University of Moratuwa, Sri Lanka
B Sc Engineering Degree Course
Final Part III Examination 1993/94

UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs 7 May 1996

Answer **F I V E** Questions Only. All Questions carry equal marks

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1 Describe briefly with the aid of suitable diagrams (where necessary) the following:

(a) streamer theory of breakdown in gasses, [20 marks]

(b) thermal breakdown of a solid dielectric, [20 marks]

(c) breakdown due to internal discharges, [20 marks]

(d) mechanism of lightning. [20 marks]

In a certain high voltage equipment, oil (ε_{r1} = 2.2,ξ_{max1} = 25 kV/mm) is present between 2 electrodes 5 mm apart. Determine the maximum permissible voltage across the electrodes. A solid dielectric material (ε_{r2} = 4.4,ξ_{max2} = 100 kV/mm) of thickness 1 mm is introduced into the oil between the electrodes in an attempt to increase the maximum voltage. Calculate the new maximum voltage and comment on the decision. [20 marks]

2 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.[30 marks]

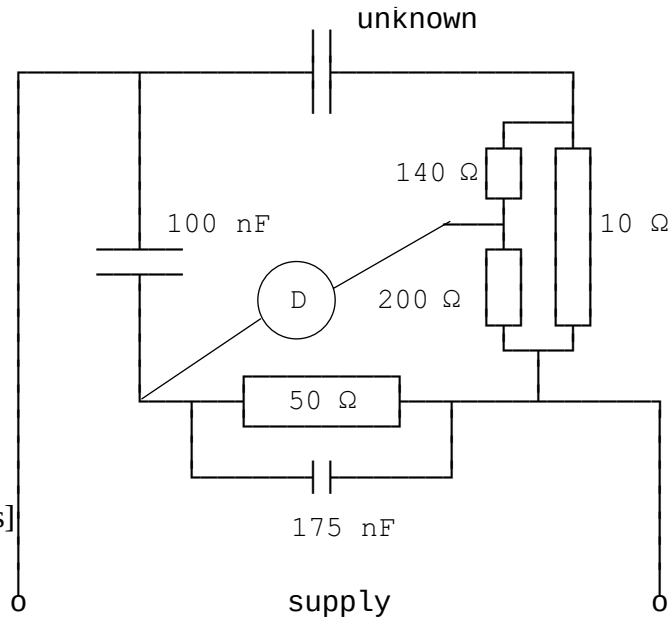
A single phase high voltage cable is to be designed for a working voltage of 38 kV. The critical breakdown stress of the insulation is 120 kV/cm (peak) and the relative permittivity of the material is 3.0. The supply transformer is centre tapped so that both 38 kV and 19 kV are available. If the conductor radius is 7 mm, determine the radii of the sheath and the intersheath required for optimum dimensions of the cable. Take the safety factor as 2. [50 marks]

What would have been the overall radius of the cable if the intersheath was absent for the same operating voltage. Determine also the ratio of the volume of insulation in the two cases. [20 marks]

3 (a) Describe briefly with the aid of suitable diagrams a method of detecting internal discharges in solid dielectrics.[30 marks]

(b) Figure Q3 shows a modified form of high Voltage Schering Bridge used. The values of the components at balance are shown on the diagram. Determine the value of the unknown capacitor and its loss tangent.[60 marks]

It is later detected that the standard capacitor used is not lossless, but has a loss factor of 0.0015. What are the actual values of the unknown capacitor and is loss tangent.[10 marks]



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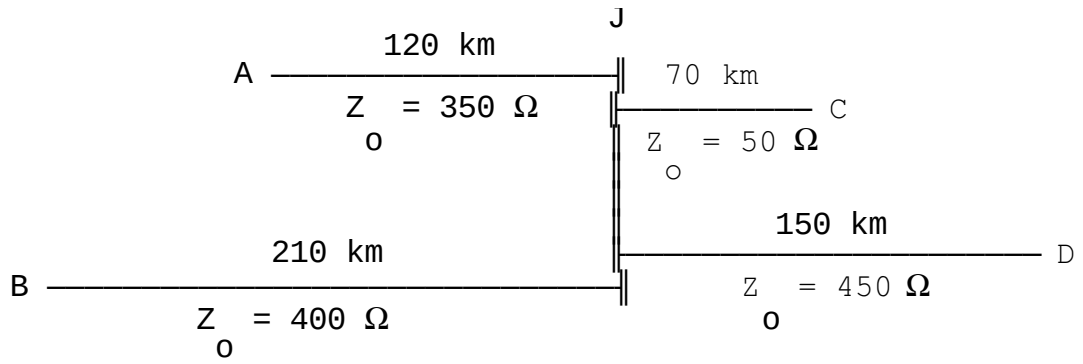


Figure Q4 shows a part of a power system, with overhead lines AJ, BJ, DJ and a cable CJ. A triangular surge of vertical front of magnitude 100 kV and duration 1000 μs originates at B and travels towards the junction J. If the line DJ is on open circuit at end D, line AJ is terminated at end A with a resistive load of 350 Ω, and the cable CJ is terminated at end C with a resistive load of 950 Ω, determine the voltage waveform appearing at J for the first 1.6 ms after the surge originates at B. Attenuation in the lines and cable can be neglected in your analysis.[70 marks]

Sketch the voltage waveform at J and mark the significant values on the waveform.

[30 marks]

[velocity of propagation: OH line - 3 x 10^5 km/s, cable - 2 x 10^5 km/s].

5

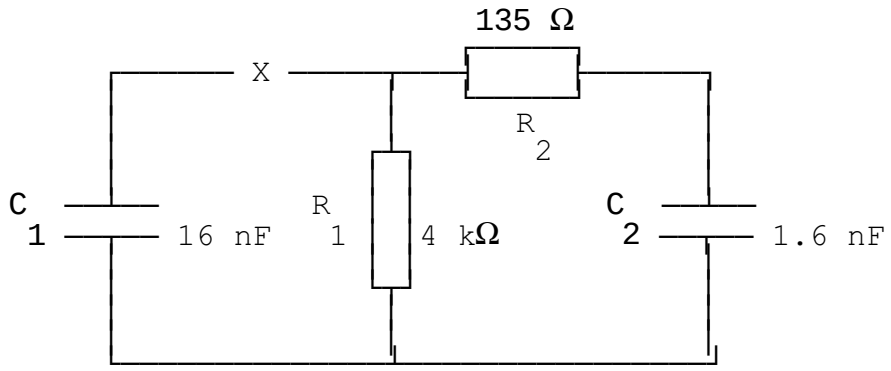
Figure Q5 shows an overhead line AB (inductance 12.2 mH, capacitance 76 nF, length 9 km) is energised from a 125 kV, 50 Hz ac source through a switching resistor R_s = 400 Ω, at an instant when the voltage is at peak value. It feeds a load (R = 1000 Ω) at C through another line BC (inductance 10.4 mH, capacitance 40 nF, length 6 km).

Determine the voltage surges in the system for the first 180 μs. Attenuation in the lines may be neglected. [60 marks]

Sketch the waveform of the voltage at C. [20 marks]

If the switching resistor becomes short-circuited at the instant 120 μs, indicate, using suitable calculations, the modification to the voltage waveform at C. [20 marks]

6 The equivalent circuit of an impulse generator is shown in figure Q6.



If the capacitor is initially charged to 200 kV, determine

(a) the approximate voltage efficiency of the impulse generator [10 marks]
(b) the output voltage waveform across C_2 [30 marks]
(c) the wavefront (based on 30% to 90%) and wavetail times [25 marks]
(d) the nominal capacity of the impulse generator [10 marks]

State any assumptions made in your calculations.
Sketch the complete circuit diagram of the above impulse generator if it has 4 stages, indicating the values of all the components on it. [25 marks]

7 Derive from first principles an expression for the ratio of the time lag (Δt) to the distance travelled (x) of a voltage element in terms of the magnitude (e), the critical voltage (e_0) and the velocity of propagation of the undistorted waveform (v). [40 marks]

A transformer (BIL = 650 kV, Z_0 = 1500 Ω) is to be operated with an insulation margin of 15% under impulse conditions. It is connected to an overhead line (Z_0 = 500 Ω), and a short length of overhead earth wire is 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 voltages of the form 600 $e^{-0.02t}$ kV (with t in μs). If the corona distortion in the line is represented by the expression $\Delta t/x = 0.015[1 - 120/e]$ μs/m, (with x in m and e in kV), determine the minimum length of shielding wire necessary in order that the transformer insulation will not fail due to the incoming lightning surges on the line.

[45 marks]

Determine whether the selected earth wire will provide adequate shielding if the incoming surge was of the form 1000 $e^{-0.05t}$ kV. [15 marks]

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

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 ($\delta_o = 10^0$, and 5^0 margin on δ_0 for deionisation). The reactance of each converter transformer can be taken as 14.8 Ω. If the converter is delivering 85 MW, determine (a) the direct current, (b) the direct voltage, (c) the commutation angle, (d) power factor, (e) a.c. current on secondary, and (f) the reactive power requirement of the converter B. [60 marks]

A brief derivation of equations used is required. [20 marks]