Automation of Energy Systems

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Reg. No.	_____
Last name	_____
Given name(s)	_____
Signature	_____

- Answer the questions in the spaces provided.

- If you run out of room for an answer, continue on the back of the page.

- Hand in *only* this booklet. No additional sheets will be accepted.

- Scoring also depends on clarity and order.

1. An AC electric generator with a nominal (maximum) power $P_n = 5MW$ and a first-order dynamics with time constant $\tau = 4s$ feeds a local load at frequency $f_o = 50Hz$, and is endowed with power and frequency control in PI form.

   (a) Draw the block diagram of the control system.
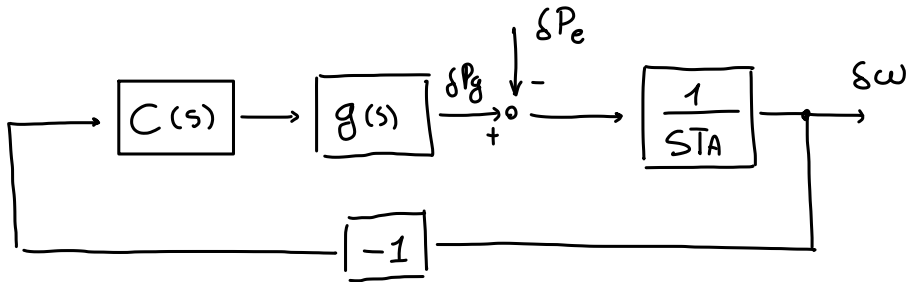
$$g(s) = \frac{1}{1 + 4s}$$

$$W_0 = 2\pi f_0 = 314.16 \text{ rad/s}$$

   (b) Assume that the equivalent time constant of the local network is $T_A = 8s$, and determine the total inertia J accordingly.

given $T_A = 8s$, you obtain

$$\frac{1}{T_A} = \frac{P_m}{J \omega_o^2} \longrightarrow J = \frac{P_m}{T_A \omega_o^2} = 6.33 \ J/(r/s)^2$$

(c) Tune the controller for a closed-loop dominant time constant of $10s$.

$$\tau_c = 10s \rightarrow \omega_c = \frac{1}{\tau_c} = 0.1 \ rad/s$$

IF we want $\varphi_m \simeq 50°$, we can set by loop shaping

$\Downarrow$

$T = \ 1/0.035 = 28.57 \sim 29$ make it 29 to be sure of phase gain

$$L(s) = \mu \ \frac{1 + \cancel{29}s}{s^{\cancel{2}} \cancel{(1+s\tau)}} = \frac{1}{s \ T_A} \ K \ \frac{1+s\cancel{T}}{s} \ \frac{1}{\cancel{1+s\tau}} \quad \leadsto \quad K = \mu \ T_A = 0.0288$$

$$\mu = (\tilde{\omega})^2 = 0.0036$$

$$C(s) = 0.0288 \ \frac{1+29s}{s} \quad \searrow \ = \ \underbrace{0.288 \cdot 29}_{} \ \frac{1+29s}{29s}$$

to get im om $\quad K_i \frac{1+sT_i}{sT_i} \qquad K_i = 8.352$

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2. Consider a system in which a thermal capacity $C = 10^4 J/^\circ K$ is connected to a heater with maximum power $P_h = 5kW$, a per-unit command u_h and a first-order dynamics with time constant $\tau_h = 10s$. Let an external temperature T_e act as a disturbance, the capacity dispersing heater toward it through a loss conductance $G = 15W/^\circ K$.
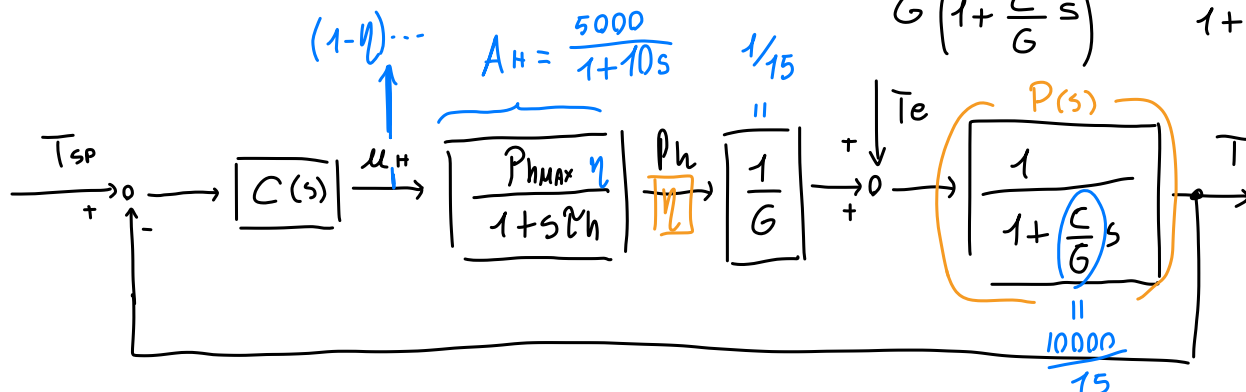
(a) Draw an electric equivalent for the system.
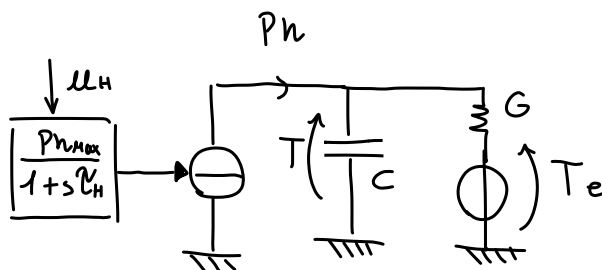
(b) Draw and tune a scheme to control the capacity temperature T through the heater command u_H, for a closed-loop settling time of $150s$.

$t_{set} = 150s \longrightarrow \tau_c = 150/5 = 30s$ closed loop time constant

$$C\dot{T} = P_h - G(T - T_e) \rightarrow T(s) = \frac{P_h}{G\left(1 + \frac{C}{G}s\right)} + \frac{T_e}{1 + \frac{C}{G}s}$$

IF we want $L(s) = \dfrac{1}{30s} = C(s) \cdot \dfrac{5000}{1+10s} \cdot \dfrac{1}{G} \cdot \dfrac{1}{1 + \frac{2000}{3}s}$

$\Rightarrow$ $C(s) = \dfrac{1}{2s} \dfrac{1+10s}{5000} \cdot (1 + (2000/3)s)$ (PI)

because $\dfrac{1}{10} > \dfrac{1}{30}$

we can neglect it!

faster than desired

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(c) Assume that the heater efficiency η_h depends linearly on u_h, taking the values 0.3 and 0.6 for $u_h = 0.1$ and $u_h = 1$, respectively. Express the power consumed by the heater as a function of the temperature set point T^o and of T_e.

$$\left.\begin{array}{l} \eta_H(u_H = 0.1) = 0.3 \\[4pt] \eta_H(u_H = 1) = 0.6 \end{array}\right\} \longrightarrow \eta_H(u_H) = \quad \dfrac{1/10 \quad 3/10}{3 \quad 9/10}$$

interpolating $\qquad \dfrac{\eta_H - 0.3}{0.6 - 0.3} = \dfrac{u_H - 0.1}{1 - 0.1} \quad \leadsto \quad \eta_H = 0.3 + \left(\dfrac{u_H}{0.9} - \dfrac{0.1}{0.9}\right) 0.3 =$

$$= \dfrac{u_H}{3} + \dfrac{3}{10} - \dfrac{1}{30} =$$

the consumed power should be :

$$\left[\begin{array}{l} T^o = T_{SP} \quad \text{im} \\ \text{my notation} \end{array} \right] \qquad = \dfrac{u_H}{3} + \dfrac{8}{30}$$

$P_h = \; ?$ how to treat efficiency (WTF)

3. Illustrate the "turbine follows" control scheme for electric generators, indicating and briefly motivating its advantages and disadvantages.

"turbine follow" is an internal control scheme logic for an electric gen. From the 2×2 internal representation of the generator we have to couple properly the input control action δ_t, δ_f associating it to controlled output e_m, p_m. In turbine follow, we couple δ_t to e_m and δ_f to p_m.

obtaining a perfect pressure control (e_m), so we avoid mechanical stress. BUT a slow response to load power request, because the control action on δ_f to p_m has to go through the slow thermal dynamic

4. Draw (without computations) the typical two-loops scheme to keep a temperature within two limits using a heating and a cooling actuator, and briefly illustrate the advantages of the said scheme with respect to a split-range one with a single control loop.

to maintain $T \in [T_{low}, T_{Hi}]$
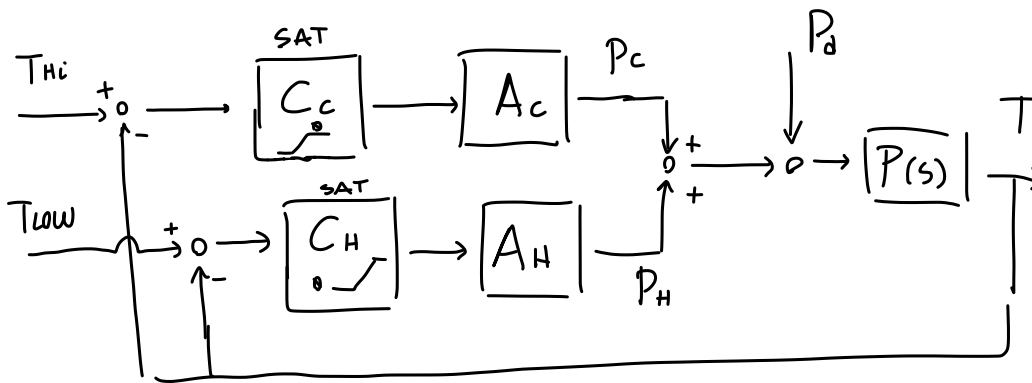
With this actuator we can tune C_H on $A_H P$ and C_c on $A_c P$, so we don't need equalization nor internal control to manage two actuators, and it is simple to link the control scheme to our desired range of T_{min}, T_{low}, obtaining a good control T.

While using a S.R and a simple loop I may need equalisation and link the T range to the S.R dead zones is very tricky...