Automation of Energy Systems

Test preparation exercises

Foreword

- This document is meant to provide you with an idea of what you can expect to be confronted with in the written test.
- The test will indicatively contain three to five questions, depending on their lengths, so that the entire assignment can be carried out in the allotted time of 1.5 h.
- The need for computations shall be reduced to a minimum, as the main purpose of the test is to assess your conceptual understanding of the matter.
- As such, computation errors will have limited consequences, unless their result is to produce something apparently inconsistent. If this happens and you do not have the time to correct, just evidence and briefly motivate the fact, and the consequent penalty will be significantly reduced.
- The quality and clarity of your presentation will be part of the evaluation.
- The expected lengths indicated after each example question are just menat to give you an idea of the required detail, not to be strict limits. Under reasonable completeness and clarity constraints, conciseness will be considered a merit.

1. Consider an electric generator with nominal (maximum) power $P_n = 20\,MW$ for which the transfer function from the command input $\theta \in (0, 1)$ to the generated power P_g has a single pole with time constant $T = 150$.

   (a) Draw a block diagram in which the generator is working in islanded mode to fulfill an electric power request P_e, the power and frequency control being carried out by a PI corresponding to the primary and secondary controls; indicate with K_P and K_s the two corresponding control parameters, with ω_o the nominal frequency ($100\pi\, r/s$), and with J the total network inertia.

   (b) In the presence of (proportional) primary control only, determine the corresponding gain K_P so that the steady-state normalised frequency error for a P_e positive step of amplitude $2\,MW$ be less than 0.01.

   (c) With $J = 4 \cdot 10^3$, the value of K_P determined above, and in the presence of both primary and (integral) secondary control, express the transfer function from electric power to normalised frequency error as a function of the secondary controller gain K_S.

   [Expected length: 2–3 pages]

2. Consider a synchronous rigid electric network with two generators $G_{1,2}$, primary and secondary power and frequency control.

   (a) Draw and briefly comment the block diagram representing the controlled network, employing the standard notation used in the course.

   (b) Express the steady-state variations of each generator's power caused by a power demand step of amplitude ΔP_e as a function of the involved parameters.

   [Expected length: 2 pages]

3. Consider an electric network with three generators. Indicate with P_{gi}, $i = 1 \dots 3$, their generated powers, and with P_e the forecast total power demand. Assume for each generator a cost rate model in the form

$$c_i(P_{gi}) = k_{i0} + k_{i1} P_{gi} + k_{i2} P_{gi}^2$$

   and operational limits $P_{gi}^{\min}$, $P_{gi}^{\max}$, with self-explanatory meaning. Write the KKT equations for the so defined generation distribution optimisation problem when all generators are active.

   [Expected length: 1 page]

4. Consider an electric network with two generator busses $B_{1,2}$, of which only B_2 has a nonzero admittance to ground, two PQ busses $B_{3,4}$, and one slack bus B_S. The network is completely connected, except for the absence of a line from B_3 to B_4, and of lines from the generators directly to the slack bus. Employing the standard notation used in the course

(a) write the bus admittance matrix,

(b) write the load flow equations.

[Expected length: 1–2 pages]

5. Briefly define the concepts of primary, secondary and tertiary power and frequency control in electric networks, also commenting on their roles and interplay in the overall control problem.

   [Expected length: 1 page]

6. Discuss in synthesis how a system-level model of a thermoelectric generator can be obtained by just accounting of its energy storage and the corresponding draw, restore and loss (equivalent) time constants.

   [Expected length: 1 page]

7. Explain whst is meant for "boiler follows" generator control, evidencing the major pros and cons of such a policy.

   [Expected length: 1/2 page]