Iowa State University
Electrical and Computer Engineering
E E 452. Electric Machines and Power Electronic Drives

Laboratory #11
Squirrel-cage Induction Machine – Dynamic Performance

Summary

In this lab you will simulate the dynamic response of the squirrel-cage induction motor using MATLAB/Simulink and ASMG.

Learning objectives

- Introduce dynamic models of induction motors (in contrast to the steady-state equivalent circuit).
- Study the response of an induction motor during start-up and changes in mechanical load.

Background material (should be read before coming to the lab)

- Krause, chapter 6

Exercises and Questions

Instructions: every student should deliver his/her own report at the end of the lab session, even though the experiments are conducted in groups. You may want to answer the questions as you go along the exercises. Time yourselves according to the recommendations below.

1. Pre-lab assignment

The overall objective of this lab is to replicate the waveforms of Section 6.9, pp. 251–26 in Krause, where computer simulation results are provided to illustrate the dynamic performance of a squirrel-cage induction motor.

In Krause 6.9, the machine that is analyzed is a two-phase machine. However, ASMG provides only a three-phase machine model. First, we will modify slightly what ASMG provides to obtain an equivalent two-phase model.

The equivalent circuits of a two-phase induction machine are provided in Fig. 6.6-1, p. 234 in Krause.

The equivalent circuits of a three-phase induction machine are provided in Fig. 6.12-2, p. 280 in Krause.

You must understand that these are different from the steady-state equivalent circuit, which is shown in Fig. 6.8-1, p. 241. These types of circuits are valid for dynamic (transient) studies, where the machine is not at steady-state (e.g., while it accelerates, or while a voltage disturbance occurs at the terminals). The circuits are based on a transformation of *abc* variables to an arbitrary *qd*-axes reference frame, in a similar fashion as was done for the space vector modulation. In particular, the speed ω shown in the circuits is the speed of the arbitrary reference frame, while the speed ω_r represents the *electrical* rotor speed (equal to mechanical rotor speed times the number of pole-pairs). For more details about this transformation you may refer to Krause section 6.5.

DELIVERABLE 1: Study the two circuits carefully, and identify their differences.

Note: One of the differences is that the three phase model has a zero-axis circuit, and the two-phase model does not. Do not worry about these. For balanced symmetric excitation, they will be completely inactive. Hence, you may leave them in the model.

2. **Set up the ASMG Simulation** [45 minutes]

Open a new Simulink model, and insert a squirrel-cage induction machine model from the ASMG library. Look under the mask of the model by right-clicking on the Simulink block, and observe what type of circuit is used.

DELIVERABLE 2: What is the speed of the arbitrary reference frame used in the ASMG model, and how can you tell?

DELIVERABLE 3: How is the motor's stator connected (Delta or Wye) and how can you tell?

DELIVERABLE 4: Confirm whether the equation for electromagnetic torque of this model is the same as (6.7-11), p. 236. In fact, since the model represents a three-phase machine, there should be a minor difference. Modify the model so that the electromagnetic torque output corresponds to a two-phase motor.

The mechanical dynamics are not included in the machine block, and must be constructed outside the induction machine model. Observe how the SCIM model outputs the electromagnetic torque, but needs the rotor speed and angle as inputs. This means you must insert two *integrator* blocks to represent the equation of motion, which is given by (6.4-4), p. 227 of Krause (neglect the damping term). One will be for the rotor speed ω_{rm}, and the other will be for the rotor angle ϑ_{rm}, which is related to speed by $d\vartheta_{rm}/dt = \omega_{rm}$.

Create a Microsoft Word document to include all simulation results and comments; this will be emailed to the T.A. upon completion of the lab.

3. Simulate the Free Acceleration from Stall [45 minutes]

Replicate the results of Fig. 6.9-1, p. 253. These correspond to a 5 HP machine, with parameters provided on p. 251 of Krause. *Note:* "Free Acceleration" means there is zero load torque.

DELIVERABLE 6: Calculate the steady-state stator and rotor currents using the equivalent circuit; these will help debug the simulation.

Hint: What is the rotor speed and slip at steady-state, under no load conditions?

Insert ASMG probes and scopes to capture the waveforms of interest.

DELIVERABLE 7: Simulate the free acceleration from stall, and compare your results to the figure. Verify your simulation using the steady-state values you computed earlier. Include your results in the Word document; comment on the results.

DELIVERABLE 8: Estimate the rated stator current of this machine. See p. 252 of Krause for more information. Comment on the behavior of the motor during the startup transient.

4. Simulate the Acceleration from Stall with a Load Torque [45 minutes]

Replicate the results of Fig. 6.9-5, p. 257. The mechanical load has a quadratic dependence on rotor speed.

DELIVERABLE 9: Simulate the acceleration and compare your results to the figure. Use the steady-state torque equation (6.8-26), p. 242 of Krause, to solve for the steady-state slip; this should match the simulated value. Email your results to the T.A.

5. Simulate a step change in load torque [30 minutes]

Replicate the results of Fig. 6.9-7, p. 259.

DELIVERABLE 10: Simulate the transient and compare your results to the figure. Email your results to the T.A.

6. Conclusion [15 minutes]

Write about one or two things you learned in this lab that you think are important or interesting, and why.