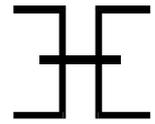




University of Moratuwa, Sri Lanka

B. Sc. Engineering Degree Course

Final Part III Examination 1996/97



UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs

29 Dec 1998

Answer FIVE Questions Only.

All Questions carry equal marks

- 1 Derive from first principles the Townsend's criteria for spark breakdown in a gaseous dielectric. Neglect the effects of space charge and electron attachment. [30 marks]

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

Table with 2 rows and 11 columns: electrode spacing(mm) and discharge current (pA) with values 1, 2, 3, 4, 6, 8, 10, 15, 20, 25 and 10, 11.5, 13.5, 16, 21, 28.5, 38.5, 84, 210, 585.

Determine the Townsend's first and second ionization coefficients. [70 marks]

- 2 (a) Show that the deflecting torque of an electrostatic voltmeter is proportional to the product of the square of the applied voltage and the rate of change of capacitance. [15 marks]

Describe the principle of operation of the attracted disc electrostatic voltmeter. [10 marks]

- (b) With the aid of suitable diagrams describe briefly the high voltage Schering bridge for the measurement of capacitance and loss tangent at power frequency. [15 marks]

From first principles, derive expressions for the quantities at balance. [10 marks]

- (c) Explain the principle and advantages of the capacitance bushing. [10 marks]

Derive an expression for the ideal axial profile of a capacitance graded bushing. [15 marks]

- (d) Describe with suitable diagrams a method of simulating the stress patterns in a 3-core belted type cable. [10 marks]

Sketch the equipotential lines and the stress pattern for any particular instant, explaining the logic behind the method used for sketching the pattern. [15 marks]

- 3 A high voltage cable is to be made with a conductor of radius 20 mm with the outermost diameter being 120 mm. Three materials A, B and C are available.

Table with 3 columns: Material, xi_max (kV/cm), and epsilon_r. Rows for materials A, B, and C with values 90, 120, 105 and 4.0, 2.4, 3.0.

Determine the optimum thickness of the materials and the order in which they should be laid, to obtain the maximum operating voltage for the cable. [70 marks]

If a safety factor of 1.5 is to be used, what is the value of this maximum voltage. [30 marks]

- 4 It is proposed to construct an impulse generator with rated output at 275 kV, utilising the following available components.

6 capacitors each of 0.12 μF and rated at 50 kV

6 resistors each of value 600 Ω

1 resistor of value 100 Ω .

Determine

- (a) the equation of the output voltage waveform of the impulse generator [50 marks]
(b) the wavefront time (based on 30% to 90%) [20 marks]
the wavetail times of the waveform [10 marks]
(c) the nominal capacity of the impulse generator. [10 marks]

Sketch the complete impulse generator indicating the values of any other components that may be deemed necessary. [10 marks]

- 5 (a) From first principles show that surges in transmission lines can be represented by a combination of forward travelling waves and reverse travelling waves. [20 marks]

(b) A simplified power system consists of three lines AB, BC and CD. The lines BC and CD are on open circuit at the ends C and D respectively. If a surge of magnitude 100 kV originates on line AB at A and travels towards B, sketch the voltage waveforms at A & B for the first 1 ms from the inception of the surge. The lines may be assumed to be lossless and that A is too far from junction B to consider reflections at A coming back to B. [Velocities of propagation in overhead line and cable are 3×10^5 km/s and 2×10^5 km/s respectively.] [50 marks]

(c) Two long overhead lines AB and CD (each of surge impedance 350 Ω) are connected through a switching resistor of value 300 Ω . A triangular wave of peak height 100 kV and duration 50 μs originates in the overhead line AB and travels towards the junction B. Determine the magnitudes of the first surges reflected towards A and transmitted towards D. [30 marks]

- 6 (a) Describe very briefly the problems associated in using a capacitive potential divider for the observation on the oscilloscope of an impulse voltage across a test device. Explain how these problems may be minimised [30 marks]

(b) A long overhead line (surge impedance = 450 Ω) is terminated in a resistive load of 1500 Ω , through another overhead line AB (length 3.6 km, surge impedance = 300 Ω , attenuation in single transit = 0.95) and a cable BC (length= 600m, surge impedance = 60 Ω , attenuation factor for a single transit = 0.90). Determine using the Bewley lattice diagram the voltage waveforms appearing at A and C for the first 25 μs after a rectangular voltage surge (vertical front 100 kV, duration 9 μs) originates at the source. [70 marks]

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

- 7 (a) Briefly describe the theory of shielding an overhead transmission line against lightning. [20 marks]
- (b) A certain surge has a linear rate of rise of 600 kV/ μ s to 120 kV. It originates in a transmission line with a surge impedance of 350 Ω and travels towards a terminal device ($Z_0 = 3150\Omega$). It is protected by a lightning arrester at a distance of 24 m from the device. If the arrester flashover voltage is 160 kV, determine the time at which the arrester operates and the maximum voltage to which the terminal equipment will rise. [80 marks]
- [velocity of propagation: overhead line 3×10^8 m/s, cable 2×10^8 m/s]
- 8 (a) Describe the Cockroft-Walton method of generating high direct voltages for testing purposes. [20 marks]
- Why is direct voltages commonly used to test the insulation strength of alternating voltage cables. [5 marks]
- (b) In a certain double star connected bridge convertor, the secondary line voltage of the transformer is 220 kV. It is required to produce 150 MW of power at a delay angle of 30^0 and the power factor on the a.c. side has to be limited to 0.8 lag.
- Deriving any necessary equations, determine
- (i) the maximum direct voltage available on the link [15 marks]
 - (ii) the direct voltage under the given conditions [15 marks]
 - (iii) the commutation angle under these conditions [15 marks]
 - (iv) the direct current [15 marks]
 - (v) the value of the commutation inductance required. [15 marks]