MEG 421 Automatic Control

Lab #3 Computer-Based Dynamic System Analysis III.

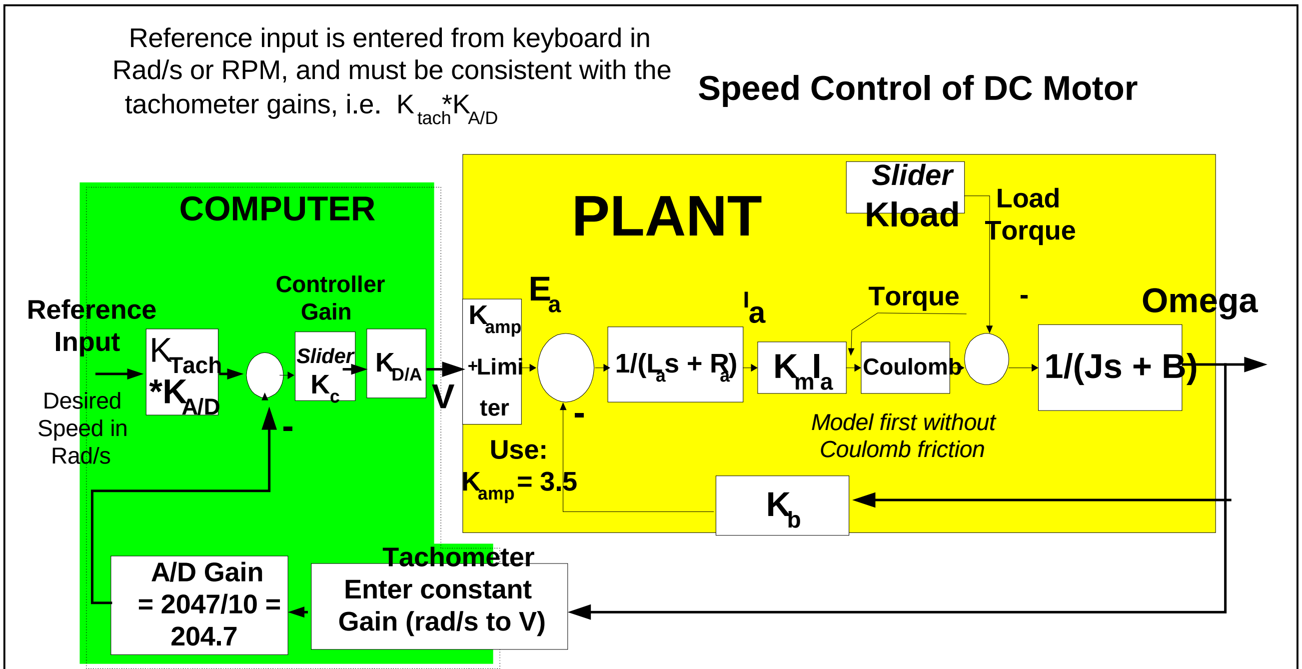

Figure 1 Detailed Block Diagram of DC Motor Speed Control

Objective: To introduce you to principles of digital control, and to prepare you for the first experiments.
Computer Based Control - The digital computer communicates with the process it controls through a data acquisition board which performs A/D and D/A conversions. The board is generally set up to convert voltages ranging from -10V to +10V DC to integer numbers ranging from -2047 to +2047. Conversely, integer numbers passed to the digital output are converted with the inverse gain, i.e. the number 2047 results in 10V DC output voltage, the number 1024 produces 5 V and so on. Normally, the experiments will give you raw, integer process data; therefore you will have to make the required conversions in your Simulation program. **Example:** you wish the motor to run at 1,000 rpm and wish to determine the necessary reference value. The tachometer delivers a 5V signal at 1,000 rpm, which after the A/D conversion will be internally represented as the integer conversion of 5*204.7 = 1023. Therefore, you would enter a reference value of 1023 for the desired 1000 rpm motor speed. The software used to control the actual experiments will also deliver raw output data as integers. Convert the raw data to rpm or Rad/s as appropriate.

Assignment:
1. 1. If you have not already done so, complete the model of the electric motor of Lab 2 in VisSim by adding the nonlinear elements, and the parameterized amplifier gains (= sliders), K_contr and a slider for the load K_load. Also enter the D/A and A/D gains. In VisSim, create a new simulation, name it ‘pmotor’ and save it. Open your Lab 2 plant model in VisSim. Copy the entire Lab2 model into ‘pmotor’ ands save pmotor. Add the other elements of the figure above and connect them as usual. See Fig. 2 below for details. Modify both the linear and the nonlinear plants by moving the multiplier in each plant to the controller, see

Fig.2. Now each compound block has only one input. Remove the second input with the ‘Remove Connector’ tool in the icon bar. Open each compound block. In each compound block, connect the amplifier input to the arrow at the far left side of the compound block. Fig. 2 shows a modified plant compound block, and the elements of the controller compound block.

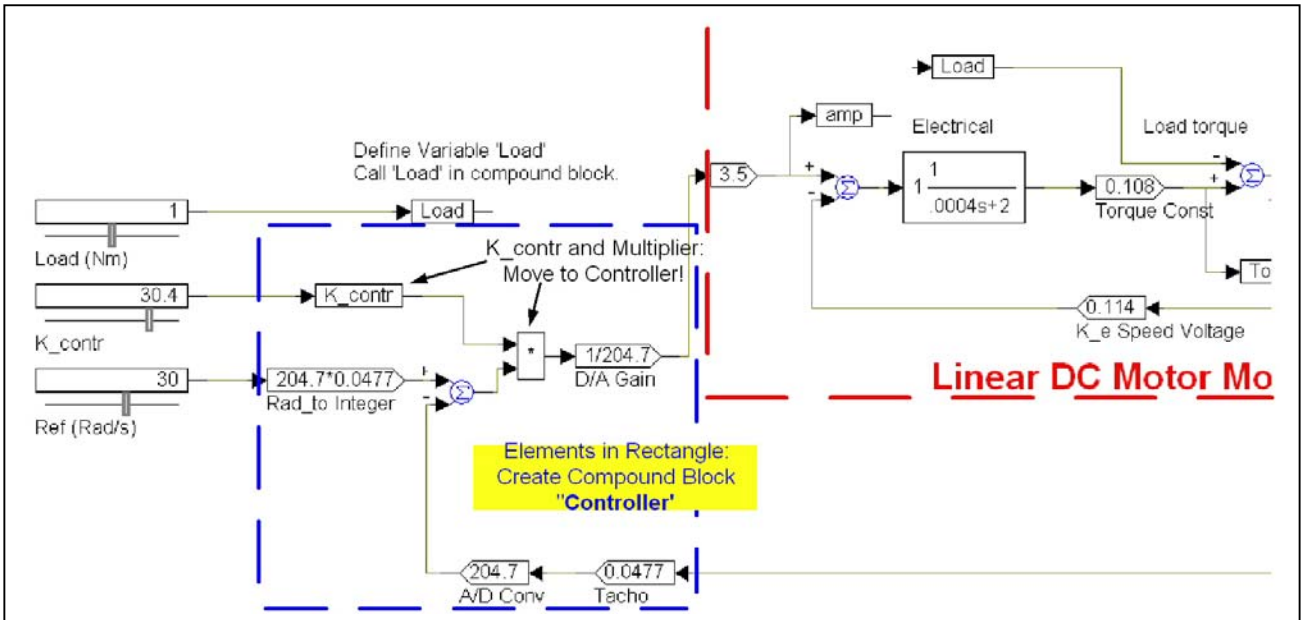

Figure 2 Controller and Modified Motor Plant

2. Design a controller (namely an amplifier with gain K_contr) to regulate the shaft angular velocity. A tachometer (actually a small DC generator) is attached to the motor. The motor data sheet informs us that the tachometer output is 5V/1000 RPM. Convert to Volts per Rad/s, which is our speed signal. Create sliders for the reference (motor speed in rad/s), controller gain and the load torque. Fig. 3 shows the VisSim diagram. Clearly label each slider so that you remember its function. The motor is fast, so in ‘Simulation properties, set the end time at 0.1 or 0.2 s, and Frequency to 500. Feel free to alter these parameters as you wish.
3. Vary the controller gain and the reference input, and observe the effects on motor speed. Observe the motor speed response for these sample parameter settings:

Ref = 30 rad/s; K_load = 0; K_contr = 1;
Ref = 30 rad/s; K_load = 0; K_contr = 2;
Ref = 30 rad/s; K_load = 0; K_contr = 10;
Ref = 30 rad/s; K_load = 0; K_contr = 20;
Ref = 30 rad/s; K_load = 0; K_contr = 30;

Plot the first four responses (of the nonlinear system only to avoid clutter) in the same plot using the ‘Overplot’ feature. Clearly label each gain associated with each trace!

Submit: one graph with four step responses of the nonlinear system, each gain setting clearly labeled in the plot.

In your report, please answer the following **questions**:

1. How is the steady state error affected by gain variations?
2. How is the system’s speed affected by gain variations?

3. How is the system's stability affected by gain variations?

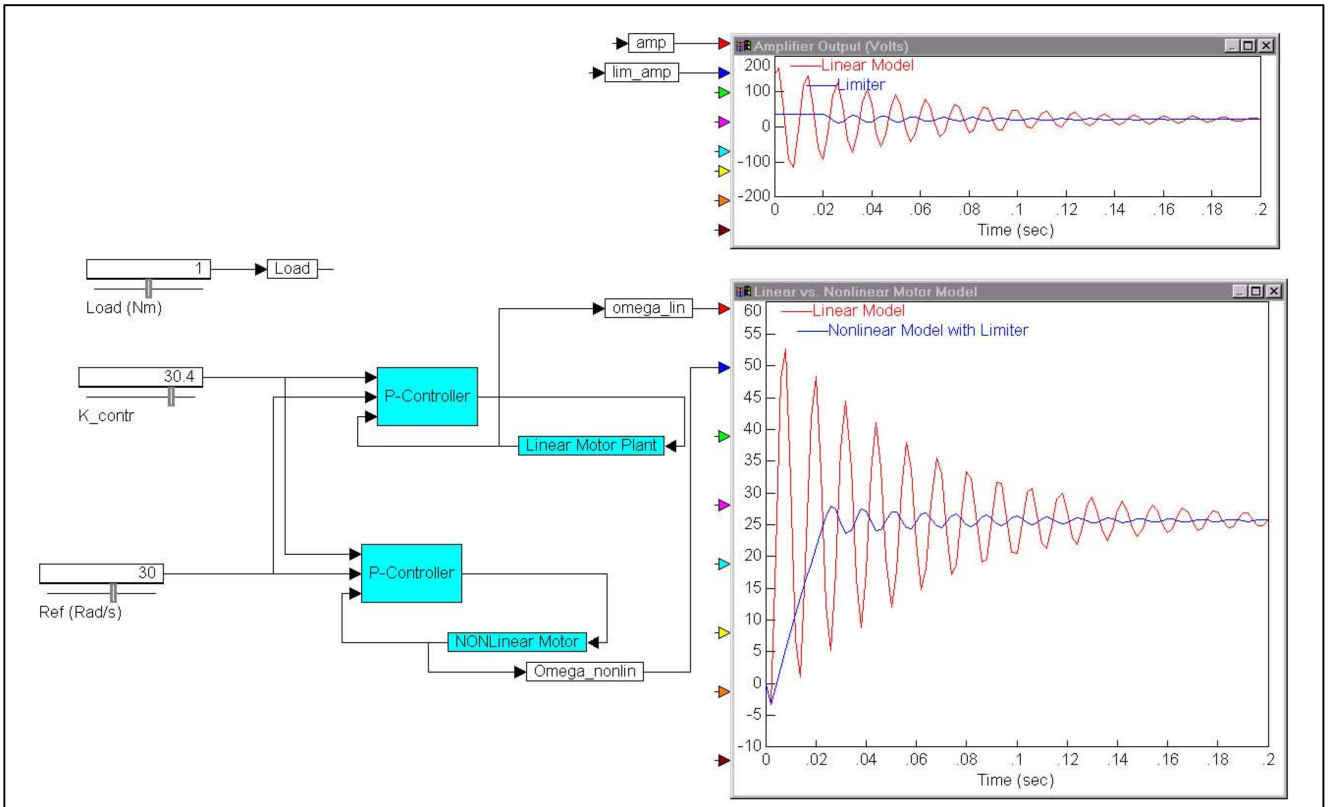

Figure 3 Closed Loop DC Motor Speed Control

4. Repeat the sequence of part 3 for KLOAD = 0.2, 1, 2 Nm etc. and plot the nonlinear system step response for these loads. Except for setting Kload = 2 once, do not let the motor run in reverse (i.e. negative speeds)!

Note: In submitted plots , add a legend to each plot containing more than one output variable.

Submit: one graph for **each** LOAD setting. Each graph with four step responses of the nonlinear system, each gain setting clearly labeled in the plot.

Total for this section: three graphs.

In addition, please answer the following **questions**:

1. Explain the differences between linear and nonlinear models in control system performance under load.
2. At Kload = 2 Nm, why does the linear control system maintain its speed, whereas the nonlinear system doesn't?
3. Why does the motor never reach the exact reference speed?