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The Insulation Evaluation of N_2:O_2 Mixture Gas

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Abstract

With the improvement of industrial society, high quality electrical energy, simplification of operation and maintenance, and ensuring reliability are being required. Also we request an urgent change from SF_6 gas to an environment-friendly gas insulation material. In this paper, the experiments of breakdown characteristics by pressure and gap change of N_2/O_2 mixture gas through a GIS (Gas Insulated Switchgear) model were described. This paper reviews basic data of the surface discharge characteristics for Teflon resin in not only pure N_2, N_2:O_2 mixture gas as being focused on environmentally-friendly insulating gas, but also SF_6. Also, insulation characteristics by breakdown voltage and surface discharge voltage of N_2:O_2 mixture gas in the experimental chamber were studied.

Key Words : N_2:O_2 Mixture Gas, Breakdown Voltage, Surface Discharge Voltage

1. Introduction

Modern society is longing for the convenience of up-to-date technology. There have been attempts of miniaturization and high reliance of power equipment in the effectiveness aspect of urban areas' usage of space while requiring more electrical energy than at present[1-2].

Owing to environmental problems, such as the greenhouse effect and global extreme weather, mankind has been focusing on environmental pollution.

Owing to environmental problems, such as the greenhouse effect and global extreme weather, mankind has been focusing on environmental pollution[3]. Specifically, air pollution caused by industrialization was revealed as the cause of the greenhouse effect[4].

This paper reviews basic data of the surface discharge characteristics for Teflon resin in not only pure N_2, N_2:O_2 mixture gas as being focused on environmentally-friendly insulating gas, but also SF_6. With the changing distance of electrodes and pressure, we can find the breakdown and surface discharge voltages respectively[5]. Surface discharge voltages of N_2:O_2 (79:21) mixture gas are higher than the N_2:O_2 mixture gases.

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Moreover, we can obtain that the surface dielectric strengths of SF_6 are approximately two times that of N_2:O_2 (79:21) mixture gas[6]. As appended results of the research, the results are fundamental data for electric insulation design of distribution Power Facilities which will be studied and developed in the future. We could make environmentally-friendly gas insulation material while maintaining dielectric strength by N_2/O_2 mixture gas which generates a lower level of the global warming effect.

2. Experimental Procedure & Method

Photo 1 shows an experimental GIS chamber which is made of stainless steel of a thickness of 20[mm]. It consists of two layers: an inner part with a diameter of 260[mm], a height of 460[mm] and a volume of 25[ℓ]; and an outer part with a diameter of 460[mm], a height of 500[mm] and a volume of 83l. There are two windows to allow observation inside the experimental chamber. These windows are made of acryl with a diameter of 110[mm] and a thickness of 20[mm]. The chamber was designed and manufactured to stand against a fixed temperature range (-90-100[℃]) and pressure (up to 10[atm]). It is also acceptable to AC 300[kV].

The pressure gauge is installed to measure the inner pressure of the chamber. The inside of the chamber can be preserved to 5×10^{-4}Torr using a vacuum pump (SINKU KIKO Co. Ltd, GUD-050[A], pumping speed 60[l/min]).

According to the partial pressure law, N_2 gas and O_2 gas are mixed as N_2:O_2 = 79[%]:21[%], 60[%]: 40[%] and 40[%]:60[%]. These gases are pressurized from 1[atm] to 5[atm] inside the chamber.

Needle-plane electrodes were used. The needle electrode(N) has the following specifications: diameter of 5[mm], and 20[°] angle of point. The plane electrode (P) is 59[mm] in diameter. Both electrodes are made of stainless steel. In this paper, basic insulation characteristics of N_2:O_2 mixture gases when there is insulation between the electrodes on the epoxy discharge characteristics were tested.

Photo 1. The Experimental Model GIS and AC 300[kV] Power Supply

Figure 1 shows the schematic diagram of experimental electrodes and solid dielectric arrangement of surface discharge characteristics.

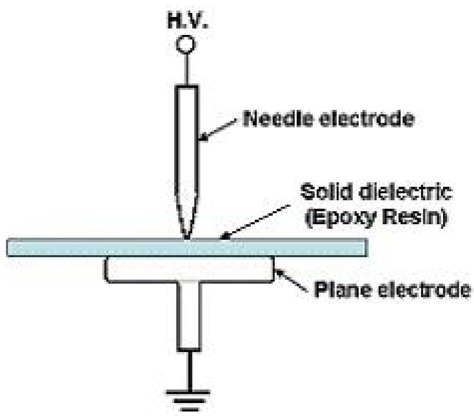


Fig. 1. Schematic Diagram of Experimental and Solid Dielectric Arrangement

The experiments are achieved under AC voltage supplied by DY-106-Korea (AC 300[kV]/120[mA]). After ventilation to 5×10^{-4}[Torr], we inserted each kind of gas, with pressure from 1[atm] to 6[atm], into the chamber. We supplied the AC voltage to the electrodes at each pressure of each gas. Then, we obtained the surface discharge breakdown voltages. After five measurements, the mean voltage was derived. It is treated and expressed as mean surface discharge voltage (VB) in this paper. The voltage rising speed was 3.15[kV/s]. The measurement method was by leader discharge of the surface.

3. Experimental Results & Discussion

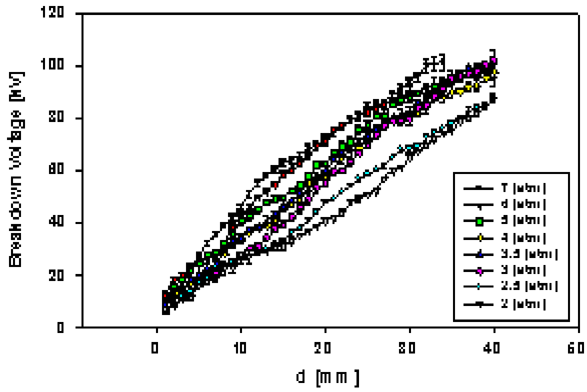
3.1 According to Insulation Characteristics of the N_2:O_2 Mixture Gases

Figure 2 shows the ratio of the change in the gap V_B. A graph with five times the voltage measurements have indicated that the average maximum and minimum values are displayed. Gap gradation shown in Figure 2 was increased in proportion to the V_B; the voltage of Figure 2-(a) is approximately 1.04 times the average growth rate. Figure 2-(b) and 2-(c), as the gap V_B, show an average cost of the change rate of approximately 1.06 and 1.07 times, respectively.

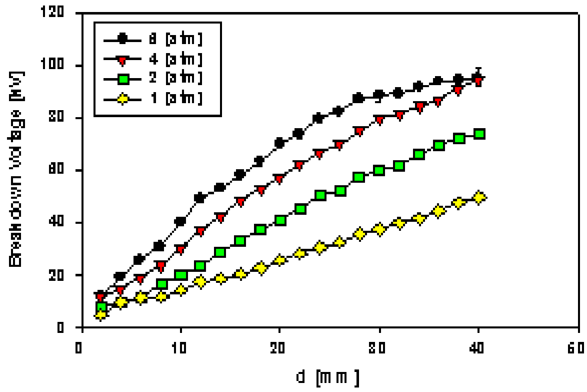
An increasing gap in the rise of the voltage applied to the law was confirmed with Paschen's law. In addition, when the gap length was more than 40[mm], voltage saturation was confirmed.

Figure 3 shows that at a constant pressure by a gas, mixture can be made by comparing the voltage.

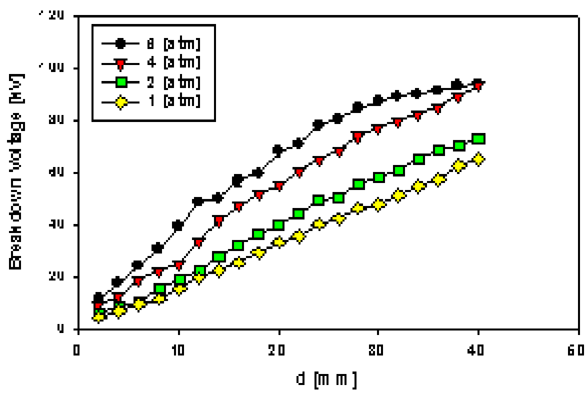
The average growth rate increased by gap VB N_2:O_2=79[%]:21[%] is approximately 1.19 times, N_2:O_2=60[%]:40[%] approximately 1.21 times, and N_2:O_2=40[%]:60[%] was confirmed by approximately 1.22 times.



(a) N_2:O_2=79[%]:21[%]



(b) N_2:O_2=60[%]:40[%]



(c) N_2:O_2=40[%]:60[%]

Fig. 2. Breakdown Characteristics by N-P Electrode at N_2:O_2 Mixture Gases

In the case of N_2:O_2=79[%]:21[%] gases, the VB is high compared to others. The molecular weight of the molecules was increased because of the shorter distance due to the accelerated discharge of gas. Therefore, a high percentage of O_2 gas in N_2:O_2=79[%]:21[%] gas shows the highest average voltage.

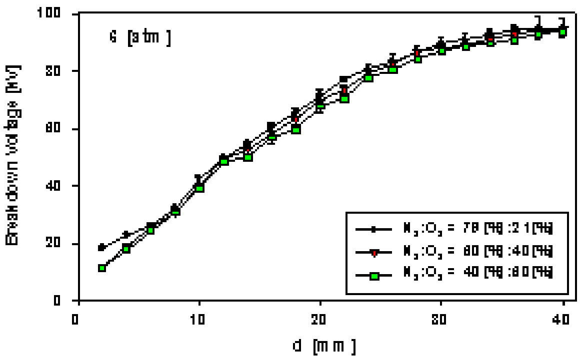


Fig. 3. Breakdown Characteristics by N_2:O_2 Mixture in N-P Electrode

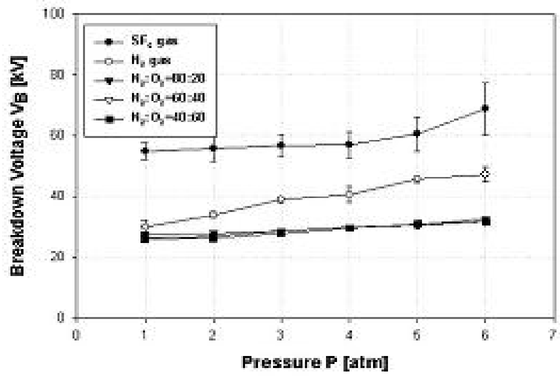
3.2 Surface Discharge Characteristics of Needle-Plane Electrode

In this section, comparisons of surface discharge characteristics for various gas dielectrics, which are SF_6, N_2 and N_2:O_2 mixture gas, N_2:O_2 = 80[%]:20[%], 60[%]:40[%] and 40[%]:60[%] under a non-uniform field as a function of gas pressure, are described. Of the characteristics, the surface breakdown voltages (V_B) in Figure 4. were shown. First, we can see that the VB at each gas commonly gets higher, as the pressure inside the chamber escalates in stages from 1 to 5[atm] in these figures. This is caused by medium effect.

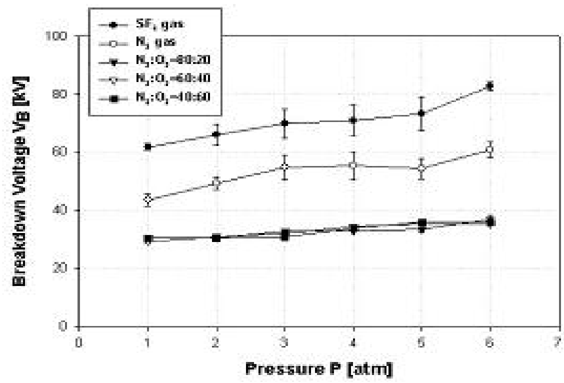
Since the surface discharge is usually initiated by the emission of electrons from the triple junction (gas, electrode, solid dielectric), if the electrode and solid dielectric are assumed to be almost the same, the surrounding gas is a potent influence to initiate the discharge. Ed (dielectric strengths) is produced to the expression of the downside.

$$E_d[kV/mm] = \frac{Average\ Suface\ Discharge\ Voltage[kV]}{Average\ Suface\ Length\ [mm]}$$

Therefore, as shown in Figure 4, SF_6 gas has the highest V_B among the considerable media in this experiment. The change of V_B according to O_2 does not appear in Figure 4. This means that these O_2 contents in mixture gas do not have much effect to enhance the electrical insulating properties during propagation of the surface discharge.



(a) t=2 [mm]



(b) t=3 [mm]

Fig. 4. Surface Breakdown Voltages for Various Gas Dielectrics Versus Gas Pressure

4. Conclusion

This paper describes the breakdown characteristics and the fundamental surface discharge characteristics under a non-uniform field in insulation dielectric gases.

SF_6, which is conventional gas in Gas Insulated Switchgear (GIS) and environmentally-friendly gases (N_2/O_2 mixture gas) are used and are compared to each other regarding surface breakdown voltages.

(1) N_2:O_2 mixture gas at a constant pressure: breakdown voltage characteristics due to changes in gap Paschen's law.

(2) When solid dielectric thicknesses are 2 or 3[mm], the breakdown voltage and dielectric strength are roughly SF_6>N_2>mixture gas. Also these O_2 contents in mixture gas do not have much effect to enhance the electrical insulating properties during propagation of the surface discharge.

(3) Since the surface discharge is usually initiated by the emission of electrons from the triple junction, if the electrode and solid dielectric are assumed to be almost the same, the surrounding gas is a potent influence to initiate the discharge. Thus, the breakdown voltage and dielectric strength of each gas gets higher when increasing the gas pressure according to the medium effect.

(4) N_2 gas is seriously affected by thickness. It has over 40[%] of the increasing rates of breakdown voltage in transition of solid dielectric thickness from 2 to 3[mm] at 1 and 2[atm]. This is higher than with any other gas.

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