# Electromagnetic Energy Conversion ELEC0431

# Exercise session 8: Asynchronous machines

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# Exercise 13: Three-phase turbo-alternator

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

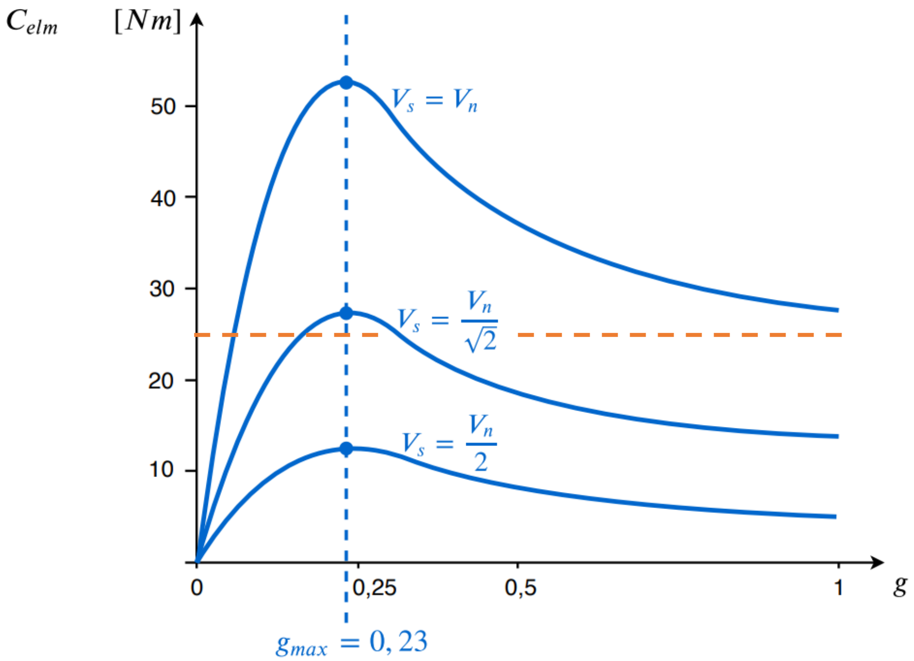
$$4.4\,kW; 230/400\ V; 15.5/9\ A; 50\ Hz; 4\,poles$$

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 $P_{3\varphi,so} = 300\,W$. 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 $X_\mu$.
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 $P_{3\varphi,sc}$ of 374 W and a three-phase reactive power $Q_{3\varphi,sc} = 1.09$ kvar. Calculate the rotoric resistance $R_r'$ and the leak reactance $X_r'$.

# Exercise 13: 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 magnetizing branch and 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 $\Gamma_{max}$?
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), 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 ferromagnetic losses and 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 $X_\mu$ 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. Assuming $R_s$, $\mathrm{R_r'}$, $\mathrm{X_s}$, $\mathrm{X_r'} \ll \mathrm{R_{H+F}}$, $\mathrm{X_\mu}$ and neglecting mechanical losses determine the values of $X_\mu$ 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. $R_{H+F} = 900\,\Omega, X_\mu = 1500\,\Omega$
2. $\dot{\theta}_s = 1800\ RPM$
3. $\dot{\theta} = 1746\ RPM, P_{3\varphi,elm} = 1462.73\ W$
4. $I_r' = 2.242\ A$
5. $P_{3\varphi,in} = 1695.44\ W$
6. $80.38\ \%$