Exercises on High Voltage Engineering (April 10, 2025)

Lecture 8: Liquid and Solid Dielectrics (3)

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**Exercise 4-15: 高压单芯电缆共 20m，**𝐭𝐚𝐧 𝜹=𝟎.𝟎𝟎𝟓**，**𝝐𝒓 =𝟑.𝟖**，现其中有 1m 因发生局部损坏，该部位的**𝐭𝐚𝐧 𝜹**增至 0.05，**𝝐𝒓**基本不变，问这时电缆的**𝐭𝐚𝐧 𝜹**应为多少？**

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**Exercise 4-17: 什么是固体电介质的累积效应？**

Under extremely non-uniform electric fields and impulse voltage, a noticeable partial breakdown phenomenon occurs in dielectrics. The effect where this partial breakdown leads to a gradual decline in insulation performance is called the cumulative effect.

**Exercise 4-20: 请定性论述外施电压下固体电介质的热击穿过程。**

Due to dielectric losses, solid dielectrics gradually heat up under an electric field. The temperature rise reduces the resistivity of the dielectric, leading to increased current and further escalation of resistive heating.

While the dielectric continuously generates heat, a simultaneous heat dissipation process occurs through the electrodes and surrounding dielectric material.

If heat generation exceeds dissipation, the dielectric’s temperature will rise uncontrollably, eventually causing thermal decomposition, carbonization, and final breakdown.

**Exercise 4-21: 纯净液体电介质的电击穿理论和气泡击穿理论，二者本质上的差别在哪里？**

Electronic Breakdown Theory posits that electrons generated in liquids (e.g., via field emission under high electric fields) are accelerated by the electric field, causing collisional ionization with liquid molecules. The process occurs in three stages: Initial ionization phase (seed electron generation), Streamer development phase (formation of ionized channels), Final breakthrough phase (streamer bridging the entire gap).

Bubble Breakdown Theory attributes breakdown to gas bubbles formed in liquid dielectrics due to various factors. Under AC conditions: The electric field distribution in series dielectrics is inversely proportional to their permittivity (ϵᵣ). Bubbles (ϵᵣ ≈ 1) experience a higher field strength than the surrounding liquid (ϵᵣ > 1). Since gases have lower dielectric strength, bubbles ionize first. The ionized gas heats up, expands, and further decomposes the liquid into additional gas. If ionized bubbles accumulate and form a conductive channel, breakdown occurs along this path.

Electronic breakdown: Direct ionization of the liquid itself.

Bubble breakdown: Ionization is initiated within pre-existing bubbles.

**Exercise 4-27: 对耐热等级是 A 级的绝缘材料，使用时有什么限制或要求？**

The maximum operating temperature should not exceed 105°C under normal conditions.

If the temperature reaches 113°C, the service life will be reduced by half.

**Supplementary Exercise 1:** There is a capacitor with the capacitance *C*=2000 pF and tan*δ*=0.01, with the insulation resistance of 2000 MΩ under DC, find:

1. Power loss at 100 kV (RMS) under power frequency;

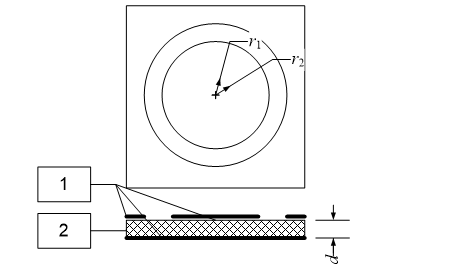
2. Loss at 100 kV DC, and its ratio to the loss under AC;

3. Equivalent resistance in the parallel equivalent circuit of dielectric losses under AC, and its ratio to the DC insulation resistance.

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**Supplementary Exercise 2:** When measuring the *ε*r and tan*δ* of polyethylene, the sample is the same as when measuring *ρ*V, as shown in the figure. The thickness of the flat sample is 2 mm, and aluminum foil electrodes can be attached with Vaseline, with a total Vaseline layer thickness of about 0.05 mm. The electrical properties of polyethylene are: *ε*r = 2.3, tan*δ* = 2×10-4. If Vaseline with *ε*r = 2.2 and tan*δ* = 2×10-3 is used and it is dirty, causing increased losses, what measurement error does this lead to?



1 - Aluminum foil electrode; 2 - Dielectric

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**Supplementary Exercise 3:** Assume an indoor bushing uses wound insulation and a conductor rod (radius *r*1 = 1 cm), with the same inner radius of the insulation as the conductor radius, an outer radius *r*2 = 7 cm, and a flange length *l*f = 20 cm. Power frequency voltage is applied to the bushing.

1. Where might sliding discharge occur first in this insulation structure?

2. To improve the performance of the bushing, 5 layers of concentric cylindrical electrode plates are installed inside. The setting method is to make the thickness of each insulation layer equal, and the potential difference between the electrodes of each layer of insulation is also equal. Try to calculate the length and radius of these plates (the edge effects of the electrodes are ignored).

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