
# 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 a nominal power $P_n$ of $20\,MW$, and a first-order dynamics with a time constant $\tau$ of $10\,s$. The generator is supposed to feed its load at a nominal frequency $f_o$ of $50\,Hz$.

   (a) Express the characteristic time $T_A$ as a function of the system inertia $J$.

   (b) Draw the block diagram of the generator, the load and a power/frequency control in the form of a "primary" block with gain $k_P$, and a "secondary" one with gain $k_S$, denoting by $\Delta P_e$ the electrical power demand variation.

(c) Express the steady-state normalised frequency error with primary control only as a function of $k_P$.

(d) Once $k_P$ is selected, indicate – motivating the answer – the corresponding admissible range for $k_S$.

2. Consider a system in which a body of thermal capacity $C = 100\,kJ/°C$ is connected to a heating and a cooling device. The former has a maximum power $P_h$ of $2\,kW$ and a first-order dynamics with a dominant time constant $\tau_h$ of $20\,s$; the latter has a maximum power $P_c$ of $1.5\,kW$ (mind the signs) and a dominant time constant $\tau_c$ of $10\,s$. The body disperses heat toward an exogenous external temperature $T_e$, through a thermal conductance $G = 2\,W/°C$.

   (a) Draw an electric equivalent of the system.

   (b) Draw a control scheme to maintain the bidy temperature between two values $T^\circ_{lo}$ and $T^\circ_{hi}$.

(c) Tune the scheme for a dominant closed-loop time constant of 50 $s$ in both the heating and the cooling action case.

3. Compare the "boiler follows" and the "turbine follows" control schemes for electric generators, particularly from the point of view of the typical response speed and equipment upset.

4. Briefly describe the main control problems encountered in the management of a heat network.