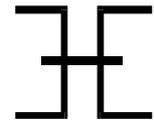




University of Moratuwa, Sri Lanka
B. Sc. Engineering Degree Course
Final Part III Examination 1997/98



UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs

9 June 2000

Answer **FIVE** Questions Only.

Question 1 carries 28 marks and all other Questions carry 18 marks each.

- 1 (a) Give a brief derivation of the Townsend's criterion for spark breakdown in a gaseous dielectric. [4 marks]
- (b) Two overhead lines AB ($Z_0 = 450 \Omega$) and CD ($Z_0 = 550 \Omega$) are connected through a switching resistor BC ($R = 500 \Omega$). A triangular surge of vertical front of 200 kV and linear decay to zero in $10 \mu\text{s}$ travels along AB. Determine and sketch the waveforms of the voltages at B and C for the first $15 \mu\text{s}$ after the surge arrives at B. [4 marks]
- [Assume that A and D are very far from the switching resistor that reflections do not occur during the period of interest.]
- (c) Draw the circuit diagram for a high voltage Schering Bridge where the standard capacitor has a known but very small loss tangent. Derive expressions for the values of the capacitance **C** and the loss tangent **$\tan \delta$** of the unknown, stating any assumptions made in your calculations. [4 marks]
- (d) For a three core belted type cable, considering any particular instant in the 3 phase cycle, sketch the equipotential lines and the stress lines. Explain very briefly how you drew these lines. [4 marks]
- (e) Explain briefly two of the common principles used in obtaining high voltage for testing purposes. State why these methods cannot be used in the generation of alternating voltage for transmission purposes. [4 marks]
- (f) Describe with the aid of suitable diagrams the phenomena of lightning. [4 marks]
- (g) Explain briefly, making use of suitable examples, what is meant by Type Tests, Sample Tests and Routine Tests. [4 marks]

- 2 (a) Describe with the aid of suitable diagrams a method of using graded insulation in a paper insulated cable to make better utilization of the insulating material. Derive the necessary conditions for optimum grading. [5 marks]
- (b) A high voltage alternating current cable is built up of an insulation with a breakdown strength of 15 kV/mm (*peak*) and dielectric constant 2.5. Two intersheaths are used to increase the working voltage of the cable. If the radius of the conductor is 8 mm and the inner radius of the outer sheath is 18 mm, show that the optimum positions for the intersheath are 10.909 mm and 14.243 mm. [9 marks]

Determine also the operating voltage of the cable and the voltages of the intersheaths if a safety factor of 2.0 is used. [4 marks]

- 3 (a) Figure Q3 shows the equivalent circuit of an impulse generator where the capacitor C_1 (= 0.02 μ F) is initially charged to a voltage of 100 kV. Determine the values of R_1 , R_2 and C_2 if the impulse generator is to have an efficiency of 90% and a voltage waveform of **1.2/50 μ s** across the capacitor C_2 . [14 marks]

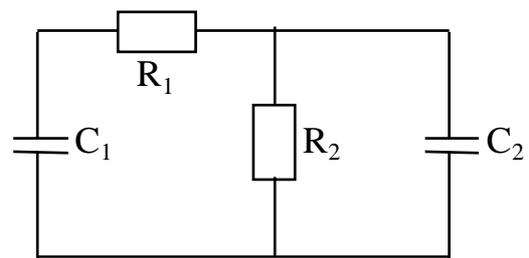


Figure Q3

- (b) It is found that the resistor R_2 has an effective series inductance of 60 mH. Using an intuitive approach, sketch what changes you would expect to the voltage waveform across the capacitor C_2 . [4 marks]
- 4 (a) Show from first principles that a surge on a transmission line can be represented by a forward travelling wave and a reverse travelling wave. [5 marks]
- (b) A long overhead line L_1 (surge impedance = 550 Ω) is connected to another overhead line L_2 (surge impedance = 400 Ω , length = 3 km) through a cable C (surge impedance = 50 Ω , length = 500 m). The line L_2 is terminated in a 2000 Ω resistive load. If a step surge of vertical front 200 kV is initiated in line L_1 and travels towards the cable, determine using the Bewley lattice diagram and sketch the voltage waveform appearing at the load for the first 21 μ s after the surge arrives at the load. [13 marks]

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

- 5 A step surge of magnitude 100 kV reaches the terminal of a transformer which has a uniformly distributed capacitance to earth of the complete winding of 4 nF and a capacitance of the winding from end to end of 160 pF also uniformly distributed. If the neutral of the transformer can be considered to be solidly grounded, derive an expression and sketch the initial voltage distribution in the winding. The effective length of the winding is 1 m. [15 marks]
- Sketch also the probable envelope of the subsequent oscillations. [3 marks]

6 (a) Derive from first principles an expression for the corona distortion as it travels along a transmission line. [8 marks]

(b) A 132 kV transformer (BIL = 550 kV, $Z_0 = 1600 \Omega$) is to be operated with an insulating margin of 15%. It is fed from an overhead transmission line ($Z_0 = 400 \Omega$) which has a short length of overhead shielding wire for protection from direct strokes. If direct strokes can give rise to voltages of the form $500 e^{-0.015t}$ kV (with t in μs) beyond the shielded length and corona distortion in the line is represented by the expression

$$\frac{\Delta t}{x} = 0.016 \left[1 - \frac{115}{e} \right] \quad \mu\text{s} / \text{m} \quad \text{with } x \text{ in m and } e \text{ in kV}$$

determine the minimum length of shielding wire necessary to protect the transformer insulation from damage. [10 marks]

7 Two 220 kV, 50 Hz transmission lines are connected through an hvdc link AB. The converter at each end has a 220/150 kV, delta/star transformer. The inverter at end B operates on constant extinction angle ($\delta_0 = 8^\circ$ and a 5° margin on δ_0 for deionization). Each converter transformer has a commutating reactance of 16.2Ω . When the hvdc line is transmitting 100 MW, determine at the end B, (a) the direct current, (b) the direct voltage, (c) the commutation angle, (d) the power factor, (e) the alternating current on the hvdc side of the transformer, and the (f) the reactive power requirement of the converter B. (g) Sketch the waveform of the alternating current in one of the phases, alongside the corresponding alternating voltage waveform, at the end B. [18 marks]