Lab 7 - Electromechanical System

Overview

In this lab we will be demonstrating a physical electromechanical system that will also record experimental data. After observing the short demonstration and saving the experimental data, we will then model the physical system within Simulink. We will then compare the simulated output to the experimental results.

Resources Required:
MATLAB
Simulink
Simscape
Simscape Multibody
Optimization Toolbox
dcMotor_Data.xlsx

Description of the System

The system, as seen in figure 1, is an Arduino Nano controlled DC motor. The model also records positional feedback of the motor shaft as it rotates, as well as the current draw of the motor. The rotary dial on the side can be used to vary the input voltage to the DC motor and thus can vary the rotational speed. A DC barrel jack is used to power the circuit board and subsequently the DC motor.

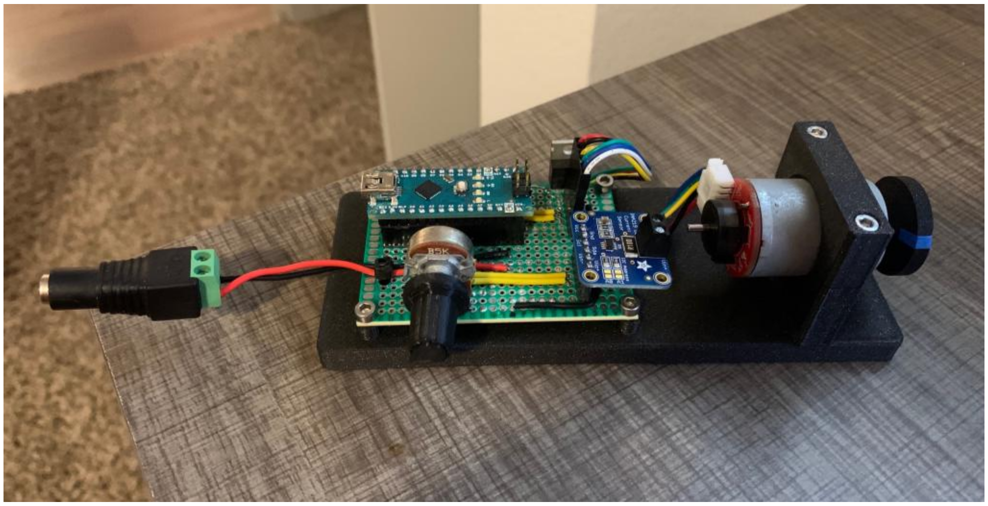

Figure 1: Physical DC Motor System

Task 1: Physical Model Demonstration and Data

For this task, the TA will perform a brief demonstration of the electromechanical system.

NOTE: A video of the demonstration can also be viewed with following link,

After the demonstration, if you have not done so already, retrieve the data file titled "dcMotor_Data.xlsx" from the lab folder in Canvas.

Open the "dcMotor_Data.xlsx" file in Excel, or if you don't have Excel, you can open it in Google Sheets. Take note of the workbook. It consists of three sheets of data for when the system was running at 6 V, 9 V, and 12 V.

For each sheet, there are four columns of data. The first column is the time in seconds, the second is the supplied voltage in Volts, the third column is the amperage in mA, and the fourth column is the angular velocity of the motor shaft in rpm.

For **each** of the **sheets** of data perform the following:

1. Add headers to the columns of the data. Remember it is also good practice to include the unit's abbreviation for the column in parenthesis after the header.
2. Add a fifth column for angular velocity (rad/s) next to your angular velocity (rpm). Look up what the conversion is between rpm and rad/s and create a formula to determine the rpm in rad/s and fill the column.
3. Create a "Scatter with Smooth Lines" plot of both the angular velocity in rad/s and amperage vs. time within the same plot.
4. Put the amperage on the primary y axis and the angular velocity on the secondary y axis. To do this double click on the line of the angular velocity plot and select the "Secondary Axis" radio button under the series option dialog window.
5. Be sure to include a proper title, legend, and x and y axis labels with units.

Now you have a plot of the experimental data and know the behavior of the system. This also lets you know how the Simulink output should appear and compare to.

Change your time range (x-axis) to 0-0.25 seconds and include that plot in your lab report for discussion.

Task 2: Modeling DC Electric Motor

A generic DC electric motor setup is shown in Figure 1 below.

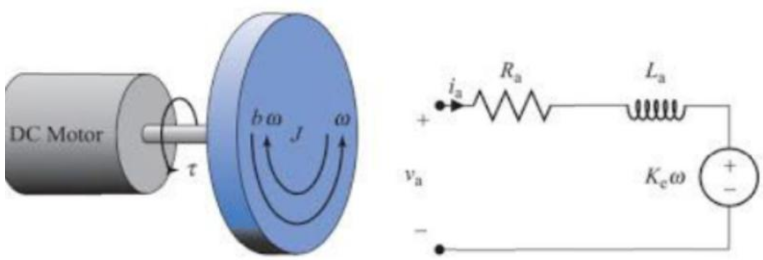

Figure 1: DC Electric Motor Model with labeled components and defined variables

Using common methods of mechanical and electrical dynamic analysis the following ODE equations as shown below can be used to model a DC motor:

$$J\dot{\omega} + b\omega = \tau \quad (1)$$
$$\tau = k * i \quad (2)$$
$$** \; eq\ 1\ and\ 2\ can\ be\ combined\ if\ necessary \; **$$
$$v = R * I + L * \dot{I} + k\omega \quad (3)$$

The variables of the following three equations are listed in Table 1 below.

Table 1: Notation for System Variables

Notation	Variable Name
J	Shaft Inertia
ω	Rotational Velocity
θ	Rotational Position
b	Rotational Damping
τ	Motor Torque
v	Supply Voltage
i	Current
R	Resistance
k	Motor Constant
L	Inductance

Include all answers to the content below within your lab report.

1. Based on the equations above what does the term $\dot{\omega}$ represent? What does $\dot{\theta}$ represent?

2. What is the name of the electro-magnetic property of a that generates '$k\omega$' in equation 3. How does this property function within a DC electric motor. Provide any resources/links/papers used to determine this.

Task 3: Modeling Spring Mass Damper System using Simscape

For task 3, we will be modeling the physical electromechanical system using Simscape. Create the system diagram to look like it is shown in figure 2.

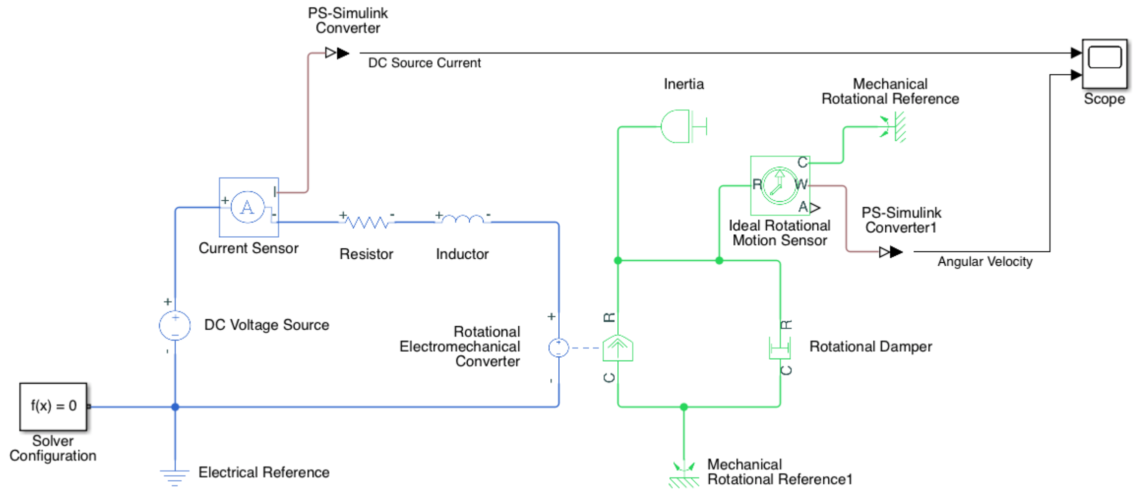

Figure 2: Spring Mass Damper System using Simscape

1. Once you have all the blocks placed and connected, you will need to update the appropriate blocks with these defined parameters
    - DC Voltage = 12 V
    - Resistor = 1 Ohm
    - Inductor =100 nH
    - Constant of proportionality K = 0.75
    - Dampening Coefficient= 0.01 Nm/ (rad/s)
    - Inertia = 0.01kg*m^2

2. Now, open the “Model Configuration Parameters” window by clicking on the “Modeling” tab at the top of the Simulink ribbon, then clicking the “Model Settings” button within the ribbon.
3. In the “Configuration Parameters” window, be sure you are on the “Solver” tab from the left side pane. Here, you need to change the following:
    - Stop time: 3 (seconds)
    - Solver: ode23t (mod.stiff/Trapesoidal)
    - Max step size: 0.2 (seconds)

   For reference, the window with the changes should look like it does in figure 3.

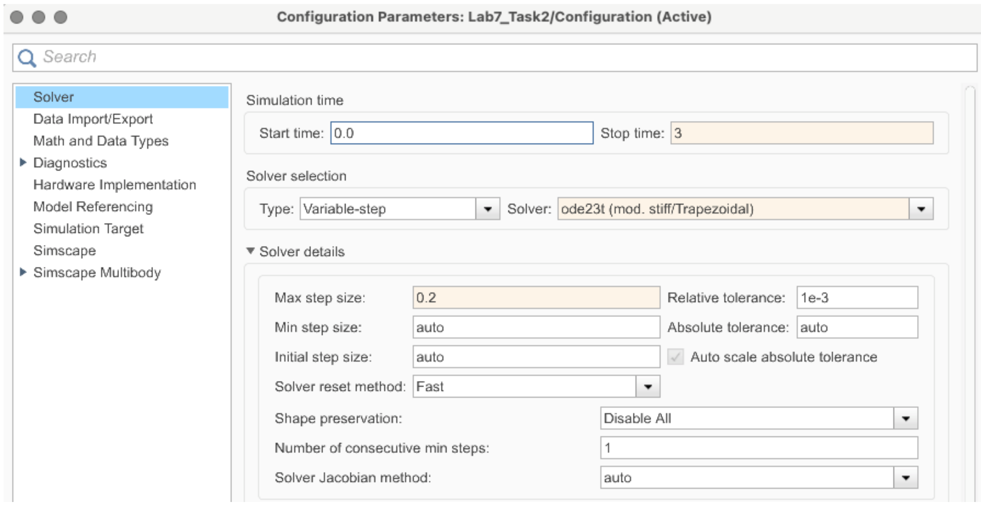

Figure 3: Configuration Parameters Window

4. Run the simulation and ensure that the scope shows a plot similar to the physical model's data.
5. Format and save the block diagram, and the plot appropriately and include them in your report.
   NOTE: Remember the layout feature within the scope from the RLC lab. Use this feature to stack the Current and Angular Velocity plots one on top of the other. This way, you can have both plots showing in one figure.
6. Go back and change the DC Voltage Source to 9 V and collect the plot for when the source voltage is at 9 V.
7. Repeat the previous step for when the source voltage is at 6 V.
8. Change your time range (y-axis) to 0-0.25 seconds and include that plot in your lab report for discussion.

Post-Lab Questions (To be Incorporated in the Results section)

1. Briefly describe the similarities between the system responses at the three different voltage levels. What is the common variable between them and how does changing it affect the systems current response and angular velocity?

2. For both the physical and simulated models of a dc motor, why does the current suddenly increase for such a short period before drastically reducing down to a steady state?

3. Briefly explain what is back emf of a DC motor and what parameter within Simulink is responsible for adjusting it?

4. Compare the plots you generated from the data that was obtained from the physical model to your Simulink model. Note down some of these comparisons and specify any potential sources of error.