CALLIBRATED ACOUSTIC EMISSION METHOD AS A NEW CONCEPTION REGARDING EVALUATION OF PARTIAL DISCHARGES FOR DIAGNOSIS OF INSULATION

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SUMMARY

A new conception regarding evaluation of partial discharges (PDs) within high voltage insulation systems is presented. Such evaluation is made on the grounds of the so-called calibrated acoustic emission (CAE) method worked out at Silesian University of Technology (Poland). Important elements of this measuring method are: registration of signals at real time, filtration of registered signals within selected frequency band, construction of an acoustic image of registered signals, analysis of amplitude distributions of AE signals made by two methods (by means of advanced AE descriptors and neuron network of Kohonen) with reference to investigations realized parallel by means of the electric method.

Keywords: *acoustic emission, partial discharge, descriptors, Kohonen network, apparent electric charge*

1. INTRODUCTION

During PD measurements, applied also to diagnose given insulation systems, evaluation of PDs is made most often basing on maximum apparent electric charge or extinction voltage. However, that may be insufficient when PD intensity exceeds the level treated as permissible one [8]. Measuring results should widely describe both such intensity and character of PDs as well as locate their sources. A new conception regarding evaluation of PDs for diagnosis of high voltage insulation systems satisfies such requirements. It is called temporarily the calibrate acoustic emission (CAE) method which consists in PD measurements by means of two independent and high advanced methods – acoustic and electric.

2. ACOUSTIC METHOD OF PD INVESTIGATIONS

2.1 Introduction to the problem

Acoustic emission phenomenon creates unique possibilities to observe deformation processes basing on the relevant acoustic emission (AE) measuring method. Essential and typical limitations of this method are caused by changes of elastic waves emitted by a PD source during propagation, detection and processing of a reiterated signal. They may be eliminated by correct choice of descriptors, i.e. quantities characterised PDs intensity. Such approach to a subject causes the AE method may be used to evaluate PDs effectively.

The presented method has been examined and improved by interdisciplinary team during realisation of the research project sponsored by the Polish Committee of Scientific Research (1999-2001). The principal goal of succeeding project is the CAE method which will be consist in parallel utilisation:

- the AE method (to measure intensity and location of PDs),
- the electric method (to characterize kind and parameters of PDs),
- both methods (to mutual verify obtained results).

2.2 AE method elements

2.2.1 DEMA COMP measuring system

The measuring AE system DEMA COMP is unique, specialise and portable apparatus set which has been design and built by Authors. It enables us to make monitoring of input data, preliminary registration of selected AE signal parts in FIFO disk memory of PCI-610E measuring card, transmission of reiterated data (within frequency band up to 2.5 MHz in each from four measuring lines) introduced to disk memory of PC III Portable PFX-12 computer as well as advanced analysis of these signals in order to create chosen AE descriptors. General view of DEMA COMP measuring system is presented in Fig. 1.

2.2.2 Measuring technique

Measurements made by means of DEMA COMP system consist in: installation of AE sensors at selected measuring points of an investigated object, energizing it by a chosen voltage and registration of AE impulses. This way all families of measuring results are obtained; each of family elements corresponds to another measuring situation. Preliminary handling data in domain of time, frequency and discrimination threshold enables to build an acoustic image of registered PD phenomenon. This image is built basing on phase and frequency characteristics as well as amplitude distributions of AE signals (Fig. 2).

2.2.3 Amplitude distributions of AE signals

Each of elements of analysed acoustic PD image can be a point of way out to a detailed analysis of AE signal properties. It has been demonstrated that amplitude distributions of AE signals, prepared to analyse their shape, can be the basis of a detailed analysis – first of AE signal and then of AE source properties. Advanced analysis relating a choice element of acoustic image, i.e. amplitude distribution, is made by means of two methods: definition of AE descriptors and application of neurone network of Kohonen.

AE descriptors

Two descriptors, resultant from properties of amplitude distributions of AE impulses, have been proposed [3, 6, 7]. These descriptors are signified by acronyms ACD and ADP. They are defined in such a way so that computation of the slope of curves describing amplitude distribution of AE counts (ACD) and power of AE signals (ADP) is possible. The lower descriptor value (more levelled fragment of a curve) signifies more advanced deformation process described by means of the AE method.

Neurone network of Kohonen

Amplitude distributions of AE impulses are images for a considered neurone network, built in domain of discrimination threshold. Work task of neurone network of Kohonen is to divide input objects into classes and then – to construct pattern winner neurones. In such a way an instrument useful to test other measurement results has obtained. The network has determined patterns neurones every time, allowed for connections between considered descriptors (ADC and ADP).

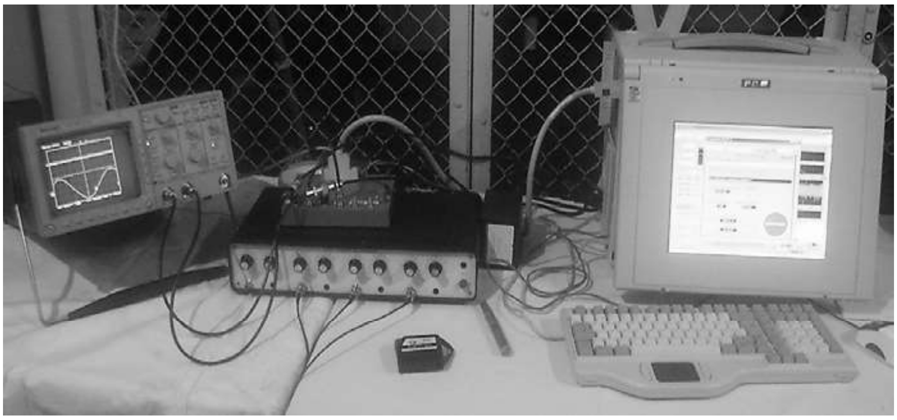

Fig. 1 General view of DEMA COMP measuring system

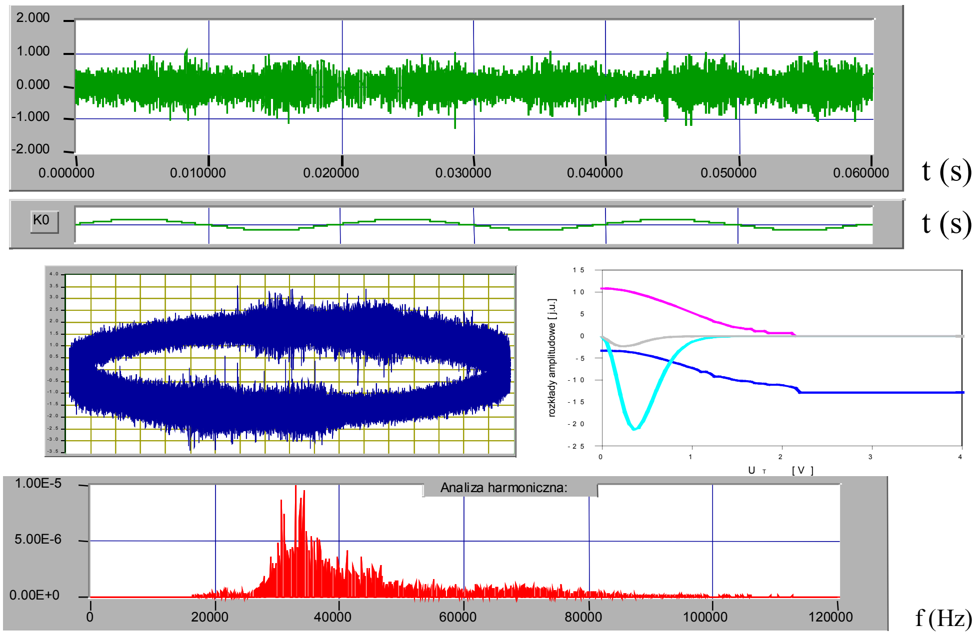

Fig. 2 An acoustic image of registered PD (exemplary measuring situation)

3. EVALUATION OF PDs

PD measurements have been also carried out by means of an electric method using the digital PD analysing system TE 571, offered by the firm Haefely Trench. This PD detector is applied to evaluate intensity PDs in high voltage insulation in accordance with actual IEC recommendations. The TE 571 system is built according to conception worked out at Technical University in Delft [1, 2]. It enables to measure and register 23 different quantities connected with PDs in registration time interval from 2 minute to 100 hours.

There is a large set of various diagrams (distributions), numerical data and protocols. According to [1] and [4], measured parameters can be divided into 3 groups:

1) parameters measured in positive and negative half of sinusoidal test voltage,
2) parameters represented statistical distributions,
3) parameters connected with statistical distributions of measured quantity versus phase angle and polarity of the test voltage.

Each of mentioned quantities transfers only a part of qualitative and quantitative information about PDs. However, simultaneous analysis of these parameters is a basis for determination of selected statistical parameters and creation of “a profile” of 29 characteristic operators describing PDs within an investigated object. Basing on specific processing program TEAS, such profile is compared with well-known PD profiles from computer database. That enables us to diagnose the analysed object at once after measurements and answer two important questions:

1) Configuration of the measuring system is correct?
2) Are there PDs of given kind and intensity within the tested object?

4. MEASURING EXEMPLARY RESULTS

The above conception of measurements has been applied practically in the firm ENERGOSERWIS (Lubliniec, Poland) during the test of stator windings of TWW-200-2 200 MW 15.7 kV (Fig. 3).

Selected measuring results for one of bars coming from the AE method is presented in Figs. 4, 5 and in Tables 1, 2 whereas from the electric method in Fig. 6. Statement of analysis results is presented in Table 3.

Table 1 contains specification of analysed measuring situations made in respect of ADC descriptor values. Inferior in rank position in the table occupied by a given measuring situation means that deformation process evaluated by means of the AE method is more advanced. On the background of measured apparent electric charge, the AE method locates – as more advanced – deformation processes connected with measuring situations: P5-3, P5-4 and P3-4. Classification of input object (measuring situations) into classes, made by the Kohonen network, is presented in Table 2. After arrangement of input objects in respect of apparent electric charge values, this classification locates – as more advanced – the deformation processes connected with measuring situations: P5-3, P5-4, P3-4 and P5-5.

Both methods applied for analysis of amplitude distributions are complementary. This means that AE signals reach sensors from large areas and create a global image of phenomenon. Elastic AE waves in such acoustic image are reiterated with weights proportional to the path between a source and AE sensor. Such summation causes that local effects prevail against a background of averaging values coming from a large area. That enables to locate “intensive” PD sources near measuring point P5 (for every supply voltage values) and near point P3 (for the supply voltage of 14.8 kV). Measurements worked out by means of the electric method have enabled to collect large quantities of data and then their statistical handling. That is why presentation of measuring results is practically impossible. Examples of statistical analysis results for selected measuring situations are presented in Fig. 6.

The results coming from the electric and AE method (Table 3) are compatible. It is important that intensive PD source has been located by means of the AE method at a right side of the bar (the measuring point P5) for different levels of the supply voltage. The same result has been obtained owing to the electric method (after statistical handling data). Intensive PD source exists outside of insulation – at points of junction of two electrodes (connection of supply cable to the bar of generator). Other PD source has been registered in the middle of the bar under 14.8 kV at measuring point P3 located by means of the AE method. This source was caused by defect of insulation (air inclusion).

5. RECAPITULATION

♦ The new conception of large evaluation of PDs can be used to diagnose some high voltage insulating systems. Location of PD sources (especially by means of the AE method) is unmistakable advantage such approach to evaluation of PDs.

♦ Connection of measuring capacities of the acoustic and electric method together with professional TEAS program (which determines character of discharges) enhances considerable quality of information about PD sources and reduces the risk of misinterpretation of results coming only from one measuring method.

♦ The presented conception can be applied both by manufacturers and constructors of insulating systems as well as in order to cyclic operating tests of high voltage equipment.

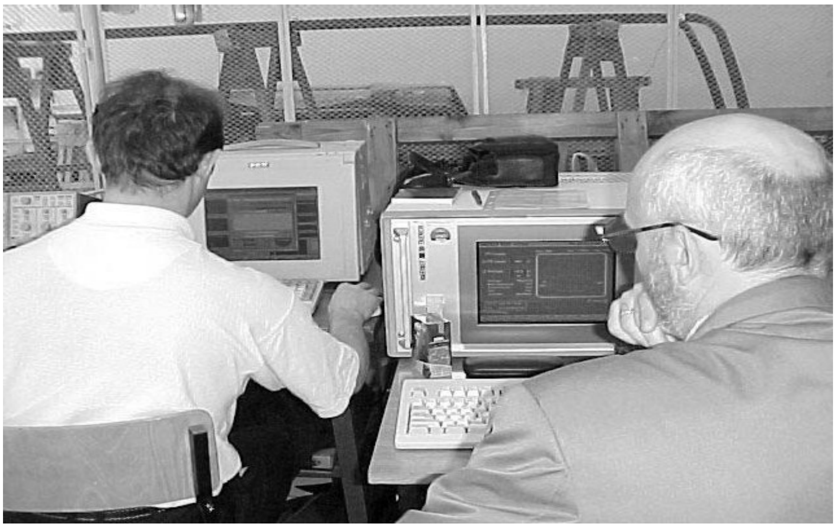

Fig. 3 A measuring stand in the firm ENERGOSERWIS (Lubliniec)

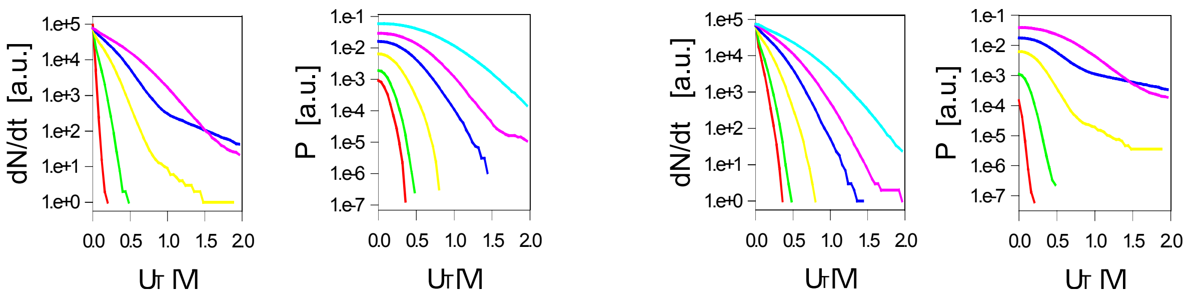

Fig. 4 Calculated amplitude distribution families of AE impulses registered at measuring points P3 (a, b) and P5 (c, d)

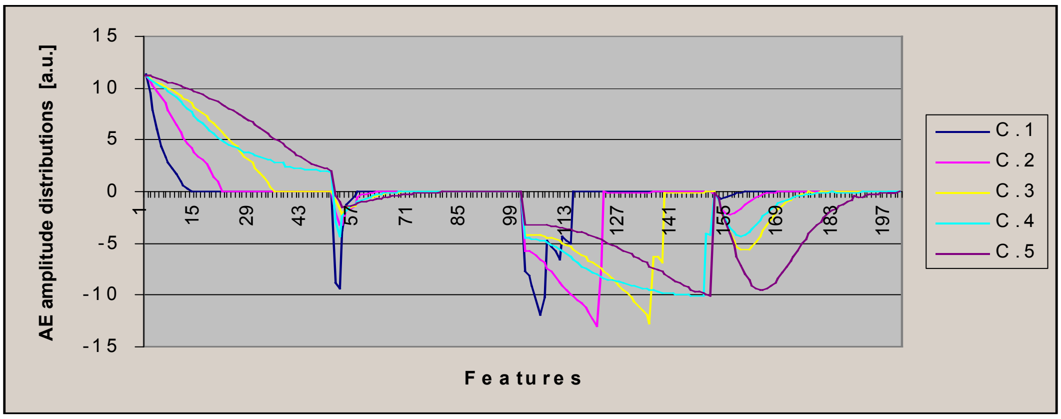

Fig. 5 Form of winner neurones for Kohonen network.
C.1 – class 1, C.2 – class 2, C.3 – class 3, C.4 – class 4, C.5 – class 5

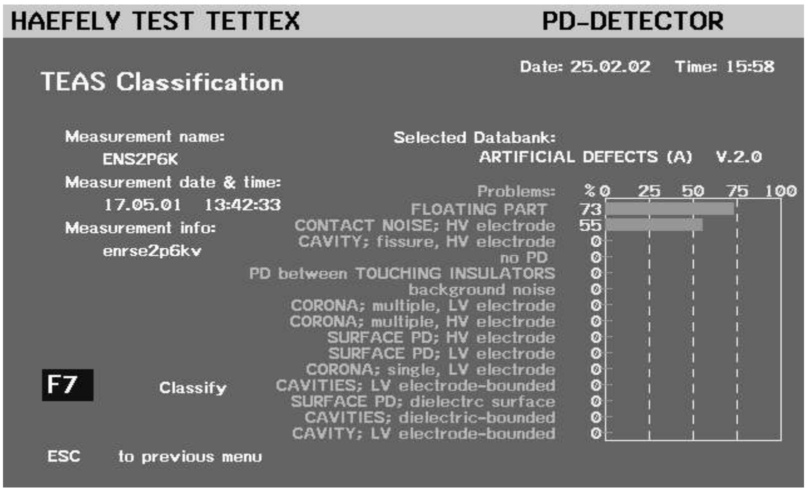

Fig. 6 An exemplary result of statistical analysis regarding PDs registered during the test of one generator bar in the firm ELEKTROSERWIS (Lubliniec)

Tab. 1 Classification of analysed measuring situations in respect of ADC descriptor values

No	Name	q (nC)	ADC
1	**P5-3***	**8**	**-1.68**
2	P4-1	11	**-1.74**
3	P3-1	11	**-1.86**
4	P5-2	10	**-2.01**
5	**P5-4***	**4**	**-2.66**
6	P3-2	10	**-2.81**
7	P4-1	10	**-2.89**
8	P3-3	8	**-3.62**
9	P4-3	7.5	**-3.66**
10	**P3-4***	**3.8**	**-5.81**
11	P4-4	6	**-6.32**
12	P3-5	1.5	**-10.07**
13	P5-5	1	**-10.68**
14	P3-6	0.13	**-12.8**
15	P5-6	0.05	**-23.79**
16	P4-5	1.4	**-26.65**
17	P4-6	0.05	**-33.28**

Tab. 2 Division of input object made by the Kohonen network

Name	U (kV)	q (nC)	C.1	C.2	C.3	**C.4**	C.5
P3-1	30	11	1	0	0	**0**	0
P4-1	30	11	1	0	0	**0**	0
P3-2	24.5	10	1	0	0	**0**	0
P4-1	24.5	10	1	0	0	**0**	0
P5-2	24.5	10	1	0	0	**0**	0
P3-3	19.7	8	0	1	0	**0**	0
P5-3*	**19.7**	**8**	**1**	0	0	**0**	0
P4-3	19.7	7.5	0	1	0	**0**	0
P4-4	14.5	6	0	0	1	**0**	0
P5-4*	**14.5**	**4**	0	0	0	**1**	0
P3-4*	**14.8**	**3.8**	0	0	**1**	**0**	0
P3-5	10	1.5	0	0	0	**0**	1
P4-5	10	1.4	0	0	0	**0**	1
P5-5*	**9.7**	**1**	0	0	0	**1**	0
P5-6	6.8	0.5	0	0	0	**0**	1
P3-6	8.1	0.13	0	0	0	**0**	1
P4-6	8.6	0.05	0	0	0	**0**	1

Tab. 3 Statement results of PD measurements made by the acoustic and the electric method

Measuring method	U (kV)	q (nC)	ADC	The results of analysis
Acoustic	9,7		-10.68	P5-5 (the right end of the bar)
Electric		1		contact noise HV electrode 63 %
Acoustic	14,5		-2,66	P5-4 (the right end of the bar)
Electric		4		contact noise HV electrode 15 %
Acoustic	14,8		-5,81	P3-4 (the middle of bar)
Electric		3,8		Cavites: LV electr. bounded 1%; dielectric bounded 1%
Acoustic	19,7		-1,68	P5-3 (the right end of the bar)
Electric		8		contact noise HV electrode 82 %
Acoustic	24,5		-2,01	P5-2 (the right end of the bar)
Electric		10		contact noise HV electrode 14 %

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BIOGRAPHIES

Zbigniew Gacek, born 13.06.1942. Received the M.Sc., PH.D and D.Sc. (Dr habilitated) degrees in electrical engineering in 1965, 1972 and 1981 respectively from the Silesian University of Technology in Gliwice (Poland). Professor degree holds from 1996. Scientific specialty – electrical power engineering. Main research interests – high voltage techniques (especially high voltage insulating system). Author or co-author of three books, four monographs, and above hundred fifty scientific articles and papers. Member of several learned societies (CIGRE, Electric Power Engineering Commission of Polish Academy of Sciences).Vice-Director for Science of Institute of Power System and Control, head of High Voltage Engineering Section in the above Institute supervision of Doctor's Studies in Electrical Department of the Silesian University of Technology.

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