<u>EE5351: CONTROL SYSTEM DESIGN</u>

LABORATORY 01

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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

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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 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):

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

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

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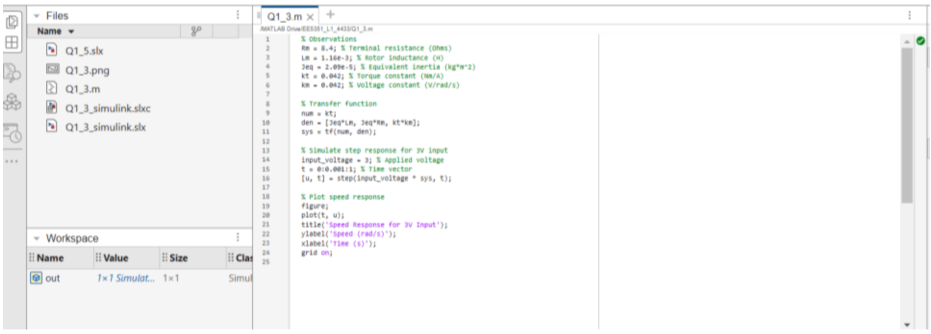

Figure 1: MathLab code for the Speed Response

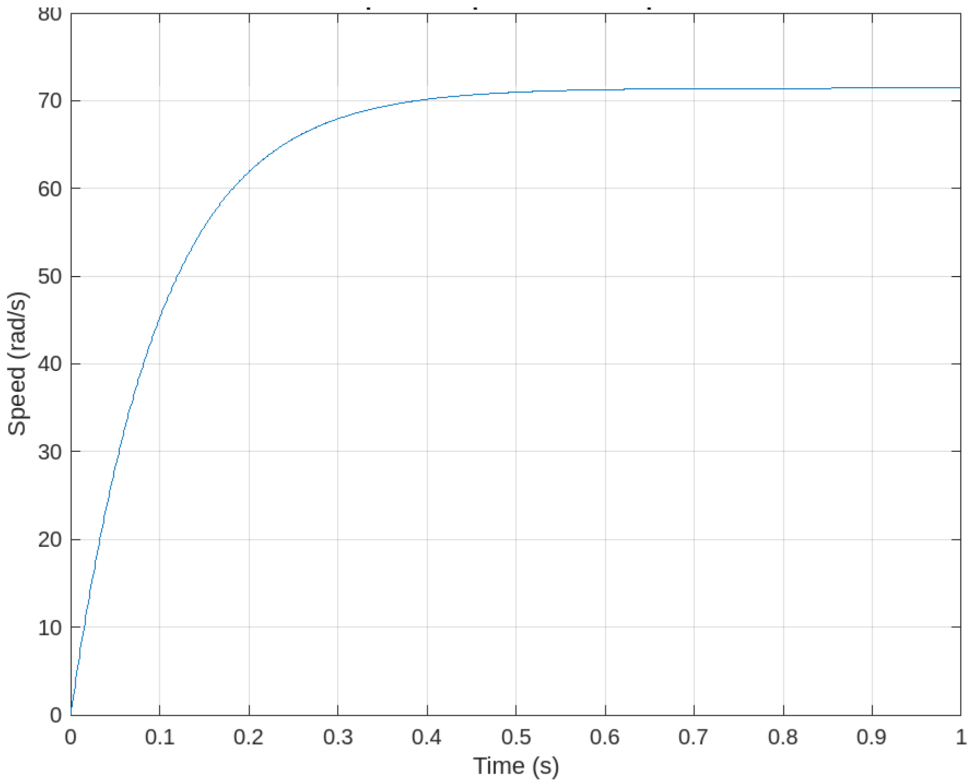

Figure 2: Speed Response Get by Mathlab

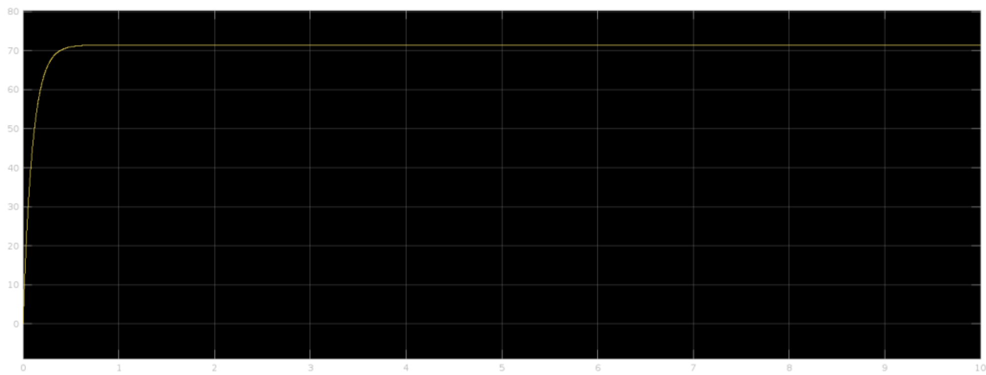

Figure 3: Speed Response Given by Simulink

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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

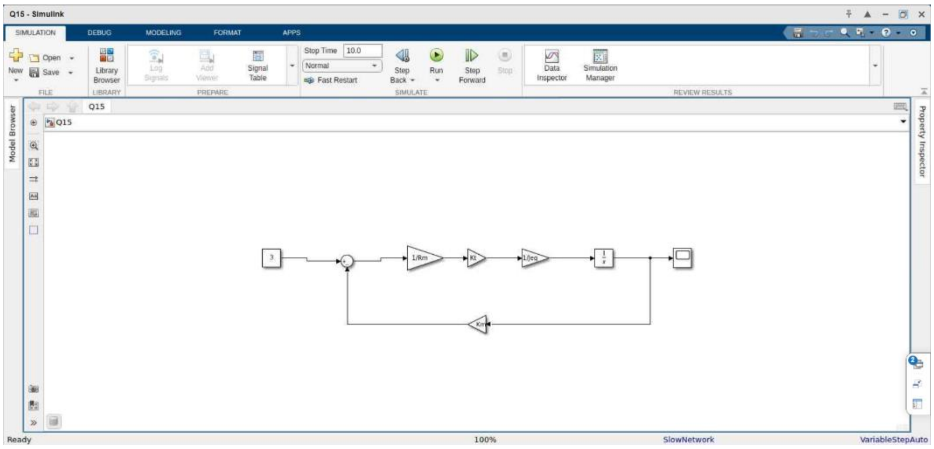

Figure 4: Simulink for simplified transfer function

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From the equations 1, 2, 3, 4;

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

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

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

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

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

$$\omega_m = [0 \quad 1] \times \begin{bmatrix} i_m \\ \omega_m \end{bmatrix} + 0 \times V_m$$

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From the simplified equations

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

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

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

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

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

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

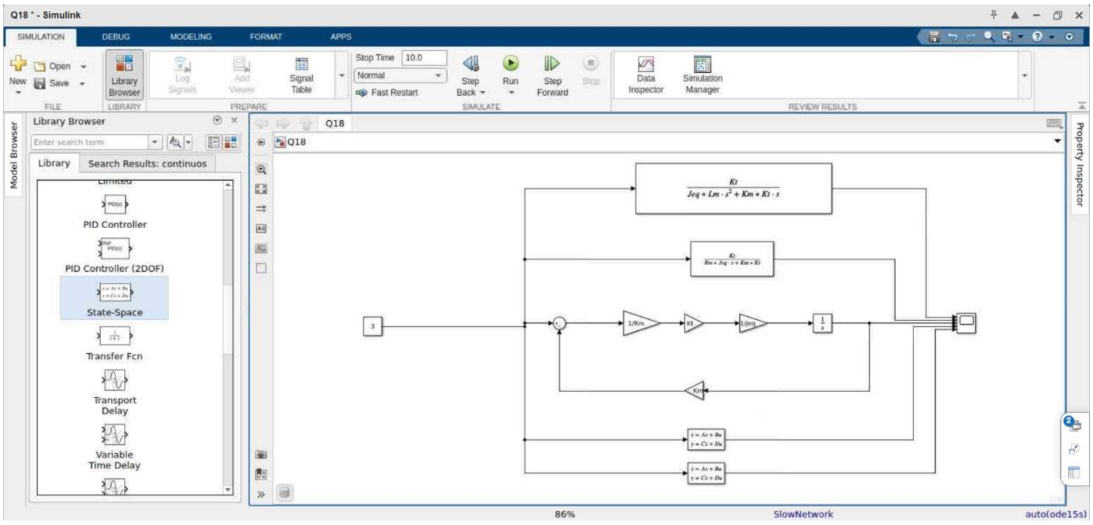

Figure 5: Simulink for combination of the state space vector, transfer function

Q2.

Figure 6: Speed Response in the Model

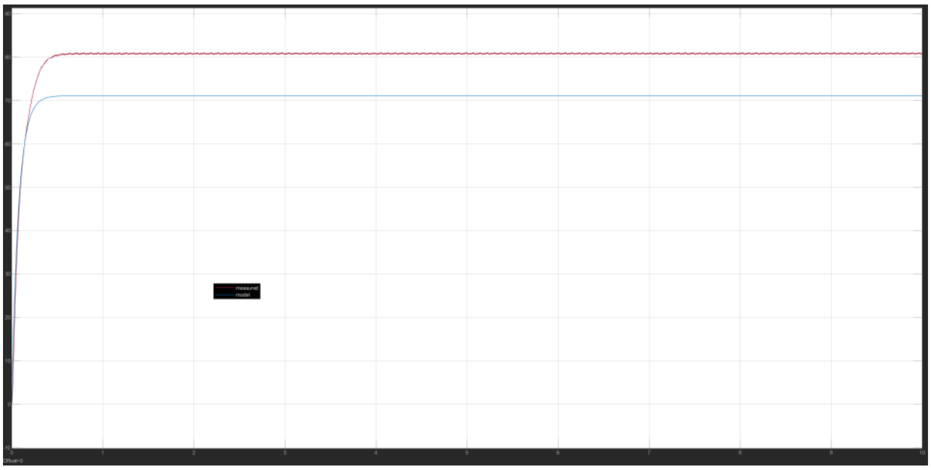

Figure 7: Comparing of the Speed Response with Model and State Vector

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.

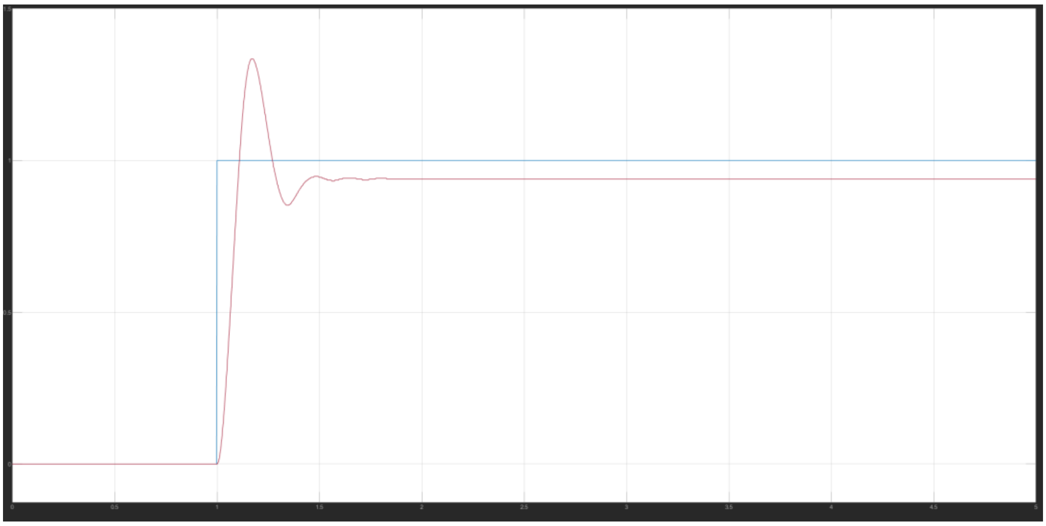

Figure 8: The Speed Response when KP=1

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.

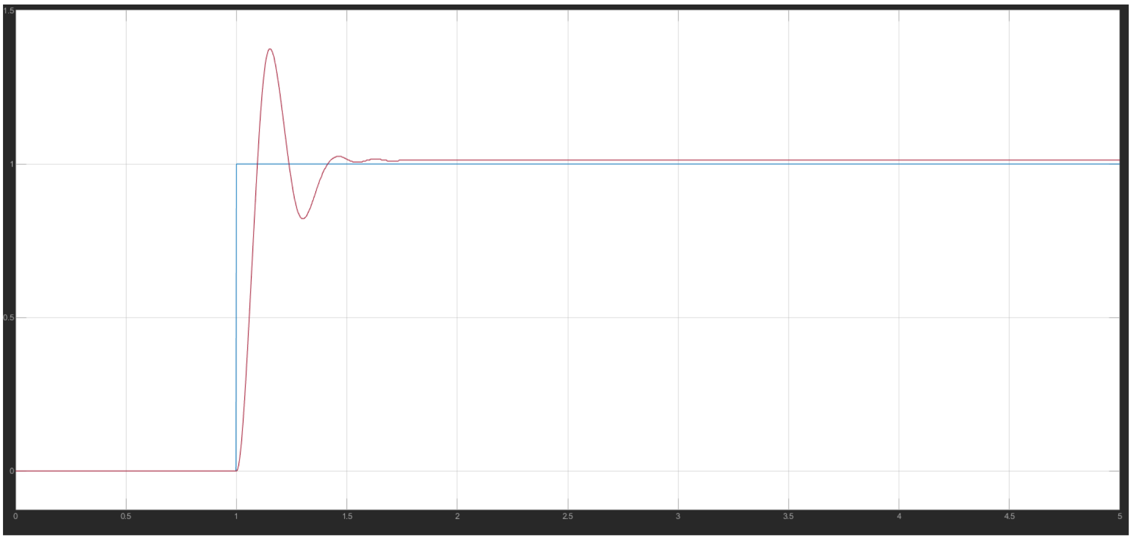

Figure 9: Speed Response from Simulink when KP=1.25

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

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

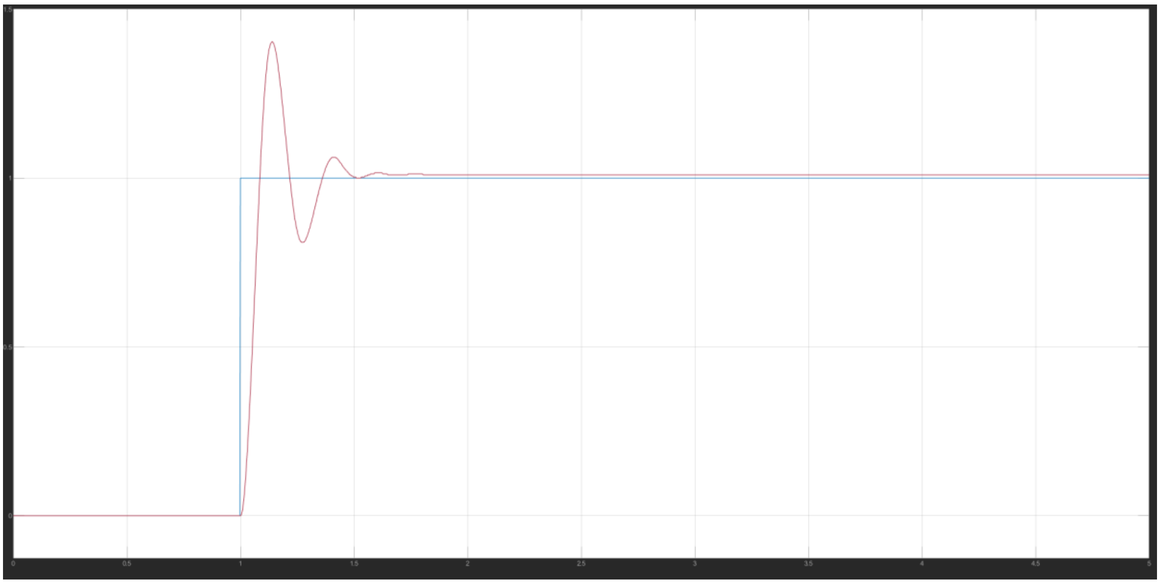

Figure 10: Speed Response from Simulink when KP=1.50

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

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

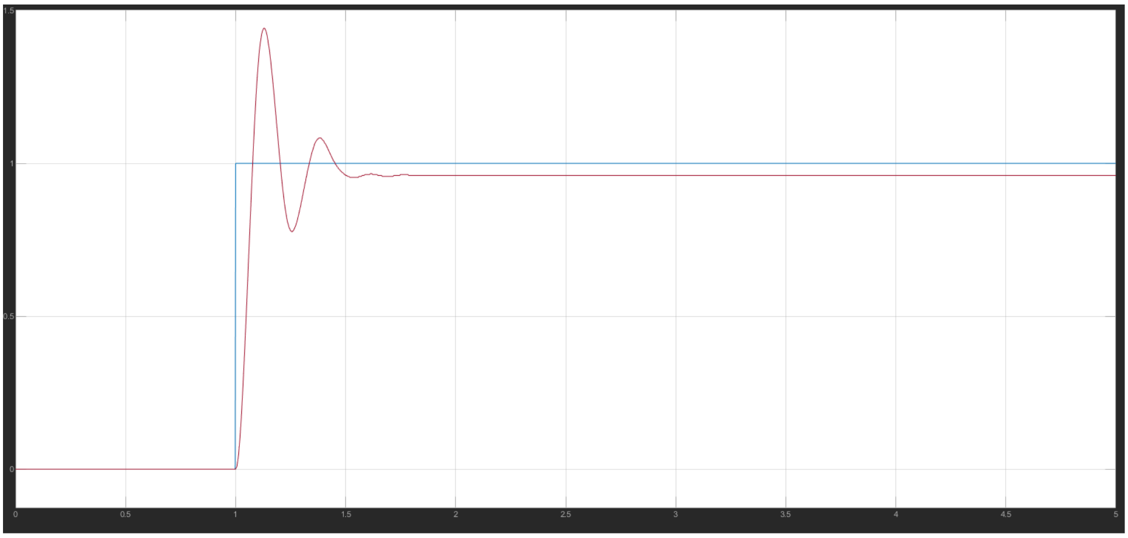

Figure 11: Speed Response from Simulink when KP=1.75

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

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

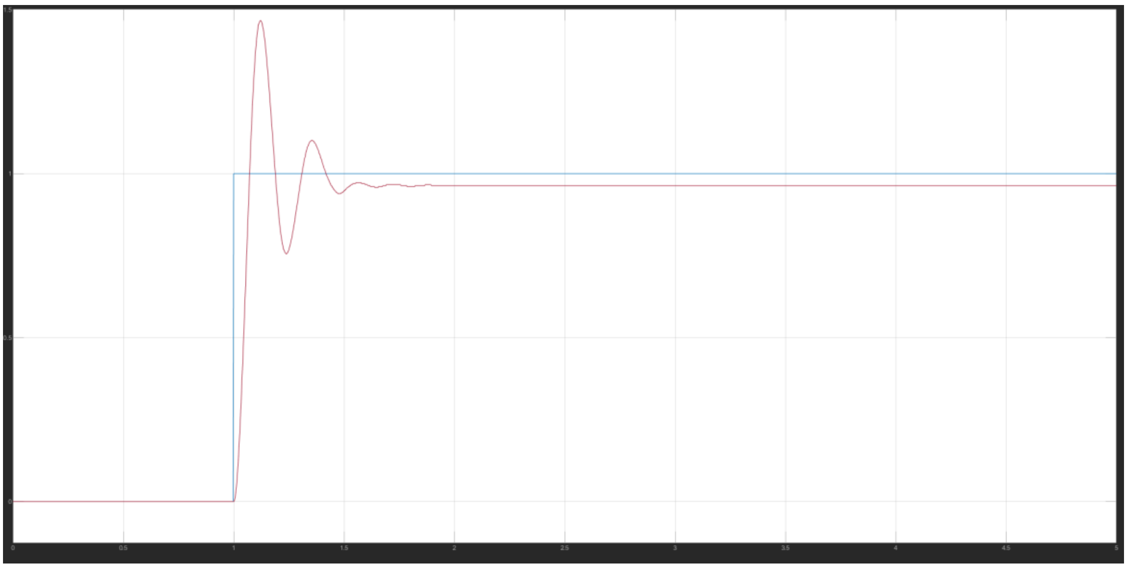

Figure 12: Speed Response from Simulink when KP=2.0

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

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

3 REFERENCES

[1] M. H. Center. [Online]. Available: https://in.mathworks.com/matlabcentral/answers/292859-how-to-find-kp-ki-kd-values-from-transfer-function?requestedDomain=.

[2] "Write Gate University," [Online]. Available: https://cecs.wright.edu/~krattan/courses/419/lecture5.pdf.