Automation of Energy Systems

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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 islanded electric generator with power and frequency control realised via a PI(D) block. Assume the generator to be described by a linear model with a gain of $10MW$ and a time constant of $15s$, the input being a command in the range 0–1.

   (a) Draw the block diagram of the control scheme.

   (b) Tune the PI(D) by cancellation for a closed-loop dominant time constant of $5s$.

(c) Supposing to disable the integral term, compute the steady-state frequency error for an electric power step variation of $-2MW$.

2. Consider a system in which a body of thermal capacity $C = 10^4 J/K$ is connected to a heater of maximum power $P_h = 2.5kW$ and described by a first-order model with command in the range 0–1 as input, the released power as output, and a time constant $\tau_h = 10s$. Finally, let two disturbances be provided by variations of an external temperature T_e, $G = 10W/K$ being the thermal conductance with which the body disperses heat, and by a spurious power P_d, assumed nonnegative, acting additively on P_h.

   (a) Discuss the opportunity of using a cascade temperature control scheme with the actual power received by the body as the internal loop's controlled variable, motivating its adoption if this is the obtained conclusion.

   (b) Draw the mentioned cascade scheme.

(c) Tune the scheme for a closed-loop temperature set point step response settling time of $120s$, guaranteeing at least half a decade of dynamic separation between the internal and the external loop.

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

4. Explain the concept of "electric equivalent" in the context of thermal systems, illustrating (with examples if deemed appropriate) its usefulness for modelling and control.