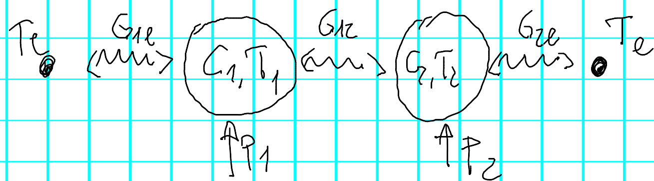
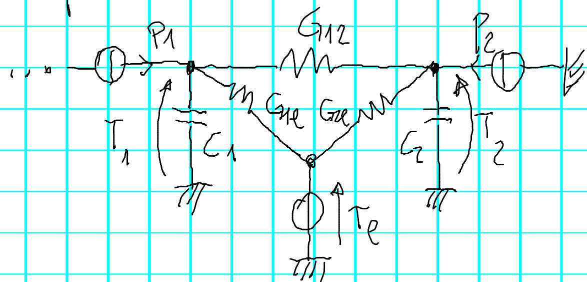
23/06/2014

1

$\boxed{E1}$ 29/06/2012, E2



2) Electric equivalent

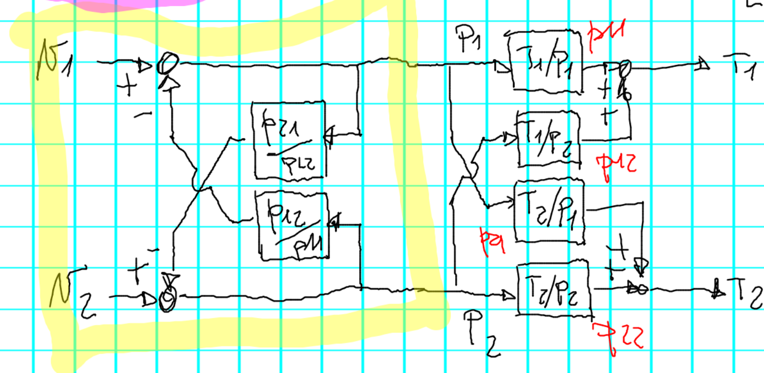


2

b) $\begin{cases} C_1 \dot{T}_1 = P_1 - G_{12}(T_1 - T_2) - G_{1e}(T_1 - T_e) \\ C_2 \dot{T}_2 = P_2 + G_{12}(T_1 - T_2) - G_{2e}(T_2 - T_e) \end{cases}$

A   B

$$\begin{bmatrix} \dot{T}_1 \\ \dot{T}_2 \end{bmatrix} = \begin{bmatrix} -\frac{G_{12}+G_{1e}}{C_1} & \frac{G_{12}}{C_1} \\ \frac{G_{12}}{C_2} & -\frac{G_{12}+G_{2e}}{C_2} \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \end{bmatrix} + \begin{bmatrix} 1/C_1 & 0 & G_{1e}/C_1 \\ 0 & 1/C_2 & G_{2e}/C_2 \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ T_e \end{bmatrix}$$



3 One could compute the tr. matrix from $\begin{bmatrix} P_1 \\ P_2 \end{bmatrix}$ to $\begin{bmatrix} T_1 \\ T_2 \end{bmatrix}$

as
$$M(s) = (sI - A)^{-1} \cdot B$$

But this is not necessary for decoupling, as

$$M(s) = \frac{1}{D(s)} \begin{bmatrix} N_{11}(s) & N_{12}(s) \\ N_{21}(s) & N_{22}(s) \end{bmatrix} \begin{bmatrix} 1/C_1 & 0 \\ 0 & 1/C_2 \end{bmatrix} = \frac{1}{D} \begin{bmatrix} N_{11}/C_1 & N_{12}/C_2 \\ N_{21}/C_1 & N_{22}/C_2 \end{bmatrix}$$

$$\frac{P_{21}}{P_{22}} = \frac{N_{21}}{N_{22}} \frac{C_2}{C_1}$$ (no need to invert the matrix)

In our case

$$H(s) = \begin{bmatrix} s + \dfrac{G_{12}+G_{1e}}{C_1} & -\dfrac{G_{12}}{C_1} \\ -\dfrac{G_{12}}{C_2} & s + \dfrac{G_{12}+G_{2e}}{C_2} \end{bmatrix}^{-1} \begin{bmatrix} 1/C_1 & 0 \\ 0 & 1/C_2 \end{bmatrix}$$

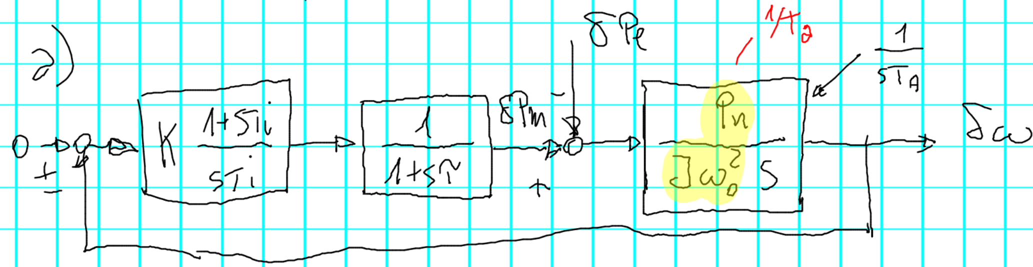
$$= \frac{1}{\eta} \begin{bmatrix} s + \dfrac{G_{12}+G_{2e}}{C_2} & \dfrac{G_{12}}{C_1} \\ \dfrac{G_{12}}{C_2} & s + \dfrac{G_{12}+G_{1e}}{C_1} \end{bmatrix} \begin{bmatrix} 1/C_1 & 0 \\ 0 & 1/C_2 \end{bmatrix}$$

$$\frac{P_{21}}{P_{22}} = \frac{G_{12}/C_2}{s + \dfrac{G_{12}+G_{1e}}{C_1}} \quad \frac{C_2}{C_1}$$

Same for P_{12}/P_{11} $\square$

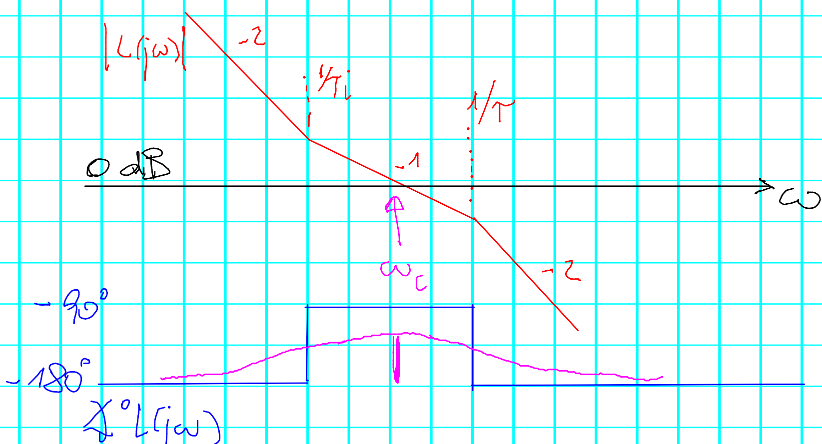
E5) 20/07/2017, E1

a)



$$K\frac{1+sT_i}{sT_i} = K_p + \frac{K_I}{s} \iff K_p = K\ ,\ \frac{K}{T_i} = K_i$$

6b) $L(s) = K \frac{1+sT_i}{sT_i} \frac{1}{1+s\tau} \frac{1}{sT_A} = \frac{K}{T_i T_A} \frac{1}{s^2} \frac{1+sT_i}{1+s\tau}$



$\varphi_m = \mathrm{arctg}^\circ(\omega_c T_i) - \mathrm{arctg}^\circ(\omega_c \tau)$

let K be such that L cuts the 0 dB axis with slope -1 (asymp.)

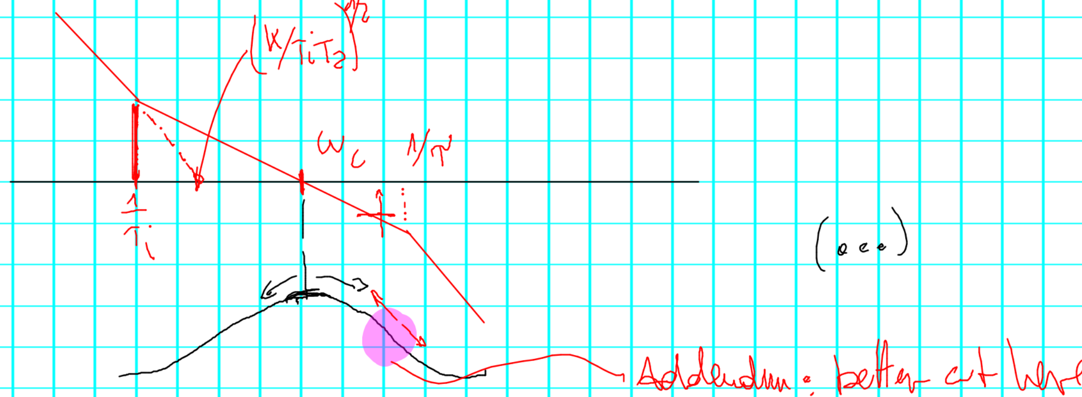
For a certain $\overline{\varphi}_m$ to be achievable, there must be T_i and ω_c such that

$$\arctan^{\circ}(\omega_c T_i) - \arctan^{\circ}(\omega_c T) = \overline{\varphi}_m$$

Now since ω_c and K are proportional, thus choosing K means choosing ω_c under the previous hypothesis, calling $\overline{\omega}_c$ the chosen one (in the range $1/T_i - 1/T$)

$$T_i > \frac{1}{\overline{\omega}_c} \tan\left(\overline{\varphi}_m + \arctan^{\circ}(\overline{\omega}_c T)\right)$$

8)



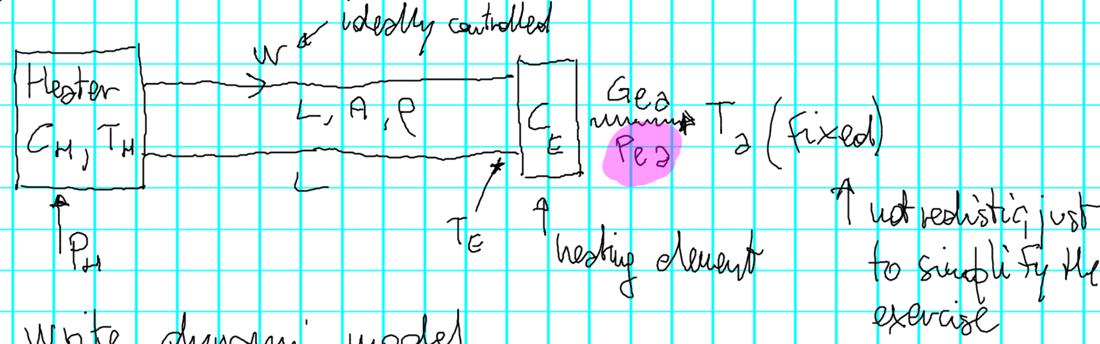
$T_i = T_{i\,min}$

$\Rightarrow$ max of phase exactly at ω_c

$\Rightarrow$ if K is increased or decreased, φ_m diminishes

$\Rightarrow$ not recommendable

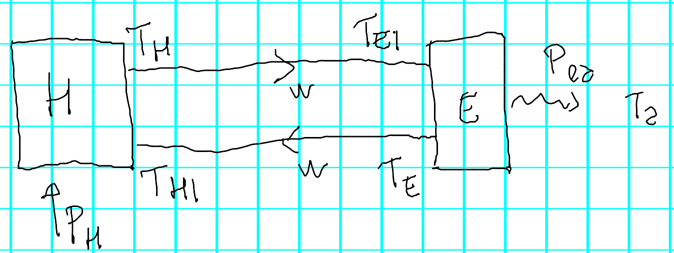
E3



a) write dynamic model

b) discuss the control of P_{ea} acting on P_H and/or w

2)



velocity

$$w = \rho A v$$

$$\Rightarrow v = \frac{w}{\rho A}$$

$$\begin{cases} C_H \dot{T}_H(t) = w(t)\, c\, T_{H1}(t) - w(t)\, c\, T_H(t) + P_H(t) \\ C_E \dot{T}_E(t) = w(t)\, c\, T_{E1}(t) - w(t)\, c\, T_E(t) - G_{e2}\left(T_E(t) - T_2(t)\right) \\ T_{E1}(t) = T_H\left(t - \frac{L}{v}\right) = T_H\left(t - \frac{\rho A L}{w}\right) \\ T_{H1}(t) = T_E\left(t - \frac{\rho A L}{w}\right) \end{cases}$$

D)1 To achieve a prescribed steady state, we must act on P_H

However, the $P_H \to P_{02}$ relationship has a significant delay

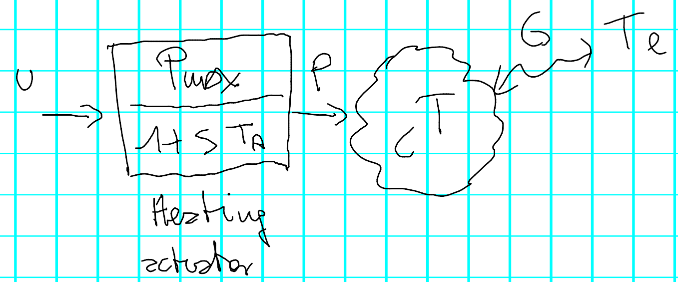
On the other hand, acting on W results in a sudden action...

...that needs then supporting by P_H

$\Rightarrow$ proposal:
- controller having P_H as output, possibly with a Smith predictor
- anticipative action from the P_{02} set point to W.

possibly plus

E12)



Goal: control T acting on U

Assignment: tune a PI(D) s.t. the settling time of the closed-loop step response is 3 times the thermal time constant in open loop.

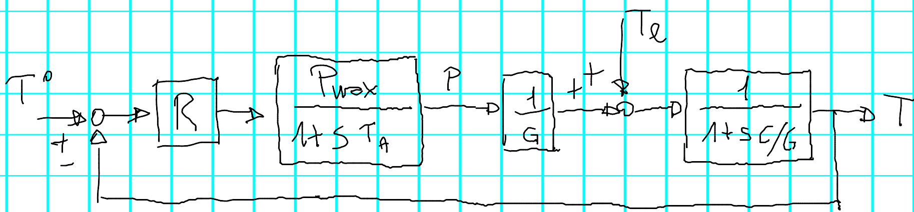
Note: unreviewed material

Model:

$$C\dot{T} = P - G(T - T_e)$$

$$T(Cs+G) = P + G T_e$$

$$T\left(1+s\frac{C}{G}\right) = \frac{1}{G}P + T_e$$



Desired closed-loop time constant $= \frac{1}{5}\left(3\frac{C}{G}\right) = \frac{3C}{5G}$

$\Rightarrow$ Desired cutoff frequency $= \frac{5G}{3C}$

$$R = \underbrace{\frac{5G/3C}{s}}_{\text{desired } L} \cdot \frac{1+sT_A}{P_{max}} \cdot G \cdot \frac{1+sC/G}{1+s/\frac{50G}{3C}}$$

required pole at $10\,\omega_c$

real PID :)

$\square$