The Open University of Sri Lanka
Bachelor of Technology
ECX 5238 - High Voltage Engineering & Electrical Machines
Final Examination 2010/2011
Duration Three hours

Date: 28/03/2011 **Time: 1400-1700 hrs**

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

SECTION-A

Q1. A high voltage cable is to be made with an insulated conductor of radius 20 mm with the outermost diameter being 120 mm. Three materials A, B and C are available for insulation.

Material	ξ max (kV/cm)	ε_r
A	90	4.0
B	120	2.4
C	105	3.0

Determine the optimum thickness of the insulation materials and the order in which they should be laid, to obtain the maximum operating voltage for the cable.
If a safety factor of 1.3 is to be used, what is the value of this maximum voltage? [20 Marks]

Q2. (a) From first principles, show that surges in transmission lines can be represented by a combination of forward traveling waves and reverse traveling waves.

(b) A simplified power system consists of three overhead transmission lines AB, BC and CD. The lines BC and CD are on open circuit at the ends C and D respectively. If a surge of magnitude 100 kV originates on line AB at A and travels towards B, sketch the voltage waveforms at A & B for the first 1 ms from the inception of the surge. The lines may be assumed to be lossless and that A is too far from junction B to consider reflections at A coming back to B.
[Velocities of propagation in overhead line and cable are 3 x 105 km/s and 2 x 105 km/s respectively.]

(c) Two long overhead lines AB and CD (each of surge impedance 350 Ω) are connected through a switching resistor of value 300 Ω. A triangular wave of peak height 100 kV and duration 50 μs originates in the overhead line AB and travels towards the junction B. Determine the magnitudes of the first surges reflected towards A and transmitted towards D.

[20 Marks]

Q3. Describe briefly:

(a) The cascade arrangement of transformers to obtain high alternating voltage for testing purposes. [5 Marks]

(b) The operation of a Voltage Multiplier Circuit to obtain high voltage direct current for testing purposes [5 Marks]

(c) One form of electrostatic generator used to obtain high direct current voltages. [5 Marks]

(d) A resonance method used to control the output of a high voltage test transformer Why is this method not suitable for power transmission? [5 Marks]

Q4. 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.

(a) 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.

(b) 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.

(c) Determine the nominal energy of the impulse generator designed. Equations used, if any, must be derived from first principles [20 Marks]

Q5. (a) Briefly explain the statistical method of insulation co-ordination with the aid of suitable diagrams.

(b) With the aid of suitable diagrams, show that wave-tail distortion due to corona in an overhead transmission line can be expressed in the form of

$$\frac{\Delta t}{x} = K\left[1 - \frac{e_0}{e}\right]$$

(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. The arrestor flashover voltage is 210 kV.

(i) Sketch the voltage waveform at the arrestor location.
(ii) Sketch the voltage at the terminal device.
(iii) Determine the time at which the arrestor operates.
(iv) Determine the maximum voltage to which the terminal equipment will rise. [20 Marks]

Q6. Figure Q6 shows the circuit arrangement of a dual bridge series diode converter used for HVDC transmission.

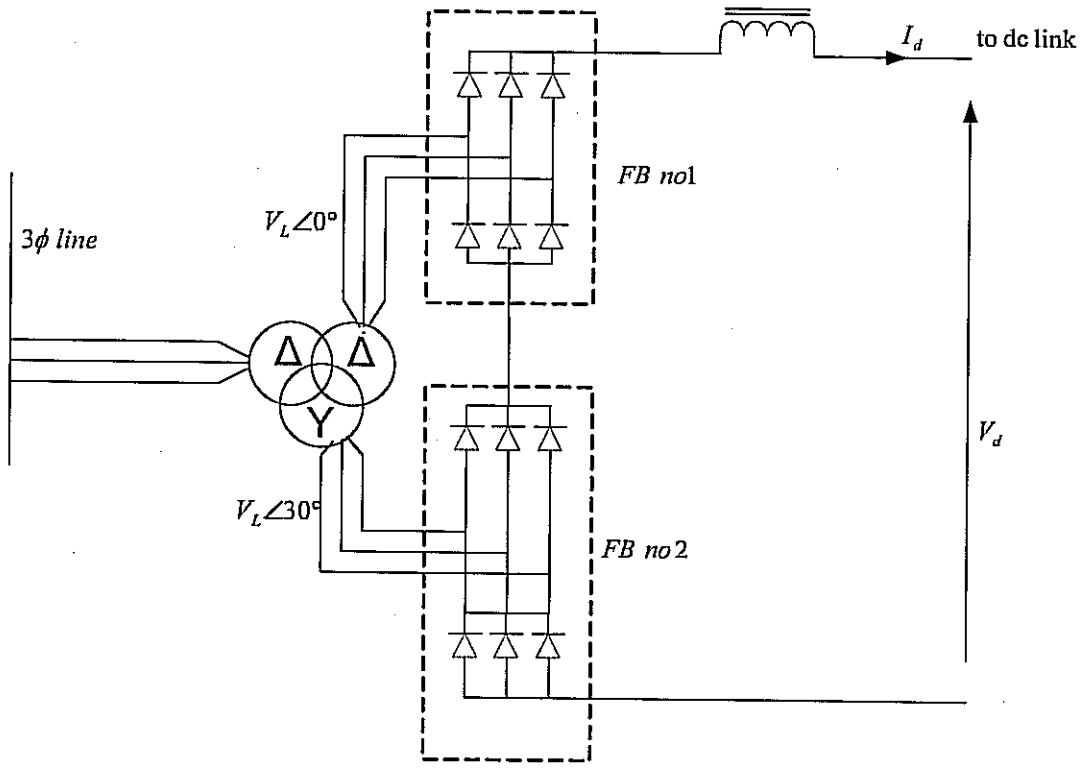

Fig Q6

(a) Discuss the advantages of the dual bridge converter.

(b) Sketch the typical waveforms of

i. Output dc voltage (before smoothing)

ii. Input line current to the transformer

(c) If the supply voltage to each converter is 110 kV, 50 Hz, What will be the average dc voltage and the peak-peak ripple voltage of the output?

(d) If the supply side inductance for each converter is 45 mH/phase, what will be the reduction in average dc voltage output at a dc current of 400 A?

(e) If instead of diode converters, thyristor converters having delayed firing angle of 9^0 are used in the above system, determine the dc voltage?

(f) Determine the active power delivered by the dc link?
(A brief derivation of equations used required

[20 Marks]

SECTION-B

Q7. (a) Induction motor speed control with constant-supply voltage and reduced supply frequency is rarely used in practice. Justify this statement.

(b) A 3-phase, 4 pole, 400 V, 970 rpm, 50 Hz, delta-connected induction motor has rotor per phase leakage impedance of (0.5+j0.2) Ω. Stator leakage impedance and rotational losses are assumed negligible.
If this motor is energized from a source of 3-phase, 400 V, 90 Hz, then compute,

(i) the motor speed at rated torque

(ii) the slip at which maximum torque occurs and

(iii)the maximum torque

(c) Suppose that motor has stator per phase leakage impedence of (0.6+j2) Ω and motor is operated at 25 Hz with DOL (direct-on-line) starting under V/f speed control. Calculate;

(i) Current, power factor and torque at the instant of starting; compare the results with normal values.

(ii) The maximum torque.

[20 Marks]

Q8 (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) 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 at constant horse power mode of closed loop control?

[20 Marks]