

POLARITY EFFECT ON CORONA DISCHARGE VOLTAGES IN SF₆-N₂ GAS MIXTURES

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Abstract:

This work is to investigate the behaviour of SF₆-N₂ mixtures that can be considered as a potential substitute of pure SF₆. The inception voltages have been determined from the measurements of the current-voltage characteristics for both polarities under high pressures and with highly inhomogeneous fields. The results show that the onset voltages increase with the increase of the gas pressure and the values of positive polarity are higher to those obtained with negative polarity.

Key Words: Inception voltages, corona discharge, sulphur-hexafluoride

Introduction

Sulphur-hexafluoride SF₆ has found a wide range of applications due to its superior insulating properties and chemical stability. As the size of the high voltage equipments increases the cost of insulating gas becomes appreciably high. The quantity of SF₆ released in atmosphere is therefore rising. Due to its ability to absorb and reemit IR make it a potent greenhouse gas [1-2]. With its high lifetime (more than 2000 years), it accumulates in the atmosphere and contribute to the global warming of the atmosphere, therefore SF₆ will be severely controlled in the next years. The by-products issued from decomposition of SF₆ exposed to electric discharges may be dangerous to the equipments (corrosion) and to the personnel (poisoning) [3]. These factors have stimulated the research of a replacement gas with little environmental impact. The most promising alternative is the use of gas mixtures of SF₆ with inexpensive common gases such as nitrogen (N₂). SF₆-N₂ gas mixtures have good dielectric strength, are non-toxic, non-flammable and they have a high arc quenching capacity with a good self healing ability. The purpose of this paper is to provide and discuss the measurements of the onset corona discharge voltages in SF₆-N₂ gas mixtures at higher pressure ranging from 3 to 15 bars and with different percentage of SF₆. The onset voltages were determined from the measurements of the current-voltage curves in both negative and positive polarities. A tip-plane configuration was used with the tip radius of few micro-meters and the gap between the electrodes is lower than 10 mm. Most of the data available deals with the breakdown voltages rather than the threshold voltage of corona discharge.

Experimental set-up

Experiments were made in a stainless-steel cell of 50 cc equipped with two quartz windows as shown in figure 1. Electrodes in a tip-to-plane configuration were mounted inside the cell. The tip electrode of few micrometers is made of tungsten and, is prepared by electrolyse technique, steel tips are also used. The gap between the electrodes varies from 5 to nearly 10 mm. The tip electrode is connected to the high D.C. voltage up to 60 kV. The stainless steel plane electrode with a radius of 12 mm is connected to a galvanometer which measures currents down to some microamperes. Before the cell was filled with the gas, pumping was undertaken pushing the vacuum down to nearly 3.10⁻² Pa. The gas was introduced in the cell without prior purification. The SF₆ used in these experiments is delivered with a purity of 99.97%. The measurements were made for pressures ranging from 3 bars to 15 bars. A partial pressure method is used to mix the gases in the cell. SF₆ was first introduced followed by nitrogen. It is supposed that SF₆ and N₂ do mix quite well. The current was measured when the voltage varies upwards and downwards and after each set of measurements a resting time is observed to allow the mixture to settle down. The tip electrode is regularly changed in order to limit

the radius variation due to the deposit of fluorine and sulphur. Analysis of used tips by electronic microscopy has been carried out.

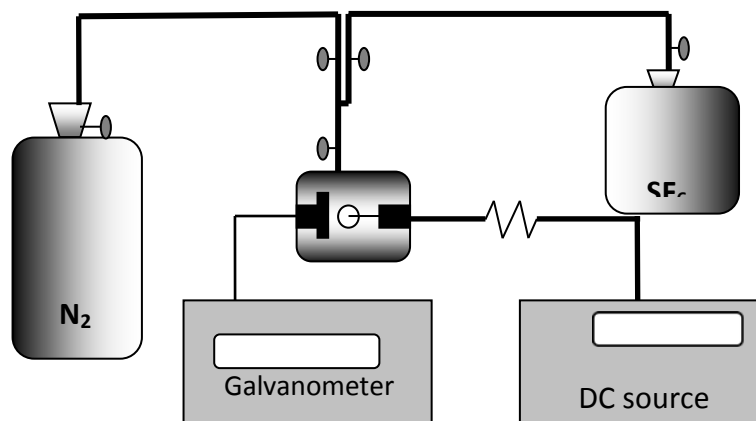


Figure 1, experimental set-up.

Results and discussion

The current-voltage characteristics $I = f(V_s)$ of corona discharge in SF_6-N_2 gas mixture show that the current follows an exponential law. The measured values of corona inception voltages (V_s) as a function of the ratio of SF_6 in the mixture are shown in figures 2 and 3 for negative and positive polarities respectively. The curves have the same tendency for both polarities and the V_s values increase with the increase of the amounts of SF_6 . This behaviour may be attributed to the decrease of the net ionisation coefficient $\bar{\alpha}$ [4-5].

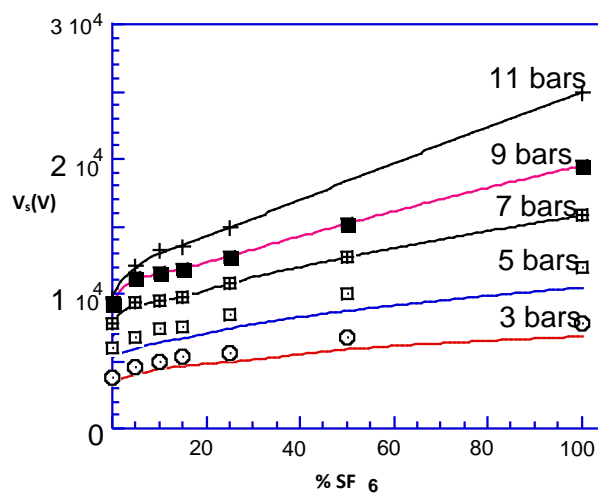


Figure 2. Curves of the onset voltages as a function of the ratio of SF_6 in the SF_6-N_2 mixture and gas pressure for negative polarity.

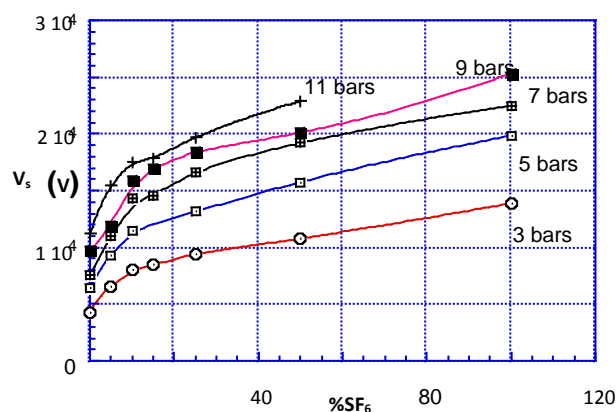


Figure 3. Curves of the onset voltages as a function of the ratio of SF₆ in the SF₆-N₂ mixture and gas pressure for positive polarity.

At higher amounts of SF₆, the onset voltages tend towards saturation. This tendency was observed in previous work [4]. The saturation may be attributed to the change of the surface of the tip electrodes. To check this assumption the surface was analysed using electronic microscopy. The analysis showed that there's some deposit on the tip after a set of electric discharge, this deposit is composed of fluorine and sulphur, but since tests are carried out with decreasing pressure such effect can't explain saturation for higher pressures, where the tip is quite free of deposit. The saturation may be the result of the concentration of space charges, which are more active at the vicinity of the tip electrode at higher pressure [5-6]. It is interesting to see that the onset voltages of the corona discharge are closer for low amounts of SF₆, which constitutes an argument for the replacement of SF₆ by SF₆-N₂ gas mixtures having very small percentage of SF₆. The onset voltages for positive and negative polarities are shown in figure 4, as a function of the gas pressure for 10% of SF₆ in the gas mixture. It can be seen that positive onset voltages are relatively higher [7]. This can be attributed to the mechanism of generation of initiatory electrons. Under positive polarity the main source for production of electrons is the detachment from negative ions and the difficulty for negative ions to reach the tip electrode. For negative polarity the field effect emission increases the probability of free electrons in the critical volume [8]. The effect of polarity is predominant for higher amounts of SF₆.

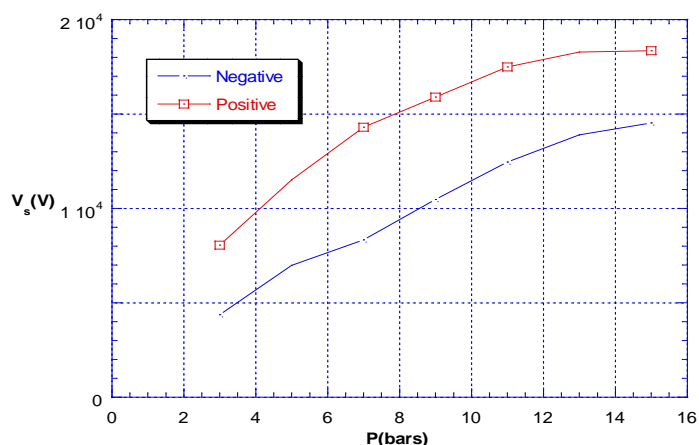


Figure 4, the onset voltages for positive and negative polarities, as a function of the gas pressure for 10% of SF₆ in the gas mixture.

Using the curves of figures 2 and 3, we were able to measure the working pressure for different SF₆-N₂ gas mixtures. In figure 8, are drawn the pressure values as a function of the percentage of SF₆ for the same onset voltage (13.8 kV) and for positive and negative polarities. In the present conditions, and for an onset voltage equals 13.8 kV a mixture of 100 % of SF₆ has a pressure

equals 3 bars for a positive polarity, whereas, for 10 % of SF₆ the pressure rises to 6.52, in order to withstand the same onset voltage. In negative polarity a mixture of 100 % of SF₆ has a pressure equals 7.3 bars; whereas, for 10 % of SF₆ the pressure rises to 13.12 bars, in order to withstand the same inception voltage (13.8 kV).

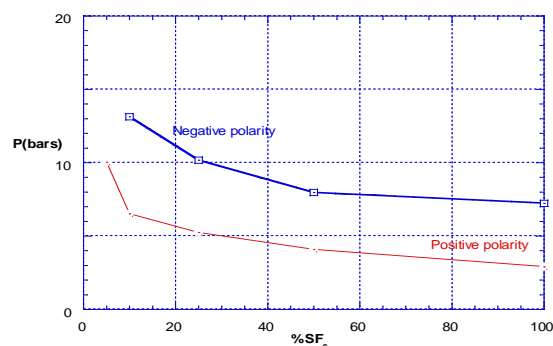


Figure 5, curves of the pressure as a function of the percentage of SF₆ for the same onset voltage (13.8 kV)

Conclusion

The corona onset voltages V_s increase with the increase of the amounts of SF₆ but at higher pressures the measured values tend to saturate. The positive onset voltages are relatively higher, especially for high percentage of SF₆. The polarity effect is predominant for higher amounts of SF₆. For the same onset voltage a mixture with 10 % of SF₆ must work approximately at twice the pressure of pure SF₆. This is true for both polarities.

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