통계처리와 패턴 인식 기법에 의한 부분방전 해석

Analysis of Partial Discharge Signals Using Statistical and Pattern Recognition Technique

변 두 균*, 홍 진 웅
(Doo-Gyoon Byun and Jin-Woong Hong)

Abstract : In this study, we detected electromagnetic waves generated in an enclosed switchgear and applied various statistical methods for detecting signals. We calculated the various statistical factors via the appropriate statistical methods. Further, we used these statistics to recognize the characteristics for each pattern by identifying the partial discharge in each case for normal, proceeding and abnormal states. The characteristics of electromagnetic wave patterns occurred in various states at electric power facilities and were used as an output variable for more efficient diagnosis. In this paper, we confirmed that the pattern of partial discharge signal can be used as one of the factors used to analyze the insulation state and to consider while estimating diagnosis of insulation states by recognizing the signal pattern to intelligence. We will utilize the proposed diagnosis method to determine insulation degradation states.

Keywords : partial discharge, wavelet transform, insulation degradation, UWB (Ultra Wide Band) antenna, enclosed switchgear

I. Introduction

With sudden increases in demand for electrical power, and trends toward building facilities with ever larger capacity, there is an urgent need for improvements in the reliability of electricity supply. The number of electric power facilities increased in the late 1960s due to industrialization, with a corresponding increase in the number of enclosed switchgear installations. As a result, this has had a direct effect on customer demands for general domestic electricity. Furthermore, since power facility accidents within enclosed switchgears have debilitating effects on the industry, reliability of power facility distribution boards is critically important to achieving stable supply of electrical power. Therefore, facility inspections within enclosed switchgears must be carried out to eliminate the causes of accidents beforehand, in order to provide a supply of stable and reliable electricity more effectively. Abnormalities in electrical insulation equipment within enclosed switchgears are generally accompanied by partial discharge, and if degradation of the insulation from discharges is allowed to continue, an accident involving the destruction of the insulation will follow. Consequently, these accidents can be prevented by detecting partial discharges from abnormalities and degradations to the insulation material [1-3,9-11]. For domestic companies, algorithms and operating technology for diagnostic systems utilized in enclosed switchgears is still underdeveloped, and abnormalities just prior to the accident stage are undetectable even when utilizing a periodic inspection schedule.

In this paper, electromagnetic wave signals generated by the enclosed switchgears were detected through an antenna, and then analyzed through statistical processing of the wavelets. Although the electromagnetic waves picked up by the antenna vary with the capability of each antenna, it was difficult to recognize partial discharge signatures because of the broad frequency band used. To solve this problem, we applied the wavelet transform, which is able to analyze the signal within the time and frequency domain as detected at the antenna. There has been previous research applying neural networks to distinguish the presence of partial discharges and the extent of their progress using transformed wavelet signals [4,5,8,10-11]. In order to apply this study in the field, there must be a diagnostic algorithm to detect the presence of partial discharges, and to classify them according to their characteristics. This paper proposes an algorithm to enable detection through the use of electromagnetic waves, by analyzing the wavelet transform of the wave measured by an antenna, then applying a statistical method to determine the presence of characteristic signals and to classify them accordingly. In order to perform an accurate diagnosis of electric power facilities, the results were classified into three different states, where normal status was indicated as normal, where partial degradation of the insulation due to corona discharge was in progress was classified as proceeding, and where condenser degradation in the electric

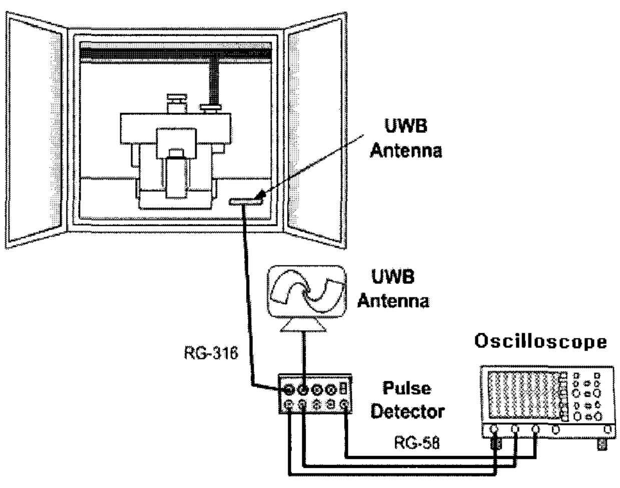

그림 1. PD 측정장치의 설치.
Fig. 1. PD measurement set up.

* 책임저자(Corresponding Author)
논문접수 : 2006. 7. 11., 채택확정 : 2006. 10. 10.
변두균, 홍진웅 : 광운대학교 전기공학과
(dgbyun@kwater.or.kr/ealab@daisy.kw.ac.kr)

그림 2. 전자파 측정용 UWB 안테나.

Fig. 2. The UWB Antenna for measure the waves.

power facility had already progressed as abnormal. The results of these experiments were utilized as base data to constitute the algorithm used to determine the respective progression states of degradation.

II. Signal Detection Using an Antenna

The equipment used to measure partial discharge are shown in Fig. 1: An UWB (ultra-wide band) antenna with a broad range of frequency band from 300 ~ 3,000 [MHz], a signal detector to detect signals for partial discharge, and an oscilloscope to analyze the pattern of measured waveforms.

Incoming electromagnetic signals from the oscilloscope were transmitted to the computer via the GPIB-488 interface, to be automatically stored with a fixed time period. Fig. 2 depicts the external appearance of the UWB antenna used to measure the waves.

III. Algorithm for Detection of Electromagnetic wave Signals

For this paper, in order to detect the partial discharges and classify them according to their discharge types, methods were employed to analyze and extract the characteristics of electromagnetic waveforms. Wavelet transforms were made within the time-frequency domain for thorough analysis of the waveform.

1. Wavelet Transform

In order to overcome the most critical limitation of Fourier transformation, wavelet transforms with localized and varied base functions have been devised for use, which enables time-frequency expressions [10,11]. Wavelet transformation produces various base functions due to the scaling and translation of the mother wavelet, and is therefore advantageous for adequately expressing time and frequency information concurrently. The mother wavelet may be expressed as shown in equation (1).

$$\Psi_{\tau,s} = \frac{1}{\sqrt{s}}\Psi(\frac{t-\tau}{s}) \tag{1}$$

Where, "s" is indicates the scale parameter and "τ" is indicates the translation parameter. And the information on time is contained under translation, and on frequency under scale.

The definition for mother wavelet includes the base form to produce other base functions. Wavelet transform in the continuous time domain is defined as shown in equation (2).

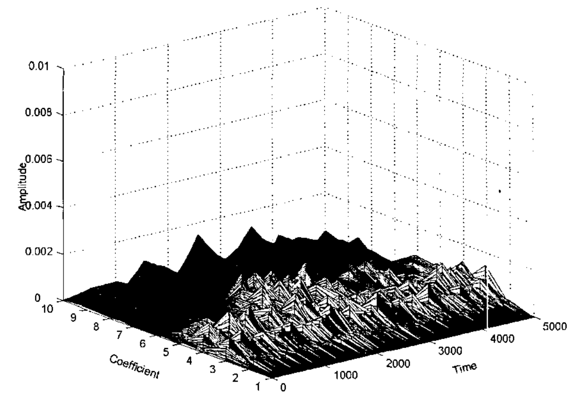

그림 3. 정상상태의 웨이블릿.

Fig. 3. Normal state wavelet.

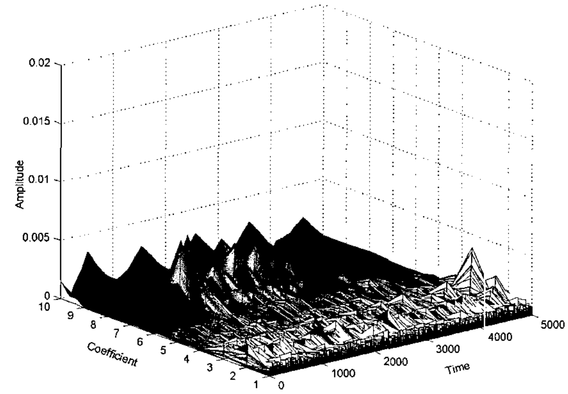

그림 4. 요주의상태의 웨이블릿.

Fig. 4. Proceeding state wavelet.

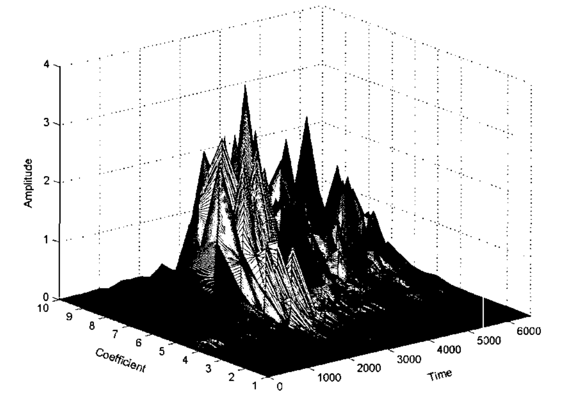

그림 5. 이상상태의 웨이블릿.

Fig. 5. Abnormal state wavelet.

$$CWT_{x(\tau,s)} = \frac{1}{\sqrt{s}}\int f(t)\Psi^*(\frac{t-\tau}{s})dt \tag{2}$$

Where, f (t) is indicates the signal to be analyzed, and ψ (t) is the mother wavelet. Since s and τ are continuous, CWT contains difficulties in redundancy and realization. To solve this problem, each parameter is discontinued through $s = s_0^j$, $\tau = k\tau_0 s_0^j$, as shown in equation (3). The discrete wavelet transform is as follows.

$$DWT_{x(j,k)} = \frac{1}{\sqrt{s_0^j}} \int s(t)\Psi^*(s_0^{-j}t - k\tau_0)dt \qquad (3)$$

Generally, values for s_0 and τ_0 are 2 and 1, respectively. Mother wavelet forms are all different, depending on the researcher who made them, such as Morlet, Haar, Shannon, Meyer and Daubechies are applied to different fields according to the signal breakdown characteristic and advantages of each mother wavelet. We used Daubechies' wavelet transform as it was suitable for antenna derived discrete signals. Daubechies' wavelet may be applied by using the down sampling method on the main signal. Measured signals were divided down to coefficients of 10. After the wavelet transform, we found there to be no partial discharge, with uniform signal strength for normal states as shown in Fig. 3.

For the proceeding state, as shown in Fig. 4, as the value of the coefficient increased, small partial discharges were detectable. However, compared to these signals, partial discharges for the abnormal state did not subside through detailed coefficients of D5-D10, but were being continually produced to maintain uniform size. Fig. 5 shows the abnormal state. From these characteristics, we were able to detect partial discharges of electromagnetic waves from insulation degradation in enclosed switchgear, and determine that partial discharges were continual at detailed coefficients above D5. However, for those that were proceeding states, we were able to verify weak signals for partial discharge at detailed coefficients of over D5.

2. Statistical Method

Although characteristics of signals measured through an UWB antenna may be roughly understood by using wavelet transformation, since partial discharges occur under a number of different scenarios, they may not always be detectable with any degree of accuracy. Statistical processing of wavelet values are then required for more accurate results [6,7,12,13].

For the statistical analysis, values for the average, skewness, and kurtosis were used, with values from the wavelet transform as the main signal. By setting x (t) as the time series signal, and P (x) as the probability density function of x (t), the statistical parameters can be obtained by using equations (4), (5), and (6).

$$\text{Mean value: } \mu = \int_{-\infty}^{\infty} |x(t)| P(x)dx \qquad (4)$$

$$\text{Skewness: } \beta_1 = \frac{\left[\int_{-\infty}^{\infty} x(t)^3 p(x)dx\right]^2}{\left[\int_{-\infty}^{\infty} x(t)^2 p(x)dx\right]^{3/2}} \qquad (5)$$

$$\text{Kurtosis: } \beta_2 = \frac{\int_{-\infty}^{\infty} x(t)^4 p(x)dx}{\left[\int_{-\infty}^{\infty} x(t)^2 p(x)dx\right]^2} \qquad (6)$$

The skewness represents the degree of balance around the average value at the center, or asymmetry, and kurtosis indicates the sharpness of the waveform. We performed a wavelet transform on the main signal, and then used the transformed wavelet values to show kurtosis and skewness.

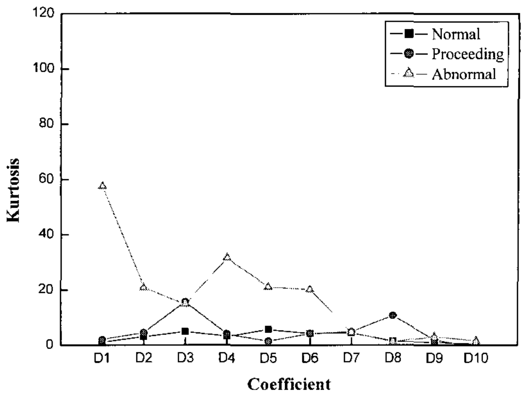

그림 6. 각 상태별 첨도값 추이.
Fig. 6. Kurtosis of various conditions.

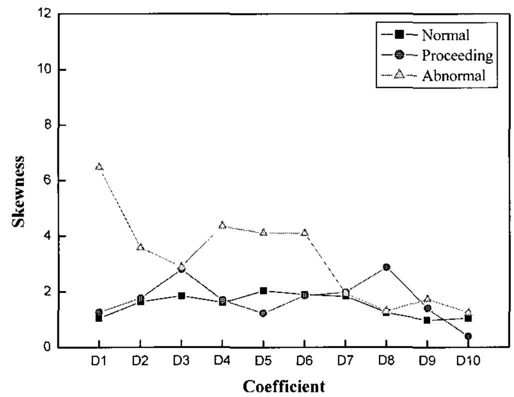

그림 7. 각 상태별 왜도값 추이.
Fig. 7. Skewness of various conditions.

Fig. 6 and Fig. 7 show kurtosis and skewness using the detailed coefficient for the transformed wavelet signal. As shown in Fig. 6, kurtosis increases gradually from normal to abnormal states. Note also that the kurtosis value tends to decrease as the detailed coefficient value increases. We can also see for lower detailed coefficient values of D1-D6 that the abnormal state shows clear signals of partial discharge when compared with the normal state. As shown in Fig. 8, while kurtosis values for normal and proceeding states do not show significant differences, in Fig. 7, the skewness value for the proceeding state is showing a large signal bias when compared with the normal state.

As demonstrated by this experiment, it is possible through the measurement of electromagnetic waves to detect partial discharges from degradations in the insulation of enclosed switchgear, whereby the signals are analyzed by wavelet transform, then processed for wave kurtosis and skewness to determine the extent of degradation.

IV. Conclusions

It is possible through the measurement of electromagnetic waves to detect partial discharges from degradations in the insulation of enclosed switchgear, whereby the signals are analyzed by wavelet transform, then processed for wave kurtosis and skewness to determine the extent of degradation.

The kurtosis value derived from the wavelet transform of the main signal increases in the following order: normal, proceeding, and abnormal states. It is especially notable that as the detailed coefficient value increases, the kurtosis value tends to decrease.

Although the signals generated under normal and proceeding states do not show significant differences in the kurtosis value, the skewness value for the proceeding state showed a large bias when compared to the normal state.

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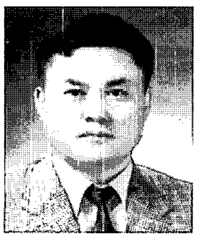
Doo-Gyoon Byun

He received his B.S. and M.S. degrees in Electrical Engineering from Kwangwoon University in 1977 and 1990. He is currently a Ph.D. candidate in Electrical Engineering at Kwangwoon University. He joined the Korea Water Resources Corporation in 1979. His current research interests are sensor and diagnosis of insulators. He is a member of the ICASE, KIEE and KIEEME.



Jin-Woong Hong

He received his B.S. degree in Electrical Engineering from the college of Engineering at Hanyang University in 1982, and his M.S. and Ph.D. degrees from Kwangwoon University in 1984 and 1987, respectively. He joined the department of Electrical Engineering at Kwangwoon University in 1989. He was a Visiting Professor at Kyushu Institute of Technology, Japan from 2000 to 2001. His current research interests are ageing diagnosis insulators and dielectrics, and panel displays of OLEDs. He is a member of the KIEE, KIEEME, JIEE and IEEE.