Automation of Energy Systems

Alberto Leva

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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 three generators, characterised by the operational limits and the cost rates shown below.

Generator	Min power [MW]	Max power [MW]	Cost rate [Unit/MW]
1	5	80	$c_1(P_{g1}) = 10 + 15P_{g1}$
2	10	100	$c_2(P_{g2}) = 40 + 5P_{g2}$
3	5	50	$c_3(P_{g3}) = 20 + 10P_{g3}$

(a) Indicating with P_e the total electric power required by the network, express the Lagrangian function for the cost minimisation problem, defining the involved quantities properly.

(b) Assuming that P_e varies in the interval [8,215] MW, identify the possible generator combinations as a function of P_e itself.

(c) Write the KKT equations for the minimisation problem.

(d) Discuss how the information on the possible generator combinations can help solve the problem.

2. Consider a thermal system in which a heater with thermal capacity $C_h = 500$ J/°C is installed in a room; the room air has a capacity of $C_r = 15$ kJ/°C, and exchanges with the external temperature T_e through a thermal conductance $G_{ae} = 20$ W/°C. The heater exchanges with the room air through a conductance G_{ha}, and disperses directly to T_e through another (loss) conductance G_{he}.

   (a) Draw an electric equivalent of the system.

   (b) Express the lost thermal power as a function of G_{ha} and G_{he}, and comment on the result.

(c) Write the state-space dynamic system needed to design a controller for the air temperature T_a acting on the heater power P_h, and suggest – motivating the choice – a controller structure. [Note: no numerical computations are required]

3. Synthetically explain what the “load flow” problem is, and what are its possible roles in the optimised operation of an electric network.

4. Illustrate the main control problems encountered in heat network based on a thermovector fluid.