Automation of Energy Systems

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Reg. No.	____________________
Last name	____________________
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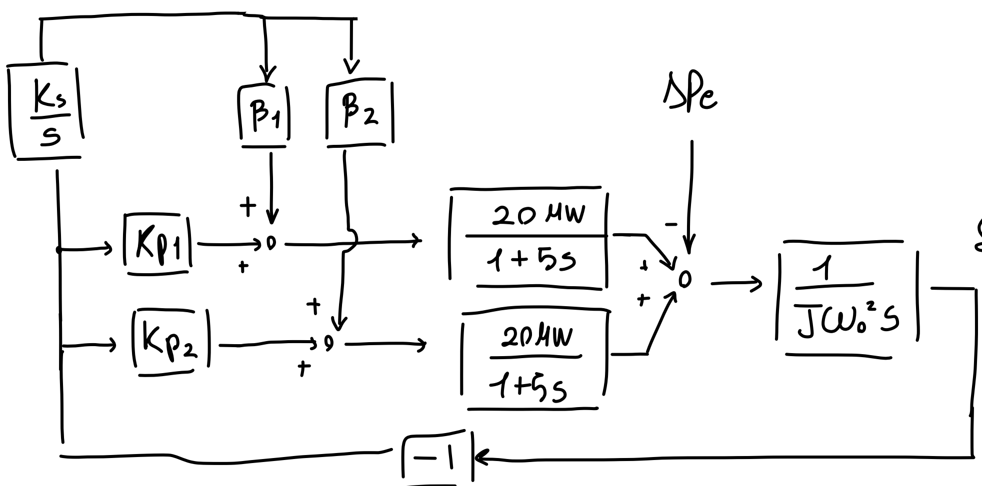
- Answer the questions in the spaces provided.
- If you run out of room for an answer, continue on the back of the page.
- Hand in *only* this booklet. No additional sheets will be accepted.
- Scoring also depends on clarity and order.

1. Consider an electric network with two generators, both having

$$G_{1,2}(s) = \frac{P_n}{1 + s\tau},$$

as transfer function from the throttling command θ, in the range 0–1, to the variation ΔP_g of the generated power, with $P_n = 20\text{MW}$ and $\tau = 5\text{s}$. The overall network time constant T_A is 10s.

(a) Draw the block diagram representing the two generators connected to the network.



consider T_A relative to both generator active

(b) Detemine the total inerta J.

find total inertia consider such that T_A is relative to both active

$\omega_0 = 2\pi f_0$

$$\frac{J\omega_0^2}{2P_m} = T_A \rightsquigarrow J_{TOT} = \frac{T_A 2P_m}{\omega_0^2} = 4.053\ KJ/(r/s)^2$$

(c) Tune a power/frequency controller in the form of a PI for a settling time of 50s for the compound of the two generators.

$t_{SET} = 50s \rightarrow \omega_c \simeq \frac{1}{(50/5)} = 0.1\,rad/s$

IF we set up the control with goal $\varphi_m \simeq 50°$

finding the equivalent scheme setting $K_{p_1} = K_{p_2} = K$
and without any specification, because the gen. have same dyn, $\beta_1 = \beta_2 = 0.5$

$\left(2K_p + \frac{K_s}{s}\right) G(s)$

my controller takes the form of a PI
$C(s) = K_s \frac{1 + 2(K_p/K_s)s}{s}$

tuning a PI as usual on G(s)

$T = 40$
$\mu = (0.05)^2 = 0.0025 \rightarrow$

$$0.0025 \frac{\cancel{1+sT}}{\cancel{s^2}(\cancel{1+s\tau})} = K \frac{\cancel{1+sT}}{\cancel{s}} \frac{P_m}{\cancel{1+s\tau}} \frac{1}{J\omega_0^2 \cancel{s}}$$

$K = K_s = 0.05$

$K = 0.0025 \frac{J\omega_0^2}{P_m} = 0.05$

$2K_p/K_s = T \rightarrow K_p = \frac{K_s T}{2} \simeq 1$

(d) Estimate (motivating your answer) a value for the desired settling time below which a PI-based structure would not be adequate.

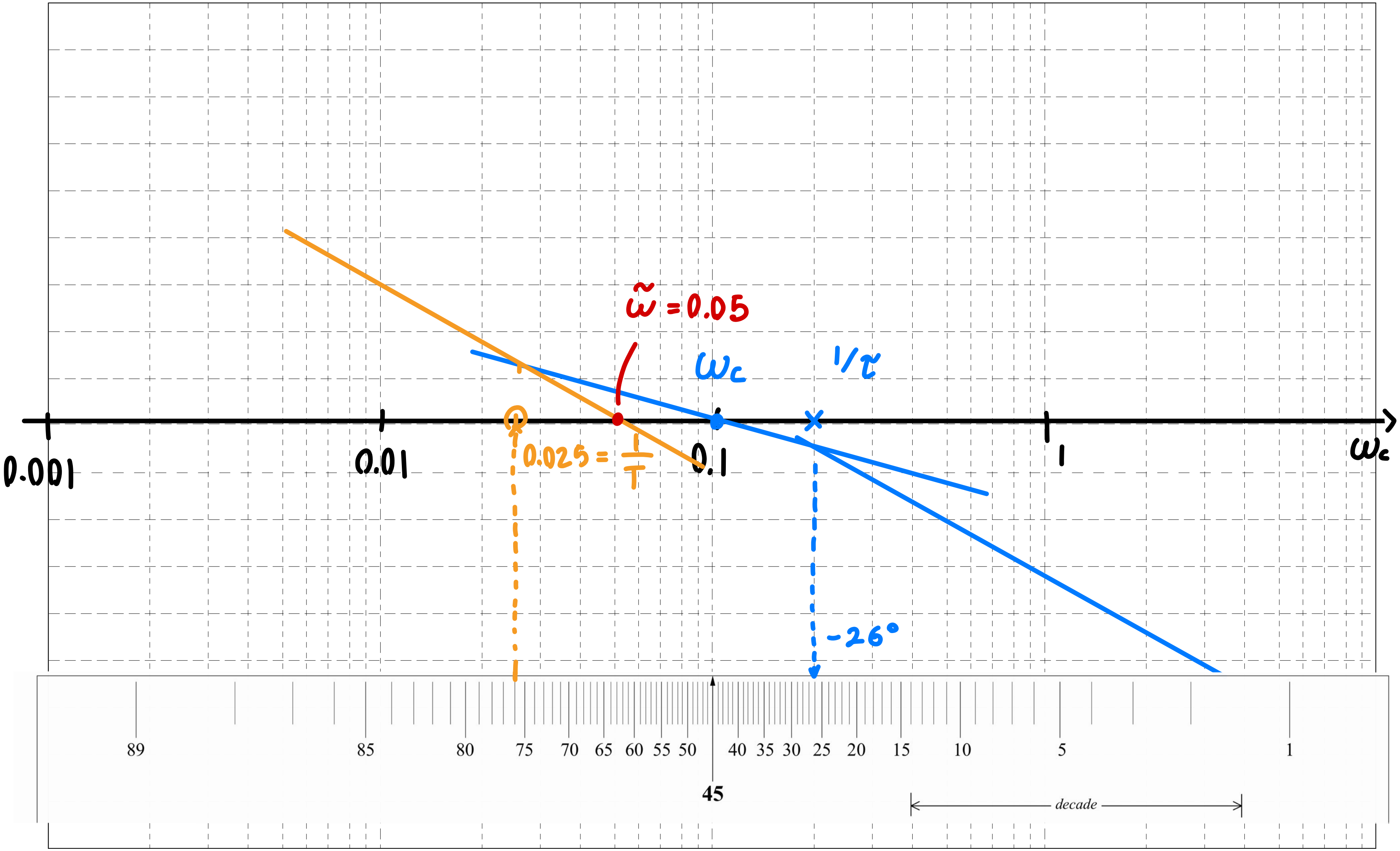
$\Downarrow$

A necessary constrain when setting up a controller properly is that $\omega_c < 1/\tau \rightarrow \omega_c < 0.2\,rad/s$

so it must be $\frac{1}{\omega_c} > \frac{1}{0.2} = 5$ so $\frac{1}{\frac{5}{t_{set}}} > 5$

(?)

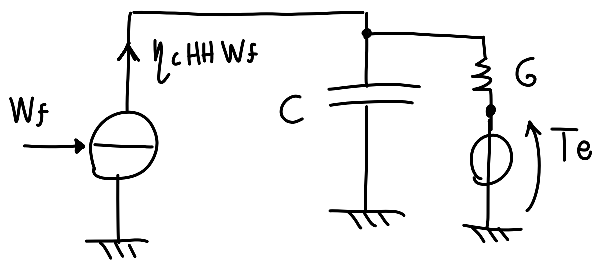
$t_{set} > 1\,sec$


ω̃ = 0.05
ωc
1/τ
0.001
0.01
0.1
1
ωc
0.025 = 1/T
-26°
89
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1
decade

$= 20 kJ/K$

2. Consider a thermal system in which a body of capacity $C = 20$ kJ/°C is heated by a combustor burning fuel with calorific power $HH = 50$ MJ/kg, and having a combustion efficiency η_c between 0.5 and 0.7. The body releases heat through a thermal conductance $G = 50$ W/°C, to a prescribed external temperature T_e.

   (a) Draw an electric equivalent of the system.



$$P_h = HH \, \eta_c \, W_f$$

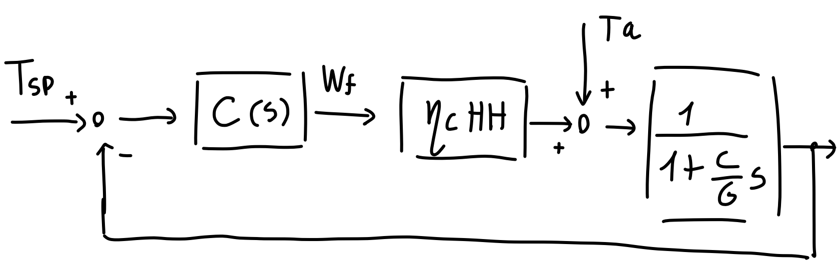
$$\eta_c \in [0.5, 0.7]$$

   (b) Determine a linear regulator acting on the fuel flow rate w_f [kg/s] to control the body temperature T, so that the settling time of the response of the controlled variable to a set point step variation, in the worst case, does not exceed 10 min.

$t_{SET} \leq 10 min$ WORST CASE: $\eta_c = 0.5$

$\hookrightarrow \frac{1}{\omega_c} 5 \leq 10 \cdot 60 \leadsto \omega_c \geq \frac{5}{600} = 0.0084$ rad/s

from the system dyn eq. $C\dot{T} = W_f HH \eta_c - G(T - T_a)$



$$T = \frac{T_a}{1 + \frac{C}{G}s} + \frac{\eta_c HH}{1 + \frac{C}{G}s} W_f$$

$$\frac{\eta_c HH}{1 + \frac{C}{G}s} = P(s)$$

$\frac{C}{G} \to 400$

set up controller $C(s)$ on

because we want

$L(s) = \frac{1}{600s}$ at least $\rightarrow$ $C(s) = \frac{1}{600s} \frac{1 + \frac{C}{G}s}{\eta_c HH}$

we should consider worst case $\eta_c = 0.5$, requiring higher gain

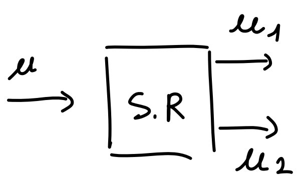
$$C(s) = \frac{1 + 400s}{(300\,HH)s}$$

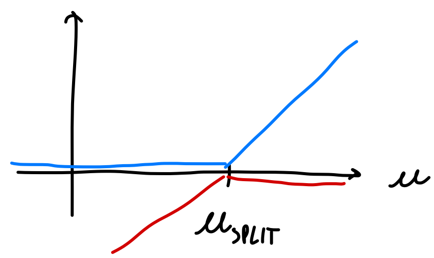
3. Illustrate the "boiler follows" control scheme for electric generators, indicating and briefly motivating its advantages and disadvantages.

"boiler follow" is one particular control strategy for the internal generator control. After we obtain a 2×2 generator description on which we have to couple input control to output controlled variable. the boiler follow control associates ϑ_t to p_m and ϑ_f to e_m.
This coupling ensure an instantaneous mechanical power responce to a throttle value command, so fast power responce for a variable load request. (advantage of it) BUT causes a short pressure transient causing mechanical stress dangerous

4. Explain, with the need of convenient schemes if you deem it useful, what is meant for "spli range" actuation, with specific reference to its use in the control of thermal systems.

"split range" is an actuation scheme which transform one control input into two (or more) outputs contrally so more actuators. In particular each one act in a specific range while the other(s) are off.





$$u_1 = \begin{cases} u, & u \geq 0 \\ 0 & u < 0 \end{cases}$$

$$u_2 = \begin{cases} 0 & u \geq 0 \\ -u, & u < 0 \end{cases}$$

sometimes Dead Zones are introduced to avoid nervous actuation switching.

This scheme Is widely used when in thermal system we have to control both an heater and cooler, so from a control action u, provide u_H, u_C output