ECE 5670/6670 - Lab 9

Slip Control of Induction Motors

Objectives

The objective of the lab is to implement a slip control strategy on an induction motor. Both velocity and position control are considered.

1. Introduction

In Lab 8, it was found that the dynamic response of an induction motor with one pole pair ($n_p = 1$) and with sinusoidal phase voltages could be approximately described by

$$\frac{d\omega}{dt} = k(\omega_e - \omega) - \frac{\tau_{LF}}{J} \tag{1}$$

Equation (1) assumes that the slip is small, and that steady-state approximations are valid. If the slip is considered to be the input of the system, so that $u = \omega_e - \omega$, the transfer function from the input to the velocity is

$$\frac{\omega(s)}{u(s)} = \frac{k}{s} \tag{2}$$

or a pure integrator. The load and friction torque is treated as a disturbance. If the position is the output, the transfer function is

$$\frac{\theta(s)}{u(s)} = \frac{k}{s^2} \tag{3}$$

or a double integrator. Both transfer functions are easy to control, except for the fact that the gain k is actually not a constant, but varies significantly with $\omega_e = u + \omega$. Despite all of the approximations, however, reasonable control performance can be achieved with a slip control strategy based on the simple models (2) and (3).

2. Experiments

You will need:

- Induction motor,
- Standalone encoder,
- Dual power amplifier,
- Cable rack,
- Encoder cable,
- A metal frame to mount the motors on, with a box of screws and a screwdriver.

2.1 Preliminary Testing

Connect the motor as in Lab 8. Download the files *Lab9.mdl* and *Lab9.lax* from the lab web page. Your layout should look like the one in Fig. 1. You can also download the recorder and trigger files if you wish to use them.

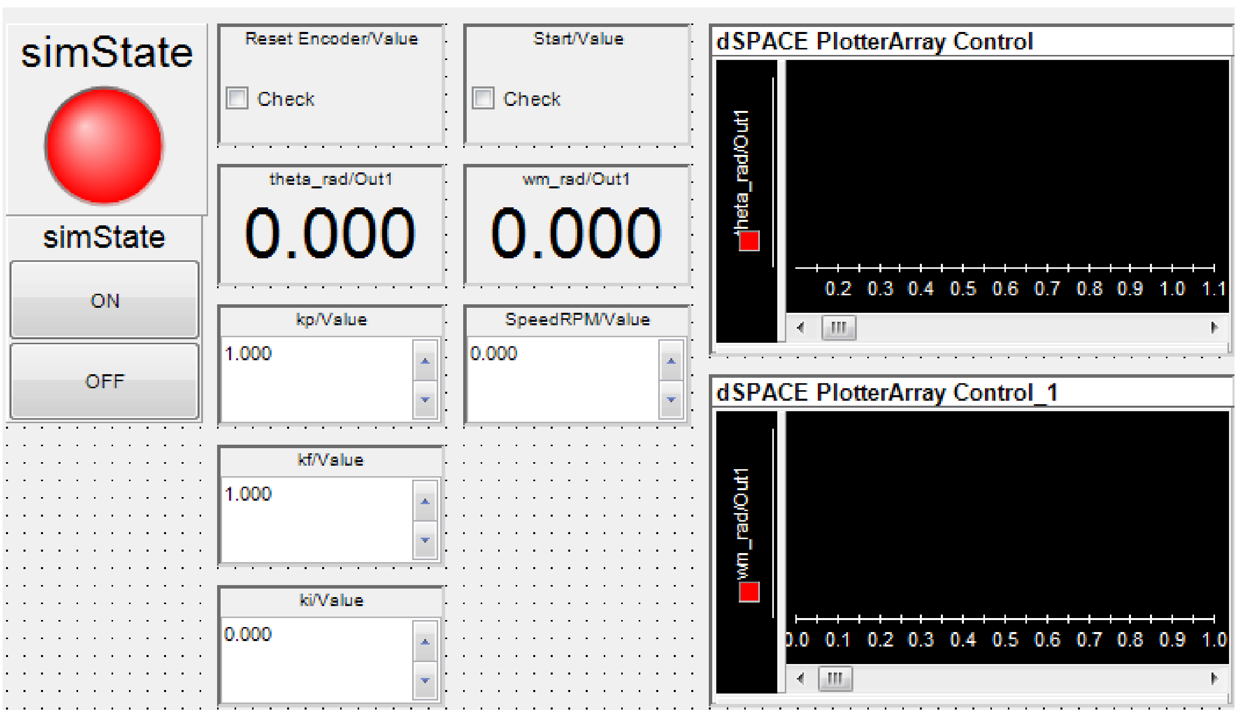

Figure 1: Layout

2.2 Proportional-Integral Control of Velocity

The Simulink model for Lab 9 implements a PI control law for the velocity, using slip as the control input. The program limits the values of the slip that can be applied to ±100 rad/s. The user may enter values for the proportional, integral, and feedforward gains. Then, reference values for the velocity can be applied and changed in real-time. To select the controller parameters, use a value of the parameter k equal to 12 (it is a good, mid-range value). First, test a proportional control law. For the proportional control law

$$u(s) = k_P(k_F * r - \omega) \tag{4}$$

Use (2) to find values of k_P and k_F such that the closed-loop pole is placed at -100 rad/s and the DC gain is equal to 1. Include a derivation of the parameters in your lab report. Plot the response of the motor for a reference velocity input stepping to 1,200 rpm, 2,400 rpm, and 3,600 rpm, giving the motor enough time to reach the steady-state speed in all cases, yet completing the experiment in 6 seconds. Observe that the response of the motor slows down as larger steps are applied, because of the decrease in gain and because of the slip limit.

Next, test the response of the motor with a proportional integral control law

$$u(s) = k_P(k_F r - \omega) + \frac{k_I}{s}(r - \omega) \tag{5}$$

Use (2) to find the values of k_P, k_F and k_I such that the control law places the two closed-loop poles at -50 rad/s, and the zero at -50 rad/s (the zero will cancel one of the poles). Be sure to include the derivation of the parameters in your lab report. Remember to implement an anti-windup modification by stopping the integration when the maximum voltage is reached (integrate zero instead of the error) in the Simulink model. Again, plot the response obtained for steps in velocity of 1,200 rpm, 2,400 rpm, and 3,600 rpm.

2.3 Proportional-Derivative Control of Position

Change the program to implement a PD control law for the position

$$u(s) = k_P(k_F r - \theta) - k_D \omega \tag{6}$$

Combine the control law with (3) to determine the PD control parameters. Design a PD control law that places the two poles at -50 rad/s (note that a similar characteristic equation is obtained as for the PI control of velocity). To test the control law experimentally, you will need to:

- Change the calculation of the reference input, so that the reference input in the layout is interpreted as a reference position in degrees.
- Change the control law according to (6).
- Update the layout so that you can change the derivative gain.

- Observe the output as the position of the motor.

Plot the response of the motor for a step input of 90 degrees, and measure the 2% settling time. Use a MAXSLIP variable of 200 rad/s for this experiment. Note that settling times can be expected to be less than 200 ms.

Requirements for Full Credit: The list below is a reference for your benefit. Be sure to include comments and explanations for all work performed and results observed/produced.

- Introduction with stated objectives.
- Derivation and calculation of the controller parameters for the proportional controller.
- Plot of the response with the proportional control law. Comparison of the response with the response for a smaller gain.
- Derivation and calculation of the controller parameters for the PI control laws for the velocity.
- Plot of the response with the PI control law.
- Derivation and calculation of parameters for the PD control law for the position.
- Screenshot of updated portion of Simulink model for PD control of position.
- Plot of the response with the PD control law for position and estimate of the settling time.
- Conclusion with reference to stated objectives. Describe what worked well and did not work well in this lab, and make suggestions for possible improvements.

***Be sure to LABEL the axes of all your plots and to include UNITS on all of your values. Comments should also always accompany any plot.**