SF6 가스중의 연면형상이 입자오손 파괴 전압에 미치는 영향

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Influence of Surface Shape on Particle-initiated Breakdown in SF_6 Gas

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Abstract

Surface breakdown characteristics are investigated under metallic-particle contaminated conditions in SF_6 gas. The main results show that a rib increases breakdown voltage by a corona stabilization effect and the elongation of discharge path. The breakdown voltage at higher pressures than 4 atm may be estimated on the basis of mean breakdown field strength(E_{BD}) and discharge length(L) which depend on gas pressure and surface shape.

1. Introduction

In practical power systems, ideal conditions never exist and any insulation gas will have certain impurities. The influence due to a metallic-particle attached on the spacer is remarkable in the decreasing of the dielectric strength of SF_6 gas insulated apparatus.

In relation with this problem, a number of investigations on factors which affect, or have been suspected to affect, the breakdown voltage in clean or particle-contaminated condition have been carried out [1-4].

In the present study, flashover characteristics along the insulator surface were investigated by varying the surface shape with a rod-plane electrode under metallic-particle contaminations in SF_6 gas.

2. Experimental method

The experiments were conducted by using a test chamber Φ50cm × 150cm volume in which electrode system in Fig.1 was installed with SF_6 gas at room temperature under 0.5-8 atms in pressures(P) after being evacuated to about 1 Pa. The distance between two electrodes is 30mm. Rod electrode with 1mm diameter and a hemi-spherical cap is cylindric type. A particle of 5mm length and 1mm diameter is located apart 1mm from positive or negative electrode, or on the top of rib. Their positions are denoted as A, B and C respectively. The applied voltage is dc with positive polarity.

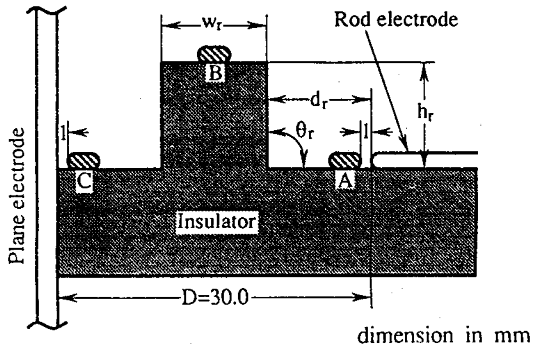

Fig.1 Electrode arrangement and shape of a rib (dimension in mm)

3. Experimental results and discussion

3.1 Surface effects on breakdown voltage without particle

According to Fig.2, in the region of 0.5 to 4 atm, the breakdown voltage with a plane-shaped surface is almost the same as that without the surface. This means that the space charge deposited on the surface parallel to the electric field influences the discharge propagation but has very little effect on the breakdown voltage.

At pressures higher than 4 atm, the mean breakdown field strength E_{BD} can be obtained by using the measured breakdown voltage V_{BD} as follows. For the clean SF_6 gas without the insulator,

$$E_{BDg} = 1.3 + 0.25P \text{ (kV/mm)} \quad (1)$$

and with the plane insulator,

$$E_{BDs} = 1.6 + 0.17P \text{ (kV/mm)} \quad (2)$$

where P is gas pressure in atm.

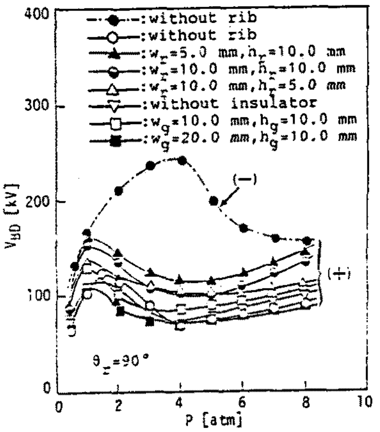

Fig.2 V_{BD}-P characteristics in the absence of particle

3.2 Rib effects on particle-triggered breakdown

It is considered that the rib influences the breakdown characteristics through the following phenomena:

(a) ionization by a local field enhancement[m=E/(V/D) > 1] on the surface, where E is electric field strength; V and D are applied voltage and gap distance respectively.

(b) barrier effect, and

(c) the space charge effect by the charge accumulated on the rib sides.

With regard to the item (a), the effect of maximum field enhancement (m_{Tmax}) on breakdown voltage is small as explained in previous section. It is known from the electric field that the smaller w_r gives the smaller m. The experimental results in Fig.3 show that a smaller w_r is effective in the increase of breakdown voltage.

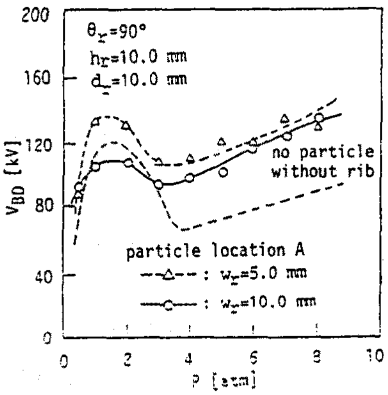

Fig.3 Influence of rib width on V_{BD} - P characteristics

Since the effect of the item (c) is small for P > 4 atm, the effect of item (b) on the characteristics of V_{BD} - P can be examined independently by varying the rib height in this pressure region. The observations of Fig.4 give that the item (b) is effective for increasing the breakdown voltage for P > 4 atm. For a high rib, the discharge from the rod electrode is interrupted by the barrier effect of a rib. With the elongation effect of surface distance by a rib, the breakdown voltage for P = 8 atm was estimated taking into account the preceding E_{BD} and the discharge path in Fig.5 and Table 1. Denoting the length of the discharge path as L (mm) and using Eq.2, the breakdown voltage V_{BD} is represented as follows:

$$V_{BDcal} = E_{BD} \times L = (1.6 + 0.17P)L \text{ (kV)} \qquad (3)$$

where L is the length of the discharge path in mm and P is pressure in atm.

It is shown in Table 2 that calculated breakdown voltages agree very well with experimental ones.

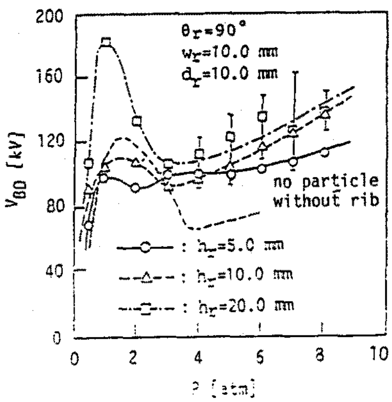

Fig.4 Influence of rib height on V_{BD} - P characteristics

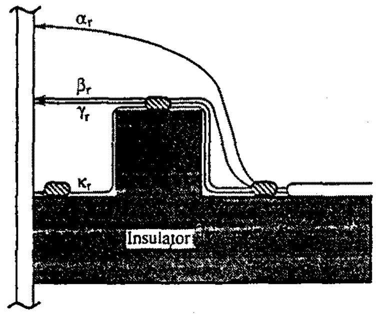

Fig.5 classification of discharge path

Table 1 observed results of discharge path for rib with varying particle location and gas pressure

Surface shape		Pressure (atm)	Particle position A	B	C
Rib	h_r=10.0 mm	1	α_r	β_r	α_r
	w_r=10.0 mm	4	γ_r	$\beta_r(\kappa_r)$	$\gamma_r(\kappa_r)$
	θ_r=90°	7	κ_r	κ_r	κ_r
	h_r=10.0 mm	1	β_r	β_r	$\beta_r(\gamma_r)$
	w_r=5.0 mm	4	β_r	β_r	γ_r
	θ_r=90°	7	$\kappa_r(\gamma_r)$	$\kappa_r(\gamma_r)$	$\kappa_r(\gamma_r)$
	h_r=5.0 mm	1	α_r	$\beta_r(\kappa_r)$	α_r
	w_r=10.0 mm	4	$\gamma_r(\beta_r)$	$\beta_r(\kappa_r)$	$\gamma_r(\kappa_r)$
	θ_r=90°	7	$\gamma_r(\kappa_r)$	$\gamma_r(\kappa_r)$	$\gamma_r(\beta_r)$
	h_r=10.0 mm	1	α_r	β_r	β_r
	w_r=10.0 mm	4	$\gamma_r(\kappa_r)$	$\gamma_r(\beta_r)$	β_r
	θ_r=60°	7	$\kappa_r(\beta_r)$	$\kappa_r(\beta_r)$	$\kappa_r(\beta_r)$

Table 2 comparision of calculated and measured values of breakdown voltage in SF_6 gas at 8 atm in pressure for particle location A

Rib condition			Discharge path		V_{BD} (kV)	
w_r (mm)	h_r (mm)	θ_r	Path	L (mm)	Measured (kV)	Calculated (kV)
5	10	90°	κ_r	50	148	145
10	5	90°	γ_r	40	118	114
10	10	90°	κ_r	50	148	142
10	10	60°	γ_r	53	157	171

According to experimental results shown in Fig.3, breakdown voltage increases with decreasing the rib width(w_r). This can be expected from the computed electric field enhancement factor along the insulator surface, as shown in Fig.6.

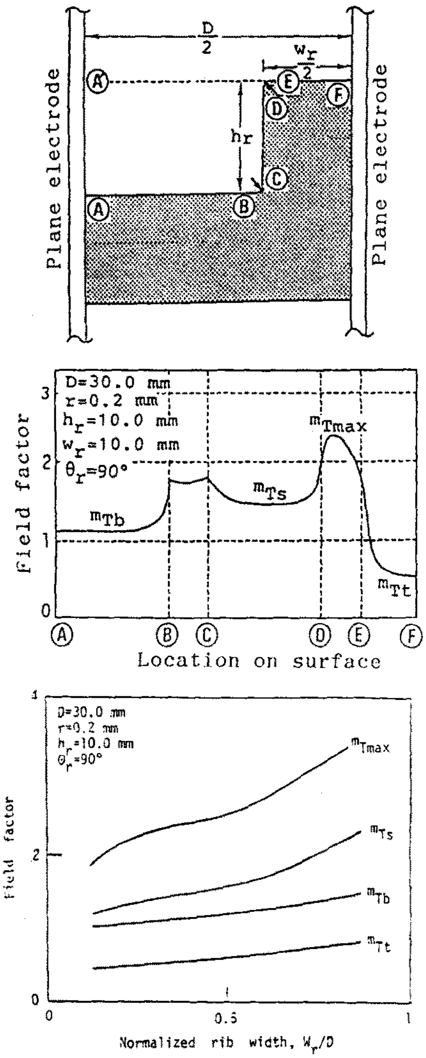

Fig.6 computed electric field along the insulation surfaces

4. Conclusions

The change in the surface shape is effective for controlling the local field enhancement along the its surface, and hence is considered to improve the withstand voltage under particle contaminated conditions. By varying the particle condition and surface shape with a rod - plane electrode, breakdown characteristics are investigated under metallic-particle contaminated conditions in SF_6 gas. Main results are summarized as follows.

(1) The rib increases breakdown voltage by charge accumulation action at lower gas pressures and by elongation of discharge path at higher gas pressures.

(2) The characteristics of breakdown voltage along the rib surface at lower pressure than 4 atm become complicated by rib condition and particle location and especially particle located near the positive electrode lowers the corona stabilization effect.

(3) Experimental equations of breakdown voltage(V_{BD}) and mean breakdown field strength(E_{BD}) with a rib at higher pressure than 4 atm can be represented as $V_{BD} = E_{BD} \times L$ [kV], and $E_{BD} = 1.6 + 0.17P$ [kV/mm], where L is length of discharge path in mm and P is pressure in atm.

(4) It is more effective for rising the breakdown voltage that the rib, if no puncture through it, is thin.

Reference

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