The Minimum Flashover Voltage Characteristics of Impulse Voltages on Solid Dielectric Surfaces

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1. Introduction

Recently,system voltages on electric power lines and plants have been increasing. Accordingly, with lightning discharges and switching of electric circuits, extraordinary higher surge voltages are frequently applied to electric power lines and installations. Thus, there remain many problems to be solved. As an example,we take "arcing horn"used for the protection insulator surfaces from being injured by electric arc discharges. However, when insulator terminals are shortened by a flashover breakdown, the arc discharge sometimes propagates along the insulator surface without discharging between the terminals of arcing horns[1]. A phenomenon is often observed under applying excess high surge voltages to the insulators. Thus, it is very important to study the discharge phenomena and flashover voltage characteristics in which impulse voltages are impressed on insulator surfaces. The authors have reported AC discharge characteristics of a needle-to-plate electrode in air with the solid dielectric[2].

In this paper, the discharge characteristics of impulse voltages of the needle-to-plate electrode in air with the solid dielectric have been discussed experimentally. As the results, it is has been found that the flashover characteristics of impulse voltages don't depend strongly on relative air humidity and with lifting the needle electrode above the dielectric surface, the flashover voltages become higher. The discharge characteristics of negative impulse voltages greatly depend upon the existence of dielectric surface. In addition to this, it has been also found that the values of flashover voltages for positive polarity are approaching the peak values of AC flashover voltages.

2. Experimental Method

In Fig.1, the experimental circuit is shown. The same electrode arrangements as the one has been reported[2]. The semicircular electrode manufactured with the copper plate (radius 60mm, thickness 2mm) is attached to one end of the frosted glass plate (300X200X2mm). The needle electrode is made from tungusten rods with the dimension of 0.7mm. The glass plate is retained horizontally on the acrylic resin insulator. The gap length G is the horizontal distance between the needle electrode and plate electrode.

The height H is the vertical distance of the needle electrode above the glass plate. The inclined angle of the needle electrode against the glass plate is kept at 30°

These installations have been set in the testing chamber of 0.9m³ and impulse voltages have been applied to the electrodes under various humid conditions. The impulse voltages of a standard wave form which the

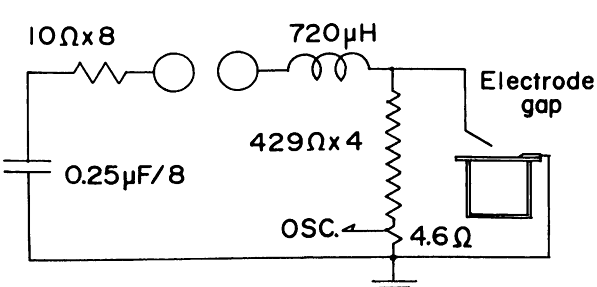

Fig. 1 Experimental Circuit

rise time and tail duration was 1.5 μs x 40μs were used. The flashover voltage and time to flashover were recorded by the storage oscilloscope .

Table.1 Minimum F.O.V (G=7cm)

	positive	negative
with solid dielectric		
H=0 (creepage discharge)	51kV	78kV
H=1cm	59kV	86kV
H=2cm	62kV	97kV
H=3cm	66kV	102kV
without solid dielectric	70kV	148kV

3. Experimental results eith discussions

3・1 Influence factors on minimum flashover voltage

3・1・1 Effect of dielectric surface

Minimum impulse flashover voltages (F.O.V.) with and without dielectric for the horizontal gap length G=7cm are shown in Table. 1 . The minimum flashover voltages are the lowest values of flashover voltages. The total number of flashover shots per electrode arrangement reached 20 for the minimum F . O . V . tests .

The results with dielectric surface are shown for the heights H of needle electrode above dielectric surface . F . O . V . of negative polarities are higher than those of positive polarities and the trend don't depend on the existence of dielectric surface . When there is a dielectric surface , the F . O . V . is reduced considerably . The reducing effect of F . O . V . is more larger for negative polarity than for positive polarity . Of all the results , the F . O . V . of negative polarity for H= 0 is decresed remarkably than without dielectric surface . Thus it is found that the F.O.V. of negative polarity for H= 0 is influenced significantly by existence of dielectric surface . On the other hand , flashover voltages with dielectric surface for both positive and negative polarities are increased with increasing the height H of needle electrode , but the increasing proportion for negative polarity is larger than that for the positive .

3・1・2 Effect of relative humidity

The minimum F.O.V. characteristics are shown in Figs.2 (a) and (b) respectively . The polarities are positive for (a) and negative for (b). The results for 90% relative humidity are

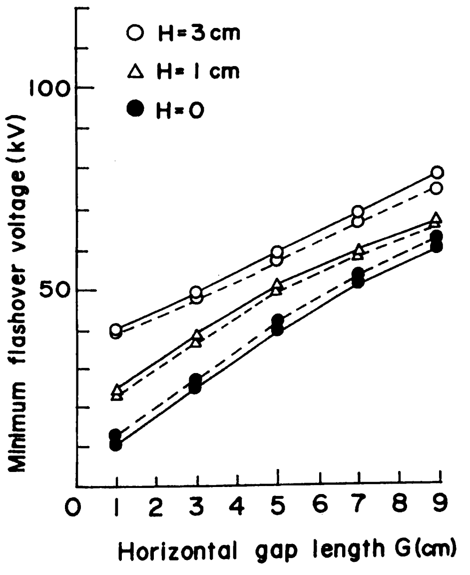

Fig. 2 (a)
Variation of minimum F.O.V for positive polarity

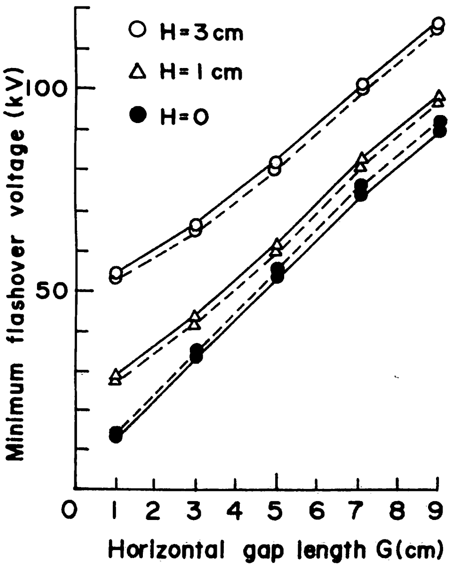

Fig. 2 (b)
Variation of minimum F.O.V for negative polarity

shown in the solid lines and those for 60% are depicted in the dotted lines . For vertical height H= 0 of needle electrode , minimum F.O.V. under high humidity are slightly lower than those under low humidity . The trend is free from polarities of applied voltages . This is because, with increasing relative humidities, the electric conductivity of dielectric surface is increased to decrease flashover voltages[2] . However , when the reducing rate of flashover voltages is compared with that for AC flashover voltages , the rate is so small .

When needle electrode is lifted up by H above dielectric surface , regardless polarities , minimum flashover voltage for higher humidity are slightly higher than those lower humidity . This will be due to the reduction of mobility of electrons and ions with increasing relative humidity[3].

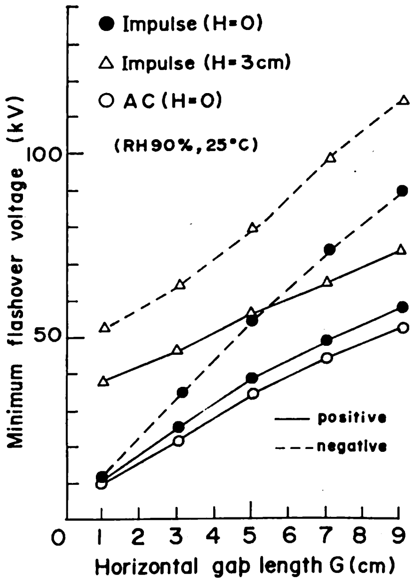

Fig. 3 Comparison of minimum F.O.V for impulse and AC

3・1・3 Effect of polarity of applied voltages

In Fig . 3 , impulse characteristics of minimum F.O.V. are shown for 90% relative humidity . The results of positive polarity are shown in solid linesd and those of negative polarity are shown in dot-ted lines . The vertical gap lengths H are 0 and 3cm respectively . Moreover , for the comparison of results , values of AC flashover voltages for H= 0 are also shown[1] . All F.O.V. of the impulse and AC are increasing with the increase of horizontal gap lengths G and vertical lengths H .

For the height H= 0 of needle electrode , the minimum F.O.V. are increasing with increasing the gap lengths G and depending on polarities , but the difference of F.O.V. for polarity is small. When the needle electrode is lifted up by 3cm , the minimum F.O.V. of negative polarity are higher than those positive polarity . For the comparison of results , the peak values of AC flashover voltage of H= 0 of needle electrode are shown under the same conditions of relative humidities . It is found that the AC flashover values are closing to the minimum flashover voltages of positive polarity .

3・2 Behaviour of pre-discharges

Characteristics of AC discharge prior to flashover greatly depend upon the elongation of positive streamer corona discharge ignited at the needle electrode . In this study , the effect of pre-discharges on the flashover phenomenon under impulse voltage impressions has been observed in terms of the elongation of creepage corona discharges .

A sheet film (ISO400,120X80mm) was placed on a glass surface and a needle-to-plate electrode was attached on the film surface . The electrode set was arranged in a dark box . Then an impulse voltage lower by a few % than the minimum F.O.V. was applied to the electrode to obtain a Lichtenberg figure prior to the flashovers . The figure is the one for corona discharges on the film surface . However, the growing state of the corona discharge for the flashover process on the dielectric surface could be observed considerably .

Fig 4 (a) and (b) are the Lichtenberg figures of creepage corona discharges for H= 0 of needle electrode , the horizontal gap length G=9cm and 90% relative humidity with glass surface . In Fig . 4(a) a positive impulse voltage of 58KV was applied . Streamer corona discharges

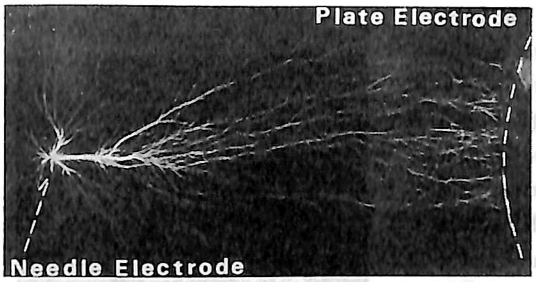

Fig. 4 (a)
positive pre-discharge

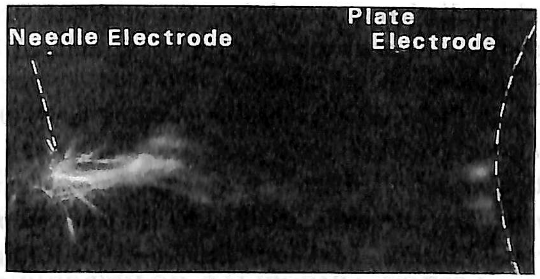

Fig. 4 (b)
negative pre-discharge

with highly brighness grow in tree-like branching from the needle-to-plate electrodes . On the other hand, a negative voltage of the same value was applied , but there were no figures obtained .

In Fig. 4 (b), a negative voltage of 85kV was applied . Creepage corona discharges elongate flom the plate electrode to the needle . However , the figure is not so clear as that for positive polarity . Thus , the creepage discharge for positive polarity ignites at lower voltages than those for negative and the discharge is easy to elongate . Accordingly , the creepage impulse flashover voltage for positive polarity is lower than that for negative polarity and the voltage value is closing to that of AC flashover as shown in Fig 3 .

Lichtenberg figures for H=1cm are shown in Fig. 5 (a) , in which a positive voltage of 60kV was applied to the gap . The discharge state at the flashover is shown Fig. 5 (b) as well. Streamer corona discharges grow and propagate in air , and finally attain the plate electrode in creeping at the electrode end. As shown in Fig. 5 (b) ,spark discharges at the flashover also grow at the needle electrode and reach the plate electrode . In Fig. 6 (a), a negative voltage 90 kV was applid . Positive corona discharges elongate from the plate electrode and is froming a

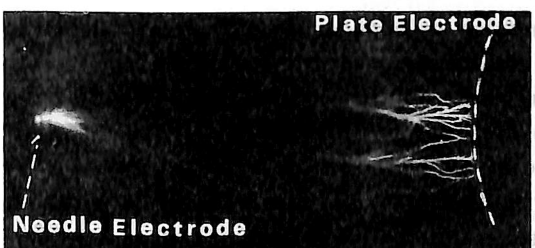

Fig. 5 (a)
positive pre-discharge

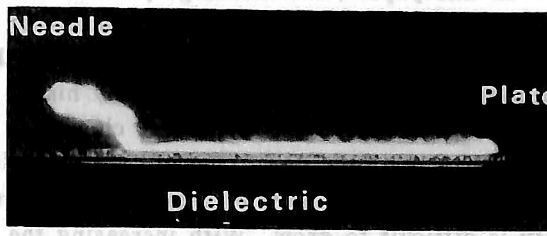

Fig. 6 (a)
Negative pre-discharge

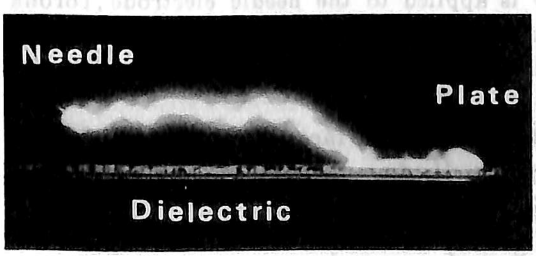

Fig. 5 (b) positive spark

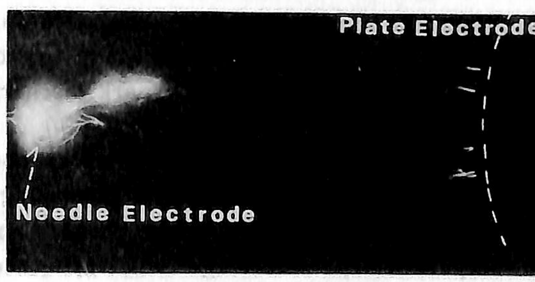

Fig. 6 (b) Negative spark

brighten discharge spot below the needle electrode . Then the flashover , as shown in Fig. 6 (b)is induced by the spark discharge ignited at the spot .

In Fig. 7 (a) and (b), the pictures made by high speed framing exposure are shown .These show the space distribution of corona dischages at 0.5μs before the flashover and the needle electrode is lifted up by H=1cm above the dielectric surface . In Fig. 7 (a) , a positive impulse voltage was applid to the needle electrode . Corona discharges elongate in circular flom the needle to the plate electrodes . In Fig. 7 (b) ,a negative voltage was applied to the needle electrode. Corona discharges grow from the plate electrode and elongate on the dielectric surface. Finally any discharges above several portions of the dielectric surface attain the needle electrode. The negative corona is dischaging in branches .

As mentioned above , the spatial distributions of corona discharges for positive and negative polarities show the dischaging state at the flashover . The negative corona dischage without dielectric surface is difficult to grow from plate electrode . When the needle electrode is lifted up above dielectric surface and a negative impulse voltage is applied to the electrode, the corona discharge is easy to grow and elongates in creeping a long route on the dielectric surface, but for the positive polarity is not so . Thus, the negative flashover voltage with the dielectric surface would be decreased remarkably as shoen in Table . 1.

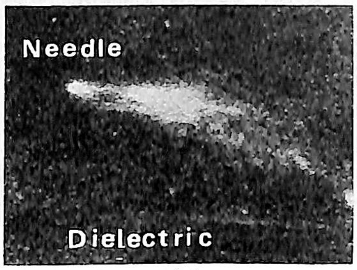

Fig. 7 (a) postive

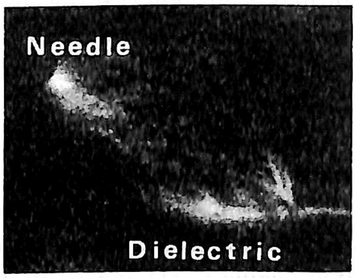

Fig. 7 (b) Negative
profile ofpre-discharge

4 . Conclusion

In this paper , the discharge phenomena of impulse voltage for needle-to-plate electrode on solid dielectric surface have been discussed . The results obtained are as follows .

(1) When impulse voltages are applied to the electrodes on dielectric surface (H= 0) , the minimum negative F.O.V. are extremely higher than those for positive polarity . And the minimum F.O.V. of positive polarity are closing to those of AC flashover .

(2) When the impulse voltage of positive polarity is applied to the needle electrode which is lifted up above the dielectric surface , the corona dischare at the plate electrode of nerative polarity is difficult to grow . With increasing the height H , therefore , the flashover voltages are increased . This is possibly because the spark discharge at the fiashover creeps only a short distance to attain the electrode on the dielectric surface .

(3) When the impulse voltage of negative polarity is applied to the needle electrode , corona discharges on dielectric surface are easily to grow at the plate electrode of positive polarity and elongate in creeping . Therefore , spark discharge at the flashover creeps long route on the dielectric surface .

(4) When the needle electrode is lifted up above the dielectric surface ,the values of negative flashover voltages are increased with increasing the height H of needle electrode and the increasing rate is also larger than that for positive polarity.

(5) Impulse flashover voltage is not influenced so greatly humidity .

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