INSTITUTION OF ENGINEERS, SRI LANKA

PART III EXAMINATION – MAY 2010

310 HIGH VOLTAGE ENGINEERING

Answer any **FIVE** questions. Time allowed : **THREE** Hours
All questions carry equal marks.

Question 1

a)
(i) Derive an expression for the disruptive critical voltage of corona inception in a two conductor system with the radious of each conductor r and the spacing between the conductors d. Modify the expression suitably to account for normal deviations in practical lines.

[6 Marks]

(ii) A 3 – phase, 220 kV, 100 km long transmission line consists of conductors of diameter 1 cm, arranged in an equilateral triangle configuration with 3 m spacing. The temperature of the surrounding is 30 cm and the pressure is 748 torr. The operating frequency is 50 Hz. Determine the disruptive critical voltage and the power loss in the line due to corona under stormy weather conditions. Assume the irregularity factor as 0.85.

[6 Marks]

b) State and explain four processes by which solid insulation may breakdown below their intrinsic strength.

[8 Marks]

Question 2

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.

[6 Marks]

b) A long overhead line L_1 (surge impedance $= 550\ \Omega$) is connected to another overhead line L_2 (surge impedance $= 400\ \Omega$, length $= 3\ km$) through a cable C (surge impedance $= 50\ \Omega$, 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 travel towards the cable, determine using the Bewley lattice diagram and sketch the voltage waveform appearing at the load for the first 21 μs after the surge arrives at the load.

Assume velocities of propagation of the overhead line is $3\times10^8\ ms^{-1}$ and the cable is $2\times10^8\ ms^{-1}$. Attenuation is negligeble.

[14 Marks]

Question 3

a) Describe very briefly with the aid of suitable diagrams the provision of shielding of overhead lines against direct lightning strokes.

[3 Marks]

b) Briefly explain five advantages of HVDC transmission compared to AC transmission.

[5 Marks]

c) An HVDC link AB operates from 220 kV/120 kV transformers operating on 220 kV, 50 Hz alternating supplies. The converter at end B operates as an inverter on constant extinction angle control ($\delta_0 = 12^0$, and 6^0 margin on δ_0 for deionisation). The reactance of each converter transformer can be taken as 15 Ω. If the converter is delivering 80 MW, determine,

i) the direct current [2 Marks]
ii) the direct voltage [2 Marks]
iii) the commutation angle [2 Marks]
iv) power factor [2 Marks]
v) ac current on secondary [2 Marks]
vi) the reactive power requirement of the converter B. [2 Marks]

Question 4

a) Determine from first principles an expression for the corona distortion as a surge travels along a transmission line.

[10 Marks]

b) A transformer has an impulse insulation level of 1050 kV and is to be operated with an insulation margin of 15% under lightning impulse conditions. The transformer has a surge impedance of 1600 Ω and is connected to a transmission line having a surge impedance of 400 Ω. A short length of overhead earth wire is to be used for shielding the line near the transformer from direct strikes. Beyond the shielded length, direct strokes on the phase conductor can give rise to voltage waves of the form $1000e^{-0.05t}$ kV, where t is expressed in μs.

If the corona distortion in the line is represented by the expression $\frac{\Delta t}{x} = \frac{1}{B}\left[1 - \frac{e_0}{e}\right]$ $\mu s/m$,

where $B = 110\ m/\mu s$ and $e_0 = 200\,\text{kV}$, determine the minimum length of shielding wire necessary in order that the transformer insulation will not fail due to lightning surges.

[10 Marks]

Question 5

a) The simplified equivalent circuit of an impulse generator is shown in figure Q5.

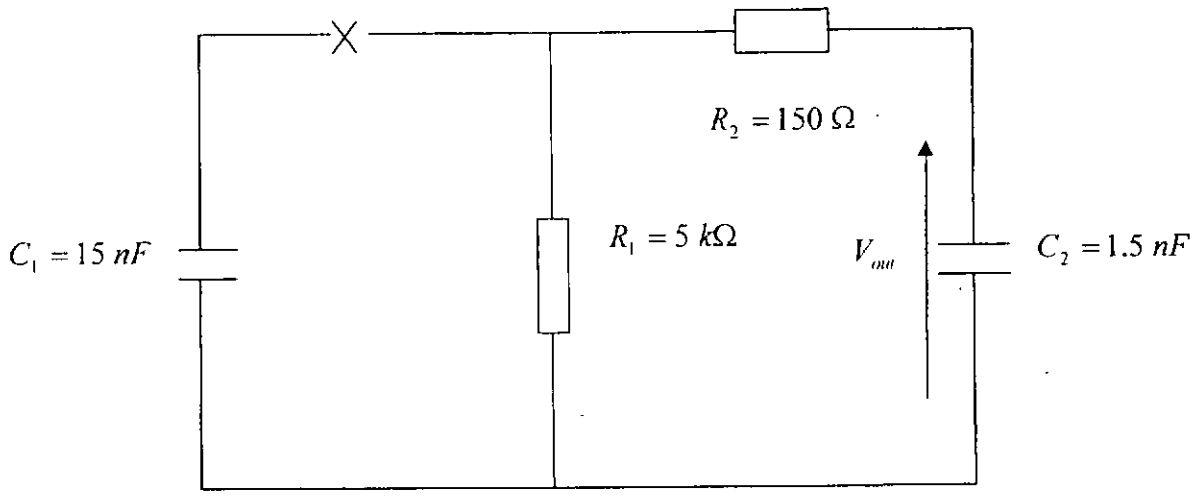

Figure Q5

If the capacitor C_1 is initially charged to 200 kV, determine

i) the approximate voltage efficiency of the impulse generator. [2 Marks]
ii) the output voltage waveform across C_2 [5 Marks]
iii) the wavefront time (based on 30% to 90%) and wavetail time. [6 Marks]
iv) the nominal energy capacity of the impulse generator. [3 Marks]
state any assumptions made in your derivations.

b) Sketch the complete circuit diagram of the above impulse generator if it has six stages, indicating the values of all the components on it.

[4 Marks]

Question 6

a) Briefly describe 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.

[5 Marks]

b) Sketch the circuit diagram of a high voltage Schering Bridge for the measurement of capacitance C and loss tangent $\tan\delta$. Describe how it can be used to measure the above mentioned parameters.

[5 Marks]

c)

i) With the aid of suitable diagrams briefly describe the test cell used in the measurements of dielectric constant and loss tangent of an insulating liquid.

[2 Marks]

ii) Explain how the properties of resonance curve is made use of in determining the Q – factor and the loss tangent.

[2 Marks]

d) Describe briefly why high voltage tests are generally classified into routine tests, sample tests and type tests (or acceptance tests).

[6 Marks]