YILDIZ TECHNICAL UNIVERSITY

FACULTY OF ELECTRICAL & ELECTRONICS ENGINEERING

DEPARTMENT OF CONTROL AND AUTOMATION ENGINEERING

KOM4221

CONTROL LABORATORY

Experiment 1

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Group 2

Asst. Prof. Levent UCUN

2020-2021

Summary of Experiment

The aim of this experiment is to design a controller that will regulate the position of the output shaft using the PV controller of a DC motor system.

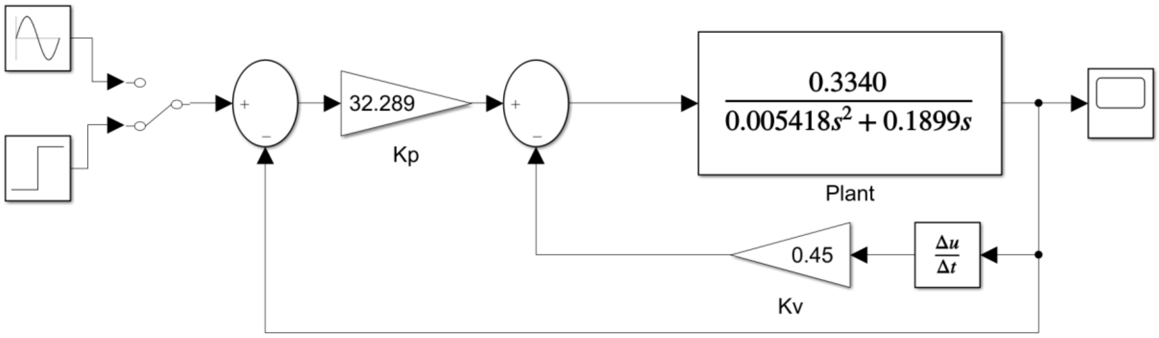

Figure 1: System Model

Theory Implementation and Numerical Calculations

Question 1)

The plant function is known to be P(s)

$$\frac{\theta_l(s)}{V_m(s)} = \frac{\eta_g \eta_m K_t K_g}{J_{eq} R_m s^2 + \left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2\right) s}$$

If we write the equivalent of the inner feedback loop and multiply by K_p

$$T_1(s) = \frac{K_p P(s)}{1 + P K_v s}$$

Then, by writing the equivalent of the outer feedback loop, the closed loop transfer function is obtained

$$T_2(s) = \frac{\eta_g \eta_m K_t K_g K_p}{J_{eq} R_m s^2 + s\left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2 + \eta_g \eta_m K_t K_g K_v\right) + K_p \eta_g \eta_m K_t K_g}$$

After arranging

$$T_2(s) = \frac{\dfrac{\eta_g \eta_m K_t K_g K_p}{J_{eq} R_m}}{s^2 + s\left(\dfrac{B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2 + \eta_g \eta_m K_t K_g K_v}{J_{eq} R_m}\right) + \dfrac{K_p \eta_g \eta_m K_t K_g}{J_{eq} R_m}}$$

$$T_2(s) = \frac{61.638\, K_p}{s^2 + s(35.167 + 61.852 K_v) + 61.638\, K_p}$$

Characteristic equation

$$s^2 + s\left(\frac{B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2 + \eta_g \eta_m K_t K_g K_v}{J_{eq} R_m}\right) + \frac{K_p \eta_g \eta_m K_t K_g}{J_{eq} R_m}$$

$$s^2 + s(35.167 + 61.852\, K_v) + 61.638\, K_p$$

If K_p increases, T_p decreases, %OS increases.

If K_v increases, T_s & %OS decreases, T_p increases. If K_v decreases the system becomes more aggressive.

Question 2)

To meet maximum overshoot criterion ζ chosen as 0.71.

From characteristic equation $\omega_n = \sqrt{61.638\, K_p}$

$$T_p = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}}$$

$$0.1 = \frac{\pi}{\sqrt{61.638\, K_p}\sqrt{1-0.71^2}}$$

$$K_p = 32.289$$

Then K_v value can be obtained from characteristic equation

$$s^2 + 2\zeta\omega_n + \omega_n^2 = s^2 + s(35.167 + 61.852\, K_v) + 61.638\, K_p$$

$$K_v = 0.45$$

Simulation Studies

Question 3)

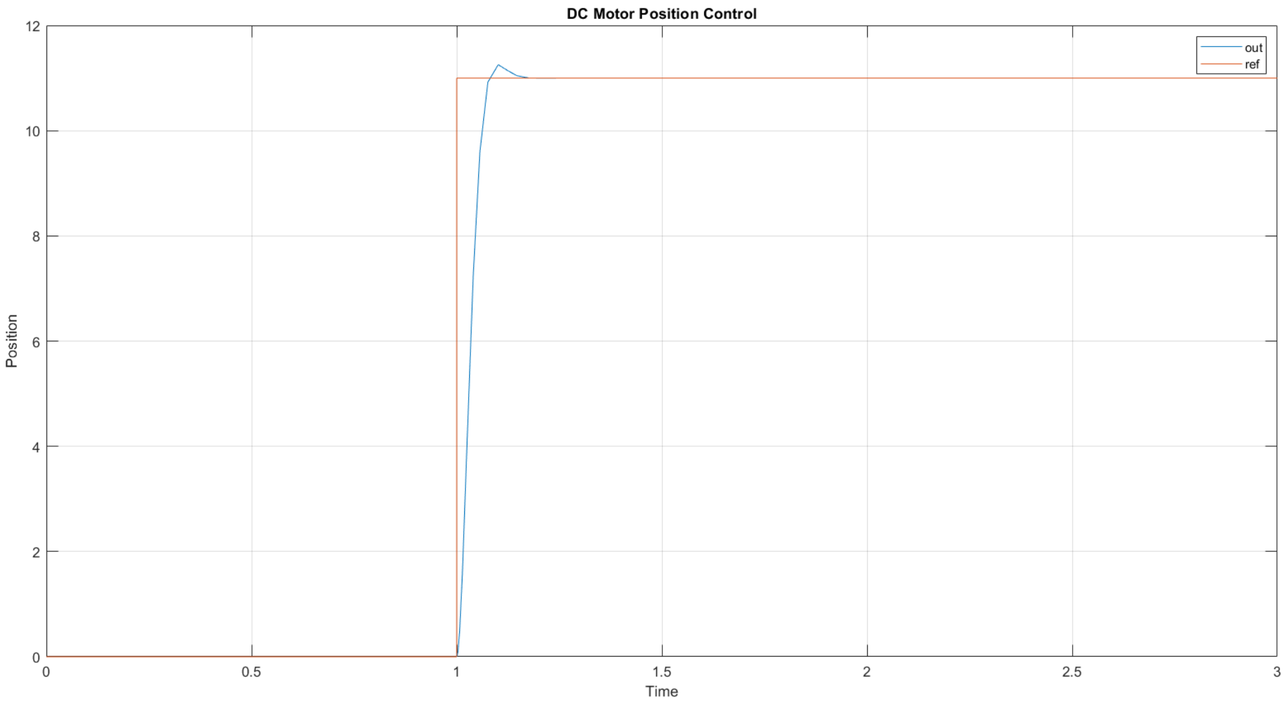

Figure 2: System Response for Step Input

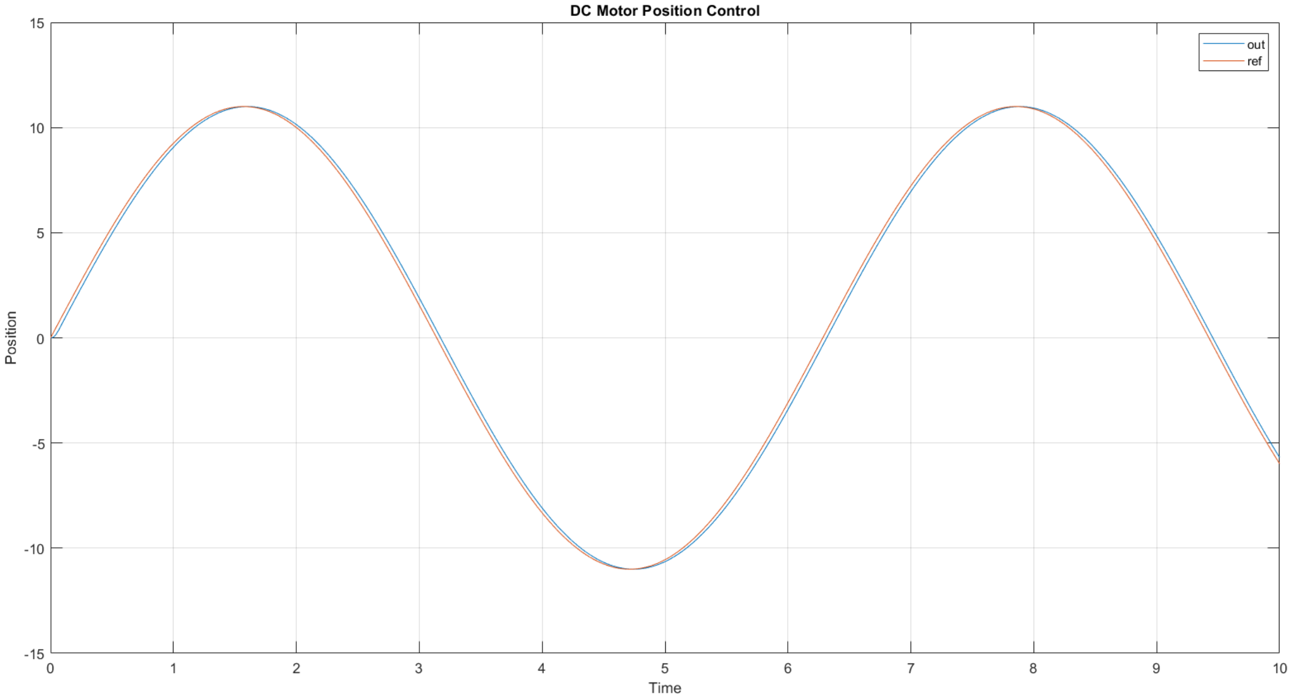

Figure 3: System Response for Sine Input

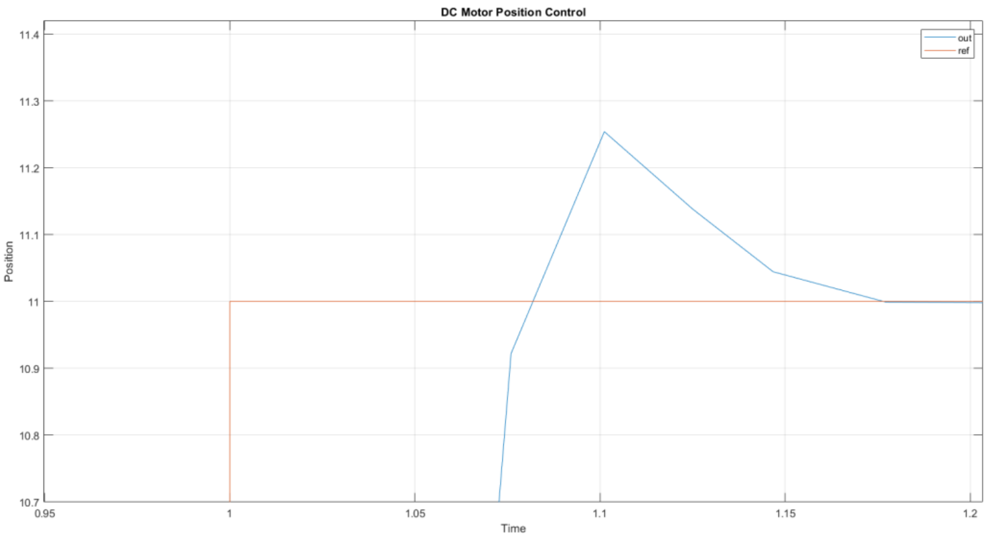

Figure 4: Zoomed System Response for Step Input

System %OS = 2.27 and T_p = 0.1 sec. Both requirements are met.

Analysis and Interpretations of Results

Question 4)

In PD controller we multiply error signal with $K_v \frac{\Delta u}{\Delta t}$ but in the PV controller we subtract the output signal multiplied by K_v from the error signal multiplied by K_p. Same case valid for PID controller and there is not integral controller in this PV type controller.

Question 5)

Since there are no integral controller some steady-state error requirements cannot meet. Even if we arrange K_p value to meet this criterion this can cause large overshoot values or oscillation and we need to consider stability.

Question 6)

We do not have any steady-state error requirement so adding an integral controller will not be logical.

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Experiment 2

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Summary of Experiment

The aim of this experiment is to design a controller that will regulate the speed of the output shaft using the PI controller of a DC motor system.

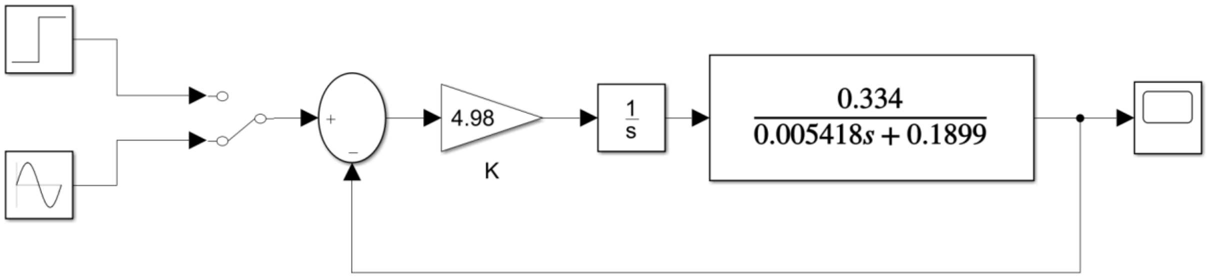

Figure 5: System Model

Theory Implementation and Numerical Calculations

Question 1)

The plant function is known to be P(s)

$$\frac{\omega_l(s)}{V_m(s)} = \frac{\eta_g \eta_m K_t K}{J_{eq} R_m s + \left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2\right)}$$

If we multiply $P(s)$by K & integrator and write the equivalent of the feedback loop, we obtain the close loop transfer function

$$T(s) = \frac{\eta_g \eta_m K_t K}{J_{eq} R_m s^2 + \left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2\right)s + \eta_g \eta_m K_t K}$$

After arranging

$$T(s) = \frac{\frac{\eta_g \eta_m K_t K}{J_{eq} R_m}}{s^2 + \frac{\left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2\right)s}{J_{eq} R_m} + \frac{\eta_g \eta_m K_t K}{J_{eq} R_m}}$$

$$T(s) = \frac{61.638\ K}{s^2 + 35.047\ s + 61.638\ K}$$

Characteristic equation

$$s^2 + \frac{\left(B_{eq} R_m + \eta_g \eta_m K_m K_t K_g^2\right)s}{J_{eq} R_m} + \frac{\eta_g \eta_m K_t K}{J_{eq} R_m}$$

$$s^2 + 35.047\ s + 61.638\ K$$

If K increases, %OS increases, T_p decreases.

Question 2)

For fastest response without over-shoot ζ chosen as 1. Then ω_n and K values are can be calculated

$$s^2 + 2\zeta\omega_n + \omega_n^2 = {}^2 + 35.047\, s + 61.638\, K$$
$$\omega_n = 17.52$$
$$K = 4.98$$

Simulation Studies

Question 3)

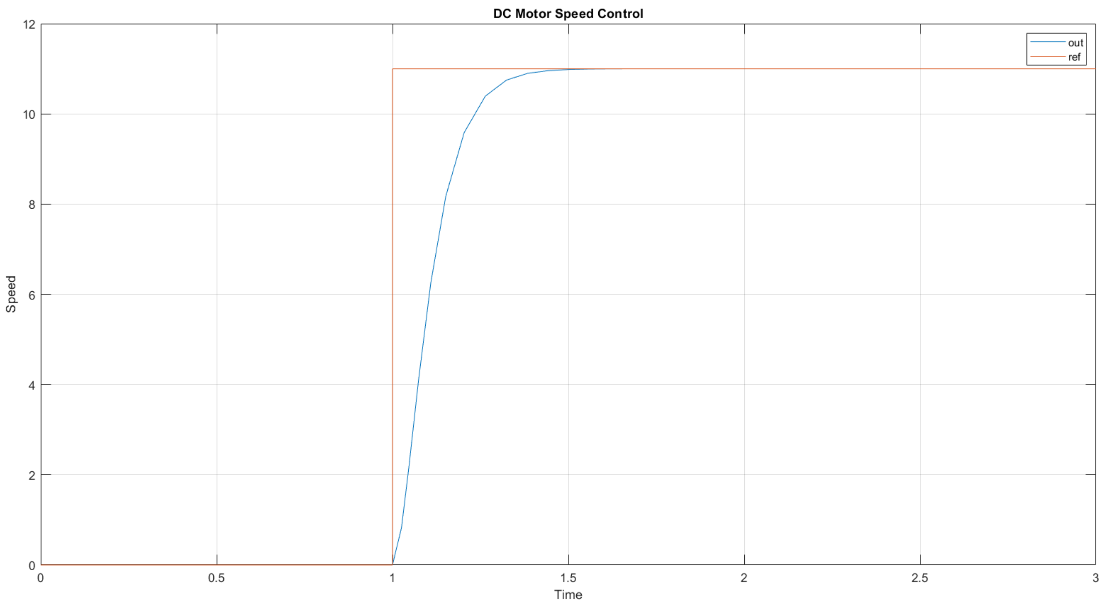

Figure 6: System Response for Step Input

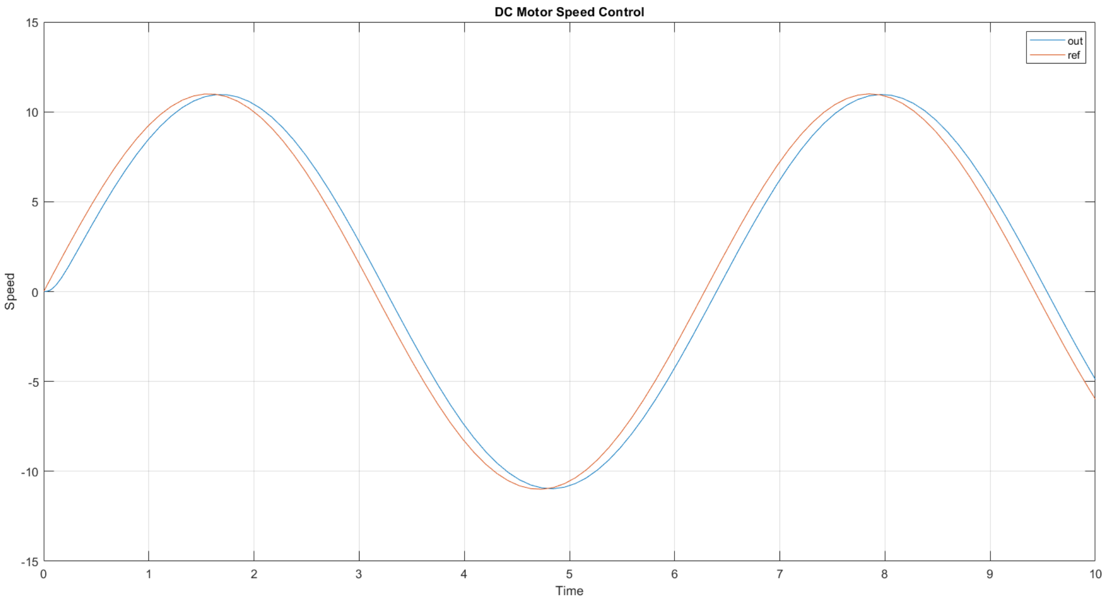

Figure 7: System Response for Sine Input

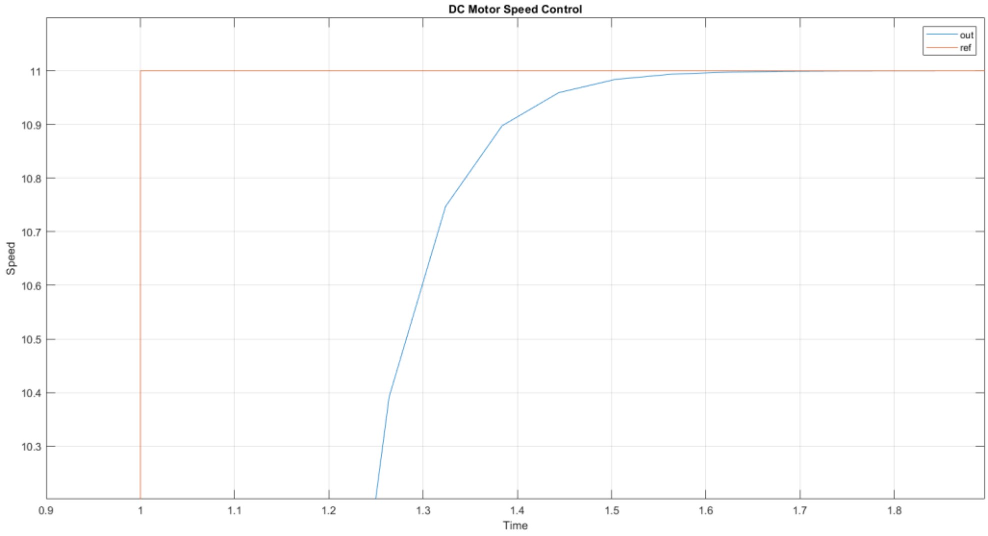

Figure 6: Zoomed System Response for Step Input

As seen in the graph at Figure 8 there is no over-shoot.

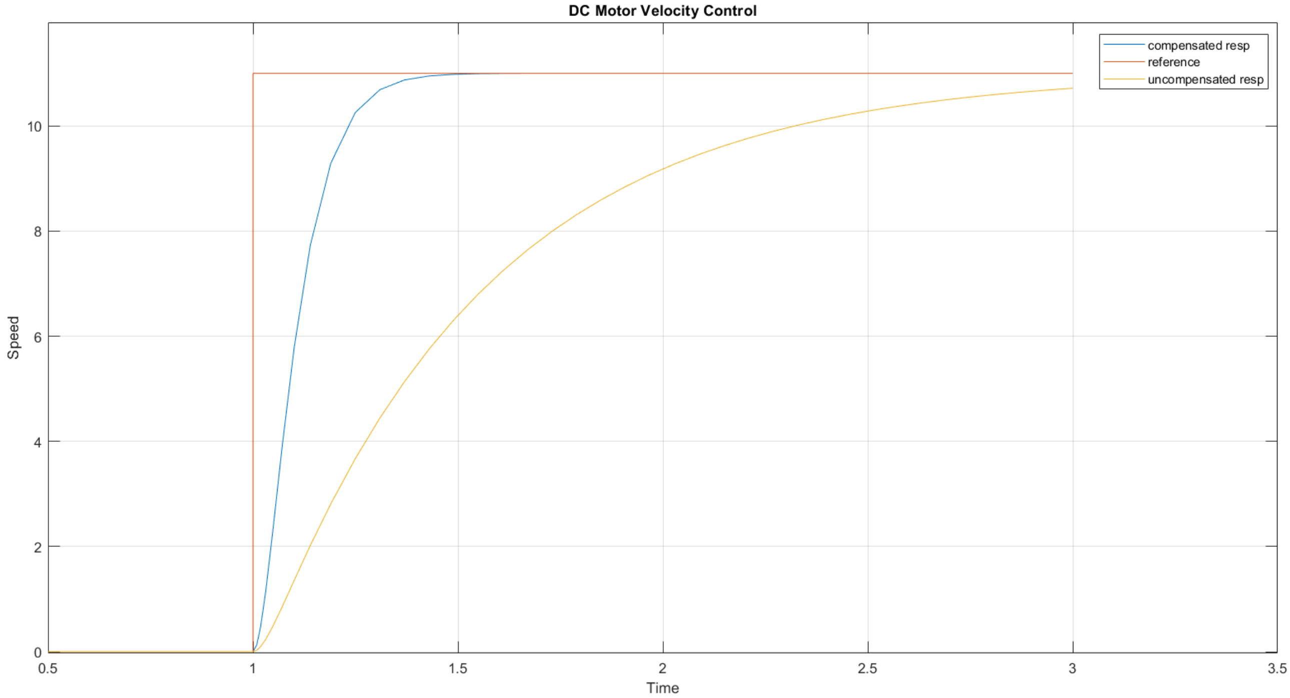

Figure 7: Compensated and Uncompensated Responses

As seen in the graph at Figure 9 compensated system has faster response.

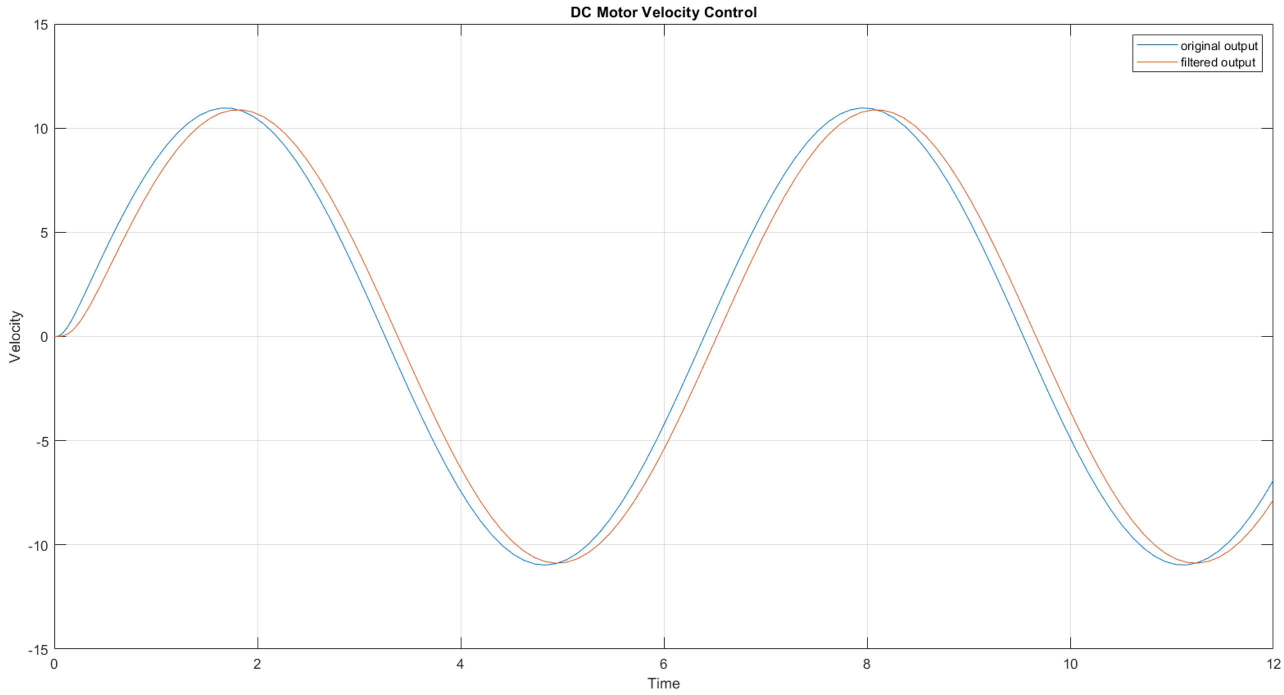

Figure 8: Original and Filtered Outputs

Low pass filters are used to reduce noise. Since this is just a simulation its effect is only phase shifting.

Analysis and Interpretations of Results

Question 4)

We use integral controller because our design criteria include zero steady-state error for step input. The goal of using the PD controller is to improve the transient response and PID controller improves both transient and steady-state response.

Question 5)

This PI type controller improves steady-state response in order to requirement. So, if design criteria include any kind of improving transient response it will not be able to meet that requirement.