ACOUSTIC METHOD OF PARTIAL DISCHARGES EVALUATION

Jerzy SKUBIS
Technical University of Opole, ul. Mikołajczyka 5, 45-271 Opole, Poland, Office phone: 48 77 4006154
fax: 46 77 4569446, skubis@po.opole.pl

SUMMARY

The paper presents possibilities of detection, measurements and localization of partial discharges appearing in high power transformers using acoustic emission method (AE). Generation of the AE signals by the partial discharges is discussed. A basic meter circuit is presented. Hypothetical results of partial discharges diagnostic in one of the transformers and also possible methods of PD localization are talked over. In the end a significance of the acoustic emission method in diagnostic of transformers is presented.

Keywords: *partial discharge (PD), acoustic emission method (AE), diagnostic of power transformer*

1. INTRODUCTION

Evaluation of PD in high power transformers during their exploitation can be carried out with the acoustic emission method (AE), which is based on detection and localization of pressure impulses generated by PD [1, 3]. At the beginning of the eighties technical applications of the AE method started: in the evaluation of PD appearing in the high power transformers, high voltage measuring transformers, energetic capacitors, transformer buskings and - at the beginning of the nineties – in the switchgears as well.

2. GENERATION OF ACOUSTIC EMISSION SIGNALS BY PARTIAL DISCHARGES

The basis of the AE method is a generation of acoustic signals by PD. During PD a part of the electric energy is being changed by impulses into the mechanical energy. From the physical point of view an individual PD can by equated to the microexplosion that appears in the dielectric. It is impossible to give an unambiguous function describing the transformation of energy from the one form into the other. Parameters of this transformation depend mainly on the speed of the transformation of the electric energy into the mechanical energy. Depending on the type of PD AE impulses have different amplitude and time. Assuming that PDs appear in the homogeneous medium they can be treated as a point disturbance source. Such an idealization is justified because a distance of the phenomenon observation is repeatedly greater than the source dimensions and a length of the emitted wave is not big in comparison with the observation distance. AE emitted by PD propagates in the medium as a spherical wave. The amplitude of the generated AE impulses is inversely proportional to the source distance of PD and the intensity of AE is inversely proportional to the square of the distance. In reality multiple PDs rather appear and not only in one point but in a certain area of the dielectric. For this reason in insulation not the single AE impulse appears but the whole group of the impulses do. The AE impulses, which appear in these circumstances, are shifted with respect to one another in time and space. A measurement transducer registers a resultant sequence of the AE impulses, which makes up a summed picture of the phenomenon.

Single PDs are accompanied by the generation of the discrete AE whereas multi-source continuous PDs are accompanied by the continuous AE [5].

3. A METER CIRCUIT

A general meter circuit can be assigned to the process of PD generation (Fig. 1). A transducer, which is applied to the receiving of the AE impulses, should enable their linear converting into the voltage signals in a frequency band up to 400 kHz, which is assured by piezoelectric transducers of different types.

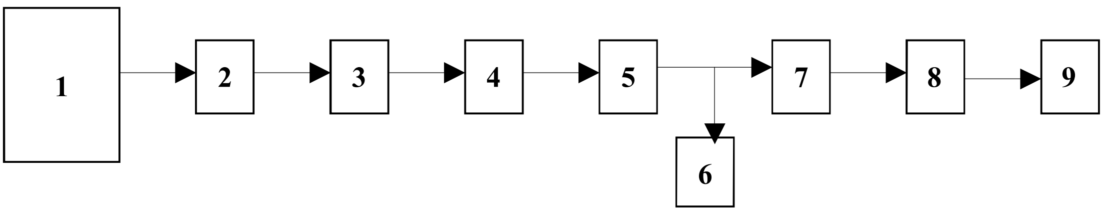

Fig. 1 A diagram of a circuit used to detection and measurements of AE from PD.
1 – a measured transformer, 2 – a transducer, 3 – a preliminary amplifier, 4 – an amplifier, 5 – a middle-seal wire filter, 6 – an oscilloscope, 7 – a threshold discriminator, 8 – an impulse scaler, 9 - a computer

In the general meter circuit a simplified part composed of the elements 1 – 6 (Fig. 1) can be separated. A circuit which is put together in this way can be used to detect and visualize the AE impulses from PD. Attaching the elements 7, 8 and 9 to that circuit enables a measurement and analysis of the results. Technical realizations of the general meter circuit depend on the metrological conditions and the scope of the diagnostic [8].

The characterized meter circuit is applied in a diagnostic of PD appearing in transformers during their normal exploitation.

4. HYPOTHETICAL RESULTS OF PARTIAL DISCHARGES DIAGNOSTIC

Applying the AE method to the transformers of power S > 250 MVA is obligatory. With reference to the transformers of lower power the AE method is applied according to the demand which is determined by the service engaged in exploitation of these transformers. Owing to the crucial significance for the faultless work of the circuit, the transformers should be measured by all available diagnostic methods [2]. For that reason a practical application of AE in the diagnostic of transformers' insulation is very desirable. Information on PDs which appear in the insulation of the operating transformers is not available in another way because none of the known PD measurement methods can be used during the normal exploitation of the transformers.

From the technical point of view it was important to work out a measurements' methodology and to establish their scope. Because of the normal working of the transformers an access to the surfaces which can be measured is limited to the zero level of the tank. For that reason an upper lid of the transformer, chimneys and buskings are excluded from the measurements. Only side walls of the tank are available for the measurements. In the performed measurements a measurement transducer was placed both on the side of upper voltage and bottom voltage, at the three different levels of the tank, in turn in phases R, S, T and between the phases as well. In this way a measurement grid arises. In the nodes of the grid a transducer is placed.

Tab. 1 presents hypothetical results of PD detection, measurements and localization, performed with the AE method in one of the diagnosed transformers. A comparison of the results of PD detection and measurements with the AE method in selected transformers are included in [6].

In transformers in which internal PDs were detected more advanced descriptors of AE generated by these PDs are registered. Hypothetical results of sum and rate measurements of AE from PD appearing in a unit transformer are presented in [6].

Currently, the AE method is the most widely applied method in unit transformers diagnostic; transformers in stations and large power plants are diagnosed more rarely.

5. LOCALIZATION OF PARTIAL DISCHARGES WITH THE ACOUSTIC EMISSION METHOD

A phenomenon of AE generated by PD makes it possible to locate an area of discharges. The localization of the PD area can by realized in two ways, i.e. by measurement of:

- AE amplitudes in different distances from the source of PD,
- times of AE signals arrival to the transducers placed in different point of the tank.

The method of PD localization using the measurements of the amplitudes is determined in literature as a maximum loudness method or an auscultation method whereas the method based on the measurements of the propagation times is determined as a triangulation method [4]. At testing stations, where there is an easy and relatively safe access to the transformer and measurement time is limited by time of the voltage test, the triangulation method is mainly applied. In the transformers being under exploitation the maximum loudness method is usually applied.

An idea of PD localization with the triangulation method presents Fig. 2.

Values of delay times are easy to measure. If on the way to the measurement transducers the signals penetrate different materials, their substitute speed should be calculated. If the signals arrive to the transducer through a single dielectric, a distance between the source of PD and the transducer is calculated directly from the speed of dispersing of the signals in that dielectric. In that case errors can occur, that can be eliminated while working out the results. On the basis of the measurements a system of *n* equations can be arranged (where *n* is a number of transducers).

Height of a tank	A side of deriving the upper voltage					A side of deriving the bottom voltage				
	Phase					Phase				
	R	R-S	S	S-T	T	R	R-S	S	S-T	T
Top	0	0	0	0	0	0	0	0	0	0
Middle	30 mv	0	0	0	0	0	0	0	0	0
Bottom	40 mv	0	0	0	0	0	0	0	0	0

Tab. 1 Results of PD evaluation with AE in a transformer of type TOWRa – 12500/13,8

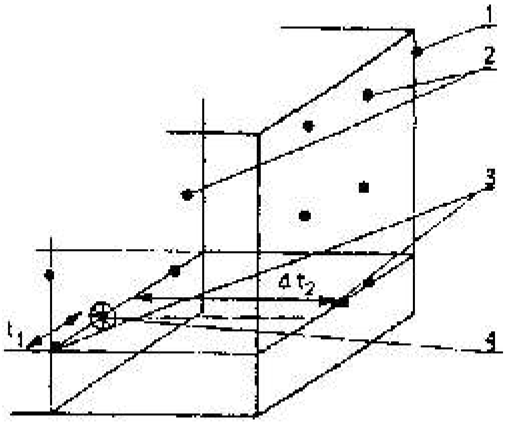

Fig. 2 An ideological presentation of a triangulation method of PD localization.
1 – a draft of a transformer tank, 2 – deployment of measurements points, 3 – points, to which AE signals arrive in the shortest time, 4 – a located point of PD appearance

A solution of that system makes it possible to determine coordinates of the place of PD appearance. Some systems can have no solution or can give the results going beyond the dimensions of the transformers. They are rejected from the calculations. Consequently, fewer results are obtained than a number of output systems of equations is. From these obtained results the mean value of the coordinates is calculated and it is considered to be the location of the source of PD. A drawback of the method is the necessity of applying a greater number of slotted lines in order to simultaneously register delay times in a few points.

To locate PD in transformers' insulation being under exploitation the maximum loudness method is preferred. The localization of PD with this method is based on the measurement of the AE amplitude values in different points of the tank and finding such a place, where the AE amplitudes are the highest. When the area of the highest audibility of AE is found, one can assume that PDs appear in that place. The maximum loudness method is the simplest way to locate PD but its usage entails a possibility of appearing significant errors. They can result from the unequal dampening of the AE impulses, especially when the impulses on the way to the transducer penetrate different dielectrics and conducting materials. An idea of PD localization with the maximum loudness method presents Fig. 3.

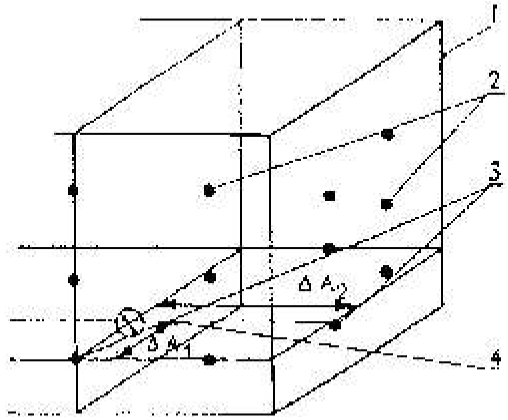

Fig. 3 An ideological presentation of PD localization with a maximum loudness method.
1 – a draft of a transformer tank, 2 – deployment of measurements points, 3 – points, in which AE signals have the highest amplitudes, 4 – a located point of PD

To precisely locate PD with the maximum loudness method it is necessary to simultaneously analyse three kinds of information: the amplitudes of the AE impulses, the spectrums of the signals and the construction of the examined transformer [7]. Undeniable advantages of the PD localization with the maximum loudness method are:

- a possibility of auscultation of the transformers during the current exploitation,
- performing measurements through the only one slotted line,
- a simple methodology of carrying out the localization.

6. A SIGNIFICANCE OF THE ACOUSTIC EMISSION METHOD IN DIAGNOSTIC OF TRANSFORMERS

The AE method is an important replenishment of methods applied in diagnostic of transformers. It gives information on existence, scale and place of PD appearance, which is impossible to obtain with other methods. It makes it possible to decide directly at the transformer if the reason for a degradation of the insulation is PD or another phenomenon. Depending on the scope of the diagnostic the AE method can by applied to detection, measurements or localization of PD.

The AE method doesn't replace methods, which have been used so far, but it only gives a new pointer characterizing the insulation, which is examined. This pointer should be treated on a par with an apparent load Q_p or with a system of codes applied to interpretation of results from a chromatographic analysis (DGA). During interpreting the results obtained with the AE method one should always take into consideration its limitations resulting from the mechanism of the AE signals propagation in the transformers. Regardless of a digital registration of the signals in order to its numerical processing one should apply a circuit, which enables a visualization of the registered signals. The AE method turns out to be particularly useful in PD localization. The choice of the PD locating technique with the triangulation method or auscultation depends on the available apparatus and the metrological conditions. The applied methods of localization differ in the respect of accuracy and the extent of complications of the executed calculations.

Compared with the electrical method of PDs measurement and their chromatographic evaluation the AE method has the following advantages:

- it enables PD detection, measurement and localization directly at the transformer during its normal exploitation,
- it is relatively little sensitive to disturbances,
- a measurement apparatus is relatively simple and available in country.

The AE method has also limitations:

- it detects only PDs which appear in dielectric with a big elasticity; PDs which appear in the paper insulation may be impossible to detect because of the intensive dampening of the AE signals by the paper,
- it is impossible to unambiguously determine the PD scale inside the insulation on the basis of the values of the AE signals in the place of reception.

The most important advantage of the AE method lies in the fact that it can by applied in very hard conditions of the exploitation of the transformers, where executing PD measurements was impossible so far.

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BIOGRAPHY

Jerzy Zbigniew Skubis, electrical engineer, educator; MSc in Engring., Silesian Tech. U., Gliwice, Poland, 1974; PhD, Silesian Tech. U., 1981, Habilitation, 1987. From asst. to prof. Technical U. Opole, Poland, 1974-97; prof. Technical U. Opole, 1997—, head dep., 1983-84, vice rector rsch., 1990-96, 99—. Author: Acoustic Emission for Insulation Testing of Electrrical Equipment, 1993, 2d edit., 1998; co-author 9 books; contbr. articles to profl. jours. Mem. N.Y. Acad. Sci., Soc. Elec. Engrs. Poland, Polish Soc. Theoretical Applied Electrotechnics. Club Cath. Intelligensia. Avocations: traveling, gardening. Home: Hubala 12A 601, 45-263 Opole Poland Office: Tech. U. Opole, Mikołajczyka 5, 45-271 Opole Poland Opole Poland Office: Tech. U. Opole, Mikołajczyka 5, 45-271 Opole Poland.
Home: Hubala 12A 601, 45-263 Opole Poland Office: Tech. U. Opole, Mikołajczyka 5, 45-271 Opole Poland Intelligensia. Avocations: traveling, gardening. Home: Hubala 12A 601, 45-263 Opole Poland Office: Tech. U. Opole, Mikołajczyka 5, 45-271 Opole Poland.
Author: Acoustic Emission for Insulation Testing of Electrrical Equipment, 1993, 2d edit., 1998; co-author 9 books; contbr. articles to profl. jours. Mem. N.Y. Acad. Sci., Soc. Elec. Engrs. Poland, Polish Soc. Theoretical Applied Electrotechnics. Club Cath. Intelligensia. Avocations: traveling, gardening. Home: Hubala 12A 601, 45-263 Opole Poland Office: Tech. U. Opole, Mikołajczyka 5, 45-271 Opole Poland.