CH3050 PDC ASSGN-6

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CH18B020

1) a) $G_c = \frac{1}{G_p} \frac{G_{cl}}{1-G_{cl}}$

$= \frac{1}{\frac{K}{(10s+1)(5s+1)}} \frac{\frac{1}{5s+1}}{\frac{5s}{5s+1}}$

$\Rightarrow G_c = \frac{50s^2+15s+1}{(\tau_c s)\cancel{K}}$

$K_{nominal} = 1 \Rightarrow G_c = \frac{50s^2+15s+1}{\tau_c s}$

Now, Consider '$1+G_pG_c$ (CCL eqn)

$\Rightarrow \frac{50s^2+15s+1}{\tau_c s} K + 1 = 0$

$\Rightarrow K+\tau_c s = 0$

$\Rightarrow s = \frac{-K}{\tau_c}$

$= \frac{-(1+\delta)}{\tau_c}$

~~⇒~~ For stability $s < 0$ (All LHP poles)

$\Rightarrow \eta > -1$

b) pole, $s = \dfrac{-1}{\tau_c}(1+\eta)$

~~For~~ ~~$|\eta|$~~ $|\eta| \geq 0.2$

$\Rightarrow \eta \geq -0.2 \Rightarrow \eta > -1$

∴ The pole remains in LHP irrespective of τ_c

⇒ Free to choose any $\tau_c > 0$ even when K is uncertain

c) $G_p = \dfrac{1.15}{80s^2 + 15s + 1}$ $\quad G_d = \dfrac{1}{5s+1}$

$G_c = \dfrac{80s^2 + 15s + 1}{5s}$ (PID controller)

Now when ff & PID both are in combinations

$Y = G_p U + G_d D_0$ — ①

$U = G_c(R - Y) + G_{ff} D_0$ — ②

~~where G_{ff} =~~

Substituting ② in ①,

$$Y(1+G_c G_p) = G_p G_c R + (G_p G_{ff} + G_d) D_o$$

$R=0$

$$\Rightarrow \frac{Y}{D_o} = \left(\frac{G_{ff} G_p + G_d}{1+G_p G_c} \right)$$

Here $G_{ff} = -\frac{G_d}{G_{pm}} \times \frac{1}{(\lambda s+1)}$ (filter added to make it realisable)

$$= \frac{-(10s+1)}{(\lambda s+1)(1.15)}$$

C.E. : ~~1+GpGc~~ Den $\left(\frac{G_{ff} G_p + G_d}{1+G_p G_c} \right)$

$$\Rightarrow (5s+1.15)^2 (\lambda s+1)(5s+1) = 0$$

For settling time of 15, $\tau \approx 3$.

But here $\tau_{dominant} > 3$.

So the best $t_{settling}$ we can get is around 25 minuts.

The same was confirmed by search trying to solve the problem

$$\min_{\lambda} | t_{settle} - 15 |.$$

λ - came to be close to 0 (10^{-3} - lowest band of search space)

$\lambda \approx 10^{-3}$,

$t_{settle} \approx 25$ minuts

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(2) a)

Since ~~chart~~ there is no delay or inverse response, we can fit a second order model

The model is estimated using lsqcurvefit on step response model as,

$$\hat{G}_p = \frac{1.781}{4.285s^2 + 4.361s + 1}$$

$\xrightarrow{}$ dcgain $(\hat{G}_p)$ $= K_p \times K_{IV} \times \hat{K}$

$\hat{K}$ is the estimate from ~~the lsqcurvefit~~ the step response curve

IMC

$$\tau_c = \frac{\min(\tau_1, \tau_2)}{2} = \frac{2.188}{2} = 1.094$$

$$K_c = \frac{\tau_1 + \tau_2}{K\tau_c} = 2.2385$$

$$\tau_I = \tau_1 + \tau_2 = 4.3611$$

$$\tau_D = \frac{\tau_1\tau_2}{\tau_1 + \tau_2} = 1.0903$$

→ All relations from table 12.1

$$G_c = 2.238\left(1 + \frac{1}{4.361s} + 1.09s\right)$$

b) Using Skogestad's half rule we obtain an FOPTD approximation (∵ tables are available only for them FOPTD)

$$\hat{G}_{p_{12}} = \frac{1.781\, e^{-\frac{2.1731}{2}s}}{\left(\left(2.188 + \frac{2.1731}{2}\right)s + 1\right)}$$

$$\Rightarrow \hat{G}_{p,FOPTD} = \frac{1.781\, e^{-1.09s}}{3.267s+1}$$

From table 12.4, [ITAE set point]

P: $A = 0.965$, $B = -0.85$, $K_c = A\left(\frac{D}{\tau}\right)^{B} \times \frac{1}{K}$

$= 1.3734$

I: $A = 0.796$, $B = -0.1465$, $\tau_I = \frac{\tau}{\left(A + \frac{BD}{\tau}\right)} = 4.374$

D: $A = 0.308$, 0.929, $\tau_D = A\left(\frac{D}{\tau}\right)^{B} \times \tau$

$= 0.3642$

$$\therefore G_{c1b} = 1.3734\left(1 + \frac{1}{4.3745} + 0.36428\right)$$

c) From table 12.4, [I TAE disturbance]

P : $A = 1.357$ $B = -0.947$, $K_c = 2.1475$

I : $A = 0.842$ $B = -0.738$, $\tau_I = 2.3101$

D : $A = 0.381$, $B = 0.995$, $\tau_D = 0.4191$

$$\therefore G_c = (2.1475)\left(1 + \frac{1}{2.315} + 0.4195\right)$$

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③ a) units of gain : K / radians

b)
$$G_{pm} = \frac{-(0.5)(-10s+1)\,e^{-10s}}{(5s+1)(3s+1)}$$

All pass factorisation : $G_{pm} = \underbrace{\frac{-(0.5)(+10s+1)}{(5s+1)(3s+1)}}_{G_{m,i}} \underbrace{\frac{(-10s+1)\,e^{-10s}}{10s+1}}_{G_{m\,ni}}$

$$\therefore Q = G_{ff} = \frac{+1}{G_{mi}} \left[\frac{1}{\lambda s+1}\right]$$ filter added to ensure that it is biproper

$$= \frac{(5s+1)(3s+1)}{(-0.5)(10s+1)(\lambda s+1)}$$

c) $\frac{Y}{R} = \frac{Q G_p}{1 + Q \Delta G}$

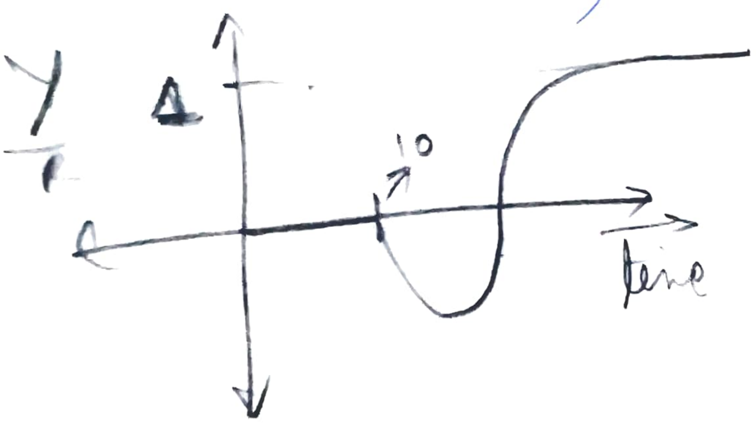
Here, $\Delta G = 0$ (given $G_p = G_m$ perfect model)

$\therefore \frac{Y}{R} = \frac{(-10s+1)e^{-10s}}{(\lambda s+1)(10s+1)}$

Since it is proper we won't have a jump.

But we have i) Delay

ii) Inverse Response ($\because$ RHP 0)



d) $\frac{U}{R} = \frac{Q}{1+Q\Delta G} = Q = \frac{(5s+1)(3s+1)}{(-0.5)(10s+1)(\lambda s+1)}$

IVT : $U(0) = \lim_{s \to \infty} \frac{10(5s+1)(3s+1)}{(-0.5)(10s+1)(\lambda s+1)}$

$= \frac{10(5)(3)}{(-0.5)(10)(\lambda)} = \frac{-30}{\lambda}$

We want this to be less than 25% = $\frac{\pi}{4}$ rad.

90°

$\pi/4$ rad

$$\Rightarrow \left| \frac{-30}{\lambda} \right| \le \cancel{\frac{\pi}{4}}\ \cancel{90^\circ}\ \frac{\pi}{4}$$

$$\Rightarrow \lambda \ge \cancel{\frac{4 \cdot 120}{\pi}}\ \cancel{\frac{k}{3}}\ \frac{120}{\pi}$$ ($\because$ λ +ve for stable θ)

($\because$ Immediate control effort should be less than 25%)

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(4) a) From the given data,

$$G_p = \frac{0.4}{25s+1} e^{-7.5s}$$

$$G_d = \exp(-10s) \left(\frac{0.5}{30s+1} \right)$$

So $Q = -\frac{G_d}{G_p}$

But we have non-invertible component $\longrightarrow$ delay.

Use Pade's first order approximation

$$\Rightarrow Q = - \left(\frac{0.5 e^{-10s}}{30s+1} \right) \frac{(25s+1)(3.75s+1)}{(0.4)(-3.75s+1)}$$

$$= \frac{-250s^2 + 40s + 2}{240s^2 - 40s - 1.6} e^{-10s}$$