

HW3 - Induction Machines

This homework is to be solved using computational tools (such as MATLAB). You should show your work (how the resultant plot is obtained analytically, and required explanations).

*The provided template must be used and the homework should be submitted by converting the .m file solution to pdf by using **publish** command. Required explanations and several tips are given in the template.*

Q.1. (25 pts) A 220 V, three phase, 50 Hz induction motor is running at 1480 rpm at no load.

- How many poles does this motor have?
- What is the synchronous speed in rpm?
- If the rotor is kept stationary, find the frequency of rotor induced currents in Hz.

Now, the motor is running at a slip of 5 percent.

- Find the speed of the rotor in rpm.
- Find the frequency of rotor induced currents in Hz.

Q.2. (75 pts) Equivalent circuit parameters (per phase) of a 600 V_{L-L}, 6 pole, 60 Hz, 300 kW, Y connected wound rotor induction motor are as follows:

$$\begin{array}{llll} R_1 = 0.015 \, \Omega & R_2' = 0.033 \, \Omega & L_1 = 0.41 \, \text{mH} & L_2' = 0.4 \, \text{mH} \\ L_m = 13.5 \, \text{mH} & R_c = 49.5 \, \Omega & & \end{array}$$

The equivalent circuit to be used throughout the question is given in Figure 1.

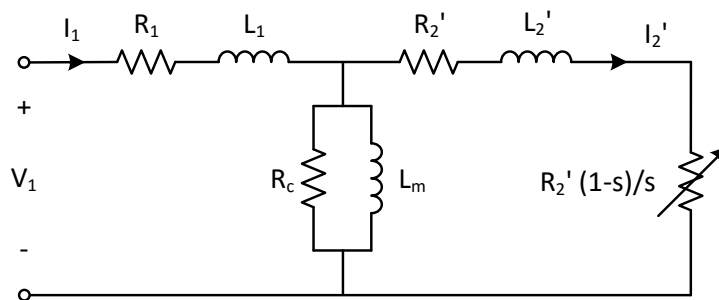


Figure 1. Equivalent circuit of the induction motor

- Obtain the **torque-speed characteristics** and the **output power-speed characteristics** of this machine for rated voltage and frequency. Plot them on separate graphs.
- Find the *starting torque*, *maximum torque in motoring region*, *slip at maximum torque in motoring region*, *slip at maximum power in motoring region*. Does maximum torque occur at the same slip where maximum power occurs? Comment.

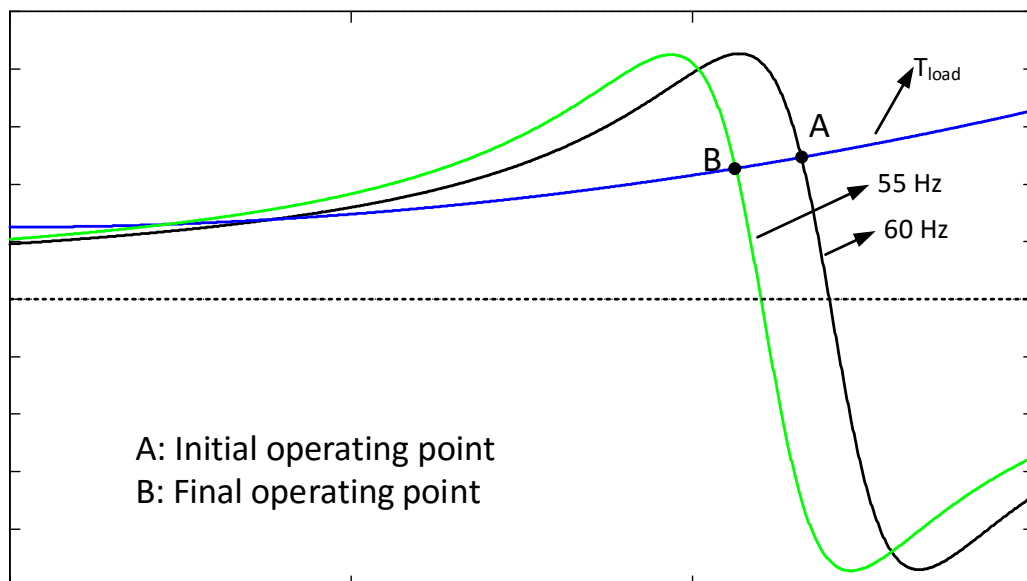
Now, the machine is connected to a mechanical system with the following specifications:

Load torque: $1253 + 0.0824 \, \omega^2 \, \text{Nm}$ where ω is the angular rotor speed in rad/sec.

- Is this motor able to start with the given load? Why? One method to increase the starting torque is connecting an external resistance to the rotor terminals. Calculate the required external

resistance (referred to the stator side) that should be connected to rotor terminals. Comment on the results.

- d. Plot the initial torque characteristics, torque characteristics with the external resistance found in (c) and the load torque on the same graph.
- e. Suppose that rated voltage and frequency is applied to this motor and after the start-up, the external resistance is removed and the rotor terminals are short circuited. The motor is running at steady state with the load connected. Find the following (parallel branch can be assumed at stator terminals):
 - 1) the rotor speed in rpm using the graph in (d),
 - 2) the electromechanical torque,
 - 3) the efficiency of the motor.
- f. If now, the frequency is suddenly reduced to 55 Hz (V_1/f ratio is kept constant) while the system is operating at point A as shown in the figure below,
 - 1) Using the template provided, obtain and plot the torque speed characteristics of the motor at 60 Hz and 55 Hz along with the load torque (your figure should look like the one given below.).
 - 2) Explain the machine operation until the motor reaches its final steady state operation point B.
 - 3) Find the operating point (torque and speed) at the instant just after the frequency reduction (use the figure you plotted in part 1).
 - 4) Find the final operating point B (torque and speed).



- g. While the machine is running at steady state under 60 Hz excitation (as in part (e)), the direction of the load torque is suddenly reversed as follows.

Load torque: $-1253 - 0.0824 \omega^2 \text{ Nm}$ where ω is the angular rotor speed in rad/sec.

- 1) Using the template provided, obtain and plot the torque speed characteristics of the motor at 60 Hz, initial and final load characteristics (your figure should look like the one given below.).
- 2) Explain the machine operation until the motor reaches its final steady state operation point B.
- 3) Find the final operating point B (torque and speed).

