00205

THE OPEN UNIVERSITY OF SRI LANKA
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Bachelor of Technology Honours in Engineering

Final Examination (2016/2017)
ECX5238: High Voltage Engineering and Electrical machines

Closed Book

Date: 07th December 2017 (Thursdays) **Time: 9:30 am – 12:30 pm**

This paper consists of Section A and Section B with 8 questions. Answer five questions selecting only one question from Section B. ***You must answer Section A and Section B in two separate answer books.***

Section A-High Voltage Engineering

Q1.

a) Briefly explain the basic ionization processes and avalanche mechanism. [4 Marks]

b) With the aid of suitable diagrams, explain the time lag characteristics. [3 Marks]

c) Determine the Disruptive Critical Voltage, the Visual Corona inception voltage, and the power loss due to corona, under fair weather conditions for a 100 km long 3 phase, 132 kV overhead transmission line consisting of conductors of diameter 1.14 cm, arranged in an equilateral triangle configuration with 3 m spacing. The temperature of the surroundings is 45 ^{0}C and the pressure is 755 torr. The operating frequency is 50 Hz. [The irregularity factors may be taken as $m_0 = 0.85$, $m_V = 0.72$] [9 Marks]

d) Briefly explain the breakdown of commercial liquids below their intrinsic strength. [4 Marks]

Q2.

A 144 kV, ideal dc voltage source connected in series with a 50 Ω resistance is switched on to a 30 km long overhead line with a surge impedance of 250 Ω at time zero. The far end of the line is terminated on a load resistance of 750 Ω as shown in Figure Q2. The velocity of surge propagation in the line is 300 μs.

i Sketch the voltage at the load end of the line over a period 0 to 350 μs.
ii What would be the current flowing into the load at 350 μs?

[20 Marks]

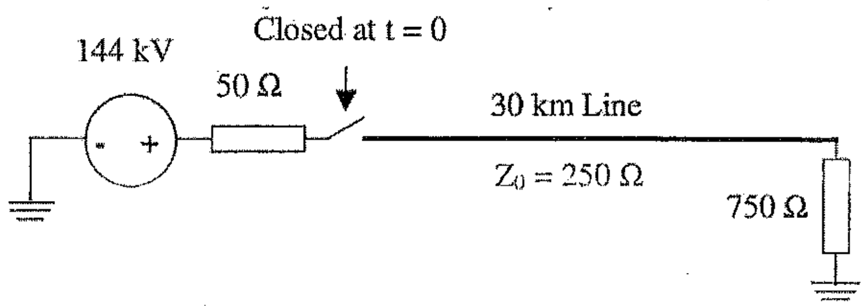

Figure Q2

Q3.

a) State two advantages and disadvantages of using bundled conductors for high voltage overhead power transmission lines. [5 Marks]

b) By deriving from first principles, show that the electric stress in a single core cable is not uniform. [5 marks]

c) With the aid of suitable diagrams, briefly explain how to identify a faulty cable using partial discharge measurements in a laboratory environment.
Your answer should include,

i. A Partial Discharge Measuring Circuit.
ii. Method of diagnosing the health of the cable.

[10 Marks]

Q4.

a) Describe briefly with the aid of suitable diagrams one form of electrostatic generator used to obtain high direct voltages. [4 marks]

b) Briefly explain the use of Klydonographs in studying lightning occurrences. [6 Marks]

c) Show that the deflecting torque of an electrostatic voltmeter is proportional to the product of the square of the applied voltage and the rate of change of capacitance. [4 marks]

d) Outline the significance of type tests, sample tests and routine tests performed on high voltage equipment, making use of suitable examples. [6 Marks]

Q5.

a) State the advantages and disadvantages of using gaseous, liquid and solid dielectrics separately and list down two applications of each type of dielectric material. [6 Marks]

b) Sketch the circuit diagram of a high voltage Schering Bridge for the measurement of capacitance C and loss tangent tan δ, when the standard capacitor has a known but very small loss tangent tan δ_1. Derive the expression for the values of C and tan δ, of the unknown, stating any assumptions made in your derivations. [6 Marks]

c) In a certain standard Schering Bridge measurement, the standard capacitor has a value of 100 nF and a loss tangent of 0.001. At balance, the remaining arms are:

i. a resistance of 210 Ω,
ii. a resistance of 100 Ω with a capacitance of 140 nF in parallel.

Sketch the circuit diagram of the high voltage Schering Bridge showing the locations of the arms, and determine the values of C and tan δ of the unknown stating any assumptions made in your derivations. [8 Marks]

Section B-Electrical Machines

Q1.

a. Calculate the basic step angle for the following stepper motor.

- **i.** Single stack, 4-phase VR motor with 8 stator poles and 6 rotor teeth
- **ii.** Three stack, 3-phase VR motor with 4 stator poles and 36 rotor teeth
- **iii.** Hybrid 2-phase stepper motor with 8 stator poles and 18 rotor teeth

[3 Marks]

b. Give sketches to show the construction of 6/4 pole, three-phase variable reluctance stepper motor. Determine the basic step angle and indicate switching pattern for normal stepping and 7half-stepping operations. [7 Marks]

c. Why does the torque output of a stepper motor fall at high speed? [4 Marks]

d. Explain briefly why the speed response of a stepper motor is always oscillatory? Give a sketch of the no load speed response of a 3-phase stepper motor to illustrate this behavior. You should draw the speed response relating it to the accelerating and decelerating torque, found by static-torque angle curves for the motor. [6 Marks]

Q2.

a. Explain briefly why the trapezoidal BLDCM (brushless DC motor) has gained wider acceptance in the industry than the sinusoidal BLDCM. How do you compare the trapezoidal BLDCM with the conventional brushed DC motor? [4 Marks]

b. Briefly describe bipolar modes of control of a trapezoidal BLDCM (brushless DC motor). You may use appropriate diagrams for the control circuit. [6 Marks]

c. A trapezoidal BLDCM has 15 cm axial length, 3.5 cm mean radius and 96 series turns per phase. Air gap flux density is 0.48 T and the winding resistance is 0.2 Ω per phase. Motor is operated in the bipolar mode and assume 1 V drop across a conducting transistor.

- i. Calculate the torque constant
- ii. Calculate the no load speed when the DC input voltage is 200 V.
- iii. What is the DC input voltage for 1200 rpm on 12 Nm load?

[10 Marks]

Q3.

a. Explain the concept of sub-transient reactance, transient reactance and steady state reactance for a synchronous generator. Sketch typical line current waveform for a generator following a sudden three-phase short circuit at its terminals and indicate the regions of the waveform, characterized by the above reactances. Assume the generator was on no-load prior to the short circuit. [6 Marks]

b. A three phase 100 MVA, 11 kV, 50 Hz turbo generator has the following parameters:

$X_d = 1.9$ pu	$T_d' = 0.55$ s	$X_q = 1.85$ pu
$X_d' = 0.25$ pu	$T_d'' = 0.02$ s	$X_q' = 0.50$ pu
$X_d'' = 0.20$ pu	$T_a = 0.17$ s	$X_q'' = 0.20$ pu

Contd.........

i. Write down an expression for the time variation of the pu current, following a sudden short circuit fault at the machine terminals at time t=0, while the machine is on no-load producing rated voltage. [5 Marks]

ii. What is the peak rms current likely to occur in a line? [5 Marks]

iii. Draw to approximate scale the rms line current showing the regions of the sub transient, transient and steady state for the conditions mentioned in (ii) above. [4 Marks]