METHOD TO REDUCE THE SPURIOUS PEAKS IN THE CROSS-CORRELATION FOR THE PD LOCATING

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Abstract Detecting partial discharge(PD) and locating its source are one of many diagnosis methods. Location the PD source is very important to reduce the time and cost of repairing power transformers. And to locate the PD source, the cross-correlation method is a well known one. But there many spurious peaks in cross-correlation, and occasionally, some peaks could be bigger than the true one. In order to analysis these spurious peaks and to reduce them, we have done many experiments and simulations. As the results we could reduce the spurious peaks, and get well defined cross-correlation from which it is easy to locate the PD source accurately.

1. Introduction

Partial discharge(PD) within high-voltage power transformers can result in serious insulation damage. This breakdown is usually predicated by the measurement of the electrical pulses generated by the discharge or chemical degradation products dissolved in insulation oil. PD also generate ultrasonic pulses which are transmitted through the oil and can be detected on the surface of the transformer tank. The time delays resulting from the signals measured in different sensors can be used to locate the PD source.

In a free space, the PD wave generated from the needle-plate electrode may propagate radially, and the cross-correlation of the two signals detected by the two sensors which are located at different place should be well defined. But in the transformer, it is not free space because of steel walls, cores and oil.

So, there are many spurious peaks in cross-correlation, and occasionally, some peaks could be bigger than the true one. This should be overcome in order to locate PD source accurately. To reduce these spurious peaks, we have been many experiments and simulations and the results are represented in this paper.

General problem of PD locating will be reviewed in ch.2. In ch.3, our hypethesis about spurious peaks is introduced with the reducing method of them.

2. Locating the PD source

PD generates electrical pulses and acoustic ones in the power transformer. Electrical pulses could be detected by Rogowsky Coil(RC) mounted on the ground wire of the transformer tank or of the neutral line. Electrical pulses propagate in light velocity so its propagation time is negligible. Acoustic pulses could be detected by the acoustic sensors mounted on the surface of the transformer tank. The speed of acoustic pulses in transformer oil is about 1300[m/s]and the main frequency range is about 150[KHz].

We measure the two ultrasonic waves by the two sensors in different locations. Some time-delay between two ultrasonic pulses arriving at the two sensors can be occured and this time-delay can be assumed to stand the different distance d:

$$d = l_2 - l_1 = (t_2 - t_1) \times v \qquad (2\text{-}1)$$

where v is the velocity of ultrasonic pulses in transformer oil, and t_1, t_2 are the time that the ultrasonic pulses propagate from PD source to the sensor A and B, respectively. The PD source located on the parabolic line croses the anothe parabolic plane which has its focus at the sensors.

If two pairs of sensors are used, two parabolic lines could be made. And with the other one sensor pair, the PD source could be located at a point at where the parabolic line crosses the another parabolic plane. The time delay information is obtained using a cross-correlation function $r_{xy}(k)$, that is

$$r_{xy}(k) = \frac{1}{N}\sum_{n=0}^{N} x(n) \cdot y(n-k) \qquad (2\text{-}2)$$

where N is the number of samples, $x(n)$ and $y(n)$ are the two acoustic signals detected by the sensors.

3. Spurious-Peaks in Cross-correlation

3.1 Propagation of pulses and the boundary condition problem.

In general, there are many spurios-peaks in cross-correlation and some peaks are bigger than the true peaks. It should be overcome in order to locate PD source accurately.

In a free space, electrode the PD wave generated from the plate-needle propagates radially interface. Then ultrasonic pulses are as sphere whose strength $q(w)$ is given by $q(w) = 4\pi a^2 v(w)$, where $v(w)$ is radial velocity. The source strength density is thus concentrated at a point $\underline{y}$ such that the source strength per unit volume is given by $q_v(w,x) = q(w)\delta(\underline{x} - \underline{y})$. In the above, no reflection and no mode conversions are produced, and the peaks of the cross-correlation of two signals will be well defined. But in our case, it is not a free space but a rectangular steel tank filled with transformer oil.

It is very complex problem to get gereral solution of propagation mechanism of pulses in case where boundary conditions exist. That is the key problem to explain the spurious-peaks of the cross-correlation. The spurious-peaks of the cross-correlation are assumed due to these reflections and mode conversions according to the boundary conditions. And we assumed that the 5 planes of steel tank and a plane of oil role as six mirrors and a point source of ultrasonic pulses have its mirror image sources as shown in Fig. 1.

These six mirror sources and one real source generate the same ultrasonic pulses in the sence of frequency and magnitude and the measured signal at sensor A or B consists of signals supercomposed of these seven source in the free space.

From these assumptions, the spurious-peaks of cross-correlation could be explained as follows. Fig. 2(a) shows the prediction of peaks of the cross-correlation when there are seven sources in the free space and they have the same frequency and magnitude, but attenuation is not accounted. Compare with peaks of the cross-correlation of measured data in Fig. 2(b). The two figures show similar patterns except their magnitude. This means that our assumptions are reasonable. We experimented many times and the results were similar as above.

3-2 Reducing the spurious-peaks

The spurious-peaks of cross-correlation make it difficult to find out the true peak. Reducing the spurious-peaks is important to reduce the measurement errors. However, the experiments show that the spurious-peaks may be caused by the reflection and mode conversions of waves in the steel tank and not by the measured error.

On the basic of these observations, the data of ultrasonic pulses detected by sensor A and B were taken data processing such as filtering (band pass), windowing and averaging etc. The spurious-peaks in the correlation were reduced by these process and for more improvement we also took account of the boundary condition to calculate the cross-correlation using intelligent processing method such as fuzzy logic etc. Fig. 3 shows the patterns of the cross-correlation calculated by this method. In Fig. 3, the spurious-peaks were reduced remarkably and it is not difficult to find out the true peak.

4. Conclusion

PD locating techniques in the power transformers could be used to improve the reliability of the transformer diagnosis. And it reduces the time and repair cost for repairing troubled transformers. In this paper, the cross-correlation method to reduce the noise sensitivity and improving accuracy in the ultrasonic-ultrasonic PD locating method using some techiques of reducing the spurious-peaks.

Laborotary experiments illustrated that this method showed good performance as we expected. The spurious-peaks were reduced and the true peak was easily recognized as if the PD source was in the free space without any boundary. Although we experimented with the steel tank filled with oil but as a model in laboratory, it was verified that the suggested PD locating method based on the cross-correlation method was very accurate and useful.

REFERENCES

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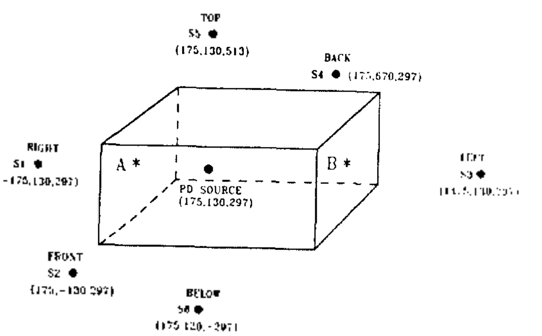


Fig.1. PD Source and its mirror images

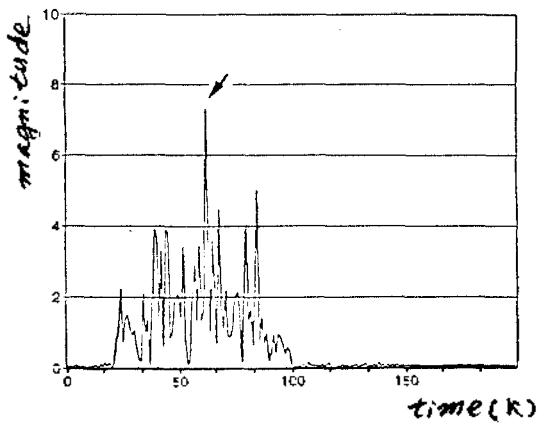
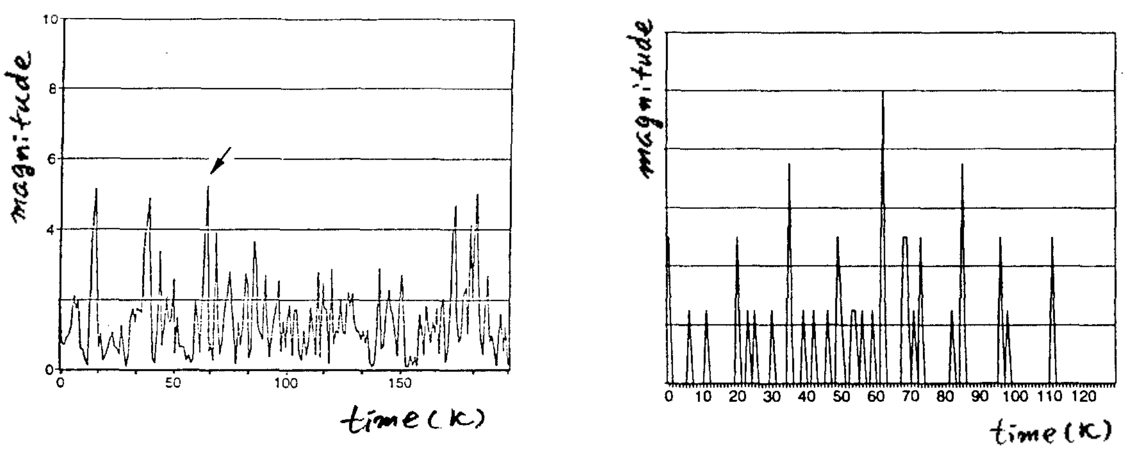


Fig. 3. typical form calculated with our methods



(a) calculated peaks from measured data (b) predicated peaks using mirror sources

Fig.2. calculated and predicted peaks