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Mechanism and Effect of DC Charge Accumulation on SF_6 Gas Insulated Spacers

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Insulating ability may be reduced by the surface charge on a solid insulating support (spacer) in gas insulated equipment when it is subjected to prolonged dc stress. We studied the mechanism of the dc charge accumulation and its effect on the insulation characteristics, based on the experiment of various cylindrical model spacers and the numerical field calculation.

The features of the charge accumulation in our experiment are summarized as follows:

(1) Accumulation of surface charge is much more rapid than decay.
(2) The charge distribution has a close relation with the normal component E_n (gas side) of the electrostatic field on the surface of a spacer before charging.
(3) Charging is also influenced by the surface roughness.

The possible charging mechanism is as follows for our experimental conditions. In the early stage of voltage application, charge carriers are generated by field emission or microdischarge at highly stressed parts of the surface of a spacer and/or an electrode. It is also possible that minute dust particles floating in the gas space act as charge carriers. They drift along electric lines of force and accumulate at the end of the lines if it is on the space surface. If the resistivity of the spacer were infinitely high in both bulk and surface, the charge accumulation would proceed to the condition of E_n = 0 owing to the natural ionization of SF_6 gas. This condition permits us to estimate the maximum charge density that accumulates on the surface.

The maximum charge density σ_m is calculated under the following boundary conditions on the spacer surface.

$$E_n=0 \qquad (1)$$

$$\epsilon_0 E_n - \epsilon_d E_{nd} = \sigma_m \qquad (2)$$

where suffix d indicates the values in the solid dielectric (spacer), and ϵ is the permittivity. Fig. 1 shows an example of the charge density distribution on the surface of a model spacer, measured after the application of dc voltage for 139 hours. The solid line in the figure designates the distribution of σ_m computed from the above boundary conditions (1) and (2). The measured charge density distribution is close to the estimated characteristic of the solid line.

The most severe situation occurs when the electric field due to the surface charge increases the maximum field of an applied voltage, as encountered at a polarity reversal or at a surge application in a reversal polarity. Fig. 2 compares switching impulse flashover characteristics for spacers with and without surface charge σ, represented as the maximum field strength without σ in an experimental arrangement. The flashover field strength is considerably lower, typically by 20 to 40%, for the case with σ than that without σ. The flashover voltage of a spacer with surface charge can be estimated by adding as vectors the two fields due to the surface charge and to the applied voltage. The lowest flashover value takes place when the surface charge is at maximum, that is σ_m for the condition E_n = 0. The solid line in Fig. 2 indicates the lowest flashover field strength thus numerically computed for a spacer with σ_m. In conclusion, it is possible to estimate the lowest flashover value, that is in the safest side,'only from numerical field calculations.

Because, according to our study, charge accumulation is due to the normal component of electric field on the surface, a spacer profile with no normal component on its whole surface is considered to show little or no surface charging. We shaped an anticharging spacer profile, the surface of which coincide with electric lines of force. Practically no charge accumulation was observed for this spacer except for near the ends after prolonged dc stress, and it showed scarcely any reduction of the insulating ability.

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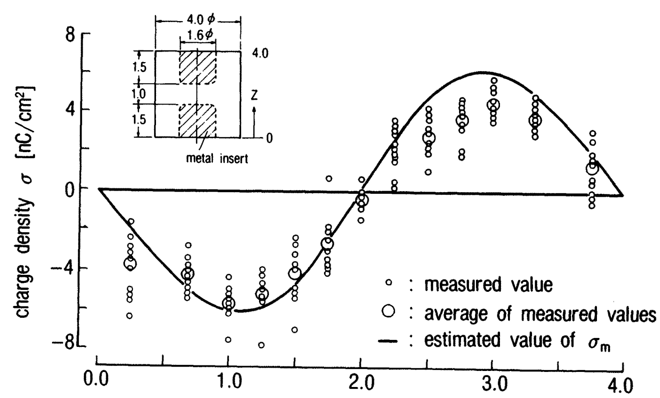

Fig. 1. Charge density distribution after long application of dc voltage (−200 kV, 139 hours, SF_6 0.3 MPa)

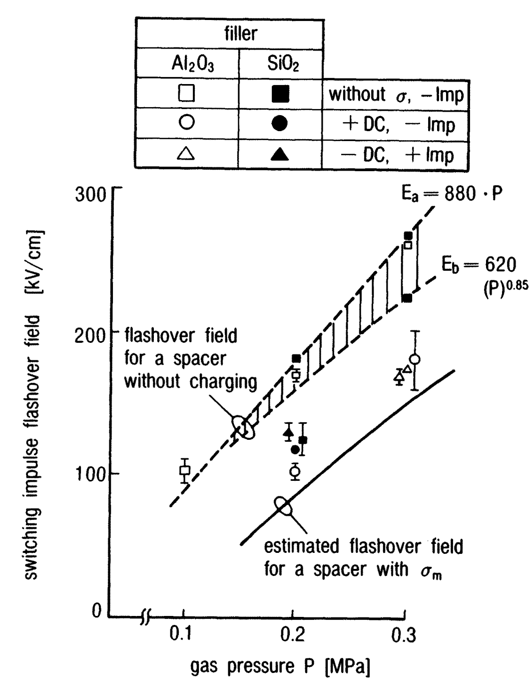

Fig. 2. Comparison of flashover field for spacers with and without surface charge