Characteristics of a Corona between a Wiring Clamp (Dead End Clamp) and a Porcelain Insulator Used in a 154[kV] Power Receptacle

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Abstract

The occurrence of a corona is that electrical discharge due to the heterogeneity that occurs when an electrical field is concentrated in an electrode due to a cusp formed on said electrode. Wire treatment at the end of a 154[kV] dead end clamp for end users accelerates the occurrence of corona, which in turn leads to power loss and noise. In this study, the characteristics of the corona which occurs between porcelain insulators and support clamps of overhead lines used in 154[kV] power receiving facilities for end users were investigated. The corona, which cannot be identified by one common method, was measured utilizing a UV image camera. A risk assessment for fire damage and its status was suggested. The stress distribution of the electrical field by length of bare wire was suggested by means of the finite element method (FEMLAB). As a result, it was found to affect a porcelain insulators. These results can be utilized for the enhancement of clamp installation and safety in power facilities.

Key Words : Corona, Dead end clamp span, Electric field, UV camera, Porcelain insulator

1. Introduction

In overhead distribution lines (154[kV]), the wire (bare wire) leading to an end-user power facility commonly uses steel towers and insulators as support materials. The wire insulation depends upon the insulators and the surrounding air.

Air is generally an insulator, but there is a limit to its insulation strength. When a potential gradient is formed over approximately 30[kV/㎝] in direct current at standard temperature and pressure (20[℃], 760[㎜Hg]), or over approximately 21[kV/㎝] for the RMS value of a sine wave alternating current, the insulation breaks down[1-3].

The occurrence of a corona is caused by increased power transmission and distribution voltage, cusps of surface contamination or projections, and an increased radius of curvature. When the potential gradient on the surface of the wire exceeds the potential gradient of the rupture

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limit, the insulation property of the surrounding air is partially destroyed, resulting in a corona discharge accompanied by sound and light. Moreover, the electrical field in this area is large locally due to contaminants such as dust on the surface of the wire and insulators at the lead-in of the bare wire as well as the enlargement of the power system, damaged wire surfaces or minute protrusions. For this reason, a corona often occurs also below the critical voltage of corona[4-5].

Among major end users, those receiving 154[kV] power often install two lines including an overhead line as a reserve in preparation for accidents on the lead line. In this case, the wire at the overhead lead-in of the power facility is not in use (the reserve overhead wire line) and is installed without any separate measures for the prevention of corona installed on the wire end with insulators and dead end clamps. Cusp treatment of the wire at the end of the overhead wire line (154[kV] overhead line) then becomes one of major reasons for the occurrence of corona [6-9].

Therefore, the characteristics of corona which occurs between porcelain insulators and the terminal wire of a dead end clamp in overhead lines that are used in 154[kV] end-user power receiving facilities were reviewed. Corona following the separation distance between the clamps and insulators installed in power facilities, states of contamination, and conditions (humidity and contamination of insulators) of the surrounding environment were determined using a UV image camera (OFIL, Israel). The stress affecting the insulators by electric field was analyzed using the finite element method (FEMLAB). By means of modeling by the finite element method, the degree of concentration between insulators by dead end clamps and wire connection points, and its impact on insulators were investigated. This data can be utilized for the improvement of installation conditions of power facilities, the maintenance and repair of clamps, and the enhancement of safety.

2. Experimental apparatus and method

The critical voltage of corona can be expressed by means of correcting the value obtained from the geometric arrangement (radius of conductor, distance between lines, etc.), with the coefficients from the surrounding environmental factors (surface status of wire, weather, relative air density, etc.). In the design of a power system, the critical voltage for corona is anticipated as being higher than ordinary operational voltage.

The applied voltage was obtained from a high-voltage facility (Hipotronics, max 200[kV], 60[Hz]) through which a maximum voltage up to 200[kV] is available. The voltage applied to the sample was modeled as 154/160[kV].

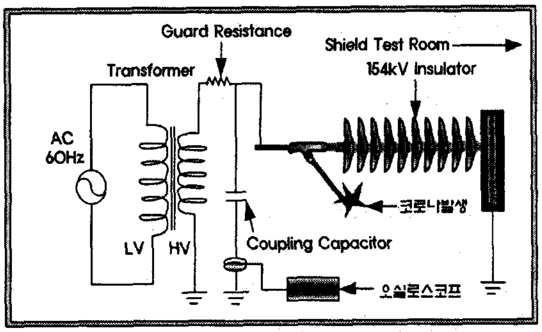


Fig. 1. Measuring circuit and shape of high-voltage experimental apparatus

After an investigation of the site, the experimental apparatus was constructed under the same conditions as that under which the phenomenon occurred. The equipment was constructed of lead-in wire (bare wire, 150[㎟]), a dead end clamp, and the end wire. The lead-out distance of steel wire (bare wire) was divided into

3 stages of 7.5, 15, and 20[cm] for testing. This is the distance between the main line insulator and the lead-out steel wire. The experiment was conducted at a temperature of 20[℃] and pressure of 760[mmHg], which are ambient conditions affecting the occurrence of corona. A stage-3 dead end clamp and porcelain insulators were used in this study.

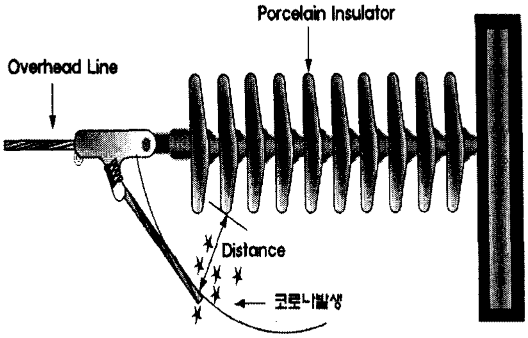


Fig. 2. Corona occurrence in porcelain insulator

3. Results of the experiment

3.1 Corona occurrence in the reserve wiring at the power facility site

In special high-voltage facilities, especially electrical facilities with outdoor exposure, deterioration occurs due to external factors such as corrosion. This deterioration causes the occurrence of corona.

Fig. 3 shows the image of corona occurring at the end of a bare wire with a dead end clamp on a reserve line at the site of a 154[kV] power facility. The use of a dead end clamp as shown in the figure is a style used mainly in the 1970s; it is no longer used in new facilities. As this type of clamp was currently installed at the site, there is an element of risk for the site.

The area where the corona occurred began from the point where the end electric field of wire is concentrated. Where there is surface contamination of some of the support insulators, it can be seen that the corona is concentrated toward the insulators from the end of the wire. In the facility using a dead end clamp as shown in Fig. 3, there was a difference in the strength of corona occurrence; this occurred in all of the power facilities. It was found that the strength of corona occurrence becomes greater as deterioration factors such as humidity and dust increase.

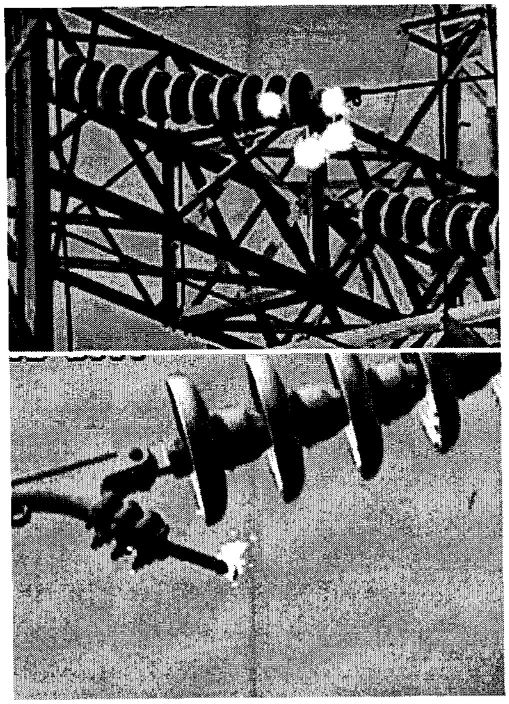
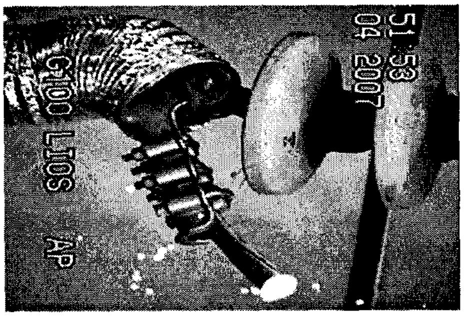


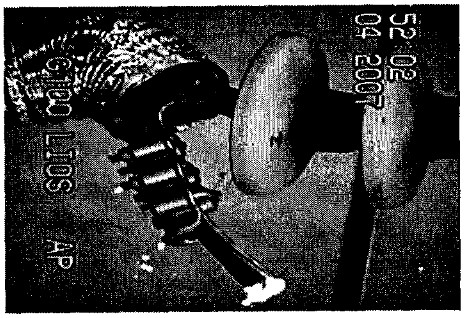
Fig. 3. Photographs of corona occurrence in the reserve wiring of 154[kV] power receiving facilities

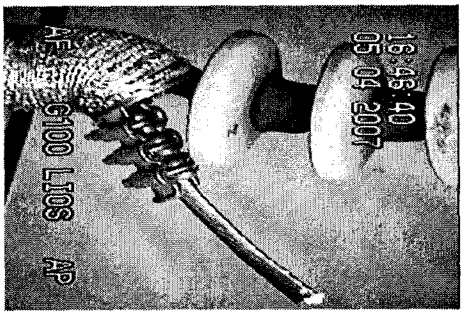
3.2 Characteristics of corona by wire length

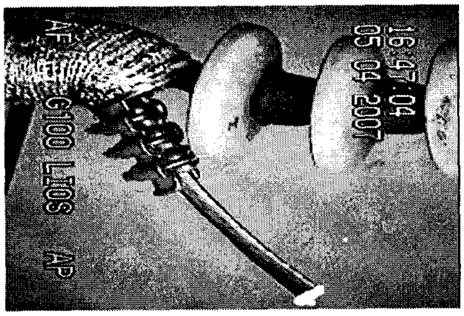
Fig. 4 shows the images of corona occurrence by the distance between bare wire and insulators and by applied voltage. These are images of corona at a distance from the bare wire of 7.5, 15, and 20[cm], respectively, at an applied voltage of 154/160[kV]. It can be seen that the size of the image increases as the lead-out length of bare wire becomes longer and the applied voltage becomes higher. In the case of Fig. 4(f), it can be seen that the direction of the corona advances toward the insulators. In this phenomenon, the size of the corona occurrence increases as the applied voltage of wire increases, and is also related to the degree of surface contamination of the insulators and the situation of the surrounding environment.

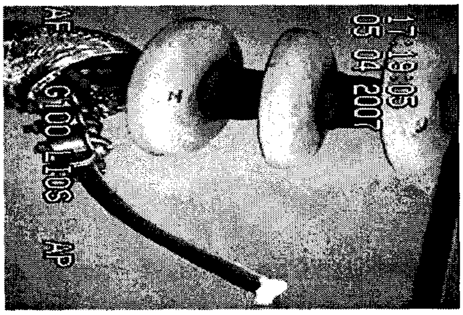
In the treatment of wire connection and terminals utilizing a dead end clamp, clamps are required to prevent corona occurrence, as can be seen in the experiment. The mitigated distribution of the electric field by use of metal clamps and the prevention of corona occurrence by insulation treatment is required.


(a) Distance of 7.5[cm] and voltage of 154[kV]


(b) Distance of 7.5[cm] and voltage of 160[kV]


(c) Distance of 15[cm] and voltage of 154[kV]


(d) Distance of 15[cm] and voltage of 160[kV]


(e) Distance of 20[cm] and voltage of 154[kV]

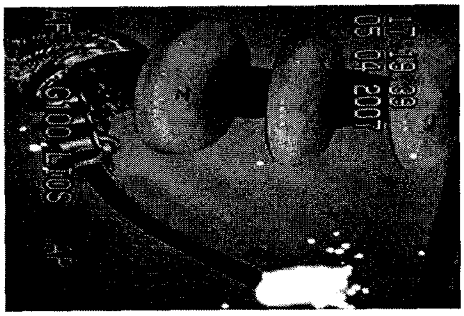

(f) Distance of 20[cm] and voltage of 160[kV]

Fig. 4. Photographs of corona occurrence by the distance of bare wire and the applied voltage

3.3 Analysis of electric field utilizing the finite element method(FEMLAB)

The finite element method is a numerical analysis method using a divided model. It obtains numerical as opposed to continuous solutions at each nodal point. By modeling via the finite element method, the degree of concentration of the electric field between a dead end clamp and an insulator by wire connection point, and its effect on the insulators was investigated.

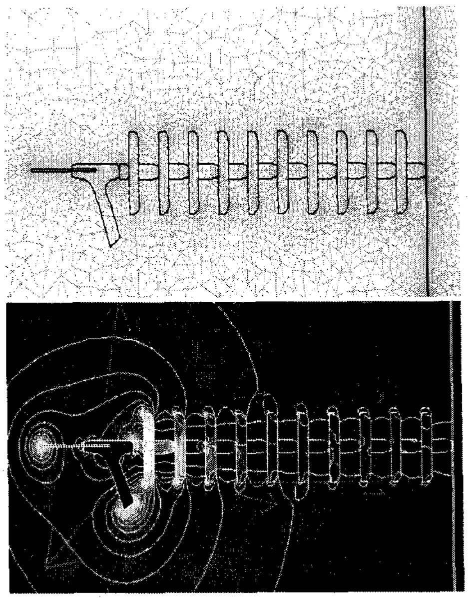


Fig. 5. Analysis of electromagnetic field when the distance of the bare wire is 7.5[cm]

The result of the modeling via the finite element method (FEMLAB) is shown in Fig. 4. Fig. 5 shows a mesh division and curve of the electric field when the distance of bare the wire is 7.5[cm]. Fig. 6 shows the same division when that distance of the bare wire is 25[cm]. In Fig. 5, the electric field is concentrated at the 1st insulator and in Fig. 6, as the wire leads out, the 2nd nearest insulator and the bottom insulator are both affected.

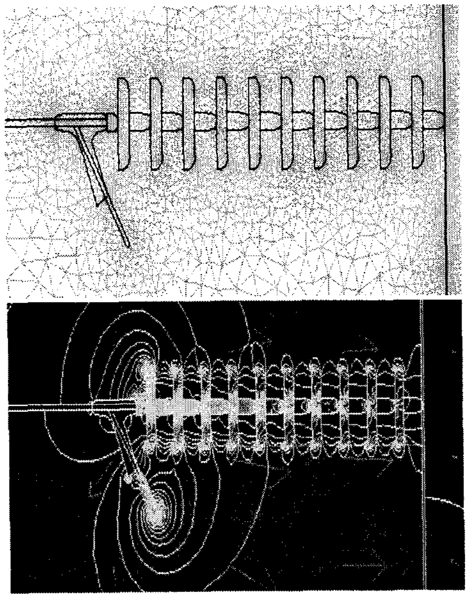
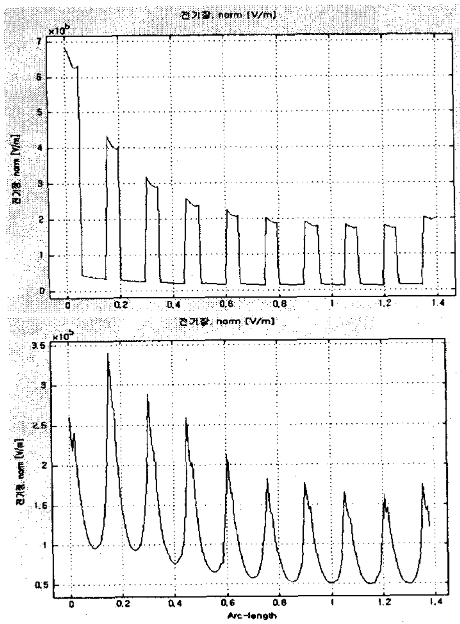


Fig. 6. Analysis of electromagnetic field when the distance of the bare wire is 25[cm]



(a) Distribution of electric field for bare wire (7.5[cm]) and insulators
(b) Distribution of electric field for bare wire (25[cm]) and insulators

Fig. 7. Distribution curve of the electric field for insulators

Fig. 7 shows the electrical field at the outer area of the insulator. When the distance of the bare wire is 7.5[cm], as in the case of (a), voltage is applied to the insulator similarly to the general distribution of the electrical field. When the distance of the bare wire is 25[cm], as in the case of (b), it appears that the strongest electrical field is distributed in the 2nd insulator and the distribution of the electrical field varies toward the bottom. This result indicated that the insulator is affected with increased corona occurrence and fire damage upon reduced insulation strength and increased surface contamination.

4. Conclusion

In this study, characteristics of corona occurring between porcelain insulators and support clamps (insulator of dead end clamp) of overhead lines used in 154[kV] end-user power facilities were investigated. The corona images following the conditions of separation distance between clamps and insulators installed in power facilities and applied voltage were detected. By means of modeling performed with the finite element method (FEMLAB), the degree of concentration of the electrical field between insulators by dead end clamps and wire connection points, and its impact on insulators was investigated.

① As a result of the measurement of corona images at the site, it was found that corona images were generated at the ends of dead end clamps and bare wire in the reserve lines of 154[kV] power facility. The strength of the corona occurrence became higher as deterioration factors such as humidity and dust increased.

② At a bare wire distance of 7.5, 15, and 20[cm], and an applied voltage of 154 and 160[kV], it was found that the size of the image increased and the direction of the corona advanced toward the surface of the insulators as the lead-out distance of the bare wire became longer and the applied voltage became greater.

③ As a result of investigating the degree of concentration of the electrical field between insulators and its effect on insulators via the finite element method, when the length of the bare wire was 7.5[cm], the electrical field is applied to insulators like a general distribution of electric field. When the length of bare wire is 25[cm], the strongest electrical field is distributed at the 2nd insulator. The insulator is affected by an increase in corona occurrence and by fire damage upon a reduction of insulation strength and a rise in surface contamination.

Applying these results, it is proposed that clamps for the prevention of the occurrence of corona are required in the case of wire connection and terminal treatment using dead end clamps. Also, the use of metal clamps is necessary to prevent corona occurrence as mitigation for the distributed electrical field or insulation treatment. The diagnosis of site facilities through the detection of corona images can be utilized for the enhancement of installation conditions at power facilities, maintenance and repair of clamps, and safety.

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