ANALYSIS OF CUMULATIVE FREQUENCY AND POLARITY OF CREEPING DISCHARGES PROPAGATING OVER SOLID / GAS INTERFACES SUBMITTED TO AC VOLTAGE

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Abstract: This paper deals with the influence of the voltage and the type of gas (mixture) and its pressure on the apparent charge of creeping discharge events propagating over a solid/gas interface and their localisation on an AC voltage cycle, in a point-plane electrode arrangement. The solid insulating we considered is epoxy resin immersed in three gases (namely N_2, SF_6 and SF_6-N_2 mixture). It's shown that the maximum apparent charge of discharges recorded during 512 cycles of voltage increases with the voltage and decreases when the gas pressure is increased; and it's higher in N_2 than in SF_6. In the case of N_2 – SF_6 mixture, it decreases with the increase of SF_6 content. Also, the amplitude of positive discharges is higher than that of negative ones.

1 INTRODUCTION

In previous work, we showed the important role of capacitive effects (dielectric constant of solid sample and its thickness) on the characteristics of creeping discharges propagating over solid/gas (mixture) interface such as their final length and morphology, the associated current and charge [1 - 3]. These characteristics are also influenced by the properties of the solid and gas constituting the interface, the gas pressure and the voltage. In the case of AC voltage, we only considered the stopping (final) length of discharge independently of the polarity of voltage alternation; the stopping length being one of the dimensioning parameters of solid/gas interface insulating system. Therefore, it should be useful in the case of AC to discriminate the positive and negative discharges initiated at each cycle of voltage.

In this work, we are interested in the analysis of cumulative frequency and polarity of discharges propagating at the solid insulating surface immersed in different gases. This is of a great interest for insulation coordination and especially for the diagnosis. Indeed, partial discharge (PD) measurement is widely used as a diagnostic tool to detect defects in a given component and to assess their severity on the state of insulation system in high voltage equipment. Their measurements enable to provide on-line diagnostic information in real time. A lot of work has been consecrated to the measurement and modelling of PD, and different measurement techniques are used [4 - 8].

This paper is aimed at the influence of voltage and the kind of gas (mixture) on the cumulative number of creeping discharge events initiated at solid/gas interface and their location during one voltage cycle. The discharges number and the amplitude of their apparent charge are analysed versus the type of gas and the applied voltage.

2 EXPERIMENTAL TECHNIQUE

The experimental setup is similar to that we used in previous work for the analysis of the morphology and length of creeping discharges at solid/gas and solid/liquid interfaces [1 - 3]. Figure 1 gives a schematic diagram of the experimental setup. The test cell containing the considered insulating structure (solid/gas or mixture) and a point-plane electrode arrangement consists of a cylindrical core of 90 mm high and 110 mm inner diameter, and two flats and circular covers; the upper cover was of Plexiglas (transparent material) enabling to visualize the discharges and to support the sharp electrode; the lower one which constitutes also the electrode plane, was of brass. The point electrode was made of tungsten the radius tip of which is 10 µm. The solid insulating samples we inserted between the electrodes are discs of 100 mm diameter and 2 mm thickness. The solid insulating samples we tested are of epoxy resin. These samples are immersed in N_2, SF_6 and N_2 – SF_6 mixture. The solid samples are changed each time we observe traces on the solid surface. And the radius of curvature of the electrode point is monitored before and after testing.

A system of taps associated to two manometers enables to fill the test cell and to control the pressure. In the case of gas mixture, the gas with the lower partial pressure (SF_6) is first admitted into the test cell and then that one of higher partial pressure (N_2) after the pressure of SF_6 is stabilized.

The voltage is supplied by a transformer 50 KV/50 Hz. The voltage is progressively applied by steps of 2 kV; it maintained at its new value during the recording.

The detection and counting of discharges are carried out thanks to partial discharges detector (DPXpert type) connected in parallel with the test cell. The DPXpert detector is previously calibrated according to a standard technique. This latter consists in the injection of impulses of electrical charge of known value and to measure the output signal recorded on the DP detector. The results are then analysed using the (φ q n) (phase, charge, number) matrix which gives a visual representation of discharges number and the amplitude of their apparent charge versus the phase. The discharges are recorded versus their amplitudes and localisations, thus enabling to compare the activities of discharges for different experimental conditions.

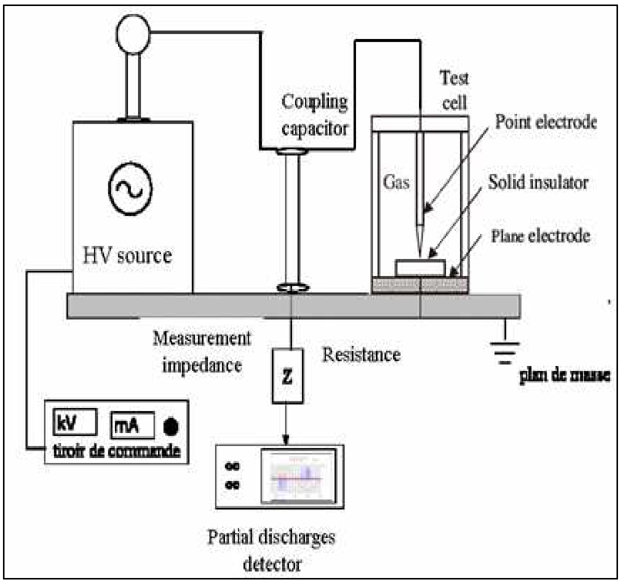

Figure 1: Sketch of experimental set-up under AC voltage

3 EXPERIMENTAL RESULTS

3.1 Influence of the amplitude of voltage on the activity and location of discharges

Figures 2, 3 and 4 show some examples of the activity of discharges corresponding to 512 cycles of ac voltages; the amplitude of which are respectively 4, 6 and 8 kV, obtained with a sample of epoxy resin immersed in 10%SF_6-N_2 mixture at 0.2MPa. We observe an increase of the activity of discharges and the apparent electrical charge with the voltage. The total number of discharges recorded during 512 voltage cycles, passes from 60 to 900 discharges when the voltage varies from 4 to 8 kV. At 4 kV, most of discharges are grouped and centred at 85° and 260° within an interval varying from 60° to 100°, and 210 to 280° respectively (Figure 2).

When the voltage increases up to 8 kV, the maximum activity of discharges shifts of 30° to the left; it's centred at 50° and 230°. Note the absenc e of discharges within the intervals [120° to 110°], and [300° to 10°] (Figure 4b). As concerns the maximum apparent charge, it's of 0.15, 0.75 and 3.3 nC, respectively for 4, 6 and 8 kV.

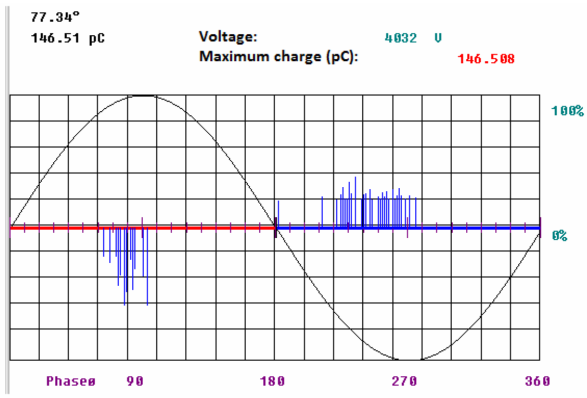

Figure 2a: Representation of the apparent charge versus the voltage phase q (φ) with 10% SF_6-N_2 mixture at 0.2 MPa for a voltage of 4 kV. The maximum apparent charge M = 0.15 nC.

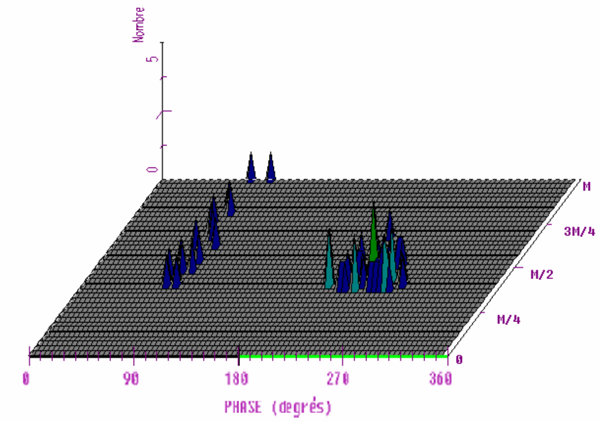

Figure 2b: Representation of the φ q n matrix corresponding to 512 voltage cycles for the same conditions as in Figure 2a

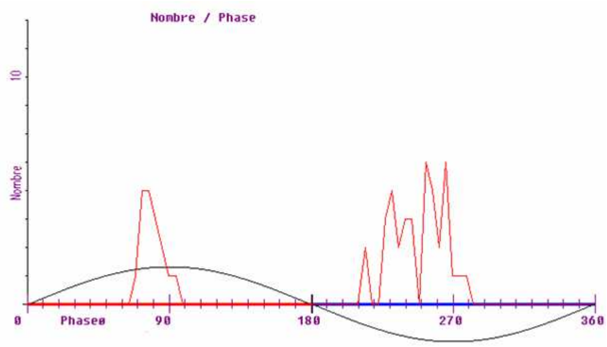

Figure 2c: Representation of the discharge number versus the voltage phase for the same conditions as in Figure 2a.

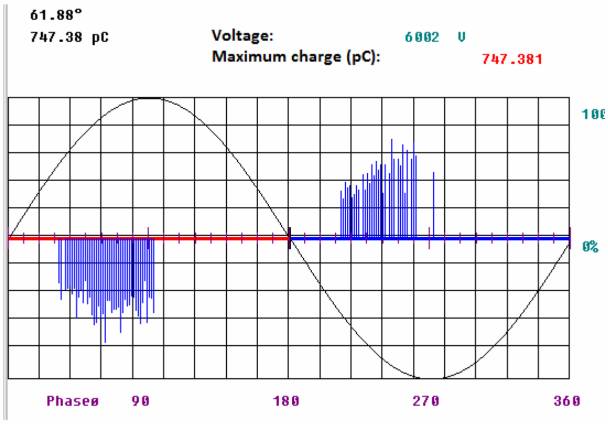

Figure 3a: Representation of the apparent charge versus the voltage phase q (φ) with 10% SF_6-N_2 mixture at 0.2 MPa for a voltage of 6 kV. The maximum apparent charge M = 0.75 nC.

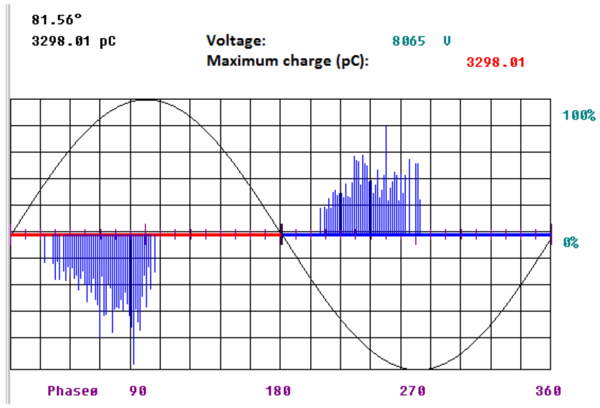

Figure 4a: Representation of the apparent charge versus the voltage phase q (φ) with 10% SF_6-N_2 mixture at 0.2 MPa for a voltage of 8 kV. The maximum apparent charge M = 3.3 nC.

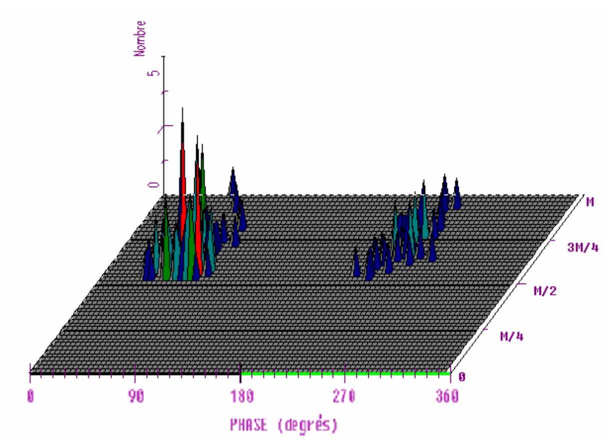

Figure 3b: Representation of the φ q n matrix corresponding to 512 voltage cycles for the same experimental conditions as in Figure 3a

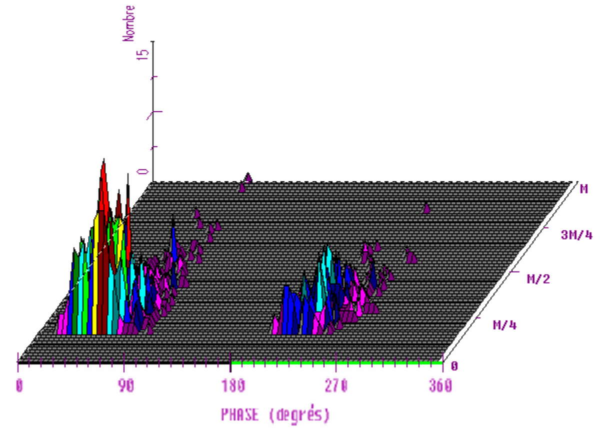

Figure 4b: Representation of the φ q n matrix corresponding to 512 voltage cycles for the same experimental conditions as in Figure 4a

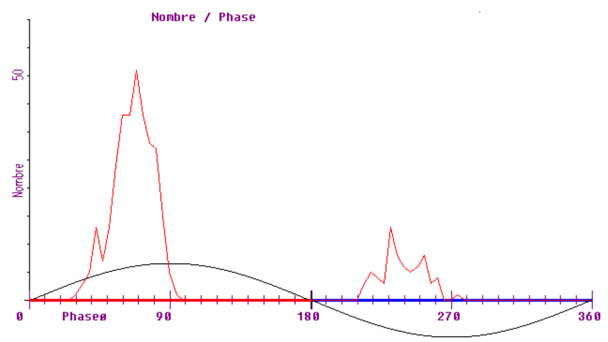

Figure 3c: Representation of the discharge number versus the voltage phase corresponding to 512 voltage cycles for the same experimental conditions as in Figure 3a.

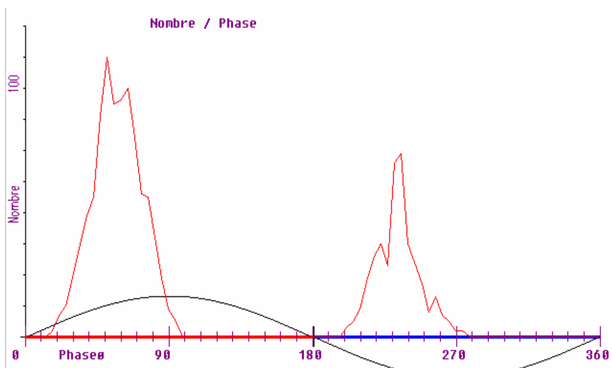

Figure 4c: Representation of the discharge number versus the voltage phase corresponding to 512 voltage cycles for the same experimental conditions as in Figure 4a.

3.2 Influence of the type of gas on the maximum apparent charge of discharges

Figures 5 and 6 show the evolution of the average value of the maximum apparent charge versus the applied voltage for different pressures of N_2 and SF_6. Each point represents an average value on ten tests. We observe that the maximum apparent charge (q_{max}) of discharges rapidly increases with the voltage and decreases when the gas pressure increases. Also, q_{max} measured in the case of N_2 is higher than that with SF_6. For instance, with a voltage of 10 kV, q_{max} = 25nC for N_2 and only 1.6 nC for SF_6 at 0.2 MPa.

In the case of N_2 – SF_6 mixture, the amplitude of apparent charge decreases when the SF_6 content in N_2 is increased (Figures 7 and 8). For instance, at 15 kV and 0.2 MPa, an increase of SF_6 content from 10% to 20% leads to a decrease of q_{max} from 90 nC to 45 nC (Figure 7).

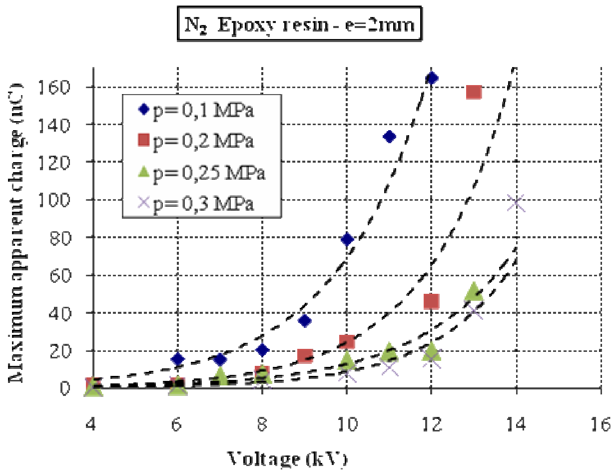

Figure 5: Evolution of the maximum apparent charge measured with epoxy resin/N_2 interface versus the voltage for different gas pressure: 0.1, 0.2, 0.25 and 0.3 MPa.

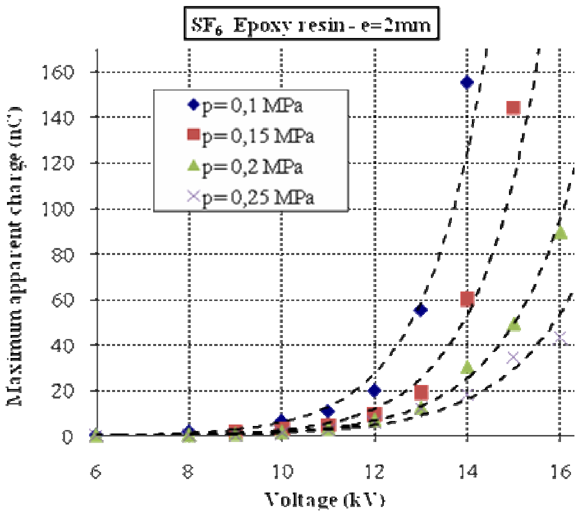

Figure 6: Evolution of the maximum apparent charge measured with epoxy resin/SF_6 interface versus voltage for different gas pressure: 0.1, 0.15, 0.2 and 0.25 MPa

Note that the maximum apparent charges we reported on these Figures don't distinguish the polarity of voltage alternation. However, q_{max} of positive discharges are higher than that of negative discharges whatever the gas and its pressure, and the voltage (Figure 9). Similar results have been observed with solid/liquid interfaces [9].

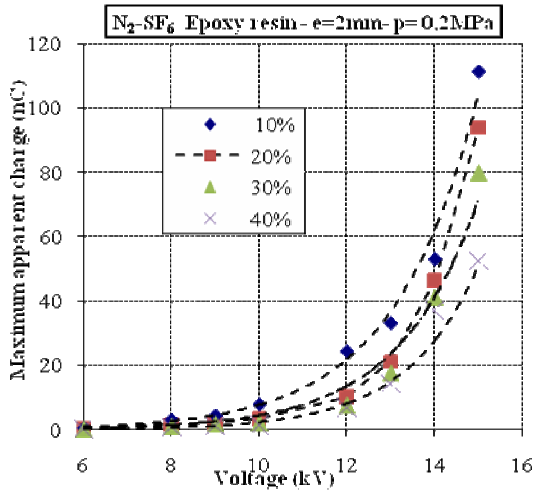

Figure 7: Evolution of the maximum apparent charge measured with epoxy resin/N_2-SF_6 interfaces at 0.2 MPa versus the voltage for 10%, 20%, 30% and 40% SF_6 content.

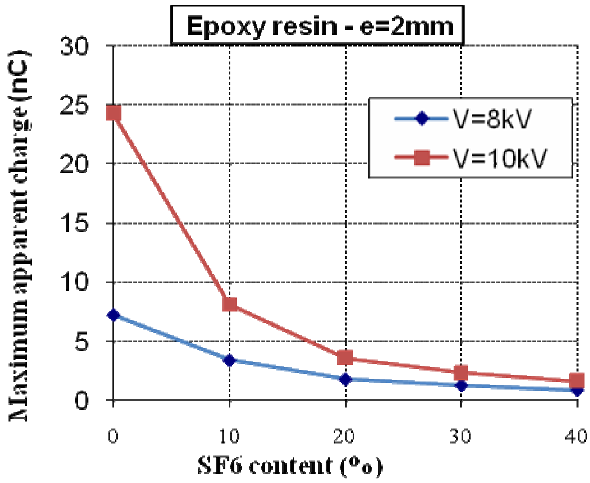

Figure 8: Evolution of the maximum apparent charge measured with epoxy resin/N_2-SF_6 interfaces at 0.2 MPa versus the SF_6 content for 8 and 10 kV.

4 CONCLUSION

This work shows that the total number of discharges recorded during 512 cycles of voltage increases significantly with the amplitude of voltage. The maximum value of apparent electrical charge q_{max} increases with the voltage and decreases when the gas pressure (mixture) is increased. In the case of N_2 – SF_6 mixture, q_{max} decreases when increasing SF_6 content. On the other hand, q_{max} of positive discharges are higher than that of positive ones whatever the gas and its pressure, and the amplitude of voltage.

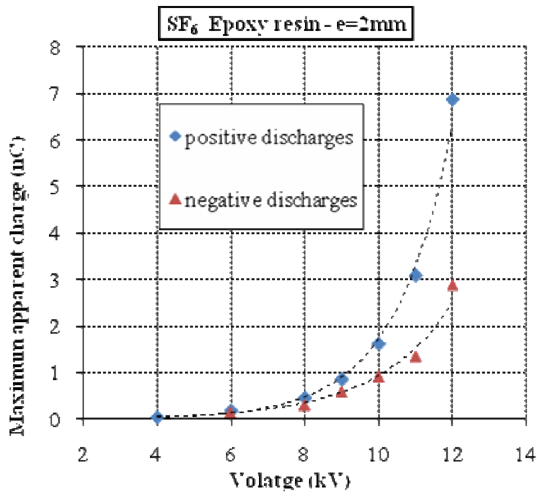

Figure 9: Evolution of the maximum apparent charge for positive and negative discharges with epoxy resin/SF_6 interface at 0.2 MPa versus the voltage.

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