Design of Simulink® -based Electromechanical Control Workstation for Load Disturbance Testing

Project Proposal

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Introduction

The aim of this project is to first model in Simulink and SimMechanics the Pittman GM9236C534-R2 DC motor, using parameters obtained from datasheets and from experimental data. Using an electronic coupling device, also modeled in Simulink, the shaft of the first motor will be connected to the shaft of a DC generator to act as a load. Controller designs to minimize the effects of this load disturbance will then be implemented in Simulink. Using Matlab's built-in GUI, the user will be able to vary numerous motor, coupler, and load parameters and view the effects of these changes on the system.

Project Description

The complete system block diagram is presented below.

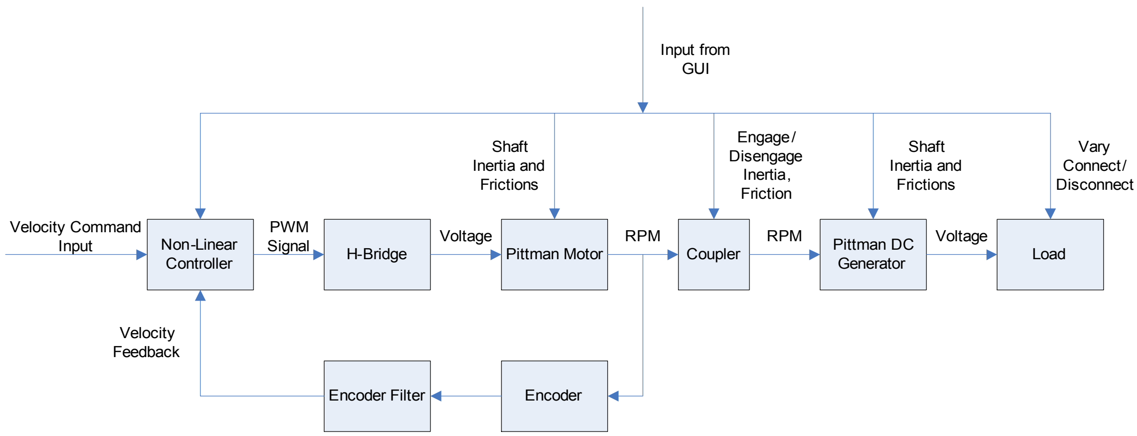

Figure 1: Complete System Block Diagram

The inputs to the system are the various motor, coupler, and load parameters, as well as the command velocity. Other command signals of interest might include position, acceleration, or torque. Outputs to be analyzed consist of motor position, velocity, acceleration, torque, and current. The blocks of significance will be described briefly in the following sections. Initially all the controller design and simulation will be done in Simulink using the models developed there. The ultimate goal is to interface the Simulink controller to the physical system through the PC serial port.

The Graphical User Interface

This interface will allow the user to modify key characteristics of the controller motor models, coupler model, and generator load. Controller parameters to be varied include the type of controller, gain, and pulse width modulation (PWM) resolution. Characteristics of interest of both the motor and generator are rotor frictions and inertia, speed-voltage constant, winding inductance and resistance, torque constant, and rotary encoder resolution. The user will be able to engage and disengage the coupler, as well as vary the inertia, friction, and time delay associated with it. Finally, the generator load size can be varied, connected, and disconnected.

The Controller

Several controller designs will be implemented to allow for comparisons on effectiveness for this particular application. Designs might include linear approaches such as proportional, proportional-integral (PI), proportional-integral-derivative (PID), and optimum phase margin design. Time permitting, more advanced linear and nonlinear controller designs might be explored.

The DC Motor

This motor will be regulated by a PWM input. The starting point for the nonlinear model of the Pittman motor will be the linear model developed in the 2006 mini-project, detailed below.

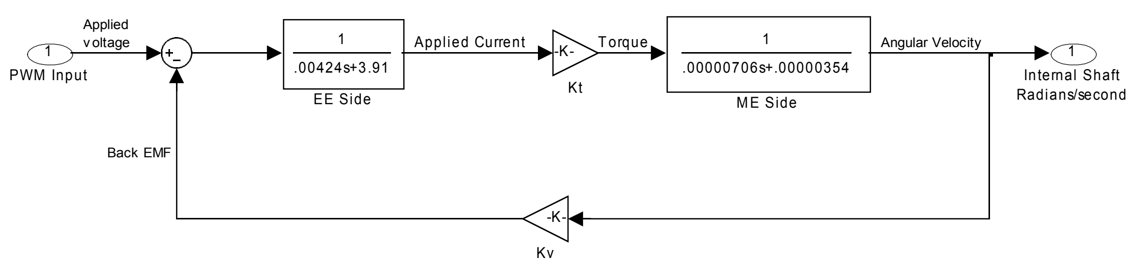

Figure 2: Linear DC Motor Model

The nonlinear model will take into account the effects of the nonlinear frictions present in the motor. The figures below illustrate the nature of these frictions.

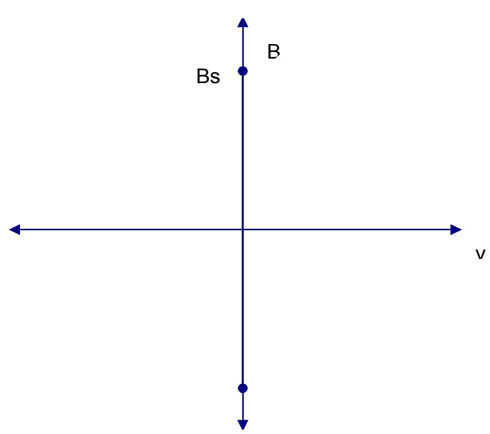

Figure 3: Static Friction vs Motor Velocity

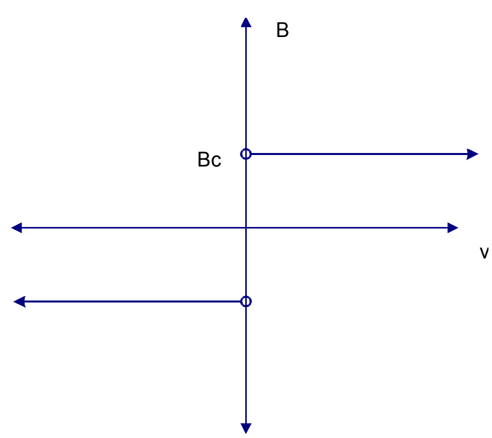

Figure 4: Coulomb Friction vs Motor Velocity

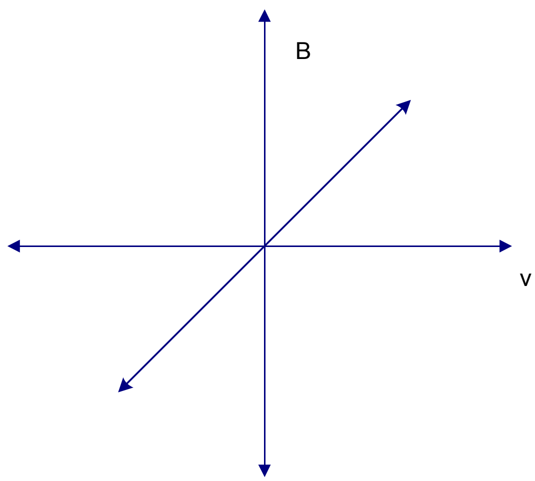

Figure 5: Viscous Friction vs Motor Velocity

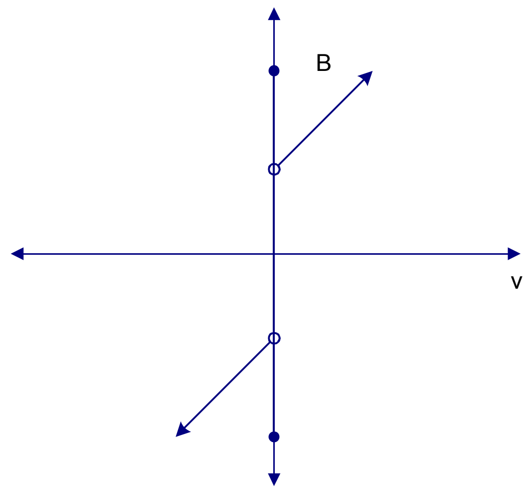

Figure 6: Combined Friction vs Motor Velocity

The Coupler (or Clutch)

This is an external device used to connect the shaft of the DC motor to that of the DC generator. The EC15 Clutch from REELL Precision Manufacturing Company was selected for this application. Ideally the clutch would engage instantaneously and have no effects of its own on the system. However, this is not the case and it must be accurately modeled in Simulink. The model will be designed based on experimental data.

Figure 7: EC15 Clutch

The DC Generator

Essentially a second DC motor connected in reverse, the input to the system is a torque delivered by the DC motor through the coupler. It then generates an output voltage proportional to the shaft velocity. A variable power resistor connected across the motor terminals can be used to increase or decrease the load on the motor.

Functional Requirements and Performance Specifications of Subsystem Components	
Subsystem	Primary Objectives
Controller	• Nonlinear characteristics of motor must be accounted for. • X% overshoot with Y load. • ___ settling time with Y load. • ___ rise time with Y load. • Regulation range: 0rpm – 500rpm.
DC Motor Model	• Initial model parameters accurate. • Motor model based on measured parameters accurate to within X% (velocity, current). • All model parameters should be variable using GUI.
Clutch	• Experimental time delay accurately depicted in clutch model. • Clutch model engaged/disengaged through GUI. • Model only works in one direction. • All model parameters should be variable using GUI, including inertia, friction, and spring constant.
DC Generator Model	• Initial model parameters accurate. • Generator model based on measured parameters accurate to within X% (voltage, current). • All model parameters should be variable using GUI. • Load varied/connected/disconnected through GUI.
GUI	• Aesthetically pleasing and intuitive layout. • Outputs of interest displayed and graphed vs. command inputs.

Preliminary Work

- SimMechanics
  - Tutorials
    - Pendulum
    - Four Bar System
  - Examples
    - Conveyor System from Matlab website
    - Quanser motor model used in EE430
  - Design
    - Designed a model for the DC motor ignoring friction
- GUI
  - Matlab GUI tutorials
  - Initiated design of a GUI for DC motor model designed during the mini-project
- Clutch Model
  - Designed a method to examine the transient response of the clutch

Spring Semester Schedule		
Week	Laith Slaton	Adesegun Sun-basorun
1-3	Coupler System ID	Motor System ID
4-5	Validation of models	
6	Single loop velocity control	
7-8	GUI design	
9	Two-loop velocity/acceleration	Single-loop feed-forward
10	Serial interface between Simulink and physical system	
11-12	Advanced Controllers (Optimum Phase Margin, Disturbance Rejection, State-variable, Three-loop with torque control, Nonlinear controller, Adaptive Feed-Forward Control)	
13-14	Final Documentation	

References

Manufacturer Site and Clutch Datasheet
http://www.reell.com/products/ec15.htm

Pittman Motor Datasheet
http://blackboard.bradley.edu/courses/1/EE450_01_06FA/content/_390613_1/gm9000_pittman.pdf

Pittman Servo Motor Application Notes
http://blackboard.bradley.edu/courses/1/EE451_01_06FA/content/_455117_1/220000ALL.pdf