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HW5
CL 302

Q1

a) $\tilde{G}(s) = \dfrac{k(\tau_3 s+1)e^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)}$

$\tilde{G}(s) = \tilde{G}^+(s) \cdot \tilde{G}^-(s)$

$G_c^*(s) = \dfrac{1}{\tau_c s+1} \cdot \tilde{G}_c^-(s)$ → F

$$G(s) = \frac{G_c^*(s)}{1 - G_c^*(s)\tilde{G}(s)} = \frac{(\tilde{G}_c^-(s))^{-1}F}{1-\cancel{(\tilde{G}_c^-(s))^{-1}}F\,\tilde{G}_c^+(s)\cdot\cancel{\tilde{G}_c^-(s)}}$$

$$= \frac{F}{(\tilde{G}_c^-)\left[1 - F\,\tilde{G}_c^+(s)\right]}$$

substituting.

$\cancel{G(s)}$ ≠ $\tilde{G}_c^+(s) = e^{-\theta s}$

$\tilde{G}_c^-(s) = \dfrac{k(\tau_3 s+1)}{(\tau_1 s+1)(\tau_2 s+1)}$

$$G(s) = \frac{1}{\left(\dfrac{(\tau_1 s+1)(\tau_2 s+1)}{k(\tau_3 s+1)}\right)\left[1+\tau_c s - e^{-\theta s}\right]}$$

$e^{-\theta s} \simeq 1-\theta s$ taylor approximation

$$G(s) = \frac{\cancel{k(\tau_3 s+1)}}{\cancel{(\tau_1 s+1)(\tau_2 s+1)}(\tau_c+\theta)s} \quad \frac{k(\tau_1 s+1)(\tau_2 s+1)}{k(\tau_3 s+1)(\tau_c+\theta)s}$$

$$= \frac{\tau_1\tau_2 s^2 + (\tau_1+\tau_2)s + 1}{ks(\tau_3 s+1)(\tau_c+\theta)} \quad \text{— (1)}$$

τ_3)

τ_3

τ_I

$$= \frac{1}{k(\tau_c+\theta)} \cdot (\tau_1+\tau_2-\tau_3)\left[\frac{(\tau_1 s+1)(\tau_2 s+1)}{(\tau_3 s+1)\, s\, (\tau_1+\tau_2-\tau_3)}\right]$$

For PID controller (parallel configuration)

$$G_c = k_c\left[1 + \frac{1}{\tau_I s} + \frac{\tau_D s}{\alpha\tau_D s+1}\right] \qquad \alpha\tau_D = \tau$$

$$= k_c\left[\frac{\tau_I \tau s^2 + \tau_I\tau_D s^2 + (\tau_I+\tau)s + 1}{\tau_I s(\alpha\tau s+1)}\right]$$

$$= k_c\left[\frac{(\tau_D+\tau)s^2 + (1+\tau/\tau_I)s + 1/\tau_I}{s(\tau s+1)}\right] \quad \text{—— (11)}$$

Comparing (1) & (11) & $\tau = \tau_3$

$$\cancel{k_c} = \cancel{\tau_1\tau_2} \qquad k_c(\tau_D+\tau_3) = \frac{\tau_1\tau_2}{k(\tau_c+\theta)}$$

$$\frac{\tau_1+\tau_2}{k(\tau_c+\theta)} = k_c(1+\tau_3/\tau_I)$$

$$\frac{1}{k(\tau_c+\theta)} = k_c/\tau_I$$

Solving

$$\tau_I = \tau_1+\tau_2-\tau_3$$

$$kk_c = \frac{\tau_1+\tau_2-\tau_3}{\tau_c+\theta}$$

$$\tau_D = \frac{\tau_1\tau_2 - \tau_3(\tau_1+\tau_2-\tau_3)}{\tau_1+\tau_2-\tau_3}$$

$$kk_c\left(1+\frac{\tau_3}{\tau_I}\right) = \frac{\tau_1+\tau_2}{\tau_c+\theta}$$

$$\frac{kk_c}{\tau_I} = \frac{1}{\tau_c+\theta}$$

$$\frac{\tau_1+\tau_2}{\tau_c+\theta} = kk_c\left[1+\frac{\tau_3}{\tau_1+\tau_2-\tau_3}\right]$$

$$kk_c(\tau_D+\tau_3) = \frac{\tau_1\tau_2}{\tau_c+\theta}$$

$$(\tau_1+\tau_2-\tau_3)(\tau_D+\tau_3) = \tau_1\tau_2$$

b) $\dfrac{K(\tau_3 s+1)e^{-\theta s}}{\tau^2 s^2+2\xi\tau s+1}$

$\tilde{G}^+(s) = e^{-\theta s}$ $\qquad F = \dfrac{1}{\tau_c s+1}$

$\tilde{G}^-(s) = \dfrac{k(\tau_3 s+1)}{\tau^2 s^2+2\xi\tau s+1}$

$G_c = \dfrac{G_c^*}{1-G_c^*\tilde{G}} \longrightarrow \dfrac{\tilde{G}_{c-}^{-1}F}{1-\tilde{G}_c^{-1}F\tilde{G}_+ \cancel{\tilde{G}_c}}$

$\dfrac{\tau^2 s^2+2\xi\tau s+1}{k(\tau_3 s+1)\left[\cancel{1+\tau-(1-\theta s)}\right]}\left[1+\tau_c s-(1-\theta s)\right]$

$\Rightarrow \dfrac{1}{k(\tau_c+\theta)}\dfrac{\tau^2 s^2+2\xi\tau s+1}{s(\tau_3 s+1)} \Longleftrightarrow$ & PID controller (parallel config) $G_c = K_c\left[\dfrac{(\tau_D+\tau')s^2+(1+\frac{\tau'}{\tau_I})s+1/\tau_I}{s(\tau_3 s+1)}\right]$

Comparing,

$\dfrac{\tau'^2}{k(\tau_c+\theta)} = K_c(\tau_D+\tau_3)$ $\qquad \dfrac{1}{k(\tau_c+\theta)} = \dfrac{K_c}{\tau_I}$

$\dfrac{2\xi\tau}{k(\tau_c+\theta)} = K_c(1+\tau_3/\tau_I)$

gives

$KK_c = \dfrac{2\xi\tau-\tau_3}{\tau_c+\theta}$ $\qquad$ & $\tau_I = 2\xi\tau-\tau_3$

$\tau_D = \dfrac{\tau^2-(2\xi\tau-\tau_3)\tau_3}{2\xi\tau-\tau_3}$

$KK_c = \dfrac{\tau_I}{\tau_c+\theta} = \dfrac{2\xi\tau-\tau_I}{\tau_c+\theta}$

$\dfrac{\tau^2}{\tau_c+\theta} = KK_c(\tau_D+\tau_I)$

$= \dfrac{(2\xi\tau-\tau_3)(\tau_D+\tau_3)}{\tau_c+\theta}$

$\tau_D = \dfrac{\tau^2}{2\xi\tau-\tau_3} - \tau_3$

$\tau_D = \dfrac{\tau^2-(2\xi\tau-\tau_3)\tau_3}{2\xi\tau-\tau_3}$

τ_I

Q2) $G(s) = \dfrac{1}{(s+1)(0.2s+1)(0.04s+1)(0.008s+1)}$

a) 1) SOPTD $\dfrac{ke^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)}$

largest neglected time constant in denominator $= 0.04$

$\therefore \theta = 1 + \frac{0.04}{2} + 0.008 = 0.028$

$\tau_1 = 1$ $K = 1$

$\tau_2 = 0.2 + \frac{0.04}{2} = 0.22$

$$\tilde{G}(s) = \frac{e^{-0.028 s}}{(s+1)(0.22 s+1)}$$

taking Condition I from table 12.1, with $\tau_3 = 0$

$$K_c = \frac{\tau_1 + \tau_2 - \tau_3}{k(\tau_c + \theta)} = \frac{1.22}{\tau_c + 0.028}$$

$$\tau_I = \tau_1 + \tau_2 - \tau_3 = 1.22$$

$$\tau_D = \frac{\tau_1\tau_2 - (\tau_1+\tau_2-\tau_3)\tau_3}{\tau_1+\tau_2-\tau_3} = 0.18$$

for $\tau_c = 0.148$ as $\theta/\tau_1 = 0.248 < 0.5$ hence $\tau_c =$ FOPTD θ

i.e default value, table 12.3 $\Rightarrow$ $\underline{K_c = 6.93}$

Q2 a) ii) FOPDT $\frac{k e^{-\theta s}}{(\tau_1 s+1)}$

largest neglected time const - 0.2

$\theta = 1 + 0.008 + 0.04 + 0.2/2 = 0.148$

$\tau_1 = 1 + 0.2/2 = 1.1$

$k = 1$

$$\tilde{G}(s) = \frac{e^{-0.148 s}}{1.1 s + 1}$$

$$K_c = \frac{1}{k}\left(0.2 + 0.45\frac{\tau}{\theta}\right) = 3.54$$

$$\tau_I = \frac{0.4\theta + 0.8\tau}{\theta + 0.1\tau}\,\theta = 0.54$$

$$\tau_D = \frac{0.5\,\theta\tau}{0.3\theta + \tau} = 0.071$$

Q3

Q2) a) iii)

$\theta = 0.148$

$\tau = 1.1$

$k = 1$

$\theta/\tau = 0.1345$

$Y = A(\theta/\tau)^B$

for Disturbance.

for P, $Y = 9.0686$ $\quad K_c = Y/k = 9.0686$

for I, $Y = 3.7$ $\quad$ ~~$\tau/\tau_I = 3$~~ $\tau_I = \tau/Y = 0.2973$

for D, $Y = 0.0518$ $\quad \tau_D = Y \cdot \tau = 0.0570$

for Set point,

for P, $Y = 5.3087$ $\quad K_c = 5.31$

for I, $Y = 0.7763$ $\quad \tau_I = 1.412$

for D, $Y = 0.0478$ $\quad \tau_D = 0.053$

Q 2) a) IV)

from tweaking on Simulink,

$K_{cu} = 30.1$

$P_{cu} = 4/7$

$\therefore$ $K_c = 0.6\,K_{cu} = 18.06$

$\tau_I = P_{cu}/2 = 0.28$

$\tau_D = P_{cu}/8 = 0.071$

b) Implemented on Simulink.

c) IMC settings provide the best result.

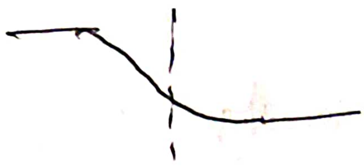
AMIGO most conservative

ITAE & ZN settings are the most aggressive & produce damped oscillatory respons.

AMIGO also damped oscillatory response.

Q3

phase diagram indicates the presense of time delay.
(tail approaches infinity)



2 → take this value

$AR_{OL}\big|_{w=0.01} = 3 \Rightarrow K = 3 \times 0.01 = 0.03$

At $w = 0.1$, slope increases, ⇒ real zero $\left(\frac{s}{0.1}+1\right)$

At $w = 2$, slope decreases, ⇒ real pole ⇒ $\frac{s}{2}+1$

At $w = 20$, slope decreases ⇒ real pole ⇒ $\left(\frac{s}{20}+1\right)$

$\cancel{\dfrac{\left(\frac{10s}{0.1}+1\right)}{(s+1)\left(\frac{s}{10}+1\right.}}$

this implies, there are two real poles & 1 real zero
the phase starts from $-90°$ implies presence of s indenominator

$$\frac{K(\tau_a s+1)}{s(\tau_b s+1)(\tau_c s+1)} \qquad \therefore \tau_a = 1/0.1$$

$\tau_b = 1/2$

$\tau_c = 1/20$

$$\therefore G(s) = \frac{0.03\,(10s+1)}{s(0.5s+1)(0.05s+1)}$$

$\left(\cdots\right)\left(-\frac{s}{5}+1\right)$

b)

Q. 3

b) $\phi_g = PM - 180^\circ = 30 - 180^\circ = -150^\circ$

for $\phi_g = -150^\circ$, $\omega_g \approx 38.93$ rad/s

At $\omega = \omega_g$ $\quad \frac{AR_{OL}}{K_c} = 0.007$

$AR_{OL}\big|_{\omega = \omega_g} = 1$

$\therefore K_c = 1/0.007 = 142.86$

ω_c is not defined for this

hence ~~Phase~~ Gain Margin is not applicable.

Q4)

a) $G_{OL} = \frac{1}{(4s+1)(2s+1)} \cdot k_c$

second order transfer function, the phase approaches $-\cancel{270}\ 180^\circ$ but never attains it, hence the system is stable for all values of k_c i.e can't be unstable.

b) $G_{OL} = \frac{1}{(4s+1)(2s+1)} \cdot \frac{k_c(5s+1)}{5s}$

$+90-90-90-90 = -180^\circ$

$\phi = -\tan^{-1}(4\omega) - \tan^{-1}(2\omega) + \tan^{-1}(5\omega) - \pi/2 \rightarrow$ min value $= -180^\circ$

Never attains phase angle -180°, hence stable, can't be unstable

c) $G_{OL} = \frac{s+1}{(4s+1)(2s+1)} \cdot \frac{k_c(2s+1)}{s}$

$\phi = \tan^{-1}(\omega) + \tan^{-1}(2\omega) - \tan^{-1}(4\omega) - \tan^{-1}(2\omega) - \pi/2$

$\min(\phi) = +90+90-90-90-90 \quad \approx -90^\circ$

Never attains -180°, hence system is stable, can't be unstable

Q4) d) $G_{OL} = \frac{1-s}{(4s+1)(2s+1)} \; k_c$

$\phi = \tan^{-1}(-\omega) \cancel{+} - \tan^{-1}(4\omega) - \tan^{-1}(2\omega)$

$\min(\phi) \simeq -270^\circ$

attains phase of -180°, hence the system can be unstable for large values of K_c

e) $G_{OL} = \frac{e^{-s}}{4s+1} \cdot k_c$

$\phi = -\tan^{-1}(4\omega) + \tan^{-1}\left(-\frac{\sin\omega}{\cos\omega}\right)$

$= -\tan^{-1}(\cancel{\omega}\, 4\omega) - \omega$

$\min(\phi) \to \infty$

$\therefore$ System can be unstable due to time delay at high frequencies. ~~(when it attains 180°)~~

Q5 $G_c = k_c\left(\frac{2s+1}{0.1s+1}\right)$ $G_p = \frac{0.4}{s(5s+1)}$

$G_v = \frac{2}{0.5s+1}$ $G_d = \frac{3}{5s+1}$

$G_m = 1$

a) $G_{OL} = G_c G_v G_p G_m = k_c\left(\frac{2s+1}{0.1s+1}\right)\left(\frac{0.4}{s(5s+1)}\right)\left(\frac{2}{0.5s+1}\right)\cdot 1$

$AR_{OL}(\omega_c) = |G_{OL}(j\omega_c)| \cancel{=1}$

$\Rightarrow k_c \frac{\sqrt{4\omega^2+1}}{\sqrt{0.01\omega^2+1}} \quad \frac{0.4}{\omega\sqrt{\cancel{0.0}25\omega^2+1}} \quad \frac{\cancel{4} \; 2}{\sqrt{0.25\omega^2+1}}$

$\phi_{OL}(\omega_c) = \angle G_{OL}(j\omega_c) \cancel{= -180}$

$\phi = 0 + \tan^{-1}(2\omega) + 0 + 0 - \tan^{-1}(0.1\omega) - \pi/2 - \tan^{-1}(5\omega)$
$- \tan^{-1}(0.5\omega)$

$G_{OL} = \frac{k_c(1.6s + 0.8)}{\frac{s^4}{4} + \frac{61s^3}{20} + \frac{28s^2}{5} + s}$

b) $\phi_g = PM - 180 = 30^\circ - 180^\circ = -150^\circ$

for $\phi_g = -150^\circ$, $\omega_g = 1.72$ rad/min

1.71822 $\approx$ 1.72 rad/mins

$\therefore$ At $\omega = \omega_g$, $\frac{AR_{OL}}{k_c} = \cancel{\frac{-16.8645}{10}}$ exp $= 0.144$ & $\therefore AR_{OL}|_{\omega=\omega_g} = 1$

$k_c = 1/0.144 = 6.94$

Q5 c) for $\phi = -180^\circ$, $\omega_c = 4.06$ rad/mins

$$\left.\frac{AR_{OL}}{k_c}\right|_{\omega=\omega_c} = 0.03205$$

$$A_c = AR_{OL}|_{\omega=\omega_c} = 0.325$$

$$GM = 1/A_c = 3.08$$

11) a) $$G_{OL} = \frac{k_c(1.6s+0.8)}{\frac{s^4}{4} + \frac{61s^3}{20} + \frac{28s^2}{5} + s} \cdot e^{-s}$$

$$e^{-s} \qquad e^{-j\omega} = \cos\omega - j\sin\omega$$

AR_{OL} : same as before

$$\phi_{OL} = \tan^{-1}(2\omega) - \tan^{-1}(0.1\omega) - \pi/2 - \tan^{-1}(5\omega) - \tan^{-1}(0.5\omega) + \tan^{-1}\left(-\frac{\sin\omega}{\cos\omega}\right)$$

$-\omega$

b) ω_g for $\phi_g = -150^\circ$ = 0.38 rad/s

At $\omega = \omega_g$, $\frac{AR_{OL}}{k_c} = 1.19$ $\quad \because AR_{OL}|_{\omega=\omega_g} = 1$

$k_c = 1/1.19 = 0.84$

c) for $\phi = -180^\circ$, $\omega_c = 0.8$ rad/s

$$\left.\frac{AR_{OL}}{k_c}\right|_{\omega=\omega_c} = 0.42$$

$$A_c = AR_{OL}|_{\omega=\omega_c} = 4.2 \qquad GM = 1/A_c = 0.24$$

Q6 $G_p(s) = \dfrac{e^{-s}}{s+1}$

$G_d(s) = \dfrac{2}{(s+1)(5s+1)}$

$G_v = G_m = G_t = 1$

a) $G_f = \dfrac{-G_d}{G_t G_v G_p}$

for steady state conditions,

$G_p = K_p = 1$

$G_d = K_d = 2$ $= -\dfrac{2}{1 \cdot 1 \cdot 1} = -2$

$G_v = G_m = G_t = 1$

$G_f = -2$

b) Dynamic Analysis

$G_f = -\dfrac{G_d}{G_v G_t G_p} \Rightarrow \dfrac{-\dfrac{2}{(s+1)(5s+1)}}{(1)(1)\dfrac{e^{-s}}{(s+1)}}$

$\Rightarrow \dfrac{2}{(5s+1)(s+1)} e^{+s} \cdot (s+1)$ from Example 15.3

$\approx \dfrac{2((1+1)s+1)}{(5s+1)(s+1)} \Rightarrow -\dfrac{2(2s+1)}{(5s+1)(s+1)}$

Q6

c) $\tilde{G} = G_v G_p G_m = \dfrac{e^{-s}}{s+1}$ $\theta = 1$ $\tau = 1$ $k = 1$ $\tau_c = 2$

from table 12.1, $\underline{G}$

taylor

$K_c = \dfrac{1}{\tau_c + \theta}$ $\tau_I = \tau$ $\tau_D = -$

$K_c = \frac{1}{3}$ $\tau_I = 1$

$$G_c = \frac{1}{3}\left[1 + \frac{1}{s}\right] \approx \frac{s+1}{3s}$$

d) $G_c = 0$, D: $d(t) = u(t)$

$D(s) = 1/s$

Closed loop

$$Y = G_d D + [G_p G_v G_t G_f]D$$

$$= \frac{2}{(s+1)(5s+1)} \cdot \frac{1}{s} + \left[\frac{e^{-s}}{s+1} \cdot 1 \cdot (-2) \cdot (1)\right] \cdot \frac{1}{s}$$

$10s - 10s^2$
$+2 - 2s$
$+10s - 8s - 2$

$$= Y(s) = \frac{2 + -2(5s+1)e^{-s}}{(s+1)(5s+1)e^{-s}} = \frac{2 - (10s+2)e^{-s}}{(s+1)(5s+1)\cancel{e^{-s}}\, s}$$

$$e^{-s} \approx 1 - \theta 1s = \frac{2 - (10s+2)(1-s)}{(s+1)(5s+1)(s)} \Rightarrow \frac{10s^2 - 8s}{(s+1)(5s+1)(s)} \Rightarrow \frac{10s - 8}{(s+1)(5s+1)}$$

$\approx$

Q6

d) $Y(s) = \dfrac{10s-8}{(s+1)(5s+1)}$

$$y(t) = L^{-1}\left\{\frac{9}{2(s+1)} - \frac{25}{2(5s+1)}\right\} = \frac{9}{2}e^{-t} - \frac{25}{2}e^{-\cancel{25t}\, t/5}$$

$$= \tfrac{1}{2}\left[9e^{-t} - 25e^{-t/5}\right]$$

Now

for $G_f = \dfrac{-2(2s+1)}{(\cancel{s+1}\,(5s+1)(s+1)}$

$$Y = \left(\frac{2}{(s+1)(5s+1)} + \frac{e^{-s}}{(s+1)} \cdot 1 \cdot \left(\frac{-2(2s+1)}{(5s+1)(s+1)}\right)\right)\frac{1}{s}$$

$$= \frac{2s+2 \mp 2e^{-s}(2s+1)}{(s+1)(5s+1)(s+1)\,s}$$

$2s+1-2s^2-s$

$-2+4s^2-2s$

taylor approximation

$e^{-s} \approx (1-s)$

$$Y(s) \quad \frac{2s+2 - 2(1-s)(2s+1)}{(s+1)^2(5s+1)\,s} = \frac{4s^2}{(s+1)^2(5s+1)\cancel{s}}$$

$$y(s) = L^{-1}\left\{\frac{4s}{(s+1)^2(5s+1)}\right\} = L^{-1}\left\{\frac{1}{4(s+1)} + \frac{1}{(s+1)^2} - \frac{5}{4(5s+1)}\right\}$$

$$= \tfrac{1}{4}e^{-t} + e^{-t}t - \tfrac{1}{4}e^{-t/5}$$

Q6) e) $G_c \neq 0$ $G_c = \frac{S+1}{3S}$

$$\frac{Y}{D} = \frac{G_d + G_t G_f G_v G_p}{1 + G_c G_p G_m G_v}$$

Y for (a) (c) $\therefore$ $G_f \, l = (-2)$

$$Y(s) = \frac{\frac{2}{(S+1)(5S+1)} + \frac{e^{-S}}{S+1}(-2)}{1 + \frac{S+1}{3S} \cdot 1 \cdot \frac{e^{-S}}{S+1}}$$

$5S+1-5S^2-S$

$5S^2-4S-1$

$10S^2-8S-\cancel{2}+\cancel{2}$

$e^{-S} \approx (1-S)$

$$= \frac{2 - 2(1-S)(5S+1)}{\frac{(S+1)(5S+1)}{3S}\left[3S\cancel{(S+1)} + \cancel{(S+1)}\, 1-S\right]}$$

$$Y(s) \Rightarrow \frac{(10S^2-8S)3S}{(S+1)(5S+1)(2S+1)} \cdot \frac{1}{S}$$

~~$y(t) = L^{-1}(Y(s)) = L^{-1}\left\{3 - \frac{27}{2(S+1)} + \frac{13}{2S+1} - \frac{5}{2(5S+1)}\right\}$~~

~~$y(t) = 3\delta(t) - \frac{27}{2}e^{-t} + \frac{13}{2}e^{-t/2} - \frac{1}{2}e^{-t/5}$~~

$$y(t) = L^{-1}\left\{\frac{27}{2(S+1)} - \frac{26}{(2S+1)} + \frac{25}{2(5S+1)}\right\} = \frac{27}{2}e^{-t} - 13e^{-t/2} + 5/2\, e^{-t/5}$$

Q6) e) (b) & (c)

$$Y(s) = \frac{\frac{2}{(s+1)(5s+1)} + \frac{e^{-s}}{s+1} \cdot \frac{-2(2s+1)}{(5s+1)(s+1)}}{1 + \frac{s+1}{3s} \cdot 1 \cdot \frac{e^{-s}}{s+1}}$$

$$Y(s) = \frac{\frac{4s}{(s+1)^2(5s+1)} \cdot 3\cancel{s}}{3s + 1 - s} \cdot \frac{1}{\cancel{s}}$$

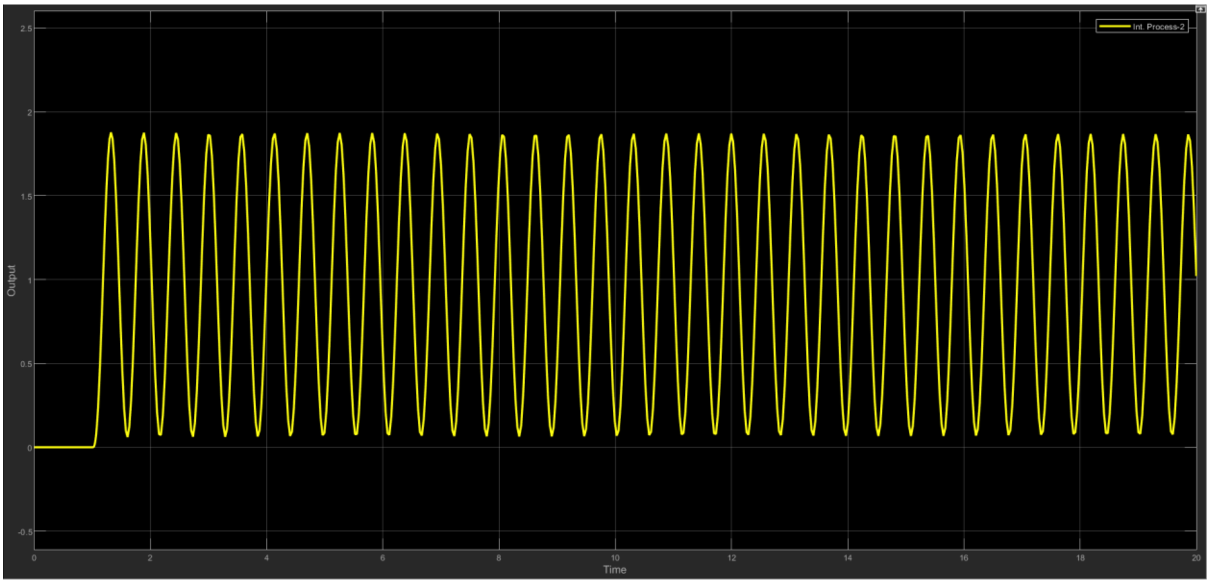
$$y(t) = L^{-1}\left\{ \frac{-27}{4} \cdot \frac{1}{s+1} - \frac{3}{(s+1)^2} - \frac{25}{4(5s+1)} + \frac{16}{2s+1} \right\}$$

$$= \frac{-27}{4} e^{-t} - 3e^{-t}t - \frac{25}{4} e^{-t/5} + 8e^{-t/2}$$

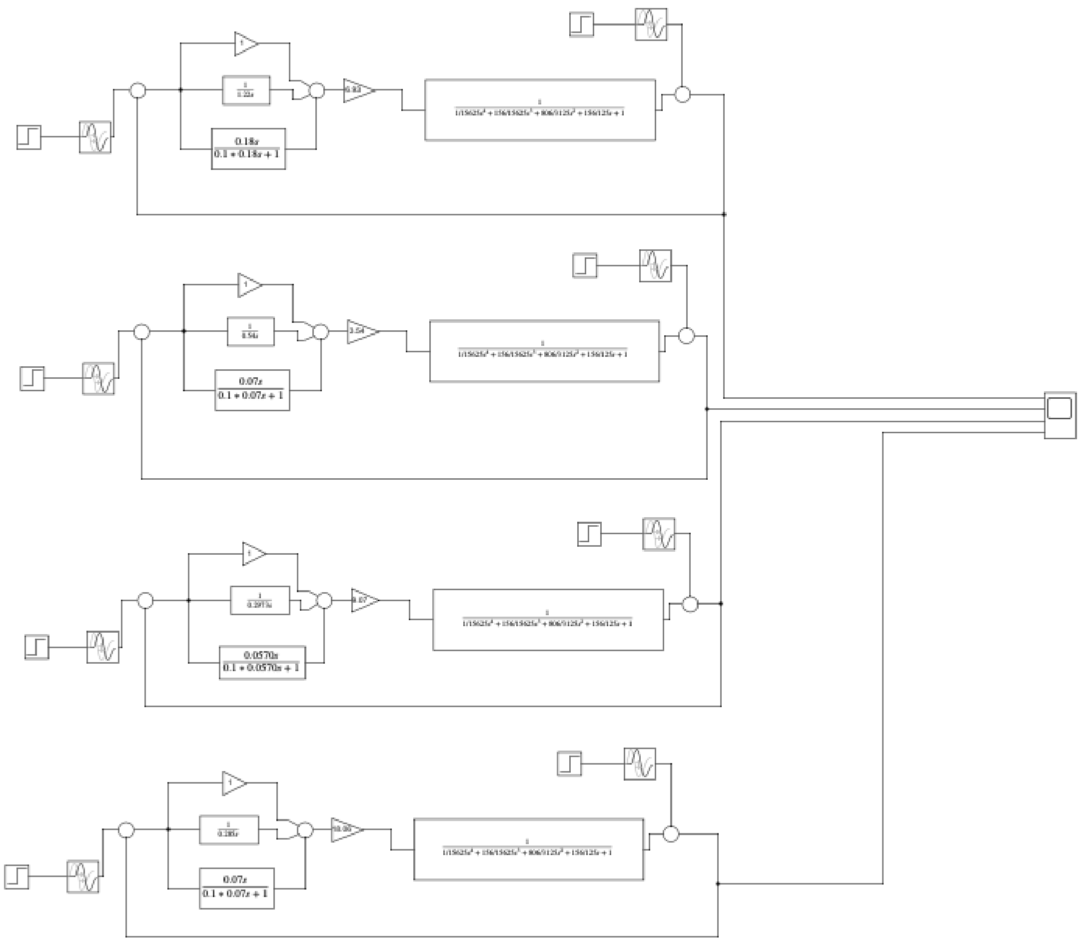
All Codes and simulink in https://github.com/MananMohnot/CL302/tree/master/Assignment%205

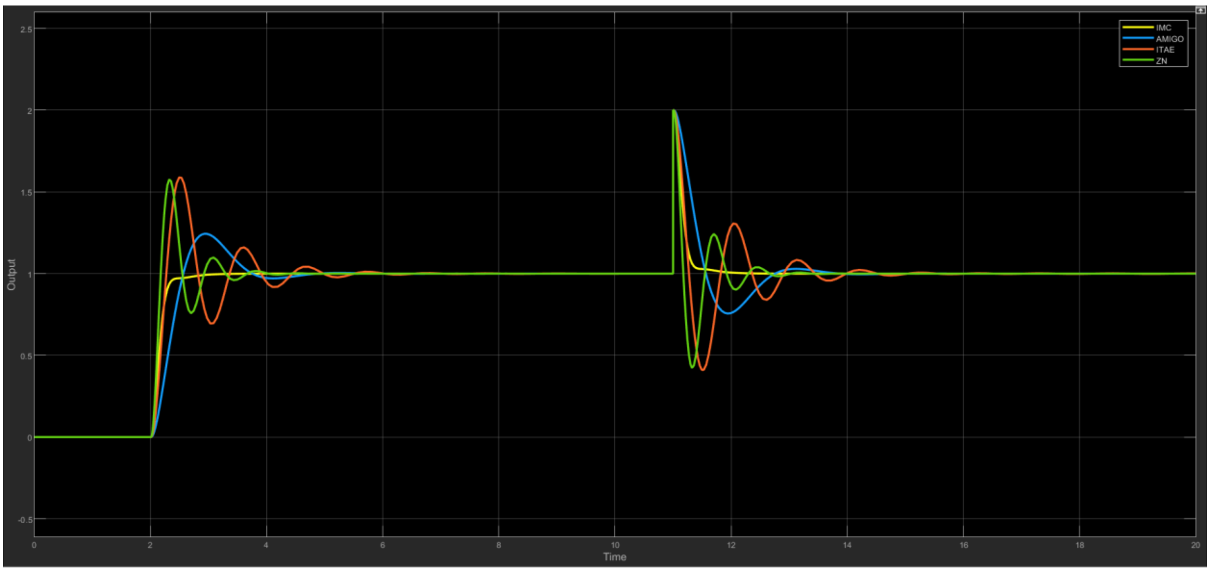
Q1) Refer paper notes

Q2) a) iv)



Q2) b)





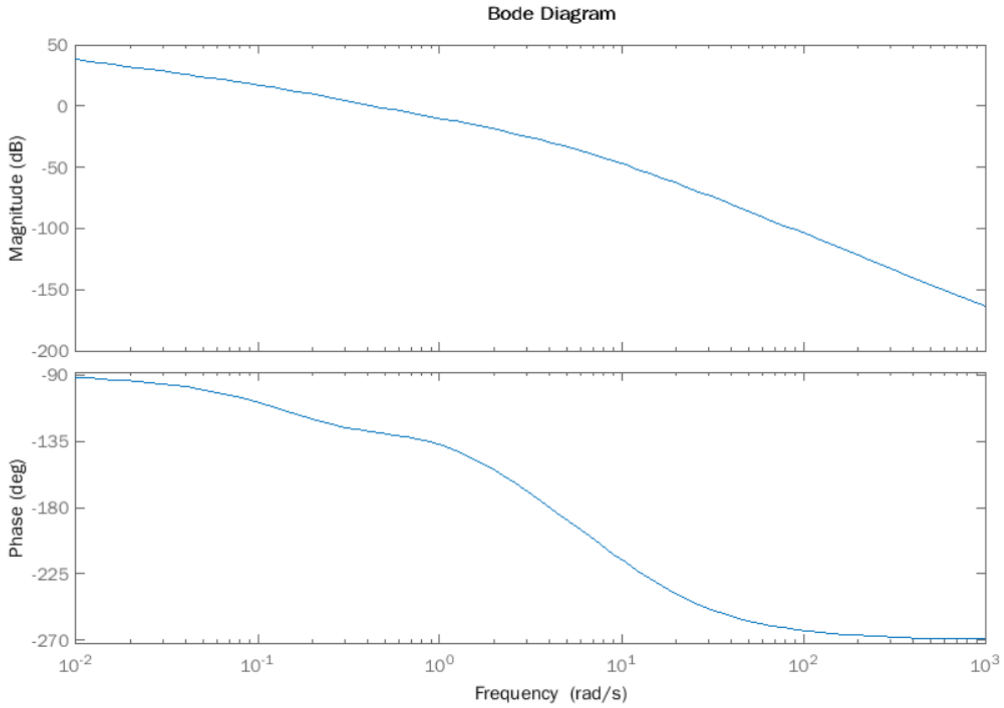
Q3)

In paper

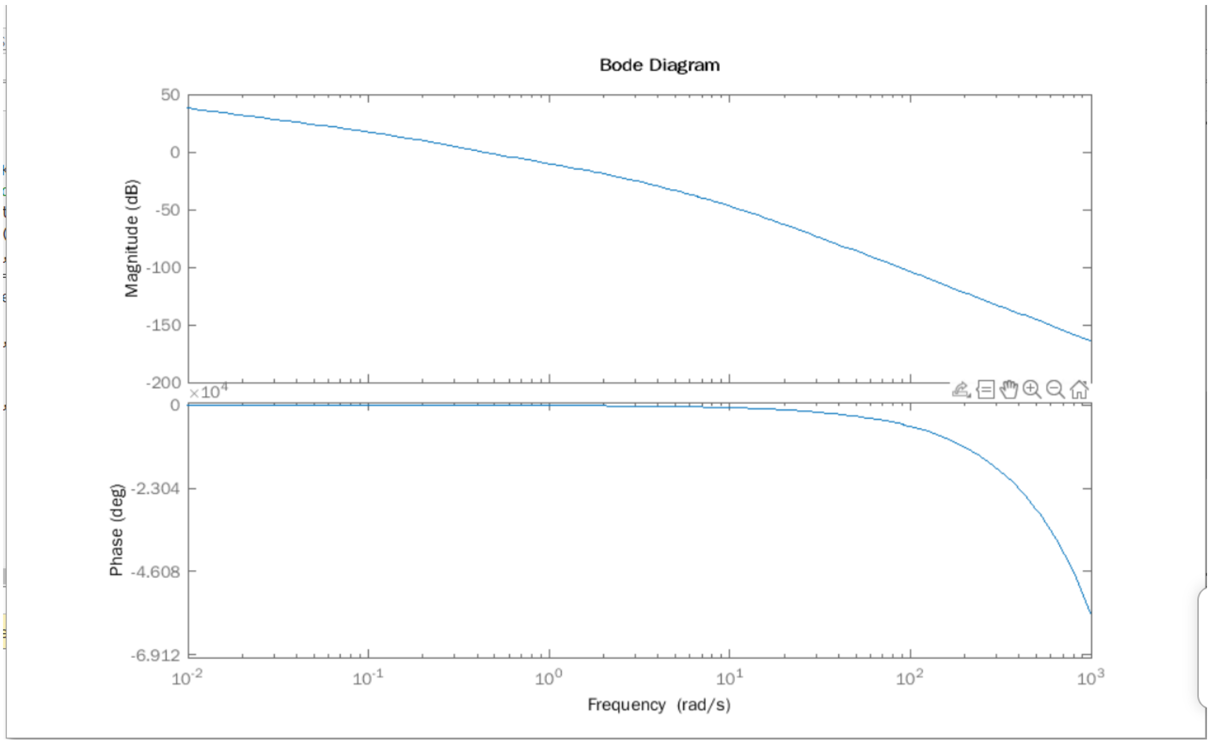
Q4)

In paper

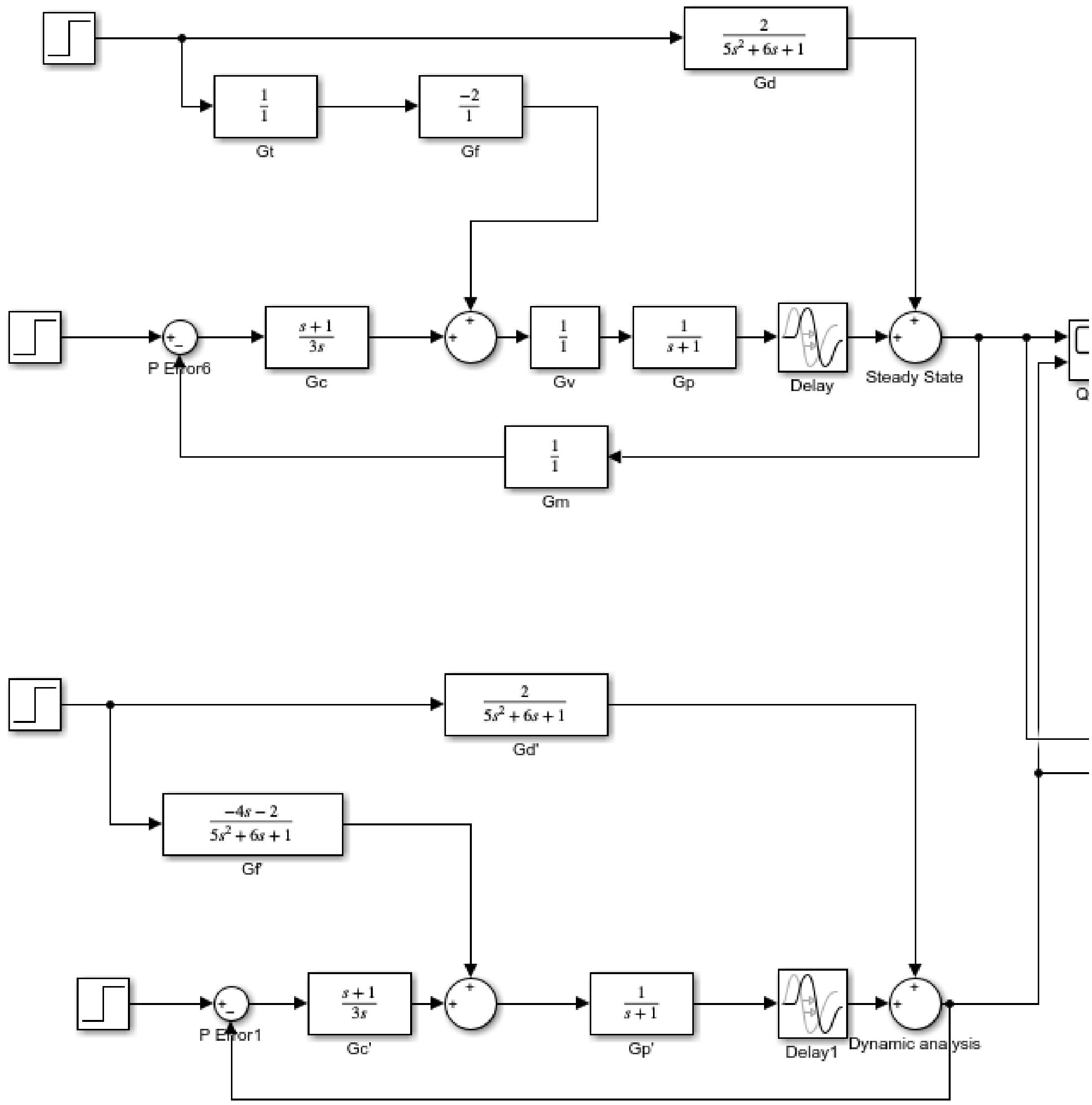
Q5) for normal



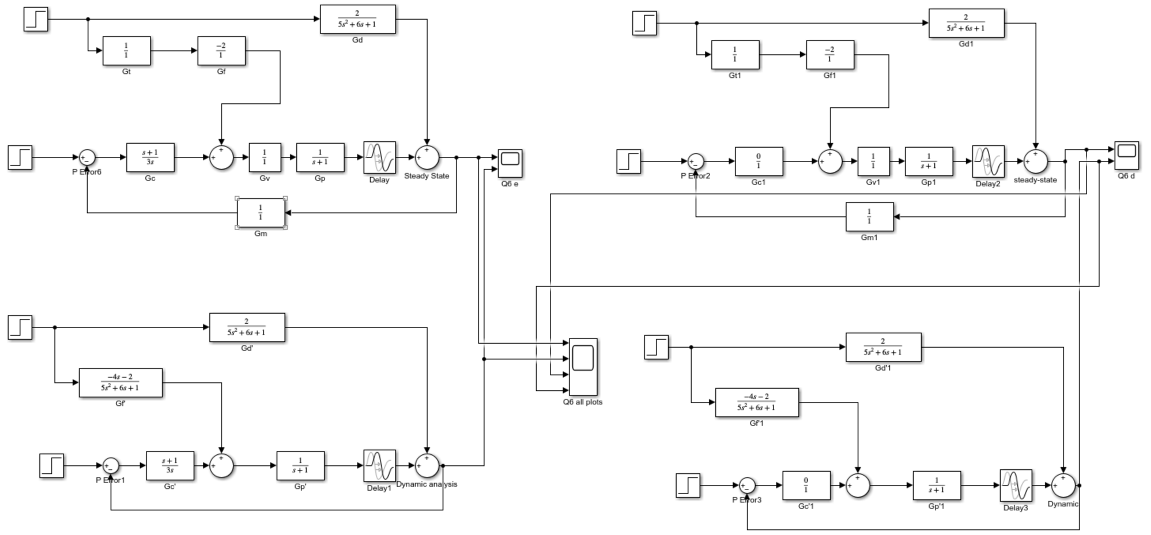
For time delay



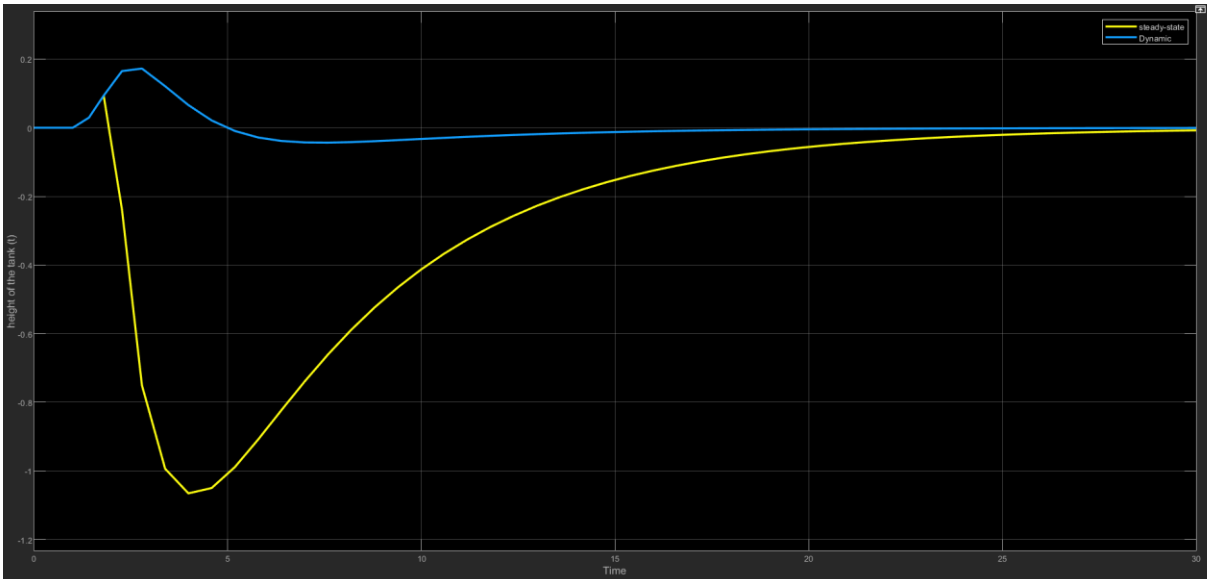
Q6)



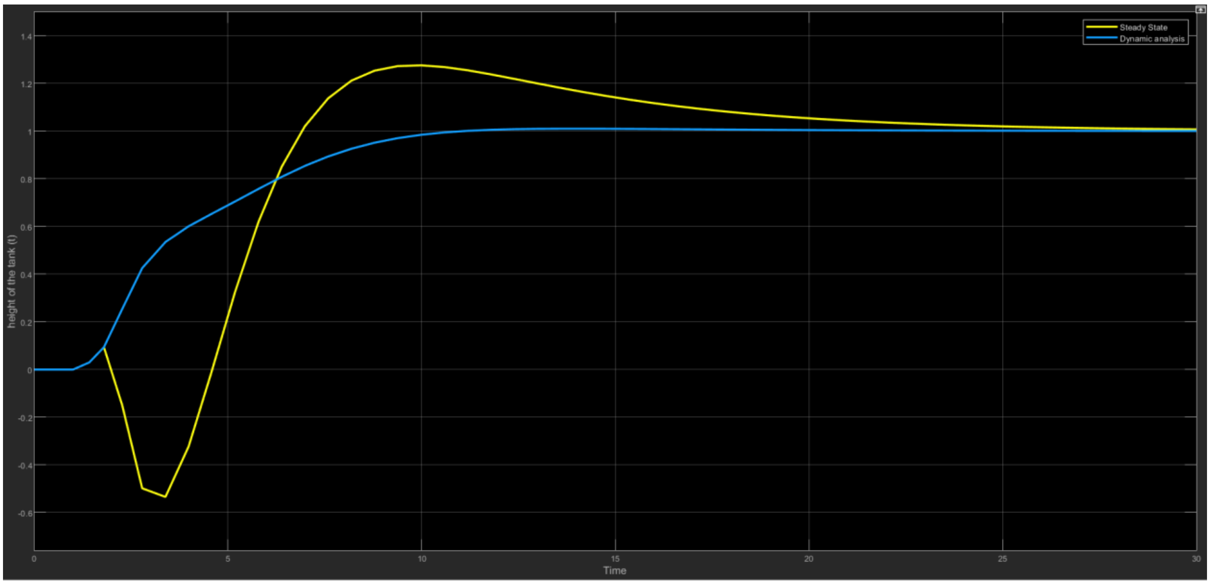
Gd
Gt
Gf
P Error6
Gc
Gv
Gp
Delay
Steady State
Gm
Gd'
Gf'
P Error1
Gc'
Gp'
Delay1
Dynamic analysis



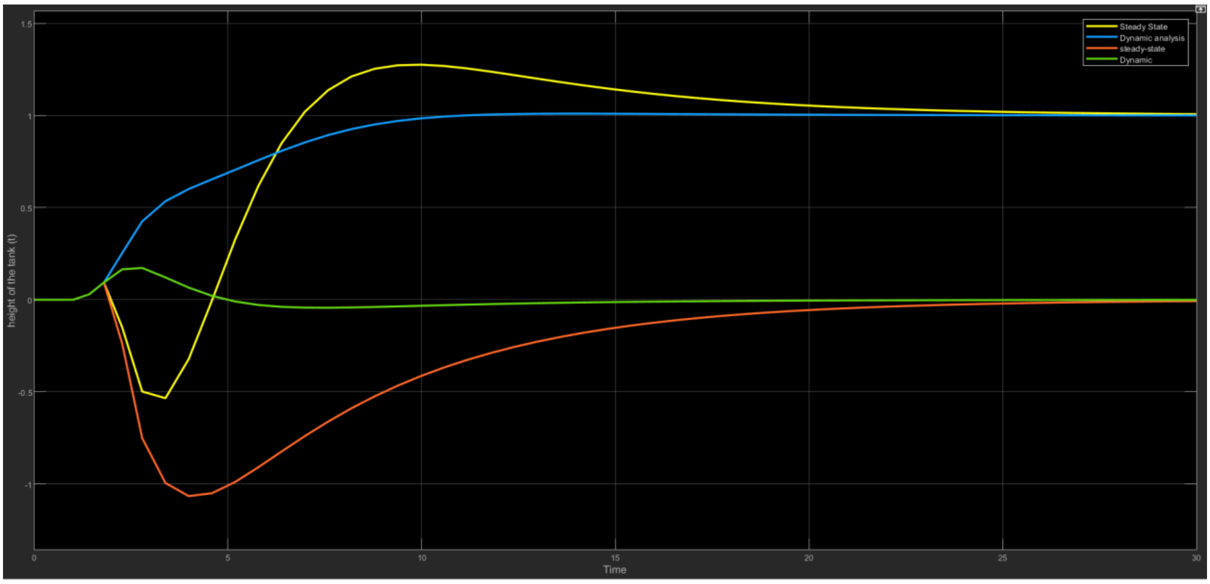
Output D)



Output E)



Mixed



Dynamic shows a better response in both of them