**EECS 160LA Lab Report**

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| Title | Lab 2: Measuring DC Motor Parameters |
| Day of Session | Friday 8-10:50 am |
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| Date of Submission | 10/25/24 |

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# Introduction/Objective

In this experiment, we learned about the control systems of a motor circuit. This circuit includes a load and a motor as well as an inductor and a resistor whose values are predetermined and will be utilized throughout the experiment. We constructed control block diagrams of this system and modeled it in Simulink. The open loop system and closed loop system versions were both discussed and analyzed to understand the differing responses of the two systems and their stability. A variety of inputs were simulated into these systems and the resulting outputs were discussed. Methods such as a ramp and a controller subsystem to address inrush current will be tested through simulations to determine their effects on the motor and maintain threshold current.

# Discussion

After determining the control block diagram of the system, the transfer functions were determined and written into MATLAB. The constants required were also written into MATLAB as shown below.

A screenshot of a computer

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Figure : Matlab Code

First, the open loop system was created in MATLAB’s Simulink. The input was a step function with a step time of 1 and final value of 60.

A diagram of a diagram

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Figure : Open Loop with Step Input

The corresponding output of the step input is then graphed below.

A screen shot of a computer

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Figure :Output of Open Loop With Step Input

A screen shot of a graph

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Figure : Pole Zero Map of Open Loop System

The closed loop system is then simulated with the step input of the same parameters. The forward gain of the closed loop circuit is the open loop circuit. The K\_e gain in the feedback section is the only difference between the two, besides the additional of the feedback itself.

A diagram of a mathematical equation

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Figure :Closed Loop Control Block Diagram with Step Input

The resulting output of the system is then plotted. As seen in the graph the response is much quicker in achieving the saturation value, but the saturation value is much smaller.

A screenshot of a computer

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Figure :Output Curve of Closed Loop System w/ Step Function Input

A graph of a graph

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Figure : Pole Zero map of closed loop system

Next, we plot multiple graphs of the same closed loop system with the same step input. Now, we are plotting the current response, torque response, and the original response from figure 5, which is the motor response.

A diagram of a mathematical function

Description automatically generated

Figure 8 – Control Block Diagram of Closed Loop System with Multiple Outputs

These three outputs are plotted below, with the current graph in red, angular speed and torque in yellow, and motor speed in blue. The motor speed graph is the same as in the previous plot.

A graph of a graph

Description automatically generated with medium confidence

Figure 9 – Outputs of Motor Speed, Torque and Current for a Closed Loop System.

Once the step input is initiated, the current spikes up before decaying back down to zero. The torque has the same behavior, albeit with a smaller spike.

The closed loop system is then tested with a different input to try to remove the current spike. A ramp and saturation input is applied to the system, and the same three outputs are graphed. The ramp has a slope of 4 and a start time of 2. The saturation has a lower limit of -0.5 and an upper limit of 60.

A diagram of a mathematical equation

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Figure 10 – Control Diagram of Closed Loop System with Ramp and Saturation Input

The subsequent graphs are then displayed below. The behaviors of all three graphs are extremely different than the previous ones.

A graph with different colored lines

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Figure 11 – Output of Current, Torque, and Motor Speed for Ramp and Saturation Input

Now the current and torque spike in a concave down fashion and continue to increase for some time before decreasing to a saturation value. Note that this saturation value is no longer zero like before.

For the next section of this experiment, the controller transfer function is greatly enhanced with its own subsystem. This subsystem is displayed below.

**A diagram of a computer

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Figure 12 – Controller Subsystem Block Diagram

We will run two different outputs on this controller, one with the gain set to 100 and the other with the gain set to 1000. The overall block diagram is only slightly changed with the connections to the subsystem.

A diagram of a mathematical function

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Figure 13 – Overall Block Diagram of Control System with Controller Subsystem

The output waveforms are then displayed below in different colors. As in the other graphs the current and torque curves have similar structures. In this case they both abruptly go up before slightly decreasing for a time before then decaying to a given saturation value.

A white sheet with red and green lines

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 Figure 14 – Closed Loop Gain with Controller Gain at 100

The controller subsystem gain is then set to 1000. One of the main concepts of control systems is how to decrease the error in the signal. Increasing the loop gain will accomplish this, but most of the gains in the loop gain are set by either manufacturers or by the environment. Thus, the only gain that control system engineers can manipulate is the controller gain, which is what we do in this experiment. The controller gain has increased by 10 times from 100 to 1000. The results are plotted below.

A white sheet with red and green lines

Description automatically generatedFigure 15 - Closed Loop Gain with Controller Gain at 1000

Comparing the graphs in figures 12 and 13, figure 13 is slightly more refined in that the slope for the current and torque is flatter in the plateau part of their curves, displaying now some of the error has been eliminated.

**Lab Questions:**

1. Open loop transfer function G(s)

2. Closed loop transfer function TCL(s)

3. Poles of open loop transfer function are s = -1229.2, -0.0001. Poles of the closed loop transfer function are s = -1227.5, -0.0018. What has changed is that one of the poles moved further to the left and away from the imaginary axis for the closed loop system The reason it has changed is due to the feedback loop present in the closed loop system. By introducing a feedback loop the system is now decaying (responding) faster in the transient domain as the real part of the poles are now farther to the left of the imaginary axis.

4. a. The problems of starting the motor with a large inrush current is that the system may not be able to support the current needs and cause the motor to fail. The inrush current is very high in the beginning because the motor is going from no movement to sudden movement which requires more power to begin. Additionally, there is no back EMF present in the motor upon start which presents no resistance.

b. The problems of using a ramp to start a motor is that there is a large delay for the motor to stabilize compared to the quicker start without the ramp present.

c. The armature current is not always less than the threshold current as displayed by the output of the circuit Figure 11. The armature current can be always kept less than the threshold current by utilizing a controller subsystem as we did in Figure 11 but we would set the controller to limit at a lower amperage such as 9.8 volts so the system would keep the armature current less than threshold current of 10A and account for error. Additionally, a larger gain would allow for more accuracy to ensure that the system does not have a large amount of errors above the desired armature current while keeping in mind that an extremely large gain is not feasible. Increasing the gain also increases the rate at which the system normalizes itself increases, also decreasing the amount of error.

# Conclusion

In this experiment we explored control systems for motors to understand their operation and how to optimize it to our desired requirements. Comparing a motor with feedback and without feedback resulted in responses that demonstrated that feedback allowed the system to reach the maximum gain value faster but came at the cost of reduced gain. The analysis on the currents demonstrated that a step input resulted in a current spike on a motor that exceeded an ideal threshold value. Using a ramp response input the spike was reduced but it also increased the time needed for the motor to reach its speed. The current limiter was better able to reduce the spike while reaching a speed faster. A higher gain demonstrated better control over keeping the current at the threshold but there was still some excess current.