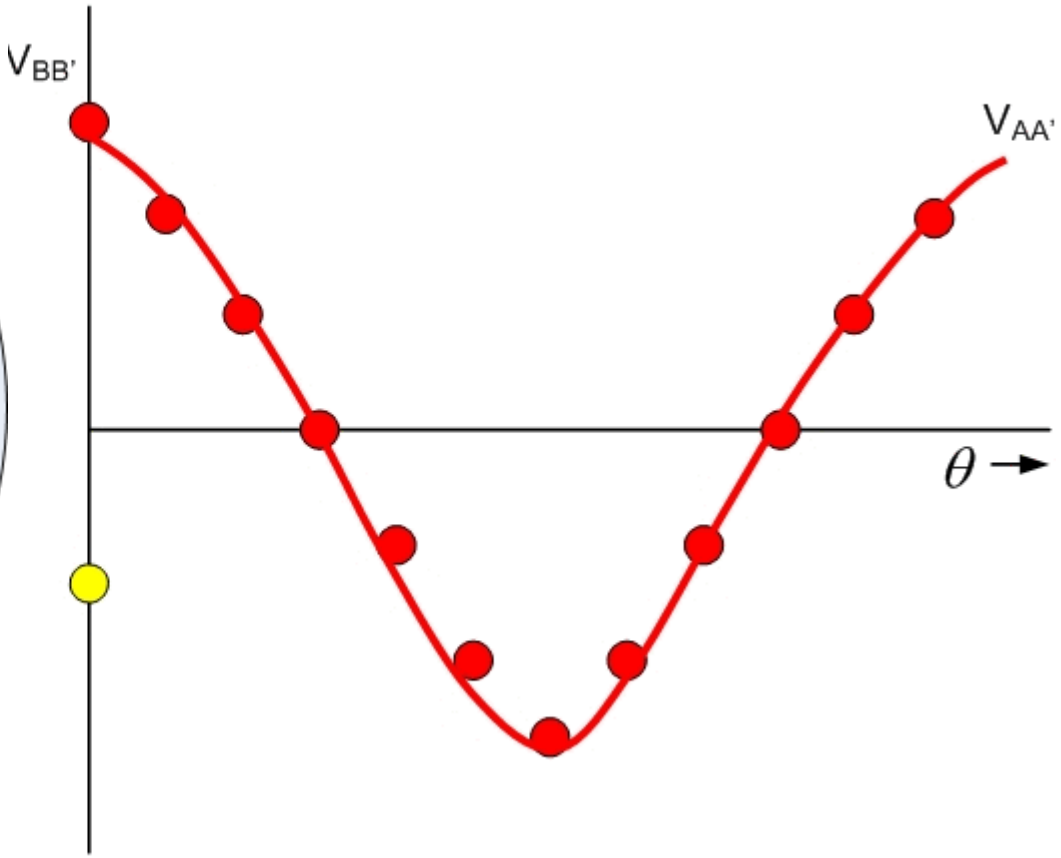




Generation of 3-phase AC signal

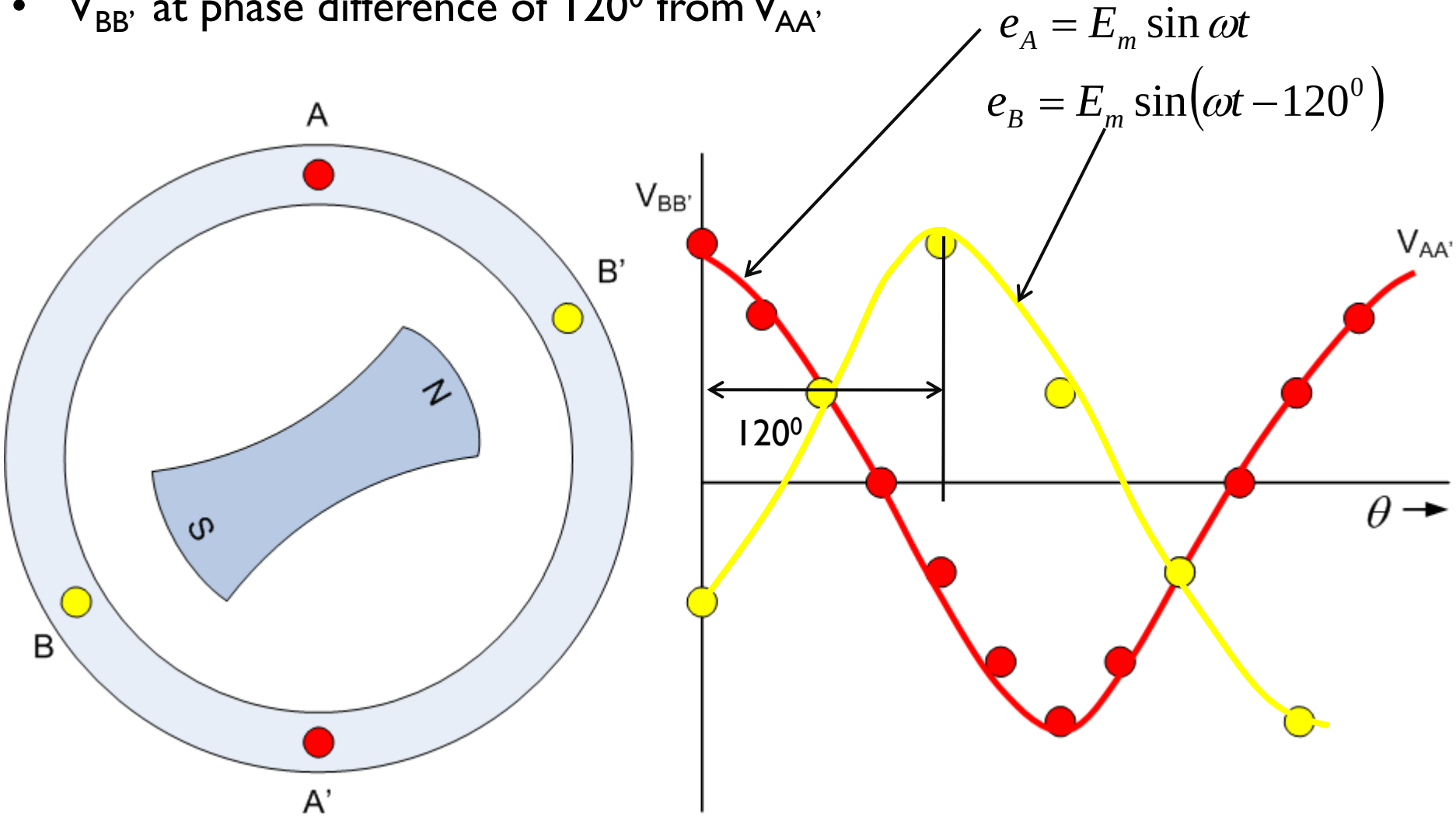
- B-B' will also have sinusoidal induced EMF $V_{BB'}$
- But $V_{BB'}$ will come after 120^0 of $V_{AA'}$ (phase difference of 120^0 from $V_{AA'}$)





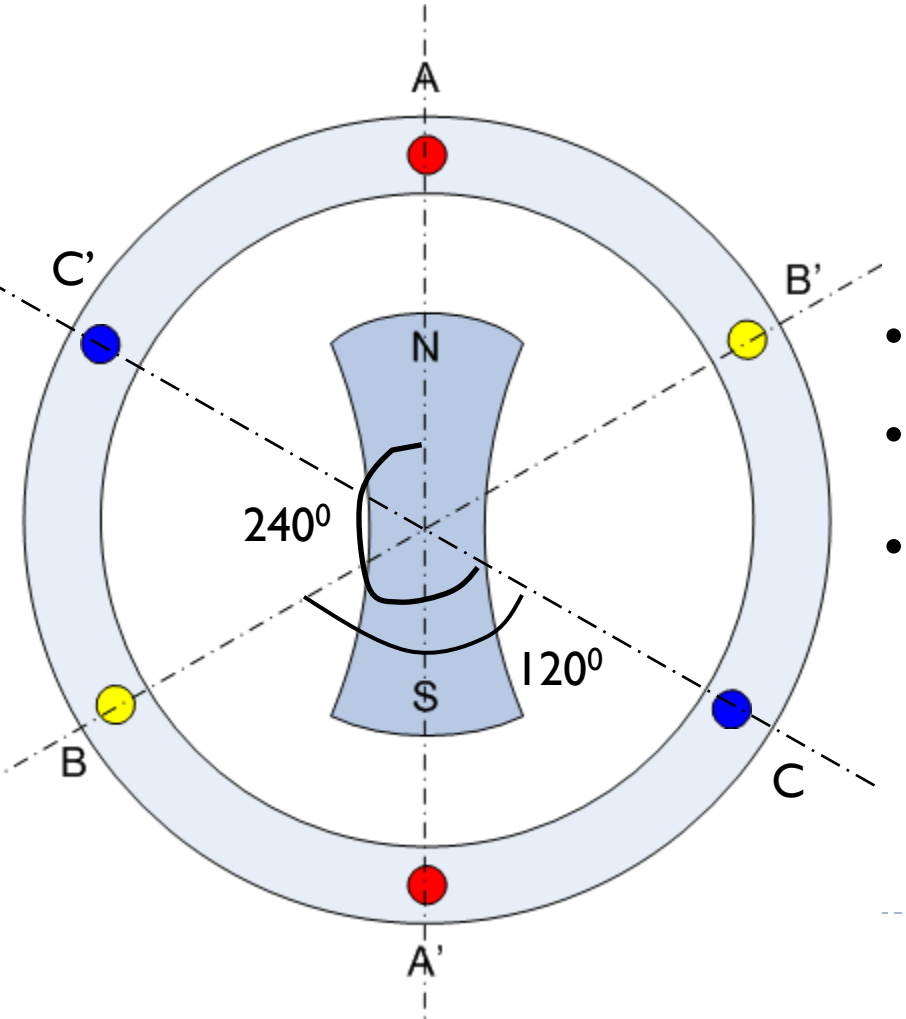
Generation of 3-phase AC signal

- $V_{BB'}$ at phase difference of 120^0 from $V_{AA'}$



Generation of 3-phase AC signal

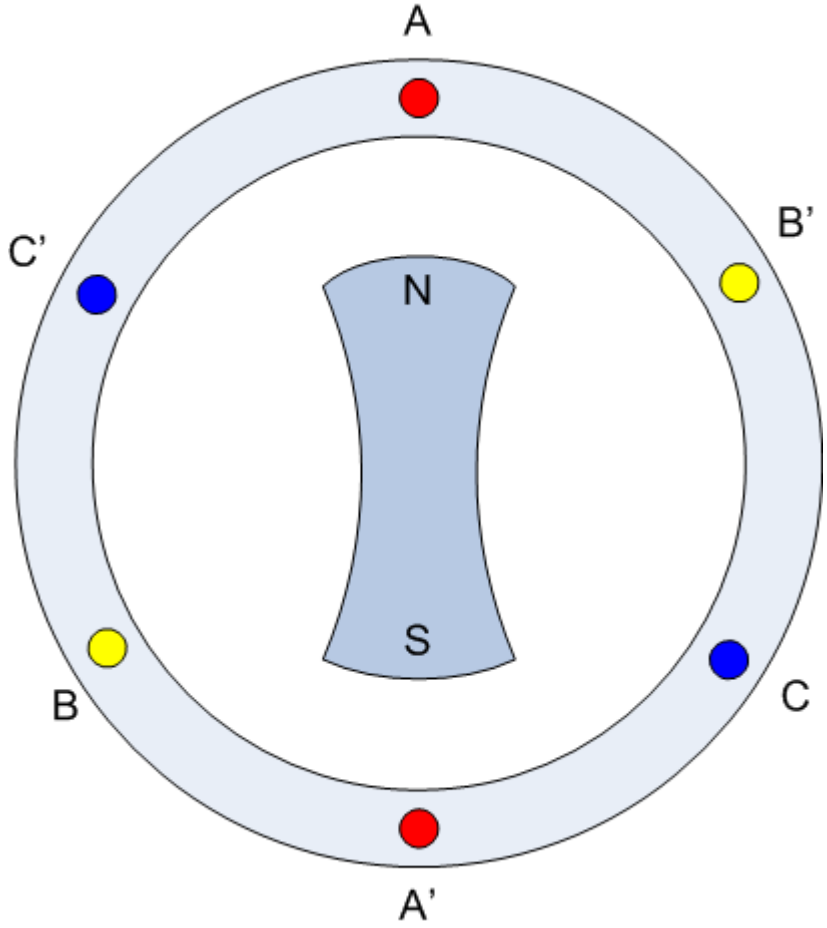
- Now have a 3rd Coil C-C' that will be 120^0 after B-B'

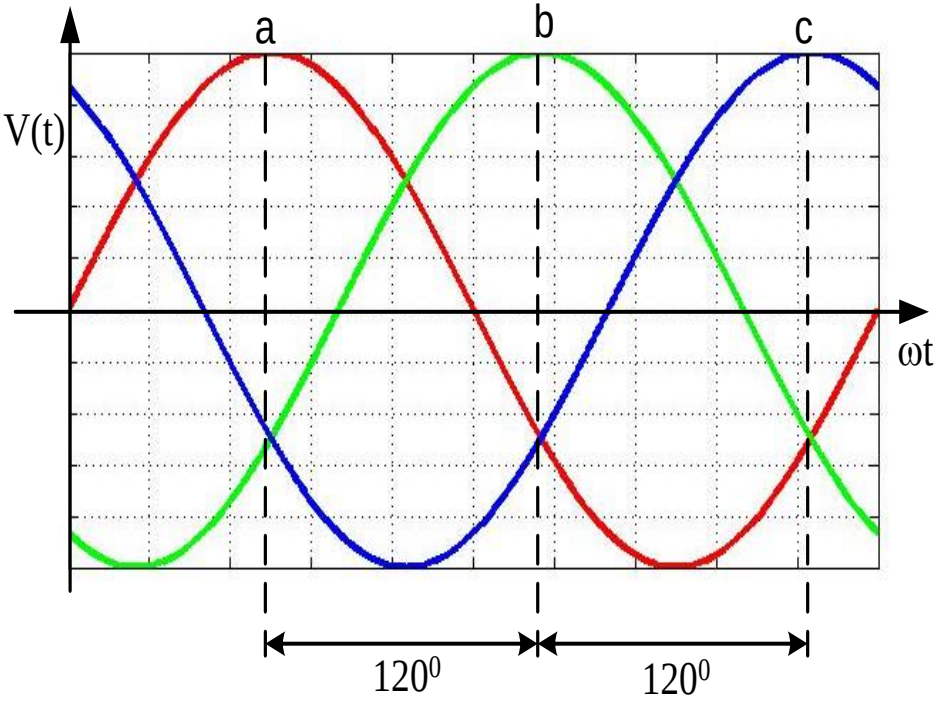


- C-C' will also have similar induced EMF
- With phase difference of 120^0 from $V_{BB'}$
- i.e. phase difference of 240^0 from $V_{AA'}$

Generation of 3-phase signal

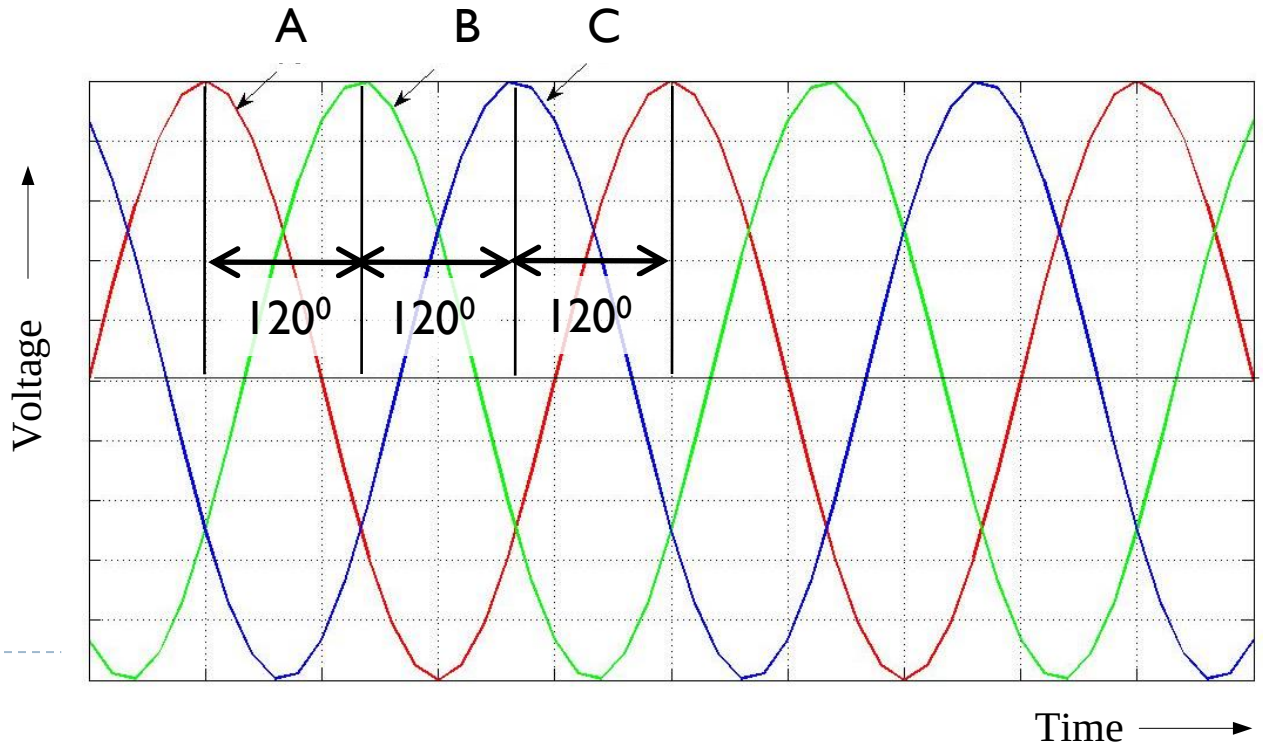
$$e_A = E_m \sin \omega t \qquad e_B = E_m \sin\left(\omega t - 120^0\right) \qquad e_C = E_m \sin\left(\omega t - 240^0\right)$$



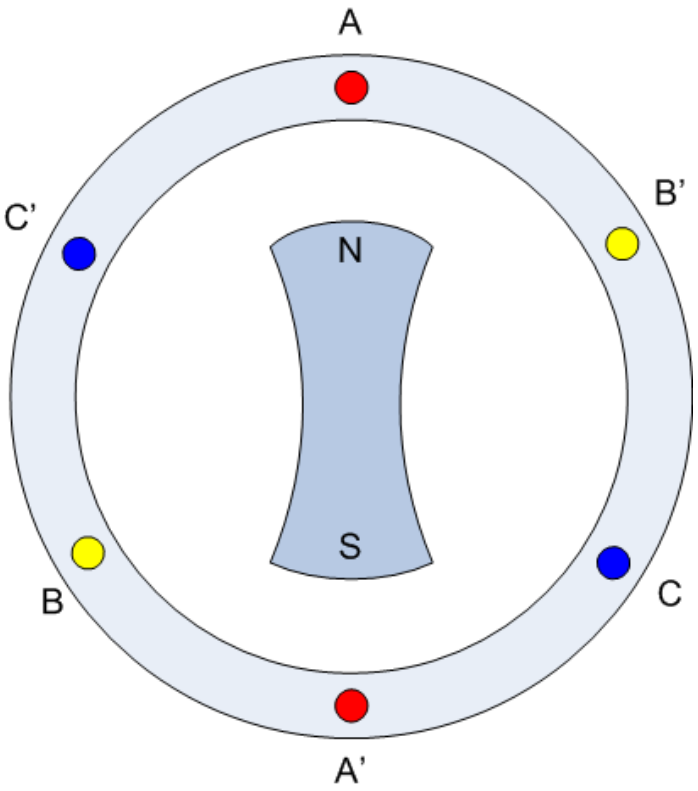


Three phase signal

- 3-phase balanced signal (voltage or current)
- Same magnitude in all three phases
- Same frequency of all three signals
- Phase angle 120^0 between them

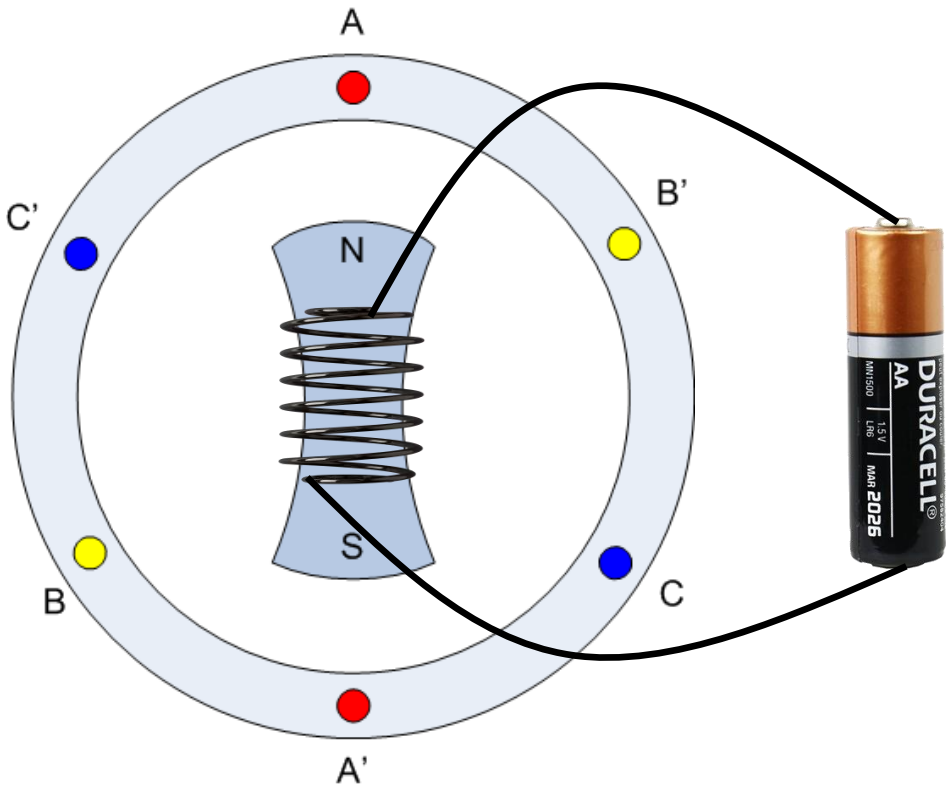


Summary so far..



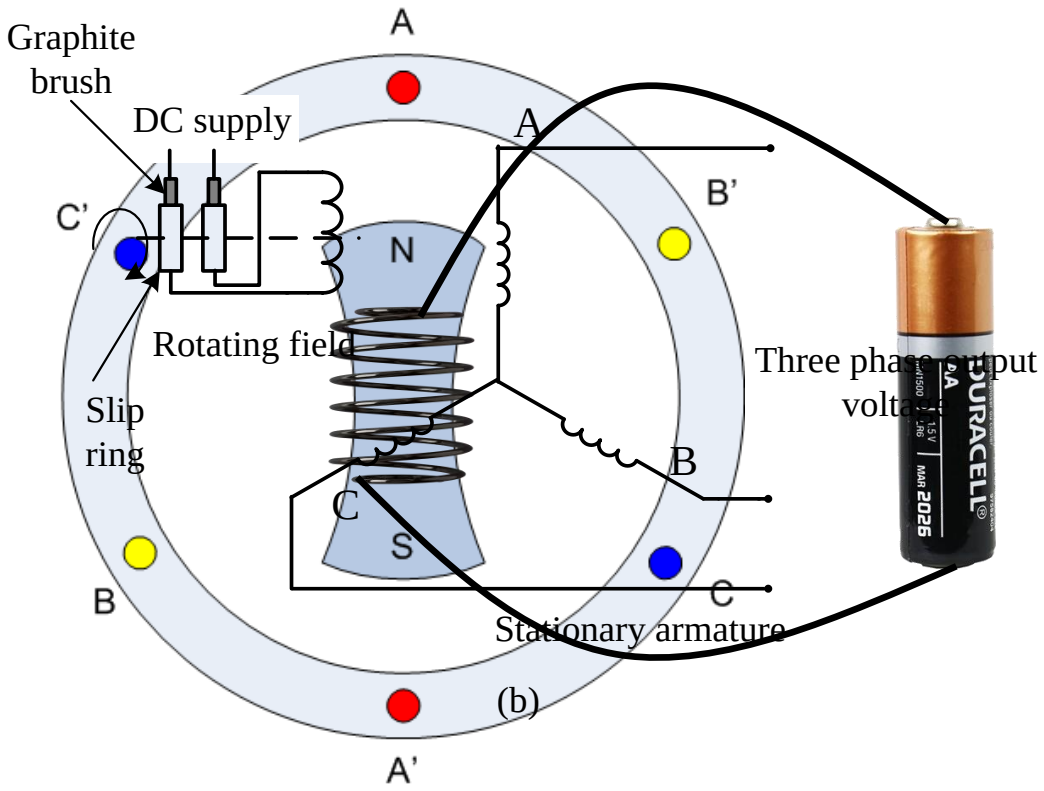
- Stator (armature) has 3 coils
- Magnet (field system) is placed in the rotor
- Rotor rotated by prime mover
- Stator coils produce 3-phase AC signal

Construction



- Small alternators can have permanent magnets in rotor
- But bigger machines need to have electromagnets in the rotor (big permanent magnets are very costly)
- These electromagnets are to be supplied from a DC source

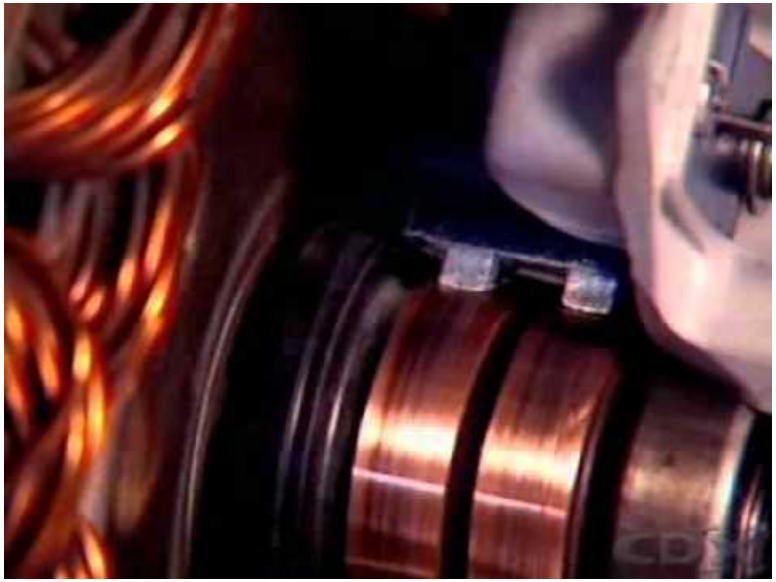
Construction

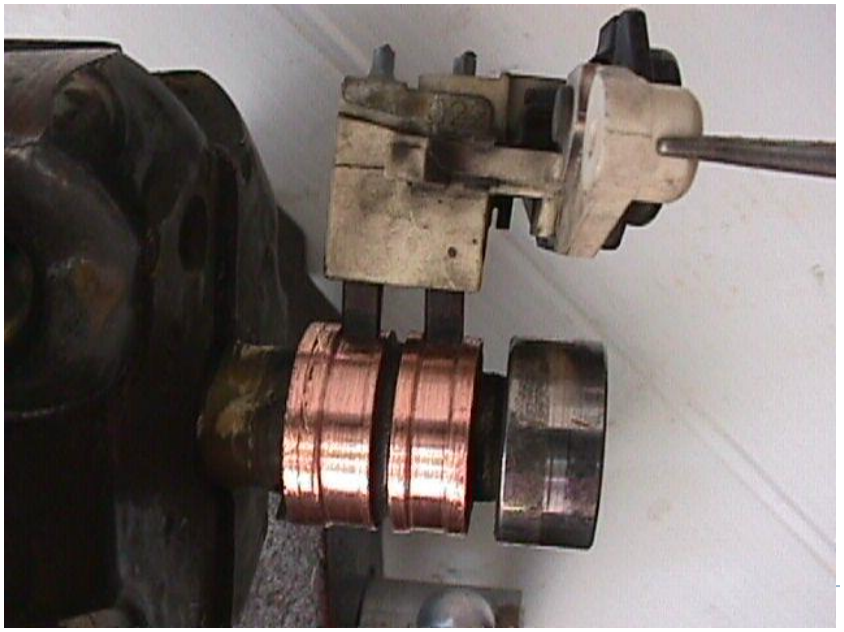


- Supplying a rotating winding in the rotor
- From an external static DC source
- Require slip rings and brushes
- How many slip rings?
  - Two
- How many brushes?
  - Two

Slip ring & brush

- Slip ring – brass
- Brush – Carbon or graphite





Demo video

Constructional details of synchronous machine

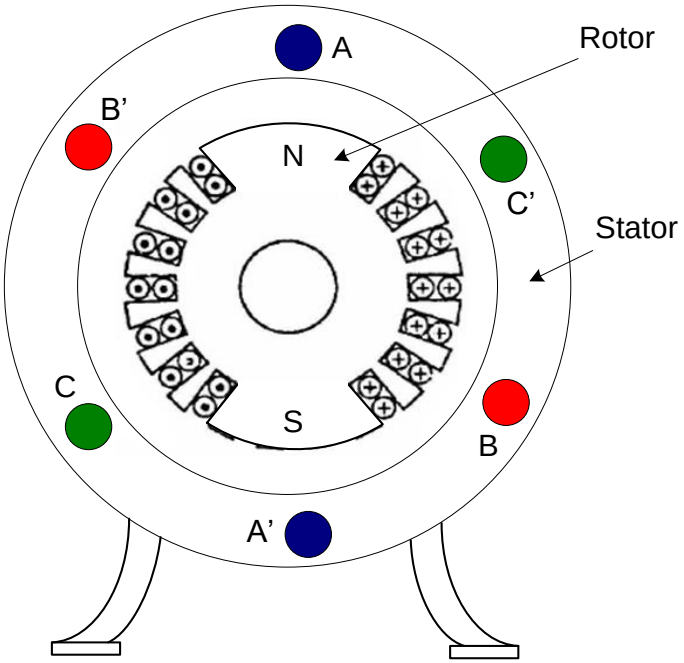
- Rotor construction
- Stator construction

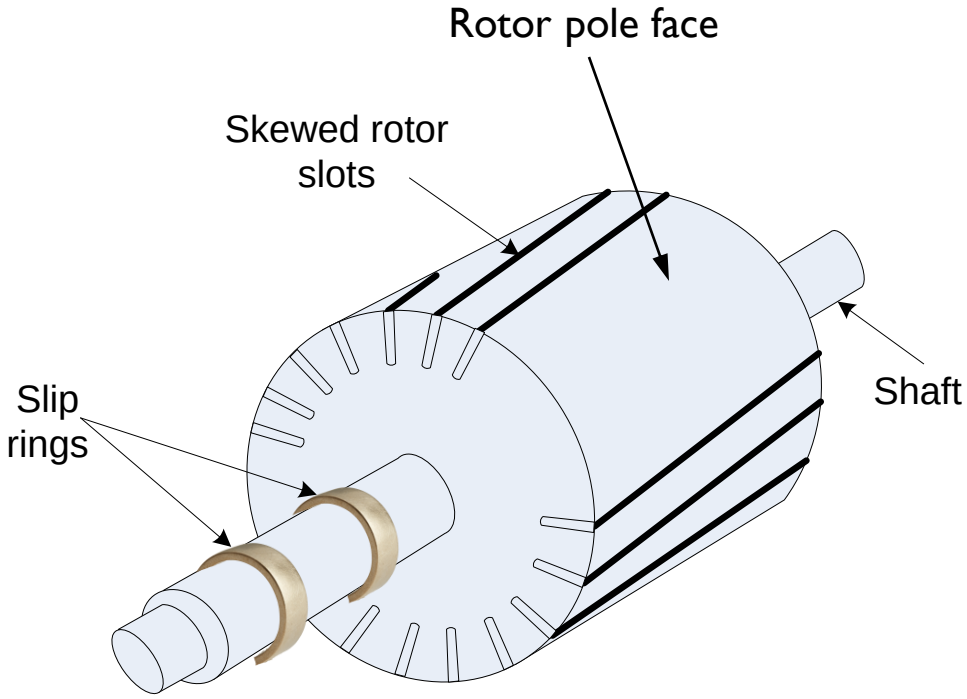
Synchronous machine rotor

- Rotor is an electromagnet
  - Cylindrical rotor
  - Salient pole type rotor

Cylindrical rotor (CR)

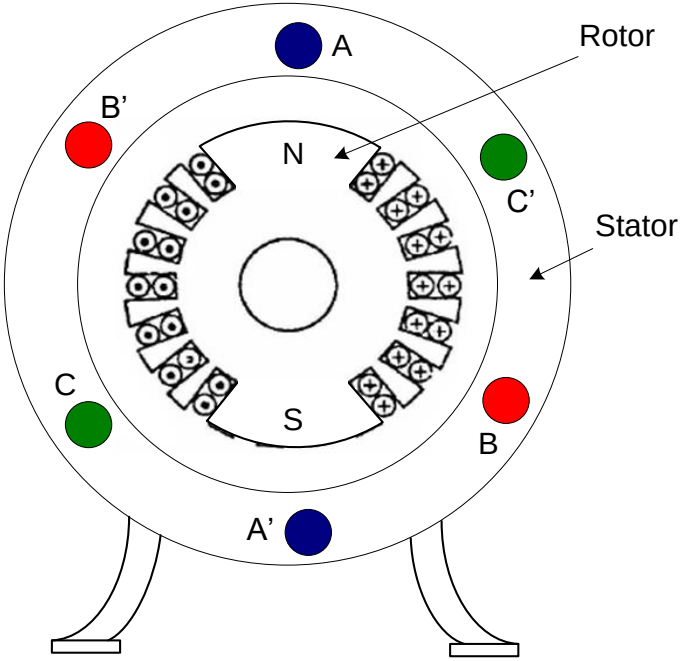
- Rotor is cylindrical in shape
- Air gap between stator and rotor is uniform all around
- Slots are punched around the rotor surface to place the field coils

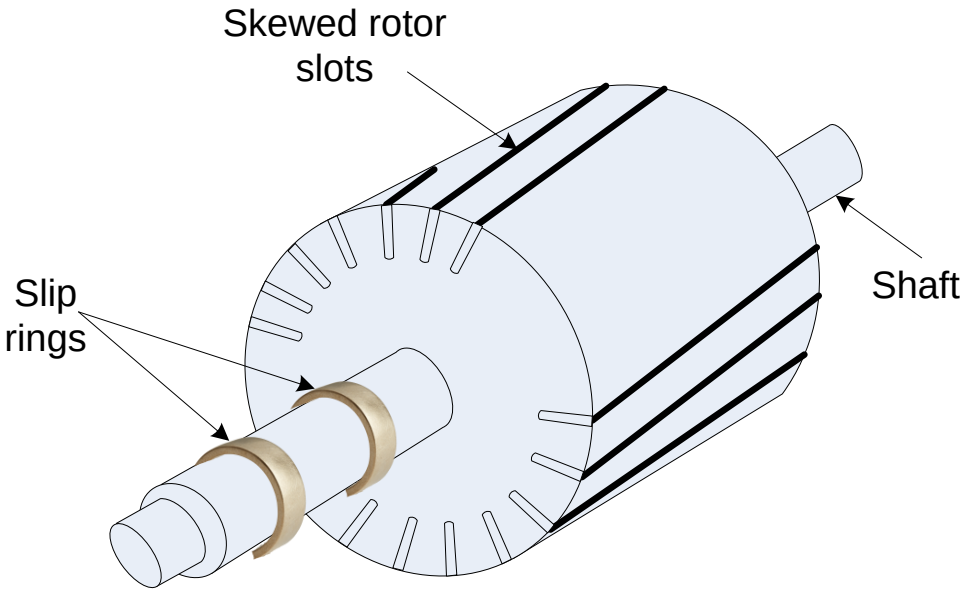




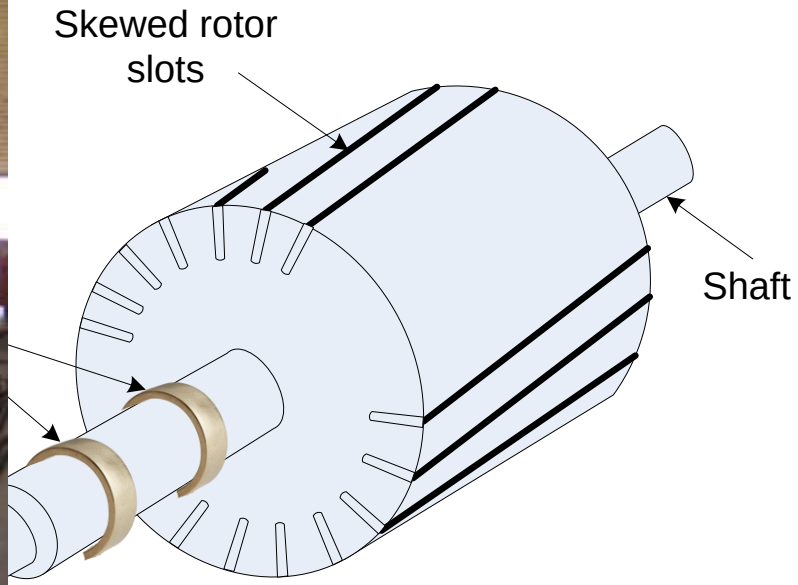
Cylindrical rotor (CR)

- Smooth surface allows it to rotate at very high speed with less friction
- CR machines are hence used in gas or steam turbine power plants that are meant to rotate at very high speeds (How much speed?)
- Rotor material is made of strong solid steel (Chromium–Nickel-Molybdenum steel) to handle the resulting high centrifugal force



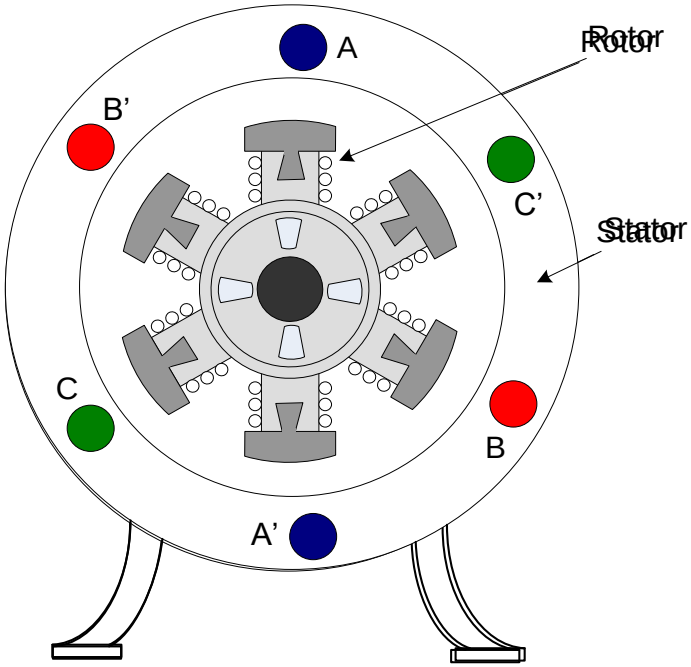


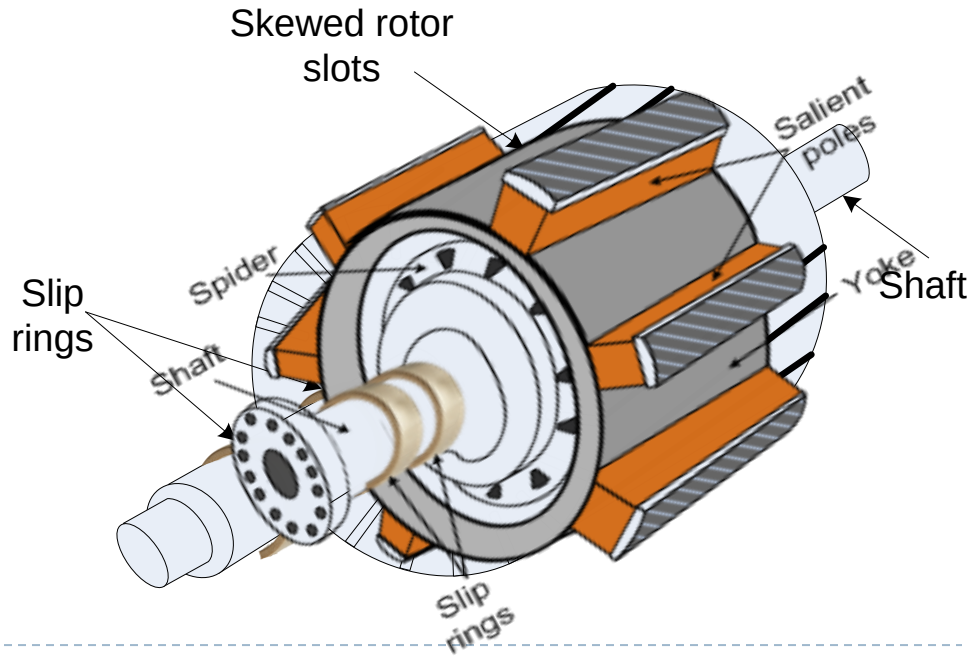
Cylindrical rotor (CR)



Salient pole (SP) type

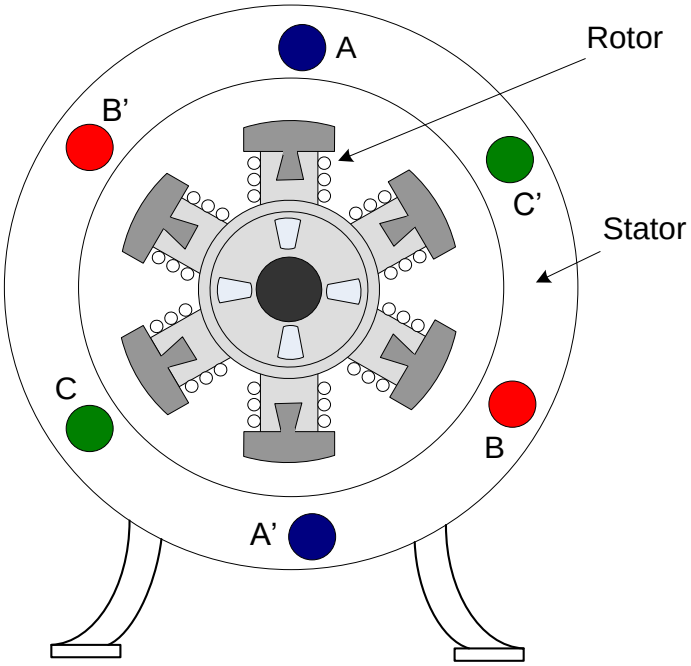
- Rotor poles are projected out from the rotor surface
- Due to saliency of the poles, the air gap between stator and rotor is not uniform at all positions

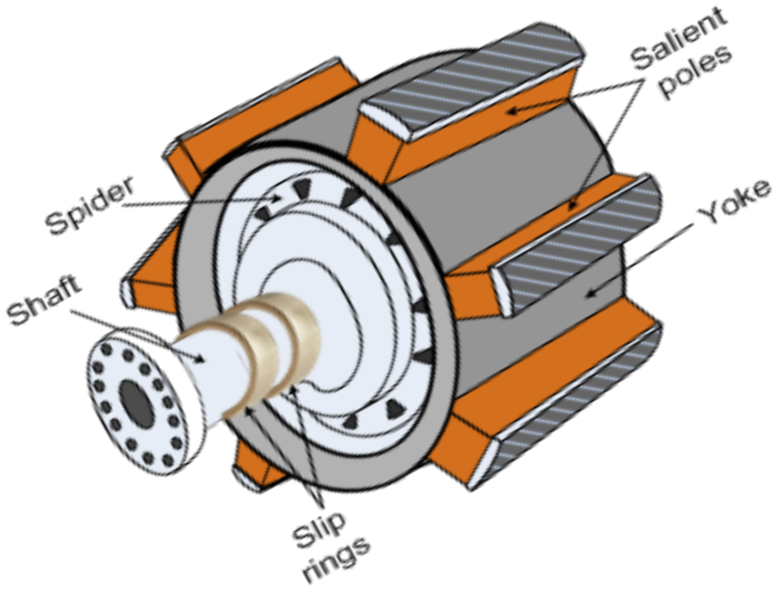




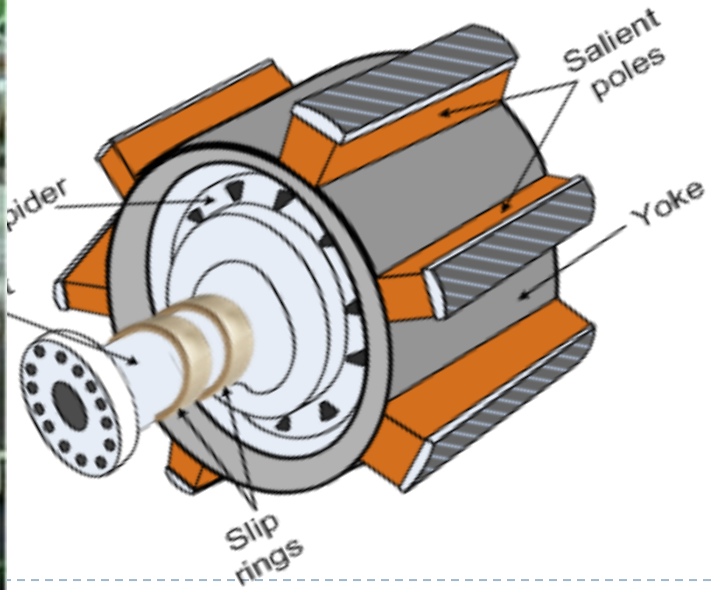
Salient pole (SP) type

- Uneven rotor surface does not allow high speed
- SP machines are hence used in hydro power plants where the turbine speed is low (How much speed?)



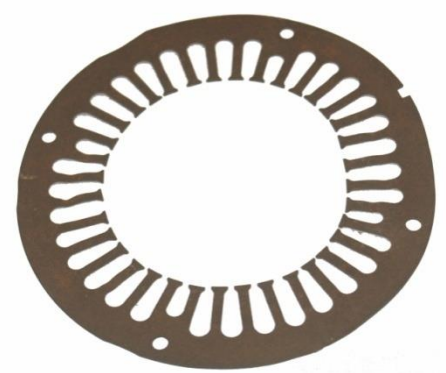


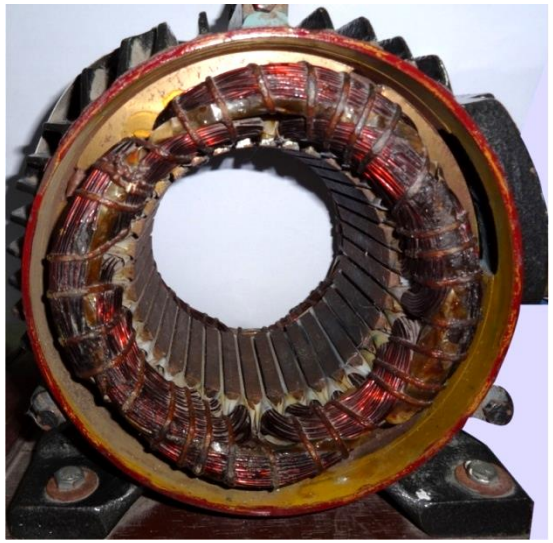
Salient pole (SP) type

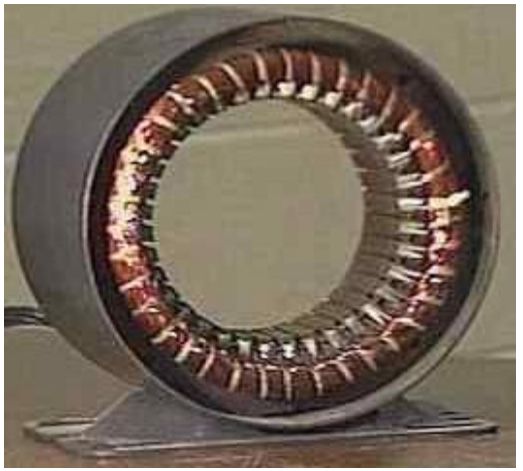


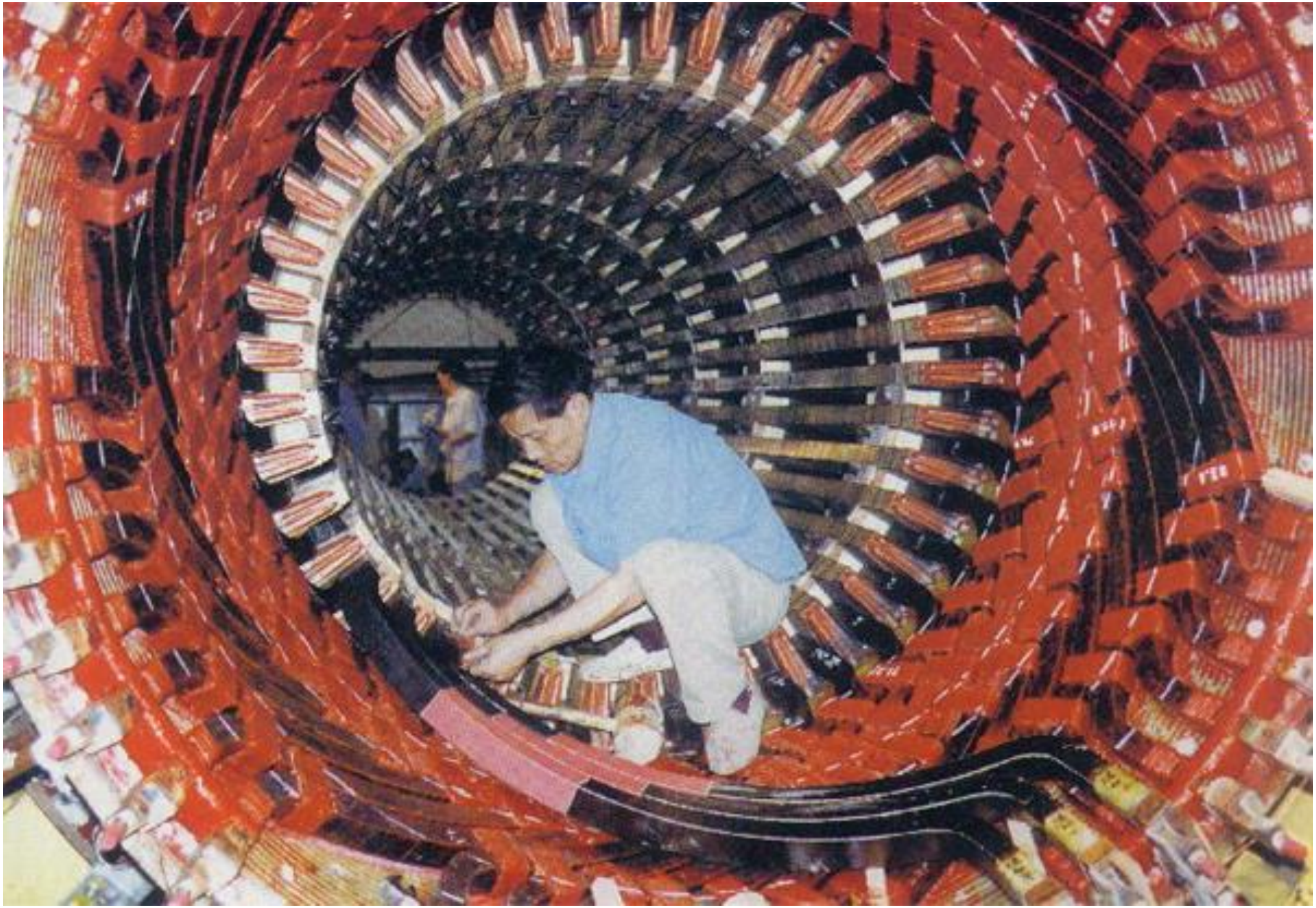
Synchronous machine stator

- Houses the 3-phase armature winding
  - Windings are placed inside slots around stator inner periphery
  - Good quality laminated Si-steel
    - Reduce Hysteresis and Eddy current losses









Activity

- The field of a synchronous generator is excited by
  a) AC supply
  b) DC supply
  c) Either by AC or by DC supply
  d) Composite of AC and DC supply