EE4010
Electrical and Electronic Power Supply Systems
Test:- Teaching Period 1 – 2007/2008

1. (a) Define what is meant by the *doubling time*, t_d in an electrical power system which demonstrates exponential growth. Hence, sketch a graph showing the doubling time, in years, as a function of the *per-unit growth rate*.

A particular national electrical power system follows an exponential growth in its peak *power* demand such that

$$P = P_o e^{\beta t}$$

where P_o is the peak power at time $t = 0$ and β is the annual per-unit growth rate. Prove that, if the per-unit growth rate remains constant, the *energy* consumed in one doubling period is equal to all of the energy consumed for the entire time prior to this doubling time.

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1. (b) A modern peat-based electrical power generating station has a rated output power of 150 MWe. The fluidised-bed boiler used to raise steam for the turbo-alternator in the station burns peat with an average calorific value of 9 MJ/kg. If the overall station efficiency is 38% and it is operating at full rated power for 11 months in the year, estimate the total mass of peat required for its annual power production.

Estimate also the required mass flow rate of cooling water to the condenser at the rated output power assuming a maximum allowable temperature rise of $10\,°\mathrm{C}$ in the cooling water.

[Specific heat of water = $4.18\ \mathrm{kJ/kg\,°C}$]

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2. (a) Draw a block diagram of a natural gas-based combined heat and power (CHP) electrical power generation system. Give a typical figure for the overall efficiency of this system compared to a simple, open-cycle electrical power generation system

[8]

2. (b) A commercial Combined Heat and Power (CHP) generation system is used to both generate electricity and provide additional space and water heating in a large apartment block. The unit produces 105 kW of electrical power and burns 363.3 kW of natural gas in the process. The waste heat is used to supplement a boiler which is used for both space and water heating in the complex. The system operates for 8000 hours per year.

(i) If 66% of the waste heat from the generation process is used to supplement the boiler, calculate the overall efficiency of the system.

(ii) If electricity costs 10c/kWh, how much money will the CHP system save in avoided electricity costs in a year.

(iii) If the boiler is 75% efficient, and is fueled with natural gas costing 2.5 c/kWh, how much money will the CHP system save annually in displaced boiler fuel.

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3. Define the terms *sequence voltage vector*, *sequence current vector* and *sequence impedance matrix* of a three-phase electrical apparatus.

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A particular three-phase electrical load in a large shopping complex is fed from the main distribution board via a three-phase cable with an equivalent per-phase series impedance of $\bar{Z}_{\ell ine} = 0.1\angle 45°$ ohms per phase.

The three-phase load consists of a balanced delta-connected electric heating system in parallel with a balanced star-connected impedance load. The impedance in each phase of the delta-connected heater is $\bar{Z}_{\Delta} = (15 + j3)\ \Omega$. The three-phase impedance load is star-connected with a per-phase impedance of $\bar{Z}_{Y} = (6 + j6)\ \Omega$. The star-connected load is grounded through a neutral impedance $\bar{Z}_n = j0.333\ \Omega$.

Unbalanced line-to-ground source voltages with sequence components $\bar{V}_0 = 10\angle 60°$, $\bar{V}_1 = 240\angle 0°$ and $\bar{V}_2 = 30\angle 200°$ volts are measured at the main distribution board.

Draw the positive, negative and zero sequence networks for this system and calculate the corresponding sequence currents and the current in Phase *a* of the cable.

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