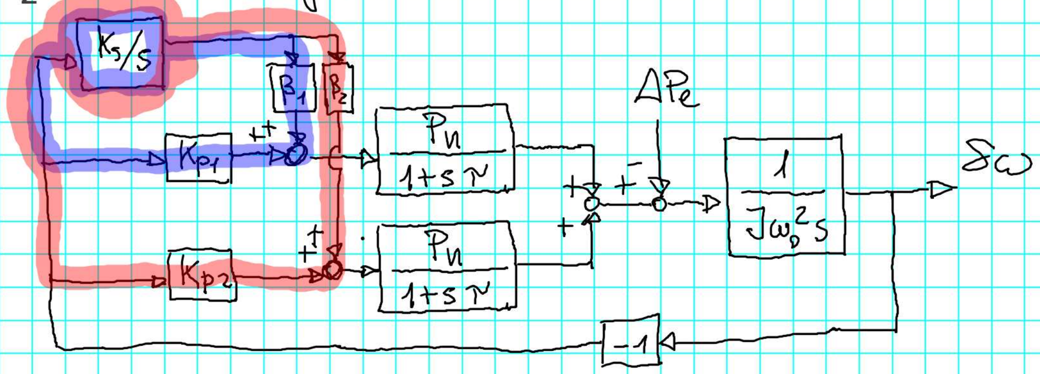
30/05/2019

E1 22/06/2018, E1

AC network at 50 Hz nominal frequency
Two identical generators, 50 MW nom. P, 1st order dynamics
with time constant 5 seconds and 0–1 command
Inertia 16.2 kJ/(r/s)^2

1) Block diagram for network with P+S control
2) Tune P+S for a settling time of 100 s, assuming equal participation to S control (Hint: use PI form)
3) Determine the achieved φ_m

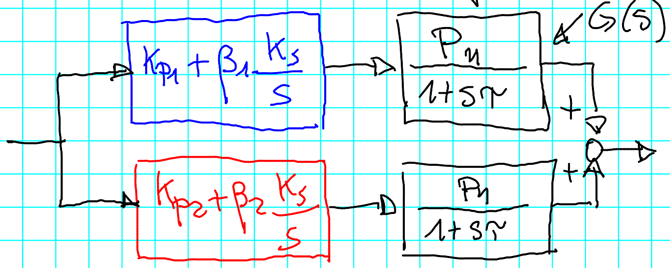
1/2) Block diagram



$P_n = 50\,MW$ $\quad J = 16.2\ kJ/(r/s)^2$ $\quad \beta_1 + \beta_2 = 1$

$\tau = 5\,s$ $\quad \omega_0 = 100\pi\ r/s$

2) Tune P+S for settling time of 100 s (Hint: PI form)



No reason to not have $K_{p1}=K_{p2}=K_p$, hence

$$\left(K_{p1}+\beta_1\frac{K_s}{s}\right)G(s)+\left(K_{p2}+\beta_2\frac{K_s}{s}\right)G(s)$$

$$=K_p G(s)+\beta_1\frac{K_s}{s}G(s)+K_p G(s)+\beta_2\frac{K_s}{s}G(s)$$

$$= 2K_p G(s) + \frac{K_s}{s} G(s) = \underbrace{\left(2K_p + \frac{K_s}{s}\right)}_{\text{PI controller}} G(s)$$

We set $2K_p + \frac{K_s}{s} = K \frac{1+sT_i}{sT_i}$

and proceed with (K, T_i) as parameters

$$L(s) = K \frac{1+sT_i}{sT_i} \frac{P_u}{1+sT} \frac{1}{s\omega_0^2 J}$$

$$= \frac{KP_u}{T_i \omega_0^2 J s^2} \frac{1+sT_i}{1+s\tau}$$

$\Rightarrow$ log paper

5 settling 100 s $\Rightarrow$ dom. TC $= \frac{100}{2} = 20$ s $\Rightarrow$ $\omega_c = \frac{1}{20} = 0{,}05$ r/s

generator pole at $\frac{1}{5} = 0.2$ r/s

$$\Rightarrow L(s) = \frac{0{,}02^2 (1+100s)}{s^2 (1+5s)}$$

$$R_{PI}(s) = \frac{0{,}02^2 (1+100s)}{\cancel{s^2} \cancel{(1+5s)}} \quad \frac{\cancel{1+5s}}{50 \cdot 10^6} \, \cancel{s} \left(100\pi\right)^2 16.2 \cdot 10^3$$

$T_i = 100$

$$\frac{K}{T_i} = \frac{0{,}02^2 \cdot \pi^2 \cdot \cancel{10^4} \cdot 16.2 \cdot \cancel{10^3}}{5 \cdot \cancel{10^7}} = 0{,}013$$

$K = 100 \cdot 0{,}013 = 1{,}3$

$\square$

3) Actually obtained phase margin

$$\varphi_m = \operatorname{arctg}^{\circ}\left(\frac{0{,}05}{0{,}01}\right) - \operatorname{arctg}^{\circ}\left(\frac{0{,}05}{0{,}2}\right) \simeq 65^{\circ}$$

$\square$

E2 | 22/06/2018, E2

Body with heat capacity $C = 10\ kJ/°C$

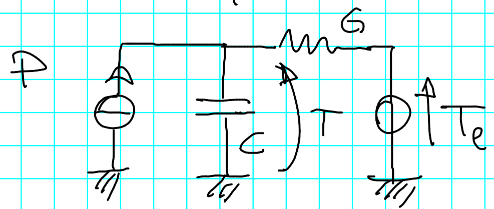
Two daisy-chained heaters, both with max power $P_{max} = 1\ kW$ and 1st order dynamics with time constant $\tau = 5s$. Heat dispersed through a conductance $G = 200\ W/°C$ to an extend fixed temperature T_e.

1) Electric equivalent (consider a single heater of power P)

2) PI scheme representing the daisy chain, tuned for a closed-loop dominant TC of 200 s maximum

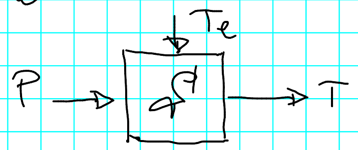
3) obtained φ_m

1) Electric equivalent



P: total heating power

g) Scheme



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

$$(sC + G)\,T = P + G T_e$$

$$T = \frac{1}{sC + G} \cdots = \frac{1/G}{1 + s\,C/G}\,(P - G T_e)$$