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Effect of SF_6 content in SF_6/N_2 gas mixtures to its AC breakdown behavior at low pressure

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ABSTRACT – In this study, a breakdown behavior of SF_6/N_2 gas mixtures under AC stress was examined at various gas mixture ratio and pressure. The SF_6 content in SF_6/N_2 was varied from 0 % to 30 %, while the gas pressure was set between 0.11 MPa to 0.15 MPa. The AC breakdown voltage test of SF_6/N_2 was conducted inside a test rig using R0.5-plane electrodes with electrodes gap distance of 10 mm and 30 mm. The results of the study show that the increasing rate of the breakdown voltage is different at both gap distances as the gas mixture ratio is varied. The breakdown voltage increment can obviously be seen at 10 % SF6 content and 30 mm gap distance. Meanwhile, it is also found that the increasing rate of breakdown voltage is less significant as the pressure is increased.

1. INTRODUCTION

Sulphur hexafluoride (SF_6) gas is one of the most commonly used insulation in high voltage application due to its high dielectric strength and good arc interruption capability [1–2]. However, SF6 gas is a strong greenhouse gas that gives unfavorable impact to the environment once released [3]. As a proof, SF_6 gas was listed in Kyoto Protocol 1997 as one of the greenhouse gas that need to be controlled its emission by either reducing or eliminating its usage [4].

Thus, previous researchers have studied various SF6 gas mixtures as the effort to replace or minimize the usage of pure SF_6 in high voltage apparatus, including SF_6/N_2 gas mixtures. The research results show that SF_6/N_2 gas mixtures have a positive synergistic effect on its dielectric characteristics [5-6]. In another word, the breakdown voltage of pure N_2 gas is obviously improved when mixed with a small amount of SF_6 gas. Furthermore, N_2 gas has unlimited resources as it is a main component in air and does no harm to the environment.

As for this study, the focus is given more on the effect of SF_6 content in SF_6/N_2 gas mixtures to its breakdown voltage under low pressure level (i.e. below 0.15 MPa) at different electrodes gap distances.

2. METHODOLOGY

In order to investigate the breakdown behavior of SF_6/N_2 gas mixtures, a series of AC breakdown voltage test was conducted inside a custom-made test rig [7]. All the test procedure of this test is complying with BS EN 60060-1 standard [8].

In this study, there are four different SF_6/N_2 gas mixture ratios were tested; 0/100, 10/90, 20/80 and 30/70. The total pressure of the gas mixtures is varied between 0.11 MPa to 0.15 MPa, while the type of electrode configuration used is R0.5-plane (refer to Figure 1), which represents a non-uniform field condition. The high voltage electrode, R0.5 has a point tip of 0.5 mm radius, while the ground electrode, plane has 50 mm radius. The gap distance between the electrodes was set to 10 mm and 30 mm.

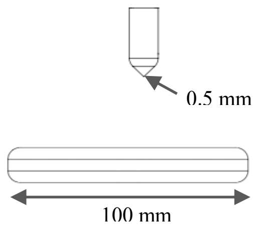

Figure 1 R0.5-Plane electrode configuration.

3. RESULTS AND DISCUSSION

Figure 2 and Figure 3 show the mean values of 30 breakdown voltage data, U_a of SF_6/N_2 gas mixtures with various gas mixture ratio and pressure. It can be seen that the breakdown voltage of SF_6/N_2 gas mixtures at all pressure increases as the SF_6 concentration ratio is increased from 0 % to 30 %. However, the breakdown voltage increment at 10 mm gap is different from 30 mm gap, especially at 0 % to 10 % amount of SF_6 content.

According to Figure 2, the breakdown voltage of 0 % amount of SF_6 (pure N_2) at 0.11 MPa has increased by 43.2 % with the addition of 10 % SF_6. As the electrode gap distance is increased from 10 mm to 30 mm (refer to Figure 3), the addition of 10 % SF_6 to pure N_2 gives results in 109.4 % breakdown voltage increment, which is about 2.5 times the increment achieved at 10 mm gap.

By observing at both gap distances, the rate of breakdown voltage increment of SF_6/N_2 seems to be less significant when the amount of SF_6 is further increased from 10 % to 30 %. For instance, the breakdown voltage of SF_6/N_2 at 0.11 MPa is only increased by 13.92 % and 12.57 % at 10 mm and 30 mm gap, respectively. That is to say, the amount of 10 % SF_6 in the gas mixture is sufficient to attach almost all of the low energy electrons, hence prevents the electron avalanche that can cause a breakdown and lead to a higher breakdown voltage.

Other than that, it is also found that the breakdown voltage of SF_6/N_2 gas mixtures at all gas mixture ratios is slightly increased as the pressure increase from 0.11 MPa to 0.15 MPa with 0.02 MPa increment. Unlike Figure 2, the breakdown voltage of SF_6/N_2 at 30 mm obviously show a saturated pattern when the pressure is increased, except for pure N_2. In the other words, further increment at low pressure does not give significant increase on the breakdown voltage of SF_6/N_2 gas mixtures.

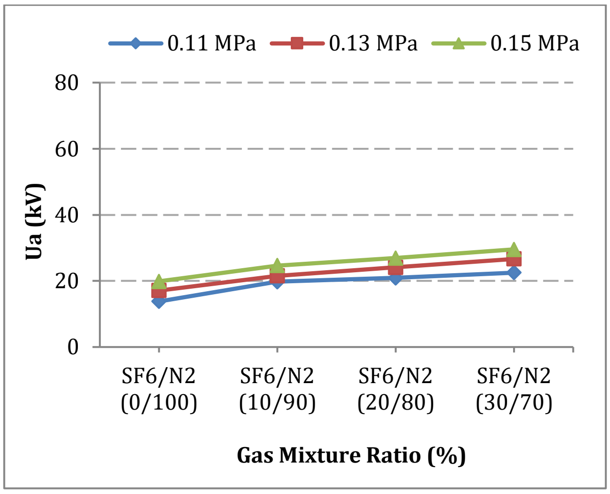

Figure 2 Mean AC breakdown voltages of SF_6/N_2 gas mixtures at 10 mm gap distance.

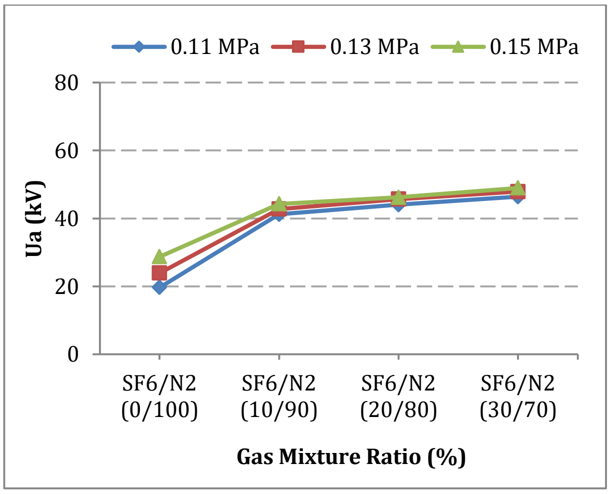

Figure 3 Mean AC breakdown voltages of SF_6/N_2 gas mixtures at 30 mm gap distance.

4. CONCLUSIONS

AC breakdown voltage test of SF_6/N_2 gas mixtures was conducted at various gas mixture ratio and pressure level under R0.5-plane electrodes configuration. The results show that the addition of SF_6 ratio at above 10 % does not significantly increase the breakdown voltage, especially at 30 mm. It is also noticed that there is not much different on the breakdown voltage as the pressure is increased at lower range.

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