Methods for Faults Localization in Power Transformers Insulation

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***Abstract*—The systematic evaluation of transformer insulation systems has become a necessity in order to avoid the sudden outages of the power transformers that generate great financial losses. Partial discharge (PD) measurement brings objective information on the nature and risk degree of transformer faults. PD source localization supports a better diagnosis and the decrease of the repair time.**
The paper presents a PD source localization method that combines the results of the PD electrical measurement with the ones of the PD acoustic measurement.

***Index Terms*—acoustic emission, diagnosis, localization, partial discharge, power transformers**

I. INTRODUCTION

Power transformers are one of the most important components of electric power networks. Most of them have been in service for many years under different environmental, electrical and mechanical conditions.

Power transformers are very expensive and form a high percentage of the investment of the power system. Extending transformer life as long as possible is not only economically valuable but also prevents losses when unexpected outages of transformers occur.

As Partial Discharges (PD) measurement is an efficient tool for diagnosis purposes, there have been extensive efforts to analyze various aspects of PD such as measurement, recognition and localization.

PD measurement on transformer in operation is very difficult because it is necessary to make the discrimination between PD and different sources of noise.

Partial discharges are usually detected acoustically or electrically.

Theoretically the PD is also a source of ultra-acoustic waves propagating in the complex power transformer insulating system under the form of a spherical front. Besides the attenuation and dispersion phenomena, the multitude of waveforms complicates the PD acoustic signal analysis in insulating structures of materials with different physical characteristics.

However, such pressure (mechanical) waves can be detected using piezoelectric contact sensors able to transform the acoustic pressure in electric signal.

The system for acoustic measurement cannot be calibrated because in its way the acoustic wave passes through different barriers with various acoustic impedances and is exposed to the reflection phenomenon.

The acoustic method is used only for monitoring and localization.

In contrast, the electric method offers both a determination of the apparent charge and PD localization.

II. ACOUSTIC PD INSTRUMENTATION

Acoustic PD detection set up is rather simple consisting of 4 (four) sensors each with integrated filter and pre-amplifier, a data acquisition system, a trigger device and a PC (Fig.1).

The acoustic waves emitted from the PD source can be detected by a suitable AE sensor placed on the transformer tank, the output of which can be analyzed using a conventional data acquisition system.

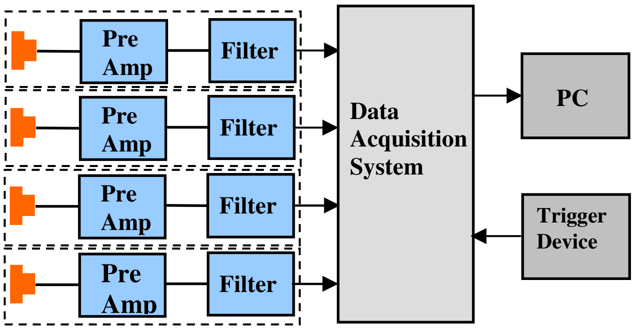

Fig. 1 Acoustic PD detection set up

The acoustic emission sensor is a piezoelectric transducer which converts the acoustic signals into corresponding electrical signals proportional with the propagation velocity of the acoustic wave in the material of the surface to which they are attached.

The operation range of the AE sensors is from 20 to 80 kHz and pre-amplifier gain is 46 dB.

The frequency band is chosen having in view the nature of the transmission for waves with different frequencies on shorter or longer distances. So, it is considered that the high frequency signals are attenuated rapidly and consequently they have a shorter detection distance while the lower frequency signals are less attenuated and consequently they have a longer detection distance.

To assure a good sensitivity and contact, the AE sensors are usually mounted with a thin layer of acoustic coupler (special grease with specific properties for acoustic signal transmission) and are fixed on the transformer tank by magnetic holder.

The coupling from the transformer tank to sensor should be considered as an integrant part of the system, as it strongly influences system characteristics.

The synchronous acquisition from the 4 measuring channels is controlled from a triggering device that detects the zero passing of the high voltage of the transformer under test.

III. ELECTRIC PD INSTRUMENTATION

In order to perform the measurement by means of the electric method according IEC 60270, it was used the PD digital measuring system MPD 600 from OMICRON. This is suitable for test facility measurements as well as for on-site measurements under strong electromagnetic interference conditions and thus provides an important contribution to maintaining the quality and value of expensive transformers. The PD measuring system MPD 600 is able to perform synchronous multi-channel measurements [1]. In contrast to conventional multiplexed systems with measuring channels switching, MPD 600 allows a really simultaneous acquisition of PD signals.

Our measuring system consists of minimum three acquisition units, an optical USB interface unit and a PC with Mtronix software installed [2].

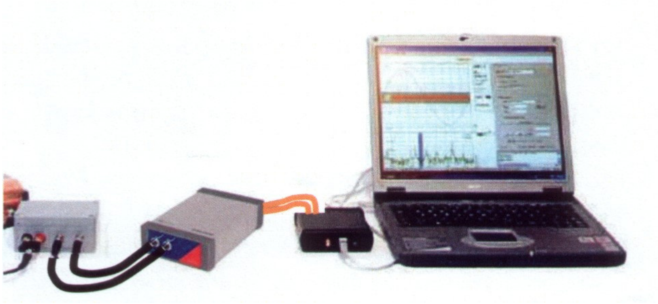

Fig. 2 MPD 600 measuring system (measurement impedance, acquisition unit, USB interface and notebook)

IV. PD LOCALIZATION TECHNIQUES USING THE ELECTRIC AND ACOUSTIC MEASURING METHOD RESULTS

The transformer is energized from the electric power network. The acquisition control is made practically at the same time both for the MPD system and for the acoustic one. Data processing is made off-line [3].

In a first stage there are removed the disturbances generated by corona effect identifying the signals having the same amplitude and are identically positioned on the time axis of the three phases with the same nominal voltage.

The next stage consists in transferring the signals processed in the first stage from time domain in frequency domain using the Fast Fourier Transform (FFT) and a window function. In the frequency domain, there are identified and removed the signals characterized by one single frequency. These signals are generated by the broadcasting stations.

In the last stage the transfer from frequency domain in time domain is made by the inverse function of FFT and the PD signal is obtained.

It is determined the time interval between the high voltage zero passing and the PD pulse position (Δt).

The time intervals from acquisition control moment to signal visualization for each of the 4 acoustic transducers are measured by visualizing the signals acquired with the acoustic measuring system. They are noted by T_1, T_2, T_3, T_4.

Fig. 3 shows how these times are connected to the unknown PD onset [4].

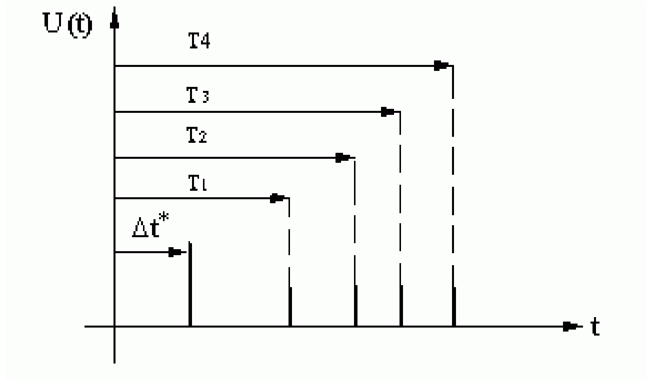

Fig. 3 Schematic visualization of acoustic time in reference to the unknown PD onset

The PD source is modeled like a point radiating acoustic waves in a homogeneous medium. Fig.4 presents a transformer tank with 4 attached acoustic transducers, PD source and the distances from transducers to PD origin.

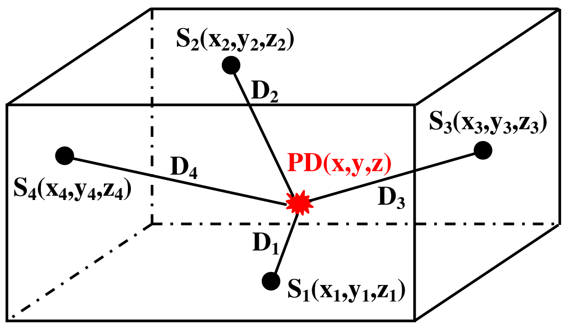

Fig. 4 Acoustic transducers on a transformer tank with PD source inside (using Cartesian coordinates)

The following equations result on the basis of the sphere functions crossing at the PD source:

$$(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2 = (v\,(T_1-\Delta t^*))^2 \quad (1)$$
$$(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2 = (v\,(T_2-\Delta t^*))^2 \quad (2)$$
$$(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2 = (v\,(T_3-\Delta t^*))^2 \quad (3)$$
$$(x-x_4)^2 + (y-y_4)^2 + (z-z_4)^2 = (v\,(T_4-\Delta t^*))^2 \quad (4)$$

Noting $T = T_1-\Delta t^*$ and representing relations $T_2-\Delta t^*$, $T_3-\Delta t^*$ and $T_4-\Delta t^*$ depending on T and on the propagation time difference between the signals from transducers 2, 3, 4 and the signal from transducer 1 there are obtained 4 equations with 4 unknowns: x, y, z and T.

Knowing v, the assumed sound velocity, T and T_1 it is obtained Δt^*.

This time (Δt^*) is compared with the one obtained by the electric measurement (Δt). If the said quantities are quite close it follows that the geometric position of the PD source is correct but if the differences are great the acoustic transducers are re-positioned and the acoustic measurement is repeated until the best closeness between the two times is obtained.

V. CASE STUDY

Neither the transformer station where the measurement was performed nor the transformer manufacturing factory were specified in the presented case study so that not to influence the manufacturer image.

The electric measurements rendered evident high PD levels on one of the 200 MVA 400/ 220kV transformer phase.

Fig. 5a presents the image of the acquired signals and Fig. 5b presents the software filtered image.

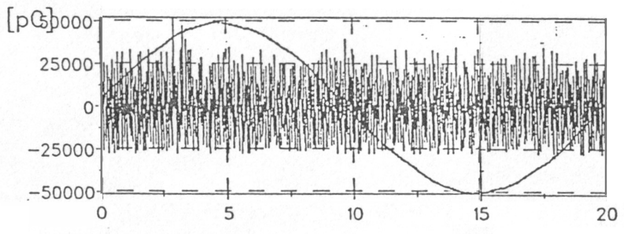

Fig. 5a Acquired signals

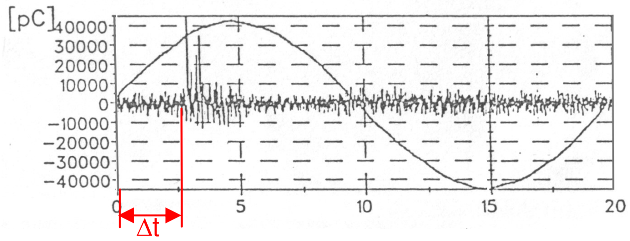

Fig. 5b Software filtered image

The PD source coordinates were determined positioning successively the four acoustic transducers so that to obtain a difference as small as possible between the inception times of the same PD signal measured by the electrical method and by the acoustic method.

When the transformer was un-tanked, it was found out that between the real position and the one determined by calculation it was a difference that could be inscribed in a circle with a 20 mm radius.

The presented case validated the viability of the PD localization method but it had some particularities that favored the working procedure namely:

- PD were generated by an important fault (see Fig.6);
- The PD source was not inside the winding insulation and consequently, the acoustic signals propagated in a relatively uniform medium;
- The PD source was unique.

Fig. 6 Picture of the fault screen

VI. CONCLUSION

In order to improve the diagnosis technique for power transformer insulation it was developed a method that enables partial discharges localization using PD electrical measurement and PD acoustic measurement.

When a transformer fault is noticed the first questions are: "Where the fault is localized and what its nature is?" Using the electric method for PD measurement, the winding with the highest PD level can be determined. The PD area localization is performed by the acoustic measurement of the propagation times and then the PD impulse position toward the zero passing of the high voltage is determined. It is considered that a good approximation of the PD source was obtained when the positioning of the electrically measured impulse is the same or almost the same with the one calculated from the acoustic measurement.

In order to establish the error margin for PD source-localization it is necessary to continue the measurement program and checks of the faults localization by un-tanking.

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