Electromagnetic Energy Conversion ELEC0431

Exercise session 8: Asynchronous machines

28 March 2025

Florent Purnode (florent.purnode@uliege.be)

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

Reminder: Laboratory schedule

Two weeks ago:

The table below presents the laboratory schedule (also available on the class webpage). There are four laboratories:

1. Transformer 2. Synchronous machines 3. Asynchronous machines 4. DC machines

All laboratory sessions start at 8:30 and last at most 4 hours (up to 12:30). They take place in the "pyramid" (building in front of the cafeteria of Montéfiore). During these laboratories, you will have to follow the steps presented in the laboratory manual (soon available on the course website), student monitors will be present to guide you and answer your questions. 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.

Group n°	Member 1	Member 2	Member 3	Member 4	Mon. 31 Mar.	Mon. 7 Apr.	Mon. 14 Apr.	Wed. 16 Apr.	Fri. 18 Apr.	Wed. 23 Apr.	Fri. 25 Apr.	Mon. 5 May	Wed. 7 May	Fri. 9 May	Wed. 14 May	Fri. 16 May
1	s224403	s222464	s222404	s221732	1	2						4				3
2	s221964	s224003	s224339	s224390				2		1	4		3			
3	s224695	s224930	s222056	s222878			1	3					2			4
4	s211223	s214765	s212198	s212585		3			1	2					4	
5	s221348	s221999	s221067	s224324		1	3						4			2
6	s223458	s222338	S221838	s221223				4			1	2			3	
7	s2409461	s214400	s2306485	s204049			4				2	3		1		
8	s213656	s220802	s220979	s211815					4		3			2		1
9	s215116	s224317	s210844	s216862		4				3			1		2	
10	s224802	s221224	s216230	s224693	2			1	3					4		
11	s2306965	s2409345	s203101	s222320	4				2			1		3		
12	s205570	s225656	s222644	s222641	3		2			4					1	

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.
Please also note that **Laboratories are mandatory** (in the event of an unexcused absence, an absence grade will be given for the entire course).

The first lab session is next Monday!

In this class…

- Exercise 12

Exercise 12: Three-phase turbo-alternator

The nameplate on a three-phase asynchronous motor provides the following information:

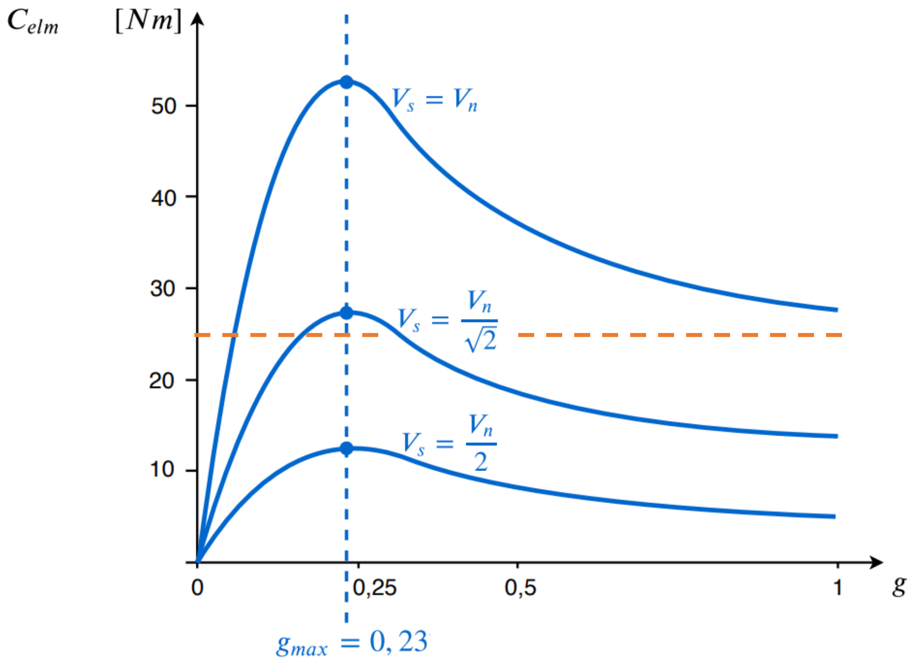
$$4.4\ kW; 230/400\ \ V; 15.5/9\ \ A; 50\ Hz; 4\ poles$$

1. Explain the meaning of each element given on this nameplate. Link power, current and voltage values.
2. If the motor is used on a 230 V network, which winding configuration (Δ or Y) should be used?
3. Calculate the synchronous speed of rotation $\dot{\theta}_s$.
4. Determine the value of the stator resistance R_s given that a DC current I_o of 30 A flows when a DC voltage U_o of 19.62 V is applied between two lines (the last line is left open-circuited).
5. A DC motor is used to bring the asynchronous motor, left unpowered, to its synchronous speed of rotation $\dot{\theta}_s$. Doing so, the mechanical power delivered by the DC motor is measured to be 86 W. Deduce the value of the mechanical losses of the three-phase asynchronous motor.
6. When the asynchronous motor is connected to the 230 V network and left unloaded, it draws a line current of RMS value $I_{so} = 3.81\ A$ for a three-phase active power $P_{in,so} = 300\ W$. Considering a single-phase equivalent model of the asynchronous motor with neglected statoric leakage reactance X_s, calculate the resistance modelling ferromagnetic losses R_{H+F} and the statoric reactance X_μ.
7. The rotor of the asynchronous motor is blocked so to maintain it motionless and an RMS line voltage U_{sc} of 57.5 V is applied at its inputs for a three-phase input active power $P_{in,sc}$ of 374 W and a three-phase reactive power $Q_{in,sc} = 1.09$ kvar. Calculate the rotoric resistance R_r' and the leak reactance X_r'.

Exercise 12: Three-phase turbo-alternator

The asynchronous motor is connected to a 50-Hz balanced three-phase power source of line voltages V_s.

8. Using the single-phase equivalent model with neglected stator resistance, express the RMS phase current J_r' in terms of V_s, R_r', g and X_r'.
9. Calculate the transmitted power from the stator to the rotor.
10. Calculate the electromagnetic torque C_{elm}. For which value of the slip is the torque maximum? Express the maximum torque Γ_{max}?
11. Plot C with respect to g for an applied voltage V_s equal to V_n, $\frac{V_n}{\sqrt{2}}$ and $\frac{V_n}{2}$. At constant torque, is it a good idea to control the speed of rotation with the voltage V_s?
12. To limit the peak current when starting the motor, a star/delta starter is frequently used. Calculate the ratio between line currents in delta and star configuration, for a same input line voltage.



Homework 20

Wind turbines are usually coupled to asynchronous generators (hypersynchronous: $\dot{\theta} > \dot{\theta}_s$), rather than to synchronous generators, since they allow more flexibility in the speed of rotation of the blades. In this exercise, a variable speed wind turbine is studied:

- When using a wound rotor, it is possible to tune its slip (typically from 0 to 10 % in absolute value) by acting on its resistance R_r'. During wind gust, the value R_r' is increased, to increase the slip value (in absolute value, since it is negative) allowing thus to increase the speed of rotation and to smoothen the power transmitted to the electrical grid.

The studied wind turbine has a 4-poles asynchronous generator of three-phase nominal output power $P_{3\varphi,n} = 800$ kW connected in delta configuration to an electrical grid having a line voltage $U_{sn} = 690$ V. The resistance values R_r' of the rotor can be tuned from 3 to 12 $m\Omega$.

Assuming $R_s = X_s = X_r' = 0$, neglecting mechanical losses, express the input mechanical torque C_{in} with respect to the speed of rotation $\dot{\theta}$, to the synchronous speed of rotation $\dot{\theta}_s$, to the output voltage U_{sn} and to the rotoric resistance R_r'.

Answer:

$$C_{in} = \frac{3U_{sn}^2}{R_r'} \frac{\dot{\theta}_s - \dot{\theta}}{\dot{\theta}_s \ \dot{\theta}}$$

Homework 21

Consider the one-phase equivalent electric circuit of a 60-Hz three-phase asynchronous motor with two pairs of poles. The values $R_s = 1\ \Omega$, $X_s = 5\ \Omega$, $R_r' = 3\ \Omega$ and $X_r' = 8\ \Omega$ have been determined from prior measurements and an additional test is conducted to find the values of X_μ and R_{H+F}:

- With the rotor rotating at the synchronous speed, an input RMS phase current of 298 mA and an input RMS phase voltage of 230 V are recorded. Additionally, the input three-phase active power is 176.3 W.

1. Neglecting mechanical losses, determine the values of X_μ and R_{H+F}.
2. The motor is now connected to an equilibrated 3-phase power supply working at 60 Hz. Determine its synchronous speed $\dot{\theta}_s$ expressed in RPM.
3. A 3-phase electromagnetic torque of 8 Nm is measured for a slip of 3 %. What is the machine rotational speed (in RPM) and the three-phase electromagnetic power?
4. Determine the value of the rotoric RMS current.
5. Without neglecting any part of the equivalent circuit, what is the value of the 3-phase input active power?
6. If the motor has 100 W of mechanical losses, what is its efficiency.

Answers:

1. $R_{H+F} = 893.56\ \Omega, X_\mu = 1505.4\ \Omega$
2. $\dot{\theta}_s = 1800\ RPM$
3. $\dot{\theta} = 1746\ RPM, P_{3\varphi,elm} = 1462.73\ W$
4. $J_r' = 2.242\ A$
5. $P_{3\varphi,in} = 1696.68\ W$
6. $80.32\ \%$