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THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
BACHELOR OF TECHNOLOGY
ECX-5238 – Electrical Machines and High Voltage Engineering
Final Examination 2005/2006

Date: 28th March 2006 Time: 1330-1630

Instructions to candidates

Answer only **Five** questions selecting at least one question from each section.
All Questions carry equal marks
Permeability of free space $\mu = 4\pi \times 10^{-7}$ H/m Permittivity of free space $\epsilon_0 = 8.854 \times 10^{-12}$ F/m

Section A

1. (a) Discuss the main reasons for HVDC when compared to AC transmission [3 marks]
   (b) Explain the inherent problems associated with the HVDC transmission. [3 marks]
   (c) Draw the systematic diagram showing the main components of a HVDC link connected with two AC systems. Explain briefly the role of each component. [3 marks]
   (d) Figure Q1 shows a 12th pulse converter used for HVDC transmission

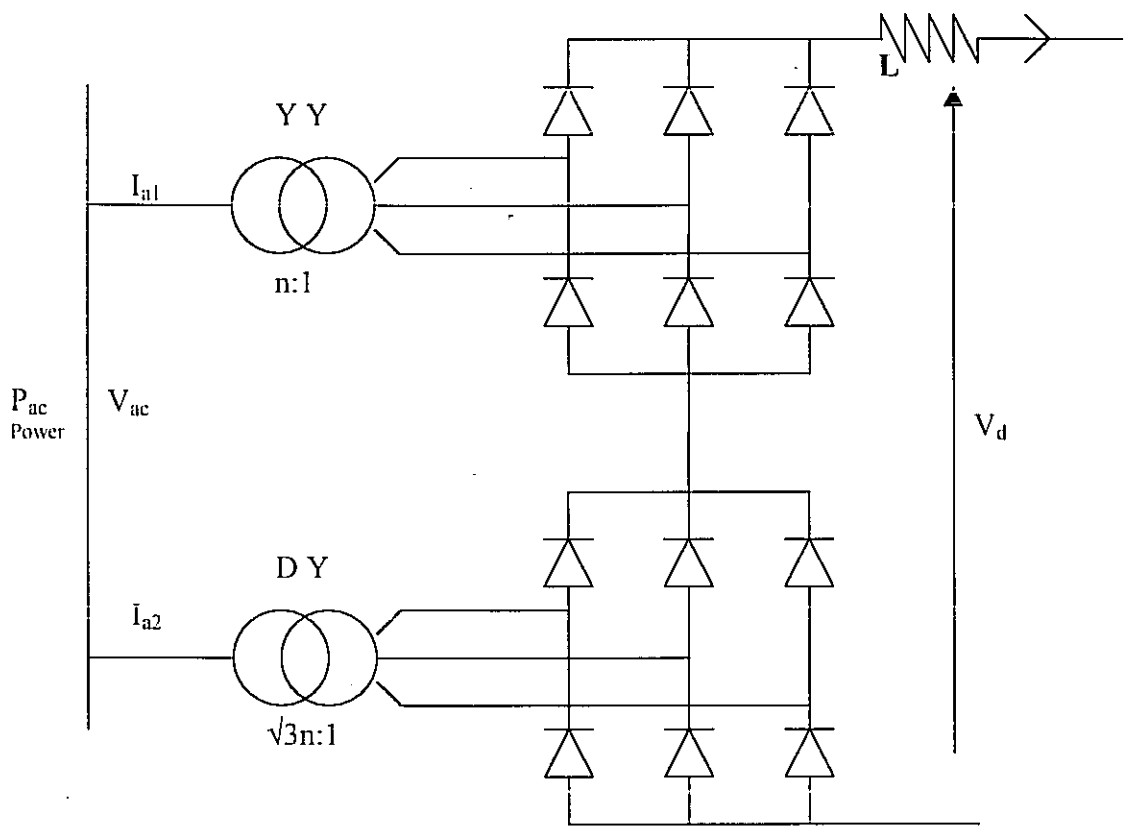


Figure Q1

(a) What is the purpose of having an Inductor L in the circuit [3 marks]
(b) Derive an equation for V_d with respect to the given terms [4 marks]
(c) Calculate the required size of the HVDC conductor in order to transmit same po compared to the AC transmission. (Hint: Use the results of part b) [4 marks]

2. By deriving from first principles, show that the thermal resistance of the soil above the gro of a buried cable is given by $\frac{k}{3\pi} \ln \frac{2h}{r}$ where the symbols have their usual meanings. [5 mar

A 220 kV, 50 Hz three phase system has a single phase cable buried in the ground at a depth 1.7 m below the surface. If the ambient temperature is 27^0 C and the maximum permissi temperature of the insulation is 85^0 C, determine the current rating of the cable for the follow data:

Diameter of the core = 38 mm

Diameter over the insulation = 90 mm

Thickness of the lead sheath = 2 mm

Resistance of the conductor at 85 ^{0}C = 0.016 /km

Relative permittivity of the insulation = 4.2

Dielectric loss factor of the cable insulation = 0.0035

Thermal resistivity of the cable insulation = 5.0 ^{0}C-m/W

Thermal resistivity of soil above the ground = 1.4 ^{0}C-m/W [15 marks]

3.

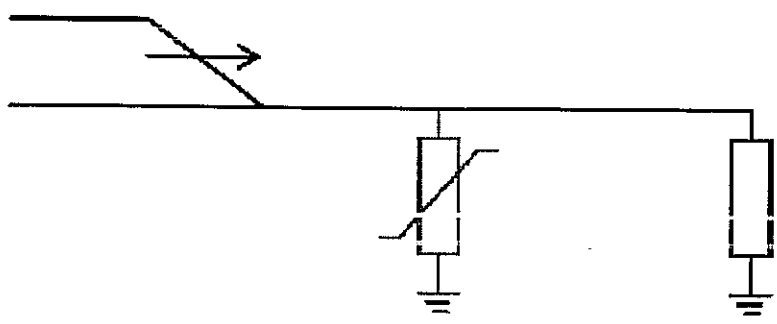


Figure Q3

A 100 kV surge has a linear rate of rise of 500 kV/μs to peak and constant value thereafter (figure Q3). It originates in an overhead transmission line with a surge impedance of 400 and travel towards a terminal device (Z_0 = 1600). It is protected by a lightning arrestor (operating voltage is 145 kV) at a distance of 9 m from the device.

(a) Sketch the voltage waveform at the arrestor location. [10 marks]

(b) Sketch the voltage at the terminal device [5 marks]

(c) Determine the maximum voltage to which the terminal equipment will rise. [3 marks]

(d) Determine the time at which the arrestor operates. [2 marks]

4. Derive from first principles the Townsend's criteria for spark breakdown in a gaseous dielectric. Neglect the effects of space charge and electron attachment. [5 marks]

In a certain Townsend type discharge, with constant electric field, the following measurements were made.

Electrode Spacing (mm)	1	2	3	4	6	8	10	15	20	25
Discharge Current (pA)	10	11.5	13.5	16	21	28.5	38.5	84	210	585

Determine the Townsend's first and second ionization coefficients. [15 marks]

5. Simplified equivalent circuit of an impulse generator is shown in figure Q5.

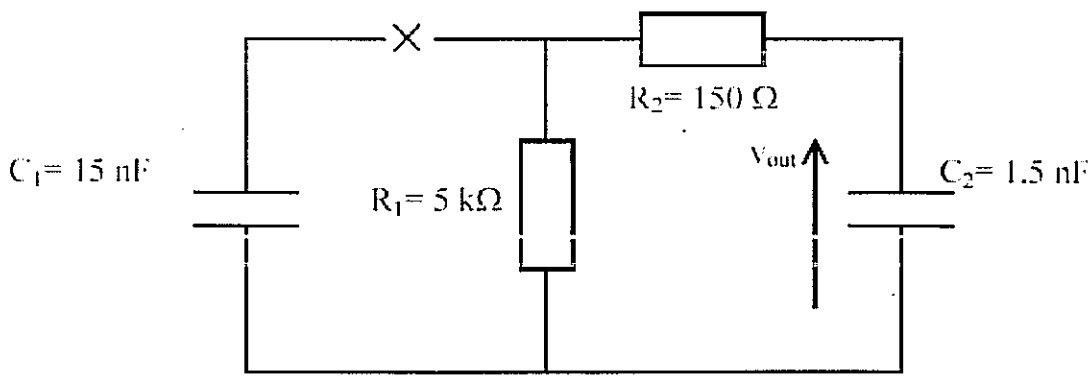


Figure Q5

If the capacitor C_1 is initially charged to 200 kV, determine

(a) The approximate voltage efficiency of the impulse generator [2 marks]

(b) The output voltage waveform across C_2 [5 marks]

(c) The wave-front time (based on 30% to 90%) and wavetail time [5 marks]

(d) The nominal energy capacity of the impulse generator [2 marks]

State any assumptions made in your derivations.

Sketch the complete circuit diagram of the above impulse generator if it has 6 stages, indicating th values of all the components on it. [4 marks]

Explain very briefly why a trigatron gap is normally used in the first stage of a multi-stage impul generator. [2 marks]

6. (a) Show from the first principles that a surge on a transmission line can be represented by a forward traveling wave and a reverse traveling wave. [5 marks]

(b) A long overhead line $\mathbf{L_1}$ (surge impedance = 550 Ω) is connected to another overhead lin $\mathbf{L_2}$ (surge impedance=400 Ω &, length = 3 km) through a cable **C** (surge impedance = 50 Ω length = 500 m). The line $\mathbf{L_2}$ is terminated with a 2000 Ω resistive load. If a step surge o vertical front 200 kV is initiated in line $\mathbf{L_1}$ and travels towards the cable, determine th voltages using the Bewley lattice diagram and sketch the voltage waveform appearing at th load for the first 21 μs after the surge arrives at the load. [15 marks]

[velocity of propagation: overhead line 3 x 10^8 m/s, cable 2 x 10^8 m/s; attenuatio negligible]

Section B

1. A 500 kVA 1-ph transformer with 0.01 pu resistance and 0.05 pu leakage reactance is to share a load of 750 kVA at pf 0.8 lagging with a 250 kVA transformer with pu resistance of 0.015 and 0.04 leakage reactance. Find the load on each transformer:

   (a) When both the secondary voltages are operating at 400V [12 marks]

   (b) When the open-circuit secondary voltages are 405V and 415 V respectively. [8 marks]

2. A three phase 440 V, Y connected wound rotor induction motor has the following equivalent circuit parameters. $R_1 = 0.2\ \Omega$, $X_1 = 0.8\ \Omega$, $R_2 = 0.06\ \Omega$, $X_2 = 0.25\ \Omega$ and X_m is very large (Hint: use the approximate equivalent circuit). The stator to rotor turns ratio is 2:1. With the slip rings short-circuited, the motor develops a full load torque at 3% slip.

   (a) Determine the voltage applied to slip rings (which in phase with the supply) which cause to develop a full load torque at 25% slip. [12 marks]

   (b) If the induction motor is fed with a slip energy recovery scheme, determine the firing angle required to achieve the same speed reduction as in part (a) while developing the full load torque. [8 marks]