UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Electrical, Electronic and Computer Engineering
ENEL4HA - High Voltage 1

Main Examination
31 May 2014

Instructions

- Answer all questions and show all working.
- Time allowed = 2 hours
- Full marks = 80

Question 1

A coaxial busbar has an inner conductor with a radius of 10 mm and an outer conductor with an internal radius of 60 mm. The system is filled with SF6 at 2.5 bar.

- Estimate the breakdown voltage given that breakdown occurs when the field exceeds 8.9×10^6 V/m/bar.
- Show how you would determine the breakdown voltage more accurately using the streamer breakdown criterion. Explain the difference in accuracy.

Electric field in a coaxial system:

$$E = \frac{V}{r \ln \frac{R_o}{r_i}}$$

Streamer breakdown criterion:

$$\int (\alpha - \eta) dx = 18$$

Ionisation and attachment coefficients for SF_6 are:

$$\alpha - \eta = 0.028E - 249 \times 10^3 p$$

[15 Marks]

Question 2

Two of the breakdown mechanisms in liquid dielectrics are suspended particle breakdown and cavity breakdown. Given the equations

$$F = \frac{1}{2} r^3 \frac{\varepsilon_2 - \varepsilon_1}{2\varepsilon_1 + \varepsilon_2}$$

$$E_b = \frac{3E_0}{\varepsilon_{liquid} + 2}$$

Briefly describe each breakdown mechanism [If necessary use clear sketches to aid your answer].

[10 Marks]

Question 3

The Cockraft-Walton generator is a method to multiply the voltage in stages. If the DC generator is supplied by an AC voltage with a peak value of V_{max} and a frequency of 50 Hz.

- Sketch a 3 stage generator. Clearly label the components and illustrate the charging and smoothing columns.
- Using a sketch, describe how the output equates to $6V_{max}$ when there is no load connected. Clearly indicate the stage voltages for the charging and smoothing columns.
- For a connected load there will be a voltage drop V_0 and a ripple δV. Sketch the expected waveform and use it to define these parameters.
- Show that the ripple voltage is given by $\delta V = \frac{I}{2f}\left(\frac{6}{C}\right)$ and hence determine the ripple if the capacitors for a 400 kV generator are equal to 0.1 μF and the load is 500 MΩ.
- Describe which capacitors are most responsible for ripple.

[25 Marks]

Question 4

A 19/33 kV single core XLPE cable has a length of 2 km and a capacitance of 0.325 μF/km. Determine the charging current at power frequency for testing at $2U_0$ as well as determine the required power rating of the source transformer. Compare this to the power required by a 0.1 Hz VLF source and a 50 Hz series resonant source where resistance is 200 Ω.

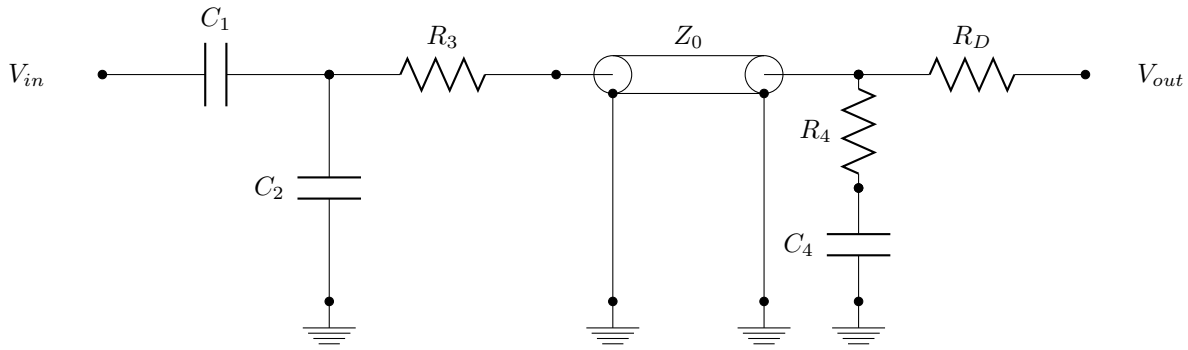
Capacitor voltage for a series resonant circuit:

$$V_c = \frac{V}{\omega RC}$$

[10 Marks]

Question 5

The divider below is to be used to measure both power frequency and VFTs up to 400 MHz in a section of 400 kV GIS busbar.



- Describe VFTs.
- Name the divider, list each component and explain its role.
- Derive a suitable design equation by considering the high frequency and low frequency division ratios.

Given the following information determine R_3 and C_4.

Anticipated peak VFT	2pu
Output V	200 V
C_1	2 pF
Cable Z_o	50 Ω
Cable l	5 m
Cable C_k	80 pF/m
$R_4 = R_D$	50 Ω
C_2	225 pF

[20 Marks]