Electromagnetic Energy Conversion
ELEC0431

Exercise session 7:
Asynchronous machines

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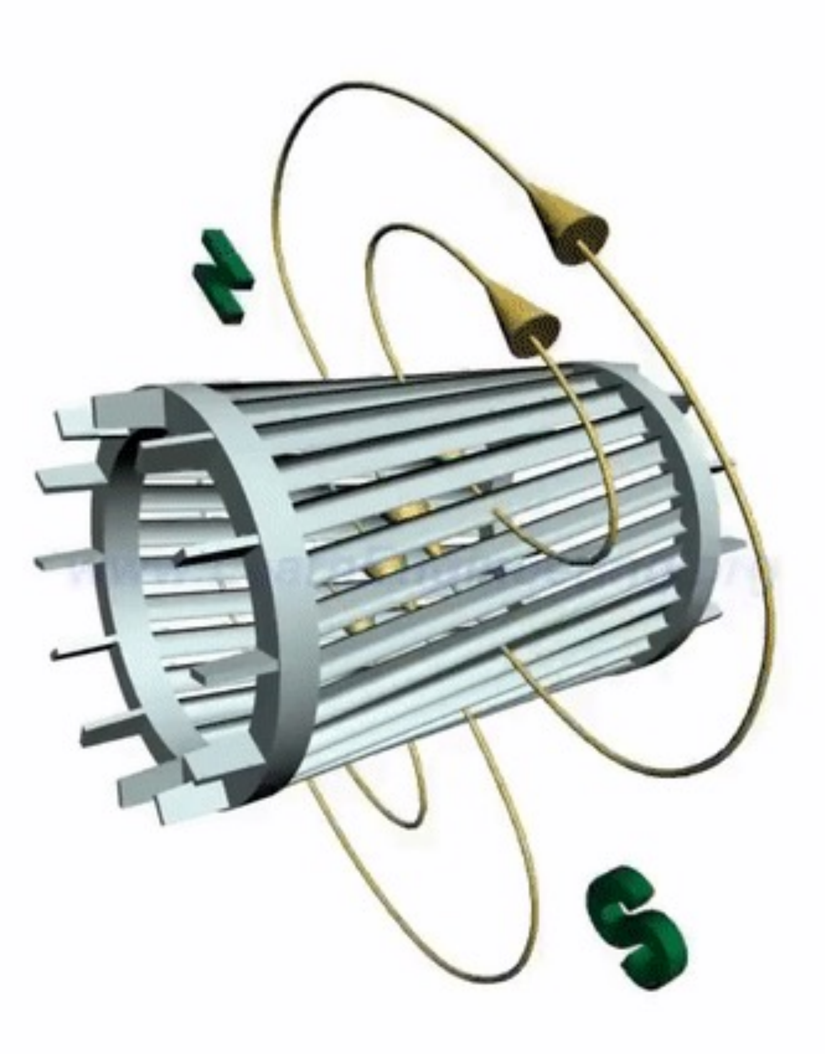
In this class…

- Asynchronous motor
- Exercise 19: Asynchronous motor for washer cleaner

The asynchronous motor



1. The stator generates a rotating magnetic field
2. Closed loop wire with varying magnetic field

   ➔ Faraday's law: emf

1. The emf leads to a current
2. Current in a magnetic field

   ➔ Laplace: $\bar{F} = q\bar{v} \wedge \bar{B}$

1. $\bar{F}$ makes the rotor rotate

✓ Self starting

✓ brushless & no permanent magnet ➔ easy to build

The asynchronous motor

If the rotor doesn't move ➔ high varying fluxes ➔ high current ➔ acceleration

If the rotors turns at the same speed as the magnetic field ➔ no varying fluxes
➔ No Laplace force ➔ Deceleration due to consumed active power (losses and load)

➔ The rotor of the asynchronous motor rotates at a speed $\dot{\theta}$ lower than the speed of the magnetic field $\dot{\theta}_s$, called the synchronous speed of rotation.

The slip g ("glissement" in French) links the two speeds:

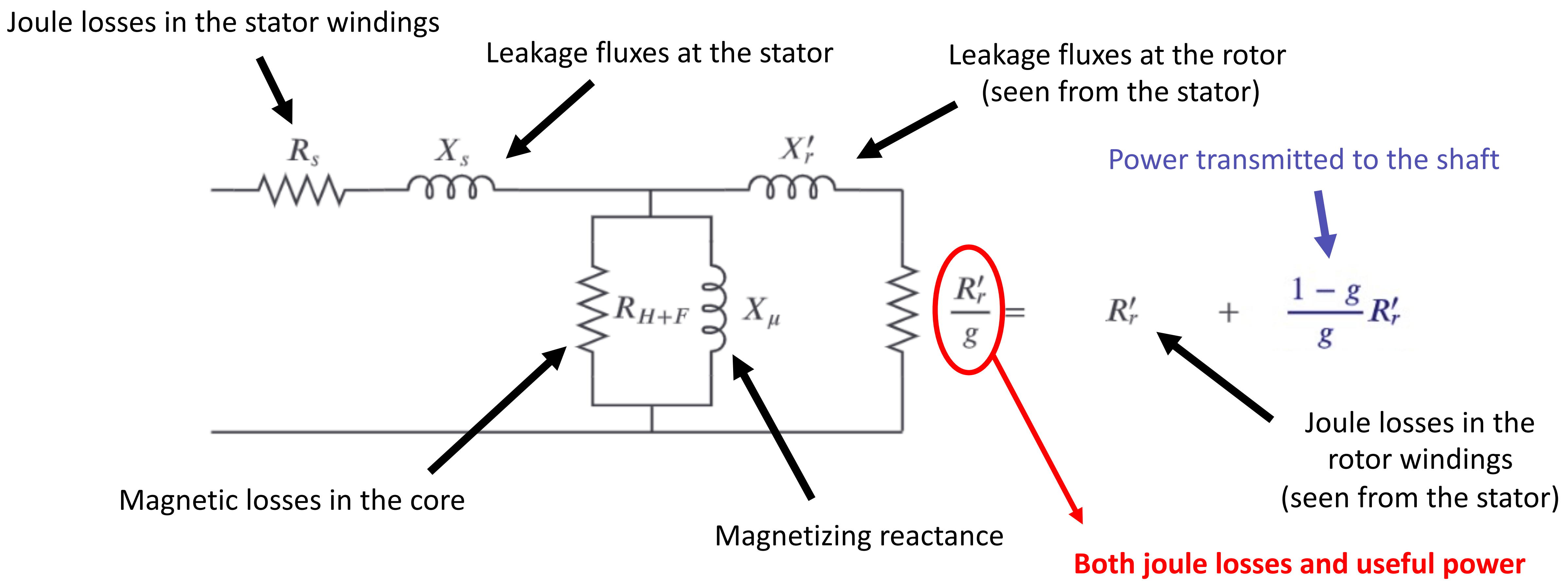
$$g = \frac{\dot{\theta}_s - \dot{\theta}}{\dot{\theta}_s}$$

Note:

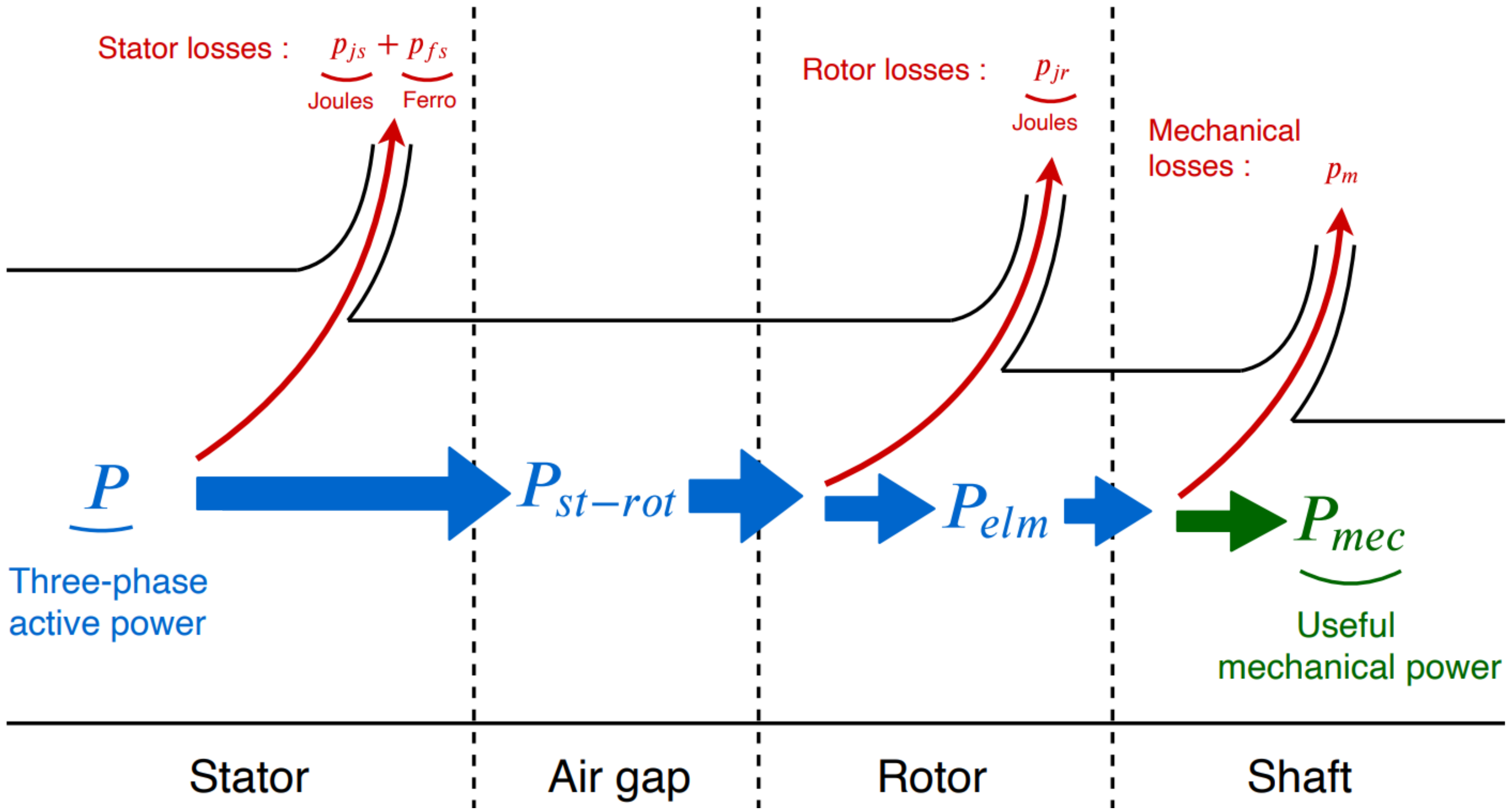
- If the stator doesn't move ➔ $\dot{\theta} = 0$ ➔ $g = 1$
- if the stator moves at the synchronous speed ➔ $\dot{\theta} = \dot{\theta}_s$ ➔ $g = 0$

The asynchronous motor

The asynchronous motor has an equivalent circuit similar to the one of a transformer:



The asynchronous motor



Exercise 19: Asynchronous motor for washer cleaner

A star-shaped asynchronous motor of a high-pressure washer cleaner has the following nominal characteristics:

- Power $P_n = 5.5\ kW$
- Frequency $f_n = 50\ Hz$
- RMS composed voltage value $U_{sn} = 400\ V$
- RMS line current intensities $I_{sn} = 11\ A$

Speed of rotation $\dot{\theta}_n = 1460\ RPM$

Assume that the stator reactance X_s is equal to the stator resistance R_s. Use a single-phase equivalent model of the asynchronous motor when needed.

1. Calculate the synchronous speed of rotation $\dot{\theta}_s$, the number of pair of poles p of the motor and the nominal slip g_n.
2. Determine the value of the stator resistance R_s given that a DC current $I_0 = 10\ A$ flows when a DC voltage $U_0 = 20.6\ V$ is applied between two lines.
3. At the nominal operating point, without mechanical load, the motor draws a current of RMS value $I_{so} = 3.07\ A$ for an active power $P_{so} = 245\ W$. Calculate the overall losses and calculate the resistance modelling ferromagnetic losses R_{H+F} and the magnetizing inductance L_μ, assuming that mechanical losses equal ferromagnetic losses;

Consider that the machine operates at nominal speed and produces the nominal mechanical power P_n to the mechanical load. The nominal mechanical power can also be denoted P_{mec}.

4. At the nominal operating point, calculate the transmitted power from the stator to the rotor and the Joules losses in the stator p_{js} and deduce the total consumed power P.
5. Calculate the rotoric resistance R_r' and the leak inductance L_r' seen from the stator.
6. At the nominal operating point, calculate the mechanical torque Γ_{un} and the electromagnetic torque Γ_n, the power factor $\cos\varphi_n$ and the efficiency η_n.
7. Compute the RMS value I_s of the line currents, and the power factor $\cos\varphi$ at a rotation speed of $0\ RPM$.