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논 문
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Wavelet-Based Flashover Prediction Using High-Frequency Components

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Abstract - In order to monitor operating performance of contaminated outdoor insulators, a wavelet-based flashover prediction method is proposed. In most cases, the low-frequency components, namely, fundamental, 3rd, and 5th harmonic components have been mainly used for the sake of the spectral analysis of the leakage current. However, in this paper, the detail coefficients of wavelet transform representing high-frequency components are used as important information to predict a flashover in the contaminated insulator. Experimental results verify that the proposed method has a superior capability for flashover prediction.

Key Words : Flashover Prediction, Contaminated Insulator, Leakage Current, Wavelet Transform, High-Frequency Components

1. Introduction

With increasing application in wet and contaminated conditions, such as salt-fog environments, outdoor insulators are exposed to long-term humidity and severe contamination. Once the moisture on the insulator surface is condensed to form continuous wet film, leakage current will be driven by source voltage to pass through the conductive layer. Thermal energy produced by the current cause evaporation of the layer and formation of dry-band gaps. Once the electric field at these gaps reaches the breakdown strength of air, dry-band discharges will occur. Due to initiation and development of the discharges, flashover may take place and affect operating reliability of power systems. From the viewpoint of reducing costs and minimizing risk of damage to people and property, it is urgent to develop methods for monitoring outdoor insulator performance in contaminated environments. Current methods include the equivalent salt deposit density (ESDD), optical measurements, and leakage current measurements. In particular, the leakage current can provide much useful information on the state of a contaminated insulators, thus, several approaches using the leakage current have already been introduced to monitor the contamination conditions of outdoor insulators, for example, deterioration pattern analysis, leakage current property comparison under various circumstances, spectral analyses, and stochastic analysis using a Hilbert transform and the level crossing rate [1-6]. However, in most case, the low-frequency components, namely, fundamental, 3rd, and 5th harmonic components have been mainly used for the sake of the spectral analysis of the leakage current. This is due to such assumption that the low-frequency components may contain more important information than the high-frequency components. Under such an assumption, most of high-frequency components were ignored and excluded from the spectrum analysis process.

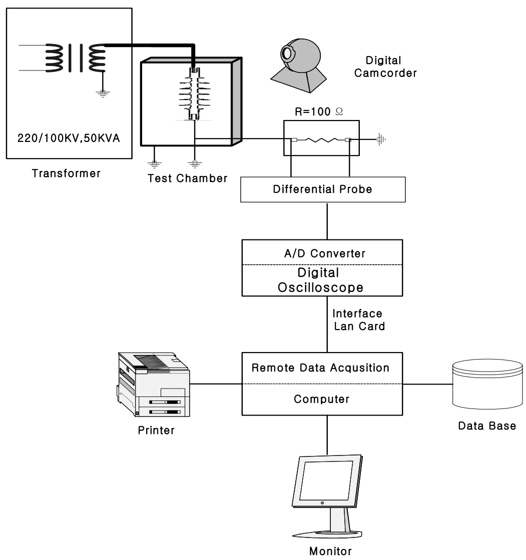

Fig. 1 The whole system diagram

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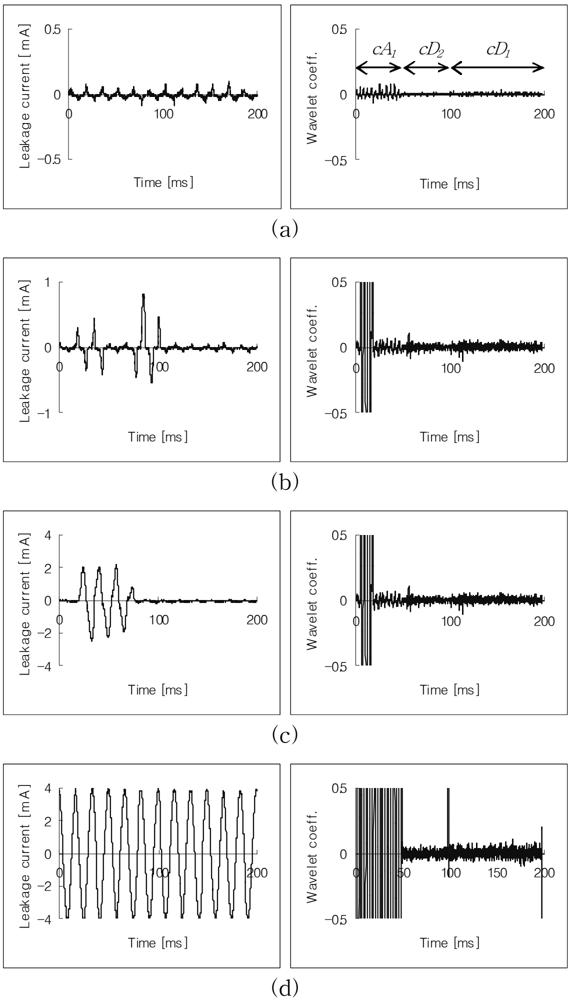

Fig. 2 Transition of leakage current waveforms and their wavelet transforms. (a) Initial stage, (b) Middle stage, (c) Just prior to flashover stage, and (d) Flashover stage.

To overcome such an assumption, Y. C. Song et al proposed a method for predicting the flashover and monitoring the contaminated condition of outdoor using high-frequency components of Fourier Transform [7]. Recently, an experiment to understand the trend of leakage current was carried out by S. Chandrasekar et al with using the high-frequency components of wavelet transform [8]. In the same view, to demonstrate the usefulness of using high-frequency components of wavelet transform, this paper proposes a new flashover prediction method using a wavelet transform under salt fog conditions, where detail coefficients representing high-frequency components are used to predict the risk of a flashover. The proposed method is not only simple but also shows a superior capability for flashover prediction. In addition, the proposed method provides a constant value as a criterion for predicting a flashover, regardless of the salt fog concentration.

2. Experimental methods

The test was based on the salt-fog method and carried out using the same equipment as reported in a previous paper [6] (refer to Fig. 1). An EPDM-distribution-suspended insulator with a diameter of 100mm was pre-contaminated in coastal areas. The NaCl concentration of the applied fog was adjusted to 25g and 50g per liter of deionized water. The leakage current waveforms during 200ms were recorded on a PC at 1-sec intervals to avoid excessive data.

3. Wavelet-based flashover prediction

Fig. 2 shows the leakage current waveforms and their wavelet transforms leading to a flashover under a 50g salt fog. The Flashover occurred through four stages initial stage (Fig. 2(a)), middle stage (Fig. 2(b)), just prior to flashover stage (Fig. 2(c)), and flashover stage (Fig. 2(d)). A two-level multi-resolution signal decomposition using the 9-7 tap Daubechies wavelet was applied to the leakage current, resulting in approximation (cA_1) and detail (cD_1, cD_2) coefficients (refer to Fig. 2(a)), where the detail coefficients represent the signal's characteristic and energy at higher frequencies, while the approximation coefficients are a blurred version of the original signal. This paper uses the detail coefficients as important information for predicting a flashover and for monitoring contamination conditions of outdoor insulators. Note that cD_1 contains higher frequency components than cD_2. As shown in Fig. 2, the relative magnitudes of the detail coefficients gradually increased until a flashover, depending on the occurrence of a discharge and formation of dry bands. It was verified that such a tendency was maintained, regardless of the salt fog concentration. Thus, as mentioned above, the sequential appearance of weak and strong local arcs until a flashover increased the high-frequency components in the leakage current with the maxima occurring in the prior to flashover and flashover stages. Fig. 3 shows the summation of the high-frequency components from cD_1 and cD_2 under a 50g salt fog, where the process until a flashover was clearly divided as four stages for both details cD_1 and cD_2. The appearance of abrupt peaks was removed by using a window consisting of 25 points. Thus, $Z_i = \min[X_{i-24}, X_{i-23} \cdots X_i]$, where Z_i eliminated the abrupt peaks from the raw data X_i. Fig. 4 shows the results after removing the abrupt peaks under 25g and 50g salt fogs. In this paper, only cD_1 was used for the flashover prediction. However, note that cD_2 also

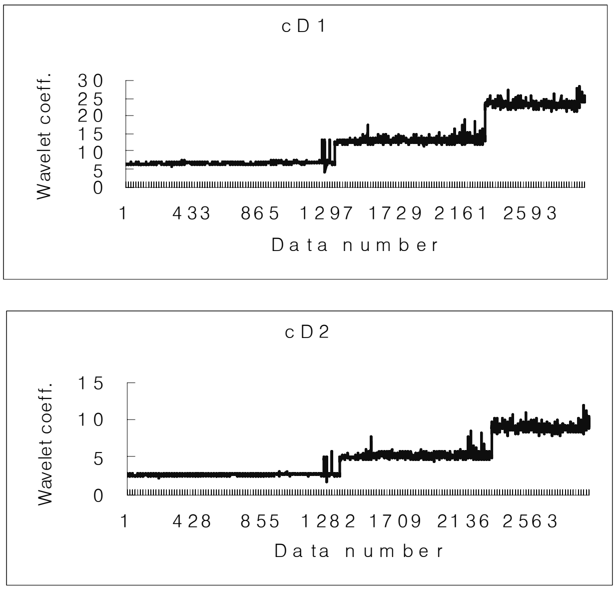

Fig. 3 Summation of details cD_1 and cD_2 under 50g salt fog.

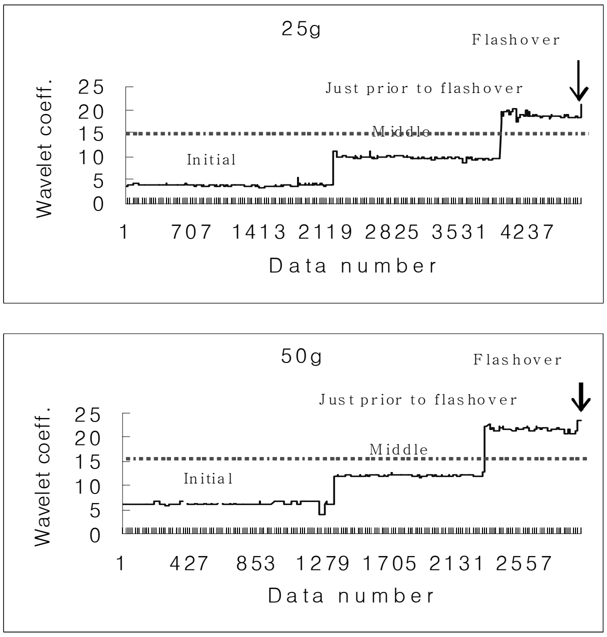

Fig. 4 Final results when using detail cD_1 under 25g and 50g salt fogs

exhibited an identical performance. As shown in Fig. 4, the process until a flashover was divided into four stages initial, middle, just prior to the flashover, and flashover stages, and the summation of detail cD_1 provided a constant criterion value for predicting a flashover. Accordingly, when the obtained values stayed above 10 in 25g and 50g salt fogs, this indicated an increased risk of a flashover (refer to Fig. 4). Consequently, the proposed method provides a constant value as a criterion for predicting a flashover, regardless of the salt fog concentration. In addition, the proposed method maintain an almost identical output level within the same stage (refer to Figs. 3 and 4), thereby eliminating the need to acquire a lot of leakage currents to predict a flashover in the field.

4. Conclusion

This paper proposed a simple flashover prediction method based on leakage current waveforms and their wavelet transforms, where the detail coefficients containing the high-frequency components were used as a tool to predict a flashover instead of the approximation coefficients representing low-frequency components. The proposed method is not only simple but also shows a superior capability for flashover prediction.

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