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THE STATE OF SCIENTIFIC DESCRIPTION AND APPLICATION OF THE ACCOUSTIC METHOD OF DETECTION, MEASUREMENT AND LOCATION OF PARTIAL DISCHARGES

1. Introduction

The information of occurrence of partial dischagges is of great importance for the estimation of the state of the insulation system. In metrology of partial discharges three methods are significant nowadays. These are: electric, chromatographic and accoustic emission method. The electric method may be applied only in laboratories and in certain testing stations considering the interference. However, it is not suitable at all for measuring PD occuring in functioning objects [24,25,27,48]. The chromatographic method is applied to estimate PD occurring in these conditions. The identification of PD basing oneself on concentrations and quantity relations of gases dissolved in oil or received from Bucholtz relay is, however, inaccurate and in certain case may lead to wrong conclusions [36,45]. The AE method is the only one which makes the direct measurement of PD occuring in insulation possible at the normal functioning of objects. This method makes detection, measurement as well as location of the region of PD possible. The method may be also applied in test fields in the course of voltage test of installations and high voltage apparatus.

The idea of applying AE concomitant with partial discharges to their detection and measurement has been presented in mid fifties [1] . However, it has not been realized till mid sixties considering the lack of suitable apparatus. First results of technical application of AE method have been published in the latter part of sixties [4,5,18,19,21]. In

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seventies, American, Japanese and other syndicates informed about the application of AE method [9,10,15,20,59]. At present studies on application of the AE method are carried out in the Soviet Union, German Democratic Republic, Romania, Hungary, France and Italy. Information about improving measurement systems and interpretation methods are being published as well [3,13,14,37,52,64].

The assistant professor Szuta suggested the application of this method in 1974 in our country. Studies and laboratory investigations followed this proposal [2,17,33]. The investigations were carried out in Energopomiar in Gliwice and in the Technical University in Opole. The discernment of physical actions of AE concomitant with PD and the scientific description of suitable measurement systems were the results of the studies [30,31,34,35,39]. In the early eighties the technical application of AE method has begun. Since 1982 the method has been initiated in diagnostic of unit transformer insulation in all more important power plants in our country [22,42,46]. In 1982 and 1983 the AE method has been applied in Elta factory in Łódź to locate partial discharges in transformers exposed to voltage tests [57,58]. In 1982 the application of AE method to measurement of PD in capacitors [61] has been suggested and in the following years the results obtained in this area have been presented [11,43,62,63]. In years 1982-1984 the results of application of the method in high voltage measuring transformers as well as in lead - in insulators of the capacitor type in the course of their voltage tests have been presented [26,38,40]. Up till now about 30 papers dealing with the AE method have been published in our country and about 25 works initiating the method in power industry plants have been carried into effect.

2. General Characterization of the Accoustic Emission Method

The AE method consists in measuring pulses of pressure generated by PD. These pulses propagate in all construction materials of the investigated object. While propagating the pulses are dampened by the medium they penetrate. While passing from one medium into another, for instance, from oil into paper or from oil into steal the pulses undergo reflection and refraction. In result a different signal from the generated one gets at the measuring transducer. Piezoelectric transducers of various types are most suitable for receiving accoustic signals [28,41,44]. The signal received by the transducer is amplified, filtered and interpreted. The system presented in Fig.1 may be applied to receive the signals.

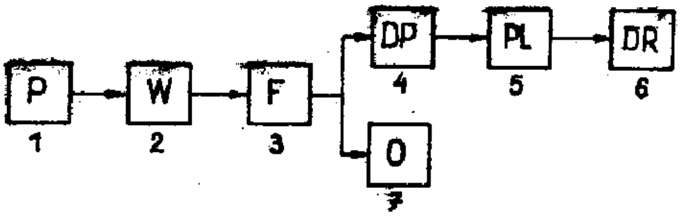

Fig.1. A block diagram of a measuring system of AE generated by PD
1 - A transducer, 2 - An amplifier, 3 - A middlepass filter, 4 - A threshold discriminator, 5 - A pulse computer, 6 - A printer, 7 - An oscilloscope

There are four basic realisations of the measuring system according to Fig.1: IPPT system, system based on the standard panel, Unipan system and Dema 10 system.

Various electromagnetic and accoustic interferences are concomitant with AE measurements. It is possible to eliminate them by the exact screening of the apparatus as well as by the choice of the suitable measurement band. The most strenuous interference in the electric method generated by the external corona discharges is insignificant in AE method considering wery intense damping of AE resulting from these discharges by the air. The maximum amplitude of the accoustic signal is the most often applied parameter which characterizes the intensity of PD in AE method. There are also other parameter to be applied, suchas the sum and velocity of pulses, the velocity and density of events of typical stochastic functions [6,7,32,49,54].

3. The Range of Technical Application of the AE Method

The AE method may be applied to measurements of PD occuring in insulation of various high voltage installatious laboratory investigations preceded the technical application of AE method. The results of these inves tigations made the determining of the sensitivity of the method and the revision of its advantages and limitations possible. The apparatus was also controlled in laboratory conditions. The obtained results confirmed the possibility of detection and measurements of PD by AE method in technical objects although the results presented by various centers are divergent and uncomparable.

The objects and conditions in which the AE method may by applied were chosen and determined on the basis of experiments carried out in laboratory conditions. It is desired to apply the method without changes in the construction of the measured objects and in their functioning. Taking this into consideration the application of the method seems advisable in the following objects:

- great power transformers,
- high voltage measuring transformers,
- lead-in insulators,
- power capacitors.

The range of application of the AE method depends on the type of the object, the way of its functioning, the acces to the object, the possible measurement time and the kind of desired information about the state of the insulation system [16]. The range of application of AE method has been presented in Fig.2.

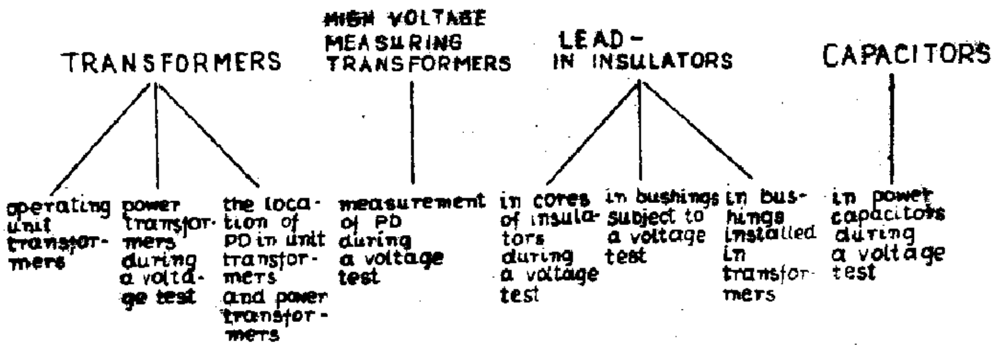

Fig.2. The range of the technical application of the AE method by the author

4. Exemplary Results of the Method Application

Exemplary results of measurements of PD by the AE method in one of the unit transformers have been presented in table 1.

Table 1

The results of measurements of PD by AE method in a unit transformer TW - 240000/220

Phase / hight of a tub	The side of top voltage					The side of bottom voltage				
	A	A-B	B	B-C	C	A	A-B	B	B-C	C
Top	50	0	0	0	0	0	0	0	0	0
Centre	120	0	0	0	0	0	0	0	0	0
Bottom	0	0	0	0	0	0	0	0	0	0

The measurement transducer was situated at the side of the top and bottom voltage on three different levels of a tub successively in phases A,B,C as well as between phases A-B, B-C. A measurement grid in the nodes of which there was a transducer was made in this way. From Tab. 1 it is evident that in the insulation of the investigated transformer PD occur from the side of the top voltage in the top and middle part of the phase A. The analysis of the shape of registered signals shows that PD occur most probably at the boundary of oil and insulation paper. The results of detection and location of PD in the unit transformer presented in Tab.1, have been verified. The transformer was taken to be repaired to the repair shop. Disassembling of it ascertained the defect of insulation in the determined before area. A hundred transformers of vatious types are controlled yearly by the AE method.

Fig.3 presents the characteristics of ionization measured by the AE method in power capacitors.

Fig.4 presents the results of measurements of AE generated by PD occurring in transformer lead-in insulator with a steered field.

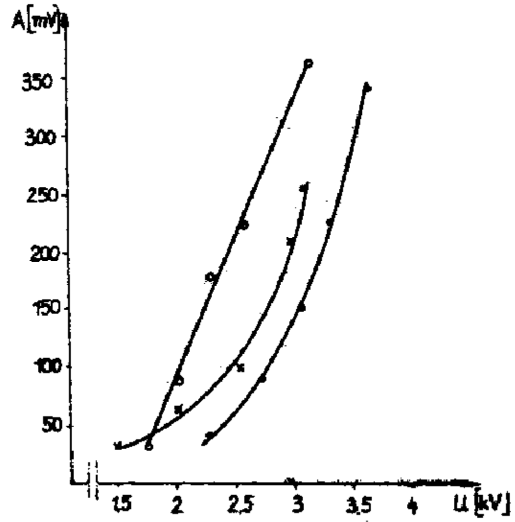

Fig.3. Exemplary characteristics of ionization of capacitors measured by the AE method (capacitors with the capacity of 9 μF and the voltage of 1130 V)

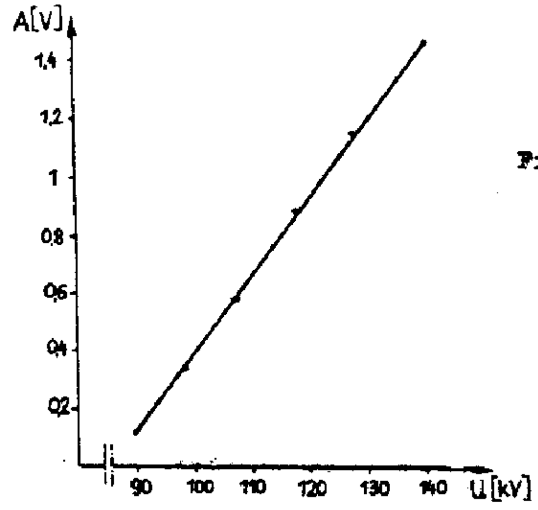

Fig.4. The dependence of the maximum amplitude of AE upon the value of the test voltage in the insulator PKTNk 123/550/630

5. The Place of the Accoustic Emission Method in the Metrology of Partial Discharges

The AE method complements in a significant way measurement methods applied up till now. It gives information about the existence, magnitude and the place of occurence of PD in normally functioning objects.This information is unattainable if PD are measured in a different way. It concerns particularly the explicit ascertainment directly on the measured object whether partial discharges occur or some other phenomenon is the cause of degradation of insulation. The range of AE method application is very broad. There is a possibility of application of the AE method to measure PD in homogeneous insulation materials [23] and in insulation systems with SF_6 [29].

The basic advantage of the AE method is that it may be applied in very difficult metrological conditions in which it was impossible to measure PD. The AE method fills the gap which existed in metrology of PD in high voltage installations. This is the basic advantage of method since considering the sensitivity the electric method is more advantageous. In relation to electric method of measuring PD and their chromatographic estimation the AE method possesses the following advantages:

- makes the detection and measurement of PD possible directly on the functioning object,
- makes the location of PD in the insulation of the object possible in simple way,
- the measurement apparatus is simple and totally attainable from Polish producers.

It should be emphasized that the AE method does not replace measurement methods used up till now and only gives a new parameter characterizing the examined insulation. The parameter should be treated equally with other parameters of PD applied up till now.

6. The Directions of Improving the Method

The present state of elaboration of the AE method made its broad application in diagnostic o. insulations of various high voltage installations possible. However, it is necessary to continue or take up new studies, particularly:

a) further analysis of various parameters characterizing the AE generated by PD. It would be advisable to elaborate such a measurement characterizing PD which would simultaneously contain information about the energy and amplitude of PD,

b) determining of a full correlation between amplitudes of AE pulses and parameters used for PD estimation up till now: between apparent charge and relations of gases liberated from oil by the method of chromatographic analysis [55,56]. It would be advisable to determine such a dependence for chosen groups and types of installations.

c) gathering in formation connected with application of the method to location of PD in various installations,

d) continuation of studies on determining the relationship between the applied measurement of AE generated by PD and the time of insulation life. The investigations should be carried out directly in works producing insulation materials as well as in those which produce high voltage apparatus,

e) improvement of measurement systems. It would be advisable to make a system with a microprocessor realizing the signal processing currently during measurements,

f) the extension of the range of application of the method to homogeneous insulation materials, such as resin, foils and polyethylene.

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