University of Moratuwa, Sri Lanka

Faculty of Engineering

Department of Electrical Engineering

BSc Engineering

Level 4 - Semester 1 Examination

EE402 - INSULATION CO-ORDINATION

January 2007

Time Allowed: 2 **Hours**

Instructions to candidate

This paper contains 4 questions. Answer AH questions.

Total marks for the paper is 70 marks.

This examination accounts for 70% of the module assessment.

Clearly state any assumptions made, data assumed or interpretations made in the

script. *Additional Materials*

Graph paper is available if required.

Only authorised calculators will be permitted.

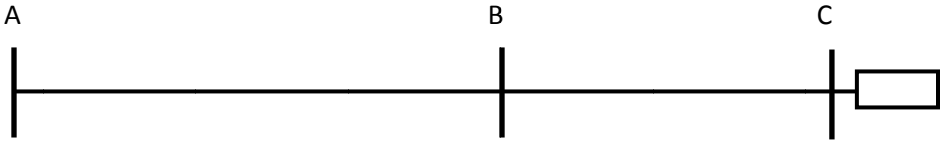
Technical information

Permeability of free space JLIQ = 4п × 10^{-7} H/m

Permittivity of free space s_0 = 8.854 × 10^{-12} F/m Velocity of light in free space = 2.998 x 10^{8} m/s

Question 1

(a) Describe very briefly with the aid of suitable diagrams the mechanism of lighting stroke generation. [4 marks]



(b) Figure 1.1 shows an overhead line AB (l = 150 km, Z_0 = 320 Ω, attenuation factor = 0.95) energized from an alternating source (surge impedance = 50 Ω, rms voltage, 100kv) at end A when the voltage is at its peak value. Another line BC (l = 60km, Z_0 = 480 Ω, attenuation factor = 0.9) connected at the end B feeds the terminal equipment (Z_0 = 1520 Ω) at C. sketch the Bewly lattice diagram indicating significant values on it. State any assumptions made in your calculations. [8 marks]

(c) Sketch indicating the significant values, the voltage at B for the first 1.5ms after the surge is initiated at A. [4 marks]

(d) What is the voltage at B, 1.5 ms after the surge is initiated at A, if line BC is open circuited at C. [4 marks]

Question 2

(a) Explain with any necessary derivations, one method that may be used to represent lumped inductances and capacitances in traveling wave solutions. [5 marks]

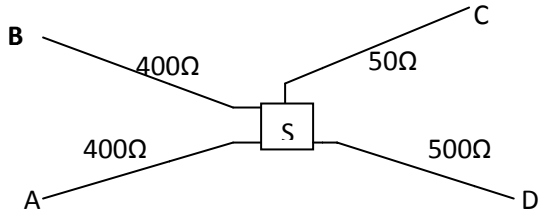


Figure 2.1

(b) Figure 2.1 shows a substation S to which 4 transmission lines AS, BS, CS and DS are connected. If a surge of magnitude 100 kV arrives along BS, determine the surge transmitted to SD and the surge reflected back on SB. [4 marks]

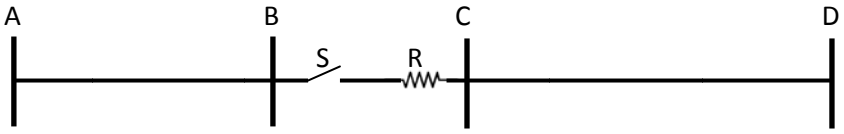


Figure 2.2

(c) Figure 2.2 shows a line CD ($Z_0 = 600\ \Omega$) energized through a switching resistor (R = 4000 Ω) from an already energized line AB ($Z_0 = 600\ \Omega$, E = 100 kV). Determine the magnitudes of the first surges transmitted on to lines BA and CD, Derive any expressions used. [6 marks]

Question 3

A six stage impulse generator designed to generate the standard waveform (1.2/50 μs) has a per stage capacitance of 0.09μF to be used to test transformers with an equivalent winding to earth capacitance of 1.2nF. A peak output voltage of 550kV is required for testing the transformer. The waveform time is to be defined based on 10% and 90% values.

(a) With the aid of appropriate calculations select the values of resistive elements in the circuit to produce the required waveform. State any assumptions made. [12 marks]

(b) Draw the basic circuit diagram of the multi-stage impulse generator indicating all the relevant values on it. Indicate also on the diagram the wave-front and wave-tail control resistors and the charging resistors. [3 marks]

(c) The impulse waveform observed from this impulse generator contains superimposed fluctuations on the impulse waveform characteristic to a higher order Laplace transform equations. Explain reasons for these fluctuations. [2 marks]

Equations used, if any, must be derived from first principles.

Question 4

(a) Derive from first principles an expression for the corona distortion as a surge travels along a transmission line. [12 marks]

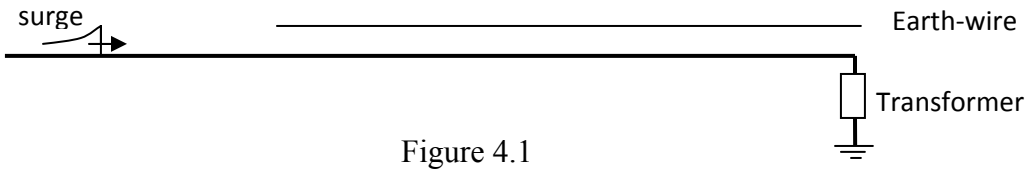


Figure 4.1

(b) Figure 4.1 shows a transformer which has an impulse insulation level of 1050kV. It is to be operated with an insulation margin of 15% under lighting impulse conditions. The transformer has a surge impedance of 2000 Ω and is connected to transmission line having a surge impedance of 500 Ω. A short length of overhead earth wire is to be used

for shielding the line near the transformer from direct strikes. Beyond the shielding length, direct strokes on the phase conductor can give rise to voltage waves of the form $960e^{-0.04t}$kV (with t expressed in μs). if the corona distortion in the line is represented by the expression $\frac{\Delta t}{x} = k[1 - \frac{e_0}{e}]$ μs/m, where k=0.01 μs/m and e_0= 300kV, determine the minimum length of shielding wire necessary in order that the transformer insulation will not fail due to lighting surges. [6 marks]