**Exercises on High Voltage Engineering (March 27, 2025):**

**Exercise 3-12:** What is the main factors influencing insulator’s pollution flashover? Please describing the process of insulator’s pollution flashover.

Influencing factors: Atmospheric pollution leading to insulator surface contamination, climatic conditions causing the accumulated pollutants to become moist, and natural conditions such as altitude.

The specific process can be divided into the following five stages:

1. Early stage of contamination, where the voltage is uniformly distributed, and leakage current is present
2. Formation of dry areas, where the voltage is mainly applied to the dry areas, and the current decreases;
3. Formation of dry arc bands, leading to a significant increase in current;
4. Arc development, where the voltage is applied to the remaining contaminated layer, and the current increases;
5. Arc penetration through the electrode, completing the surface flashover.

**Exercise 3-13:** Why insulators of OHL in polluted area is more frequently looks like “burned” and flashover resulting power outage in fog, condensation or drizzle weather? but this phenomenon is rare in thunderstorm season?

Under humid climatic conditions, the contaminated layer becomes moist, and the electrolyte components in the pollutants dissolve in water, forming a conductive water film that generates leakage current along the surface.

Light fog, drizzle, condensation, melting snow, and melting ice, although they may not result in heavy precipitation, create a very damp environment. In such conditions, the contaminated layer becomes significantly moist but loses very little, making it one of the most dangerous weather conditions for surface flashovers.

Although thunderstorms also have a moistening effect on the contaminated layer, their cleaning effect is more pronounced. Therefore, from the perspective of surface flashovers, thunderstorms generally pose no significant threat.

**Exercise 3-14:** Why does power utility worry about the pollution flashover of insulators? What are the measures to increase the pollution flashover voltage of porcelain insulator?

Contamination and moisture on the surface of insulators is a common issue faced by all insulator strings over a large area. When flashover occurs on one insulator string, other neighboring insulator strings on the same line or in the same region tend to have similar contamination and moisture conditions, leading to a higher probability of flashover. Additionally, cleaning the insulator surface and restoring its insulation after a flashover is not a quick or localized task, meaning the impact range of surface flashover is large.

Measures:

1. Choose appropriate insulator umbrellas.
2. Ensure sufficient creepage distance.
3. Perform regular contamination cleaning.

**Exercise 4-1:** The basic types of dielectric polarization? What are their main features?

1. Electronic displacement polarization: The microscopic particles involved in polarization are electrons, present in all media. The time to establish polarization is very short. The degree of polarization depends on the electric field strength and is independent of the power frequency and temperature. It is an elastic polarization with no energy loss. The polarization phenomenon will disappear immediately once the external electric field is removed.
2. Ionic displacement polarization: The microscopic particles involved in polarization are ions, present in ion-structured dielectric materials. The time to establish polarization is very short. The degree of polarization depends on the electric field strength and is independent of the power frequency. However, it slightly increases with temperature (𝜖𝑟 generally has a positive temperature coefficient). It is an elastic polarization with no energy loss. The polarization phenomenon will disappear immediately once the external electric field is removed.
3. Orientation polarization: The microscopic particles involved in polarization are dipoles and ions, present in polar dielectrics and loosely structured ionic dielectrics. The time to establish polarization is relatively long. The degree of polarization depends on the electric field strength and is related to the power frequency (at higher frequencies, polar molecules cannot orient themselves quickly enough with changes in the electric field). The relationship with temperature is more complex (the degree of orientation polarization increases and then decreases with temperature). It is an inelastic polarization, where the orientation requires overcoming intermolecular forces, and the energy consumed in this process cannot be recovered. The polarization cannot be restored once the external electric field is removed.
4. Space charge polarization: This is formed by the movement of charged particles. The microscopic particles involved in polarization are more complex and present in various inhomogeneous engineering dielectrics. The time to establish polarization is long, and there is energy loss involved. The degree of polarization depends on both the electric field strength and temperature, but it can only occur at low frequencies. It is an inelastic polarization, and the polarization cannot be restored once the external electric field is removed.
5. Interface polarization of layered dielectrics: The microscopic particles involved in polarization are more complex and present in heterogeneous layered dielectrics. Other characteristics are similar to space charge polarization.

**Supplementary Exercise 1:** From the outdoor insulation experience of China's power grid in the past 50 years, what are the main factors that threaten the reliable operation of OHLs? And in recent 20 years, how the frequently experienced large-scale pollution flashover accidents effectively avoided?

Large-scale surface flashovers, lightning strikes on power lines, station misoperations, natural disasters, equipment failures in stations.

Measures:

1. Adjust the creepage distance according to the contamination zone classification and make appropriate adjustments for the contamination level.
2. Adopt new synthetic organic external insulation for transmission lines and substations on a large scale.

**Supplementary Exercise 2:** An 1000kV UHVAC OHL passes through the area with pollution Class d.

1. One suggests that U300BN disc porcelain insulator as shown in Figure 3-4(a) of the textbook should be used for suspension string. How many such disc insulators should be used per string? What is the total creepage distance per string, and what is the string length?
2. Other one suggests that the two parallel strings should be used for tension-string, and the alternating shed disc insulator (U840BP/300T) at the bottom of page 37 of the document 2024-3-28-1 is used. How many such disc insulators should be used per string? What is the total creepage distance per string, and what is the string length? What is the total weight of the paralleled string? (The parameters of this type disc insulator are: diameter *D*, installation height *H*, creepage distance *L* are 420mm, 300mm, 650mm respectively, and weight of single piece is 35kg)

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**Supplementary Exercise 3:** Compared with porcelain insulator, what are the advantages and disadvantages of silicone rubber composite insulator?

Advantages:

1. It has excellent hydrophobic migration properties, resulting in a high flashover voltage. The insulator string is shorter, with a smaller size and lighter weight.
2. Superior mechanical properties, good seismic performance, and strong impact resistance.
3. Stable chemical properties, excellent resistance to atmospheric aging, ozone aging, and electrical corrosion.

Disadvantages:

1. High cost, expensive to manufacture.
2. Composite insulators endure very little radial stress, so any radial load is prohibited when used on suspension-type high-voltage insulators, as it can cause breakage.
3. The umbrella part is made of silicone rubber, which is soft and easily damaged, compromising its sealing properties and reducing insulation performance. Therefore, it is strictly prohibited for hard objects to fall or rub against it.

**Supplementary Exercise 4:** According to the relation curve between HC6 hydrophobicity and surface pollution flashover gradient provided in Figure 3-28 of the textbook, if an 1000kV composite insulator is selected for pollution level of SDD = 0.12mg/cm2, what is the creepage distance (m) of the composite insulator (the pollution withstand voltage could be 80% of the pollution flashover voltage)? If the ratio of creepage distance to string length is 3.2:1, what is the string length (m) of the composite insulator?

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