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 $P_n = 100\,MW$, and where the normalised transfer function from the command θ, in the range 0–1, to the normalised variation δP_g of the generated power, is

$$g(s) = \frac{1}{1 + 0.5s}.$$

(a) Draw the block diagram representing the generator connected to a local network of inertia $J = 0.5\,MJ/(r/s)^2$ (the nominal frequency being $50\,Hz$ as usual) and endowed with primary and secondary power/frequency control in the form of a PI with gain K and integral time T_i, indicating with ΔP_e the variation of the electric power demand.

(b) Determine K and T_i so that the closed-loop system exhibit a phase margin φ_m of $30°$ at least, aiming in the design at maximising the cutoff frequency ω_c. Hint: use the semilogarithmic sheet enclosed in the booklet to ease computations.

(c) Based on the so obtained regulator tuning, provide an estimate of ω_c.

2. Consider a thermal system in which a solid body, of mass $M = 10\,kg$ and specific heat $c = 1200\,J/kg°C$, is connected to a heater of maximum power $P_{h,max} = 1.5\,kW$, and disperses heat toward a fixed external temperature T_e through a thermal conductance $G = 50\,W/°C$.

   (a) Draw an electric equivalent of the system.

(b) Tune a PI to control the body temperature T acting on the heater power P_h, so that the dominant closed-loop time constant be (approximately) $100\,s$.

(c) Supposing that the system has to maintain the body temperature at the constant value of $20\,°C$ while $T_e = 4\,°C$, determine what percent of the available heating power is used at steady state.

3. Illustrate, with the help of an example if you deem it convenient, how the problem of optimising the power generation distribution in an electric network, subject to generators' operational constraints, is stated and addressed by means of the KKT equations.

4. Briefly explain what is the “time division output” actuation scheme, and which are its most typical uses in the context of thermal systems.