Electromagnetic Energy Conversion ELEC0431

Exercise session 7: Asynchronous machines

20 March 2026

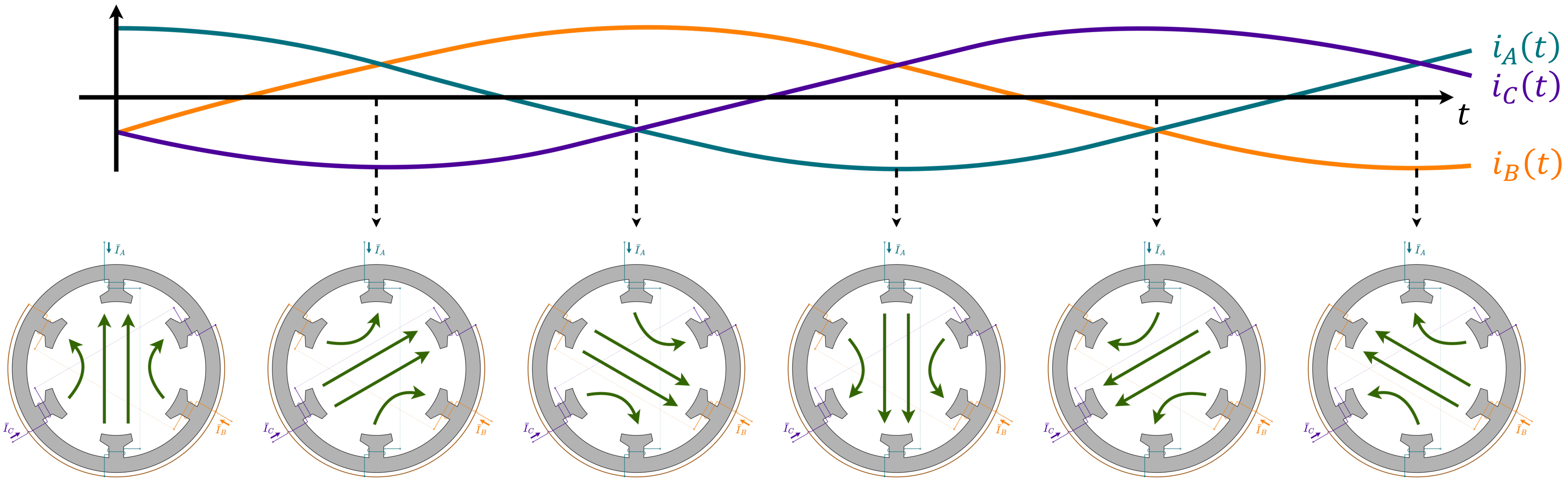
Florent Purnode (florent.purnode@uliege.be)

Montefiore Institute, Department of Electrical Engineering and Computer Science,
University of Liège, Belgium

In this class...

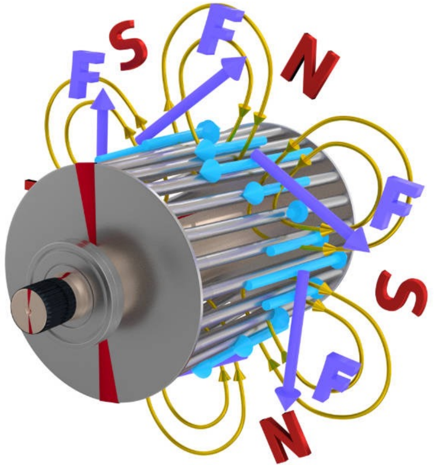
- Reminder: Magnetic field in three-phase motors
- The asynchronous motor: working principle
- Equivalent circuit of an asynchronous motor
- Exercise 11

Reminder: Magnetic field in three-phase motors



The magnetic field generated in the stator is constant in amplitude and rotates at the frequency of the three-phase power source.

The asynchronous motor: working principle



https://www.lesics.com/tesla-model-3_s-ipm-synrm-electric-motor.html

1. The stator generates a magnetic field rotating at a speed $\dot{\theta}_s = f/p$, with f the frequency of the stator currents and p the number of pairs of poles. $\dot{\theta}_s$ is called the synchronous speed (it would be the speed reached by a synchronous motor).
2. Currents are induced in the rotor as it perceives a varying magnetic field (Faraday).
3. The induced currents flow through the magnetic field generated by the stator and hence produce a torque (Laplace), which puts the rotor into movement.
4. The rotor reaches a speed $\dot{\theta}$, which remains lower than $\dot{\theta}_s$ as no current would be induced in the rotor otherwise.

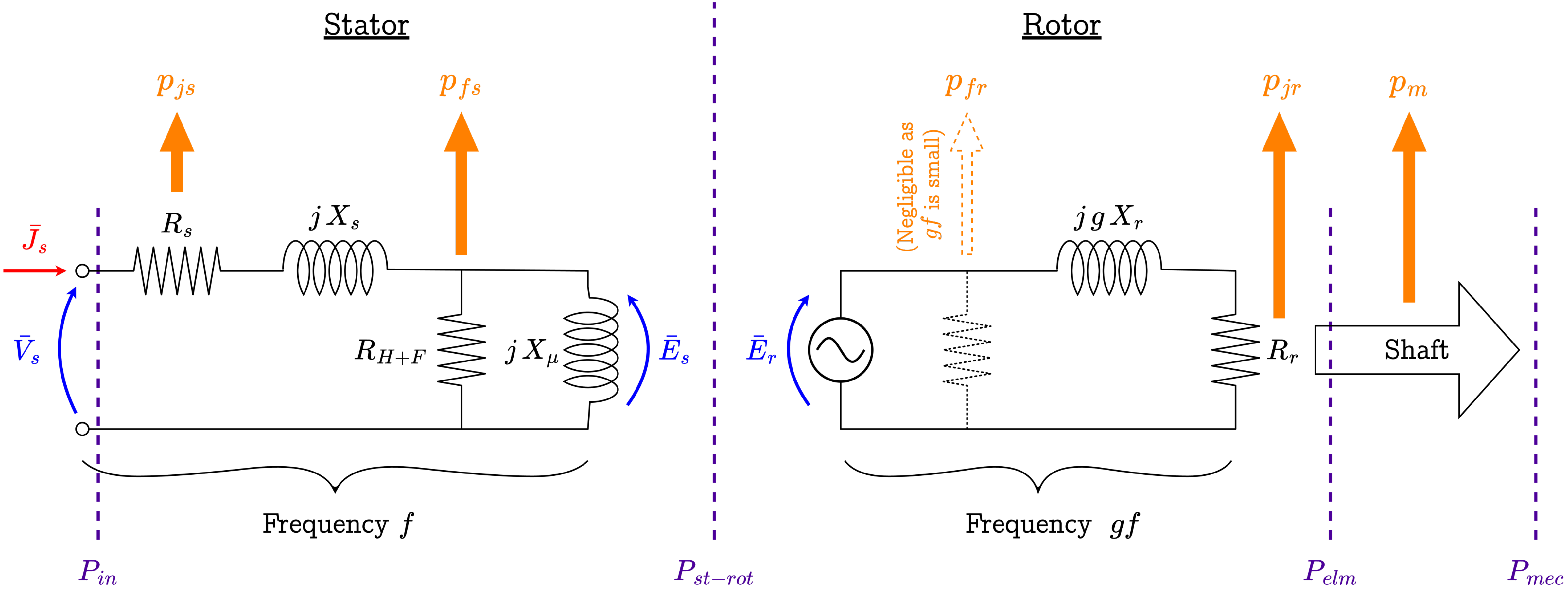
The slip g (or “glissement” in French) is defined as a normalized difference between $\dot{\theta}_s$ and $\dot{\theta}$:

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

$g = 0 \rightarrow \dot{\theta} = \dot{\theta}_s$

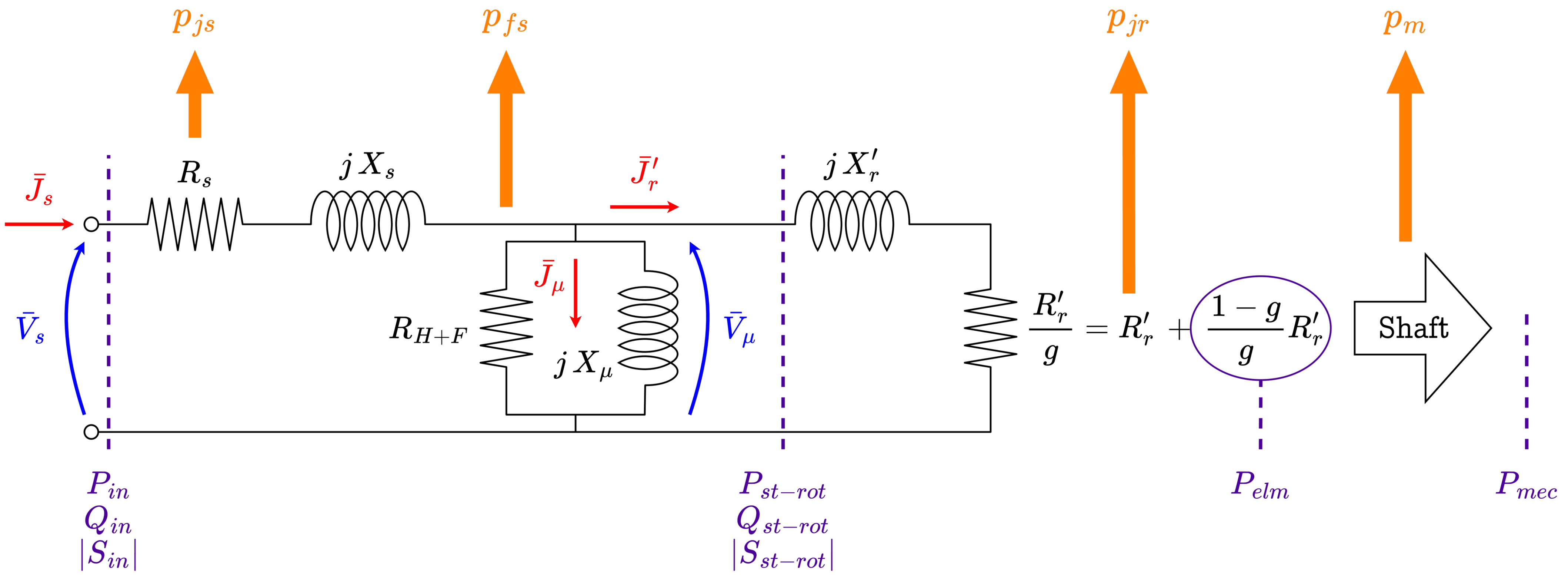
$g = 1 \rightarrow \dot{\theta} = 0$

Equivalent circuit of an asynchronous motor



Equivalent circuit of an asynchronous motor

The previous equivalent circuit can be simplified as:



Power transmitted from the stator to the rotor: $P_{st-rot} = P_{in} - p_{js} - p_{fs} = \mathrm{P_{in}} - \mathrm{R_s}\, \mathrm{J_s^2} - \frac{V_\mu^2}{R_{H+F}}$

Electromagnetic power: $P_{elm} = P_{st-rot} - p_{jr} = P_{st-rot} - R'_r\, {J'_r}^2$

Useful mechanical power: $P_{mec} = P_{elm} - p_m$

Exercise 11: Asynchronous motor for washer cleaner

The asynchronous motor of a high-pressure washer cleaner has the following nominal characteristics:

- Three-phase mechanical power $P_{out,n} = 5.5\ kW$
- Frequency $f_n = 50\ Hz$
- RMS line voltage $U_n = 400\ V$
- RMS line current $I_n = 11\ A$
- Speed of rotation $\dot{\theta}_n = 1460\ RPM$
- Star configuration

1. Calculate the synchronous speed of rotation $\dot{\theta}_s$, the number of pair of poles p and the nominal slip g_n.
2. Determine the value of the stator resistance R_s given that a DC current I_o of 10 A flows when a DC voltage U_o of 20.6 V is applied between two lines (the last line is left open-circuited).
3. When applying nominal line voltages without mechanical load, the motor draws RMS line currents I_s of 3.07 A for a three-phase active power P_{in} of 245 W. Calculate the overall losses and calculate the resistance modelling ferromagnetic losses R_{H+F} and the magnetizing inductance X_μ. Use a single-phase equivalent model of the asynchronous motor assuming the stator reactance X_s equals the stator resistance R_s, and assuming mechanical losses p_m equals ferromagnetic losses p_{fs}.
4. At the nominal operating point, calculate the transmitted power from the stator to the rotor P_{st-rot} and the Joules losses in the stator p_{js}. Assuming identical ferromagnetic and mechanical losses as for point 3, deduce the three-phase input power P_{in}.
5. Calculate the rotoric resistance R_r' and the leak inductance X_r'.
6. At the nominal operating point, calculate the mechanical torque C_n and the electromagnetic torque C_{elm}, 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 $\cos\varphi$ considering a nominal input voltage and a rotational speed of $0\ RPM$.