Electromagnetic Energy Conversion
ELEC0431

Exercise session 7:
Asynchronous machines

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Laboratory manuals

The laboratory manuals are now available on the class webpage:

- Lab 1 - Transformers: https://people.montefiore.uliege.be/geuzaine/ELEC0431/ELEC0431_Lab1_2025.pdf
- Lab 2 - Synchronous machines: https://people.montefiore.uliege.be/geuzaine/ELEC0431/ELEC0431_Lab2_2025.pdf
- Lab 3 - Asynchronous machines: https://people.montefiore.uliege.be/geuzaine/ELEC0431/ELEC0431_Lab3_2025.pdf
- Lab 4 - DC machines: https://people.montefiore.uliege.be/geuzaine/ELEC0431/ELEC0431_Lab4_2025.pdf

You are asked to prepare each lab session by reading carefully beforehand the corresponding lab manual.

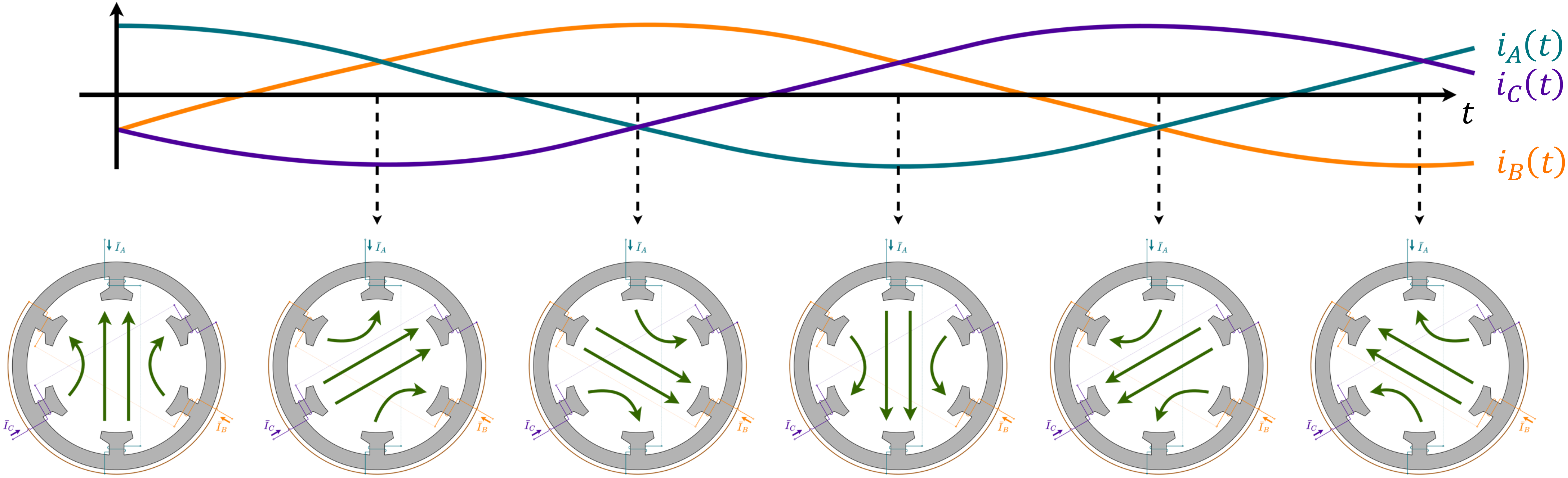
Note that you will have to answer individually a quick evaluation (focusing only on concepts seen during the laboratory) at the end of each laboratory.
Each evaluation represents $3.75\ \%$ of your final grade. That is $15\ \%$ of the grade for the four laboratories.

An active participation to the laboratories is the best way to experiment and to understand the important concepts of the course. Do not miss this opportunity!
You are encouraged to ask questions whenever you encounter difficulties, student monitors will be present to answer them.

In this class…

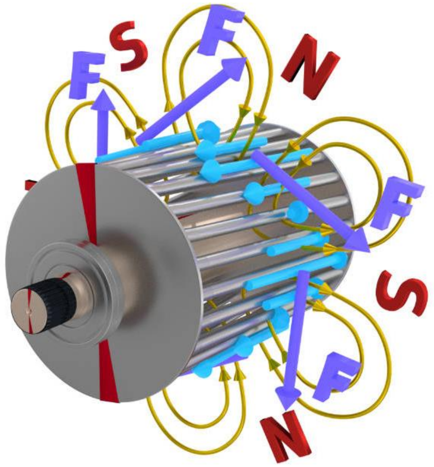
- Reminder: Magnetic field in three-phase motors
- The asynchronous motor: working principle
- Equivalent circuit of an asynchronous motor
- Exercise 11

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.

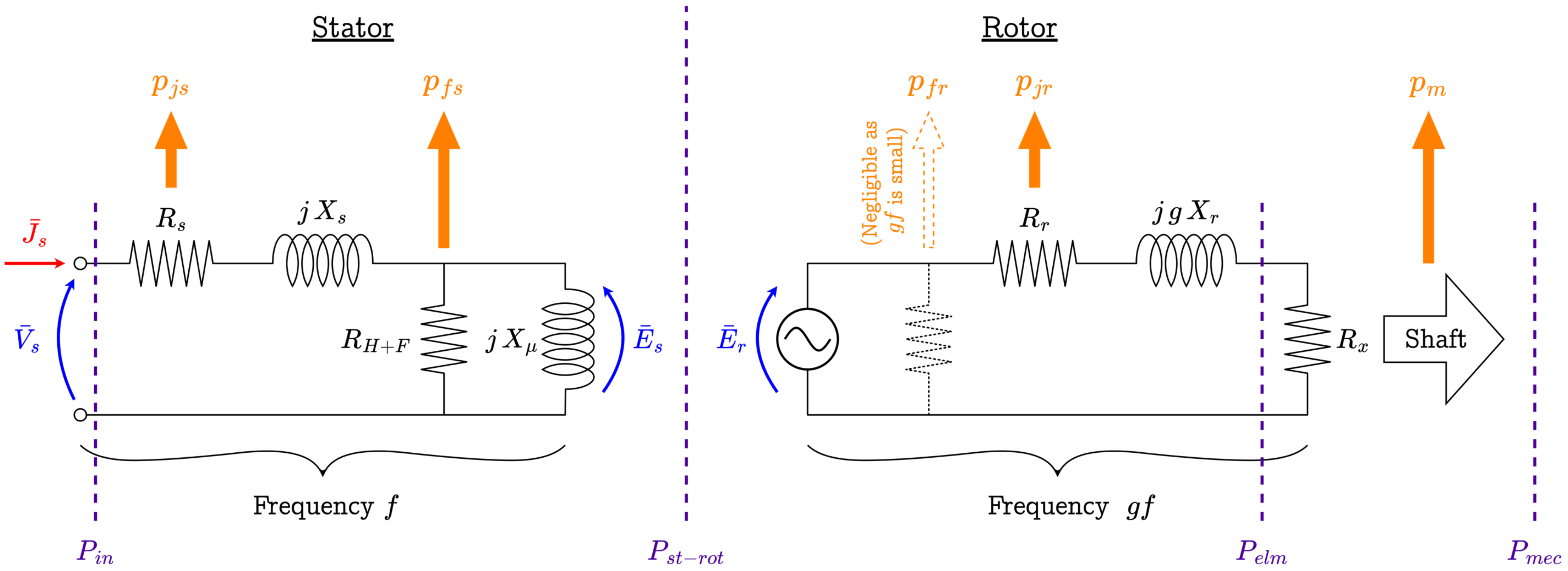
The slip g (or “glissement” in French) is defined as a normalized difference between $\dot{\theta}_s$ and $\dot{\theta}$:

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

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

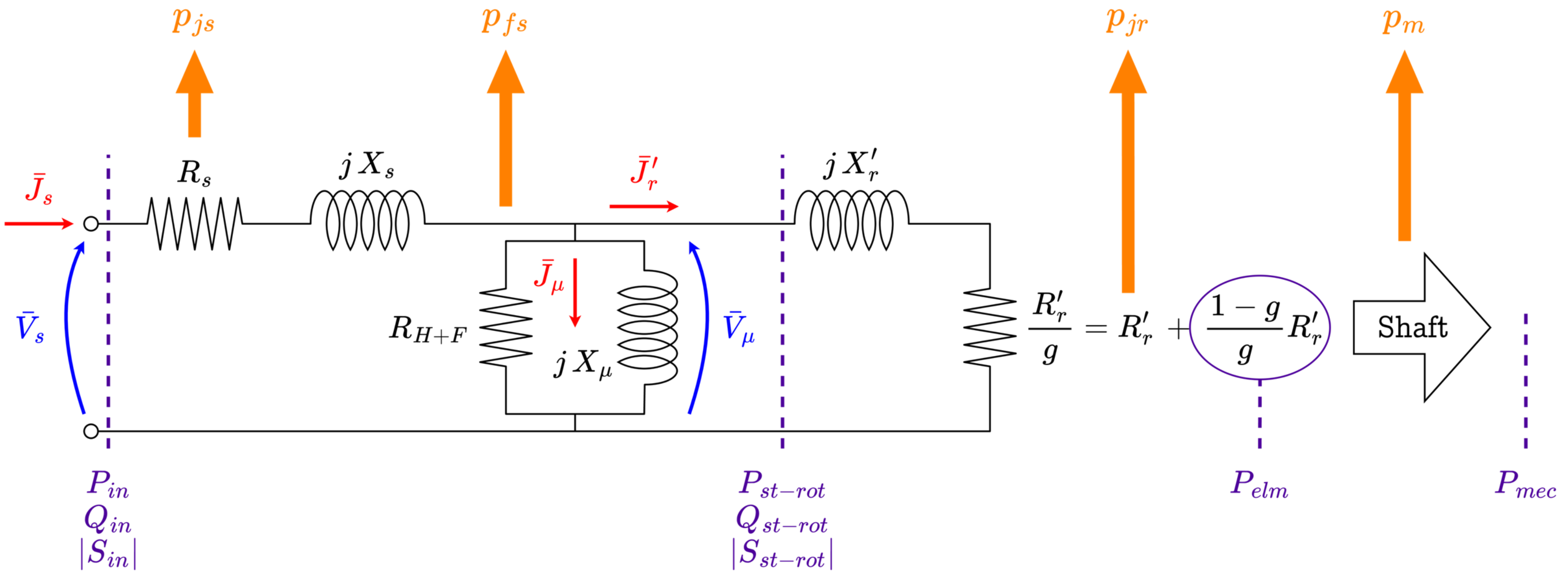
$g = 1 \rightarrow \dot{\theta} = 0$

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 $0\ RPM$.