# ELEC0431 : Exercise session 5

# Synchronous machine

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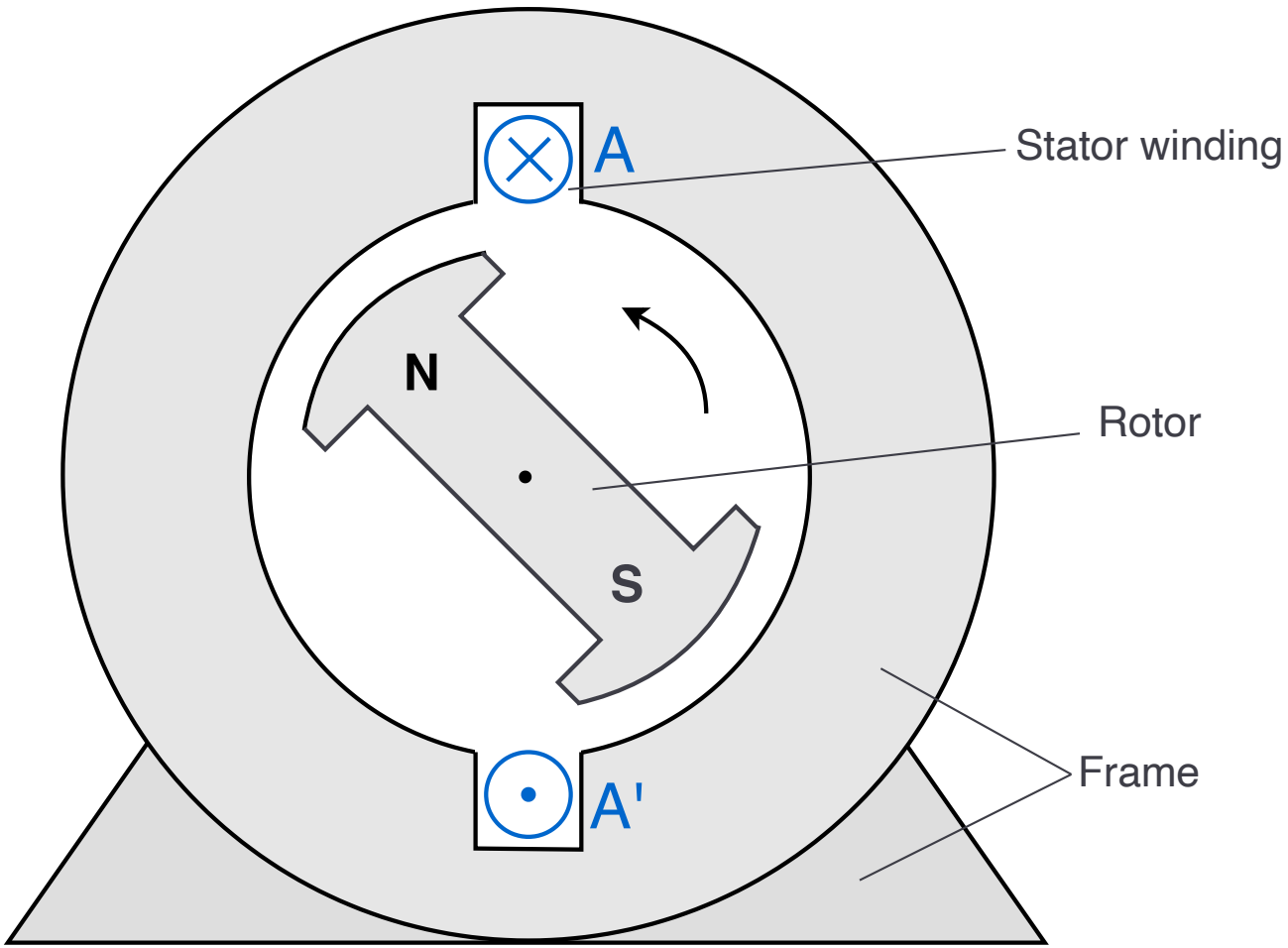
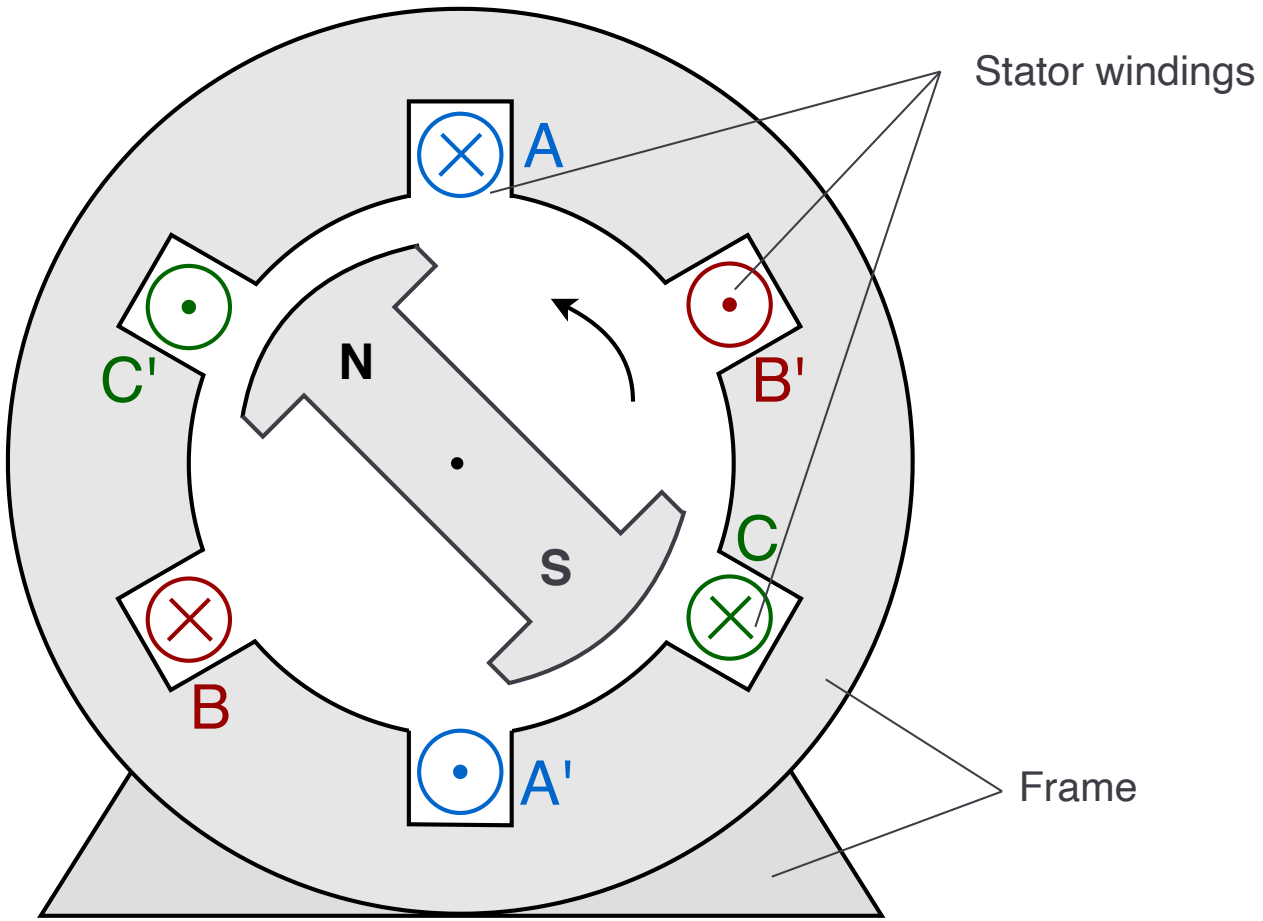
# Building of synchronous machines

## Single-phase synchronous machine



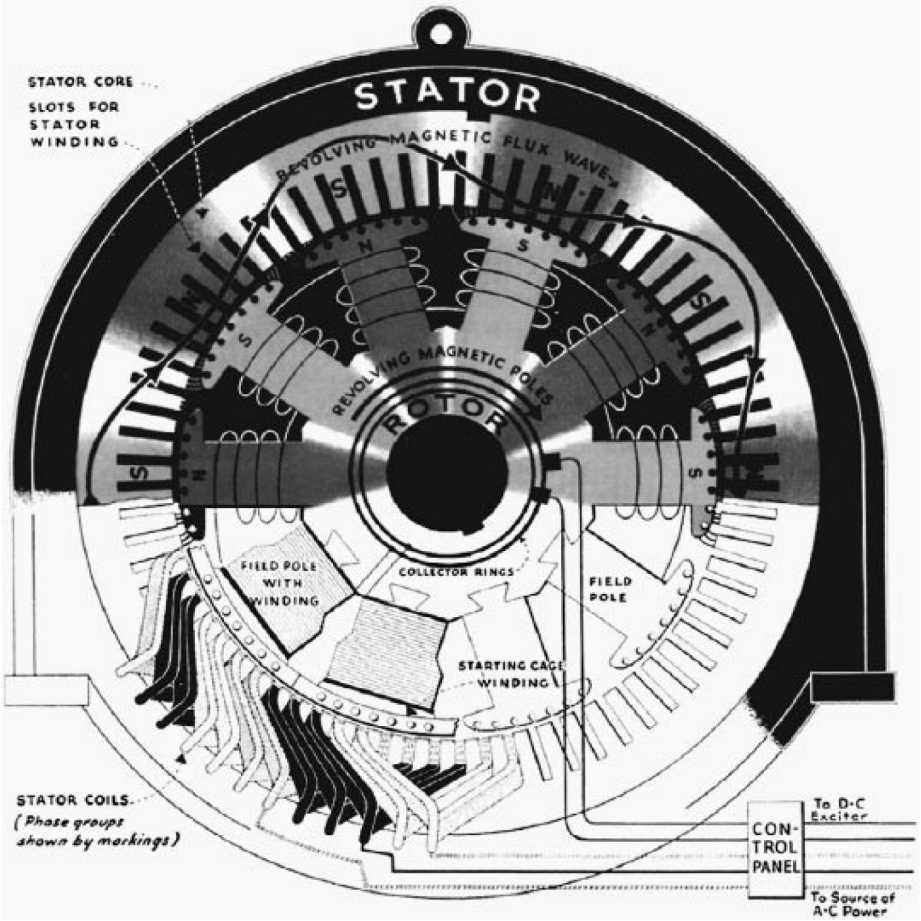
# Building of synchronous machines

## Three-phase synchronous machine



# Synchronous AC machines - Working Principle

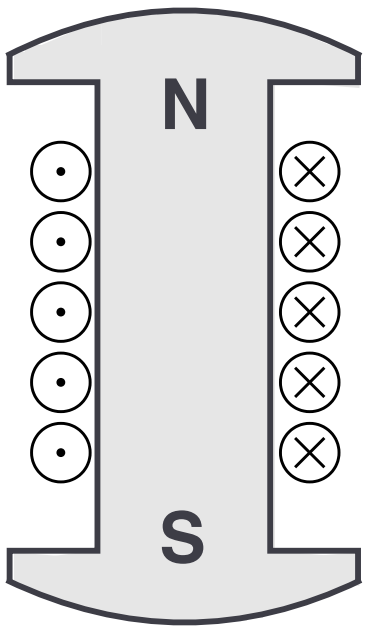
The rotor is made up of permanent magnets or DC electromagnets. The electromagnets are often referred to as the excitation (and excitation winding). The stator generates a rotating magnetic field rotating at $\frac{f}{p}$ rpm. The rotor follows the rotating magnetic field of the stator, lagging behind it or ahead of it by the mechanical angle.



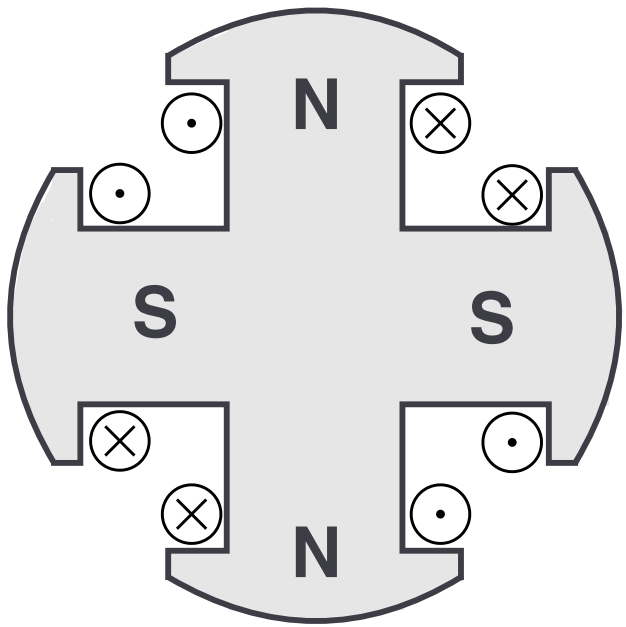
# Number of pairs of poles and synchronous speed

## Number of pairs of poles on the rotor

### 1 pair of poles (p=1)

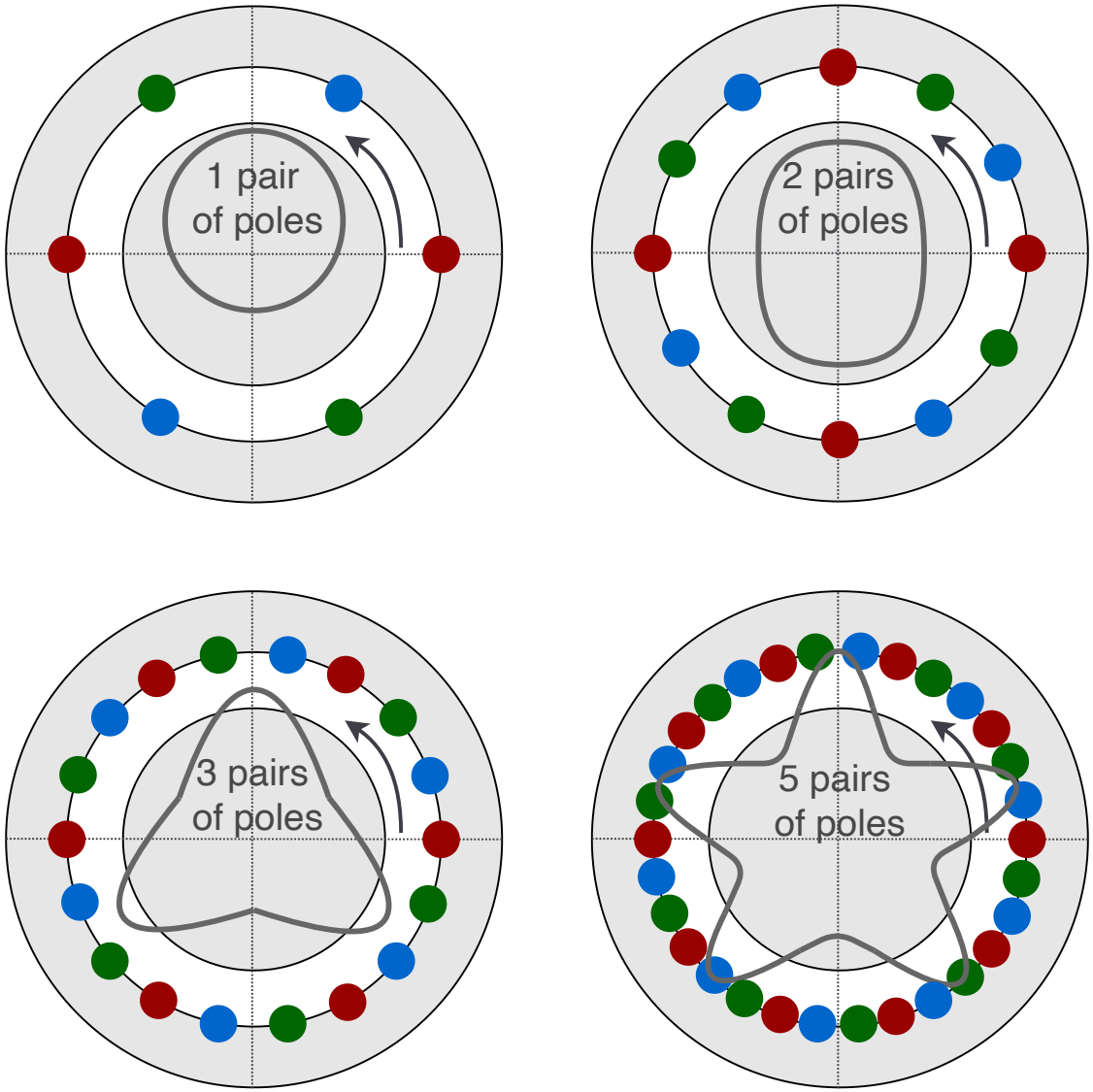



### 2 pairs of poles (p=2)



# Number of pairs of poles and synchronous speed

## Number of pairs of poles on the rotor and the stator



# Number of pairs of poles and synchronous speed

## Synchronous speed

The frequency $f$, the synchronous speed of the machine, $\dot{\theta}_s$ and the number of pairs of poles $p$ are linked by

$$\boxed{\dot{\theta}_s = \frac{f}{p}} \tag{1}$$

Therefore, an alternator with 1 pair of poles must rotate at 3 000 rpm in order to produce a 50 Hz signal.

The reasoning is the same for the synchronous motor. A 1 pair of poles synchronous motor powered with 50 Hz voltages will rotate at 3 000 rpm.

# Number of pairs of poles and synchronous speed

## Synchronous speed

| Number of pairs of poles | 50 Hz | 60 Hz |
|---|---|---|
| | Speed in rpm | |
| 1 | 3000 | 3600 |
| 2 | 1500 | 1800 |
| 3 | 1000 | 1200 |
| 4 | 750 | 900 |
| 20 | 150 | 180 |

## Mechanical angle

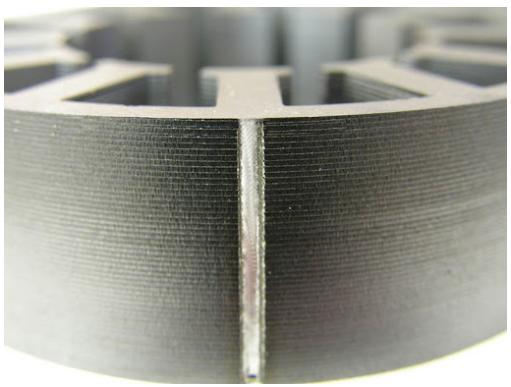
The mechanical angle $\delta_{mec}$ is related to the internal angle $\delta_{int}$ by the number of pairs of poles as

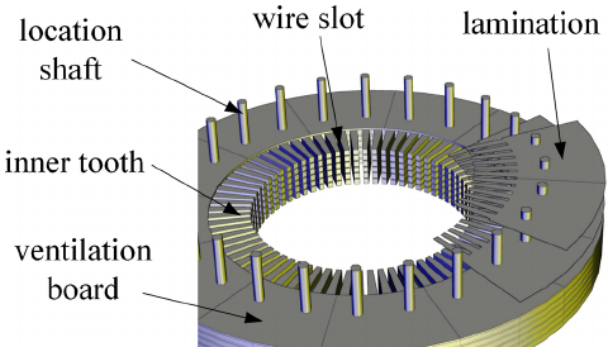
$$\boxed{\delta_{mec} = \frac{\delta_{int}}{p}} \tag{2}$$

# Building of the synchronous machine

## Stator core

The stator core is laminated in order to reduce the eddy current losses. That is why stators are build with the stacking of metal sheets.



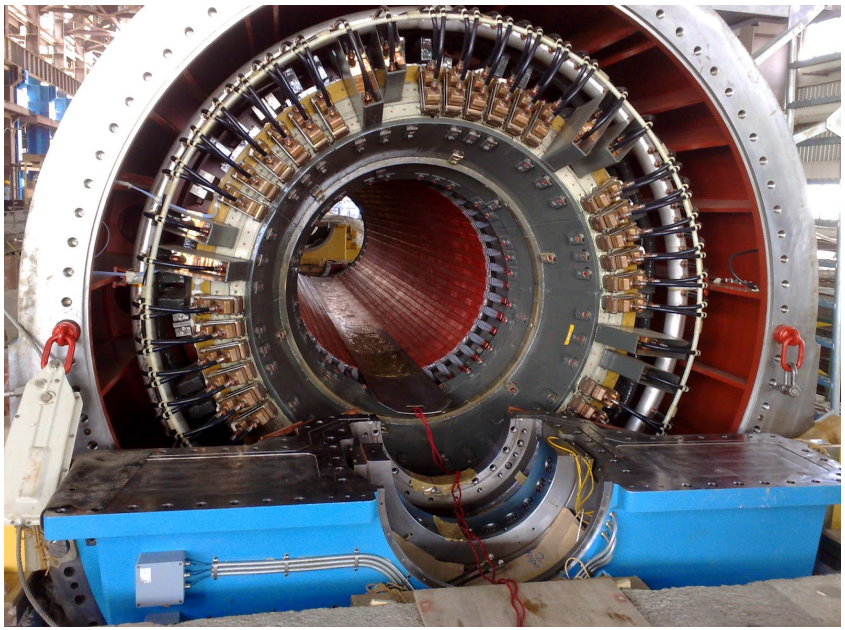


# Building of the synchronous machine

## Stator windings

The stator windings are fixed to the core and placed into the slots. The windings are either made of copper wires or of copper bars for large currents (high power) applications. (ex : small stator wiring)

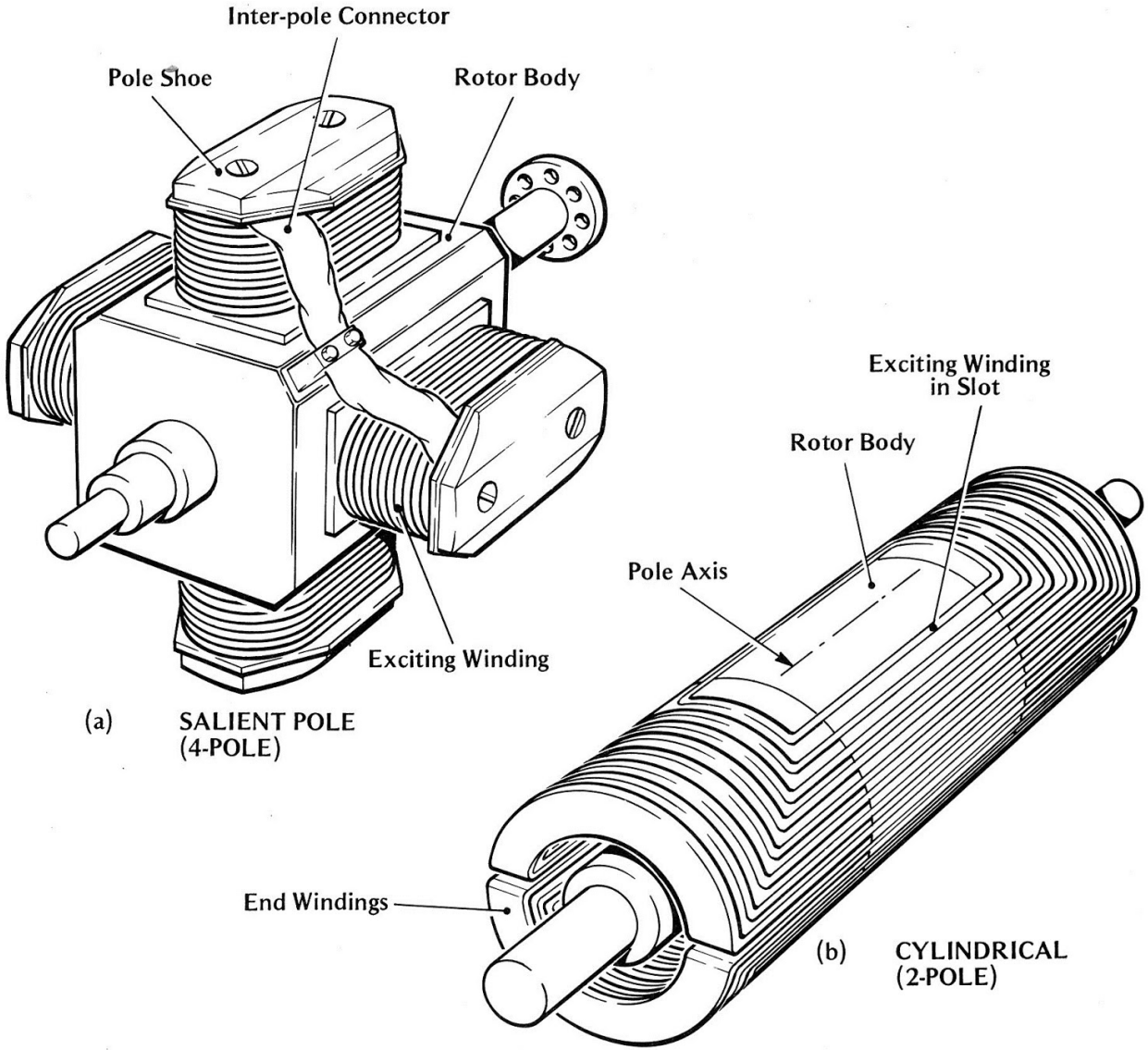
copper wires



copper bars

# Building of the synchronous machine - the 2 types of rotor

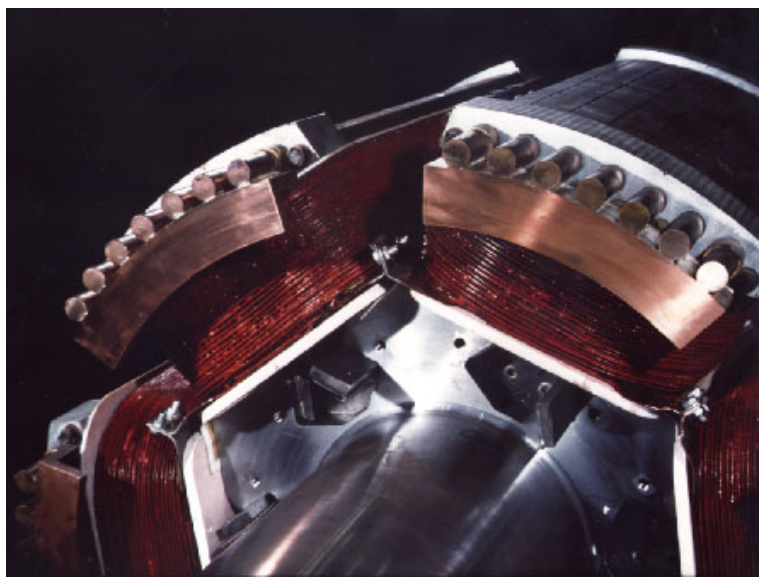
## Salient pole rotor and round-rotor



# Building of the synchronous machine - the 2 types of rotor

## Salient pole rotor

- Driven by low speed prime movers (in hydropower)
- High number of pairs of poles
- Big diameter and small length
- Air gap is not constant
- Made of laminated sheets (cheaper and easier to construct)



The windings of the rotor are held in place thanks to the pole head.

# Building of the synchronous machine - the 2 types of rotor

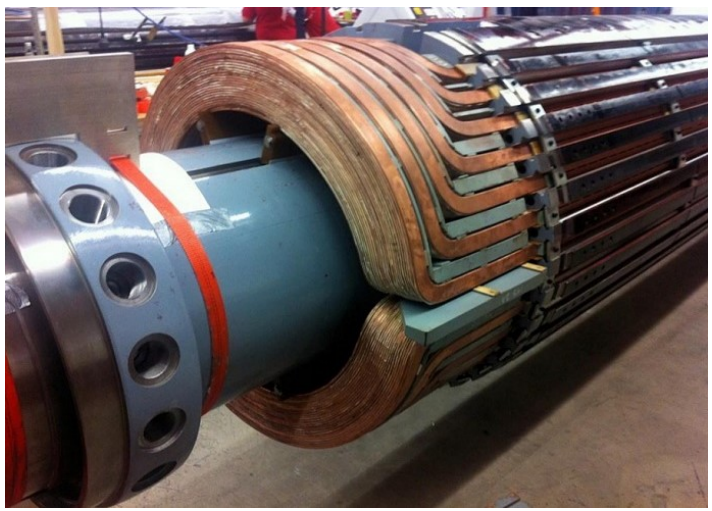
Round-rotor core

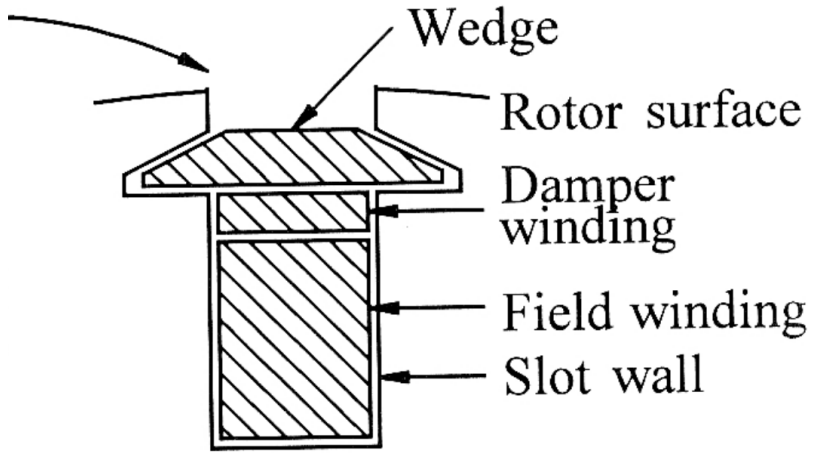
- Driven by high speed turbines
- Low number of pairs of poles (1 or 2)
- Small diameter and big length
- Constant air gap (almost)

# Building of the synchronous machine - the 2 types of rotor

## Round-rotor winding

- Copper bars
- Stay in place thanks to wedges

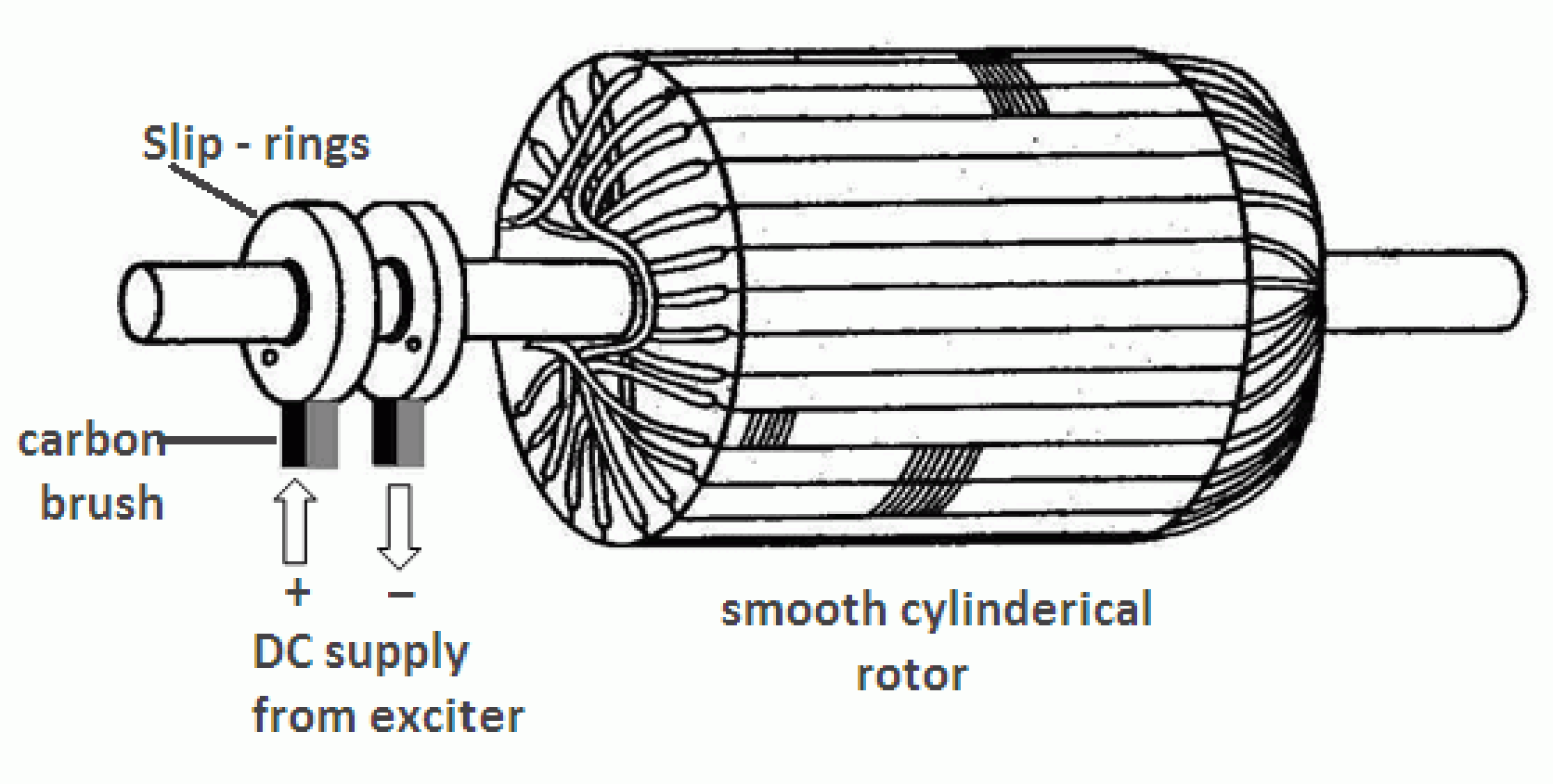





Rewinding of round rotor example

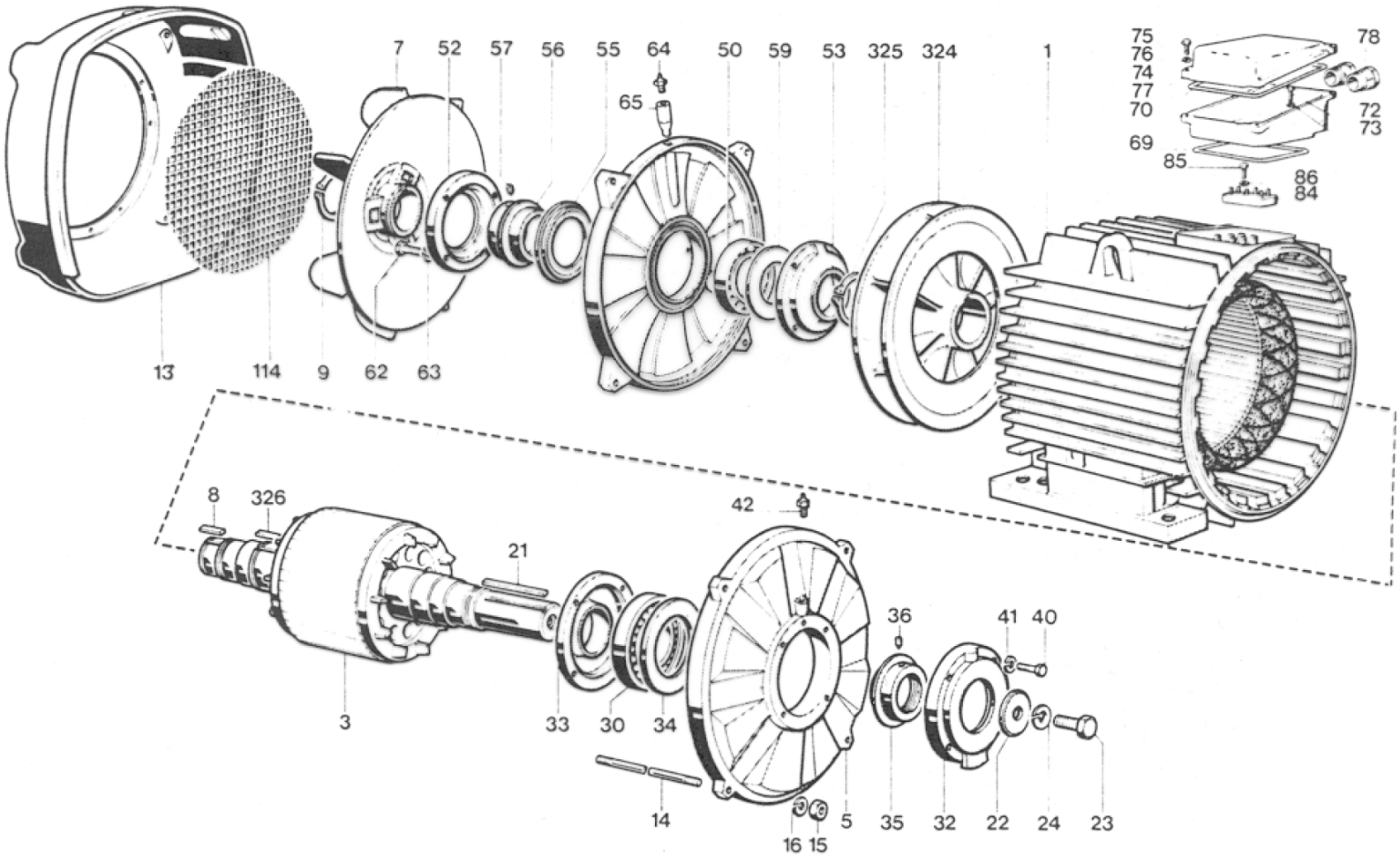
# Synchronous machine - slip rings

The electric current carried by the rotor is called the excitation current, $I_e$. This excitation current is brought to the rotor windings by means of slip rings.



# Synchronous machine - exploded view

The following view presents how the different parts of the machine are assembled together.



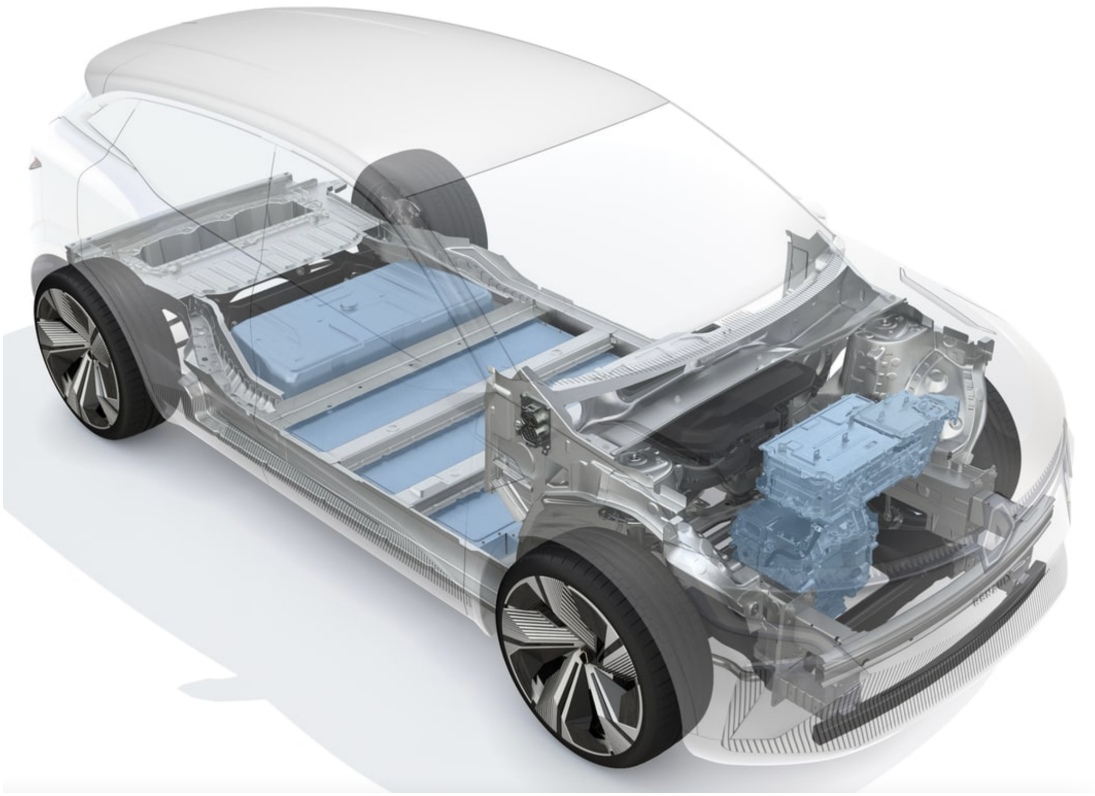
# Synchronous machine - further readings

The alternator

The alternator (history and further explanations)

Example of motor construction

Renault Zoe



# Exercises