Breakdown Characteristics of SF_6/CF_4 Mixtures in Test Chamber and 25.8kV GIS

Shin-Woo Park, Chung-Ho Hwang, Nam- Ryul, Kim, Ki-Taek Lee, and Chang-Su Huh

***Abstract*—: SF_6 gas has excellent dielectric strength, but it causes global warming about 23900 times more than CO_2 gas which is the main cause of global warming. This shows necessity of the environment friendly dielectric gas which can replace SF_6 gas. We made the test chamber which simulated inner of the gas insulation switchgear (GIS) and 25.8kV GIS of 3 phase unity bundle operation tank type. The breakdown characteristics are carried out experiment with using impulse, the power frequency and partial discharge (PD) test. In this paper, shows breakdown characteristics of mixed rates and total pressure of SF_6/CF_4 mixture under the ac voltage and standard lighting impulse voltage. In the result, it was observed that dielectric strength is increased by increasing content of SF_6 gas and increasing pressure of SF_6/CF_4 mixtures. The PD inception voltages have hardly any effect on mixed rate of SF_6 gas in 25.8kV GIS.**

***Index Terms*— SF_6, CF_4, GIS, impulse withstand voltage, power frequency withstand voltage**

. INTRODUCTION

SF_6 gas possesses excellent dielectric properties and high degree of chemical stability. SF_6 gas has used the wide range of application in the field of high voltage insulation, such as gas-insulated switchgear and gas insulating transmission line[1]. According to Kyoto protocol (2005.2), despite its many important advantages, SF_6 gas made an issue of environmental influence. No single gas meets all the require property imposed by recent demands on power system, and this mixtures seems to be an appropriate alternative. Environmental point of view, intensive investigations have been focus on the breakdown characteristics of mixed gas which were made of SF_6 gas and buffer gas, such as N_2 gas or CO_2 gas[2][3].

PFCs (Perfluoro carbons) gases that are one of several substitute gas possess many advantages such as non-flammable, non-toxic and relative strong dielectric characteristics. There are CF_4, C_2F_6, C_3F_8, and C_3F_6 among PFC gases. PFCs gases are apt to adsorb on the surface of electrode and insulator because activation energy is very high, and it is electronegative gas that number of electrons decreases with the time by inelastic collision. Because PFCs gases have high dielectric strength, PFCs are promised as substitute gas of electric power application. But it is difficult to carry out the experiment used SF_6 / PFCs mixtures because of various restriction and expense. Among PFCs, CF_4 have good electron attachment properties for electron energies higher than 2.5eV. It has a much lower critical temperature and much higher critical pressure than other fluorocarbons. Also CF_4 gas has much lower GWP (Global Warming Potential) than SF_6 or other PFCs gases.

In this paper, we want to provide the basic data on the characteristics of the breakdown characteristics of SF_6/CF_4 mixtures under ac voltage and standard lighting impulse voltage. In addition, PD (partial discharge) characteristics of 25.8kV GIS carried out under ac voltage.

. EXPERIMENTAL

Figure 1 shows a schematic diagram of the experimental setup. In order to simulate the uniform condition inside 25.8kV GIS, arrangement of gap between spheres was chosen. As decreasing ratio which divide sphere-sphere gap by diameter of sphere, the field becomes homogeneous[4]. The diameter of sphere is 12.5mm and the material of sphere is stainless steel. The experiments were carried out with gap separations of 1mm.

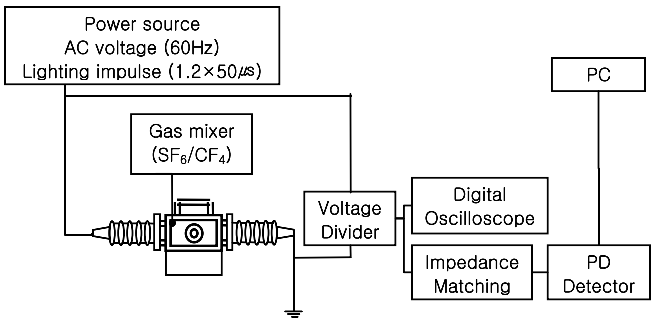

Fig. 1. A schematic diagram of the experimental

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Shin-Woo Park. Author is with the Inha University Electrical Engineering & Energy Conversion Lab, Yonghyun-Dong, Nam-Gu, Incheon, Korea (corresponding author to provide phone: 82-32-860-7408; fax: 82-32-863-5822; e-mail: pakas00@hotmail.com).

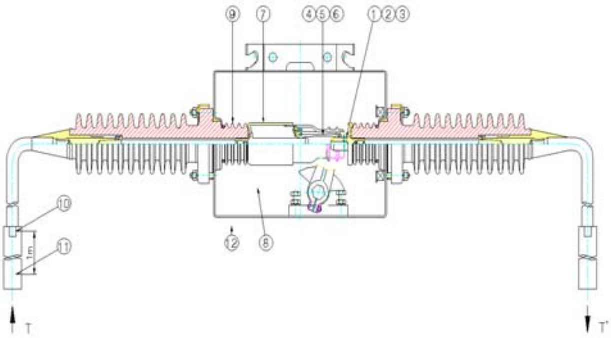
Chung-Ho Hwang. Author is with the Inha University, Yonghyun-Dong, Nam-Gu , Incheon, Korea (e-mail: hch7642@hanmail.net).

Nam-Ryul Kim. Author is with the Joongwon Electric Corporation, Danwon-Gu, Ansan-si, Gyeonggi-Do, Korea (e-mail: nrkim@joongwon.co.kr).

Ki-Taek Lee. Author is with the Korea Electrotechnology Research Institute, Uiwang-city, Gyeonggi-do, Korea (e-mail: ktlee@keri.re.kr).

Chang-Su Huh. Author was with the Korea Electrotechnology Research Institute, He is now with the Inha University, Yonghyun -Dong, Nam-Gu, Incheon, Korea (e-mail: cshuh@inha.ac.kr)

Fig. 2. Photograph of the 25.8kV GIS



Part 1,2,3	Fixed contact conductor A,B, C-phase
Part 4,5,6	Moving contact conductor a, b, c-phase
Part 7	Fixing shaft housing
Part 8	Inside of a tank
Part 9	Bushing surface of B-phase
Part 10	Lead wire
Part 11	1m point at Lead-in Cable
Part 12	Outside temperature

Fig. 3. Cross section of the 25.8kV GIS

Figure 2 shows the picture of 25.8kV GIS. The 25.8kV GIS which were made of 3 phase unity bundle operation have good electrical, mechanical quality and each of parts was simple and strong. The materials of bushing have good characteristics under electrical switching impulse. Figure 3 shows the section of 25.8kV GIS. The test of 25.8kV GIS were carried out according to IEC60694. The pressures of gas are limited to the maximum pressure of 0.4MPa in test chamber and 0.05MPa in 25.8kV GIS. Before filling with the gas, the test chamber and 25.8kV GIS was evacuated at 10^{-2} torr by vacuum pump (pumping speed: 120L/min, the max degree of a vacuum: 10^{-3} torr). For accurate mixing rate, gas mixer was used (gas: SF_6/CF_4, error: ±2%, flow meter: 5L/min). SF_6 (99.99% purity) gas and CF_4 (99.9% purity) gas were connected the chamber

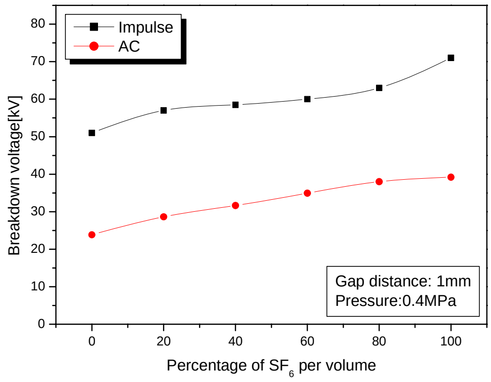


Fig. 4. Breakdown voltage as a function of SF_6 in SF_6/CF_4 mixtures of 0.4MPa

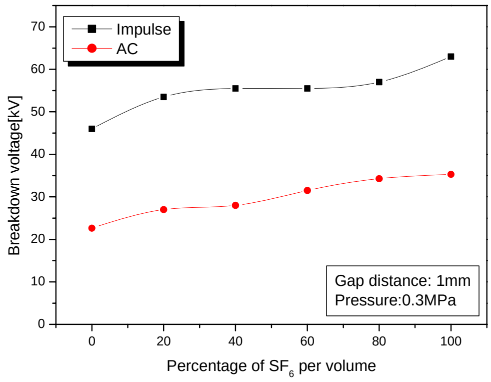


Fig. 5. Breakdown voltage as a function of SF_6 in SF_6/CF_4 mixtures of 0.3MPa

and GIS via gas mixer, and the pressure of the gas were controlled by the regulators. The ac voltage generated the high voltage ac transformer (frequency: 60Hz). The analog peak voltmeter built in the panel of the high voltage ac transformer was used for monitoring the breakdown characteristics. The standard lighting impulse voltage (1.2㎲×50㎲) of positive polarity was applied using a Marx generator (maximum voltage: 300kV). The voltage divider(max charging voltage: 600kV, high/low voltage resistance: 8.1kΩ/75Ω) were used for measuring high voltage. The PD test carried out in 25.8kV GIS under the shielding room. The 25.8kV GIS was made for actual experiment which was used the SF_6/CF_4 mixture substituting for pure SF_6 gas.

Ⅲ. RESULTS AND DISCUSSION

A. The characteristics of SF_6/CF_4 mixtures in test chamber

The breakdown voltages as content of SF_6 gas in SF_6/CF_4 mixtures are shown in figure 4, 5, 6, and 7 for four different pressures. Each standard lighting impulse voltage and ac voltage experiment was carried out 10 times per test. The

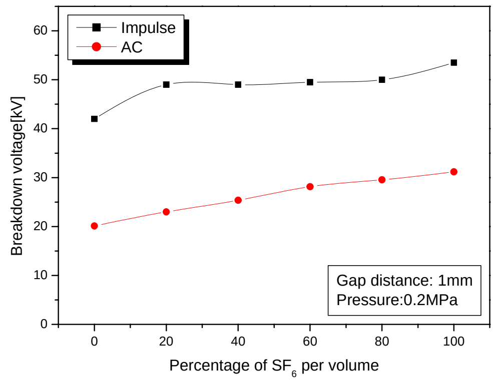


Fig. 6. Breakdown voltage as a function of SF_6 in SF_6/CF_4 mixtures of 0.2MPa

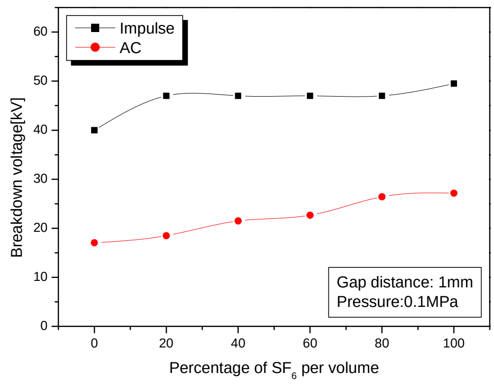


Fig. 7. Breakdown voltage as a function of SF_6 in SF_6/CF_4 mixtures of 0.1MPa

breakdown voltages of SF_6/CF_4 mixtures were showed a dramatic increase within 20% content of SF_6 gas under standard lighting impulse voltage. And it was observed gradual increment of breakdown voltages when the contents of SF_6 gas were increased above 20%. The SF_6/CF_4 mixtures have breakdown voltage that increase linearly with the percentage of SF_6 content under ac voltage. The impulse breakdown voltages are higher than ac breakdown voltage. It is suggested that the time for the establishment of space charge within the gap was insufficient[5].

SF_6 gas attaches the electron which has the energy of 0.1eV with an energy range of 0.05eV. The formed negative ions are

Table. Breakdown voltage as a pressure of pure SF_6 and CF_4 gas in 25.8kV GIS

	SF_6 (0.03MPa)	CF_4 (0.12MPa)	CF_4 (0.2MPa)	Standard (25.8kV GIS)
AC	60kV OK	57kV	63kV	60kV
Impulse	150kV OK	80kV	105kV	150kV

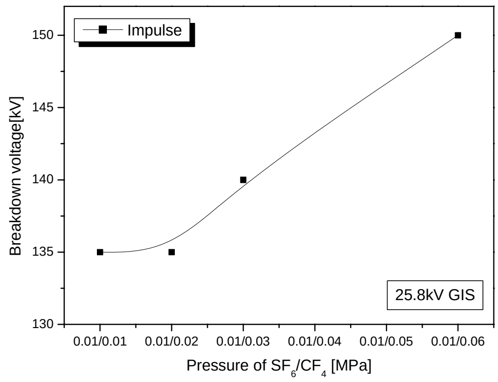


Fig. 8. Breakdown voltage as add CF_4 gas to SF_6 gas in 25.8kV GIS

heavy compared to the free electrons .Therefore the ions do not accumulate sufficient energy to lead to ionization under a given electric field. CF_4 gas has high electronegative property for higher electron energies (typically ≥ 2.5eV). CF_4 gas has low property than SF_6 gas. It was possible that there is not much electron that has energy more than 2.5eV when electrons collide against the neutral molecule.

B. The characteristics of SF_6/CF_4 mixtures in the 25.8kV GIS

The basic dielectric strength test of pure SF_6 and CF_4 gas were executed by the impulse withstands voltage and power frequency withstand voltage test in 25.8kV GIS. Table 1 shows result of pure SF_6 and CF_4 gas. As a result of experiment, SF_6 gas (0.03 MPa) satisfied standard voltage of 25.8kV GIS in power frequency withstand voltage test and impulse withstand voltage test. The CF_4 gas showed low property compared with SF_6 gas when power frequency and impulse withstand voltage test were experiment same condition. CF_4 gas (0.2 MPa) has similar breakdown voltage of SF_6 gas (0.03 MPa) in power frequency withstand voltage test. However, property of impulse withstand voltage test did not satisfied 150kV that is standard of impulse withstand voltage. Figure 8 shows the breakdown voltage of SF_6/CF_4 mixtures as add CF_4 gas to SF_6 gas (0.1MPa). All SF_6/CF_4 mixtures which have SF_6 gas of 0.01MPa satisfied the standard of 25.8kV GIS in power frequency withstand voltage test. Mixed gas of SF_6 (0.01MPa) and CF_4 (0.01~0.06MPa) show more good dielectric characteristics than pure CF_4 gas (0.2MPa) in impulse and power frequency withstand voltage test. According as increase the pressure of CF_4 gas in SF_6/CF_4 mixture under impulse withstand voltage test, total pressure of SF_6/CF_4 mixtures increases and could confirm that dielectric strength improved. It is suggested that mean free path was shorted as increase the pressure. The SF_6 (0.01MPa) /CF_4 (0.06MPa) mixture satisfied both standard of ac voltage test and standard of impulse test. The breakdown characteristics of CF_4 gas improved significantly with the addition of a small percentage

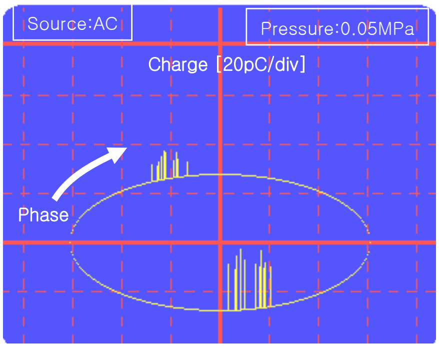


Fig. 9. PD graph in 25.8kV GIS under ac voltage

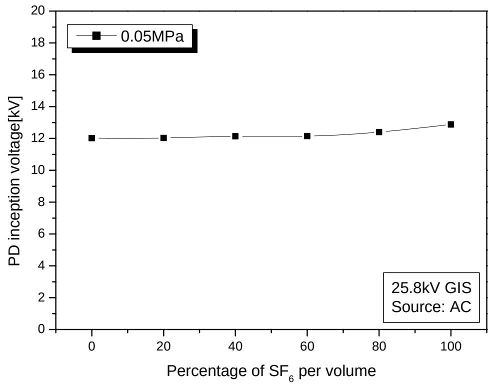


Fig. 10. PD inception voltage as a function of SF_6 in SF_6/CF_4 mixtures in 25.8kV GIS

of SF_6 gas.

C. PD test of SF_6/CF_4 mixtures in the 25.8kV GIS

The PD test was analyzed for different contents of SF_6 gas on SF_6/CF_4 mixtures. Figure 9 shows the PD graph in 25.8kV GIS under ac voltage and the figure 10 shows the PD inception voltages at the total gas pressure 0.05MPa under ac voltage. The level of PD inception voltage is 20pC. The PD inception voltages test showed the similar voltage as increase the content of SF_6 gas in SF_6/CF_4 mixture. It is possible that the characteristics of PD inception voltage was influenced pressure of mixed gas or shape of electrode than content of SF_6 gas in uniform field at low pressure[6].

. CONCLUSION

We investigate the dielectric characteristics of SF_6/CF_4 mixtures in 25.8kV GIS and test chamber, the results can be summarized as follows.

1) Under standard lighting impulse voltage, the SF_6/CF_4 mixtures showed a dramatic increase of breakdown voltage within 20% content of SF_6 gas.
2) The SF_6/CF_4 mixtures have breakdown voltage that varies linearly with the percentage of SF_6 content under ac voltage.
3) In the 25.8kV GIS, the mixed gas of SF_6 (0.01MPa) and CF_4 (0.01~0.06MPa) show better insulation characteristics a pure CF_4 gas (0.2MPa) in impulse and ac voltage test.
4) The PD inception voltages in 25.8kV GIS are almost same as increase contents of SF_6 gas under AC voltage.

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