Location of Partial Discharge in Model Transformer

R.Ozaki, A.O.Akumu, H.Ihori, M.Fujii and K.Arii
Department of Material Science and Engineering, Faculty of Engineering, Ehime University,
3 Bunkyo, Matusyama, Ehime 790-0828
Tel +81-89-927-9892
E-mail: ozaki@diana.mm.ehime-u.ac.jp

Introduction

With the much higher rated voltage of power equipment, PD has become one of the main causes that lead to the erosion of insulating materials. Therefore precise positioning of PD has become significantly important in insulation diagnosis. Some of the PD location methods are acoustic and electromagnetic methods [1][2]. The advantage of electromagnetic method is that one can carry out detection and location of PD without touching the electric power equipment. However, the detected electromagnetic signal is hidden by noises. In contrast, the acoustic method is immune to electromagnetic interference. Furthermore the velocity of acoustic signal is slower so that the acoustic method has an advantage for PD location. Of cause it is also important for the acoustic method to distinguish between PD signal (sound) and noise. So this method has to note the frequency of PD signal. Many researchers have developed the frequency analysis; FFT (fast fourier transformation), filter technique, etc. The location method has been reported by using these analyses which distinguish between a peculiar frequency of PD and noise. Actually the frequency spectrum varies with the material of PD source [3]. But these reported methods only could pick up a frequency. Therefore the analysis of wide band frequency is necessary for actual PD location. In this paper, authors distinguish between the PD signal and noise by using Wide Band Cross Ambiguity Function on the Wavelet Domain [4] and suggest a new method to locate PD position in the model transformer. The result and effectiveness are also discussed.

Location Method

Wavelet analysis is one of the time t frequency analysis which is defined

$$W_\psi f(a,b) = \int \frac{1}{\sqrt{|a|}} \overline{\psi\left(\frac{x-b}{a}\right)} f(x)dx \cdot \qquad (1)$$

In this paper mother wavelet is Gaussian wavelet which is smooth for the frequency. This given by

$$\psi(t) = \left(\frac{1}{90}\right)\left(t^{8} - 28t^6 + 210t^4 - 405t^2 + 90\right)\exp\left(-\frac{t^2}{2}\right) \cdot \qquad (2)$$

WBCAF can detect the common part between signals transformed to same mother wavelet and is defined by

$$WBCAF(s=1,\tau) = \int \frac{da}{a^2} \int \left[W_\psi f_1(a,b)\right]\left[W_\psi f_2(a,b-\tau)\right] db \cdot \qquad (3)$$

Calculation of WBCAF can pick up τ which is time of highest correlation. This τ is delay time between two signals from different positions. If the sensor position coordinating (x_1,y_1), (x_2, y_2) and

(x_3, y_3), the sound velocity v and delay time τ are known, then the PD position (x, y) can be calculated from equation (4).

$$\sqrt{(x-x_1)^2+(y-y_1)^2}-\sqrt{(x-x_2)^2+(y-y_2)^2}=\tau_{12}v=r_{12} \quad \text{(4-a)}$$
$$\sqrt{(x-x_1)^2+(y-y_1)^2}-\sqrt{(x-x_3)^2+(y-y_3)^2}=\tau_{13}v=r_{13} \quad \text{(4-b)}$$
$$\sqrt{(x-x_2)^2+(y-y_2)^2}-\sqrt{(x-x_3)^2+(y-y_3)^2}=\tau_{23}v=r_{23} \quad \text{(4-c)}$$

Experimental Procedure

Figure 1 shows experimental apparatus; Transformer model consisted of the iron core (15 cm×15 cm×15 cm) set in the steal tank (24 cm× 24 cm×35 cm, Thickness of 2 mm) filled with transformer oil. The experimental electrode system was a sphere - plane configuration which was consisted of a PET film coated on one side by evaporated Aluminum and a steal sphere. These were mounted on top of the iron core. Test voltage of 8 kV and frequency of 60 Hz was applied to generate PD. PD acoustic signal was measured by AE sensor attached to the steal case. And AE sensor position was set on the same level as the sound source. Detected acoustic signal was amplified and monitored by digital oscilloscope. In this experiment, sensors and PD position were as follows: PD position (15.5, 7.0), sensor 1 (15.5,0.0), sensor 2 (24.0, 16.0) and sensor 3 (12.5, 24.0), and all measuring height was the same as the sound source.

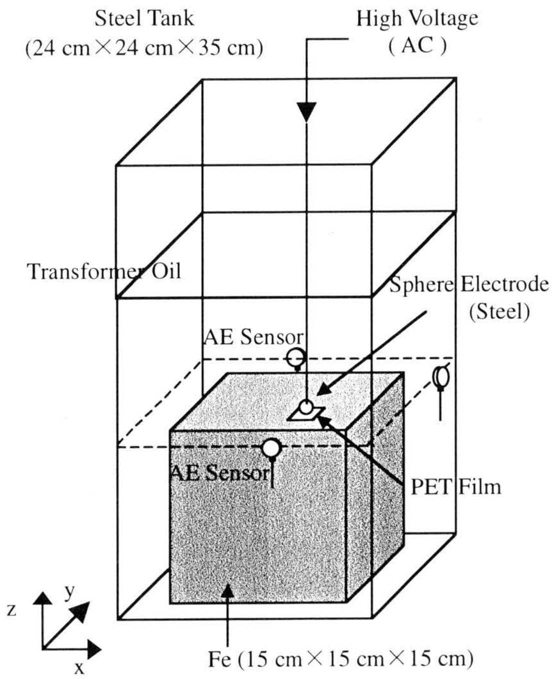

Fig.1 Experimental Setup

Results and Discussions

Figure 2 shows measured signals. Trigger was set on 1 mV at signal 1 so that the first peak time of signal at sensor 1 is 0 sec. First peak of signal 1 and 3 is clear. But first peak of signal 2 is not clear. It is not difficult for signal 1 and 3 to detect the arrival time at each sensor but it is difficult for signal 2. Wavelet transformed results are as shown in figure 3. In this figure vertical axis, horizontal axis and color shows frequency space, time space, signal intensity respectively. We can find out that PD signal exists in signal 1 and 3. Frequency of around 400 kHz was detected at sensor 1 and sensor3. And signal 2 include common frequency. Therefore we can confirm that signal 2 is PD signal. And we can find out the arrival order at each sensor from these wavelet transforms (signal 1, signal 2, signal 3). Here, to detect delay time is important from this result. But it is difficult to

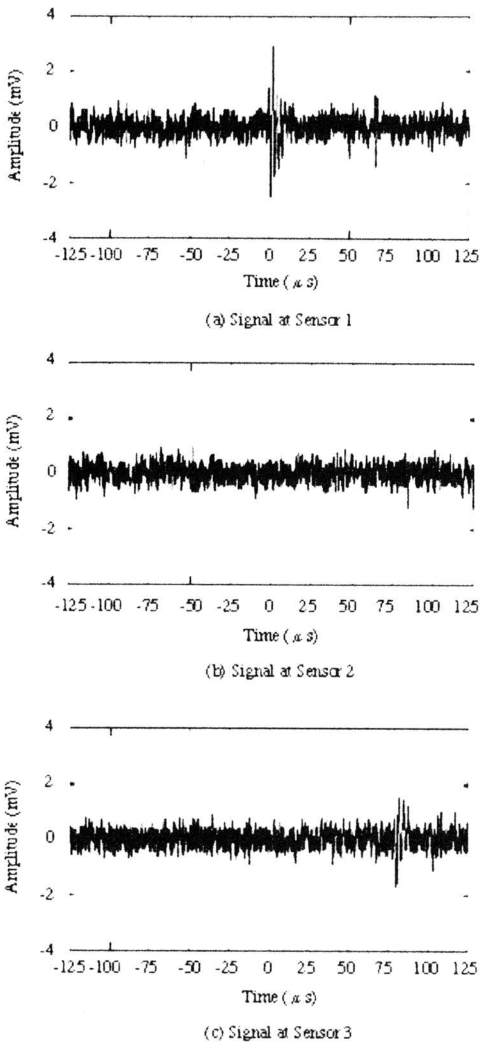

Fig.2 PD Signal

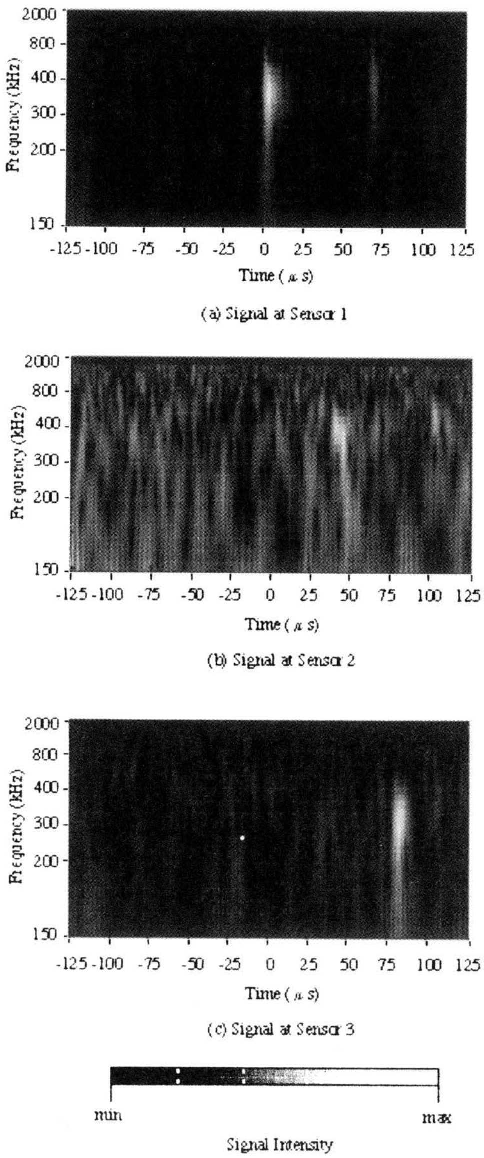

Fig.3 Wavelet analysis

determine accurately from these. Then we use WBCAF on wavelet domain as shown in figure 4. In this figure vertical and horizontal axis also shows frequency and time space, respectively. On the other hand color shows commonality between two compared signals, that is, this peak corresponds to the delay time. For figure 4 τ_{12}, τ_{13} and τ_{23} are 42 μs, 79 μs and 39 μs, respectively. We can pick up this and find out distance between PD position and each sensor from delay time, when distance is just expressed by product of delay time and velocity of transformer oil (1425 m/s, at 25℃).

$$\sqrt{(x-24)^2+(y-16)^2}-\sqrt{(x-15.5)^2+y^2}=6 \quad \text{(5-a)}$$

$$\sqrt{(x-12.5)^2+(y-24)^2}-\sqrt{(x-15.5)^2+y^2}=11.3 \quad \text{(5-b)}$$

$$\sqrt{(x-12.5)^2+(y-24)^2}-\sqrt{(x-24)^2+(y-16)^2}=5.6 \quad \text{(5-c)}$$

Next we can get equation (5) from setting sensor position and distance detected by WBCAF. Solution of these equations is the PD location, as shown in figure 5.

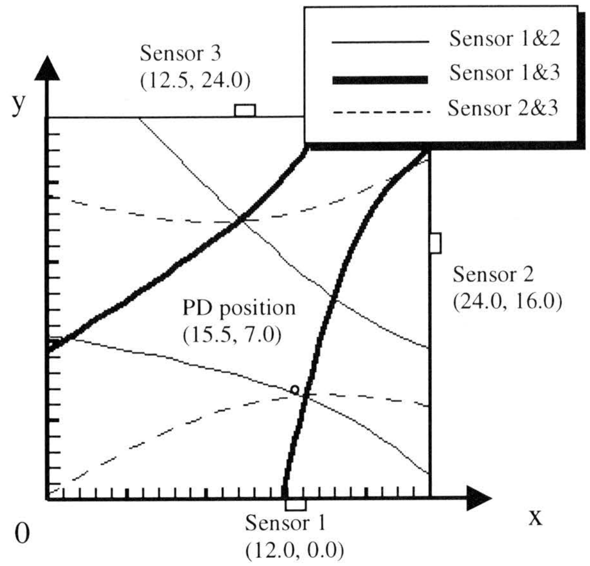

Fig.5 PD location

Error of result from our detecting method is 8 mm. This error is allowable because the sensor diameter is 12 mm. We could detect PD position from small signal that could not determine delay time directly by signal waveforms.

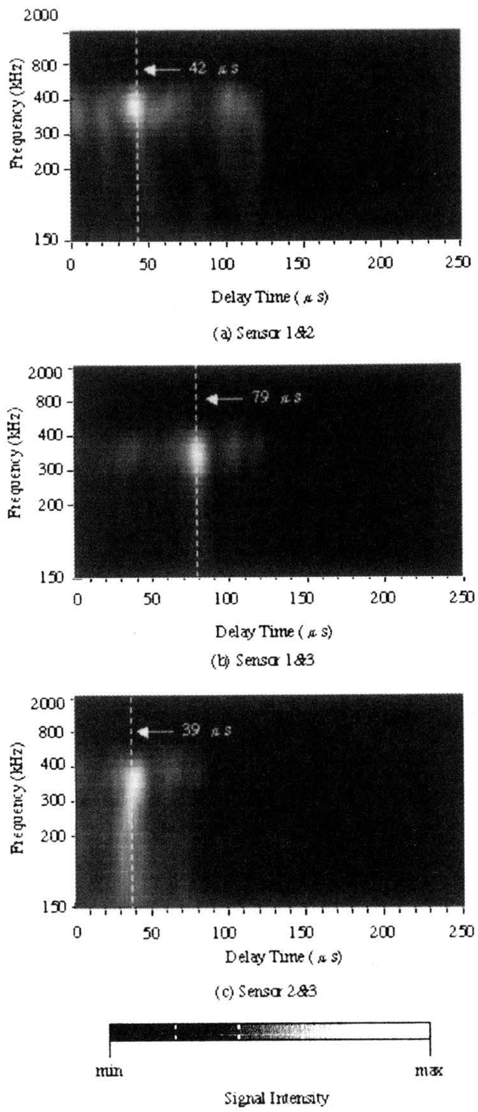

Fig. 4 Result of WBCF

Conclusion

We measured the sound signal from generated PD and tried to locate the PD position. Our location method using WBCAF can distinguish between PD signal and noise, and also accurately detect the delay time. As a result of location, this error is only 1cm or less. This indicates that WBCAF is effective for PD location. Future theme is the measurement of acoustic signal propagating through some media with different acoustic impedance.

References

(1) K. Arii et al; "Separation of Noise from Partial Discharge Signals by Wavelet, Podc. 5th ICPADM, pp232-235, 1997

(2)M. Kawata et al; "Non-Contact Detection of Electromagnetic Noise Occurrence due to Partial Discharges", IEEJ vol.115-B No.10, pp1168-1173, 1995

(3) R.T.Harrold, "Ultrasonic spectrum signature of under-oil corona sources", IEEE Trans.El.vol.10, no.4, pp109 -112, 1975