Automation of Energy Systems

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Reg. No. ______________________

Last name ______________________

Given name(s) ______________________

- 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 islanded electric generator of nominal power $P_n = 200\,MW$, and let the normalised transfer function from the command θ, in the range 0–1, to the normalised variation δP_g of the generated power, be

$$g(s) = \frac{1}{1+2s}.$$

   (a) Draw the block diagram representing the generator connected to a local network of inertia J and nominal frequency ω_o – expressed respectively in $J/(r/s^2)$ and in r/s – with primary and secondary power/frequency control in the form of a PI with gain K and integral time T_i; indicate with ΔP_e the variation of the electric power demand.

(b) Assuming the presence of primary control only (i.e., $Ti = \infty$) determine the value of K corresponding to a steady-state normalised frequency error of 0.01 in response to a unit step variation of ΔP_e.

(c) Setting K to the previously found value, $\omega_o = 100\pi$ and $T_i = 2$, express the closed-loop transfer function from ΔP_e to the normalised frequency error.

(d) Based on the computations above, express the obtained closed-loop dominant time constant as a function of J.

2. Consider a thermal system in which a body of mass $M_b = 50\,kg$ and specific heat $c_b = 1000\,J/kg^{\circ}C$, is connected to a heater of maximum power $P_{h,max}$. The body exchanges heat with a containment of mass $M_c = 500\,kg$ and specific heat $c_b = 800\,J/kg^{\circ}C$, via a thermal conductance $G_{bc} = 200\,W/^{\circ}C$. The containment in turn disperses heat toward a fixed external temperature T_e through a thermal conductance $G_{ce} = 100\,W/^{\circ}C$.

   (a) Draw an electric equivalent of the system.

(b) Express the transfer function from the heater command u_h, assumed in the range 0–1, to the body temperature T_b.

(c) Suggest a controller structure to regulate T_b acting on u_h, motivating your choice.

3. Illustrate, with the help of an example if you deem it convenient, how primary and secondary control cooperate in coordinated power and frequency control for AC electric networks, evidencing the role of the two control actions and explaining how they are realised and why.

4. Sketch out the typical structure used to maintain a controlled temperature within two bounds, and synthetically motivate the energy-related advantages of said structure with respect to one centred on set point tracking.