

INSTITUTION OF ENGINEERS, SRI LANKA
PART III EXAMINATION –NOVEMBER 2012

319-HIGH VOLTAGE ENGINEERING

Duration : 03 Hours

Answer **Five** questions only

All questions carry equal marks.

Question 1

- a) Describe briefly with the aid of suitable diagrams (where necessary) the following:
- i. Electrostatic generator used to obtain high direct voltages, [15 marks]
 - ii. Type tests, sample tests and routine tests performed on HV equipments, [15 marks]
 - iii. Breakdown due to internal discharges, [15 marks]
 - iv. The Kydonograph for the measurement of lightning. [15 marks]
- b) By deriving from first principles, show that the electric stress in a single core cable is not uniform. Describe briefly two methods that may be used to distribute the stress more equally. [40 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. [40 marks]
- b) A long overhead transmission line AB ($Z_0 = 450 \Omega$) is connected to another overhead line CD (surge impedance = 550Ω , length = 3 km) through a cable BC (surge impedance = 50Ω , length = 500 m). CD line terminates to a 2000Ω device at D. A triangular surge (100 kV vertical front, $6 \mu\text{s}$ duration to zero) originates in the overhead line AB and travels towards the cable. Sketch the voltage waveform at D for the first $21 \mu\text{s}$ after the surge arrives at the load. A may be assumed to be too far from junction B to consider reflections at A coming back to B. [velocity of propagation: overhead line 3×10^8 m/s, cable 2×10^8 m/s; attenuation negligible] [60 marks]

Question 3

a) Derive from first principles an expression for the disruptive critical voltage of air for a two conductor system. State any assumptions made. [20 marks]

b) Show from first principles that the thermal resistance of a buried cable is given by

$$S = \frac{k}{3\pi} \ln \frac{2h}{r}$$

where the symbols have their usual meanings. [20 marks]

c) A single phase, composite cable operating at 132 kV, 50 Hz is buried in the ground at a depth of 1.5 m below the surface. If the ambient temperature is 30 °C and the maximum permissible temperature of the insulation is 70 °C, determine the current rating of the cable for the following data. [60 marks]

Diameter of core	= 35 mm
Diameter over inner layer of insulation	= 55 mm
Diameter over outer layer of insulation	= 72 mm
Thickness of lead sheath	= 2 mm
Resistivity of conductor at 70 °C	= 0.015 Ω/km
Relative permittivity of inner layer of insulation	= 4.4
Relative permittivity of outer layer of insulation	= 3.2
Overall dielectric loss factor of cable insulation	= 0.003
Thermal resistivity of cable insulation	= 5 °C-m/W
Thermal resistivity of ground	= 1.2 °C-m/W

Question 4

a) Draw a schematic diagram of control of a HVDC system. Sketch the full voltage current characteristic of the system. [20 marks]

b) Derive equations for DC current, DC voltage, power factor of an HVDC system (You may use standard notations). [10 marks]

c) An HVDC transmission link has 220 kV secondary line voltage at the transformer.

i. Calculate the direct voltage output if the delay angle and the commutation angle are absent. [10 marks]

ii. Calculate the rms value of the ripple voltage in the absence of smoothing. [20 marks]

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

iv. Determine the operating power factor of the system. [10 marks]

Question 5

- a) Describe the process of impulse initiation and the breakdown of successive gaps in multi-stage impulse generators. [20 marks]
- b)
- c) The equivalent circuit of an impulse generator is shown in figure Q5.

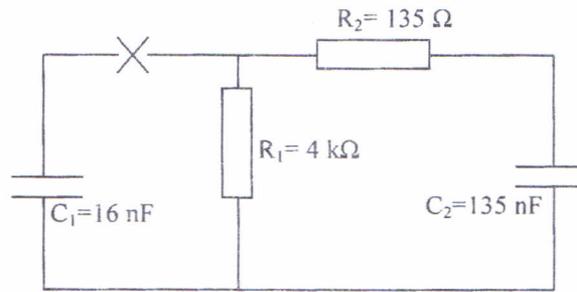


Figure Q5

If the capacitor is initially charged to 200 kV, determine

- i. the approximate voltage efficiency of the impulse generator [10 marks]
- ii. the output voltage waveform across C_2 [20 marks]
- iii. the wavefront (based on 10% to 90%) and wavetail times [20 marks]
- iv. the nominal capacity of the impulse generator [10 marks]

State any assumptions made in your calculations.

- d) Sketch the complete circuit diagram of the above impulse generator if it has 4 stages, indicating the values of all the components on it. [20 marks]

Question 6

- e) 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]
- f) In a certain Townsend type discharge, with constant electric field, the following measurements were made.

Electrode spacing (mm)	1	2	3	4	5	6	8	10	12	14	16
Discharge current (pA)	18	20	25	30	38	42	75	100	145	243	410

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

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