EE4010
Electrical and Electronic Power Supply Systems
Test:- Teaching Period 1 – 2006/2007

1. (a) Prove that the *doubling time,* t_d is inversely proportional to the *per-unit growth rate,* α, in a national electrical power system which demonstrates exponential growth.

The electrical energy consumption curve over time in a given electrical power system is such that the per-unit growth rate increases from an average of 2.5% per annum to 10% per annum. Calculate the doubling times corresponding to these growth rates and comment on the likely consequences of the higher level of growth if it is sustained over a number of years.

[10]

1. (b) Derive an expression for the electrical output power available from a pumped storage hydroelectric power generating station in terms of the overall efficiency η, the flow rate of water Q $\mathrm{m^3/s}$ and the head of water H m.

Assume that the average head between two reservoirs in a pumped storage electrical power generating station is 300 m. The reservoirs each have an area of 1 $\mathrm{km^2}$. Calculate the change in the water level of the reservoirs in order to produce an average output power of 200 MW over a period of 6 hours. Assume that the overall efficiency of the system is 70%.

[Density of water = 1000 $\mathrm{kg/m^3}$]

[10]

2. (a) Write down an expression for the theoretical maximum power available from a wind turbine in terms of the swept area of the blades, A m^2, the velocity of the wind, u m/s and the density of air at standard temperature and pressure (STP), ρ kg/m^3.

[4]

(b) A small wind generator has a diameter of 2 m. It operates at an efficiency of 60% of the theoretical maximum when connected to a three-phase induction generator.

What is the electrical output power at a wind velocities of (i) $4.5\ \text{ms}^{-1}$, (ii) $9.0\ \text{ms}^{-1}$.and (iii) $18.0\ \text{ms}^{-1}$.

What is the value in € of the energy generated over a 100 hour period at a ***constant*** wind velocity of $9.0\ \text{ms}^{-1}$?

What is the value in € of the energy generated over a 100 hour period if the average wind velocity for one third of this time is $18.0\ \text{ms}^{-1}$ and the average wind velocity is $4.5\ \text{ms}^{-1}$ for the remainder of the time?

Comment briefly on the significance of this last result compared to the calculation based on an average annual wind speed of $9.0\ \text{ms}^{-1}$ over the 100 hour period?

[Density of air at STP = 1.29 kg/m^3]

[Cost per kWh= 10 c/kWh]

[16]

3. Part of the distribution system in a small factory consists of a three-phase cable with an equivalent series impedance of $\overline{Z}_{\ell ine} = 1\angle 45°$ ohms per phase. The cable feeds a balanced star-connected load with a per-phase impedance of $\overline{Z}_Y = 10\angle 25°\,\Omega$. This star-connected load is grounded through a neutral impedance of $\overline{Z}_N = j0.333\,\Omega$.

A fault in the factory distribution system results in ***unbalanced*** phase-to-ground source voltages $\overline{V}_{Ag}, \overline{V}_{Bg}, \overline{V}_{Cg}$ being applied to these loads. The ***sequence components*** of this unbalanced set of voltages are calculated to be $\overline{V}_0 = 10\angle 60°$ V, $\overline{V}_1 = 230\angle 0°$ V, and $\overline{V}_2 = 50\angle 200°$ V.

(a) Draw the positive, negative and zero sequence equivalent circuits of this distribution system.

(b) Calculate the current in Phase *A* of the cable.

(c) Calculate the current in the neutral impedance.

(d) Calculate the load star point to ground voltage if the neutral conductor goes on open circuit.