Experimental Study of Critical Cascading Flashover on Insulator Assembly Using Model Arrangements (Part II)

(The Influence of a Floating Electrode, Placed on a Porcelain Board, on the Formaiton of a Flashover Path)

By

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Abstract

This paper describes the phenomena of cascading flashovers in model arrangements for experimental analysis of critical cascading flashovers occuring in an insulator assembly used on high voltage transmission lines.

The testing model used consisted of a pair of rod-rod electrodes, a potentially floating copper wire and a porcelain board. The applied lightning impulse voltage of positive or negative polarity was much higher than the breakdown voltage, when the flashover occurred for only a short time lag. The experimental results included flashover paths and pre-breakdown corona distributions, and cascading flashover rates.

The flashover phenomena on the testing model clarified that the cascading flashover rate was related to the position of the porcelain board with the floating wire and that the corona from the floating wire was generated just before the corona from the rod electrode reached the floating wire.

In the summary, the influence of the floating electrode on the formation of flashover paths discussed in comparison with previous reports. As a result of this series of experiments, it was clarified that a cascading flashover occurred only through coexistence with the porcelain surface and floating metal.

1. Introduction

For a transmission system to be reliable, the transmission lines must be sufficientyl protected from streaks of lightning. Even though we try to protect them perfectly, the insulator assembly can be flashovered in a reversible breakdown by lightning striking

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transmission tower, followed by the insulator assembly breaking down due to the heat from a critical cascading flashover (C.C.F.). It is feared that this can also lead to serious faults in the transmission system.

In the previous two reports, we clarified the conditions of a C.C.F. occurrence on the insulator assembly, and clarified the influence of a floating electrode placed in the air at mid-gap.

In this report, we describe a series of basic experiments[1)~4)] to observe discharge phenomena, using the model equipment shown in Fig. 1. To investigate the influence on the flashover part of the presence of metal fittings on the suspension insulator, a porcelain board (15×25 cm) and a pair of rod-rod electrodes (1.0 cm in diameter, hemi-spherical ends, gap length ; 15 cm) were used. The floating electrode was placed at position L far from the end of voltage applied rod electrode on the porcelain board at distance H from the rod-rod electrode axis. Then, by varying L and H, the conditions of the flashover occurring in the air gap between rod-rod electrodes were investigated.

These experiments were executed using copper wire put on the porcelain board instead of the usual metal fittings between the insulators. Both its ends were smoothly curled to allow an undistorted electrical field, and it was floated electrically.

A voltage wave of the lightning impulse (0.6×40 μsec.) was applied to the model equipment, because C.C.F. phenomena on the insulator assembly occurred eary in the front of the wave, as explained in the previous report. On the model equipment,

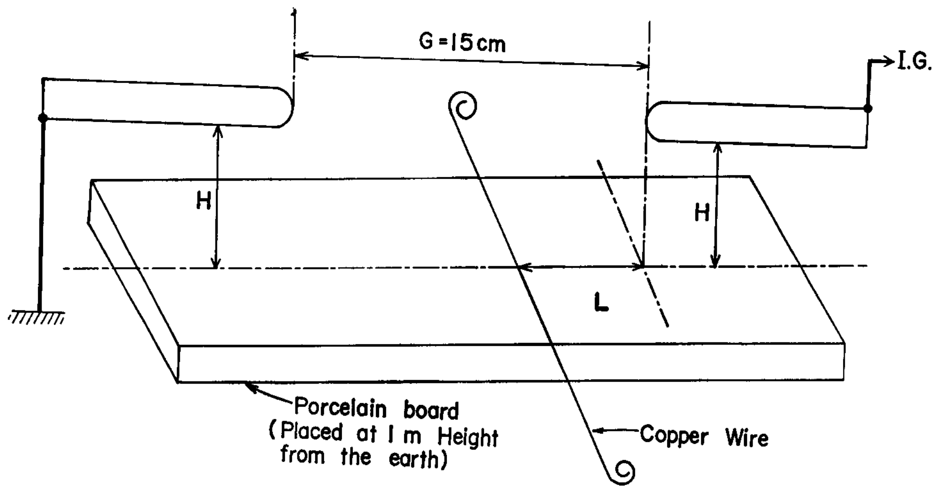


Fig. 1 Arrangements of the model insulator assembly. The horn gap and connecting metal fittings are replaced with rod-rod electrode and floating copper wire, and the insulator is in a plane shape for simplification.

over-voltage was applied in order to cause a breakdown quickly. Observations were conducted on the rate of cascading flashover, the distribution of pre-breakdown corona, and the sequential development of the corona.

2. Influence of Floating Electrode, Placed on a Porcelain Board, on the Formation of Flashover Path

A flashover was tested with a floating electrode, made of copper wire placed on a porcelain board, as shown in Fig. 1, in order to obtain cascading flashover rates with the copper wire placed at different points on the board, and to observe the prebreakdown phenomena before a flashover. The purpose of this test was to examine the state of coronas generated from copper wire on a porcelain board on the assumption that such copper wire might be one of the factors causing the C.C.F. in the insulator assembly.

2.1 Flashover Characteristics when Using a Porcelain Board and Rod-Rod Electrodes (Without a Floating Electrode)

A test was conducted by placing a porcelain board at a distance H from the electrode axis without using copper wire.

The result was as described below:

a) The creeping flashover rate

The creeping flashover rate that occurred on the porcelain board was examined by vafying the distance between the rod-rod electrode axis and the surface of the porcelain board as chosen by $H=4$, 3, and 2cm. The polarity of applied voltage was positive (preset value : 300 kV). The voltage was applied 20 times at each position (H). In the test resuts, the creeping flashover rate was determined as follows :

When $H=4$ cm, the rate was 0%, when $H=3$ cm, the rate was 5% and when $H=2$ cm, the rate was 30%. There, the limit of the creeping flashover was set at $H=3$ cm.

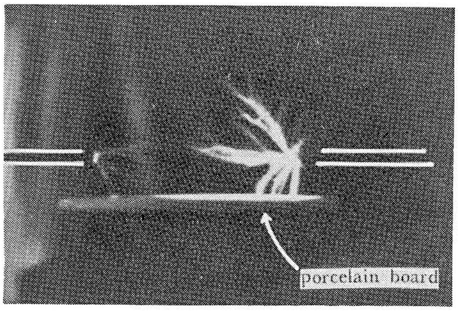
b) Corona growth

To observe the growth of corona between the electrodes with the porcelain board placed near the electrode axis, the prebreakdown phenomena before the arc generation were observed using the voltage-chopping method. The results are as shown in Fig. 2. The voltage-chopping time was divided into four stages; $T_c=0.17$, 0.19, 0.23 and 0.28 μsec.. The polarity of the applied voltage was positive (preset value : 300 kV).

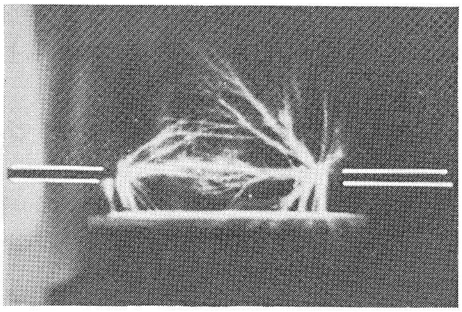
The porcelain board was placed at $H=3$ cm (the probability of the creeping flashover at this point was 5%).

* The lst stage ($T_c=0.17$ μsec.) :

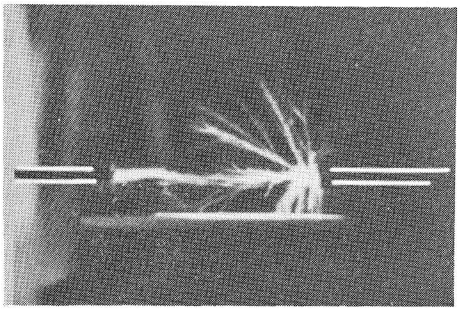
H=3.0 cm



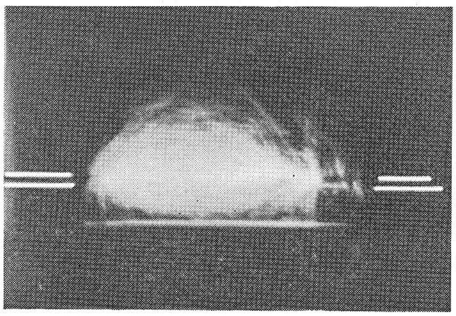
The 1st stage (T_c=0.17 μsec.)



The 3rd stage (T_c=0.23 μsec.)



The 2nd stage (T_c=0.19 μsec.)



The 4th stage (T_c=0.28 μsec.)

Fig. 2 Sequence of pre-breakdown corona for rod-rod gap with a porcelain board (Positive voltage appilcation)

A positive corona was generated from the voltage-applying electrode, a part of which reached the porcelain board, then advanced toward the ground electrode. A minor negative corona was generated from the ground electrode, a part of which reached the porcelain board. At this stage, however, positive and negative coronas had not yet connected.

* The 2nd stage (T_c=0.19 μsec.) :

Positive and negative coronas were unified in the air. The positive corona was transformed into a creepage corona upon reaching the porcelain board.

* The 3rd stage (T_c=0.23 μsec.) :

At this stage, a main negative corona had been formed between the ground electrode and the porcelain board. The porcelain board was fully covered by the creepage coronas. The connection of coronas fully covered by the creepage coronas. The connection of coronas coming from opposite directions in the air was further intensified.

* The 4th stage (T_c=0.28 μsec.) :

Main leader coronas had started from both electrodes into the air. So the arc was achieved directly between the rod-rod electrodes, without any creepage.

2.2 Flashover Characteristics When a Copper Wire Was Placed on the Porcelain Board

a) Position of the copper wire and creeping flashover rate

The distance from the electrode axis to the surface of the porcelain board was designated as H, and the distance from the level of the voltage applied electrode to the copper wire was designated as L. The creeping flashover rate was examined by changing H and L, in the same manner as when the copper wire was suspended dielectrically in the air (as reported in Part I[4]). The experimental results are shown in Fig. 3. When the copper wire was floated in the air without the porcelain board, the flashover that passed through the wire was expressed as the cascading flashover rate. When the porcelain board was put in place, the flashover that crept along its surface was expressed as the creeping flashover rate.

Fig. 3 presents the following:

1) When the porcelain board was used without placing the copper wre in the gap between the electrodes, the creeping flashover rate was 5% at $H=3$ cm (the distance from the electrode axis).

When the copper wire was used, the rate exceeded 50% at $H=3$ cm, as well as at $L=2.5$, 7.5 and 12.5 cm, the axial dstances from the voltage applied electrode. The reason the rate exceeded 50% will be considered later, based on photos taken with the voltage chopping method shown in Fig. 4.

2) When the copper wire was placed on the porcelain board, the creeping flashover rate increase in this sequence: ground electrode side, middle point and voltage applying electrode side.

The creeping flashover rate (in this case equal to the cascading flashover rate) was increased by using both porceain board and copper wire. When $L=2.5$ cm and $H=3$ cm, the rate increased 15 to 60%; when $L=7.5$ cm and $H=3$ cm, 10 to 80%,

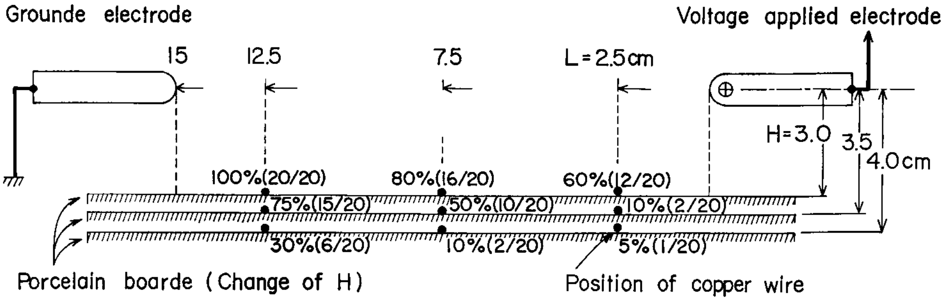
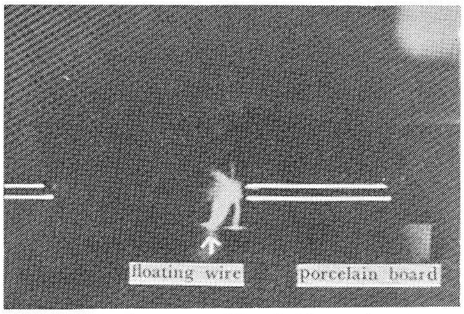
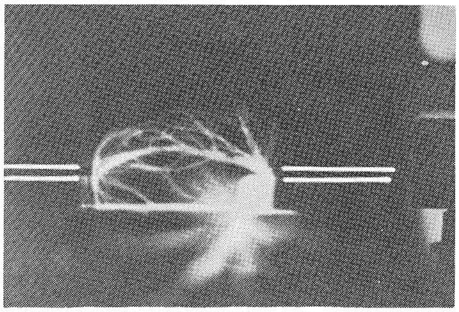


Fig. 3 The cascading flashover rates changing positions of porcelain board and floating wire

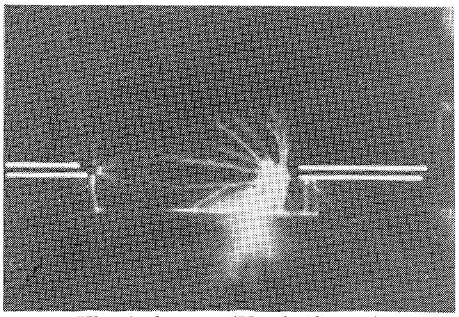
1) L=2.5 cm, H=3.0 cm



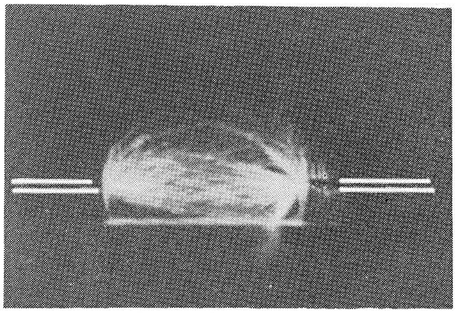
The 1st stage (T_c=0.17 μsec.)



The 3rd stage (T_c=0.23 μsec.)

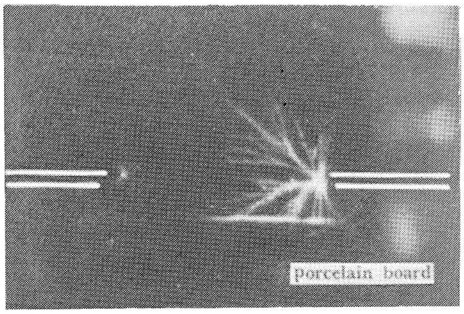


The 2nd stage (T_c=0.19 μsec.)

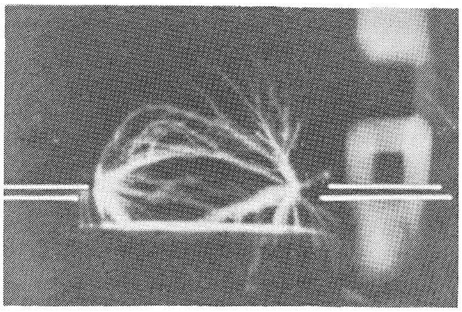


The 4th stage (T_c=0.28 μsec.)

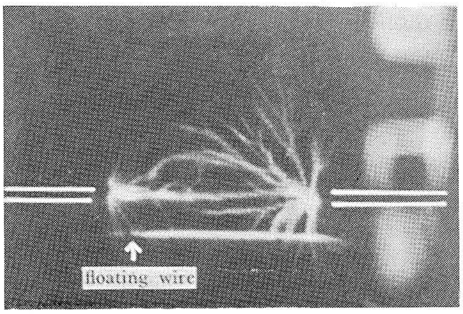
2) L=12.5 cm, H=3.0 cm



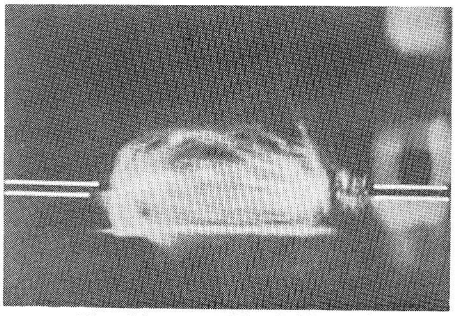
The 1st stage (T_c=0.17 μsec.)



The 3rd stage (T_c=0.23 μsec.)

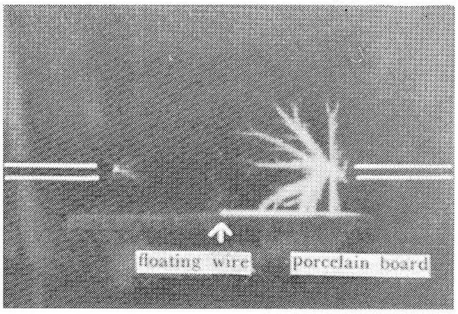


The 2nd stage (T_c=0.19 μsec.)

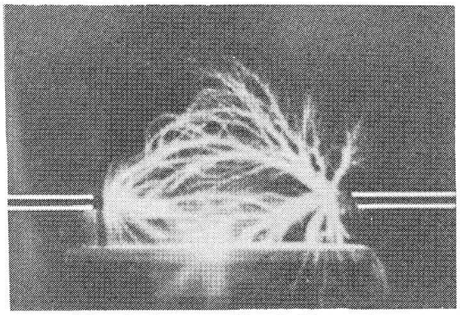


The 4th stage (T_c=0.28 μsec.)

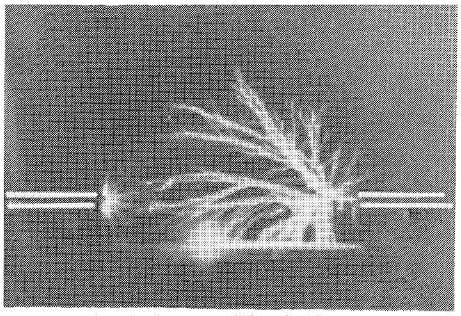
3) L=7.5 cm, H=3.0 cm



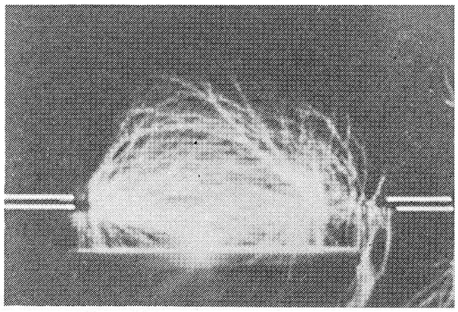
The 1st stage (T_c=0.17 μsec.)



The 3nd stage (T_c=0.23 μsec.)



The 2nd stage (T_c=0.19 μsec.)



The 4th stage (T_c=0.28 μsec.)

Fig. 4 sequence of pre-breakdown corona for rod-rod gap and a floating wire on the porcelain board

and when L=12.5 cm, 65 to 100%. The creepng flashover rate increase at the middle point was much greater than when only the copper wre was used. For comparison, in testing for the cascading flashover rate, as shown in Fig. 6 in the previous report[4], when the copper wire was floating in the air, with H remaining constant, the cascading flashover rate large in this sequence: ground electrode side (L=12.5 cm) — voltage applying electrode side (L=2.5 cm) — middle point (L=7.5 cm).

The reason for this is considered to be as followws:

When the copper wire was used alone, floated in the air, the corona, growing toward the copper wire, developed a flashover through the copper wire. When the copper wire was placed on the porcelain board, the corona was transformed into a creepage corona when it reached the porcelain board. Therefore, the corona should pass through the copper wire in all cases.

The reason for the increase of the creeping flashover rate in the sequence: ground electrode side — middle point — voltage applying electrodes side is considered to be as follows:

Comparison was made between the creeping flashover rates obtained with the copper wire on the board near the ground electrode, and near the voltage applying electrode. Due to the difference in the length of their advances, positive and negative coronas were unified at a point closer to the ground electrode. When the copper wire was placed at $L=12.5$ cm, where the coronas were unified, as can be seen in the photo in Fig. 4, the copper wire, generating short length coronas, facilitated the completion of the arc. Therefore, the creeping flashover rate was increased by placing the copper wire on the board near the ground electrode.

On the other hand, when the copper wire was placed near the voltage applying electrode, it was then no longer at the position where the positive and negative coronas exactly met, but a position of $L=2.5$ cm, where only the positive corona advanced a little. Thus, the connection of both polarity coronas was not facilitabled by the opper wire.

Therefore, the copper wire has little to do with the creeping flash-over rate, which is consequently lower than when the wire was placed on the board near the ground electrode.

Thus, the wire which was placed at the middle point was near the position at which the positive and negative coronas statistically met most often. The creeping flashover rate was thus higher than when the wire was placed near the voltage applying electrode.

The corona density, however, was higher when the wire was placed near the ground electrode than when placed near the voltage applying electrode. The creeping flashover rate was thus higher with the wire at the ground electrode than at the middle point. This indicates clearly that the creeping flashover rate differed depending on the position of the copper wire.

b) Relationship between the position of the copper wire and flashover path

It was therefore confirmed that the flashover path differed, depending on the position of the copper wire on the porcelain board. When the wire was placed near either electrode, the arc generated from the electrode into the air reached the wire directly. When the wire was placed far from the electrode, the arc crept along the porcelain board, then passed through the wire. Measurements were taken, varying the position of the copper wire, to determine the rate of the cascading flashover connecting directly with the copper wire, without previous creepage.

Fig. 5 shows the tested result when the polarity of the applied voltage was positive (preset value: 300 kV), and $H=3$ cm. The figure represents the following: When the copper wire was placed near the ground electrode, the percent of flashovers reaching the copper wire directly from that electrode was high. On the other hand, when the copper wire was placed near the voltage applied electrode, the arc paths often crept along the porcelain board first, and then passed through the copper wire. For instance, when $L=10$ cm, about 20% of the leader coronas reached the copper

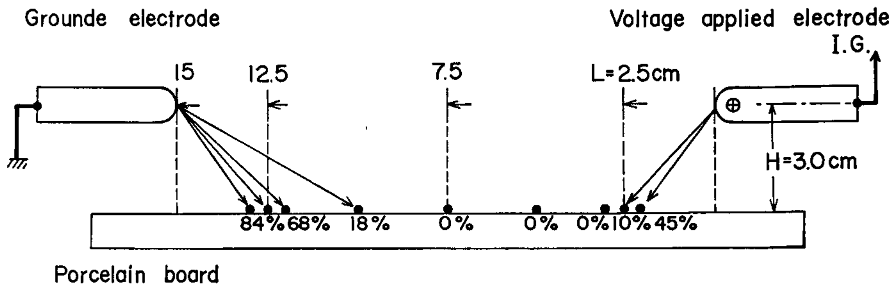


Fig. 5 The rates of dilectly cascading flashover from rod electrode to floating wire

wire directy from the ground electrode. When $L=3$ cm, the copper wire was far from the ground electrode. Thus, neither the positive nor negative corona reached the copper wire directly. The reason will be considered in item e.

c) Position of the copper wire on the porcelain board and advance of corona

Corona advanced as described below:

The creeping flashover rate and the various flashover paths have been described in previous paragraphs. To determine the causes of these cascading flashover rates decribed above, the advance of the pre-breakdown corona to flashover was observed, with the copper wire at three different positions.

1) $L=$ 2. 5 cm, $H=3.$ 0 cm
2) $L=12.$ 5 cm, $H=3.$ 0 cm
3) $L=$ 7. 5 cm, $H=3.$ 0 cm

The voltage-chopping time was divided into four stages, $T_c=0.$ 17, 0. 19, 0. 23 and 0. 28 μsec..

The polarity of the applied voltage was positive (preset value: 300 kV). The creeping flashover rate (R_1), and the cascading flashover rate when the flashover path reached the copper wire directly (R_2) were as shown below:

At position 1) $R_1=65\%$, $R_2=45\%$
At position 2) $R_1=95\%$, $R_2=85\%$
At position 3) $R_1=80\%$, $R_2=$ 0%

The photo of the pre-breakdown corona, Fig. 4, taken with the voltage chopping method, shows the process leading to flashover wth the copper wire placed at 1), 2) and 3), as analyzed below.

* The 1st stage ($T_c=0.$ 17 μsec.):

When the copper wire was placed at position 1), most of the positive corona, generated from the voltage applying electrode, came near to or reached the wire on the porcelain board, and then traveled along the board toward the ground electrode. The coronas were firmly unified between the voltage applying electrode and copper wire. When the wire was at position 2), most of the positive coronas were dispersed in the air wthout reaching the porcelain board. The other coronas which reached the porcelain board grew a litte toward the ground electrode. At postion 3), the corona traveling toward the ground electrode along the porceain board unified only slightly with the copper wire generated corona.

* The 2nd stage (T_c=0. 19 μsec.) :

When the copper wire was placed at position 1), the poistive corona, advanced from the copper wire along the porcelain board, unified only faintly with the negative corona, and reached the porcelain board, at a position 4 ～ 5 cm from the end of the ground electrode. (The corona was weaker at ths position on the porcelain board than it was at both ends.) A few positive and negative coronas were unified in the air. At position 2), the influence of the copper wire on the corona development had not yet been observed. As compared with T_c=0. 17 μsec., at this stage, the corona advanced onto the porcelain board at the same rate as into the air. At position 3), the positive corona passed along the porcelain board and reached the copper wire. The corona generated from the copper wire started to advance toward the ground electrode.

* The 3rd stage (T_c=0. 23 μsec.) :

When the copper wire was placed at position 1), positive and negative coronas were completely connected on the porcelain board, and were bright. At position 2), the influence of the copper wire was not clearly observable. The negative corona was concentrated on the copper wire. At position 3), a glow could be seen around the copper wire, showing that positive and negative coronas were drawn to the copper wire, showing postive and negative coronas were drawn to the copper wire.

* The 4th stage (T_c=0. 28 μsec.) :

At postions 1), 2) and 3), coronas on the porcelain board unified with the positive and negative coronas growing toward the porcelain board more strongly than to any coronas in the air. The photo shown in Fig 4, indicates where creepage is likely to occur.

The description above shows the pre-breakdown phenomena of the creepage which occurred, when copper wire was placed at 1), 2) and 3).

d) Phenomena of creepage coronas to the copper wre placed on the porcelain board

As mentioned in item 2. 1, the creeping flashover rate was R_1=5% when the porcelain board was placed at H=3 cm without the copper wire. As mentioned in item 2. 2, the creeping flashover rate was increased to R_1=80% when copper wire was placed on the porcelain board (L=7. 5 cm). The reason will be considered based on Fig. 4, the photos being taken by the voltage chopping method.

In the 1st stage photo (T_c=0. 17 μsec.) with the copper wire at 3), all the positive pre-breakdown coronas dispersed in the air, including the positive leader corona, at an angle too wide to connect with the negative leader corona, grown toward the copper wire when they reached the porcelain board. When the applied voltage was increased, causing more coronas to grow toward the copper wire along the porcelain board, creepage occurred at the 3rd stage ($T_c=0.23$ μsec.).

For the reasons given above, the creeping flashover rate was sharply increased when copper wire was placed on the porcelain board.

e) Determination of flashover path according to the position of the copper wire

The flashover path when the copper wire was placed on the porcelain board has been deterimined as follow:

The growth rate of the positive corona is high. The direction of the flashover path is determined by the growth direction of the initial corona near the electrode. Thus, even if the copper wire was placed near the electrode, the leader corona reached the porcelain board immediately, but the rate of the cascading flashover which was directly connected to the copper wire was low.

On the other hand, when the copper wire was placed near the ground electrode, as shown in Fig. 4, the negative leader corona was dispersed in the air at the 2nd stage, while at the 3rd stage, it was drawn to the copper wire to form a flashover path.

For these reasons, the flashover rate was higher when the copper wire was placed near the ground electrode than when it was placed near the votage applying electrode. In Fig. 5, no flashover paths go directly through the air to the 0% surrounding area near the middle of the gap. This is because the coronas whose paths go first to the porcelain board, creep along it, and then, on reaching the copper wire, form tighter flashover paths than those which reach the copper wire directly from the electrode.

3. Summary of Influence of Floating Electrode (Copper Wire) on Formation of Flashover Path

3.1 Influence of Floating Electrode Suspended at the Mid-Gap, on Formation of Flashover Path (This was clarified in the previous report[4])

The influence of the floating electrode suspended at mid-gap on the formation of the flashover path will be summarized here, based on the test results shown in item 4 of the previous report[4].

In the distribution of flashover paths without the floating electrode, the lateral growth of the corona from the electrode axis was maximum at $H=2.5$ cm. However, extremely few flashover paths were formed through this point. This indicates that the lateral growth of the corona in the presence of the floating electrode was at least 3 cm or more, and that the influence of the floating electrode depends on its position.

When the floating electrode was placed near rod electrodes which had high density coronas, highly dense coronas grew, reaching the floating electrode, while coronas were generated from the floating electrode.

Coronas were also thus firmly connected between the rod-rod electrode and floating electrode. There is a high probability that they will be a part of the flashover path. When the floating electrode was placed far from the end of the rod electrode where the corona density was low, a flashover path was formed regardless of the position of the floating electrode. There was a flashover path through points far from the rod-rod electrode axis. The frequency was, however, extremely low. When main leader coronas reach the floating electrode at points far from the electrode axis, the floating electrode-generated corona facilitates formation of the flashover path.

This is a cascading phenomenon that occurs when the floating electrodes is placed where the cascading flashover rate is low, far from the rod-rod electrode axis. The floating electrode suspended in the air generates a corona toward the highly dense leader corona, thus connecting them and facilitating the formation of the flashover path. The floating electrode does not change the growth direction of the initial coronas from the electrode nor draw them to the floating electrode. As shown by the test results in the previous report, in spite of the change of position, and the difference in its size and shape, the electrostatic field around the floating electrode does not affect the cascading flashover rate.

3.2 Influence of Floating Electrode Placed on Porcelain Board, on Formation of Flashover Path

The influence of a floating electrode placed on a porcelain board, on the formation of the flashover path, will be summarized here, based on the test results shown in item 2.

When the porcelain board was used without the floating electrode, the cascading flashover rate was extremely low, 5% at $H=3$ cm when overvoltage was applied (preset value: 300 kV). With such applied voltage, the fiashover path was likely to form directly through the air, without passing through the surface of the porcelain board. When the floating electrode was placed on the porcelain board, the creeping flashover rate was sharply increased. When $H=3$ cm, the rates were 60, 80 and 100% at the voltage applied electrode side ($L=2.5$ cm), the middle point ($L=7.5$ cm) and the ground electrode side ($L=12.5$ cm), respectively.

The reason for the rate decreasing sharply is summarized as follows:

With the floating electrode placed on the porcelain board, positive and negative coronas advanced through the air.

Coronas which reached the porcelain board were transformed into creepage coronas

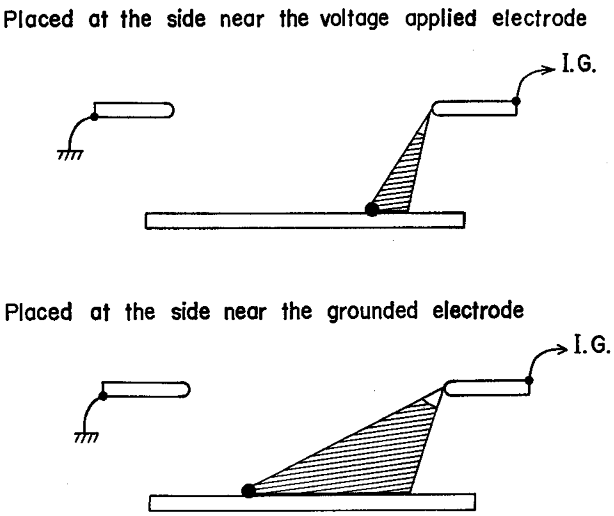


Fig. 6 Corona density related to the location of a floating wire on the porcelain board

and advanced along the board. When the creepage coronas approached the floatng electrode, the floating electrode generated-corona acted as a bridge to facilitate connection of the positive and negative coronas. Coronas which grew spatially from both the rod electrodes and collected on the porcelain board were transformed into creepage coronas, which grew toward the floating electrode placed perpendicular to the creepage corona growth direction. Therefore, when suspending the floating electrode in the air and placing the porcelain board where the corona density was low, coronas gathered on the porcelain board, thus increasing the corona density on the board as shown in Fig. 6. The coronas were strongly met by the floating electrode generated coronas, leading to an arc generation. For this reason, the cascading flashover rate was sharply increased when the floating electrode was placed on the porcelain board.

The reason that the cascading flashover rate was highest when the floating electrode was placed at a certain point near the ground electrode is as follows:

There is a certain point, between the two rod electrodes, at which the positive and negative coronas are most likely to join. If the position at which the floating electrode is placed happens to be the near that point, the floating electrode facilitates the connection between the coronas coming from directions. As the floating electrode is displaced toward the voltage applied electrode, the floating electrode becomes farther from that optimal point, thus the rate decreases. When the floating electrode is placed too near the ground electrode, the rate decreases again.

3.3 Comparative Analysis of the Influence of the Floating Electrode when Placed in the Air or on the Porcelain board, on Formation of Flashover Path

The influence of the floating electrode, when placed in the air or on the porcelain plane, on the formation of the flashover path is summarized in items 3.1 and 3.2, respectively. The comparison of both influences will be analyzed here, based on the test results shown in the previous report[4] and in this report.

The tests conducted so far are classified as follows:

A) Rod-rod electrode

B) Floating electrode between two rod electrodes

C) Porcelain board at distance H far from electrode axis

D) Floating electrode on the porcelain board at distance H from rod-rod electrods axis

These four cases will be comparatively analyzed. Using A), the lateral spread of the flashover path is maxtmum at $H=2.5$ cm.

With the porcelain board between electrodes C), the creeping flashover rate is 5% at $H=3$ cm, and 30% at $H=2$ cm.

With overvoltage applied (Preset value: 300 kV), the maximum lateral spread of the flashover path, in the case of a rod-rod electrode gap of type A), does not vary sharply when the porcelain board is placed between the electrodes. A corona creeps along the surface of the porcelain board when the board is placed within the limit of the flashover path spread in the gap between rod-rod electrode of type A), and strong leader coronas spread laterally toward the porcelain board. Thus, an arc may not be drawn to the porcelain board when the floating electrode is placed at a position beyond the limit of the maximum lateral spread of the flashover path.

In using type B), however, even if the floating electrode is placed beyond the limit of the maximum lateral spread of the flashover path in the absence of the floating electrode, the flashover creeps along the floating electrode. This means that the floating electrode affects the flashover path formation. The cascading flashover rate is high when the floating electrode is placed near the electrode, where the highly densely grown coronas reach. When the floating electrode is placed at mid-point in the air gap, where the corona density is low, the cascading flashover rate is extremely low. The rate of cascading flashover onto the floating electrode in the air is as explained below, except when the floating electrode is placed near the electrode where the highly densely grown corona reaches. The density of the corona spreads spatially from the voltage applied electrode toward the floating electrode, and the direction of leader coronas likely to become the arc, is affected by the growth direction of initial coronas near both the rod electrodes.

When the floating electrode is placed on the porcelain board D), the cascading flashover rate is higher at all points than when the floating electrode is placed in the air. The rate differs very sharply around the mid-point. The creepage corona consists of the corona spread spatially from the electrode and gathered on the porcelain board. When placing the floating electrods on the porcelain board, even if the floating electrode is placed where the corona density is low, coronas develop highy densely, toward the floating electrode along the surface of the board. The coronas generated from the floating electrode connect tightly to the other coronas from the rod electrode. Thus, a high cascading flashover rate can be obtained.

The variation in the cascading flashover rate relative to the position of the floating electrode is not related to the density of the corona growing toward the floating electrode, but is related to the positiod where the positive and negative coronas meet.

The floating electrode also serves to gather the positive and negative coronas on the porcelain board as highly dense coronas.

4. Conclusion

In this study, fundamental research was conducted on the characteristics of a fiashover on insulator assembly model equipment, consisting of a pair of rod-rod electrodes, a floating electrode made of copper wire, and a porcelain board.

It is clear that the cascading flashover rate is related to the position of the porcelain board and to the position of the floating electrode.

The results of this series of basic experiments (the two previous reports[3],[4] and this report) have been discussed here in comparison with each other. The analysis of a cascading flashover clearly shows the following:

1) A critical cascading flashover occurs when coronas generated from the rod electrode forming a horn gap creep onto the surface of the porcelain, and are gathered to the floating electrode. As a result, creeping flashover is completed.

2) A cascading flashover occurs more often on the porcelain board than in the air, when the porcelan board coexists with the floating electrode. The reasons are as follows:

2-1) When placing the porcelain board near the rod-rod electrode axis, a flashover that creeps along the porcelain board occurs even if the porcelain board is placed at a position ($H=30$ cm) which is somewhat far from the distribution range of the flashover path ($H=2.5$ cm) when the porcelain board is not present. This is because the coronas growing toward the porcelain board gather on the board, thereby increasing corona density.

2-2) If the floating electrode is placed on the porcelain board near the electrode axis, the cascading flashover rate depends on the position of the floating electrode. However, this differs sharply, depending on the position of the floating electrode. The rate is highest when the floating electrode is placed at the point at which the positive and negative coronas are connected.

Therefore the floating electrode position at which the cascading flashover rate is highest differs, depending on the polarity of the applied voltage. If positive, the rate is high near the ground electrode. If negative, the rate is high at the middle point of the gap.

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