Electromagnetic Energy Conversion ELEC0431

Exercise session 8: Asynchronous machines

31 March 2023

Florent Purnode (florent.purnode@uliege.be)

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

Exercise 16: Three-phase turbo-alternator

On the nameplate of an asynchronous motor of a fan used in an air handling unit, the following characteristics are read:

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

Using a single-phase equivalent model of the asynchronous motor and neglecting the statoric leak inductance X_s:

1. Explain the meaning of each element on the nameplate.
2. The motor is used on a $230\ V$ network, explain which winding coupling should be used for the stator.
3. Calculate the synchronous speed of rotation $\dot{\theta}_s$.
4. Given that the (DC) resistance value measured between two stator terminals is $R_a = 0.654\ \Omega$, compute the value of the statoric resistance R_s of the equivalent single-phase model.
5. A calibrated motor is used to rotate the shaft of the unpowered considered motor, upto reaching the synchronous speed, at which the calibrated motor consumes $86\ W$. Calculate the mechanical losses of the motor and explain why assuming that these mechanical losses remain constant is a good approximation.
6. At the nominal operating point, without mechanical load, the motor draws a current of RMS value $I_{so} = 3.82\ A$ for an active power $P_{so} = 300\ W$. Calculate the resistance modelling ferromagnetic losses R_{H+F} and the statoric inductance L_μ.
7. The rotor shaft of the motor is stalled while a voltage of RMS value $U_{sc} = 57.5\ V$ is applied for a consumed three-phase active power $P_{sc,3\varphi} = 374\ W$ and three-phase reactive power $Q_{sc,3\varphi} = 1.09\ kvar$. Calculate the rotoric resistance R_r' and the leak inductance X_r' seen from the stator.

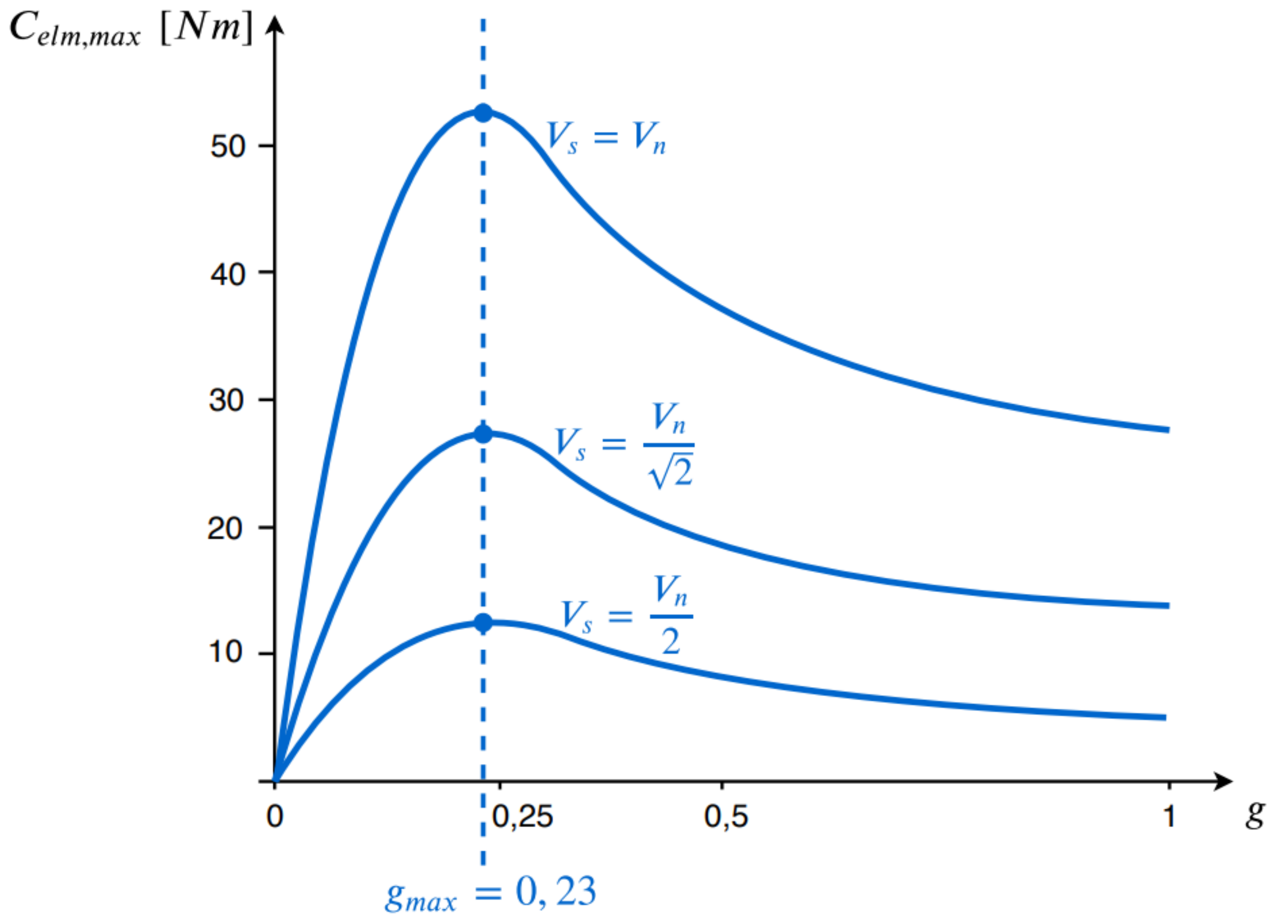
Exercise 16: Three-phase turbo-alternator

A direct voltage of value V_s and frequency f is applied on each phase of the motor. Neglecting the magnetizing branch:

8. Using the single-phase equivalent model of the asynchronous motor, express the RMS phase current value J_s in terms of V_s, R_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} and give the maximal reachable torque Γ_{max} after showing that C_{elm} is maximal for a slip value g_{max}.

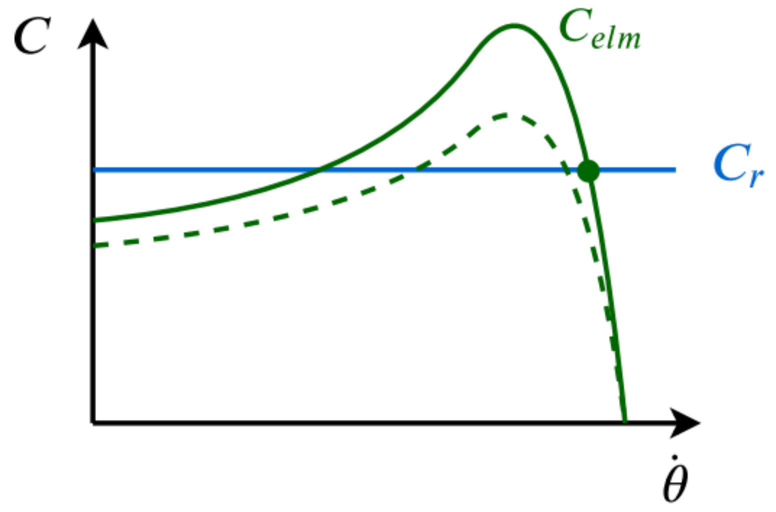
Exercise 16: Three-phase turbo-alternator

11. Plot C with respect to g for an applied voltage V_s equal to V_n, $\frac{V_n}{\sqrt{2}}$ and $\frac{V_n}{2}$.



Exercise 16: Three-phase turbo-alternator

12. Explain why a control on the rotor voltages is not suitable for speed variation for load having constant resistive torque.



➔ Modifying the voltage has a very small impact on the rotation speed.
➔ the machine must remain in the stable region which is narrow.

13. To limit the peak current when starting the motor, a star/delta starter is frequently used. Assuming that this transient mode is much longer compared to the period corresponding to the frequency f of the applied voltages, calculate the RMS current values of the line currents compared to those drawn by using a star/delta starter.