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The Open University of Sri Lanka
Bachelor of Technology
ECX 5238 - High Voltage Engineering & Electrical Machines
Final Examination 2009/2010

Duration Three hours

Date: 5th April 2010 **Time: 1400-1700**

Answer five questions only. Select at least one question from section B. All questions carry equal marks.

Section A

Q1.

(a) Describe very briefly with the aid of suitable diagrams the mechanism of lightning stroke generation.

(b) Explain, with respect to surges originating in an overhead line, the effect of connecting the overhead line to the terminal equipment via a short length of cable.

(c) Explain the use of sphere-gaps in high voltage measurements.

(d) Derive an expression for the deflecting torque of an electrostatic voltmeter used to measure high voltages.

(e) Obtain an expression for spark breakdown in the Townsend breakdown process, stating any assumptions made.

Q2.

(a) Derive from first principles an expression for the corona distortion as it travels along a transmission line.

(b) A 132 kV transformer (BIL = 550 kV, $Z_0 = 1600\,\Omega$) is to be operated with an insulating margin of 15%. It is fed from an overhead transmission line ($Z_0 = 400\,\Omega$) which has a short length of overhead shielding wire for protection from direct strokes. If direct strokes can give rise to voltages of the form $500e^{-0.015t}$ kV (with **t** in μs) beyond the shielded length and corona distortion in the line is represented by the expression.

$$\frac{\Delta t}{x} = 0.016\left[1 - \frac{115}{v}\right] \text{ with } \mathbf{x} \text{ in m and } \mathbf{v} \text{ in kV}$$

Determine the minimum length of the shielding wire necessary to protect the transformer insulation from damage.

Q3.

(a) Figure Q3 (a) shows the equivalent circuit of an impulse generator where the capacitor C (=0.02 μF) is initially charged to a voltage of 100kV. Determine the values of R_1, R_2 an C_2 if the impulse generator is to have an efficiency of 90% and a voltage waveform c 1.2/60 μs across the capacitor C_2.

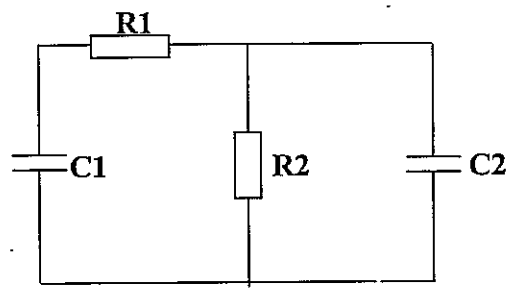


Figure Q3 (a)

(b) It is found that the resistor R_2 has an effective series inductance of 60 mH. Using a intuitive approach, sketch what changes you would expect to the voltage wavefor across the capacitor C_2.

Q4.

(a) From first principles, show that surges can be represented by a combination of travelir waves.

(b) Assuming standard expressions for inductance and capacitance of a transmission lin obtain an expression for the velocity of propagation of surges. State also what tl symbols in the equation represent.

(c) A certain surge has a linear rate of rise of 600 kV/μs to 120 kV. It originates in transmission line with a surge impedance of 350 Ω and travels towards a terminal devi (Z_0 =3150 Ω). It is protected by a lightning arrestor at a distance of 24 m from the devic If the arrestor flashover voltage is 160 kV, determine the time at which the arrest operates and the maximum voltage to which the terminal equipment will rise.
(Velocity of propagation: overhead line 3 x 10^8 m/s, cable 2 x 10^8 m/s)

Q5.

(a) Describe very briefly the problems associated in using a capacitive potential divider f the observation on the oscilloscope of an impulse voltage across a test device. Expla how these problems may be minimized.

(b) A very long overhead line (surge impedance = 450 Ω) is terminated in following mann Through a resistive load of 1500 Ω, and then through another overhead line AB (leng 3.6 km, surge impedance = 300 Ω, attenuation in single transit = 0.95) and then throug cable BC (length= 600m, surge impedance = 60 Ω, attenuation factor for a single tran = 0.90). Determine using the Bewley lattice diagrams, the voltage waveforms appeari at A and C for the first 25 μs after a rectangular voltage surge (vertical front 100 k duration 9 μs) originates at the source. (Velocity of propagation: overhead line 3 x 1 m/s, cable 2 x 10^8 m/s)

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Q6.

(a) By deriving from first principles, show that the electric stress in a single core cable is not uniform.

(b) A single phase cable for a 3-phase 132 kV system, is to be designed using 3 insulating materials A, B, and C with peak critical breakdown stresses of 180 kV/cm, 200 kV/cm and 250 kV/cm and corresponding relative permittivities of 4.2, 3 and 2.6 respectively. If the conductor radius is 10 mm, determine the order and thickness of the insulation for optimum dimensions of the cable. Take a safety factor as 2 in the design.

(c) By considering a particular instant of time, sketch the field pattern in a three core belted type cable.

(d) Derive the basic equations that you used in sketching the above field pattern

Section B

Q7.

(a)

(i) Give sketches to show the construction of a 12/8 pole, three phase variable reluctance stepper motor. What is the basic step angle of this motor?

(ii) Indicate the switching pattern for normal stepping and half stepping operations?

(iii) Explain briefly why the speed response of a stepper motor is always oscillatory.

(b) Give a block diagram structures of a closed loop 3-phase induction motor drive that use current limit control and slip regulation control. Describe briefly the operation of each.

A 50 Hz, 4 pole, 3 phase induction motor runs at 1460 rpm at rated condition. Its pull out speed is 1350 rpm. Determine the range of speed of constant horse power mode of closed loop control?

Q8.

(a) Explain briefly why the synchronous generators tend to produce very large initial fault current following a sudden 3-phase short circuit fault at the terminals.

(b) A certain generator subjected to sudden 3-phase short circuit at its terminal while no-load with 11 kV between lines produces short circuit fault current given by the following expression.

$$i = \left(8 + 12e^{-2t} + 20e^{-50t}\right) Sin(\omega t + \theta_0) - 25e^{-20t} Sin\theta_0 \quad kA$$

(i) What is θ_0 in this expression?

(ii) What are the values of sub transient time constant, transient time constant and armature time constant under short circuit condition?

(iii) Determine the values of reactance's $x_d, x_d^{'}, x_d^{''}$ and $x_q^{''}$ for the generator?

(iv) Calculate approximate initial rms fault current.

(c) A 3-phase, 150 MVA, 13 kV, salient pole synchronous generator has direct axis synchronous reactance 1.7 pu and quadrature axis synchronous reactance 1.0 pu. The generator delivers 130 MVA at 0.95 p.f over excited at rated voltage to an infinite bus. Calculate the internal voltage and the load angle.