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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: EEX5538/ECX5238 High Voltage Engineering and Electrical machines
Academic Year	: 2018
Date	: 20th February 2019
Time	: 0930-1230hrs

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in two sections, **Section A** and **Section B** in **Four (4)** pages.
3. Answer any **five (05)** questions. All questions carry equal marks. Select at least **one question** from **section B**.
4. **Answer scripts for Section A and section B should be in separate books**
5. Graph papers will be available on your request.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.

SECTION-A
HIGH VOLTAGE ENGINEERING

Question 1

a) Briefly describe the Townsend's breakdown process for gaseous dielectrics and determine an expression for the spark breakdown criteria. **[5 Marks]**

b) If the following measurements were made in a Townsend type discharge, determine the value of the Townsend's first and second ionization coefficients. **[8 Marks]**

d (mm)	1	2	3	4	5	6	8	10	12	14	16
I (pA)	22	26	30	35	42	50	75	110	185	400	1060

c) Describe very briefly with the aid of suitable diagrams the mechanism of the lightning stroke generation above a high voltage transmission line. **[5 Marks]**

d) Show with the aid of suitable diagrams how the time lag characteristic of spark breakdown may be determined for the standard impulse voltage waveform. **[2 Marks]**

Question 2

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) State three high voltage testing techniques that can be used to assess the condition of power transformers. Discuss the testing techniques and how the results of each technique can be used to assess the condition of the asset. **[6 Marks]**

Question 3

An impulse generator is to be designed to generate 600 kV standard impulse voltage waveform (1.2/50 μs) to the test equipment. The nominal energy desired for the impulse generator is 10 kJ. A 65kV single phase transformer is available.

a) Obtain the values of the coefficients α and β for the standard waveform. **[7 Marks]**

b) With the aid of suitable calculations, determine the required number of stages for the impulse generator. **[3 Marks]**

c) Sketch the basic impulse generator circuit and determine the values of the associated elements in the circuit to produce the required waveform. **[7 Marks]**

d) Sketch the basic impulse generator circuit and determine the values of the associated elements in the circuit to produce the required waveform. **[3 Marks]**

Question 4

a) Briefly explain, with the aid of suitable diagrams, the statistical method of insulation co-ordination. **[5 Marks]**

b) A certain surge has a linear rate of rise of 250 kV/μs to 100 kV and constant thereafter. It originates in a transmission line with a surge impedance of 350 Ω and travels towards a terminal device (Z_0= 3150 Ω). It is protected by a surge diverter at a distance of 21 m from the device. If the arrestor operates at 140 kV, determine the time at which the diverter operates. Derive any equations that are used for the calculations. **[10 Marks]**

c) Sketch the voltage at the terminal device and determine the maximum voltage to which the terminal equipment will rise. **[5 Marks]**

Question 5

a) Show that the electric stress in a single core cable is not uniform, by deriving from the first principles. **[4 Marks]**

b) Describe briefly two methods that may be used to distribute the stress more equally in the dielectric. **[4 Marks]**

c) Briefly explain the power loss that can incur in a high voltage cable. **[4 Marks]**

d) In a 220 kV, 3-phase system, the insulation of a single-phase cable has a relative permittivity of 2.25 and a critical breakdown stress of 400 kV/cm (peak). In addition to the nominal supply voltage, transformer can supply an additional voltage of 60 kV. If the conductor radius is 19 mm, determine the radii of the sheath and of the intersheath for optimum utilization of the cable. Take the safety factor as 2.5 in the design. **[8 Marks]**

SECTION-B
ELCTRICAL MACHINES

Question 6

a) State the difference between a reluctance stepper motor and a permanent magnet stepper motor? **[2 marks]**

b) Calculate the basic step angle for the following stepper motor.
3-phase variable reluctance (VR) motor with 6 stator poles and 16 rotor teeth **[2 marks]**

c) Give sketches to show the construction of stepper motor mentioned in **(b)**. Indicate the switching pattern for normal stepping and half-stepping operations. **[4 marks]**

d) Sketch typical pullout-torque versus stepping-rate characteristics for a stepper motor and give typical step responses in the modes of multistep, resonant, and slewing. What do you understand by the terms start rate, stop rate and detent torque? **[6 marks]**

e) The torque speed characteristics of the stepper motor mentioned in **(b)** is given in figure Q1. Calculate the power developed by motor when it is slewing

i. At 500 steps per second
ii. At 200 steps per second **[6 marks]**

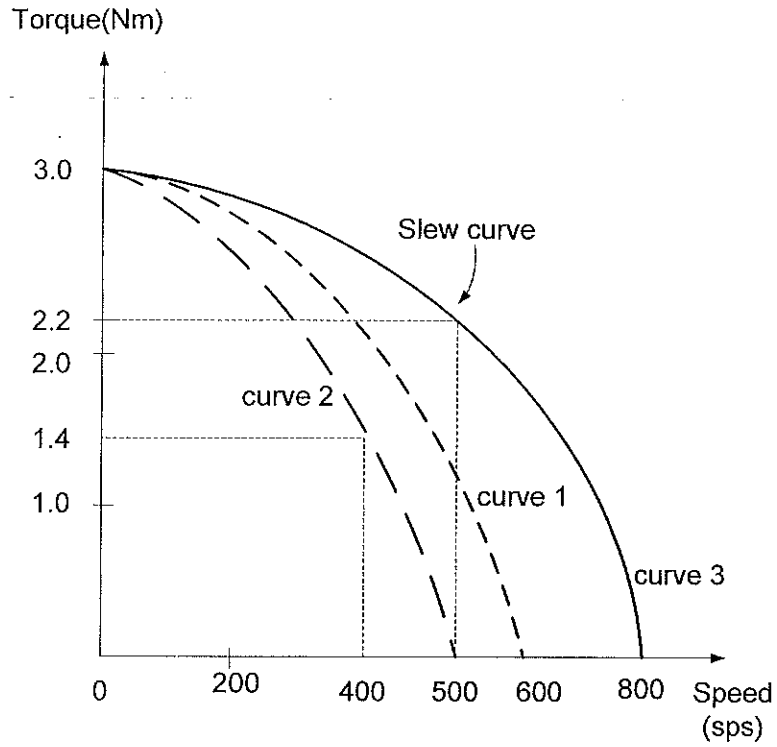

Figure Q1: start-stop and slewing characteristics of a typical stepper motor

Curve 1: Only stepper motor inertia,
Curve 2: Same conditions as curve 1 with additional load inertia,
Curve 3: Slewing curve)

Question 7

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) Three phase 100 MVA, 11 kV, 50 Hz cylindrical rotor synchronous generator has the following parameters in usual notation:

X_d=1.40 pu	T_d'=0.50 s
X_d'=0.25 pu	T_d''=0.02 s
X_d''=0.20 pu	T_a=0.17 s
X_q''=0.20 pu	

The generator is equipped with a circuit breaker that operates after 6 cycles following a short circuit fault.

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. **[4 marks]**

ii. Determine the maximum likely per unit rms current that the breaker would interrupt **[6 marks]**

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

Question 8

a) Draw a block diagram of the complete speed control system for a sinusoidal brushless DC motor and briefly explain its operation. **[4 marks]**

b) List basic differences between the trapezoidal and sinusoidal BLDCMs. For what type of application is the sinusoidal BLDCM better? **[4 marks]**

c) A trapezoidal BLDC motor has an armature resistance of 0.6 Ω/phase and the voltage drop across conducting transistor is 0.7 V. Motor is operated in the bipolar mode. This motor runs at 2000 rev/m on no load drawing negligible current from 200 V DC input.

i. At what speed the motor run when loaded to 5 Nm torque. **[6 marks]**

ii. To what value should the input voltage be reduced to lower the speed to 500 rev/m for the same torque. **[6 marks]**