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June 08

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2008

EEE PART IV: MEng and ACGI

HIGH VOLTAGE TECHNOLOGY AND HVDC TRANSMISSION

Wednesday, 30 April 10:00 am

Time allowed: 3:00 hours

There are SEVEN questions on this paper.

Answer FIVE questions.

All questions carry equal marks.

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	B. Chaudhuri
	Second Marker(s) :	B.C. Pal

Answer any 5 questions out of 7

1. a) Explain how string efficiency can be improved using a grading ring.

[4]

b) The individual phase conductors of a three phase overhead line are suspended from the cross arms using suspension insulators each comprising of 4 units. The voltage across the second and third unit is 14.2 kV and 20 kV, respectively. Find the voltage between the phase conductors and the string efficiency.

[10]

c) A suspension insulator string comprising of 4 units has to be equipped with a grading ring such that the string efficiency is 100%. Find the line to pin capacitances required to achieve this in terms of the pin to earth capacitance C.

[6]

2. a) Explain why the formation of voids within the dielectric can be detrimental for HV cables?

[4]

b) Derive the expression for the variation of electric stress along the radial direction of a HV cable. Use this expression to find the optimum dimension in order to ensure the best use of the dielectrics of the cables.

[5]

c) A single core cable has a conductor of 10 mm diameter and two layers of different insulating materials, each 10 mm thick with relative permittivity 3.0 (inner) and 2.5 (outer). Decide whether it is safe to use a material of dielectric strength of 5 kV/mm for the inner layer of the insulation given the maximum voltage between the conductor and the sheath is 60 kV.

[11]

3. a) What is corona?

[2]

b) Explain why corona is self-checking?

[2]

c) Explain how the corona inception voltage depends on the polarity of the overhead HVDC line.

[5]

d) A porcelain bushing having relative permittivity $\varepsilon_r = 4.0$ is used to isolate the HV conductor of 3.0 cm diameter from the tank of a 33 kV (rms) three-phase transformer. The internal and external diameters of the bushings are 3.3 and 10 cm, respectively.

i) Determine whether or not the corona will be present in the air space surrounding the conductor.

[7]

ii) Would the situation be different if an oil filled bushing is used with oil having relative permittivity $\varepsilon_r = 2.5$?

[4]

4. a) What are the requirements for a surge arrester?

[4]

b) Why are arcing horns or rod gaps not the best option for diverting surges?

[2]

c) Explain the function of the ground wires on HV transmission lines.

[4]

d) Lightning strikes the ground wire nearby a 30 m high transmission tower. The lightning current is 15.0 kA, the surge impedance of the ground wire is 500 ohms, that of the tower is 125 ohms and the tower footing resistance is 10 ohms. Find the voltage that would appear across the line insulators after 0.2 μs from the lightning strike. The speed of propagation of the travelling wave through the tower can be assumed to be 3×10^8 m/s

[10]

5. a) What factors make the DC transmission a superior alternative over its AC counterpart?

[5]

b) What are the major applications areas for which HVDC transmission is considered?

[3]

c) A mono-polar DC line is operating at its rated voltage of 200 kV and rated current of 1 kA with an extinction angle of 15 deg at the inverter end. The line to line AC voltage is 176 kV at the rectifier end. The DC line resistance is 20 ohms and the commutating resistance at either end is 10 ohms. Calculate the reactive power at both ends assuming lossless 6-pulse bridge converters.

[12]

6. a) Explain the constraints on the variables used for the control of a HVDC system.

[3]

b) Explain the behaviour of a HVDC system following a fault in the link.

[3]

c) A 250 kV, 500 MW mono-polar DC link has the following parameters. Line resistance R_d = 10 ohms, commutating resistance, R_c = 6 ohms at either end. The rectifier is initially operating under CC control with α = 18 deg whereas the inverter is set a CEA control with γ = 15 deg. The minimum limit for the rectifier firing angle (α) is 5 deg and the current margin is set at 15%. Calculate the real and reactive power at either ends for a 20% drop in the AC system voltage at the rectifier end.

[14]

7. a) Explain which harmonics are likely to be present in the DC side for a bipolar HVDC system with two six pulse bridges connected to YY and YΔ transformer.

[4]

b) Explain the differences between voltage source converter (VSC) and current source converter (CSC) technologies used in HVDC transmission.

[5]

c) What is the main advantage and application area of VSC technology over CSC?

[4]

d) A six-pulse rectifier has a direct voltage output of 40 kV. The transformer leakage reactance is 10 ohms/phase. Calculate the power delivered by the rectifier for a firing angle of 15 deg with the AC side line to line voltage at 70.7 kV.

[7]