한국전기전자재료학회 춘계학술대회 논문집, 1995.

Dielectric Behaviors and Prebreakdown Phenomena of SF_6 Gas in Inhomogeneous Field Caused by a Conducting-Particle

Bok-Hee Lee, Gyung-Suk Kil, Chang-Jun Lee*

Department of Electrical Engineering
College of Engineering, Inha University
253, Yonghyun-dong, Nam-gu
Inchon 402-75, KOREA

Abstract

This paper deals with the dielectric characteristics of SF_6 gas stressed by non-oscillating and oscillating impulse voltages in inhomogeneous field perturbed by a fixed needle shaped-protrusion. The breakdown voltage-time characteristics were measured for both polarities and over the gas pressure range from 0.1 to 0.5 [MPa], and the temporal developments of the prebreakdown were observed. The dependence of the leader stepping time on the gas pressure were obtained.

1. Introduction

The sulphur-hexafluoride(SF_6) is a gas of wide spread use as the insulating and quenching mediums in high-voltage equipments, because of its high dielectric strength and excellent heat transfer properties. However, the dielectric strength of SF_6 gas stressed by FTOs is very sensitive to the local electric field disturbed by the surface roughness of conductors or conducting-particles.

In order to improve the reliability of GIS, the understanding of the breakdown phenomena of SF_6 gas and the detailed study for the influences of conducting particles on the discharge development are of great important[1][2].

The purpose of this work is to present informations on the dielectric characteristics and prebreakdown phenomena of the conducting-particle-initiated breakdown for the sake of the insulation and coordination in GIS.

The breakdown voltage-time characteristics and prebreakdown developments for both polarities were measured. In addition, the prebreakdown behaviors are discussed in detail based on the waveform of corona current pulses.

2.Experimental Apparatus and Procedure

The apparatus used here was designed to simulate the fast transient overvoltages that might be generated in GIS during the switching operation of disconnector, and was fabricated by real-sized GIS arrangement.

Fig. 1 shows a cross-sectional view of the experimental apparatus. The voltage applied to the test gap was measured by a conical type field probe[2].

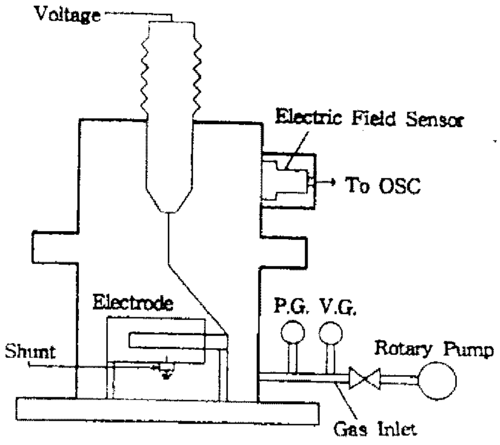


Fig. 1 Schematic diagram of the experimental apparatus

The test voltages were non-oscillating impulse of 1.7/44 [μs] and oscillating impulse voltage of 400 [ns]/1.14 [MHz]. A pair of coaxial cylindrical electrodes was mounted in the pressure vessel. The electric field of test gap was disturbed by a stainless steel needle-shaped protrusion on the earthside electrode. In order to minimize the displacement current, the needle-shaped protrusion was electrically isolated from the electrode.

The prebreakdown current was observed by a shunt of 50 [Ω]. The pressure vessel was evacuated to 0.13 [Pa] and then commercial grade SF_6 gas is filled.

3. Experimental Results and Discussion

3.1 V-t characteristics

Fig. 2 shows the V-t curves depending on the waveform of applied voltage for the positive and negative polarities. The V-t curves were depicted by taking the maximum voltage recorded prior to electrical breakdown, according to ICE standard 60.2. Also, Fig. 3 shows the breakdown points for oscillating impulse voltages in the positive and negative polarities. The majority of breakdowns occurs at the rising parts of oscillation and/or around the crests. The breakdown voltages of the negative polarity are higher than ones of the positive polarity, and the difference between the positive and negative breakdown voltages is prominent.

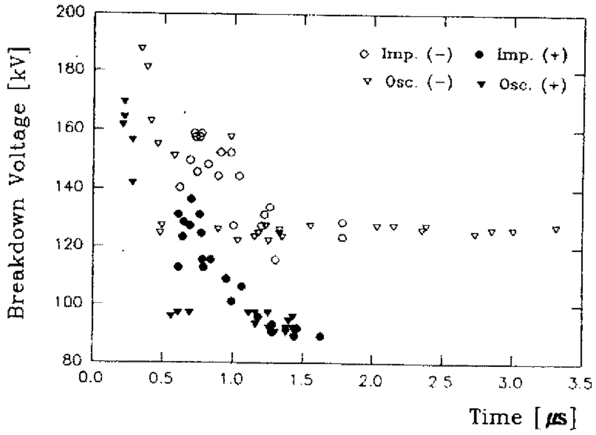
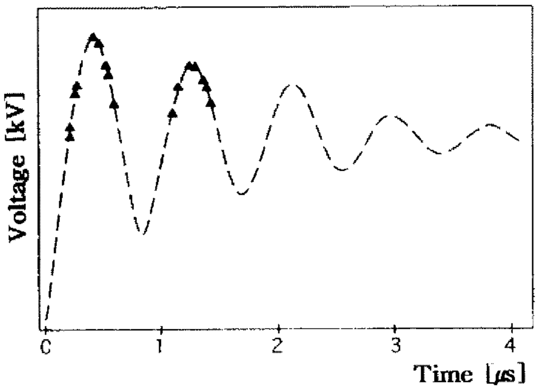
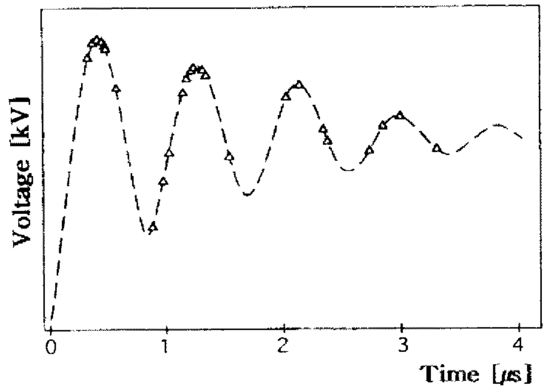


Fig. 2 Dependence of the V-t characteristics on the polarity of applied voltage

The time to breakdown in the positive polarity is on the whole shorter than that in the negative polarity. The result is attributed to a leader breakdown controlled by space charges due to the streamer corona. The prebreakdown developments strongly depend on the applied voltage waveform. The time-lag of electrical breakdown on the wave tail is mainly subject to the field stabilization due to space charges. An electrical breakdown at the falling and/or trough part of oscillation can only take place if the leader overcomes the reduction of electric field caused by the variation of the applied voltage and space charges. The prebreakdown development is interrupted as soon as the electric field is decreased by an oscillation of applied voltage. The consequence causes a long time lag between the leader steps. However, the prebreakdown development for non-oscillating impulse voltage is continuous and leads to an breakdown in the short time.



(a) Positive



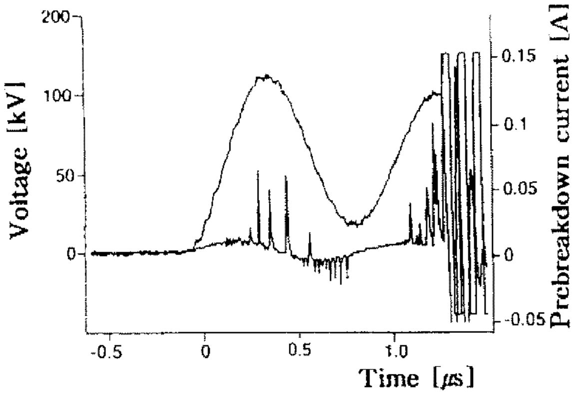
(b) Negative

Fig. 3 Breakdown Point

In addition, in case of oscillating impulse voltage the displacement current, which is due to the derivative of applied voltage and the capacitance between the leader tip and the opposite electrode, flows through the leader channel. This displacement current is decisive for the leader development and the subsequent breakdown.

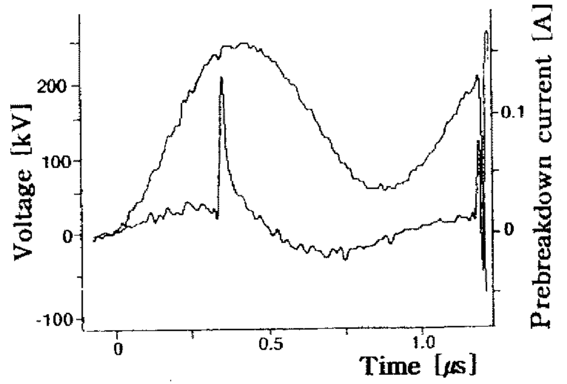
3.2 Prebreakdown phenomena

Fig. 4 shows the voltage-prebreakdown current waveforms for the positive and negative oscillating impulse voltages. The prebreakdown currents in the positive polarity are bipolar corresponding to the oscillation of applied voltage. The first corona at the rising part of applied voltage takes place in front of the needle-shaped protrusion and forms positive ion space charges. The positive leader then propagates with stepwise toward the opposite electrode. As the potential of the needle-shaped protrusion is decreased by the oscillation of applied voltage, there exists the potential difference between the needle-shaped protrusion and the positive space charges. This process reforms an electric field in the direction opposite to the leader development, and then the negative pulselike current flows.



Upper trace : Applied voltage [kV]
Lower trace : prebreakdown current [A]

(a) Positive



Upper trace : Applied voltage [kV]
Lower trace : prebreakdown current [A]

(b) Negative

Fig. 4 Voltage-current waveforms in the positive and negative oscillating impulse voltages for a gas pressure of 0.2 MPa.

The diffusing time of positive space charges determines whether a bipolar current flows or not. The bipolar prebreakdown current is mainly related to the oscillation frequency of applied voltage, gas pressure and gap geometry.[3] The negative prebreakdown current waveform is essentially similar to the positive prebreakdown current waveform. But after the appearance of strong corona current pulse, the leader is stopped, and a bipolar current is very faint.

The leader stepping time is required to create a new leader precursor and is strongly dependent on the gas pressure. Fig. 5 shows the relationship between the leader stepping time and the gas pressure in the positive polarity under the oscillating impulse voltage. The leader stepping time Ts decreases with increasing the gas pressure and its change is insignificant for gas pressure of more than 0.3 [MPa].

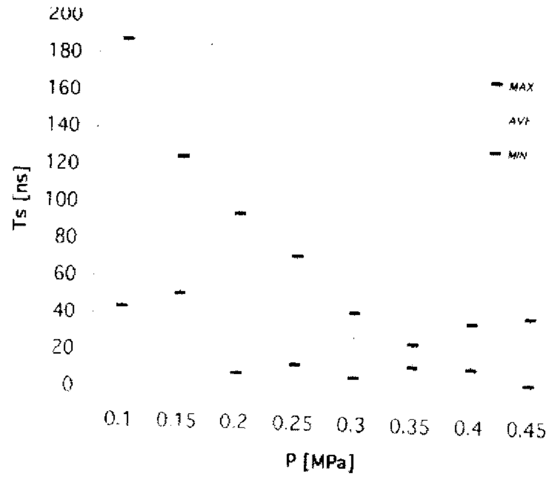


Fig. 5 Leader stepping times plotted as a function of gas pressure.

Irregularity of the leader stepping time Ts is prominent for lower gas pressures and exhibits the declining tendency as the gas pressure increases. In the range of lower gas pressures, the streamer corona current is more intensive and the probability of direct breakdown which indicates a space charge controlled streamer breakdown is increased. The leader propagation for a low gas pressure seems to be markedly influenced by the space charge effect due to streamer corona current level. As the gas pressure increases accordingly, the attachment coefficient of SF_6 gas is increased and the radial development of the streamer corona sheath is reduced, the stepwise leader is frequently propagated.

4. Conclusions

A single avalanche alone in inhomogeneous field contaminated by a conducting-particle is too weak to give rise to the electrical breakdown of the gas gap. The breakdown voltages of SF_6 gas in inhomogeneous field are noticeably influenced by the polarity of applied voltage and are caused by the different emission mechanism of initial electrons. Comparing breakdown voltages in the presence of the positive polarity between the data for the non-oscillating impulse voltage and that for the oscillating impulse voltage, there is little difference. However, it was found that the outstanding difference between the prebreakdown developments for non-oscillating and oscillating impulse voltages results from the space charge effects.

REFERENCES

[1] T. Kawamura, B.H. Lee, T. Nishimura and M. Ishii, "Breakdown Characteristics of SF_6 Gap Disturbed by a Metallic Protrusion under Oscillating Transient Overvoltages", Jpn. J. Appl. Phys., Vol.33, No.4A, pp.2043-2049, 1994

[2] B.H. Lee, T. Kawamura and M. Ishii, "V-t Characteristics of SF_6 Gap Disturbed by a Needle-Shaped Protrusion under Oscillating Transient Overvoltages", T. of IEE of Japan, Vol.114-B, pp.664-669, 1994

[3] S. Matsumoto, H. Okubo, H. Aoyagi and S. Yanabu, "Non-uniform Flashover Mehanism in SF_6 Gas under Fast-oscillating and Non-oscillating Impulse Voltages", Proc. of 6th ISH, Paper No.32-16, 1989.