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Critical Conditions of Flashover on a New Model of Polluted Insulators

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Abstract: In this study we present an experimental research on a new laboratory model for flashover studies. This model looks like a real outdoor insulator with respecting its shape and pollution. The experimental results of this model and their analysis were performed in two groups: The first is the measure of pollution resistance between the ground electrode and a static discharge for many discharge positions; the second is the measure of critical current and critical voltage according to the position of the discharge starting point. A comparison with the case of point to point gap reveals that the electric field in the air in the vicinity of the electrolyte surface is the responsible of the discharge elongation and the critical conditions of flashover are the weakest initial electric conditions necessary to create this field distribution.

Key words: Discharge, flashover, high voltage, insulator, pollution

INTRODUCTION

The flashover of the high voltage air lines of insulators, has always posed a disturbance of transport and electric distribution of power, because the studies carried out on this phenomenon are realized on simple models, which are very different from the real shape of the insulator. To study these problems, we have now achieved a model of laboratory. This model looks like a real insulator of electric lines in its shape and also in its pollution. The suggested model is valid to act well as go-between the real insulator and simple laboratory models which have been carefully studied.

The deposit of the pollution on the upper and lower surfaces of the insulator, followed by a humidification of this deposit, generates an electrolytic layer of a complex geometrical form, which takes the shape of the insulator and occupies the entire surface between the cap and the pin. The applied voltage between the two electrodes (the cap and the pin) causes the circulation of a current in the electrolytic layer. The Joule effect due to the passage of this current generates a partial draining of the pollution layer on the surface of the insulator. If the critical conditions of the discharge elongation are realized, the discharge propagates on the surface of pollution to the total short circuit between the cap and the pin. The phenomenon he said a flashover.

To be able to study the phenomenon of flashover as well as the influence of the various sizes on it; and to take into consideration the complexity of the form of pollution and that of the spatial distribution of the electric quantities on the real insulators; the researchers studied several models of a simple geometry (Obenaus, 1935; Labadi, 1971; Matsuo *et al.*, 2000) to determine the criterion, the critical conditions as well as the physical mechanism of this phenomenon. The assumptions which were extracted from the results obtained by using these models (Hampton, 1964; Wilkins, 1969; Rahal, 1979) cannot be applied to the real insulators. The principal cause of this failure is due to the qualitative geometrical difference between these models and the real insulators.

In order to seek more general methods for the determination of the critical conditions of flashover, we resumed the study of the phenomenon on multidirectional models (2, 4 and 8 grooves) (Flazi, 1987; Benchaib, 1985; Boudjella, 1986; Boudjella *et al.*, 1997). The result obtained by using these models show that:

- The critical conditions of flashover are determined by the effect of the leakage current during its circulation in the electrolyte and not by that of the discharge current. (Flazi, 1987, 2000; Benchaib, 1985; Boudjella, 1986; Boudjella *et al.*, 1997).
- The total current does not determine the critical conditions of flashover but the current in the direction of the propagation of the discharge which determines them.

These results enabled us to say that the distribution or the geometrical shape of lines current is very important in the problem of flashover. By taking these observations

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into account we proposed a new laboratory model which represents better geometrically and electrically the real insulators.

EXPERIMENTAL SETUP

This model presented, for the first time, at CEIDP'2001 (Flazi *et al.*, 1999) looks like a real insulator of electric lines in its shape and its pollution. It's a circular insulating disk (ϕ =21 cm) which carries on his upper surface a metallic cylinder that represents the cap or the pin of the insulator and the high voltage electrode too (Fig. 1). The low voltage electrode is shown as a second metallic cylinder placed on the lower surface of the disk. We put this disk in a cylindrical insulating container filled with (H_2O+NaCl), so that we can change the liquid thickness on its top, bottom and on the edge of the disk.

From the geometrical resemblance between the disk model and the real insulator, results a geometrical resemblance of several electrical quantities:

- A geometrical resemblance in the distribution of the current in the electrolyte between the foot of the discharge and the electrode on the opposite side. The one-way models do not take into account the existence of the current lines in all directions around the foot of the discharge. Our models multi ways take into account several directions of the current around the foot of the discharge, but these currents are separated by existing insulation between the grooves. i.e., the current lines around the foot of the discharge are discontinuous.
- A geometrical resemblance in the voltage distribution and its gradients in the electrolyte of our model and that in the pollution of a real insulator.
- A similarity between the distributions of the electric field in the air in the neighborhood of the electrolyte surface of our model and that of the neighborhood of the real insulator pollution.
- A geometrical resemblance in the form and the value of the resistance between the foot of the discharge and the electrode on the opposed side, during the evolution of the discharge. This resistance is essential for the modeling of flashover in dynamic state, i.e. during the evolution of the discharge

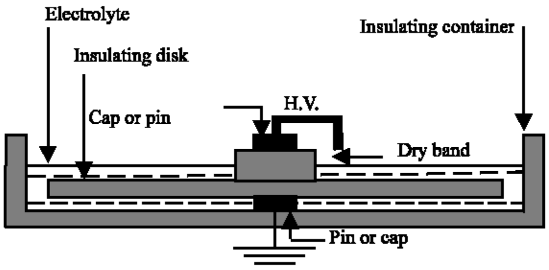

Fig. 1: The two surfaces polluted disk model of flashover

EXPERIMENTAL RESULTS

The measurement of electrolyte resistance: We measured the value of the electrolyte resistance between a given point A, of distance x of the dry band external edgeand the ground electrode at the bottom of the disk (Fig. 2 and 3), by using two methods of measurements:

- The first method is founded on the use of an electrolytic resistance measurer which contains two electrodes of measurement: The first has a diameter of ϕ_ = 3 mm placed at the measurement point A, the second is connected with the ground electrode at the bottom of the disk (Fig. 2).

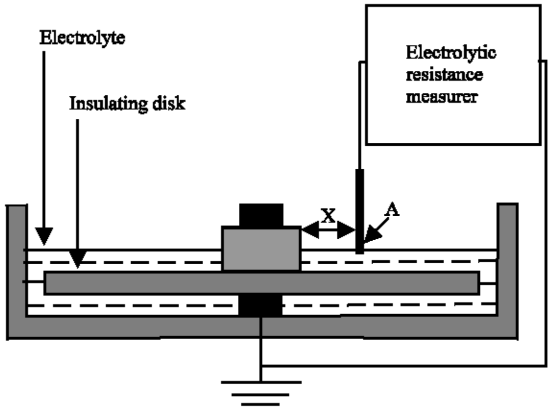

Fig. 2: Experimental setup for measuring the electrolyte resistance by a measurer

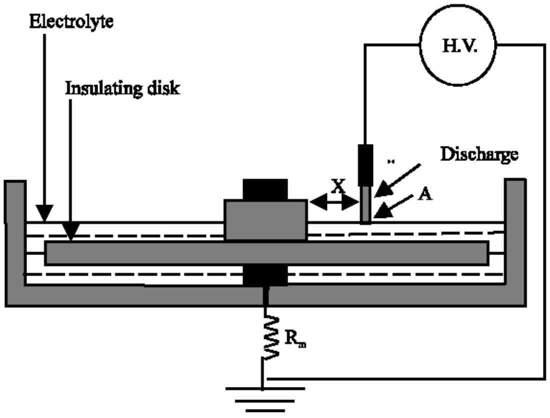

Fig. 3: Experimental setup for measuring the electrolyte resistance by Up/I ratio

- The second method is based on the measure of the circuit current I for a given applied voltage. By applying a voltage of 7 kV (lower than the critical voltage of flashover) between HV electrode placed directly over the point of measurement A at 2 mm height of the electrolyte surface and that of the ground (Fig. 3), a discharge starts between HV electrode and point A. The measurement of the circuit current I (done by using the measurement resistance Rm), with the calculation of the U_p (voltage difference between the point of measurement A and the ground electrode), by reducing the voltage difference of the discharge V_d = 840 V (Labadi, 1971; Flazi, 1987) from the applied voltage V_{app} = 7 kV, enables us to find the resistance of electrolyte $R = U_p/I$.

Figure 4 presents the influence of the measurement point position on the electrolyte resistance value by using the first method of measurement. The distance x varies from 1 to 7 cm, the depth of the electrolyte e = 0.3 cm maintained constant and the resistivities used are 2, 4, 6 and 8 kΩ.cm. It is noticed that the reduction in the resistance value during the displacement of the measurement point is very slow. We can say, for the four resistivities, that the resistance decreases by 10%, when the distance decreases by 30%.

Figure 5 shows the depth effect of the electrolyte on the value of the electrolyte resistance. Two depths were used e = 0.3 cm and e = 0.4 cm for two values of resistivities ρ = 2 and ρ = 8 kΩ.cm. We notice that the curve for e = 0.4 cm has the same appearance as that for e = 0.3 cm.

On Fig. 6, we represent the comparison between the two methods of measurement for a depth of 0.3 cm and two values of resistivity 2 and 8 kΩ.cm. We can notice that the value of the resistance measured with the Up/I ratio is lower than that measured directly with the electrolytic resistance measurer. We can explain this

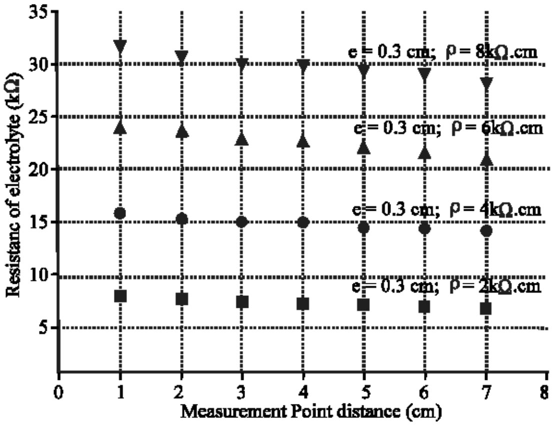

Fig. 4: The electrolytic resistance according to distance

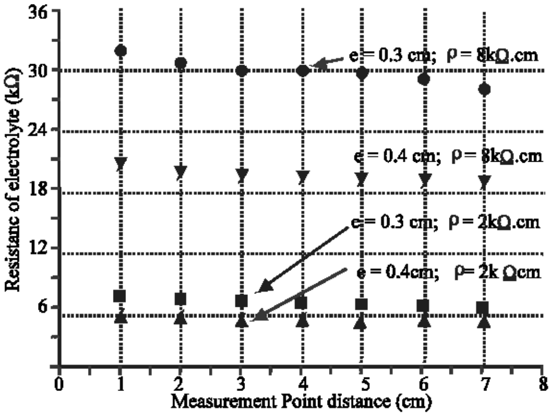

Fig. 5 : The influence of the electrolyte depth on its resistance

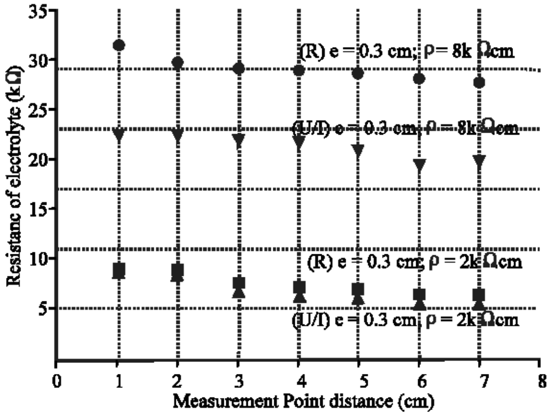

Fig. 6: Comparison between the two methods of measurement of resistance

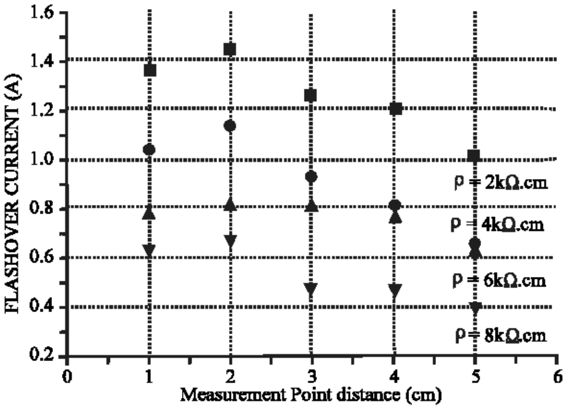

Fig. 7: Critical current according to the starting point position

difference by the difference of the diameters between the foot of the discharge and that of the measurer electrode. Indeed, the diameter of the foot of the discharge is larger than that of the measurer electrode because the used currents are relatively large.

Measurement of the critical current: The Fig. 7 gives us the critical current according to the position of the starting point of the discharge on the surface of the electrolyte and this for e = 0.3 cm and ρ = 2, 4, 6 and 8 kΩ.cm. We can notice from the shape of these curves that the resistivity has a very significant influence on the critical current value of the discharge evolution: the increase in the resistivity involves a reduction in the critical current. We can notice also that the critical current value varies considerably according to the position of the discharge starting point, while the variation of resistance is much smaller.

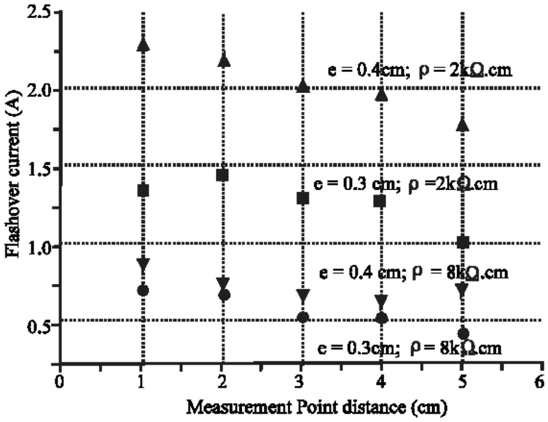

Fig. 8: The electrolyte depth influence on the critical current

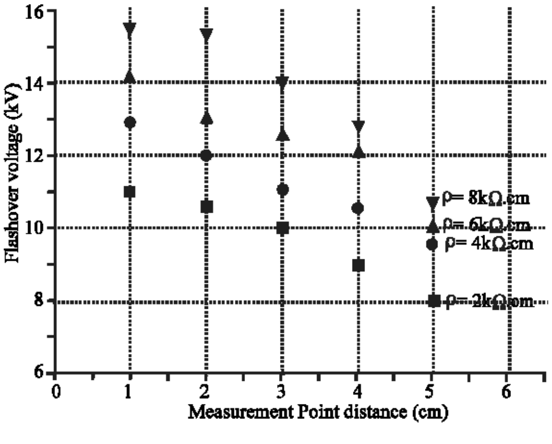

Fig. 9: Critical voltage according to the starting point position

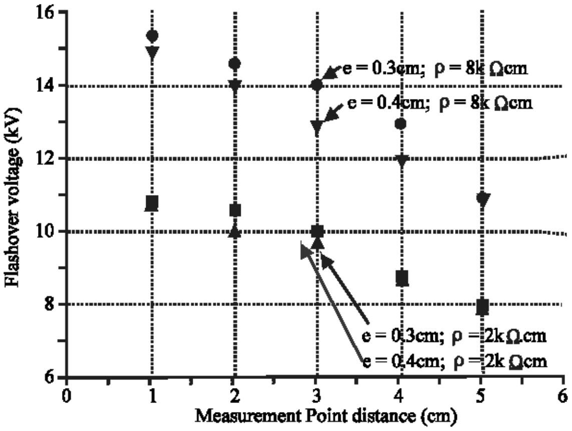

Fig. 10: The electrolyte depth influence on the critical voltage

On Fig. 8 we present the critical voltage values for two depths 0.3 and 0.4 cm and for two resistivities 2 and 8 kΩ.cm. We notice that the critical current is proportional to the depth, because the ratio I_c/e is constant, i.e., for a given resistivity the critical current per millimeter of depth is constant.

Measurement of the critical voltage: Figure 9 shows us the critical voltage according to the position of the starting point of the discharge and this for e = 0.3 cm and ρ = 2, 4, 6 and 8 kΩ.cm. We can notice that the resistivity has a very significant influence on the critical voltage value of the discharge evolution; the increase in the resistivity involves an increase in the critical voltage. We can notice that the critical voltage value varies considerably according to the position of the discharge starting point, while the variation of resistance is much smaller.

On Fig. 10 we present the critical voltage values for two depths of 0.3 cm and 0.4 cm and for two resistivities of 2 and 8 kΩ.cm. We notice a very small influence of the depth on the critical voltage. I.e. for a given resistivity, the depth of the electrolyte does not influence the value of the critical voltage, other wise its influence is tiny (very weak).

DISCUSSION

We notice that a decrease of 30% of the total distance, between the measurement point and the ground electrode, produces a decrease of 30% of the critical voltage and a decrease of 10% of the total electrolyte resistance value. This equality between the variation of the total distance and that of the critical voltage adds another proof on the very significant role of the electric field in the air meadows of thesurface of pollution during the evolution of the discharge (Flazi, 1999).

While taking into account that the increase depth for a given resistivity does not involve a variation of the critical voltage but it involves a proportional increase of the critical current, we can say that it is the voltage and not the current which determine the critical conditions, as opposed to what we found in the cases of the rectangular grooves (Flazi, 1987, 2002) where the size which determined the critical conditions was the current.

There is only one voltage critical value for each resistivity value. The increase in the voltage value during the increase in the resistivity value and the decrease of the voltage value with that of the distance lead us to believe that the evolution of the discharge is only a progressive breakdown of air between the discharge and the ground electrode favored, or assisted, by the electrolyte.

When the resistivity of the electrolyte increases, the breakdown becomes more difficult and the critical voltage becomes larger. If we increase the resistivity of the electrolyte to the maximum, with replacing it by the air, the interval reaches its maximum dielectric rigidity.

A comparison with the case of point to point gap reveals that the electric field in the air along the distance, between the discharge and the ground electrode in the neighbourhood of the electrolyte surface is the responsible of the discharge elongation. If its distribution is sufficient for the discharge evolution (by ionisation), the flashover is produced. The critical conditions of flashover are the weakest initial electric conditions necessary to create this field distribution along the way of the discharge evolution.

CONCLUSION

The use of a new laboratory model which represents better, geometrically and electrically the real insulators, allowed us to:

- Measure the value of the electrolyte resistance between a given point A of distance x of the dry band external edge and the ground electrode, by using two methods of measurements: The first method is based on the use of an electrolytic resistance measurer and the second method is based on the measure of the circuit current I for a given applied voltage.
- Say that voltage is the size which determines the critical conditions and not the current, as opposed to what we found in the cases of the rectangular grooves where it was the current which determines the critical conditions.
- Believe that the evolution of the discharge is only a progressive breakdown of the air between the discharge and the grounding electrode favored, or assisted, by the electrolyte.

A comparison of the case of point to point gap reveals that the electric field in the air in the neighbourhood of the electrolyte surface is the responsible of the discharge elongationand the critical conditions of flashover are the weakest initial electric conditions necessary to create this distribution of field.

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