THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY
ECX-5238 – High Voltage Engineering and Electrical Machines
Final Examination 2013/2014
Duration: Three Hours

Date: 9th September 2014 Time: 0930-1230

Instructions to candidates: Answer any ***five (05)*** questions. Select at least ***one*** question from section **B**. Graph papers will be available on your request.

Section A: High Voltage Engineering

1. a) Describe very briefly with the aid of suitable diagrams the mechanism of the lightning stroke generation. [2 marks]

b) Describe, 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. [2 marks]

c) A steady current of 600 μA flows through the plane electrode separated by a distance of 0.5 cm when a voltage of 10 kV is applied. Determine the Townsend's first ionization coefficient if a current of 60 μA flows when the distance of separation is reduced to 0.1 cm and the field is kept constant at the previous value. [8 marks]

d) The following table gives two sets of experimental results for studying Townsend's mechanism. The field is kept constant in each set:

I st set 30 kV/cm Gap distance (mm)	II nd set kV/cm Observed current (A)	
	I st set	II nd set
0.5	1.5×10^{-13}	6.5×10^{-14}
1.0	5.0×10^{-13}	2.0×10^{-13}
1.5	8.5×10^{-13}	4.0×10^{-13}
2.0	1.5×10^{-12}	8.0×10^{-13}
2.5	5.6×10^{-12}	1.2×10^{-12}
3.0	1.4×10^{-10}	6.5×10^{-12}
3.5	1.4×10^{-10}	6.5×10^{-11}
4.0	1.5×10^{-9}	4.0×10^{-10}
5.0	7.0×10^{-7}	1.2×10^{-8}

The minimum current observed is 6×10^{-14} A. Determine the values of Townsend's first and second ionization coefficients. [8 marks]

2. **a)** Explain and compare the performance of half wave rectifier and voltage doubler circuits for generation of high d.c. voltages.

   b) Why Cockcroft-Walton circuit is preferred for voltage multiplier circuits? Explain its working principle with a schematic diagram..

   c) Explain clearly the basic principle of operation of an electrostatic generator. Describe with neat diagram the principle of operation, application and limitations of Van de Graf generator.

   d) Explain the different schemes for cascade connection of transformers for producing very high a.c. voltages.

   e) Why is it preferable to use isolating transformers for excitation with cascade transformer units, if the power requirement is large?

   f) Describe the use of sphere gaps in high voltage measurements.

   g) Derive an expression for the deflecting torque of an electrostatic voltmeter measureing high voltage.

   h) Derive an expression for spark breakdown in the Townsend breakdown process, stating any assumptions made.

   [8*2.5 marks]

3. **a)** By deriving from first principles, show that the electric stress in a single core cable is not uniform. [2 marks]

   b) A single phase cable for a 3-phase 66 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 4.4, 3.2 and 2.8 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. [8 marks]

   c) A surge with a magnitude of 160 kV has a linear rate of rise of 800 kV/μs. It originates in a transmission line with a surge impedance of 450 Ω and travels towards a terminal device ($Z_0 = 2550\Omega$). It is protected by a lightning arrestor at a distance of 20 m from the device. If the arrestor flashover voltage is 210 kV, determine the time at which the arrestor operates and the maximum voltage to which the terminal equipment will rise.

   [10 marks]

   [velocity of propagation: overhead line 3×10^8 m/s, cable 2×10^8 m/s, Permittivity of free space $\varepsilon_o = 8.854 \times 10^{-12}$ F/m]

4. **a)** A ten-stage impulse generator has 0.25 μF condensers. The wave front and wave tail resistances are 75 Ω and 2600 Ω respectively. If the load capacitance is 2.5 nF, determine the wave front and wave tail times of the impulse wave. [8 marks]

b) A six-stage impulse generator designed to generate the standard waveform (1.2/50 μs) has a per stage capacitance of 0.06 μF to be used to test transformers with an equivalent winding to earth capacitance of 1 nF. A peak output voltage of 550 kV is required for testing the transformer. The wave front-time is to be defined based on 30% and 90% values.

I. With the aid of appropriate calculations select the values of the resistive elements in the circuit to produce the required waveform. State any assumptions made. [8 marks]

II. Draw the basic circuit diagram of the multi-stage impulse generator indicating all relevant values on it. Indicate also on the diagram the wave-front and wave-tail control resistors and the charging resistors. [4 marks]

5. **a)** 33 kV, 50 Hz high voltage Schering bridge is used to test a sample of insulation. The various arms have the following parameters on balance. The standard capacitance 500 pF, the resistive branch 800 ohm and branch with parallel combination of resistance and capacitance has values 180 ohms and 0.15 μF. Determine the value of the capacitance of this sample its parallel equivalent loss resistance, the p.f. and the power loss under these test conditions. [8 marks]

b) A surge of 100 kV traveling in a line of natural impedance 600 Ω arrives at a junction with two lines of impedances 800 Ω and 200 Ω respectively. Find the surge voltages and currents transmitted into each branch line. [4 marks]

c) If E = 240 kV, Z_1= 500 Ω, Z_2= 400 Ω, and R = 300 Ω, travel time of CD is 100 μs, D is on open circuit and A is too far from B for reflections to be considered during the period of interest, determine and sketch the voltages at B and C for the first 250 μs after the breaker shown at B is closed at time t = 0.

(Assume that the line AB is initially energized with the breaker at B open.)

[8 marks]

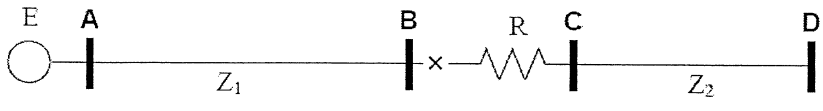

Figure Q5c

Section B: Electrical Machines

1. a) Is it possible to have the full load terminal voltage greater than the no load terminal voltage of an alternator? Explain [4 Marks]

b) A 100 MVA, 11 kV, 3 phase generator (salient pole rotor) has $X_d = 1.6\ \Omega / Phase$ and $X_q = 0.5\ \Omega / Phase$. Calculate the internal e.m.f and load angle when the generator delivers 75% full load at 0.85 power factor lag, at rated voltage. [8 Marks]

c) The load in a factory of 3 phase, 400 V supply is 800 kVA at 0.85 power factor lagging and in addition there is a synchronous motor having an input of 200 kW. Determine the input to the synchronous motor in kVA and the power factor at which it must operate, if the power factor of the combined load should be 0.95 lagging. [8 marks]

2. a) The user of an electrical machine should understand the meaning of different ratings printed on the nameplate and modify these figures accordingly as and when required for the safe and best overall operation of the motor. Describe, in the context of 3-phase induction motors, the meaning of rated voltage, rated current, rated speed, rated power & rated power factor. [8 Marks]

b) What will be the revised nameplate data for a 3-phase, 60Hz, 480V, 30A, 20 kW, 1435 rpm totally enclosed fan ventilated induction motor in the following circumstances?

i. For the use on 3-phase 50Hz supply without modification [4 marks]

ii. After rewinding the motor with coils having half as many turns using wires having twice the cross sectional area [4 marks]

iii. For a modified construction of the motor with 10% increase of the active length [4 marks]

3. a) Calculate the basic step angle for the following stepper motors:

(i) 12/8 pole, 3-phase, single stack VR motor [1.5 mark]
(ii) 4/6 pole, 2-phase, PM stepper motor [1.5 mark]
(iii) 4/36 pole, 3-phase, multi stack VR motor [1.5 mark]
(iv) 4/9 pole, 2-phase, PM hybrid motor [1.5 mark]

b) Sketch typical pullout-torque versus stepping-rate characteristics for a stepper motor and give step responses in the modes of multi-step and slewing [6 marks]

c) What do you mean by the terms start rate and stop rate [4 marks]

d) From the phasor diagram of a synchronous machine with constant synchronous reactance X_s operating a constant terminal voltage V_t and constant excitation voltage E_f, show that the locus of the tip of the armature current phasor is a circle. On a phasor diagram with terminal voltage chosen as the reference phasor, indicate the position of the center of this circle and its radius. Express the coordinates of the center and the radius of the circle in terms of V_t, E_f, and X_s [4 marks]