EE 56◎ – Electric Machines and Drives Prof. N.J. Nagel

Homework #3 – Due November 30th, 2020

Analysis of AC Induction Motors

You are the controls engineer for XYZ Company and your boss has asked you to analyze the performance of an induction motor. The induction motor has the following parameters:

$r_s = 0.4\ \Omega$	stator resistance
$r_r = 0.8\ \Omega$	rotor resistance
$L_m = 70.0\ mH$	magnetizing inductance
$L_{ls} = 2.0\ mH$	magnetizing inductance
$L_{lr} = 2.0\ mH$	magnetizing inductance
$V_{\varphi_{rms}} = \frac{230}{\sqrt{3}}\ V$	phase voltage
$\omega_e = 2\pi 60\ \frac{rad}{sec}$	excitation frequency
$J = 0.1\ kg \cdot m^2$	rotor inertia
$b = 1.0 \cdot 10^{-3}\ \frac{Nm}{\left(\frac{rad}{sec}\right)}$	magnetizing inductance
$L_s = L_m + L_{ls}$	stator self inductance
$L_r = L_m + L_{lr}$	rotor self inductance

You will develop a transient model of the induction machine using the stator referred differential equations from class (repeated below) in PLECS. Use native blocks in PLECS, do not use the induction motor model provided (this will be used for comparison).

To do:

a. Turn in your PLECS model. Each of the variables should be clearly labeled.
b. Plot the following start-up transient variables:
    a. Stator phase currents (abc)
    b. Rotor phase currents (dq)
    c. Rotor speed
    d. Electromagnetic torque
c. Apply a step change in load torque from 0 to 10 Nm after 0.5 seconds. Plot this with the variables of part b. (Parts b and c should be plotted on the same plot.)
d. Compare your model with the PLECS induction motor model results.

Equation Summary for Simulation:

The following is a listing of state equations which can be used in simulating an AC machine:

$$p\lambda_{qs}^{s} = v_{qs}^{s} - r_s i_{qs}^{s}$$

$$p\lambda_{ds}^{s} = v_{ds}^{s} - r_s i_{ds}^{s}$$

$$p\lambda_{qr}^{s} = v_{qr}^{s} - r_r i_{qr}^{s} + \omega_r \lambda_{dr}^{s}$$

$$p\lambda_{dr}^{s} = v_{dr}^{s} - r_r i_{dr}^{s} - \omega_r \lambda_{qr}^{s}$$

$$T_e = \frac{3}{2}\frac{P}{2} L_m (i_{qs}^{s} i_{dr}^{s} - i_{qr}^{s} i_{ds}^{s})$$

where

$$\lambda_{qs}^{s} = L_s i_{qs}^{s} + L_m i_{qr}^{s}$$

$$\lambda_{ds}^{s} = L_s i_{ds}^{s} + L_m i_{dr}^{s}$$

$$\lambda_{qr}^{s} = L_r i_{qr}^{s} + L_m i_{qs}^{s}$$

$$\lambda_{dr}^{s} = L_r i_{dr}^{s} + L_m i_{ds}^{s}$$

so

$$i_{qs}^{s} = \frac{1}{\sigma L_s}\left(\lambda_{qs}^{s} - \frac{L_m}{L_r}\lambda_{qr}^{s}\right) \qquad \sigma = 1 - \frac{L_m^2}{L_s L_r} \text{ (coupling factor)}$$

$$i_{ds}^{s} = \frac{1}{\sigma L_s}\left(\lambda_{ds}^{s} - \frac{L_m}{L_r}\lambda_{dr}^{s}\right)$$

$$i_{qr}^{s} = \frac{1}{L_r}\left(1 + \frac{L_m^2}{\sigma L_r L_s}\right)\lambda_{qr}^{s} - \frac{L_m}{\sigma L_r L_s}\lambda_{qs}^{s}$$

$$i_{dr}^{s} = \frac{1}{L_r}\left(1 + \frac{L_m^2}{\sigma L_r L_s}\right)\lambda_{dr}^{s} - \frac{L_m}{\sigma L_r L_s}\lambda_{ds}^{s}$$