Automation of Energy Systems

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Last name _____

Given name(s) _____

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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, where power and frequency control is realised via proportional primary blocks of gain k_p, one per generator, and a single integral secondary block of gain k_i.Assume both generators to be described by a linear model with a gain of $50MW$ and a time constant of $25s$, the input being a command in the range 0–1.

   (a) Draw the block diagram of the controlled network.

   (b) Tune the (identical) primary blocks so that each of the two generators, when feeding the network with the other disabled, results in a normalised frequency error $\delta\omega$ not exceeding 0.01.

(c) Express the transfer function from electric power variation ΔP_e to normalised frequency error $\delta\omega$, with both generators active and both primary and secondary control in place (k_p being that calculated at the previous step),et as a function of the secondary integral gain k_i and the overall network inertia J, the nominal frequency ω_o being clearly $50Hz$.

2. Consider a system in which two bodies of thermal capacity $C = 5000 J/K$ are connected each to a heater of maximum power $P_h = 1kW$, that is supposed to respond algebraically to its commend input in the range 0–1. Let both bodies (1 and 2 to name them) release heat to a fixed external temperature T_e of $10°C$ through two identical conductances $G_{1e} = G_{2e} = 40W/°C$, and also mutually via a thermal conductance $G_{12} = 5W/°C$.

   (a) Draw a control scheme with backward decoupling and PI blocks for the control of the two bodies' temperatures $T_{1,2}$.

   (b) Tune the scheme for an ideal decoupling if possible, or for an effective decoupling action with a bandwidth of $0.1r/s$ in the opposite case, guaranteeing in both cases a settling time of each temperature's response to a step variation in the corresponding set point, not exceeding 30 minutes.

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

4. Synthetically explain how the problem of generation cost minimisation in the context of electric networks is addressed, referring to some example if deemed appropriate and helpful (although the scope of the question does not necessarily require examples).