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Department of Electrical Engineering and Automation,

Aalto University

ELEC-E8409 - High Voltage Engineering

Final Exam- December 9, 2019

INSTRUCTIONS:

- A formula sheet will be provided during the exam.
- Answer ALL the questions.
- State clearly Any assumptions made.
- Total Marks: 100 + 10 (Bonus).

Part 1: Quick Questions. (Bonus: <u>10</u> Marks)

1) True or False? In relatively clean and homogenous liquids, the breakdown mechanism is similar to breakdown in gas.
   a. True   b. False

2) True or False: Flashover forms a highly conducting channel bridging the electrodes.
   a. True   b. False

3) In lightning impulses, what does 1.2/50 μs mean?.
   a. The lightning period is 0.24 μs b. Time to half value is 50 μs

4) Cables with LC or TLC responses:
   a. Should be replaces immediately   b. Can remain in service for several years

5) What can be the cause of damage in the following figure:
   a. Water treeing   b. birds

Part 2: Definition and concepts. (<u>45</u> Marks)

D1. What are the breakdown mechanisms in solid insulations? i) Name at least five of the mechanisms, ii) mention the fastest and slowest mechanism (out of your list), and iii) explain one of them in detail. (<u>10</u> Marks)

D2. Describe the streamer breakdown mechanism using a sketch if necessary. (<u>7</u> Marks)

D3. Describe the differences between lightning ad switching impulses using impulse curves? (<u>3</u> Marks)

D4. What are the different ways of determining the distribution of electric field in an insulating structure? Name at least four and explain one of them in detail. (<u>8</u> Marks)
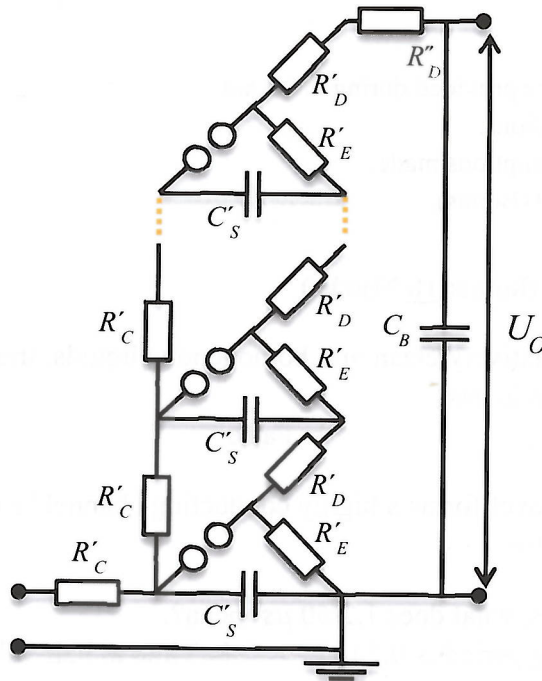
D5. Please provide detail explanations regarding the following figure, e.g., for what application(s) it is used, how it works, and how the U_0 is obtained? (12 Marks)

D6. What are the common methods to measure the partial discharge? Name three methods and explain one of them in detail. (5 Marks)

Part 3: Problems. (<u>55</u> Marks)

P1. Given the following data, compare the maximum electric field in Plane-, Cylinder-, and Sphere-based insulators. Provide your interpretation about the obtained results. (<u>15</u> Marks)

Insulation material: Mika with permittivity 3

Distance between the electrodes: 150 mm (the inner and outer radiuses are 50 and 200 mm, respectively).

Applied Voltage: 150 KV

P2. In the following figure, find the output potential at the green-circled point. (<u>20</u> Marks)

$Z_2=30$ $Z_1=145$ $Z_0=1$ $Z_1=145$ $Z_2=30$

$\bar{\tau}_2\,\bar{\rho}_2$ $\bar{\tau}_1\,\bar{\rho}_1$ $\bar{\rho}_1\,\bar{\tau}_1$ $\bar{\rho}_2\,\bar{\tau}_2$

$\bar{\rho}_3\,\bar{\tau}_3$ $\bar{\tau}_3\,\bar{\rho}_3$

t1 t2 t3

$\dot{D}_2$ $\dot{D}_1$
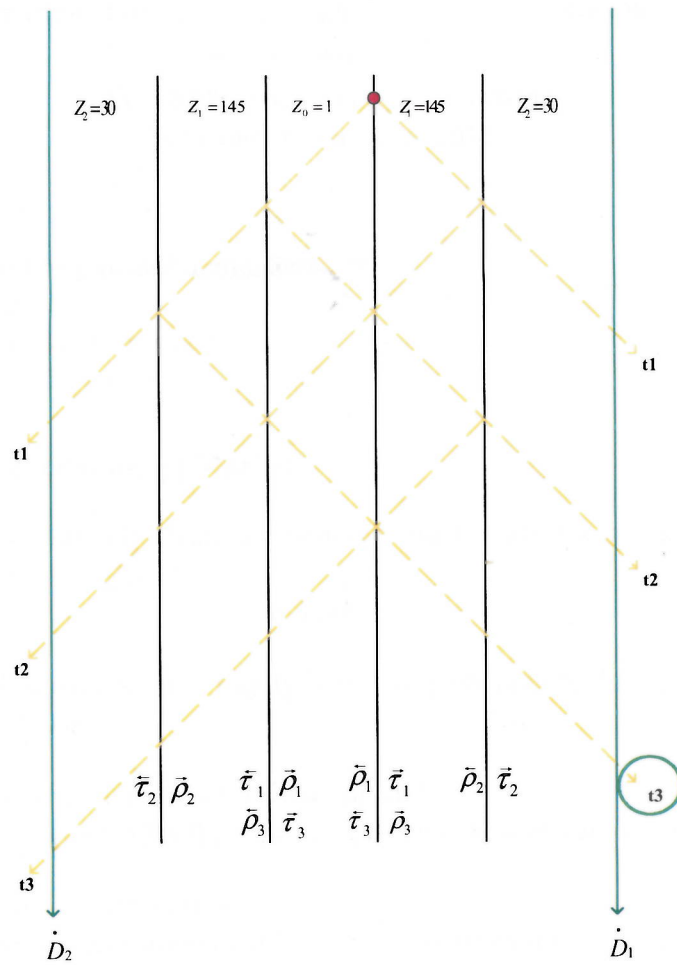
P3. Assuming that the protective device T is at a distance D of the arrester A, a **2250 kV/ μs** steep propagating wave is approaching a transformer along a 123 kV line. The voltage **withstand level** of the transformer is **500 kV**. The arrestor is located **10 m** away from the transformer and has a **protection level** of **400 kV**. **Voltage drop** caused by joint and earthing coupling (d_1, d_2) is assumed to be **25 kV**. Calculate the effective protection level and interpret the result. In case the protection level is not OK what is your most economical recommendation and how it affects the results? (<u>20</u> Marks)