EE5351: CONTROL SYSTEM DESIGN

LABORATORY 01

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Summative Laboratory Form

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1 OBSERVATIONS

Q1)

I.

$$V_m = i_m R_m + L_m \frac{di_m}{dt} + e_b \quad \cdots \quad 1$$

$$e_b = k_m \omega_m \quad \cdots \quad 2$$

$$T_m = J_{eq} \frac{d\omega_m}{dt} \quad \cdots \quad 3$$

$$T_m = i_m k_t \quad \cdots \quad 4$$

II. Considering the above equations Speed Control Given as:

$$\frac{\omega_m(S)}{V_m(S)} = \frac{k_t}{[J_{eq}S(R_m+L_mS]+k_mk_t]}$$

$$= \frac{0.042}{[2.09\times10^{-5}S(8.4+1.16\times10^{-3}S)+0.042\times0.042]}$$

$$= \frac{0.042}{2.424\times10^{-8}S^2+1.756\times10^{-4}S+1.764\times10^{-3}}$$

Considering the above equations Position Control Given as:

$$\frac{\theta_m(S)}{V_m(S)} = \frac{k_t}{S[J_{eq}S(R_m+L_mS]+k_mk_t]}$$

$$= \frac{0.042}{2.424\times10^{-8}S^3+1.756\times10^{-4}S^2+1.764\times10^{-3}S}$$

III.

```
% Parameters
Rm = 8.4; % Terminal resistance (Ohms)
Lm = 1.16e-3; % Rotor inductance (H)
Jeq = 2.09e-5; % Equivalent inertia (kg*m^2)
kt = 0.042; % Torque constant (Nm/A)
km = 0.042; % Voltage constant (V/rad/s)

% Transfer function for speed control
num = kt;
den = [Jeq*Lm, Jeq*Rm, kt*km];
sys = tf(num, den);

% Simulate step response for 3V input
input_voltage = 3; % Applied voltage
t = 0:0.001:1; % Time vector
[u, t] = step(input_voltage * sys, t);

% Plot speed response
figure;
plot(t, u);
title('Speed Response for 3V Input');
xlabel('Time (s)');
ylabel('Speed (rad/s)');
grid on;
```

Figure 1:MathLAB code for the Speed Response

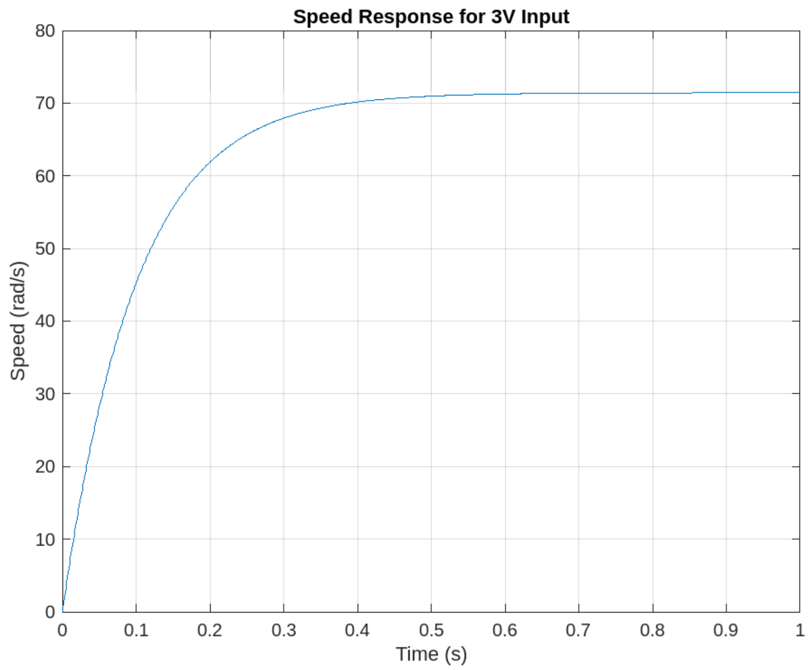

Figure 2: Graph For the Speed Response When input Voltage as 3V

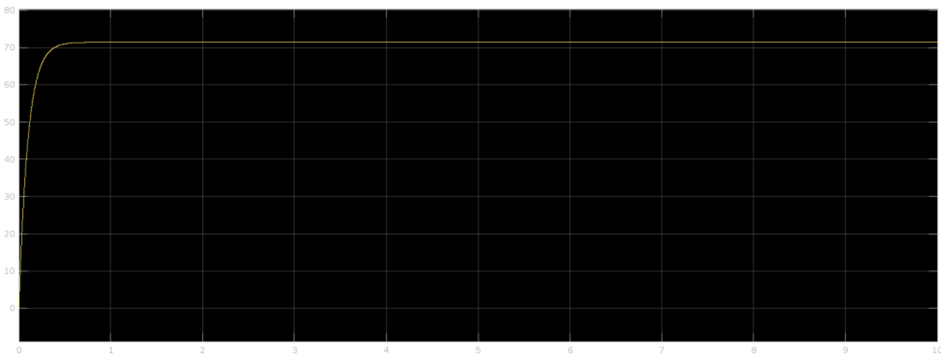

Figure 3:Simulink for Speed Response

IV. Speed Control Given as:

$$\frac{\omega_m(S)}{V_m(S)} = \frac{k_t}{[J_{eq}S(R_m]+k_m k_t]}$$

$$= \frac{0.042}{1.756\times10^{-4}S+1.764\times10^{-3}}$$

Position Control Given as:

$$\frac{\theta_m(S)}{V_m(S)} = \frac{k_t}{S[J_{eq}S(R_m]+k_m k_t]}$$

$$= \frac{0.042}{1.756\times10^{-4}s^2+1.764\times10^{-3}S}$$

V.

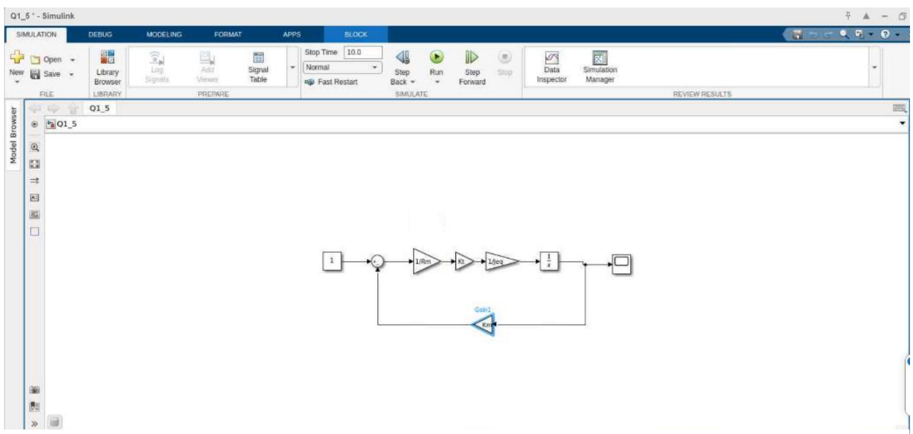

Figure 4: Simulink for simplified version

VI. Considering the equations given above:

$$\dot{i_m} = -\left(\frac{R_m}{L_m}\right) I_m - \left(\frac{k_m}{L_m}\right)\omega_m + \frac{V_m}{L_m}$$

$$\dot{\omega_m} = -\left(\frac{k_t}{J_{eq}}\right) I_m - 0 \times \omega_m + 0 \times V_m$$

$$\omega_m = 0\times I_m + 1 \times \omega_m + 0 \times V_m$$

$$\begin{pmatrix} \dot{i_m} \\ \dot{\omega_m} \end{pmatrix} = \begin{bmatrix} -\frac{R_m}{L_m} & -\frac{k_m}{L_m} \\ \frac{k_t}{J_{eq}} & 0 \end{bmatrix} \begin{pmatrix} I_m \\ \omega_m \end{pmatrix} + \begin{pmatrix} \frac{1}{L_m} \\ 0 \end{pmatrix} V_m$$

$$\begin{pmatrix} \dot{i_m} \\ \dot{\omega_m} \end{pmatrix} = \begin{bmatrix} -7241.38 & -36.21 \\ 2009.57 & 0 \end{bmatrix} \begin{pmatrix} I_m \\ \omega_m \end{pmatrix} + \begin{pmatrix} 862.07 \\ 0 \end{pmatrix} V_m$$

$$\omega_m = [0 \;\; 1] \times \begin{pmatrix} I_m \\ \omega_m \end{pmatrix} + 0 \times V_m$$

VII. Considering the simplified version

$$\dot{\theta} = 0 \times \theta_m + \omega_m + 0 \times v_m$$

$$\dot{\omega_m} = 0 \times \theta_m - \left(\frac{k_t k_m}{R_m J_{eq}}\right)\omega_m + \left(\frac{K_t}{J_{eq} R_m}\right) V_m$$

$$\omega_m = 0\times \theta_m + 1 \times \omega_m + 0 \times V_m$$

$$\begin{pmatrix} \dot{\theta} \\ \dot{\omega_m} \end{pmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -\left(\frac{k_t k_m}{R_m J_{eq}}\right) \end{bmatrix} \begin{pmatrix} \theta_m \\ \omega_m \end{pmatrix} + \begin{pmatrix} 0 \\ \frac{K_t}{J_{eq} R_m} \end{pmatrix} V_m$$

$$\begin{pmatrix} \dot{\theta} \\ \dot{\omega_m} \end{pmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -10.05 \end{bmatrix} \begin{pmatrix} \theta_m \\ \omega_m \end{pmatrix} + \begin{pmatrix} 0 \\ 239.23 \end{pmatrix} V_m$$

$$\omega_m = [0 \;\; 1] \times \begin{pmatrix} \theta_m \\ \omega_m \end{pmatrix} + 0 \times V_m$$

VIII.

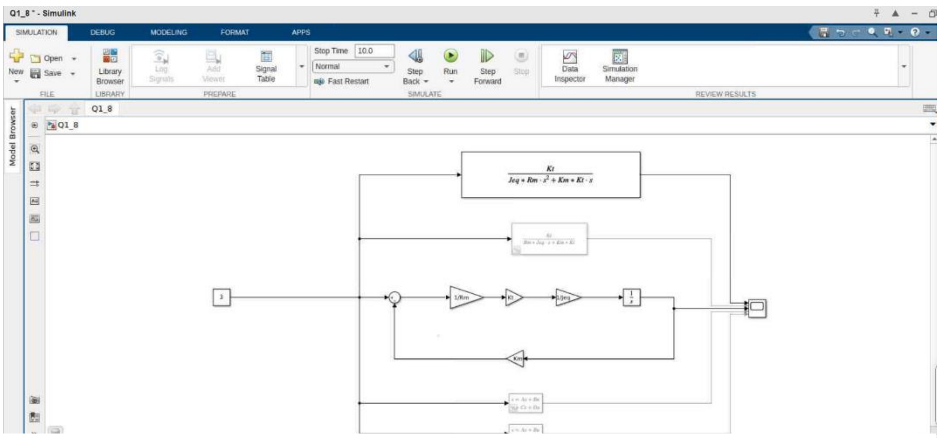

Figure 5: Combination of the Simulink for 2,4,5,6,7 Questions

Q2)

i.

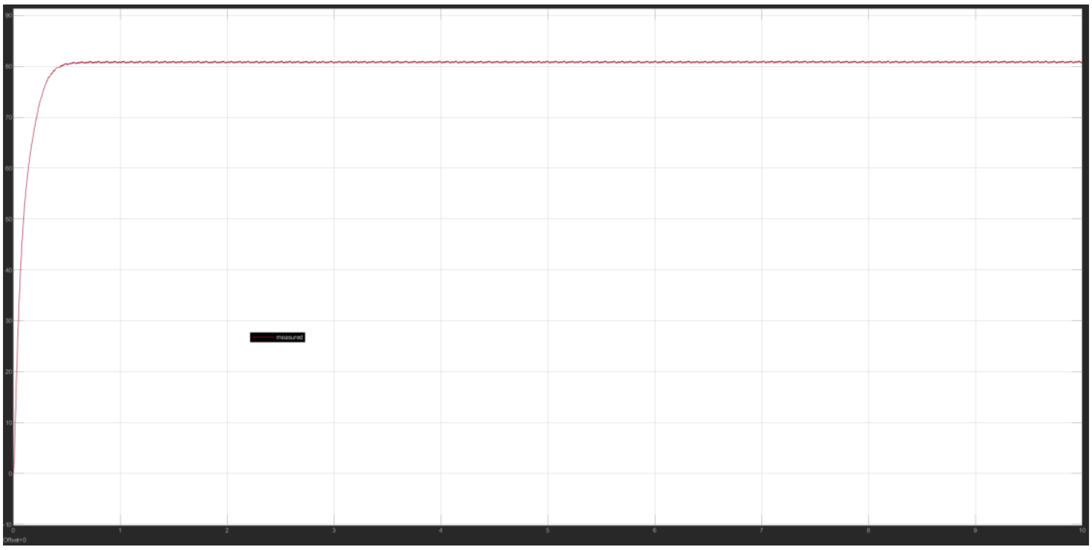

Figure 6: Speed Response given by the Model that had created

Figure 7: The graph given by state space model and Simulink Model

i. Comparing the graphs there can be error as 10 .
So considering the error the reasons can be achieved by the models value was get by running the rotor so there can be a error that has negligible . not only that but also considering the assumption that the rotor and the modelspace there can be done the errors doing in the the simulate of the equations. As well as when running of the software which can be also happened the errors as can be stucked etc.

Q3)

1.

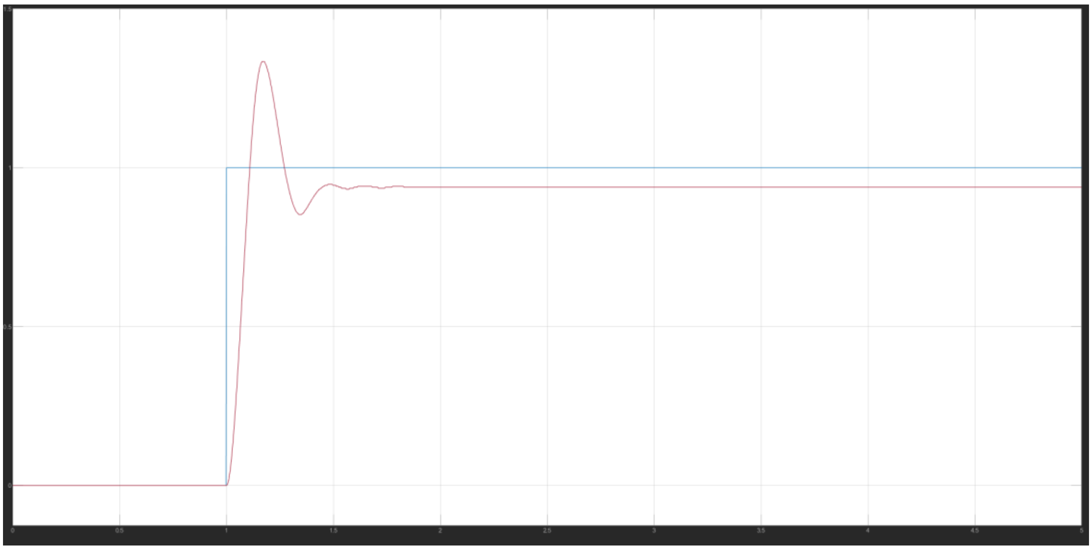

Figure 8: Time Domain Response

2.

Steady State Error: $1 - 0.938$: 0.062

3. When K_p= 1

Steady State Error	:	$1 - 0.938$	:	0.062
Overshoot	:	$\frac{1.335-0.938}{0.938} \times 100\%$		
	:	<u>42.32%</u>		

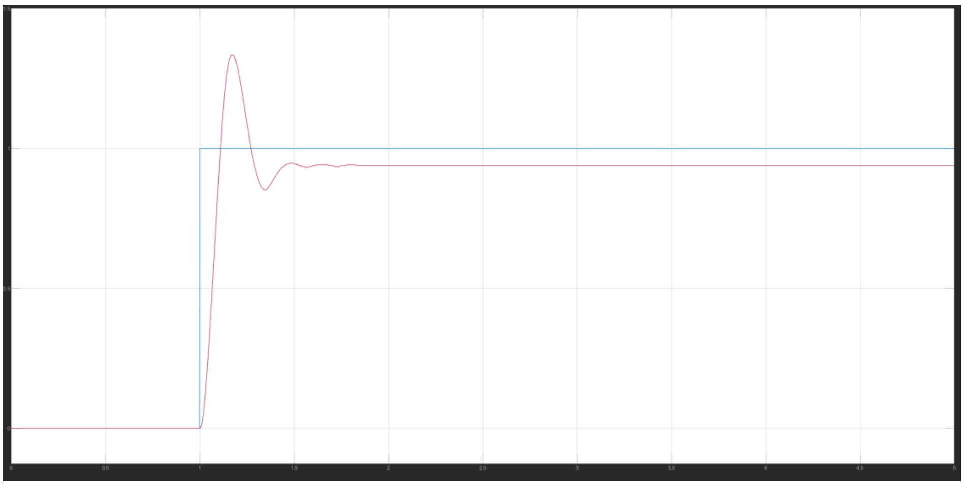

Figure 9: Time Domain Response (K_p= 1)

When K_p= 1.25

Steady State Error	:	$1 - 1.012$	:	0.012
Overshoot	:	$\frac{1.374-1.012}{1.012} \times 100\%$		
	:	<u>35.77%</u>		

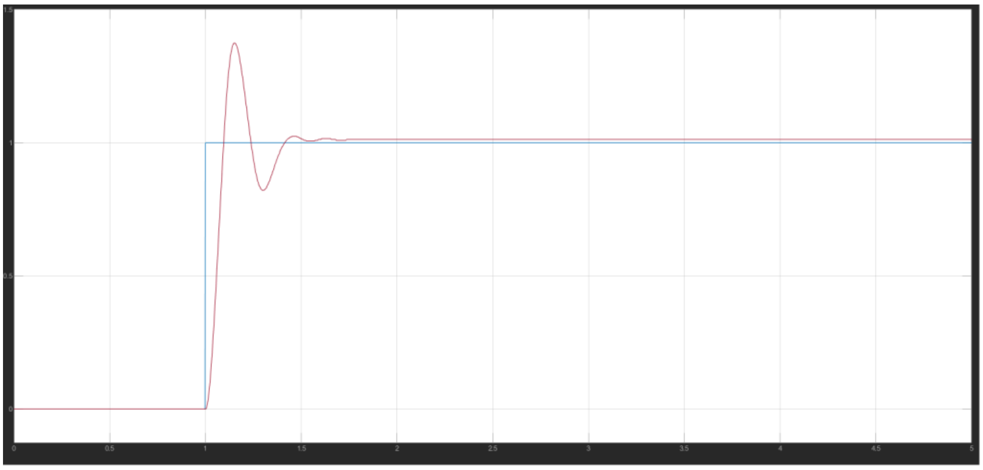

Figure 10: Time Domain Response (K_p= 1.25)

When K_p= 1.50

Steady State Error	:	$1 - 1.009$	: 0.009
Overshoot	:	$\frac{1.405-1.009}{1.009} \times 100\%$	
	:	<u>39.246%</u>	

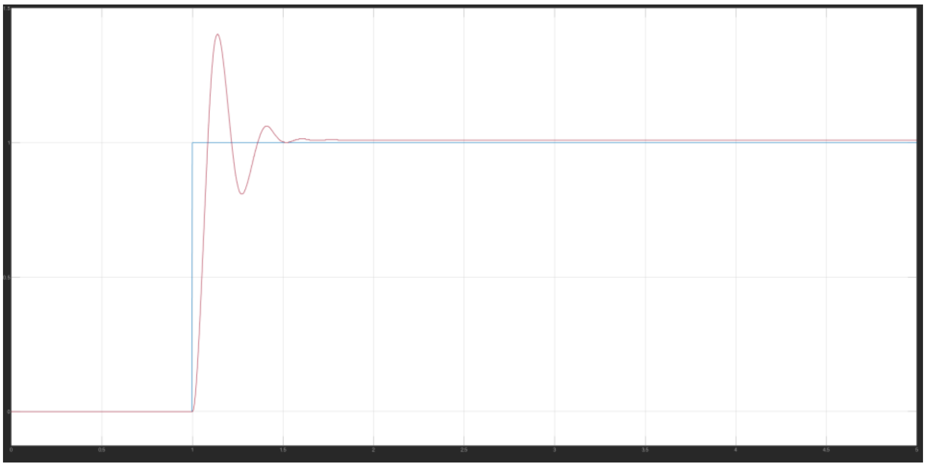

Figure 11: Time Domain Response (K_p= 1.50)

When K_p= 1.75

Steady State Error	:	$1 - 0.9603$	: 0.039
Overshoot	:	$\frac{1.442-0.9603}{0.9603} \times 100\%$	
	:	<u>50.16%</u>	

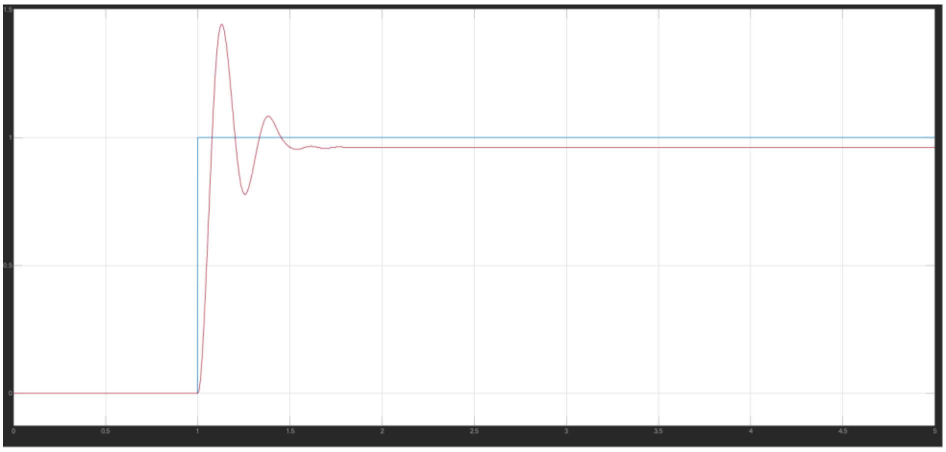

Figure 12: Time Domain Response (K_p= 1.75)

When K_p= 2.00

Steady State Error	:	$1 - 0.9633$	: 0.0367
Overshoot	:	$\frac{1.466-0.9633}{0.966} \times 100\%$	
	:	<u>52.18%</u>	

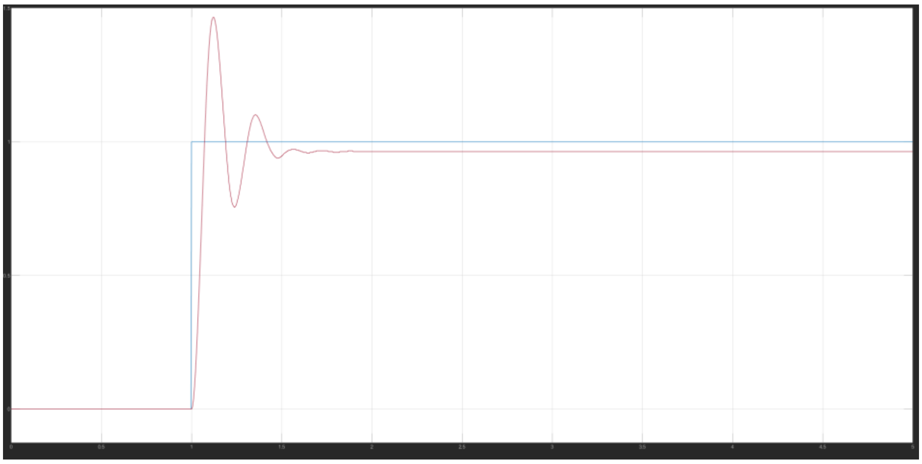

Figure 13: Time Domain Response(K_p= 2.00)

2 REFERENCES

[1] "GREEKFOGGREEK," [Online]. Available: https://www.geeksforgeeks.org/proportional-controller-in-control-system/.

[2] "Control Tutorials," [Online]. Available: https://ctms.engin.umich.edu/CTMS/index.php?example=Introduction&section=ControlPID.