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BROAD BAND PULSE DETECTION STUDIES OF PARTIAL DISCHARGES IN PRESENCE OF SOLID DIELECTRICS IN SF_6-N_2 MIXTURES

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ABSTRACT - Experiments were conducted to detect partial discharge (PD) pulses in presence of solid dielectrics (PTFE and glass filled epoxy) as well as breakdown pulses in SF_6, N_2 and SF_6-N_2 mixtures under uniform field conditions using a broad band detection system. The effects of circuit parameters, overvoltages, pressure of the gas and the distance between electrodes on pulse shapes were studied in detail for various mixture proportions of SF_6 in SF_6-N_2 mixtures. The observed PD pulses are similar to those of breakdown pulses for longer electrode gaps (>0.3 cm). In case of surface discharges the pulses are oscillatory in nature and inconsistent in shape and magnitude. The effect of saturation in increase in breakdown voltage of SF_6-N_2 mixtures with increase in percentage of SF_6 (i.e., synergism) is also observed in the presence of solid dielectric. This synergistic effect is also reflected in corresponding observed PD pulse shapes.

INTRODUCTION

The study of partial discharge (PD) pulses using a broad band detection system has the following advantages over conventional narrow band detection system. 1) Contribution of different types of charge carriers (e.g., electrons, positive ions and negative ions) can be understood [1,2] which can possibly be correlated to the damage to the insulation. 2) Different pulses and types (e.g., streamer-like Townsend-like etc.) of discharges can be distinguished [2,3]. 3) True pulse shapes [2,4-7] of PD pulses can be observed and correlated to electron and ion transport and basic discharge phenomena. Thus with the help of transport coefficients, the discharges can be modelled [8,9]. 4) The method has possible use in a system for detecting faults in gas insulated system (GIS) as well as other electrical equipment.

EXPERIMENTAL DETAILS

The experimental set-up is the same as described previously [6]. A stainless steel chamber having both diameter and depth of 22.5 cm and fitted with a quartz window was used as a test cell. A 80 watt Hg-arc discharge lamp was used as a source of u.v. radiation which was horizontally incident on both the electrodes as well as the solid dielectric. The uniform field stainless steel 2Π/3 Rogowski profile electrodes (finely polished) of diameter 5.8 cm were mounted at the center of the chamber. While studying PD pulses, a circular disk of solid dielectric was placed above the bottom electrode. Figure 1 shows the details of the measurement circuit. The output of the 100 kV discharge free high voltage transformer (T) was varied through two dimmerstats connected in series. Two 50 Ω cables connected in parallel and terminated with their resultant characteristic impedances were used to detect PD pulses. The RC time constant of the detection circuit was of the order of 0.1 ns. Maximum precautions were taken to reduce the inductance in the circuit and the high frequency response of the detection circuit was tested using fast rise pulse generators. The complete set-up was enclosed in a shielded room and was discharge free up to 50 kV voltage level.

RESULTS AND DISCUSSIONS

Experiments have been conducted to obtain pulse shapes under various experimental conditions. However, only some of the results are discussed here.

I) PD pulses in SF_6

PD pulses were studied in SF_6 in the pressure range of 0.668 kPa to 26.711 kPa using solid dielectric PTFE (thickness 0.218 cm) and glass filled epoxy (thickness 0.251 cm). Figures 2 and 3 show the variation of PD inception voltages with gaseous gaps at different pressures. There is an increase in PD inception voltage with increasing gaseous gap (i.e. fraction of the interelectrode gap that contains gas) between electrodes. However, this increase is significant only at higher pressures (e.g., 26.711 kPa). In case of 0 cm gaseous gap both the electrodes touch the solid dielectric and surface discharges occur at the edges of electrodes. For all other gaseous gaps, actual breakdown occurs in the gaseous gap between electrodes. Hence, this PD inception voltage is the same as the breakdown voltage of the gas in the presence of solid dielectric.

Concerning the surface discharges in SF_6, both positive and negative pulses are present at inception and their shapes, rise times and fall times are nearly identical. The polarity of the pulse corresponds to the polarity of the applied voltage to the top

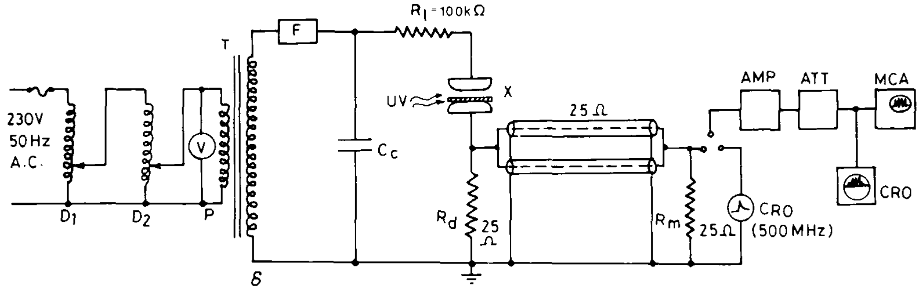

Figure 1 - Schematic diagram of measurement circuit.

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electrode connected to the high voltage side. At 0.668 kPa, Townsend-like pulses are observed while at higher pressures streamer-like pulses are observed. The streamer-like pulses exhibit large electronic component corresponding to the first peak which is followed by an oscillatory decay.

Concerning the rise time, fall time and magnitude of PD pulses it is observed that the general behavior is similar to that of the breakdown pulses between two metallic electrodes. The rise time of the pulse corresponds to the development of electron avalanche and hence the area corresponding to the rise time of the pulse represents the electronic charge in the avalanche head. The fall time corresponds to the current induced due to the movement of the positive

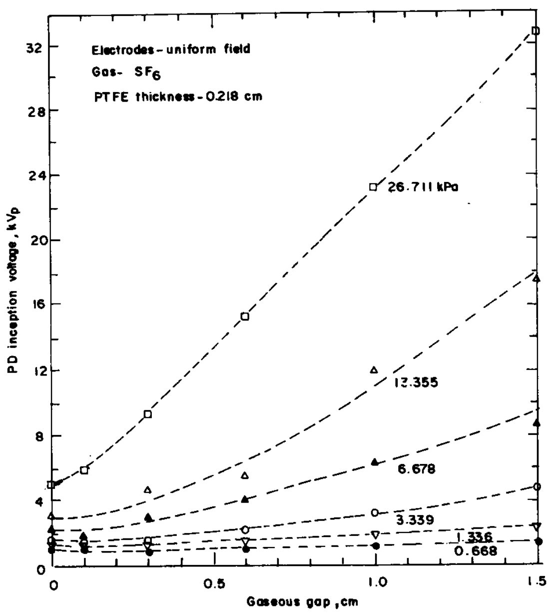

Figure 2 - Measured PD inception voltages in SF_6-PTFE composite dielectric.

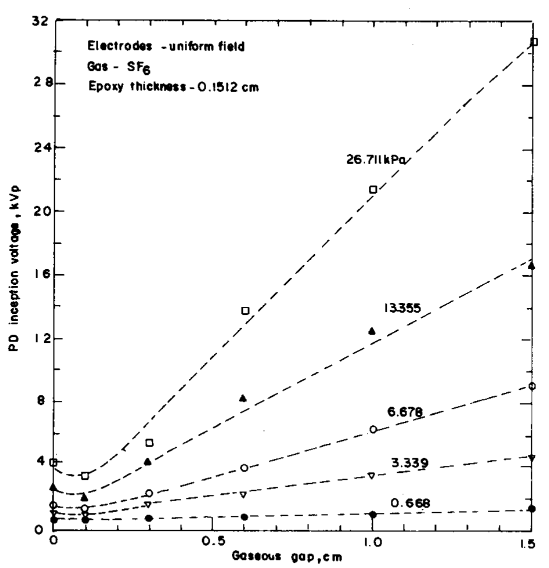

Figure 3 - Measured PD inception voltages in SF_6-Epoxy composite dielectric.

ions, negative ions and sometimes, detached electrons in case of SF_6.

By comparing the rise and fall times of PD and breakdown pulses under similar conditions, it is usually, but not always, observed that the rise and fall times of PD pulses increase and the magnitudes of the pulses decrease with the introduction of a solid dielectric. The electronic component corresponding to the rise time of PD pulse has a relatively high magnitude and is short in duration. This behaviour is similar to that observed for breakdown pulses. Although breakdown pulses in SF_6 always exhibit a tail of relatively low magnitude and long duration, this is not always seen for PD pulses in presence of solid dielectric. This may be the consequence of ion recombination processes on the surface of solid dielectric.

It is also observed at inception that, in the presence of the solid dielectric, both positive and negative pulses are present for the different polarities associated with applied alternating voltage. However, the magnitudes of negative pulses are larger than those of positive pulses. This difference in magnitudes of different polarities of pulses is not observed in case of breakdown pulses between two metallic electrodes. It can be expected that the photoelectron production is inhibited in cases where the dielectric covered electrode becomes the cathode so that the presence of u.v. radiation becomes ineffective. The positive pulse development then depends upon the availability of electrons near the high voltage electrode. When the uncovered electrode is negative, photoelectric action is more effective. Also, any charges present on the solid dielectric that modify the field in the gap may also depend on the polarity of the applied voltage. Hence, the mechanisms of PD pulse formation can be expected to differ for different polarities of applied voltage with corrsponding differences in rise times, fall times and magnitudes of the detected pulses. Also the difference in the secondary ionization coefficients for the metallic and dielectric surfaces may be a factor in influencing the discharge developement for different polarities.

In order to study PD pulses under overvoltage conditions, the applied voltage was increased to twice the inception voltage at 26.711 kPa of SF_6 with 0.1 cm to 0.6 cm gaseous gaps between electrodes. It is observed that with the increase in the degree of overvoltage, the development of negative pulses is suppressed and their magnitudes decrease with an increase in the degree of overvoltage. However, the magnitudes of positive pulses continue to increase with increasing overvoltage. A decrease in fall times of positive pulses with overvoltage is also observed in case of PD pulses indicating the increase in the drift velocity of charge carriers. However, the fall times of negative pulses are not affected significantly indicating their suppression to further development with increase in the degree of overvoltage.

II) PD pulses in SF_6-N_2 mixtures

The PD pulses were studied in mixtures of SF_6 and N_2 in the presence of PTFE dielectric at different pressures and gap spacings. Figures 4, 5 and 6 show PD inception voltages for various percentages of SF_6 at 0.0 cm, 0.6 cm and 1.5 cm gaseous gaps between electrodes. As noted previously, 0.0 cm gaseous gap corresponds to the behavior of surface discharges (Fig. 4), while 0.6 cm and 1.5 cm behavior corresponds to the breakdown of the gaseous gap. It can be seen that although the PD inception voltage is higher in pure SF_6 compared to that in pure N_2, the increase in PD inception voltage is not directly proportional to the SF_6 content in the mixture. Thus the synergistic effect observed for breakdown voltages in mixtures with SF_6 is also observed in the case of PD inception voltages in the presence of a solid dielectric.

Concerning the surface discharges in SF_6-N_2 mixtures, both positive and negative pulses are observed at inception. In most cases the fall time is negligible for PD pulses in SF_6, while the PD pulse tails or fall times tend to increase with increasing nitrogen content. It is also observed that the variation in fall times is highest in the range of 0% SF_6 to 25% SF_6 and is insignificant for more than 25% SF_6. This behavior is also observed in case of rise time, pulse magnitude and even in the case of the oscillations observed on the fall off or decay of the surface discharge pulses. At 13.36 kPa, positive and negative oscillatory pulses of similar shapes and magnitudes exist in SF_6 while these oscillations are absent in case of N_2.

Concerning the PD pulses in SF_6-N_2 mixtures, it is observed that the magnitudes of positive PD pulses in SF_6 are lower than those for the positive PD pulses in N_2; whereas the behavior of negative PD pulses is exactly opposite, i.e., the magnitudes of negative PD

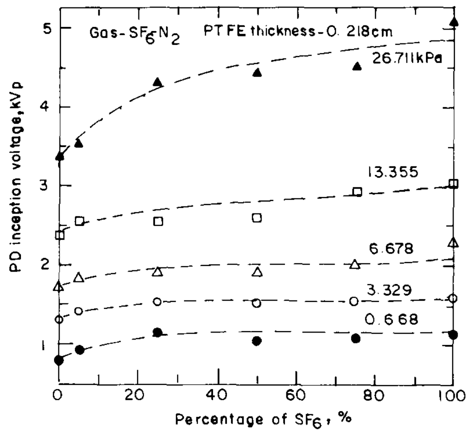

Figure 4 - Measured PD inception voltages in SF_6-N_2-PTFE composite dielectric at different percentages of SF_6 in case of surface discharges (0.0 cm gaseous gap).

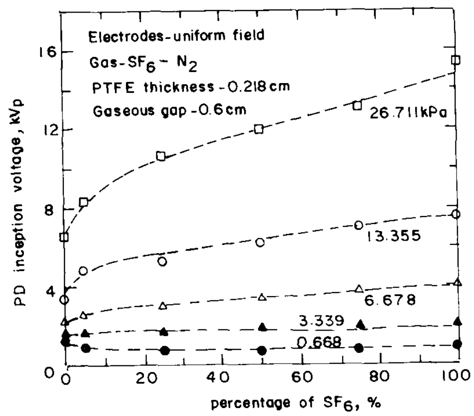

Figure 5 - Measured PD inception voltages in SF_6-N_2-PTFE composite dielectric at different percentages of SF_6 for a 0.6 cm gaseous gap.

pulses in SF_6 are greater than those of N_2 under similar conditions. The reason for this behavior is no doubt related to the electronegative nature of SF_6. Figure 7 shows the PD pulses on PTFE dielectric at 26.711 kPa for different gaseous gap spacings. The fall time of negative PD pulse in N_2 is longer than that of the negative pulse in SF_6 under similar conditions. This suggests the less ionic contribution for PD pulses in SF_6 possibly due to prominent recombination processes on the surface of the dielectric. The shapes of PD pulses do not show any significant change with the variation of SF_6 concentration. The pulse shape is nearly the same from 100% SF_6 to 25% SF_6 in the mixture. Therefore, it can be said that the synergistic effect observed for the breakdown voltages of mixtures is also seen in case of PD pulses in mixtures.

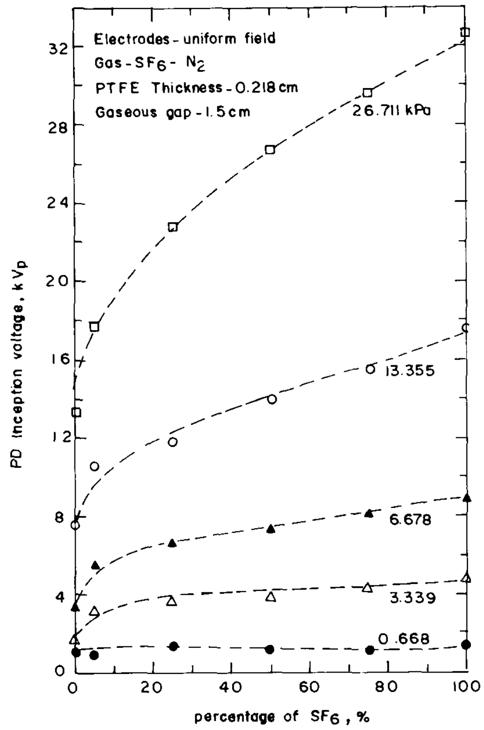

Figure 6 - Measured PD inception voltages in SF_6-N_2-PTFE composite dielectric at different percentages of SF_6 for a 1.5 cm gaseous gap.

CONCLUSIONS

Partial discharge and breakdown pulse shapes were studied under uniform field conditions in SF_6-N_2 mixtures using a broad band detection system. The solid dielectrics studied are glass filled epoxy, and PTFE. The synergistic effect in breakdown voltages of SF_6-N_2 mixture with increase in percentage of SF_6 is also observed in the presence of solid dielectric and is reflected in corresponding PD pulse shapes.

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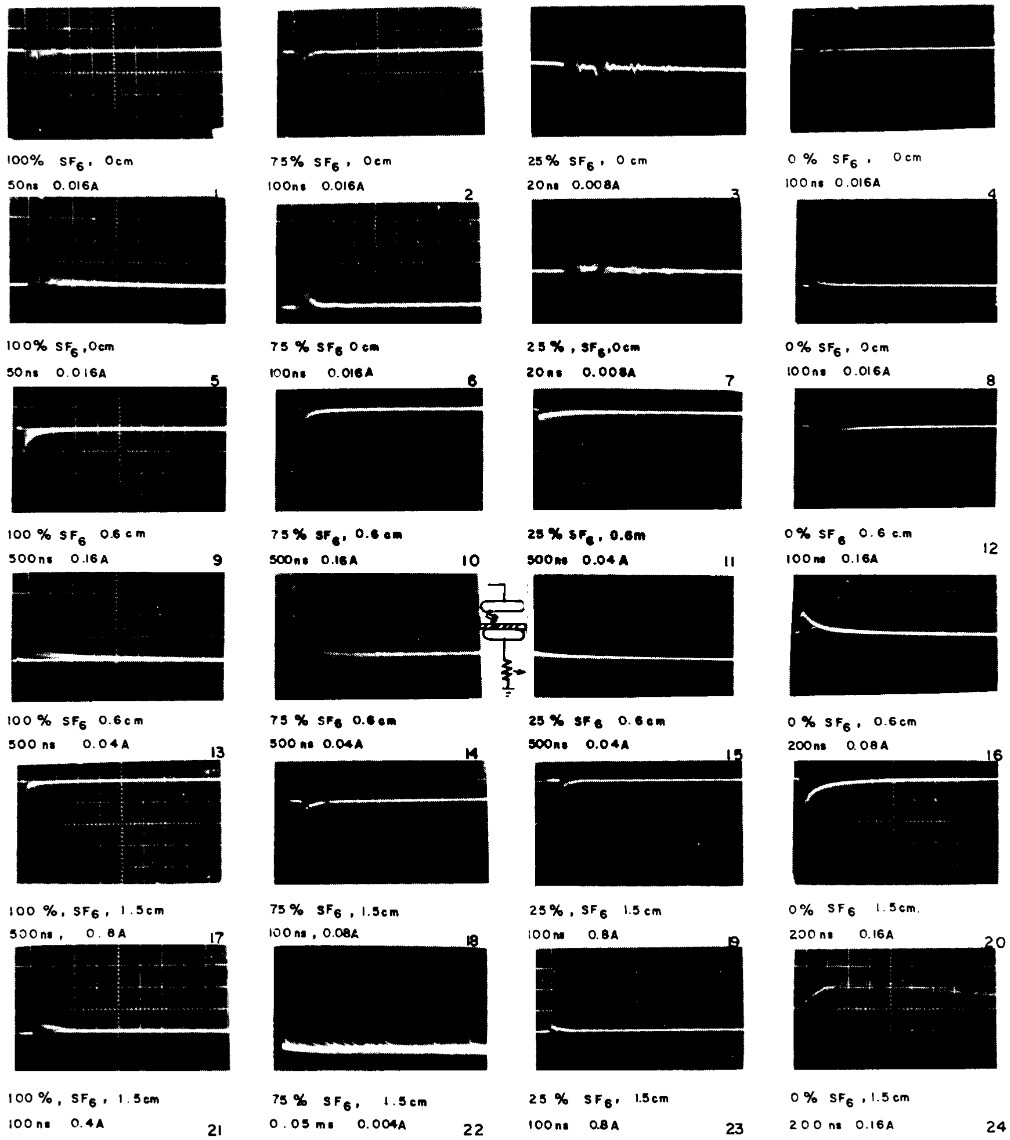

Figure 7 - Pd pulses in SF_6-N_2-PTFE combination at 26.71 kPa at different percentages of SF_6 and at different gaseous gaps. (Scale divisions are given by indicated times and currents).

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