T5 – THE INDUCTION MACHINE

The aim of this tutorial is to study the induction machine using the equivalent model and the evolution of the mechanical torque-speed characteristic when the machine is supplied by a variable-frequency network.

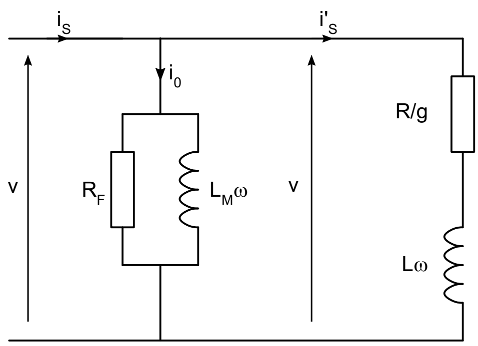
The selected machine is an induction motor of brand “ABB” and type “M3AA 132 SMF 4”, whose main information is as follows:

400V Y - 50Hz - 4 poles - 15kW

Study of the equivalent model of a machine stator winding

Equivalent model

The diagram shows the equivalent model of a machine stator winding.



1) **Remind** the meaning of the quantities R_F, $L_M.\omega$, R and $L.\omega$.

No-load test

The machine was tested at no load. The results of this test are as follows:

U = 400V Y - f = 50Hz - I_0 = 14.70 A - P_0 = 420W.

2) **Remind** the rotational speed during this test and **calculate** the slip, g.
3) **Show** that the active and reactive powers, absorbed by the motor during this test, are absorbed only in the resistance R_F and the magnetizing reactance $L_M.\omega$ respectivively.
4) **Calculate** the power factor, the resistance R_F and the magnetizing reactance $L_M.\omega$.

Blocked rotor test

The machine was tested with blocked rotor and reduced voltage. The results of this test were as follows:

U_{RB} = 73,9V Y(phase voltage) - f = 50Hz - I_{RB} = 29,70 A - P_{RB} = 1330W

5) **Remind** the rotational speed during this test and **calculate** the slip, g.
6) **Show** that the active and reactive powers, absorbed by the engine, are absorbed only in the resistance R /g and the reactance X = L.ω.

The machine is wye-connected. Measurement of the hot resistance between two terminals (U1 and V1) gave **0.319 0 Ω.**

7) **Calculate** the power factor, resistance R and reactance X = L.ω.

Exploiting the tests

8) **Show** that the electromagnetic torque, noted C_E, can be written: $\boldsymbol{C_E = 3.\frac{p}{\omega}.\frac{V^2.R}{\frac{R^2}{g}+g.(L.\omega)^2}}$

9) **Show** that the electromagnetic torque has a maximum, noted C_{EMax}, for the value noted g_{MAX} of the slip in motor operation. **Define** and **calculate** g_{MAX} and C_{EMax}.

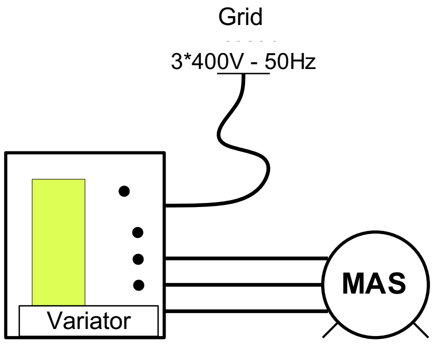
10) From the torque expression, **calculate** C_{DEM}, the motor starting torque.

11) **Linearize** the torque characteristic in the useful part (sliding much less than g_{MAX}). **Then, express** C_E as a function of V, p, ω, R and g.

Association with a converter

A frequency converter is conected between the power grid and the induction machine. It modulates the frequency f of the stator currents while keeping the V/f ratio constant. In this section, the slip remains low with respect to g_{MAX}.

12) **Justify** the action of such a converter on the motor rotating speed n.



13) **Write** the torque as $C_E(n)= \alpha.(\beta.f - n)$. It is reminded that the V/f ratio is constant.

14) For f = 50Hz, f = ⅔.50Hz and f = ⅓.50 Hz, **plot** the characteristics $C_E(f;n)$ on the same graph.

The motor drives a machining system whose resistant torque is:

$$C_R = 0,04.n + 40$$

C_{RES} in N.m,
n in rpm.

15) **Calculate** the coordinates of the operating points for each of the three frequencies.

16) **Decompose,** through a simple diagram, a frequency inverter and **represent** the shape of the characteristic voltages in the variator.