EE5351: CONTROL SYSTEM DESIGN

LABORATORY 03

NAME : BANDARA LRTD

REG No. : EG/ 2021/ 4433

GROUP NO: CE07

DATE : 24/01 /2025

Table 1: Summative Laboratory Form

Semester	05
Module Code	EE5351
Module Name	Control System Design
Lab Number	03
Lab Name	Laboratory Section 3
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.

By using equations (1), (2), (3), and (4):

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

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

Due to the negligible rotor inductance the simplified version is:-

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

$$\frac{\theta_m(s)}{V_m(s)} = \frac{0.042}{1.756 \times 10^{-4}S^2 + 1.764 \times 10^{-3}S}$$

iii.

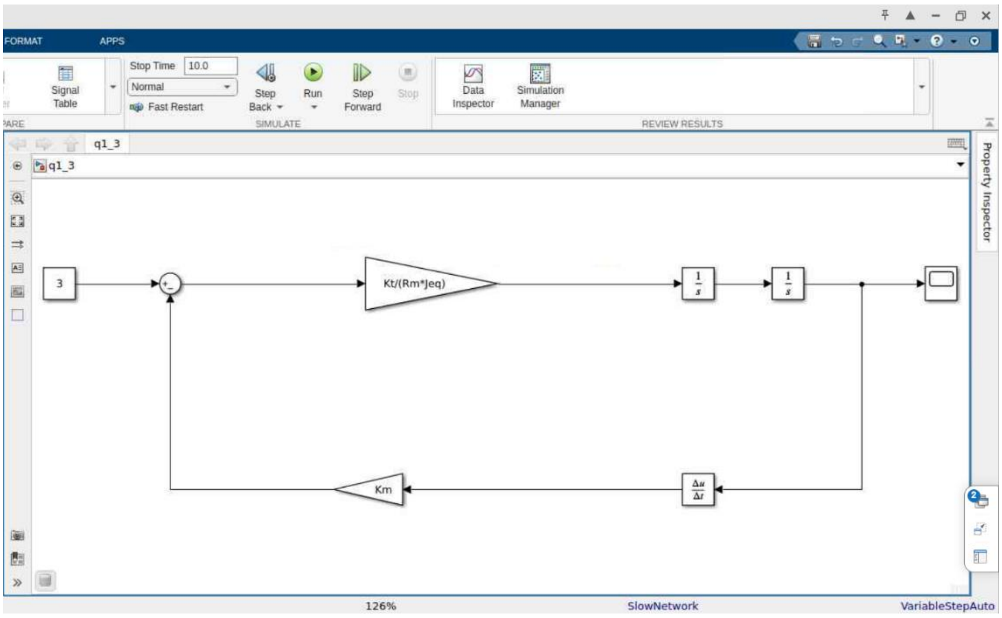

Figure 1: Simplified t/f Simulink Model

iv. By considering the closed loop transfer function

$$\frac{\theta_m(s)}{\theta_{ref}(s)} = \frac{\frac{\theta_m(s)}{V_m(s)}}{1+\frac{\theta_m(s)}{V_m(s)}}$$

$$\frac{\theta_m(s)}{\theta_{ref}(s)} = \frac{0.042}{1.756 \times 10^{-4}S^2 + 1.764 \times 10^{-3}S + 0.042}$$

v.

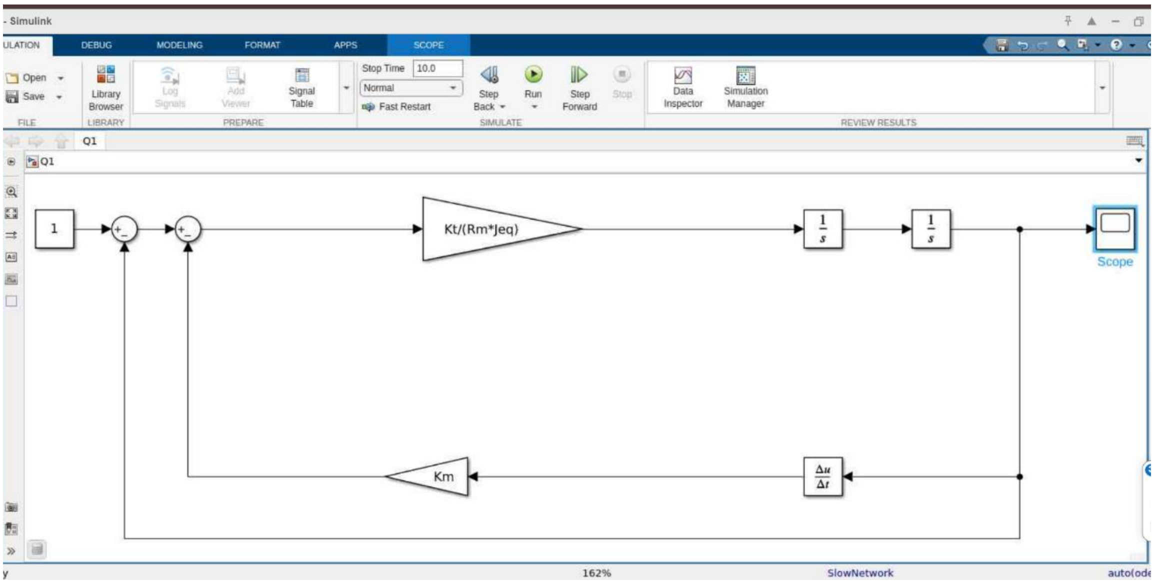

Figure 2: By creating closed loop function giving input as 1

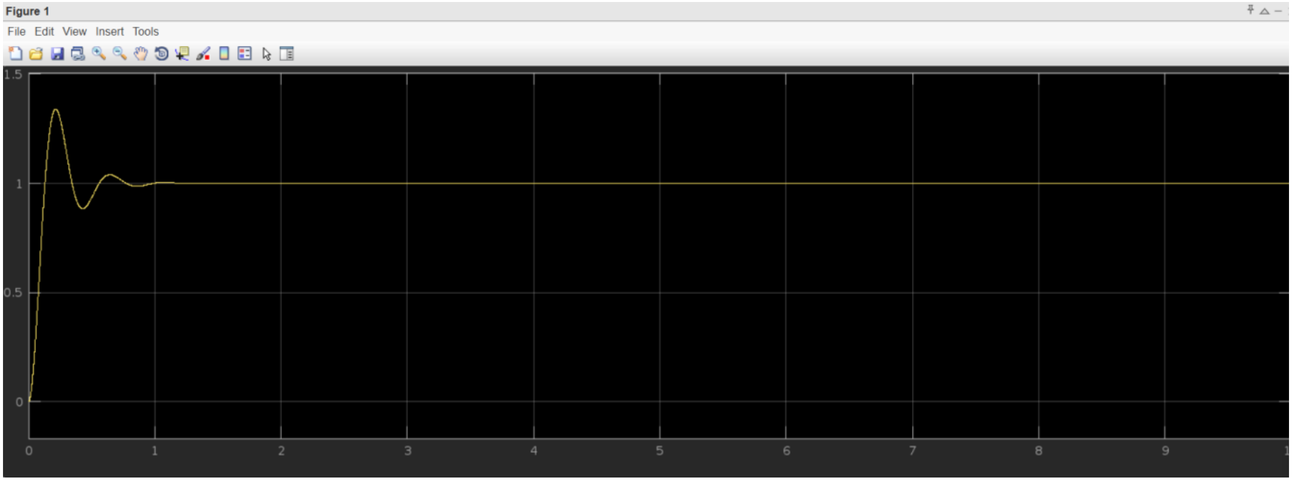

Figure 3: Output from the closed loop function

Q2.

I.

```
% Define numerator and denominator of the transfer function
num = 0.042;
den = [17.556e-5, 1.764e-3, 0.042];

% Create the transfer function
G = tf(num, den);

% Plot the root locus
rlocus(G);
title('Root Locus of DC Motor Position Control System');
grid on;
```

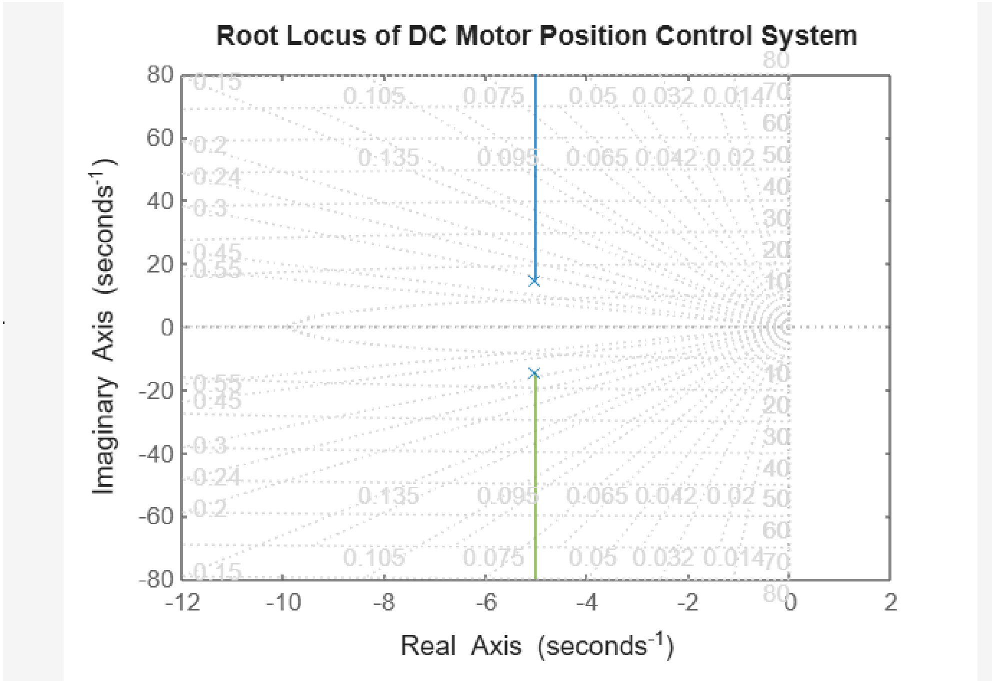

Figure 4: Root Locus of DC Motor Position Control System

II.

Characteristic equation given as ;

$1.756 \times 10^{-4} S^2 + 1.764 \times 10^{-3} S + 0.042 = 0$

By calculating the ω given as

$2\varepsilon\omega_n \quad = \quad 10.0455$

$\omega_n \quad = \quad 10.05$

III.

Q2_3.m

/MATLAB Drive/EE5351_L3_4433/Q2_3.m

```
% Increase natural frequency by 10%
omega_n = 10.045;
omega_n_new = 1.1 * omega_n;

% Adjust denominator to achieve new ωn
den_new = den;
den_new(1) = den_new(1) * (omega_n_new / omega_n);

% Create new transfer function
G_n = tf(num, den_new);

% Plot root locus of modified system
figure;
rlocus(G_n);
title('Root Locus After Increasing Natural Frequency by 10%')
grid on;
```

Figure 5: Math Lab code for increase the Omega by 10%

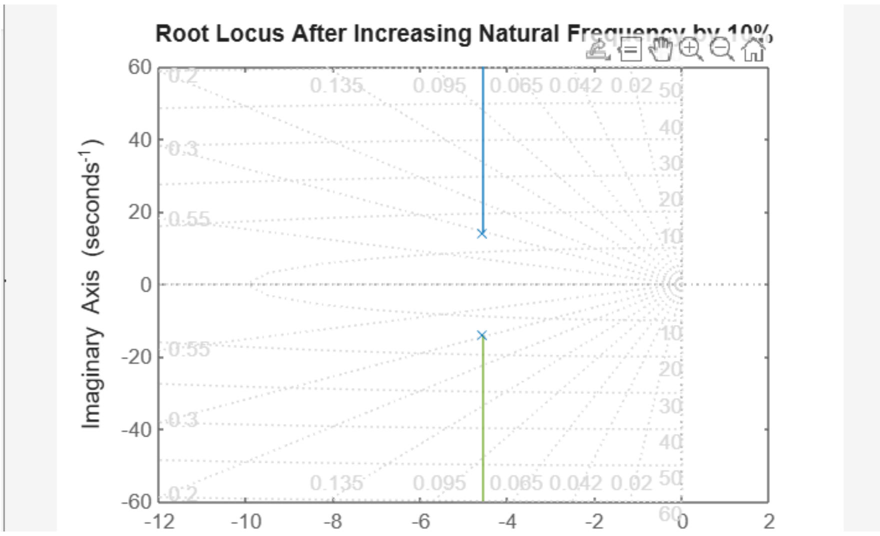

Figure 6: Root Locus for By increasing the omega

IV.

```
% Plot time response of both systems
figure;
step(G, 'b', G_new, 'r');
title('Time Response: Original vs Updated System');
grid on;
```

Figure 7: MathLab code for implement Step response

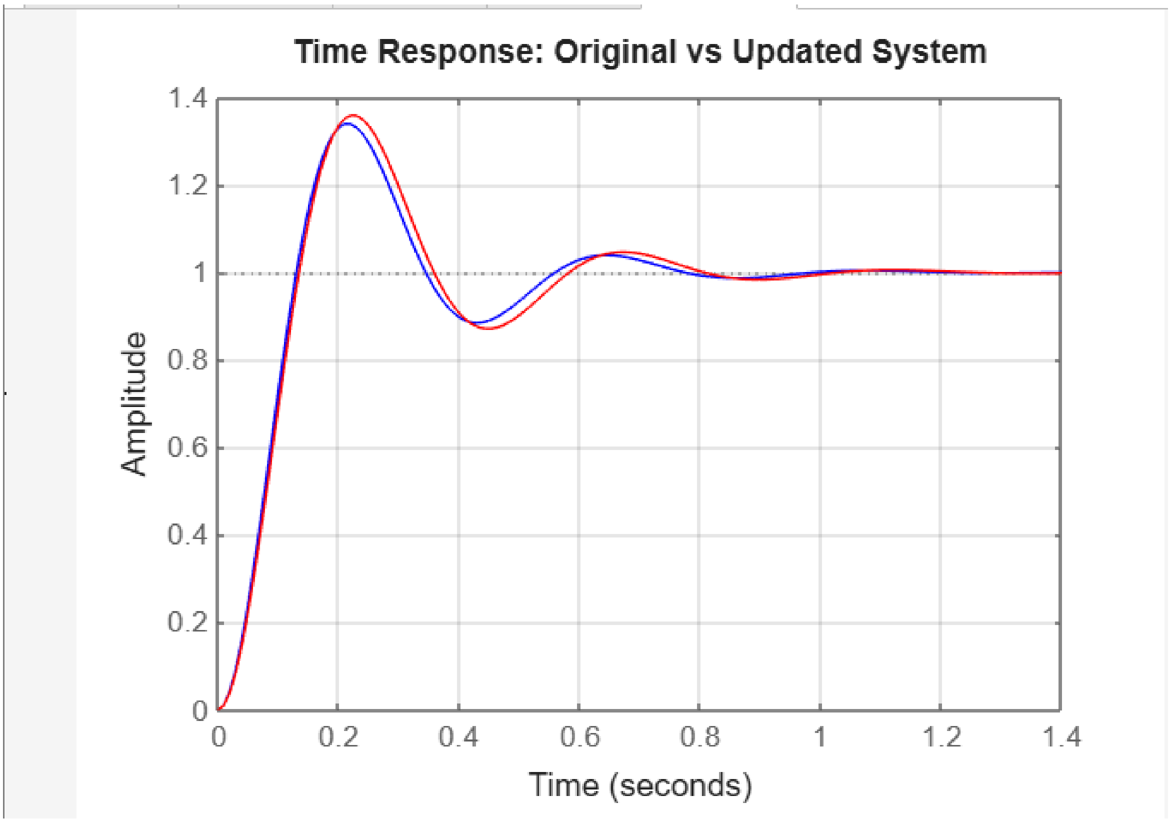

Figure 8: Time response before and after changing the omega

Q3)

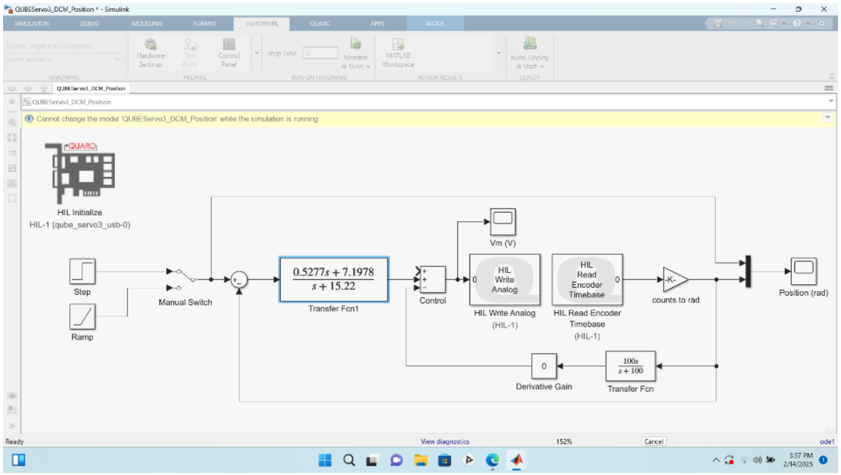

Figure 10: Design a compensator **for** the DC motor position control system

Figure 9: Time Domain Response [θm(t)] of the closed loop

3 REFERENCES

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

[2] [Online]. Available: https://medium.com/@csoham358/a-hackers-guide-to-understanding-controllers-62fb26bed952.

[3] "LibreTexts," [Online]. Available: https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Chemical_Process_Dynamics_and_Controls_(Woolf)/09%3A_Proportional-Integral-Derivative_(PID)_Control/9.02%3A_P_I_D_PI_PD_and_PID_control.