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The analysis of corona discharge for aging diagnosis of a power facility

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When the corona occurs due to partial discharge (PD) of a power facility, various signals such as ultraviolet (UV) rays, nitric oxide (NO), ozone (O_3) and electron impact are detected. In particular, an UV camera and the ease of inspecting and diagnosing their safety features have attracted a great deal of interest. One of the most important and difficult problems is the basic research of the filter design, materials and corona discharge. In this paper, the electric characteristics and UV image of corona discharge were investigated using a prototype Korean UV camera.

Keywords: Corona, Ultraviolet, Aging diagnosis, Partial discharge.

Introduction

If a local electric field concentration occurs in high-voltage power facilities, corona takes place due to partial discharge. In turn, various types of signals such as ultraviolet rays, nitric oxide, ozone and electron impact are detected [1]. The detection of these signals can prevent electrical accidents such as short circuits and electrical fires [2]. The general detection methods include analyses of current-voltage characteristics, heat detection, ultrasound, detections of electromagnetic waves, gas detection, and ultraviolet rays [3-6]. The ultraviolet method analyzes the degradation of power facilities using UV camera images. The UV camera intensifies the ultraviolet rays which are produced by electric discharge and displays visible-ray images on a monitor. Since it shows exactly where the ultraviolet light occurs and how much it produced, the ultraviolet rays can be analyzed on a live wire. As a result, this method can minimize loss by power failure. In terms of efficiency of facility maintenance, it is one of the best methods for detecting the degradation of power facilities.

In this study, the characteristics of ultraviolet rays at corona discharge were investigated using an UV camera. The voltage characteristics of a discharge model and UV images were measured using a simulated electrode system. Based on the results, a basic direction for degradation detection techniques has been proposed.

Experimental apparatus and Method

Fig. 1 shows an experimental apparatus and a simulated electrode system. The experimental apparatus consists of a high-voltage generator, an UV camera and a simulated electrode system. The high-voltage generator uses both AC and DC voltages (up to 100 kV). An UV camera prototype fabricated by EO System of Korea was used. A puncture and creeping discharge simulated an electrode system. Needle-plane electrodes were used to simulate a puncture by ranging electrode gaps from 15 to 100 mm depending on the voltage source. The creeping discharge was measured by placing the triangle-plate electrodes on the 5 mm-thick GFRP board with a 17-70 mm gap distance. The voltage was applied at 2 kV/s. UV images were measured by turning off lights and blocking solar lights with a dark curtain.

Results and discussion

Fig. 2 shows the characteristics of the puncture and creeping discharge when both AC and DC voltages were applied in the air. In the figure, ‘ ◇ ’ is the mean value of AC voltage while ‘ □ ’ and ‘ △ ’ represent the mean values of DC voltage at positive and negative polarity, respectively. Like general insulation characteristics, discharge voltage increased as the electrode gap widened. When the gap distance was the same, the negative polarity of DC voltage was the highest, followed by the positive polarity of DC and AC voltage with respect to discharge voltage.

Fig. 3 shows UV images depending on voltage source at puncture breakdown in the air. With 25 mm of gap distance, 90% breakdown voltage was applied. High voltage was applied to a needle electrode, and the ground was connected to a plane electrode. Also, the distance between the electrode system and UV camera is 1 m. As shown in this figure, doughnut-shaped UV rays occurred around the needle electrode, regardless of voltage source. In terms of the amount of UV production,

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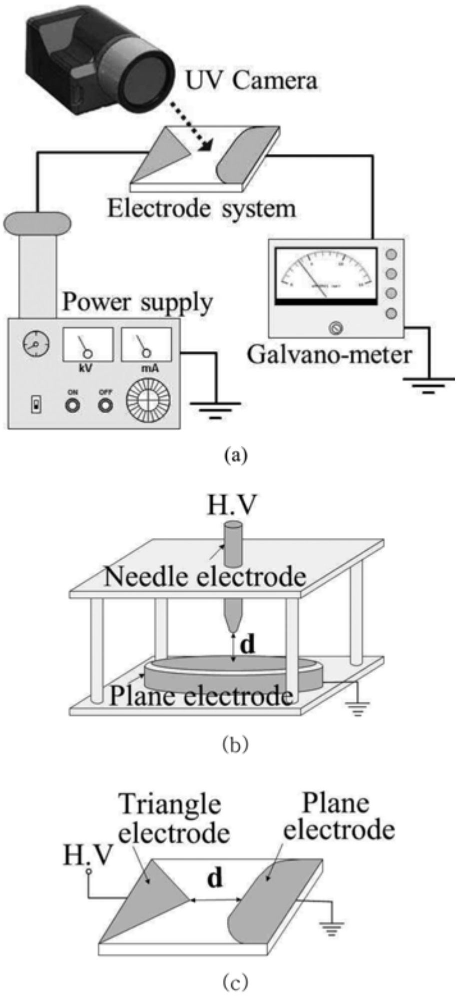

Fig. 1. Experimental apparatus; (a) testing equipment, (b) puncture breakdown electrode system, (c) creeping discharge electrode system.

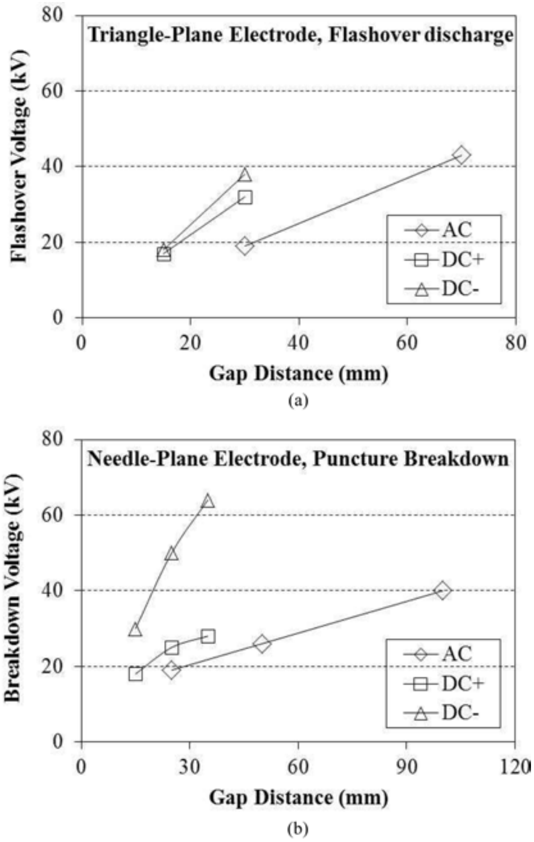

Fig. 2. Breakdown voltage depending on gap distance; (a) creeping discharge, (b) puncture breakdown.

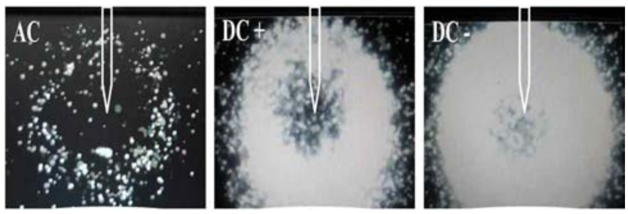

Fig. 3. UV images depending on voltage source.

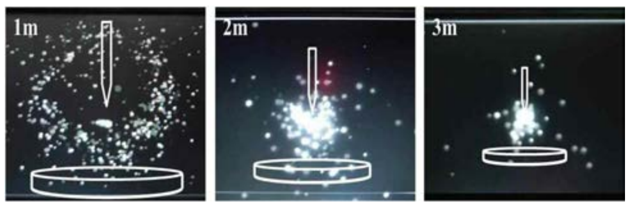

Fig. 4. UV images depending on measurement distance.

DC was far greater than AC. In DC voltage, UV rays were slightly greater at negative polarity than at positive polarity.

Fig. 4 shows UV images depending on measurement distance at puncture breakdown in the air. With 25 mm of gap distance, 90% breakdown voltage was applied. For voltage source, AC was used. The distance between the electrode system and UV camera was changed to 1 m, 2 m and 3 m. As shown in the figure, UV images are larger and clearer as the distance gets closer, but when the distance widens the images become smaller. However, they become darker with higher density. Also, ball-shaped UV rays were observed around the tip of the needle electrode. This pattern was detected in DC as well as in AC. Therefore, it appears that the results could be used as basic data to estimate the amount of corona through the shape and size of UV images by applied voltage and measurement distance.

Fig. 5 shows UV images depending on applied voltage levels. The creeping discharge of the triangle-plate electrode was measured, using AC and DC positive polarity. The distance between the electrodes was 15 mm with 2 m measurement of distance. In DC voltage, very few or no UV rays were detected at a breakdown voltage of 60% or lower. When 70% or higher voltage was applied, however, UV levels dramatically increased as voltage increased. In AC voltage, UV rays were observed even at a low voltage of 40%. And then, they increased linearly. Therefore, a detection of UV rays in DC electrical facilities could mean that they are already in severe degradation. It

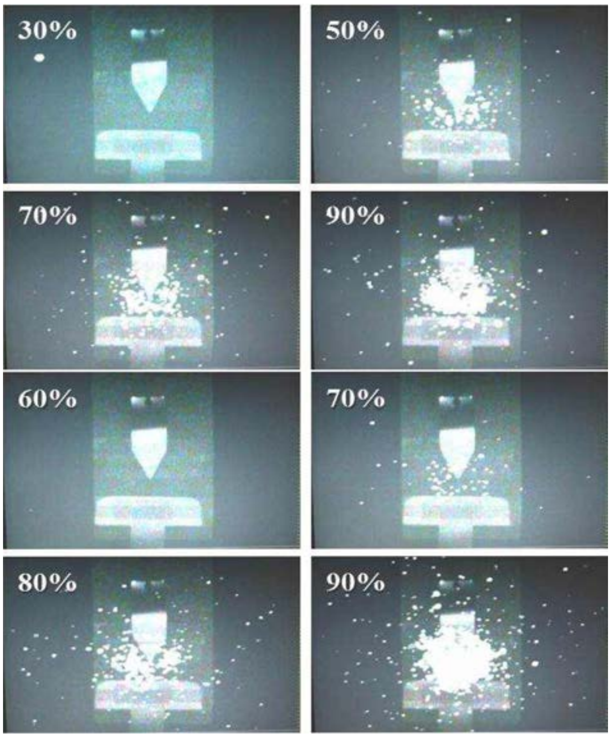

Fig. 5. UV images depending on applied voltage level.

would be necessary to perform a thorough safety inspection to be more certain.

Fig. 6 shows UV images depending on a simulated contaminant. The creeping discharge of the triangle-plate electrode was measured, and applied AC voltage. Electrode gap and measurement distance was 70 mm and 2 m, respectively. The salt was the highest, followed by dust, fog and rain with respect to discharge voltage. Especially, the rain has only one-third the voltage in comparison with a non-contaminant. As shown in this figure, the UV images of dust and fog were doughnut-shaped around the triangle electrode. It was similar to that of a non-contaminant. However, the UV image of salt occurred evenly in all areas between electrodes, rain was observed only around the tip of each electrode.

Conclusions

This study analyzed UV images and the voltage characteristics of the corona discharge of the simulated electrode system to examine the causes of power facility degradations. When voltage was applied in the air, breakdown voltage increased as the electrode gap widened. When the gap distance was the same, the negative polarity of DC voltage was the highest, followed by the positive polarity of DC and AC voltage. Under the same electrode, UV levels were higher in DC than in AC and at positive polarity of DC voltage rather than at negative polarity. When the distance between the simulated electrode system and the UV camera increased, UV images got smaller, however, they became clearer with higher density. In AC voltage, UV rays linearly increased as applied voltage increased. In DC voltage, UV rays began to dramatically increase starting at 70% of breakdown voltage. The contaminants on the surface have decreased voltage. Besides, the shape of UV image depends on the kind of contaminants.

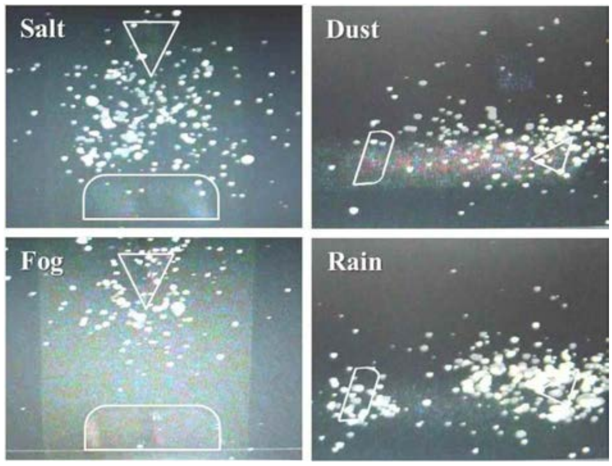

Fig. 6. UV images depending on contaminent.

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