EE5351: CONTROL SYSTEM DESIGN

LABORATORY 02

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GROUP NO: CE07

DATE : 24/01 /2025

Table 1: Summative Laboratory Form

Semester	05
Module Code	EE5351
Module Name	Control System Design
Lab Number	02
Lab Name	Laboratory Section 2
Lab conduction date	2024.11.05
Report Submission date	2025.01.24

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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. Transfer function

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. H

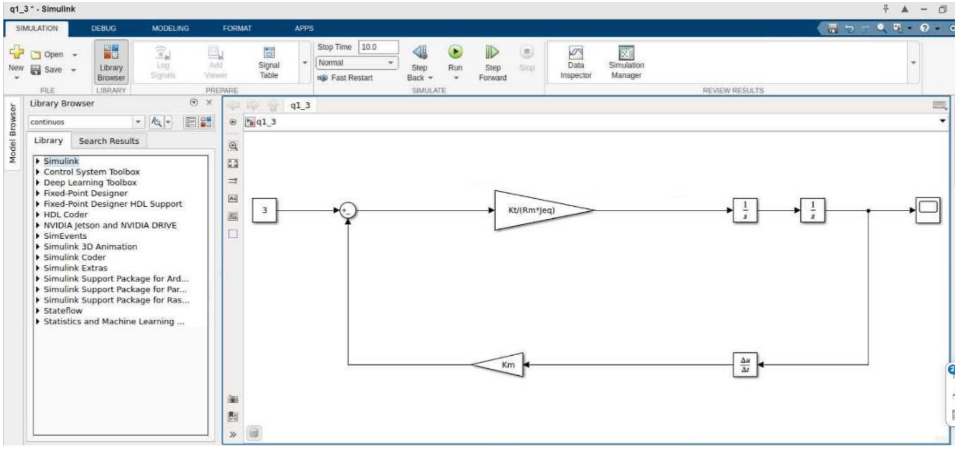


Figure 1: Simplified Simulink

iv. By considering the closed loop transfer function

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

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

v.

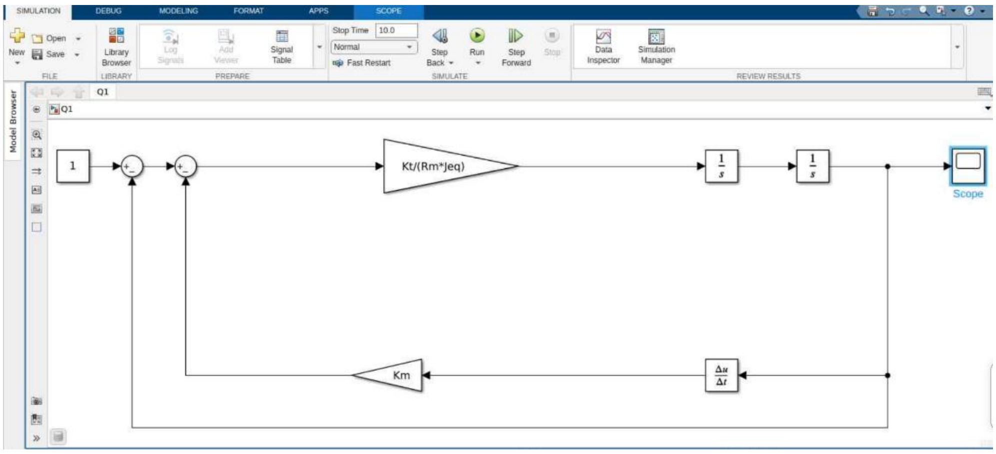
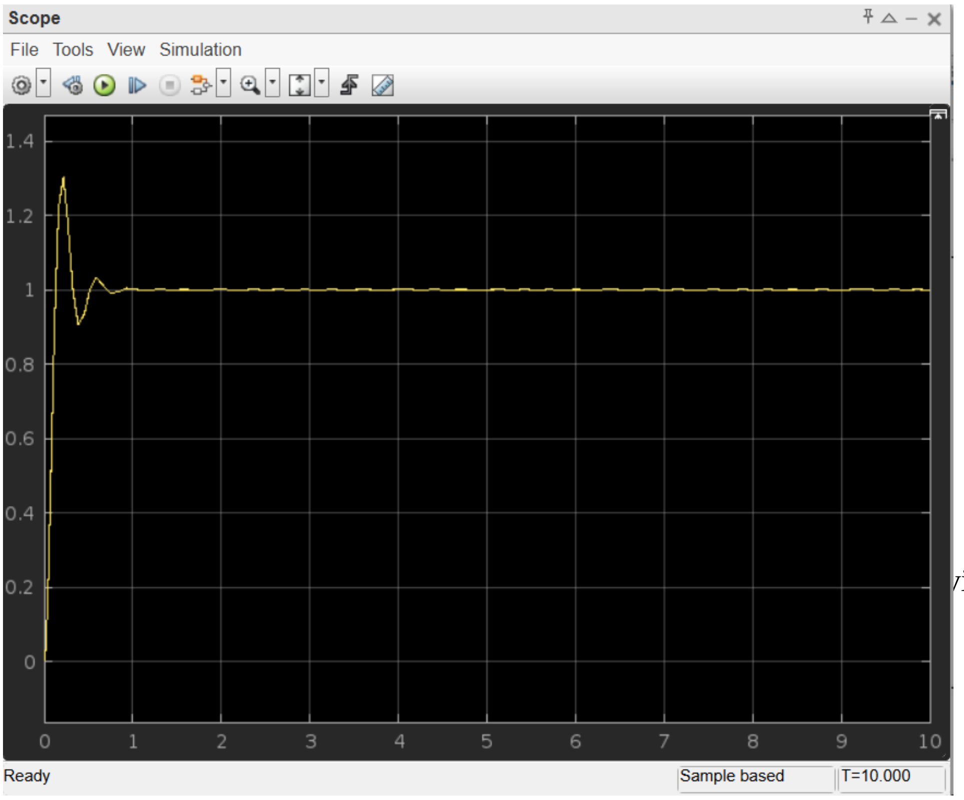


Figure 2: Closed Loop T/f



vi.

Figure 3: O/p diagram

Overshoot given as $= \frac{1.33-1}{1} \times 100\%$

$= 33\%$

Q2.

i. Characteristic equation given as :

$S^2 + 10.047S + 239.23=0$

ii. By considering ;

$2\epsilon\omega = 10.047$

${\omega_n}^2 = 239.23$

$\epsilon = 0.3248$

$\omega_n = 15.47$rad/s

Overshoot $= e^{-\frac{\pi\epsilon}{\sqrt{1-\epsilon^2}}} \times 100\%$

Figure 4:output from closed loop transfer function

$= e^{-\frac{\pi\times 15.47}{\sqrt{1-15.47^2}}} \times 100\%$

$= 33.99\%$

iii. $\frac{33.99\times 70}{100} = e^{-\frac{\pi\epsilon}{\sqrt{1-\epsilon^2}}}\times 100\%$

$\varepsilon_{new} = 0.415$

$t_p < 2$

$\frac{\pi}{\omega_{n(new)}\sqrt{1-\varepsilon_{(new)}{}^2}} < 2$

According to that to maintain $t_p < 2$

The PD characteristics equation is given as

$S^2 + 2\left(\varepsilon_{old} + \frac{k_d\omega_{n(new)}}{2}\right)\omega_{n(new)}S + \sqrt{k_p}\omega_{n(old)}{}^1 = 0$

Considering that $\omega_{n(new)}$ can replace by $\sqrt{k_p}\omega_{n(old)}{}^1$.

From that given as:

$\frac{\pi}{\sqrt{k_p}\omega_{n(old)}{}^1\sqrt{1-\varepsilon_{(new)}{}^2}} < 2$

$k_p > 0.01762$

From that k_p can consider as 1.

According to that

$\varepsilon_{new} = \left(\varepsilon_{old} + \frac{k_d\omega_n}{2}\right)$

$0.415 = \left(0.325 + \frac{k_d 15.47}{2}\right)$

$k_d = 0.011635$

Q3)

I.

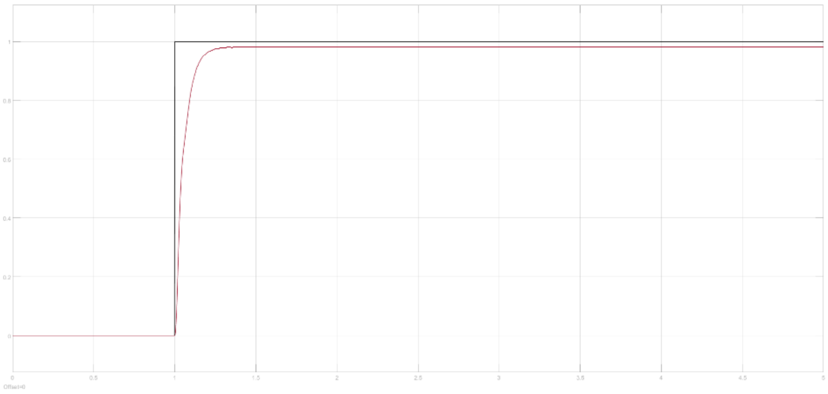


Figure 5:Time domain response of the closed loop function

II. The overshoot is given by: $\frac{1.3622 - 0.9725}{0.9725} \times 100\%$

$:40.0717\%$

III.

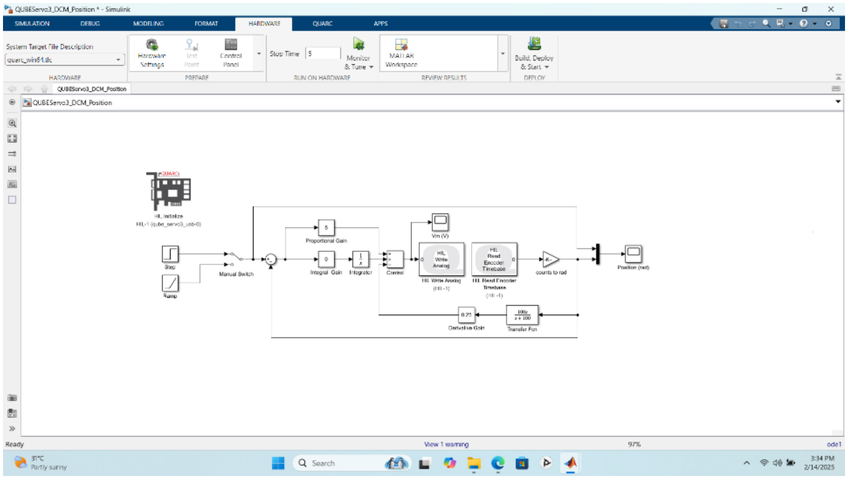


Figure 6: Design a PD Controller

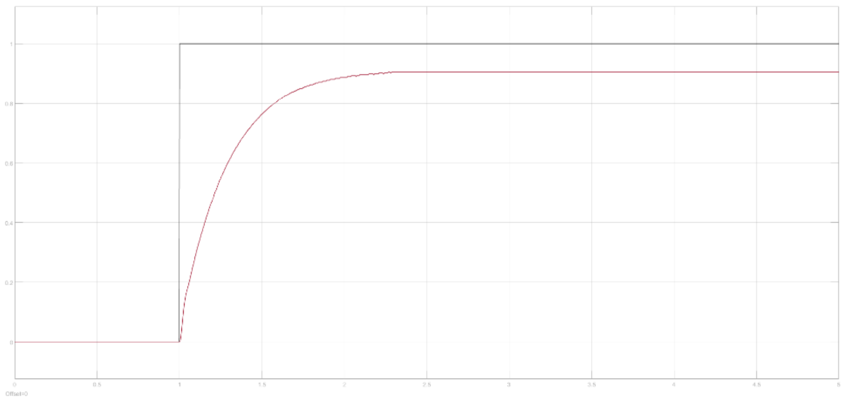


Figure 7: Overshoot is reduced by 30%

3 REFERENCES

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