University of Moratuwa, Sri Lanka

B. Sc. Engineering Degree Course

Level 3 – Semester 2 Examination 2002/03

EE402 - INSULATION CO-ORDINATION

Time Allowed: Two Hours — 29 April 2003.

Answer **All** Questions. — Total marks for the paper is 70 marks.

Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m Permittivity of free space $\varepsilon_o = 8.854 \times 10^{-12}$ F/m

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1. (a) Describe very briefly with the aid of suitable diagrams the mechanism of lightning stroke generation. [3 marks]

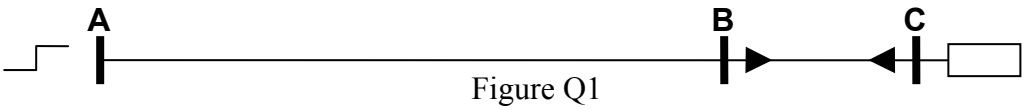

Figure Q1

(b) An overhead line AB (l = 90 km, Z_o = 450 Ω, attenuation factor = 0.95) is fed from a step source (negligible internal impedance, amplitude 100 kV) at end A (figure Q1). A cable BC (length 20 km, Z_o = 50 Ω, attenuation factor = 0.9) connected at end B feeds the terminal equipment (Z_o = 1200 Ω) at C. Sketch the Bewley lattice diagram indicating significant values on it. State any assumptions made in your calculations. [10 marks]

(c) Sketch, indicating significant values, the voltages at A, B and C for the first 550 μs after the surge is initiated at A. [5 marks]

2. (a) Using first principles show that surges can be represented by a combination of travelling waves. [3 marks]

(b) A 100 km line has a series inductance of 135 mH and a shunt capacitance of 0.83 μF. Determine the surge impedance of the line and the velocity of propagation. [2 marks]

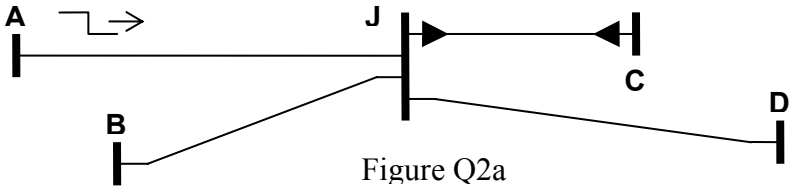

Figure Q2a

(c) Four lines AJ (Z_o = 300 Ω), BJ (Z_o = 350 Ω), CJ (Z_o = 50 Ω) and DJ (Z_o = 300 Ω) meet at a junction J (figure Q2a). For a surge originating on AJ, determine from first principles the reflection coefficient and the transmission coefficients. Determine also the magnitudes of the currents in the lines if the incident surge is of magnitude 100 kV. [6 marks]

(d) Show how a lumped inductance L may be represented by a very short transmission line (travel time Δt) for use on travelling wave techniques. [3 marks]

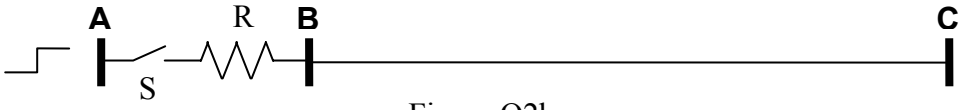

Figure Q2b

(e) A line BC (Z_o = 600 Ω) is energised from a constant voltage source of magnitude (E = 100 kV) through a switching resistor (R = 400 Ω) (figure Q2b). Determine the magnitude of the first surge transmitted on to line BC. Derive any expressions used. [3 marks]

3. (a) Draw the simplified equivalent circuit of a single stage impulse generator to generate a double exponential waveform. Mark on it the output voltage, wavefront control resistor and the wavetail control resistor. [1 marks]

Using suitable approximations derive expressions in terms of the components of the equivalent circuit

(b) for the wavefront time, and [6 marks]

(c) the wavetail time [3 marks]

(d) It is required to generate an output voltage of 1000 kV at the standard 1.2/50 μs impulse waveform with an energy capacity of 10 kJ. Determine the value of the components of the single stage impulse generator. [4 marks]

(e) Draw the 6 stage impulse generator, indicating the values of the components, that would be used to generate the above waveform in practice. [3 marks]

4.

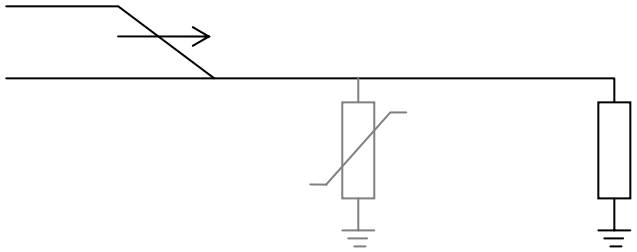

Figure Q4

(a) A 100 kV surge has a linear rate of rise of 500 kV/μs to peak and constant value thereafter (figure Q4). It originates in an overhead transmission line with a surge impedance of 450 Ω and travels towards a terminal device (Z_0 = 2550 Ω). It is protected by a lightning arrestor (operating voltage is 150 kV) at a distance of 21 m from the device. Sketch the voltage waveforms at the arrestor location. [10 marks]

(b) Determine the time at which the arrestor operates. [4 marks]

(c) Sketch the voltage at the terminal device and determine the maximum voltage to which the terminal equipment will rise. [4 marks]

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