UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: November 2017

Module Number: EE8301 **Module Name: High Voltage Engineering**

[Three Hours]

[Answer **all questions**, each question carries 12 marks]

Q1. a) Explain how the constructional features of the Dryformer help to achieve superior performance.

[2.0 Marks]

b) Discuss Ferroresonance in high voltage power system and stress imposed by it on insulation.

[3.0 Marks]

c) Voltage dividers used in high voltage measurements consist of resistors or capacitors or a convenient combination of these elements. Explain why inductors are not used for this purpose.

[1.5 Marks]

d) Discuss the effect of capacitance to earth on the accuracy of Schering's bridge and how Wagner's earth can be used for eliminating stray capacitance to earth of high voltage Schering's bridge.

[3.0 Marks]

e) Explain the extra precautions required to ensure the accuracy of high voltage resistance divider.

[2.5 Marks]

Q2. a) Show that for a surge travelling along a transmission line

$$v + Z_0 i = 2v^+\left(t - \frac{x}{u}\right)$$

$$v - Z_0 i = 2v^-\left(t + \frac{x}{u}\right)$$

where, Z_0 – The characteristic impedance of the line, v – Voltage associated with the travelling surge , i – Current associated with the travelling surge, $v+$ – Forward voltage associated with the travelling surge , $v-$ – Reverse voltage associated with the travelling surge , x – Distance from the origin and u – Velocity of the surge.

Thereby deduce that for forwarding wave, $v + Z_0 i$ is equal to a constant and for reverse wave, $v - Z_0 i$ is equal to a constant.

[3.0 Marks]

b) Explain the Bergeron diagram method using the results in part (a).

[3.0 Marks]

c) Draw the Bergeron diagram (wave plan) for a constant voltage source V_0 with internal resistance R_0 terminated by a resistor at the other end of a lossless line. Assume that the line is dead before switching the voltage source. Also plot the voltage at each end against time.

[6.0 Marks]

Q3. a) What are the typical recommendations that can be obtained from an Insulation Coordination Study?

[3.0 Marks]

a) A linear ramp type surge is approaching a transformer. Break down voltage of the insulation of the transformer behave with respect to time as below

$$V_{bt}(t) = 1000\,(e^{-1.5t} + e^{-20t})$$

The air gap type surge protection devise used for protecting the insulation has below characteristic for break down voltage.

$$V_{ba}(t) = \frac{100}{t - 0.1} \qquad t > 0.1$$

All times are measured in microseconds (μs) and voltages are in kilo volts (kV)

i. Describe what is meant by critical slope of the incoming surge.

ii. Calculate the critical slope.

[6.0 Marks]

b) Explain the necessity of air gaps in SiC surge arresters and why such gaps are not needed for ZnO surge arrestors.

[3.0 Marks]

Q4. a) Discuss the necessity of Flexible AC Transmission Systems (FACTS).

[3.0 Marks]

b) A series compensated transmission line is shown in Figure Q4. The compensator $V_{ss'}$ which is generating voltage phasor $V_{ss'}\, e^{j\beta}$, is located very close to end A. Assume that line impedance can be lumped to a series inductor X. Active power P, reactive power Q, and voltage V at various points of the system are shown in the figure. Show that

$$(P_s - P_{sn})^2 + (Q_s - Q_{sn})^2 = \left(\frac{V_s\, V_{ss'}}{X}\right)^2$$

where P_{sn} and Q_{sn} are the active and reactive power transferred along the line when the compensator $V_{ss'}$ is not installed.

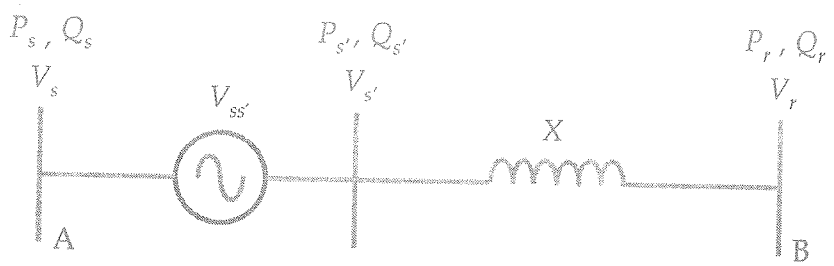

Figure Q4

[9.0 Marks]

Q5. Using Electro-geometrical method of lightning protection:

a) Draw a diagram showing the most vulnerable area of a phase conductor for a lightning when the tower has shielding wire at the top. Clearly show the shielding angle of the tower.

[2.0 Marks]

b) Explain the boundaries of the areas identified in part (a).

[2.0 Marks]

c) Power transmission tower shown in Figure Q5 has H=30 m and h=25 m. Calculate the shieling angle θ. The striking distance of the lightning is 50 m. Prove any formula you use.

[6.0 Marks]

d) What are the assumptions you made in part (c)?

[2.0 Marks]

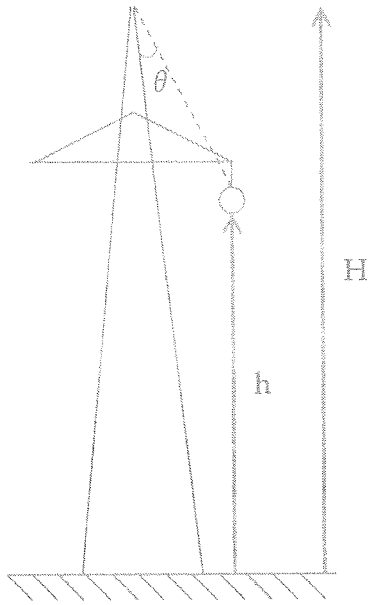

Figure Q5