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Breakdown characteristics of SF_6 and Imitation Air in Temperature Decline

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Abstract

This paper describes experiments of the breakdown characteristics by temperature change of SF_6 gas and Imitation Air(I-Air) in model GIS(Gas Insulated Switchgear). From the results of the experiments, the breakdown characteristics classify the vapor stage of SF_6 according to Paschen's law, in which the stage of coexistence for gas & liquid of the voltage value increases. This results in large deviation and the breakdown of the voltage(VB) low stage as the interior of the chamber is filled with a mixture of SF_6 that is not liquefacted and remaining air that can not be ventilated. The ability of SF_6 liquid(LSF_6) insulation is higher than high-pressurize SF_6 gas. The VB of the I-Air decreases as the temperature drops and the VB also drops. It is considered that the results of this paper are fundamental data for the electric insulation design of superconductor and cryogenic equipment that will be studied and developed in the future.

Key Words : Imitation-Air, GIS, Phase transition, SF_6

1. INTRODUCTION

Modern society longs for the convenience of up-to-date technology. There currently are attempts at miniaturization and a high reliance on power equipment related to the effectiveness of urban area usage of space while at the same time requiring more electrical energy. As a result, transformer devices using a high pressure SF_6 gas with excellent insulation characteristics are increasing in use both domestically and internationally. Also, power equipment that uses the application of SF_6 gas is expanding in supply range and is even being installed in areas of severe cold.

Malfunctions are targeted as the biggest problem with this system because insulation characteristics can cause a huge change due to the depreciation of temperature resulting in liquefaction. Because of these reasons, it is necessary to research and develop the presently applied SF_6 gas in accordance with the ultra-high voltage era that is approaching.

As the interest in and restrictions on the environment is increasing, the issue of

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environmentally-responsible sources of power lay behind the Kyoto Protocol, which became officially effective(February, 2005) as regulations on greenhouse gases. The SF_6 gas currently being used in power equipment is harmless, extremely stable chemically and not only does it have far better insulation characteristics compared to other gases, it also has excellent arc cancellation abilities when used as an insulation material for most GIS that have been developed so far.

Since environmental issues are highlighted for SF_6, which is a typical greenhouse gas, research of dry-air is currently in progress as a substitute.

The purpose of this study is to provide data on designing insulation for power equipment by investigating the insulation characteristics of SF_6 and I-Air according to changes in pressure and temperature when there are certain amounts of gas in the chamber.

2. Experimental Procedure & Method

The exterior of the experimental chamber is as shown in Photo 1. This chamber was designed and produced to research the insulation characteristics of SF_6. The highest voltage allowed was AC 300[kV]. DY-106-Korea(AC 300[kV]/120[mA]) and (-)DC 300[kV](Pulse Electronic Eng. Tokyo; HDV-300 KIV-N) was used as the source of electricity. In order to observe the inner temperature of the experimental imitation chamber, a temperature sensor(-90~90 [℃]) was installed 8cm from the vertical central axis parallel to the electrode at the center of the experimental chamber interior. A pressure gauge(WISE, 0~15[atm]) was installed to measure the inner pressure of the chamber. The interior of the chamber can be maintained up to -68[cmHg] using a vacuum pump(SINKU KIKO Co., Ltd, GUD-050[A], pumping speed 60[ℓ/min]) and a vacuum layer was created between the interior and the exterior of the chamber for heat insulation. A window(diameter, 110[mm]; thickness, 20[mm]) was installed to allow the observation of the temperature sensor and the electrode installed inside the experimental chamber. The material for this window was transparent acrylic and was installed in a cylindrically-shaped space.

The main specification of the experimental chamber was such that it can withstand the pressurization of 10 Atmospheric Pressure to allow for pressure variation(2~8[atm]), and to maintain isolation within the experimental chamber. Also, the insulation was designed to accommodate up to 300[kV] for testing the internal insulation force of SF_6, with which temperature variation(-90~90[℃]) or maintenance is possible due to the high insulation characteristics.

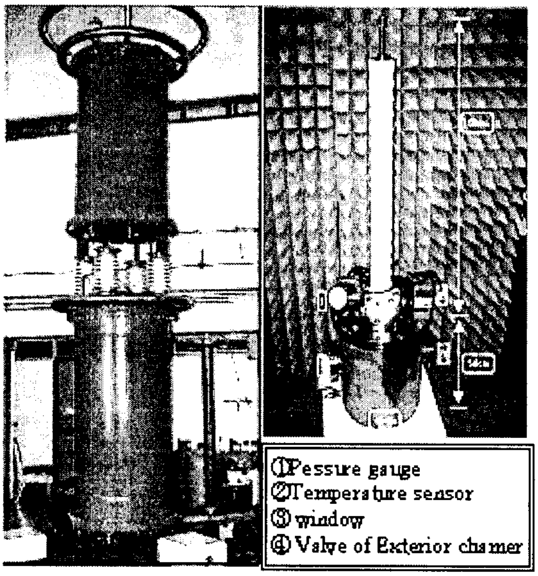

Photo. 1. The experimental chamber and AC high voltage source

The electrode used was a Needle-Plane electrode(upper part: Needle; lower part: Plane, N-P; Needle: Diameter, 50[mm] angle of a 20°point; Plane: Diameter, 590[mm]) and the distance between electrodes was set to 30[mm]. The temperature of the temperature sensor section was lowered up to 30~-40[℃] in the case of each atmospheric pressure after ventilating the inner chamber up to -68[cmHg] and inserting 4, 5 or 6[atm] before adding the SF_6 and I-Air. The resulting phase transition characteristics and the Breakdown Voltage (VB) characteristics were studied. In regards to the voltage of the breakdown characteristics, the average value of ten measurements was used.

The voltage was set to a rising speed of 1[kV/s] during the VB measurement. Voltage was measured after approximately the first 10 discharges.

3. Experimental Results & Discussion

3.1 Temperature Dependence with the Maintenance of a Fixed Amount of Gas, Insulation Characteristics and Phase Transition Characteristics

3.1.1 AC High-Voltage Source

Fig. 1 shows the VB characteristics toward temperature and pressure when N-P are installed inside the chamber and a fixed amount of SF_6 gas is maintained at 4, 5 and 6[atm] air pressure at 30 [℃] at the AC source. This helps to identify the inner status of SF_6 and the insulation characteristics according to changes in the power equipment temperature using SF_6 in areas of severe cold.

In Fig. 1, Section I is the phase in which pressure decreases according to the temperature in a gaseous state toward each pressure. Pressure gradually decreases as the temperature drops and, in this section, the VB also drops because of this. The application of Paschen's law is possible in this field.

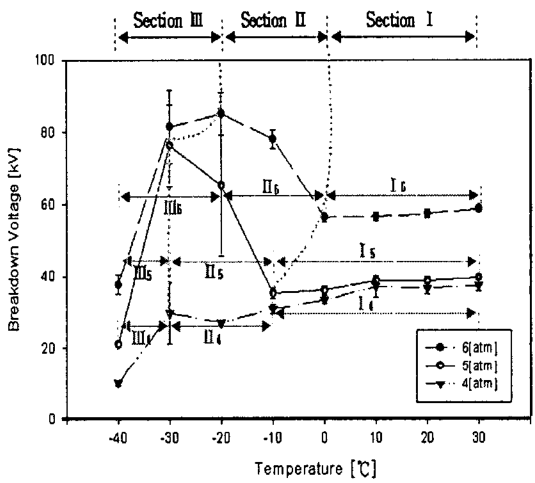

Fig. 1. The breakdown voltage of SF_6 on variations of temperature-pressure with a regular gas volume(AC)

In Section II, the SF_6 is gradually liquefacted from the needle electrode area and inner walls of the chamber. In this field, the general trend of the voltage value increases. The VB value presents great deviation, which results from the high value shown at the occurrence of breakdown characteristics while SF_6 surrounds the needle electrode and liquid SF_6 is covered on the plane electrode. A low value is found when measurement is made immediately following LSF_6, which surrounded the needle electrode after being dropped onto the lower part. Liquefaction is in progress in this step and the insulation media between N-P can be seen as an insulation characteristic of the field where SF_6 and LSF_6 coexist.

Section III is the phase in which most of SF_6 inside has been liquefied. LSF_6 is collected at the lower part of the imitation GIS and becomes considerably lower by turning into a state of extremely low pressure where the area surrounding the electrode is filled with a mixture of SF_6 that has not been liquefacted and the remaining air that was not ventilated. In this step, the VB is lowered considerably.

3.1.2 (−)DC High-Voltage Source

Fig. 2 shows the VB characteristics toward temperature and pressure when N-P are installed inside the chamber and a fixed amount of SF_6 gas is maintained at 4, 5 and 6[atm] air pressure at 30[℃] at the DC source.

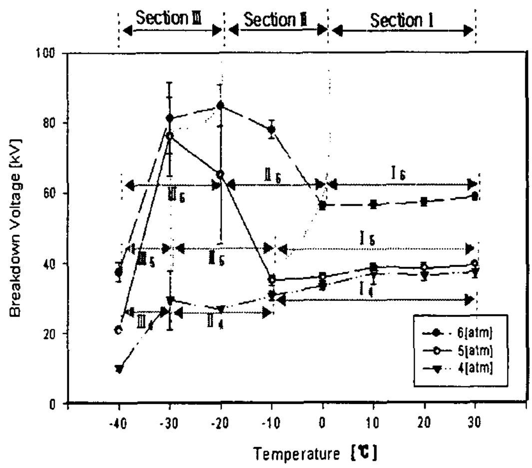

Fig. 2. The breakdown voltage of SF_6 on variations of temperature-pressure with a regular gas volume(DC)

The DC source experiment was performed under the same conditions as the AC source. From the results of this experiment, Fig. 2 shows that Section I is the phase in which the pressure gradually decreases as the temperature drops; the VB also drops because of this. Section II is the process in which the SF_6 is gradually liquefacted while the general trend of the voltage value increases in this field. In this step, liquefaction is in progress and the insulation media between N-P can be seen as the insulation characteristics of the field in which SF_6 and LSF_6 coexist. Finally, in Section III most of the SF_6 inside has been liquefied. LSF_6 is collected at the lower part of the imitation GIS. In this step, the VB becomes considerably lower.

3.2 The Variations of Temperature-Pressure with a Regular Gas Volume

Fig. 3 is a graph of the characteristics of the pressure variation according to temperature variation. At each field of the fixed temperature section, the pressure dropped as shown in the graph as the temperature was lowered after filling the inner chamber with a fixed amount of gas according to the Boyle-Charles Law(from 30[℃], 4, 5 and 6[atm] air pressure). It can be seen that 30[℃] with 4,5 and 6[atm] air pressure, respectively, becomes 0.3, 1 and 1.5[atm] air pressure at -40[℃]. Therefore it was observed that the pressure is considerably lowered--by 7.5, 20 and 25[%], respectively--as compared to a temperature of 30[℃].

As shown in Fig. 3, the pressure decreases linearly with each fixed temperature sector. A linear shape is not observed in all temperature sectors because the volume taken by the gas differs with when the SF_6 inside the chamber is in a gas state and when the SF_6 and the LSF_6 coexist in a gas state.

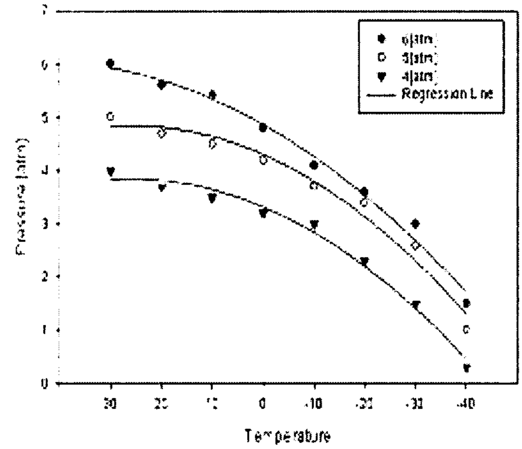

Fig. 3. The variations of temperature-pressure with a regular SF_6 gas volume

3.3 Breakdown Characteristics of Imitation-Air in Temperature Decline

Fig. 4 shows the VB characteristics toward temperature and pressure when N-P are installed inside the chamber and a fixed amount of I-Air is maintained at 4, 5 and 6[atm] air pressure at 30[℃] at the AC source.

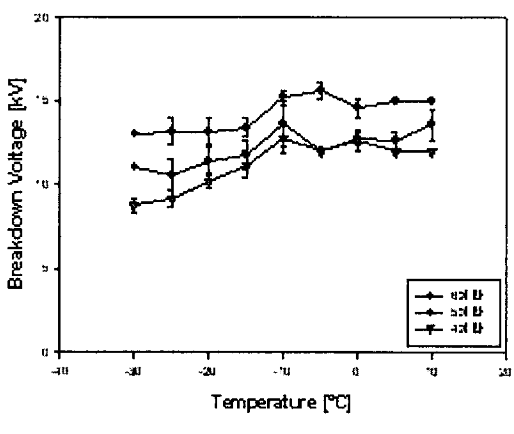

Fig. 4. The breakdown voltage of I-Air on variations of temperature-pressure with a regular gas volume (AC)

The graphed characteristics of breakdown voltage of I-Air show similar results to that of SF_6 Section I. That is, the VB value displays characteristics exemplifying Paschen's law. Fig. 4 represents the phase in which pressure decreases according to temperature at a gaseous state toward each pressure. Pressure gradually decreases as the temperature drops and because of this, the VB also drops.

Fig. 5 is a graph of the characteristics of pressure variation according to the temperature variation of I-Air. According to the Boyle-Charles Law, it is comparatively linear in shape.

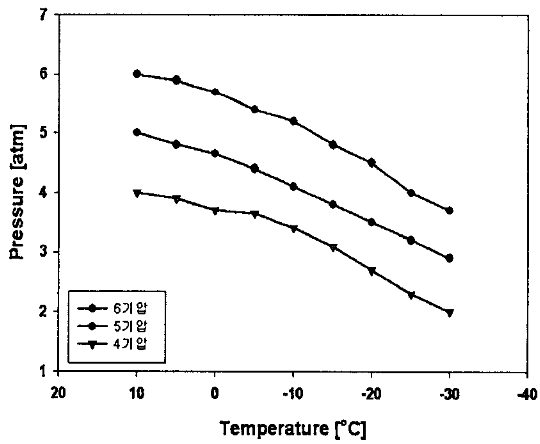

Fig. 5. The variations of temperature-pressure with a regular I-Air volume

4. Conclusions

This study researched the phase transition characteristics, the temperature-pressure characteristics of SF_6, and the temperature thereof according to the fixed amount of the gas-pressure VB characteristics of Imitation-Air.

4.1 Breakdown characteristics of SF_6

1) The characteristics of Paschen's law were confirmed at the vapor stage of SF_6 according to each pressure(Section I).
2) As the liquefaction of SF_6 progresses, the VB increases considerably and there is a great deviation between the highest and lowest VB. This phenomenon is a result of the high value that results when the breakdown characteristics occur at the time the LSF_6 surrounds the needle electrode area as the LSF_6 descends the electrode after the SF_6 gradually liquefacts from the needle electrode area and the inner walls of the chamber. A low value results if measured immediately following the LSF_6, which surrounded the needle electrode area when dropped to the lower section.
3) When the liquefaction progresses further, the area surrounding the electrode is filled with low density SF_6 gas and remaining air; the VB becomes considerably lower due to the extremely low pressure state at this time.
4) The temperature at which gaseous SF_6 becomes LSF_6 differs according to pressure but liquefaction occurs when the temperature of the electrode was 0~-10[℃] in this experiment. The actual liquefaction point is the upper chamber where the refrigerant dry ice is attached, so it can be seen that the liquefaction temperature is lower than this temperature.
5) If fixed pressures of 6, 5 and 4[atms] are maintained, the liquefaction point is higher due to the lowered temperature as the pressure is raised while the actual liquefaction point is determined at a lower temperature than the one measured according to the Boyle-Charles Law.

4.2 Breakdown characteristics of Imitation-Air

For the insulation characteristics followed by the temperature decline of I-Air, the tendency of temperature to be proportionate to the decline as based on Paschen's Law to also decrease VB was verified. Also, for temperature-pressure changes of fixed amounts of I-Air gas, the pressure decreased linearly as the temperature became lower based on the Boyle-Charles Law.

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Biography

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Chang-Ho Lim was born in Korea in 1958. He received his B.S. and M.S. degrees in Electrical Engineering from Kyungil University and Yeungnam University, Korea, in 2001 and 2003, respectively. Currently, he is working on earning his Ph.D. in Electrical Engineering from Yeungnam University.

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