Influence of Tank Inner Side Dielectric Coating on the Particle Behaviour and Flashover Voltage in SF_6 Gas Insulated System

Bang-Wook Lee and Ja-Yoon Koo

Abstract

In this work, the influence of wire type conducting particles on the insulation reliability of GIS has been systematically investigated when the epoxy resin based dielectric coating was made on the inner side of outer electrode. For this purpose, coaxial cylinder-type electrode was adopted in 362 kV chamber and various sizes of Cu conducting particle were used under different gas pressures. In order to elucidate the coating effect on the gas insulation, different thickness of dielectric coating has been considered and then the lift-off voltage and flashover voltages have been measured. The results show that the dielectric coating has a remarkable influence by restraining the movement of particle in GIS system, and thus GIS insulation reliability is noticeably improved.

I. Introduction

Since recent increase in high power demands requires rapid development of electric power apparatus, the progress of gas insulation system has been achieved in the past few years, for which various investigations have been carried out in many advanced countries for improving the reliability of the GIS equipment.

SF_6 gas has been usually used as a quenching medium for gas insulation due to its excellent dielectric strength and thermal recovery characteristics[1]. But, it is well pointed out that the presence of particles in gas insulation system could reduce dielectric strength of SF_6 gas as much as 70 % and finally flashover in the gas gap could be occurred. Particularly, the dielectric strength of GIS has been reported to be drastically reduced ascribed to the presence of free conducting particles[2, 3].

Therefore, in order to prevent the insulation failure caused by particle contamination, protection against particle contamination is required, at first absolutely, during the assembly process and on-site operation. On the other hand, unfortunately under the presence of particles, it is important to develop related technologies improving dielectric strength and particle detection including its evacuation.

Precedent technologies, for preventing particle contamination and deactivation, have proposed different counter measures such as modification of GIS inner structure to impede particle lift-off, dielectric coating onto the inner conductor, dielectric coatings on the inner surface of outer coaxial conductor, and installation of the particle trap to immobilize particle movement[4, 5].

If some particles are present inside the gas gap, their lift-off voltage could be raised by the dielectric coating on the surface of the inner tank. In this way, the reliability of GIS can be improved even under the normal operating voltage[4, 6].

With a view to elucidating the effect of dielectric coating to improve gas insulation strength in real scale, following investigations were conducted for this work.

- observation of flashover voltage of GIS when particle exists on the inner surface of the outer coaxial conductor
- analysis of particle behavior between bare conductor and coated conductor
- observation of the particle movement and its behavior under high AC
- investigation of the dielectric coating effect on the particle lift-off and gas gap breakdown

In order to bring our results to real industrial product, 362kV real scale test chambers were constructed into which coaxial cylinder type electrode was arranged and Cu conducing wire particles were put into the electrode gap. The experimental results show that the dielectric coatings on the outer surface of the inner tank play a remarkable role to restrain the movement of particles

Manuscript received March 21, 1997; accepted June 12, 1997.
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II. Experimental Set-Up

Fig. 1 shows the configuration of the coaxial cylinder-type electrode adopted in 362 kV chamber.

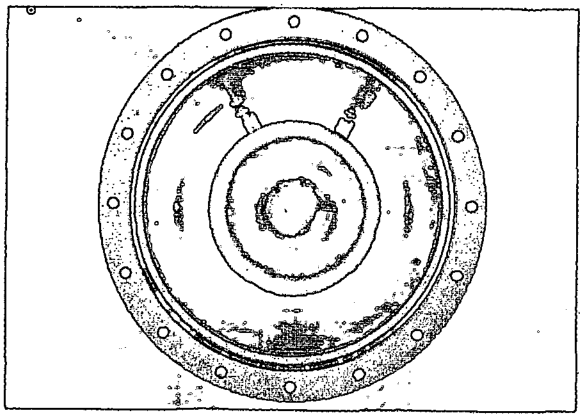


Fig. 1. Picture of the coaxial electrode in 362 kV chamber.

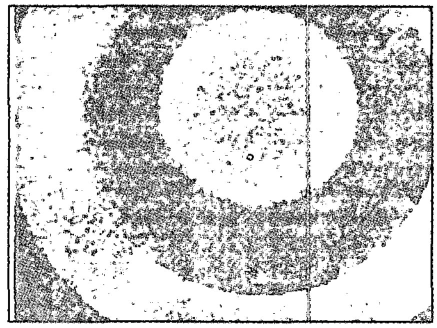
Various sizes of Cu conducting particles were 8 mm, 10 mm, 12 mm and diameter of particle was 1 mm. Ten particles for each respectively were laid on the bottom coaxial electrode. Different gas pressure was applied from 1 atm to 3 atm. In order to elucidate the coating effect on the gas insulation, different thickness of dielectric coating has been considered and then the lift-off voltage and flashover voltages have been measured by applying high AC voltage to the test chamber. Each epoxy coating thickness was measured as 12 μm (No. 1), 38 μm (No. 2), and 57 μm (No. 3) respectively and coating ratio was 1 : 3 : 5.

III. Results and Discussion

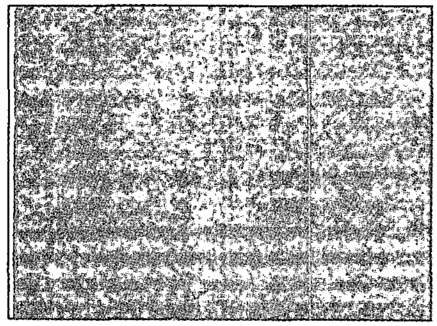
When AC source was applied to the test chamber, particle movement was observed by use of video camera, and the image of the particle movement was handled by means of computer system. With the increase in applied voltage, the vertical erection of particle on the bottom electrode was observed, and afterward particles slowly jumped longitudinally along the surface of the electrode. At the moment of contact of the particle tip with electrode, microdischarges are observed and intensified with voltage increase.

When the electrostatic force of particle seems to exceed the gravitational force, particles begin to lift-off from the electrode and traverse over the gap. Floated particles take flight up and down within the gas gap and finally reach to the inner electrode, taking place of the breakdown.

Based on our observation, microdischarge become stronger on the dielectric coated electrode than on the uncoated electrode, which may imply that dielectric strength decreases drastically between particle tip and coated surface.



(a)



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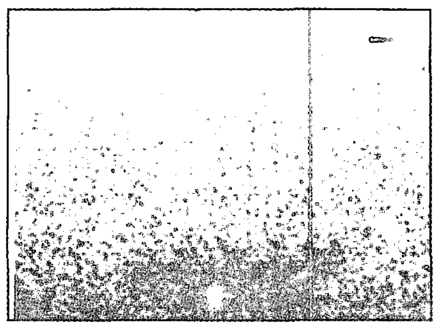

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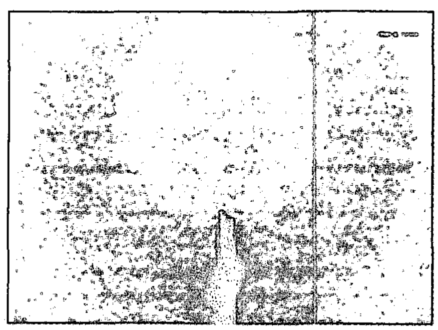

(d)

Fig. 2. Particle lift-off, microdischarge, flashover between the gas gap.

Fig. 2 shows some steps to particle initiated breakdown : (a) Particles were put onto the bottom electrode and (b) microdischarge was taken place due to the erection of the particle and then (c) microdischarge is intensified and (d) finally the flashover was observed by the particle lift-off.

The breakdown characteristic depending on the SF_6 pressure within the tank is shown in Fig. 3 in order to describe the difference between the epoxy coated electrode and uncoated one. Breakdown voltage was measured using 8 mm long wire particles put on the bottom electrode where various thickness of epoxy coating was made.

Based on these results, it could be pointed out that flashover voltage is improved by the dielectric coating and coating effect on the breakdown voltage is more pronounced with the increase in coating thickness.

The increasing ratio in breakdown voltage due to dielectric coating with respect to the bare electrode depends on the coating thickness such as 34 % with 12 μm, 40 % with 38 μm, 49 % with 57 μm.

Especially, corona stabilization effect has been observed throughout our experiments around 2 atm and became pronounced with increase in coating thickness. These results could be explained by the fact that coating seems to have a little particular relationship with corona stabilization. Because the particle tip could be enclosed by the corona stabilization effect and thus the space charge accumulation would be increased. Eventually the breakdown threshold could be increased.

Fig. 4 shows the breakdown voltage and lift-off voltage with various coating thickness as a function of gas pressure using 12 mm long wire particles that were put on the bottom electrode. Lift-off voltage is slightly increased with the increase in coating thickness, however its effect on the particle lift-off is not considerable. And lift-off voltage for the coated conductor is higher

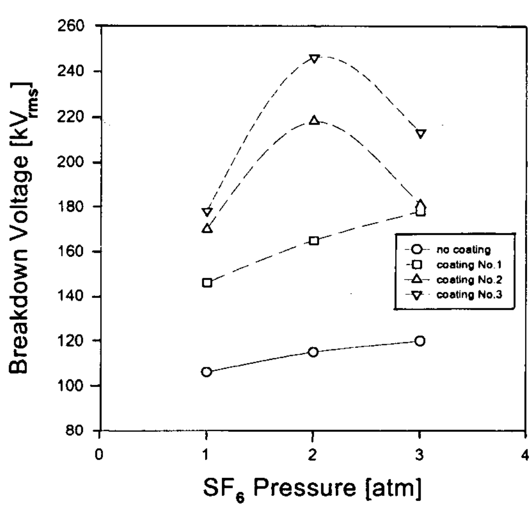

Fig. 3. Breakdown voltage when 8 mm conducting particle put on the bottom electrode.

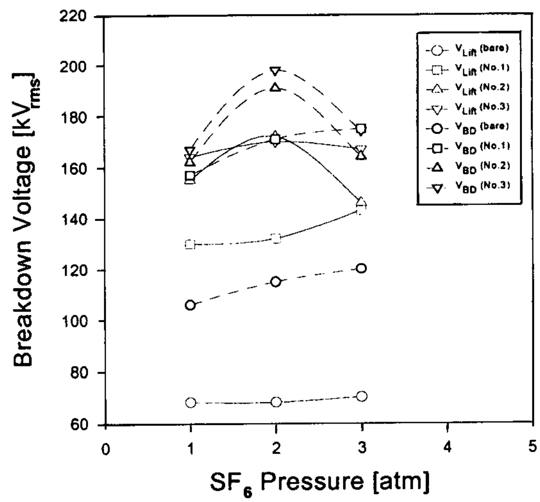

Fig. 4. Effect of coating thickness on breakdown and lift-off voltage when 12 mm particles were introduced.

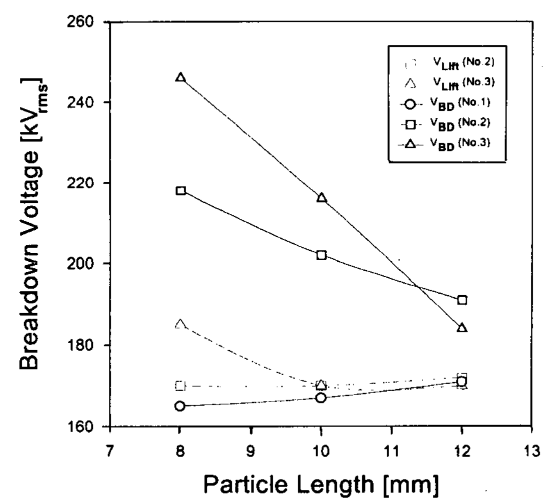

Fig. 5. Lift-off and breakdown voltage for different particle lengths (at 2 atm).

than that for the uncoated one.

At low gas pressure, considerable corona occurs at the contact point of the electrode with the particle, and sudden breakdown occurs without any lift-off of some particles, which could imply that particle could not acquire sufficient charges gradually due to dielectric coating layer.

Fig. 5 shows the lift-off and breakdown voltage for the various particle length at 2 atm gas pressure. Breakdown voltage is reduced by increasing particle length, whereas lift-off voltage does not change considerably.

In particular, with the coating thickness of 12 μm, lift-off voltage could not be observed. These phenomena could explain that attractive force of the particle is relatively weak than that with thick dielectric coating.

In Fig. 6, it is observed that the longer is the particle length, the lower is the breakdown voltage whereas for the same particle length, breakdown voltage is increased by increasing gas pressure. Furthermore, breakdown voltage is greatly improved for the thick dielectric coated electrode. But it is also noticed that dielectric coating effect for the short particle length is more significant than that for longer one.

Fig. 7 shows the influence of coating thickness on breakdown voltage for different particle lengths. Increase in dielectric coating thickness is observed to enhance breakdown voltage and coating effect at high gas pressure is more considerable than that for lower one, which may be explained by the suggestion that the microdischarge is considerably restrained by the increase in gas pressure.

Throughout our experiments for the dielectric coating effect on the gas insulation, several remarks have been deduced. Since the dielectric coating prevents the direct contact between bare electrode and conducting particle, particles could acquire less charges for its lift-off and thus particles should require much higher electric field to lift-off from the bottom electrode. As a consequence, the breakdown voltage is enhanced when the dielectric coating is applied [7]. In addition, electric field distortion caused by electrode surface roughness could be overcome by dielectric coating.

Regarding particle charging mechanism, a number of suggestions have been made as follows : conduction through the coating, charging by the contact with already charged dielectric surface, partial discharge between the particle and the coating. Throughout our results, it is likely that partial discharge between the particle and the coated electrode may be a principal cause related to the particle charging, for which elaborated works should be made.

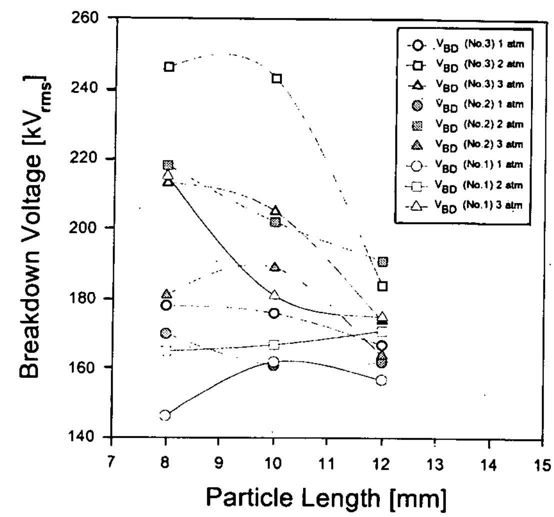

Fig. 6. Breakdown voltage with various particle lengths.

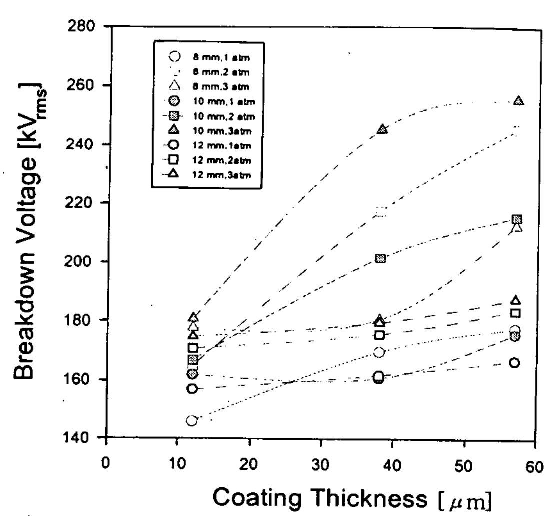

Fig. 7. Correlation between breakdown voltage and coating thickness.

Ⅳ. Conclusion

The influence of wire type conducting particles on the insulation reliability of GIS has been systematically investigated when dielectric coating by epoxy resin was made on the outer electrode. From our experiments, it can be deduced that

- Effect of coating thickness on the particle lift-off is not considerable.
- It is observed that GIS insulation strength increased with dielectric coating and coating effect is increased with increase in coating thickness.
- Coating effect is more pronounced at high pressure than lower one.

Based on these results, it is required, however, to clarify the particle charging mechanism and dielectric coating effect. Furthermore, application of dielectric coating to full size GIS is remained to be our future investigation.

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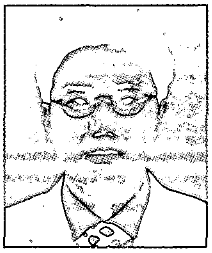

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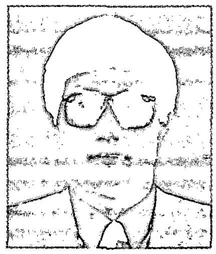

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