University of Moratuwa, Sri Lanka

B. Sc. Engineering Degree Course

Final Part III Examination 1998/99

UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs 15 May 2001

Answer **F I V E** Questions Only.

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

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1 (a) The lossless standard capacitor used in the high voltage Schering Bridge has a value 100 pF. In a certain measurement, the other arms of the bridge at balance are (i) a resistance of 641 Ω, and (ii) a capacitance of 0.052 μF in parallel with a resistance of 2500 Ω. Determine the capacitance and loss tangent of the specimen at 50 Hz. *[4 marks]*

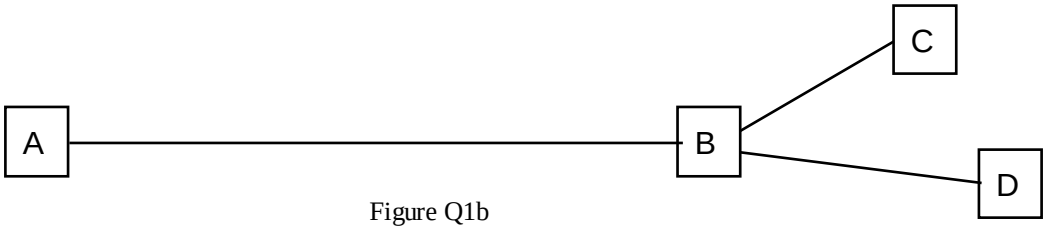

Figure Q1b

(b) Substations A, B, C and D, shown in figure Q1b, are connected by an overhead line AB (length = 180 km, surge impedance = 450Ω), a cable BC (length = 50 km, surge impedance = 50Ω) and an overhead line BD (length = 90 km, surge impedance = 500Ω). If a step surge of magnitude 100 kV originates at C at time t=0, and travels towards B, assuming no losses in the lines and cable, determine the magnitude of the first surge arriving at A and the time at which it arrives. *[4 marks]*

[velocity in overhead line = 3×10^8 m/s, velocity in cable = 2×10^8 m/s]

(c) A high voltage cable is built up of three types of dielectric materials P, Q and R with critical breakdown strengths of 100 kV/cm, 150 kV/cm and 90 kV/cm; and dielectric constants of 3.0, 3.6 and 4.0 respectively. For optimum grading, calculate and draw a diagram showing how the 3 materials should be ordered, and the value of the radius of the sheath, if the radius of the conductor is 15 mm. *[4 marks]*

(d) Describe the Cockroft-Walton method of generating high direct voltages for testing purposes. *[4 marks]*

(e) Describe briefly, with the aid of suitable diagrams, the breakdown of solid insulating materials due to internal discharges. *[4 marks]*

(f) Describe briefly, with the aid of suitable diagrams, the matching of the cable connecting the impulse generator to the oscilloscope to obtain minimum distortion when a capacitive potential divider is used to reduce the voltage. *[4 marks]*

(g) Describe briefly, with the aid of suitable diagrams, the mechanism of the lightning strike onto a transmission line. *[4 marks]*

2 Derive from first principles the criterion for the spark breakdown of gaseous dielectrics. *[4 marks]*

The following set of observations were obtained while studying the Townsend phenomena in a gas in a uniform electric field.

d (mm)	0.5	1.0	1.5	2	3	4	5	6	8	10	12	14	16
I (pA)	0.58	0.67	0.8	0.9	1.25	1.7	2.3	3.1	5.8	11	22	50	150

Calculate the values of the Townsend's first and second ionization coefficients. *[14 marks]*

3 A long overhead transmission line AB (Surge impedance = 550 Ω) is connected to the terminal equipment (Surge impedance = 2450 Ω) through a cable (Length = 1 km, Surge impedance = 50 Ω , attenuation in single transit = 0.95) as shown in figure Q2.

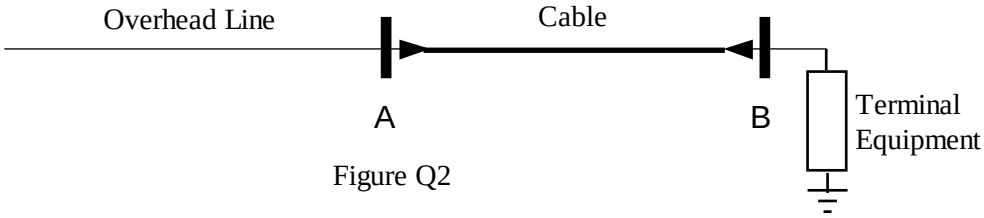

Figure Q2

If a triangular voltage surge (vertical front, 200 kV peak decaying to zero in 40 μs) originates in the overhead line and arrives at A at time t = 0, determine using the Bewley Lattice diagram, and sketch the voltage variation at A and B for the first 25μs. *[18 marks]*

[velocity in overhead line = 3×10^8 m/s, velocity in cable = 1.6×10^8 m/s]

4 A single core cable, with an oversheath diameter of 60 mm is buried in the ground at a depth of 1.6 m. Determine, deriving any equations and stating any assumptions used, the thermal resistance of the ground surrounding the cable for a unit length of cable. The thermal resistivity of the earth is 1.8 ^{o}C m/W. *[6 marks]*

Derive from first principles an expression for the current rating of a single core cable buried below the surface of the ground, considering only the thermal effects. *[6 marks]*

A 76.2 kV, 50 Hz, single phase cable is made up of an insulating material with a permittivity of 4.4 and a loss factor of 0.003. If the diameter of the core is 30 mm and the diameter over the insulation is 45 mm, determine the dielectric loss per unit length of cable. *[6 marks]*

5 Draw the basic circuit diagram of a six stage impulse generator, designed to obtain a double exponential voltage waveform. Indicate on the diagram the wavefront and wavetail control resistors. *[3 marks]*

A six stage impulse generator is to be designed to deliver 600 kV at the standard waveform (1.2/50 μs). Energy required for the impulse generator is 1.44 kJ and the voltage efficiency desired is 90%. Indicate, with the aid of suitable calculations, the values of the associated elements in the circuit to produce the required waveform. *[15 marks]*

[It may be assumed that the standard impulse wave can be represented by the equation

$v(t) = V_m (e^{-0.014\,t} - e^{-4.9\,t})$, with t expressed in μs.]

6 A Lightning arrester with a spark over level of 621 kV is used to protect a transformer (surge impedance 9600 Ω) from surges originating in an overhead transmission line (surge impedance 400 Ω). If the BIL of the transformer is 825 kV, and the maximum anticipated surge has a peak value of 500 kV with a rate of rise of 600 kV/μs, determine the maximum distance away from the transformer that the arrester could be located, if the protective margin required is 20%. *[12 marks]*

Sketch also the voltage variation at the arrester location and at the transformer location under this condition. *[6 marks]*

[velocity of propagation in the line is 3×10^8 m/s]

7 Sketch the circuit diagram of a double-star connected bridge converter. *[3 marks]*

The secondary line voltage of the transformer is 220 kV. Calculate the direct voltage output if the delay angle and the commutation angle are absent. *[3 marks]*

Calculate the rms value of the ripple voltage in the absence of smoothing. *[4 marks]*

Calculate also the rms value of the harmonic current on the ac side, when transferring 30 MW of power, at a delay angle of 28^o and negligible commutation angle, for a ripple free output current. *[6 marks]*

Determine also the operating power factor. *[2 marks]*