EE5351: CONTROL SYSTEM DESIGN

LABORATORY 01

NAME : BANDARA LRTD

REG No. : EG/ 2021/ 4433

GROUP NO: CE07

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Table 1: Summative Laboratory Form

Semester	05
Module Code	EE5351
Module Name	Control System Design
Lab Number	01
Lab Name	Laboratory Section 1
Lab conduction date	2024.11.05
Report Submission date	2025.01.24

Contents

List of Tables

List of Figures

1 OBSERVATION

Table 1: Observations

Terminal Resistance (R_m)	8.4	Ω
Rotor inductance (L_m)	1.16	mH
Equivalent(J_{en})	2.09×10^{-5}	kgm^2
Torque constant (K_t)	0.042	Nm/A
Voltage constant (K_m)	0.042	Nm/A

2 CALCULATION

Q1.

i .

1. Voltage equation:

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

2. Back EMF equation:

$$e_b = k_m \omega_m$$

3. Torque equation:

$$T_m = J_e q \frac{d\omega_m}{dt}$$

4. Motor torque relationship:

$$T_m = i_m k_t$$

ii From equations (1), (2), (3), and (4), the speed control transfer function is derived as:

$$\frac{\omega(s)}{V_m(s)} = \frac{k_t}{J_e q s[R_m + L_m s] + k_m k_t}$$

$$\frac{\omega(s)}{V_m(s)} = \frac{0.042}{2.09 \times 10^{-5} s[8.4 + 1.16 \times 10^{-3} s] + 0.042 \times 0.042}$$

$$\frac{\omega(s)}{V_m(s)} = \frac{0.042}{2.4244 \times 10^{-8} s^2 + 17.556 \times 10^{-5} s + 1.764 \times 10^{-3}}$$

From equations (1), (2), (3), and (4):

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

$$\frac{\theta_m(s)}{V_m(s)} = \frac{0.042}{2.4244 \times 10^{-8} s^3 + 17.556 \times 10^{-5} s^2 + 1.764 \times 10^{-3} s}$$

iii

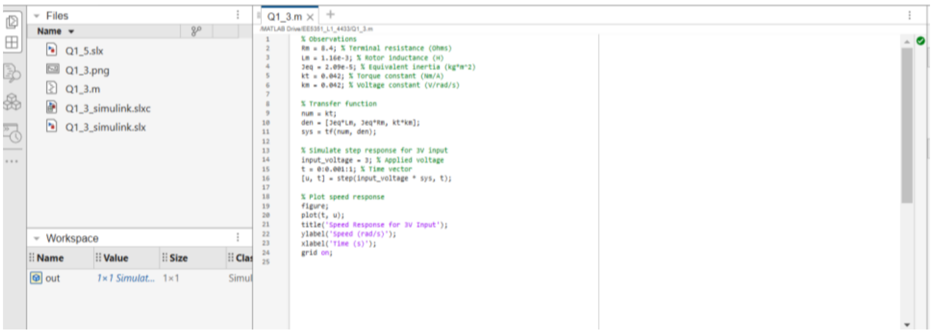

Figure 1: MathLab code for the Speed Response

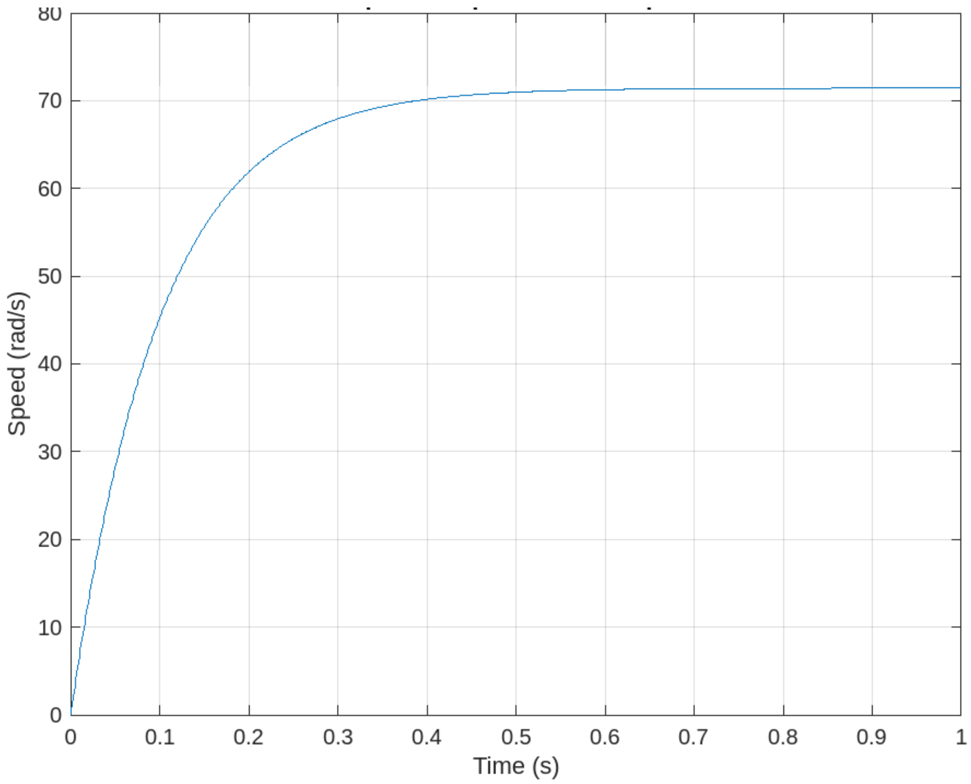

Figure 2: Speed Response Get by Mathlab

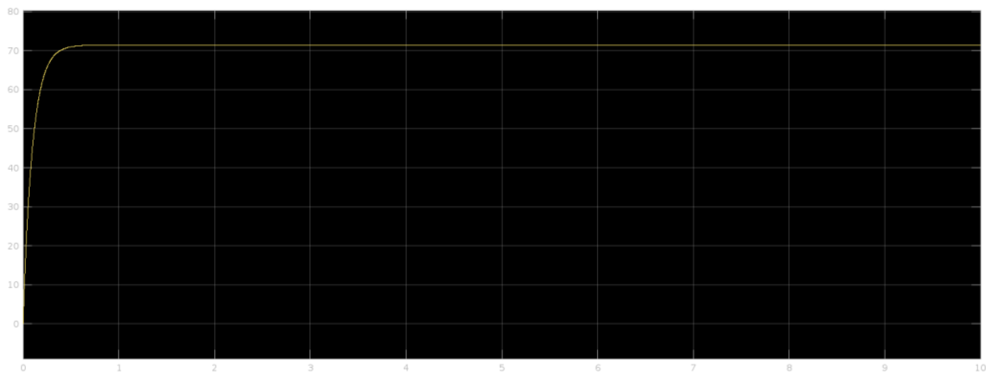

Figure 3: Speed Response Given by Simulink

iv

Simplified Equations for Speed Control Transfer Function

$$\frac{\omega(s)}{V_m(s)} = \frac{k_t}{J_{eq}R_m s + k_m k_t}$$

$$\frac{\omega(s)}{V_m(s)} = \frac{0.042}{\{2.09 \times 10^{-5} \cdot 8.4s + 0.042 \times 0.042\}}$$

$$\frac{\omega(s)}{V_m(s)} = \frac{0.042}{\{1.7556 \times 10^{-4}s + 1.764 \times 10^{-3}\}}$$

Simplified Equations for Position Control Transfer Function

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

$$\frac{\theta_m(s)}{V_m(s)} = \frac{0.042}{s\{1.7556 \times 10^{-4}s + 1.764 \times 10^{-3}\}}$$

v

vi

From the equations 1, 2, 3, 4;

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

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

$$\begin{bmatrix} \dot{i_m} \\ \dot{\omega_m} \end{bmatrix} = \begin{bmatrix} -\left(\frac{R_m}{L_m}\right) & -\left(\frac{k_m}{L_m}\right) \\ \left(\frac{k_t}{J_{\text{eq}}}\right) & 0 \end{bmatrix} \begin{bmatrix} i_m \\ \omega_m \end{bmatrix} + \begin{bmatrix} \frac{1}{L_m} \\ 0 \end{bmatrix} V_m$$

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

vii

From the simplified equations

$$\dot{\theta_m} = 0 \cdot \theta_m + \omega_m + 0 \cdot V_m$$

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

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

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

Q2.

Figure 4: Speed Response in the Model

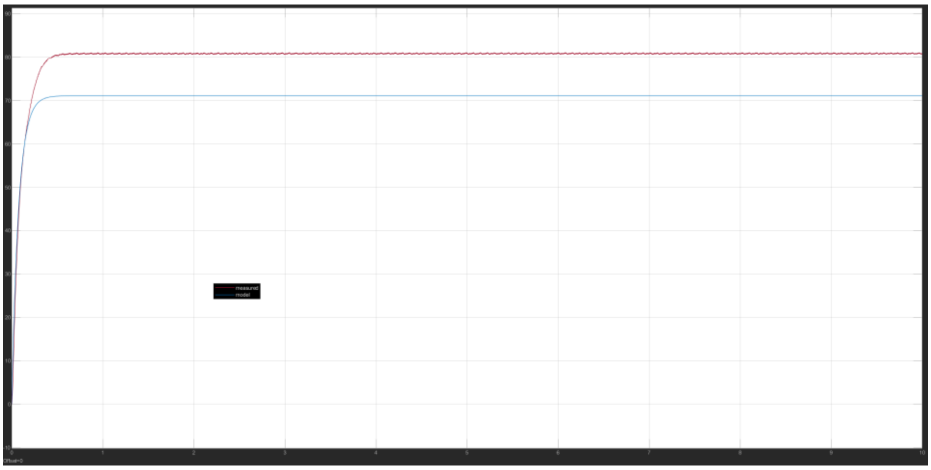

Figure 5: Comparing of the Speed Response with Model and State Vector

2. According to my knowledge I think the basic thing for happening those kind of the error is negiligence of the resistance where having in the rotor and also mathlab is the software which required the best performance of the computers so considering the computers which has been used there can be errors as the performance.

Q3)

1.

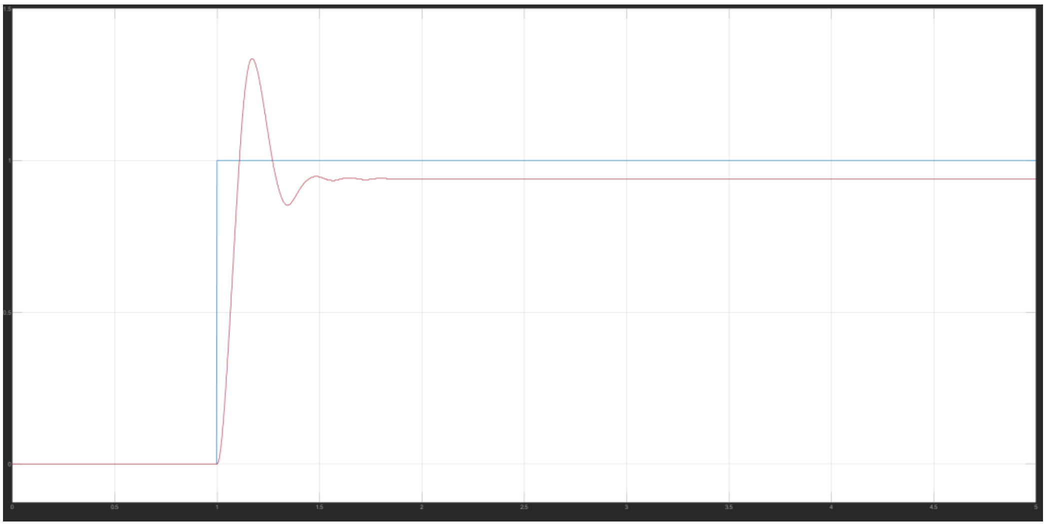

Figure 6: The Speed Response when KP=1

2.

Steady State Error: 1-0.938 : 0.062

$$\text{Overshoot} = \frac{1.335-0.938}{0.938} \times 100\%$$
$$= \underline{\underline{42.324\%}}$$

3.

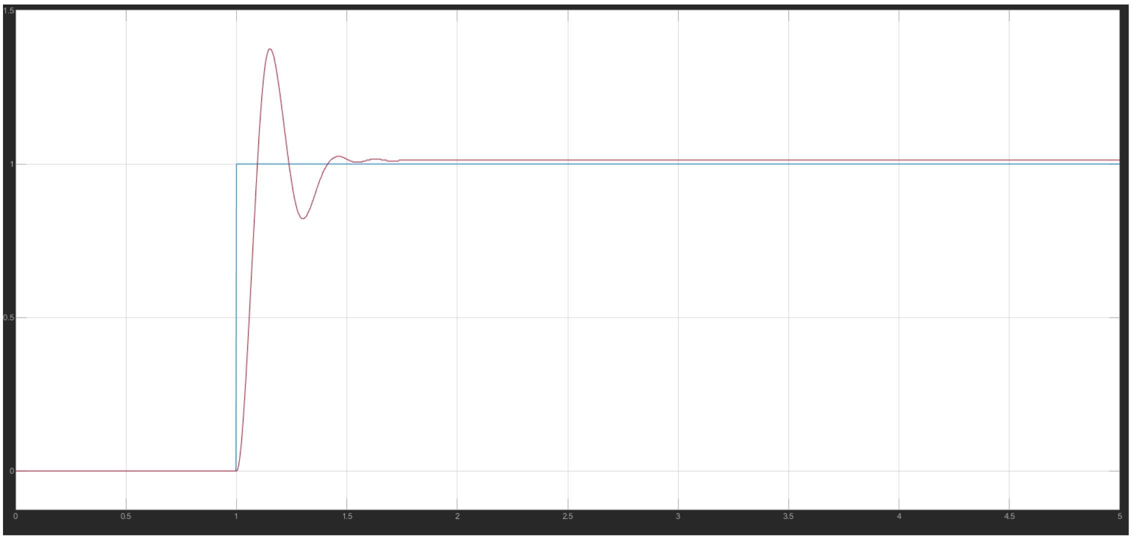

Figure 7: Speed Response from Simulink when KP=1.25

According to the Figure 5 when K_p = 1.25,
Steady state error = 1-1.012 =0.012

$$\text{Overshoot} = \frac{1.374-1.012}{1.012} \times 100\%$$
$$= \underline{\underline{35.770\%}}$$

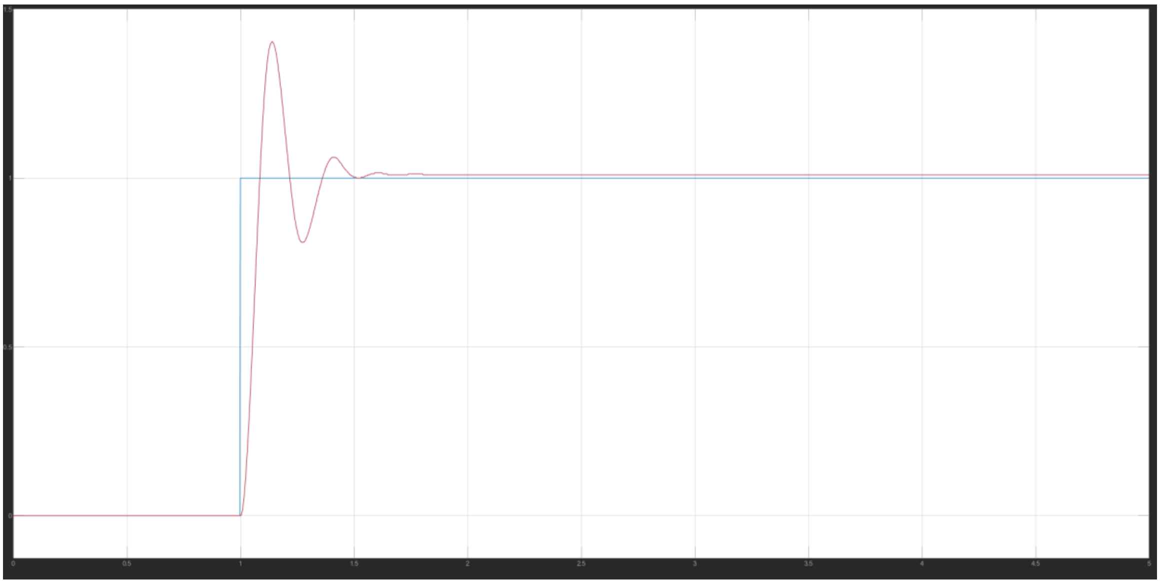

Figure 8: Speed Response from Simulink when KP=1.50

According to the Figure 6 when K_p = 1.5,
Steady state error = 1-1.009 = 0.009

$$\text{Overshoot} = \frac{1.405-1.009}{1.009} \times 100\%$$
$$= \underline{\underline{39.25\%}}$$

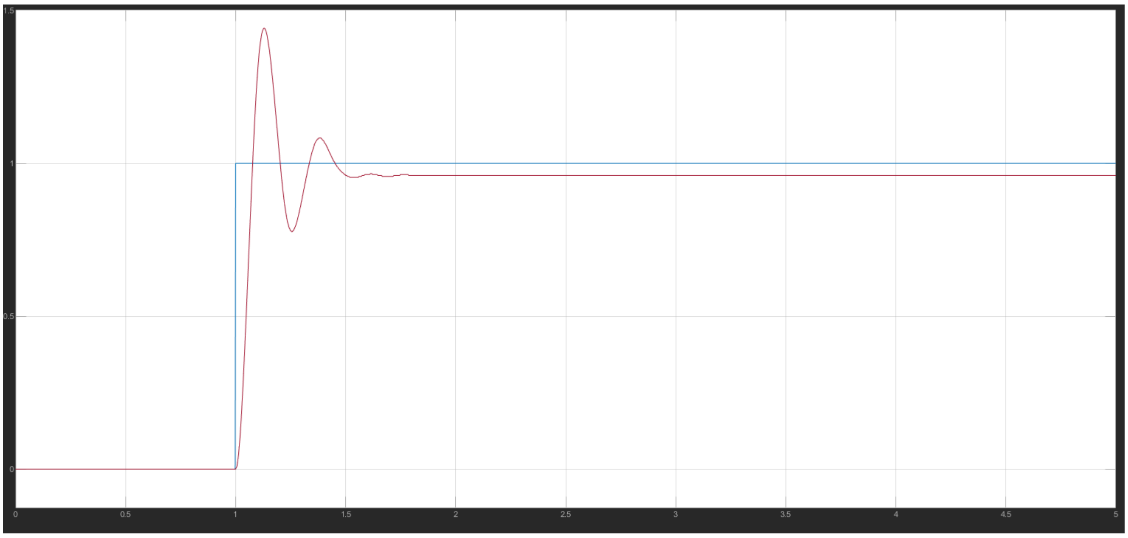

Figure 9: Speed Response from Simulink when KP=1.75

According to the Figure 7 when $K_p = 1.75$,
Steady state error = 1-0.96 = 0.04

$$\text{Overshoot} = \frac{1.442 - 0.9603}{0.9603} \times 100\%$$
$$\underline{\underline{= \ 50.161\%}}$$

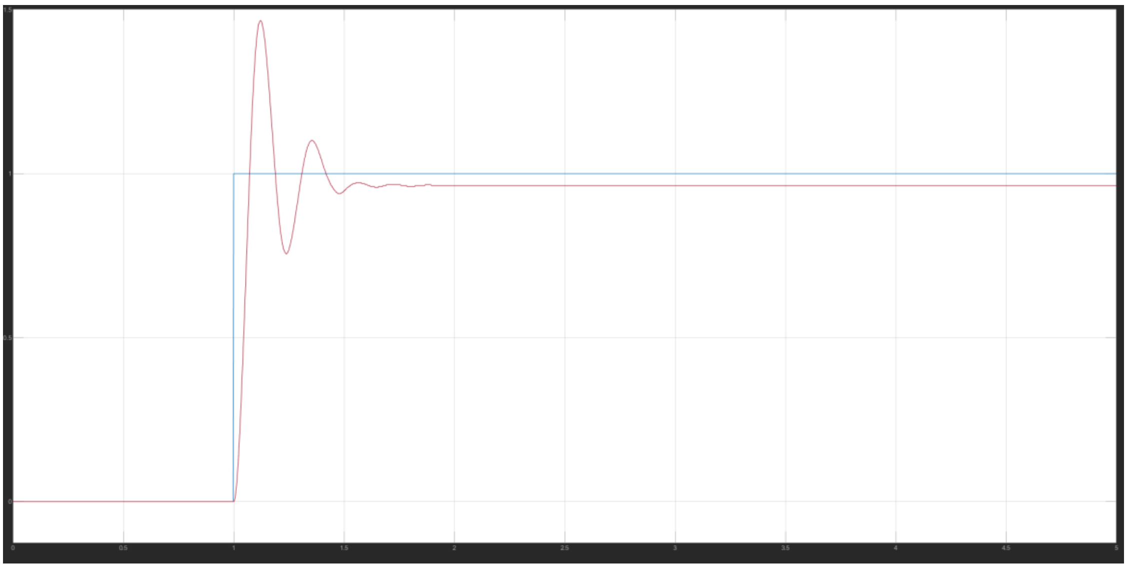

Figure 10: Speed Response from Simulink when KP=2.0

According to the Figure 8 when $K_p = 2$,
Steady state error = 3.35×10^{-2}

$$\text{Overshoot} = \frac{1.466 - 0.9633}{0.9633} \times 100\%$$
$$\underline{\underline{= \ 52.19\%}}$$