# EE5351: CONTROL SYSTEM DESIGN

## LABORATORY 02


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| GROUP NO. | : CE 07 |
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Summative Laboratory Form

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| Semester | 05 |
| Module Code | EE5351 |
| Module Name | Control Systems Design |
| Lab Number | 02 |
| Lab Name | Laboratory Session 2 |
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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 Transfer Function Given as:

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

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

Simplified t/f:

$$\frac{\theta_m(S)}{V_m(S)} = \frac{k_t}{J_{eq}R_m S^2 + k_m k_t S}$$

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

III.

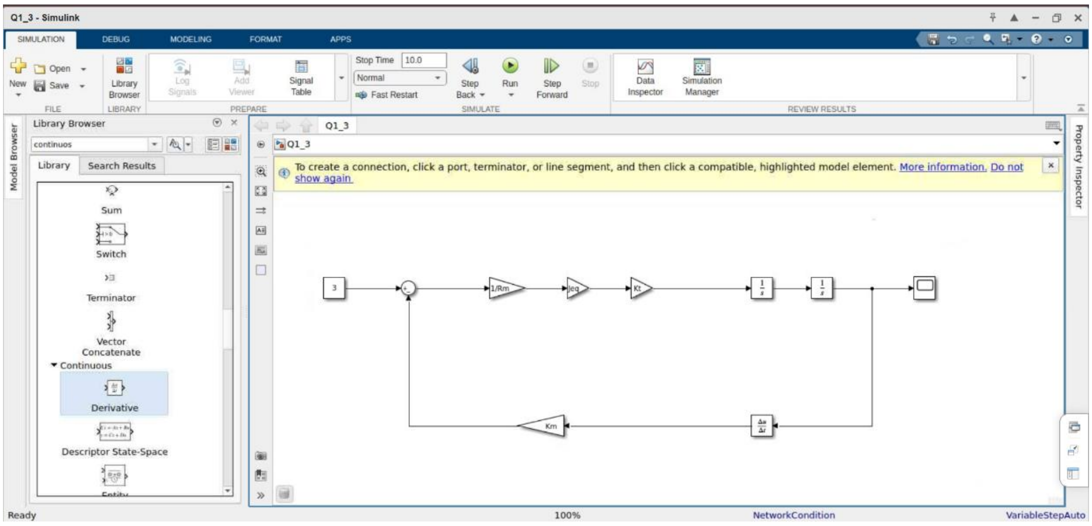


Figure 1: Simulink for Simplified version

IV. This is unity feedback system

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

$$= \frac{k_t}{J_{eq}R_m S^2 + k_m k_t S + k_t}$$

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

V.

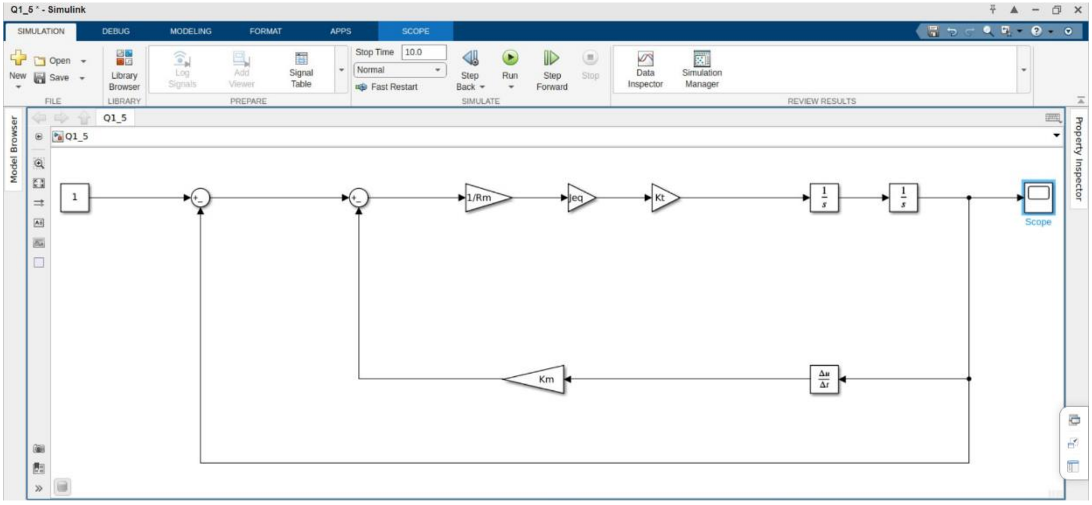


Figure 2: Simulink for the unity feedback system

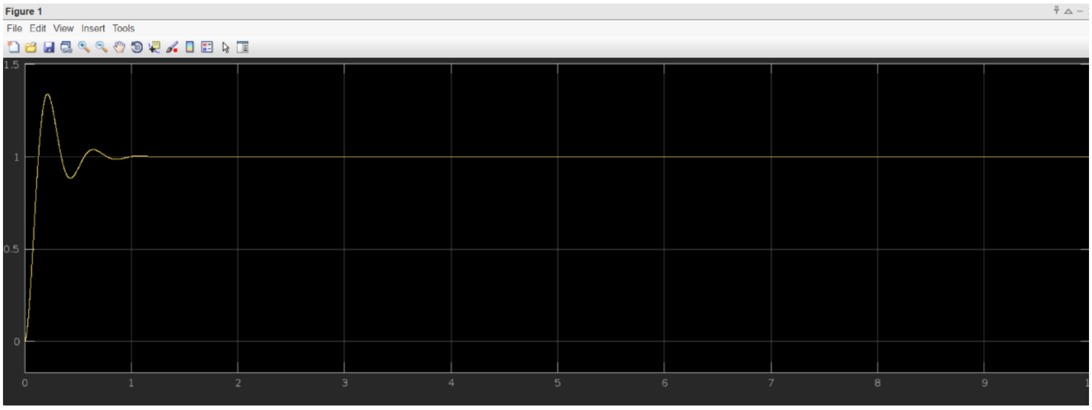


Figure 3:output from the unity feedback system

$$\text{Overshoot} = \frac{1.339-1}{1} \times 100\%$$

$$= 33.9\%$$

Q2)

i.

$$\frac{\theta_m(S)}{\theta_{ref}(S)} = \frac{0.042}{1.756\times10^{-4}s^2+1.764\times10^{-3}S+0.042}$$

By considering above t/f the characteristic equation given as follows:

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

$s^2 + 10.04S + 239.199$=0

ii. For the standard 2nd order system characteristic eqn>>

$s^2 + 2\varepsilon\omega_n S + {\omega_n}^2$ =0

Thus :

$\omega_n$ =15.465rad/s

$\varepsilon$ =5.70$\times$ $10^{-5}$

=0.325

Overshoot $= e^{-\frac{0.325\pi}{\sqrt{1-0.325^2}}} \times 100\%$

=33.97%

iii. By reducing overshoot new overshoot is 0.7×34.60% =23.78%

23.78 $= e^{-\frac{\varepsilon\pi}{\sqrt{1-\varepsilon^2}}} \times 100$

$\varepsilon$ =0.415

Then

By considering the PD controllers characteristic equation:

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

Considering $T_p$ <2

2 $> \frac{\pi}{\sqrt{k_p}\omega_n\sqrt{1-0.415}}$

$k_p$ > 0.01763

By considering as $k_p$=1

$\varepsilon_{new}$ $=\varepsilon+\frac{k_D\omega_n}{2}$

$0.325+\frac{k_d\omega_n}{2}$=0.415

$K_D$ =0.016

Q3)

I.

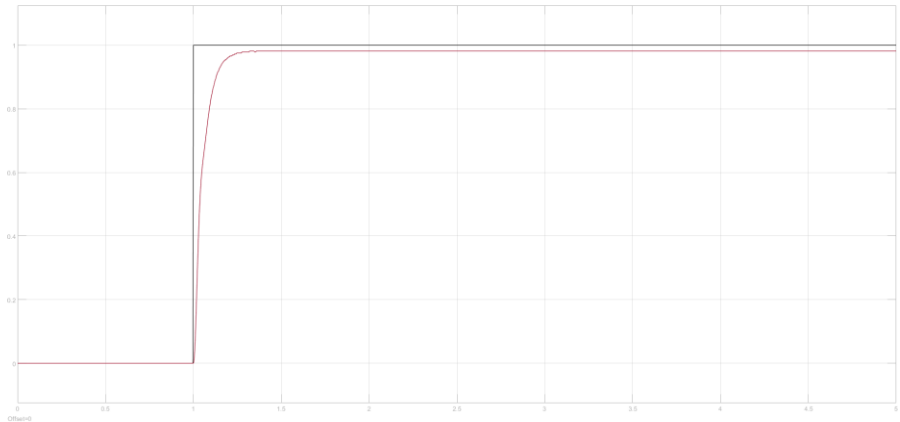

Figure 4: Time domain response [$\boldsymbol{\theta_m(t)}$] of the closed loop position control system for an applied $\boldsymbol{\theta_{ref}(t)}$ of **1 rad.**

II. Calculated Overshoot:

$$=\frac{1.36-0.973}{0.973}\times 100\%$$

$$=39.77\%$$

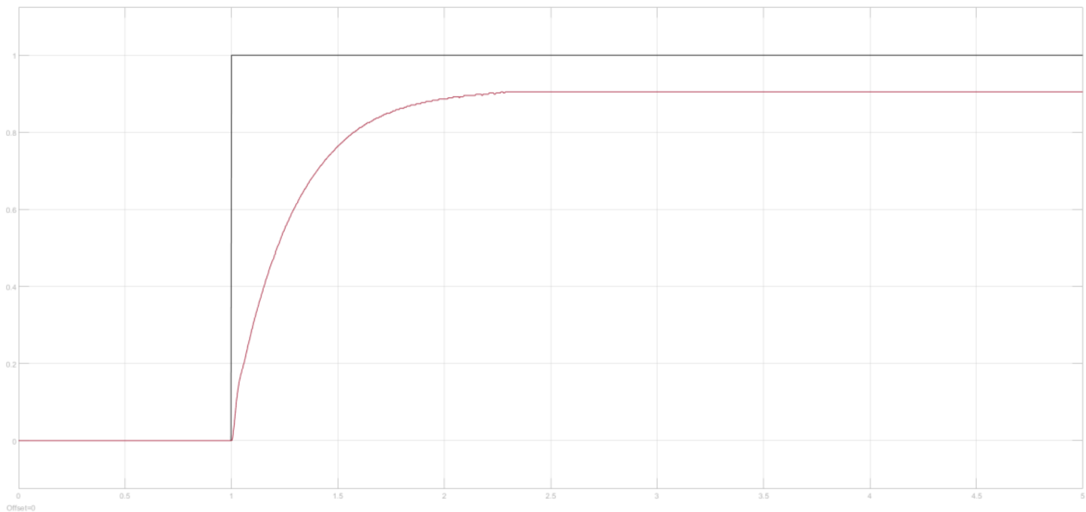

Figure 5: Reducing the overshoot by 30%

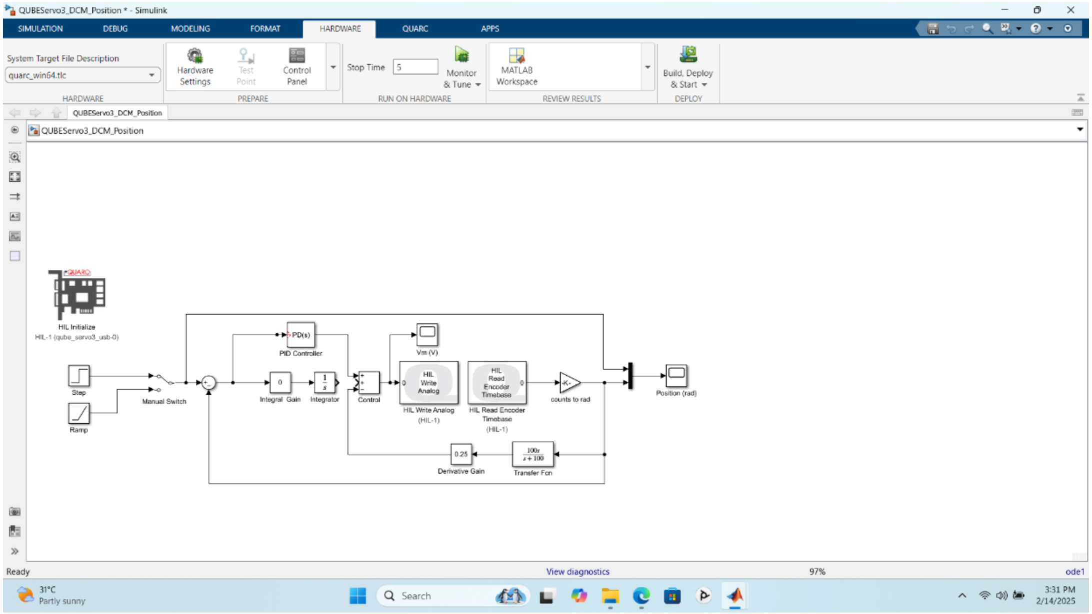


Figure 6: Design of PD controller

# 2 REFERENCES


[1] "PD,PI,PID Controllers," [Online]. Available: https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Introduction_to_Control_Systems_(Iqbal)/03%3A_Feedback_Control_System_Models/3.3%3A_PI_PD_and_PID_Controllers.

[2] "Tutors Point," [Online]. Available: https://www.tutorialspoint.com/control_systems/control_systems_controllers.htm.