ARCHIVES OF ACOUSTICS
27, 1, 65–77 (2002)

A NEW ACOUSTIC EMISSION DESCRIPTOR FOR MODELLED SOURCES OF PARTIAL DISCHARGES

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Partial discharges (PD) generated by differently modelled PD sources have been studied by the acoustic emission (AE) method. The results obtained were compared with the measured apparent electric charge values. Acoustic images of the PD phenomena were created by recorded waveforms, phase diagrams, frequency characteristics and calculated amplitude distribution diagrams. Basing on the amplitude distributions, a new AE descriptor — the **ADP descriptor** (**A**mplitude **D**istribution of **P**ower of AE signal descriptor) was evaluated. The ADP descriptor distinguishes the physical processes connected with the PD. For the described measuring situations, the calculated values of the ADP descriptor show a good correlation of the ADP descriptor values with the value of the apparent electric charge.

1. Introduction

One of the fundamental problems in the exploitation of high-voltage systems is their diagnostics [6], particularly, the investigation of partial discharges (PD) [2, 3, 5]. Electric methods are most intensively developed, though a large set of non-electric methods is dealt with, too, among them the method of acoustic emission (AE) [5, 7].

The methods of acoustic emission gain more and more importance in the diagnostics of the state of materials and technical systems as well as in the control of processes [4]. Also in the diagnostics of insulation systems the method of acoustic emission may become an important method of measurements. It is expected to make it possible to localize partial discharges in the case of electromagnetic interferences, and when the transition function is known, this method distinguishes and determines the sources of partial discharges.

2. AE measuring system

The block diagram of the measuring system is shown in Fig. 1. The set of DEMA instruments is applied exclusively for conditioning the AE signals and to transmit them to the four measuring lines. Each of these lines is composed of a differential pre-amplifier, a band filter and a line amplifier. The measuring card and the portable computer provide information record on a disc of twelve bit data with 5 mega-samples per second. Dataengine V.I. for Windows 95/98 NT under Labview 4.0 was the basic software for programming the measuring card (programs for monitoring the processes and recording the data) as well as for specific programmes used to data handling.

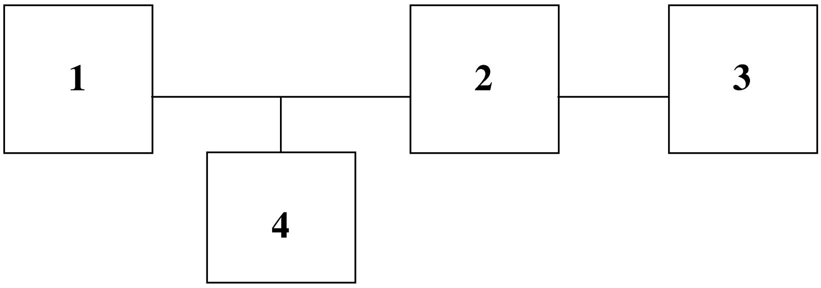

Fig. 1. Block scheme of the AE measuring system called COMP-DEMA: 1 — set of DEMA instruments, 2 — CB6-TP measuring terminal and PCI-610E measuring card, 3 — PCIII portable PFX-12, 4 — oscilloscope.

The measuring system designed and built in this way enables the registration of signals within real time and in the frequency band up to 2.5 [MHz] (both in the laboratory and in site conditions) as well as a subsequent use of the measuring data in order to make any AE descriptors.

3. Research method and measuring stand

Investigations have been made in order to registrate and analyse the AE signals coming from modelled PD sources as well as for a comparison of the results obtained on the basis of the AE and by the electric method. PD sources have been modelled using different ends of the bushings:

A — the bottom end of the insulator placed in oil,

B — the bottom end of the insulator placed inside of a spherical electrode,

C — the bottom end of the insulator placed inside of a spherical electrode with a spike.

For each end of the bushing and selected values of the supplied voltage the AE signal and the apparent electric charge were measured simultaneously. The investigations were carried out in a High Voltage Laboratory of the IZO-ERG factory in Gliwice using the measuring stand shown in Fig. 2. The apparent electric charge was measured by means of the ERA instrument made by the F.C. Robinson firm.

The investigations conducted by the AE method have been planned as follows:

The use of measuring lines: K0 line — monitoring of a reference voltage, K1 line — piezoelectric sensor with resonance frequency of 100 kHz, preamplifier, DEMA, K2 line — R6 type AE sensor, preamplifier, DEMA, K3 line — WD type AE sensor, preamplifier,

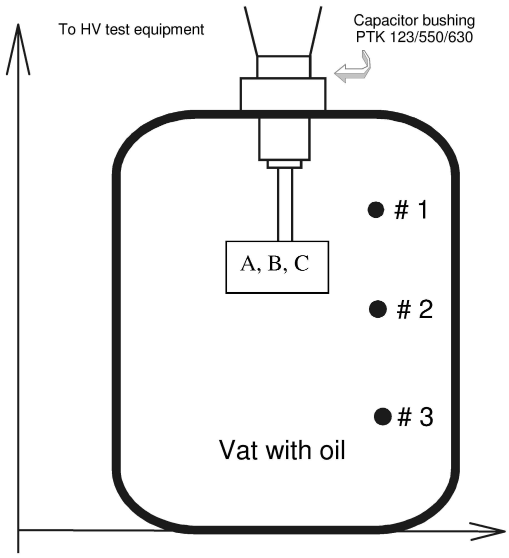

Fig. 2. Set of elements for the testing of partial discharges: — vat with oil, — bushing with different endings A, B, C — acoustic emission measuring system AE COMP-DEMA, — HV test equipement (supply voltage, ERA system).

DEMA. The R6 and WD type AE sensors (Physical Acoustic Corporation) give together any observation band of the signal within about 20 kHz – 1 MHz.

The AE sensors have been placed side by side at selected measuring points. A voltage of selected value has energized the bushing. One-seconds fragments of the output time functions have been registered four times within every measuring line.

4. Results and their processing

PD investigation results carried out by the AE method registrated with the K2 line when a R6 type AE sensor was placed at the measuring point #2 have been applied in this paper. A full description of the measuring situation is determined by the following set of parameters:

a) the kind of the bushing end,

b) value of the voltage applied to the bushing,

c) measured apparent electric charge,

d) amplification of the DEMA line amplifier.

Examples of AE impulses recorded in different measuring situations are presented in Figs. 3 – 6. The impulses in Fig. 6 are a part of these shown in Fig. 5. Basing on Figs. 3 – 4 a, b, c the simultaneously periodic and random character of such phenomena is visible. The AE impulses are registered twice for a reference voltage period. In case A, when the bottom end of the insulator is placed in oil, there is no symmetry in both the groups of signals generated within one period. In case C, when the bottom end of the

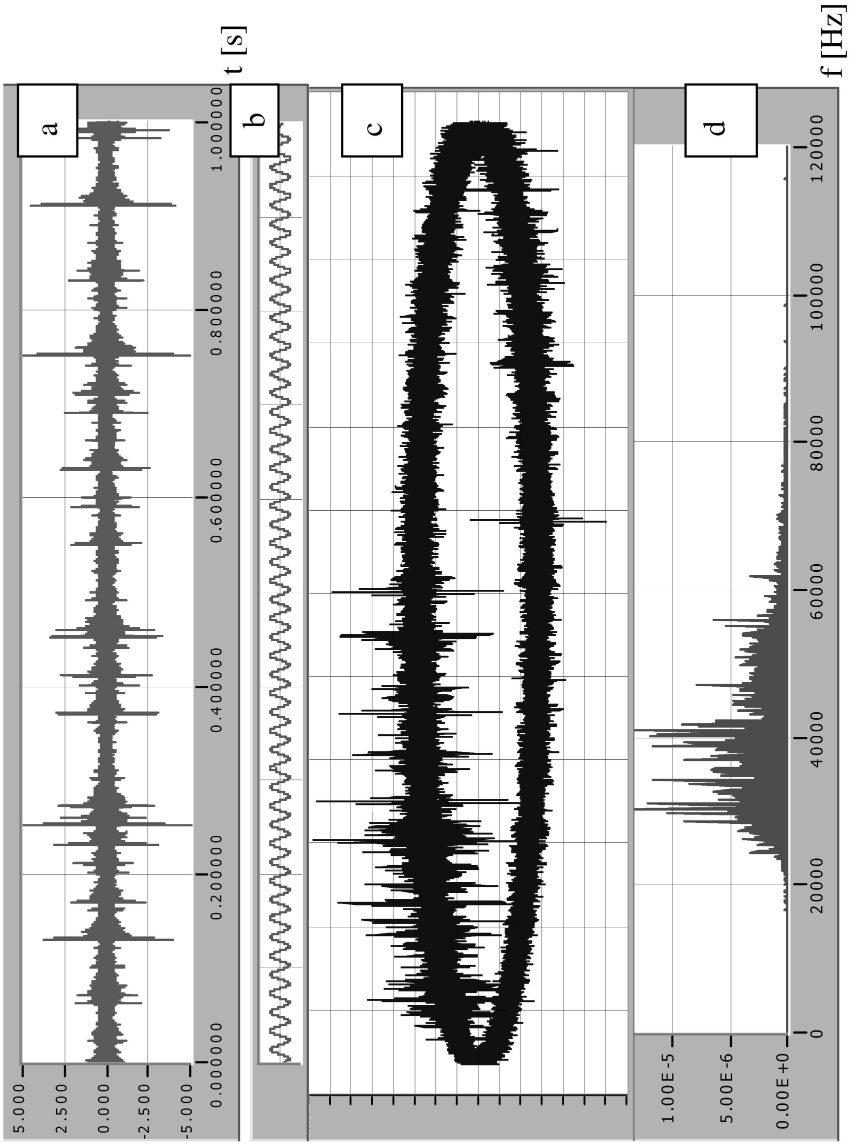

Fig. 3. AE impulses recorded in the following measuring situations: PD source modeled with A, $U = 123\,\mathrm{kV}$; $q \gg 1600\,\mathrm{pC}$, 30 dB, a) waveform of the AE signal, b) reference voltage, c) phase diagram, d) frequency characteristic. Values of all the functions are in arbitrary units.

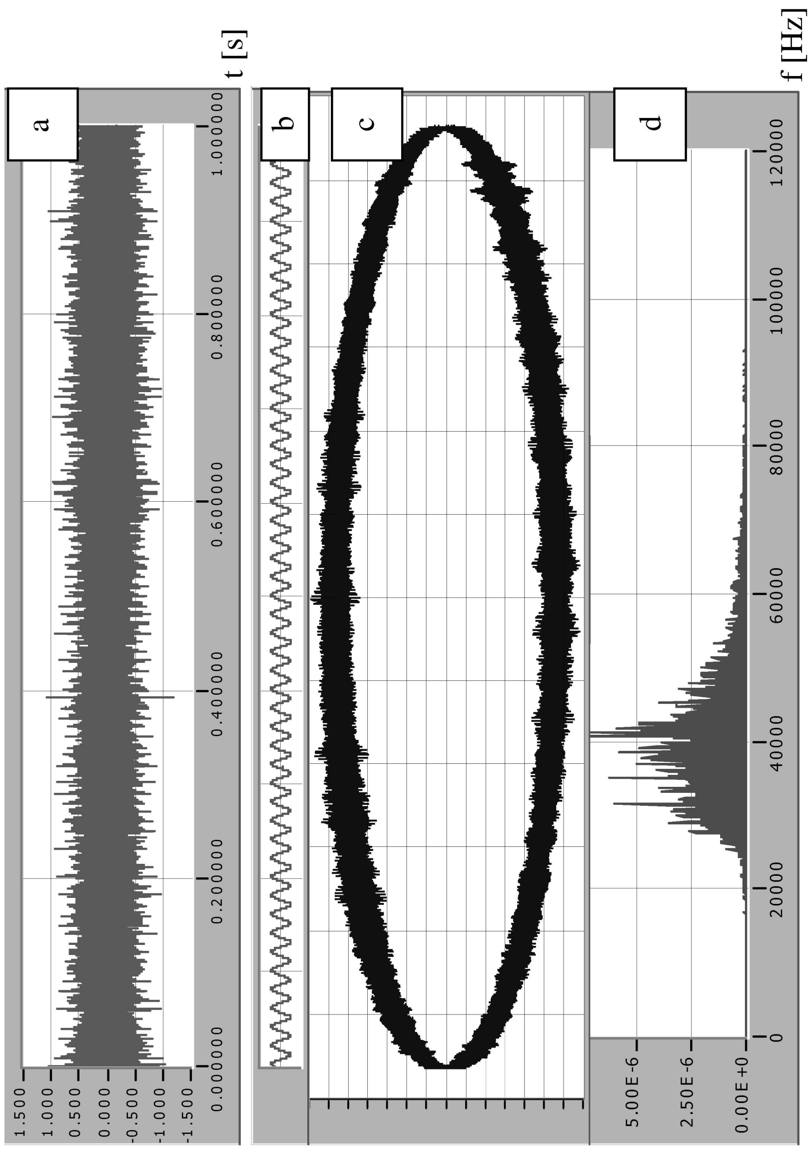

Fig. 4. AE impulses recorded in the following measuring situations: PD source modeled with B, $U = 123\,\mathrm{kV}$, $q > 1600\,\mathrm{pC}$, 40 dB, a) waveform of the AE signal, b) reference voltage, c) phase diagram, d) frequency characteristic. Values of all the functions are in arbitrary units.

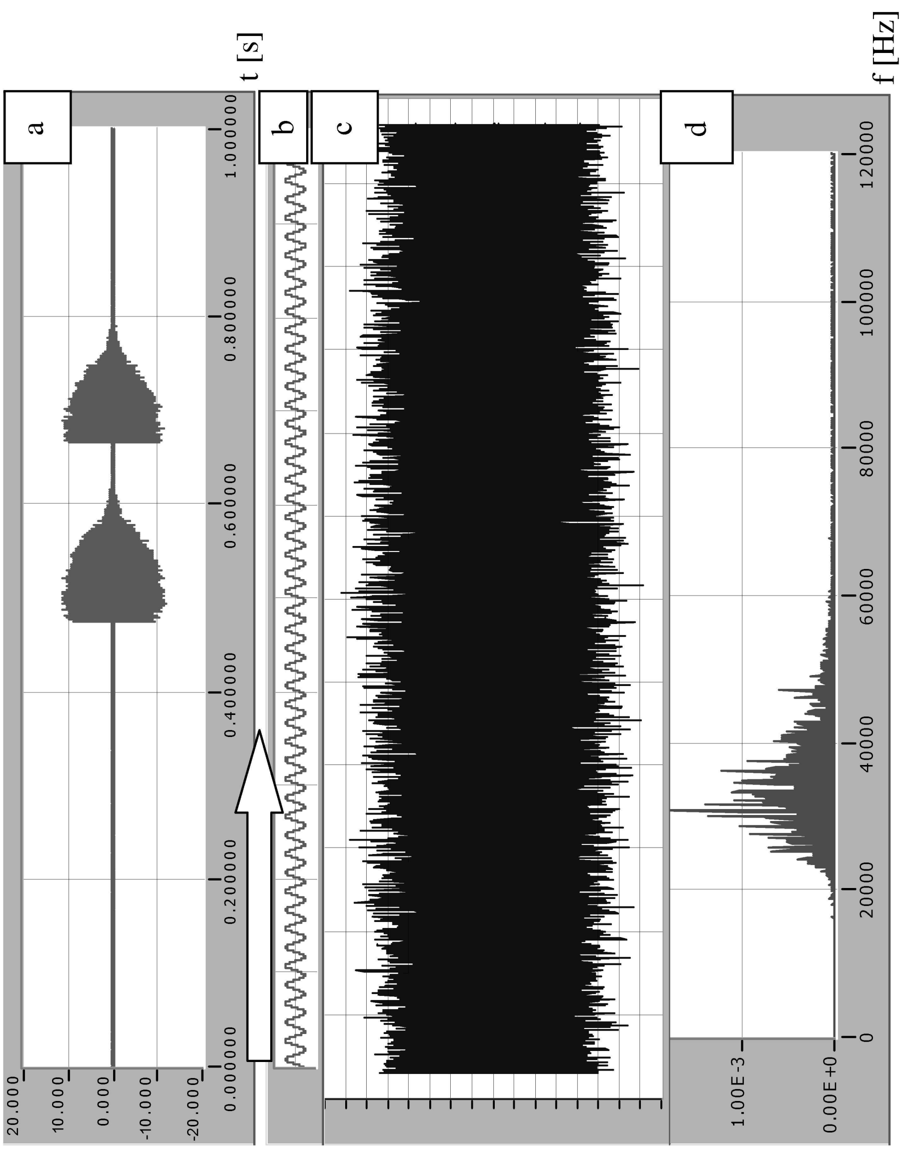

Fig. 5. AE impulses recorded in the following measuring situations: PD source modeled with C, $U = 95\,\mathrm{kV}$, $q \gg 1600\,\mathrm{pC}$, 30 dB, a) waveform of the AE signal, b) reference voltage, c) phase diagram, d) frequency characteristic. Values of all the functions are in arbitrary units.

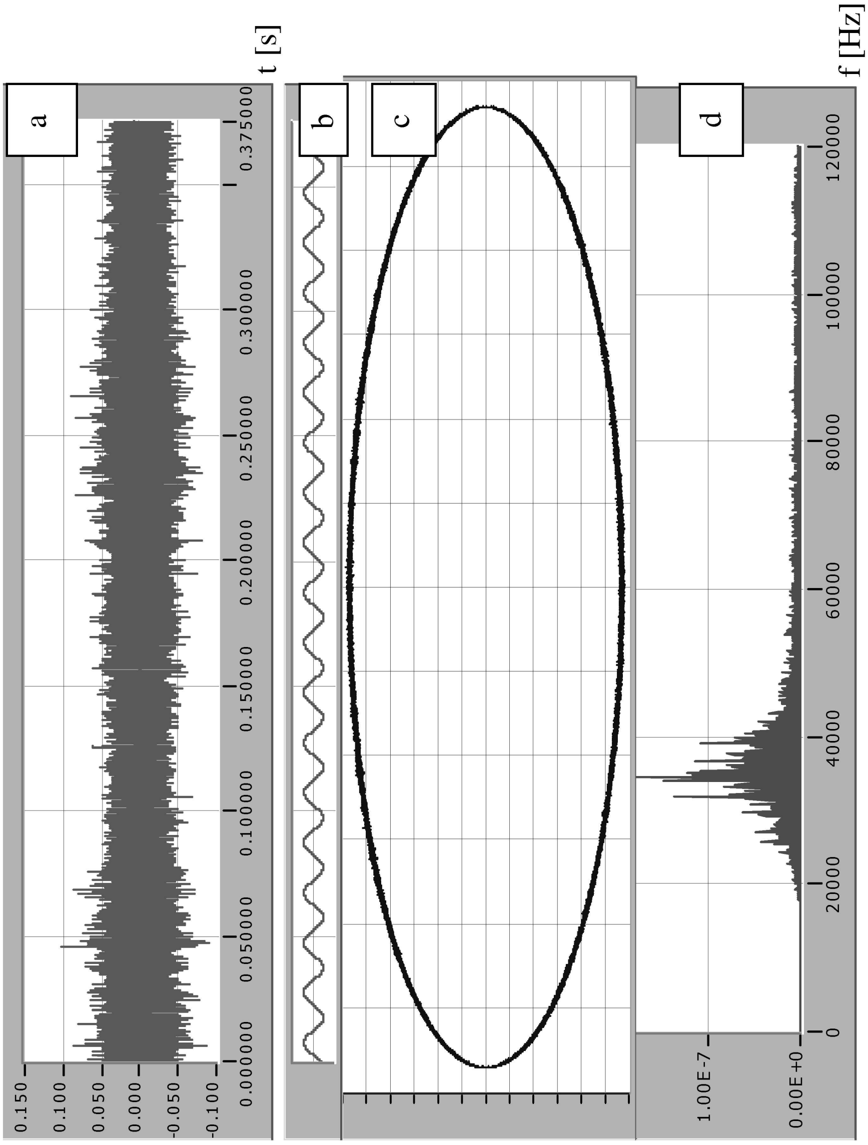

Fig. 6. The beginning part of the AE impulses from Fig. 5 (marked on Fig. 5 ⇒) with its characteristics.

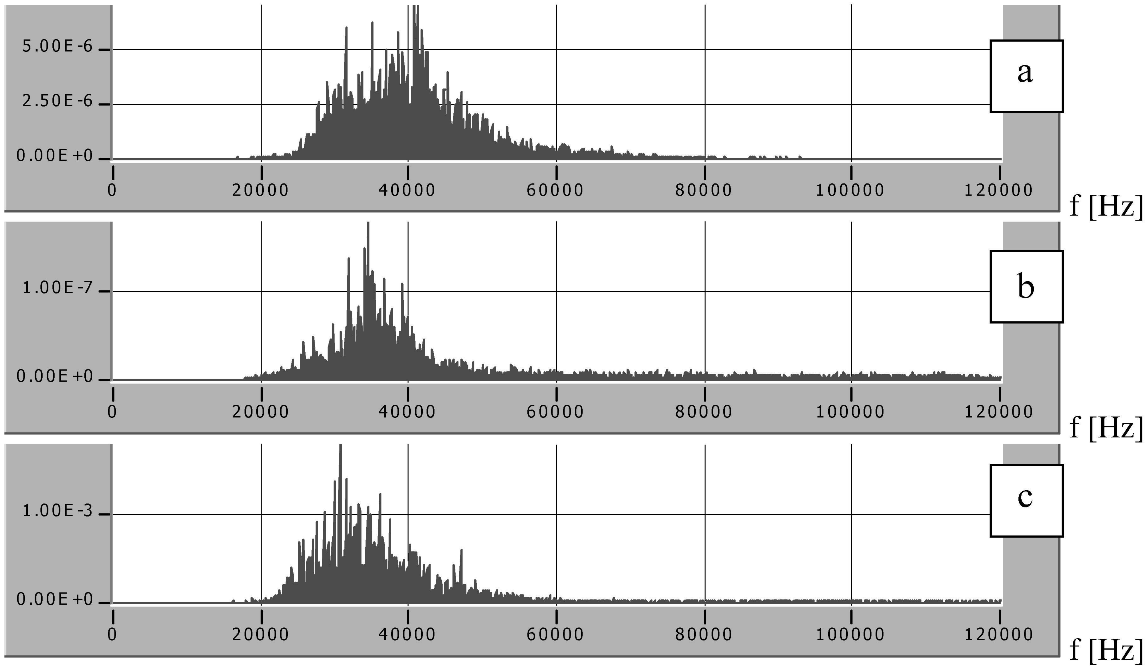

Fig. 7. The comparison of frequency characteristics for different kind of deformation processes; a) PD source modeled with B, $U = 123\,\mathrm{kV}$, $q > 1600\,\mathrm{pC}$, 40 dB, b) PD source modeled with A, $U = 123\,\mathrm{kV}$, $q \gg 1600\,\mathrm{pC}$, 30 dB, c) PD source modeled with C, $U = 95\,\mathrm{kV}$, $q \gg 1600\,\mathrm{pC}$, 30 dB. Values of all function are in arbitrary units.

insulator is placed inside of the spherical electrode with a spike, the random generated PD sources within oil dominate giving the recorded AE impulses with a duration about one millisecond. However, after neglecting this kind of waveforms, the AE signal still possesses simultaneously periodic and random character (Fig. 6 a – c).

The investigated measuring situations shown in Figs. 3 – 5 are different according to the stage of advancing of the deformation process. The frequency characteristics of the processes are presented in Fig. 7 (the advancing of the stage increases from a to c). It is likely that, the rise time of the AE source function distinguishes the stage of advancing of the deformation process [8, 9]. We shall deal with the problem in the nearest future.

The measuring data have been processed using the program prepared for the preliminary data handling in order to calculate the amplitude distributions for the following

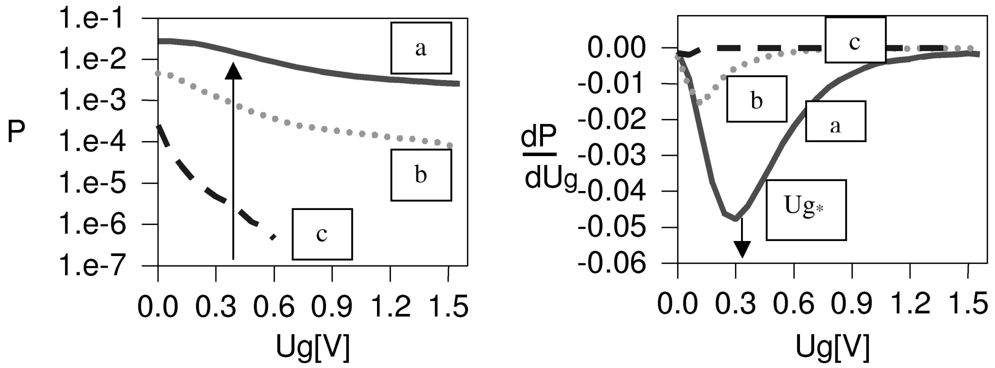

Fig. 8. The amplitude distributions of power of the AE signal P and the first derivative of the amplitude distributions of power of the AE signal dP/dU_g versus the discrimination threshold level U_g in the following measuring situations: a) PD source modeled with A, $U = 123\,\text{kV}$; $q \gg 1600\,\text{pC}$, 30 dB, b) PD source modeled with A, $U = 106\,\text{kV}$; $q \gg 1600\,\text{pC}$, 30 dB, c) PD source modeled with A, $U = 74\,\text{kV}$; $q \gg 1600\,\text{pC}$, 30 dB.

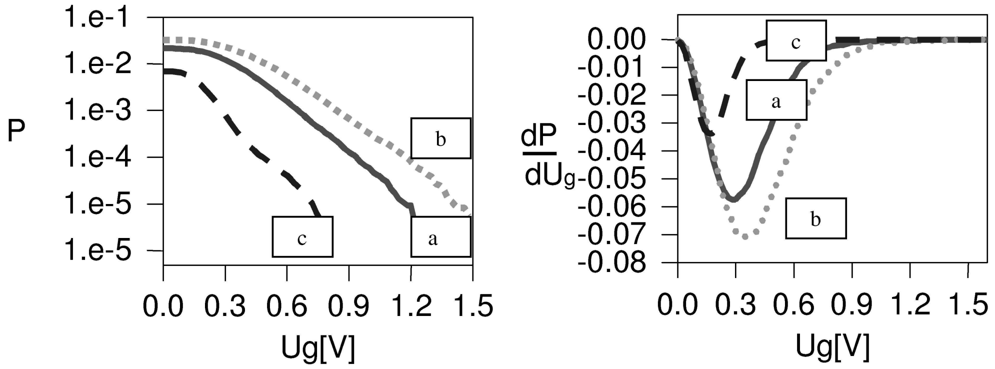

Fig. 9. The amplitude distributions of power of the AE signal P and the first derivative of the amplitude distributions of power of the AE signal dP/dU_g versus the discrimination threshold level U_g in the following measuring situations: a) PD source modeled with B, $U = 123\,\text{kV}$, $q \gg 1600\,\text{pC}$, 40 dB, b) PD source modeled with B, $U = 106\,\text{kV}$, $q = 560\,\text{pC}$, 50 dB, c) PD source modeled with B, $U = 90\,\text{kV}$, $q = 36\,\text{pC}$, 50 dB.

quantities: P — power of the AE signal, dP/dU_g — first derivative of the power of the AE signal versus the discrimination threshold value.

The results after processing are presented in Figs. 8–10. Each of the curves is calculated from the recorded data during four seconds, i.e. it describes the AE phenomena generated by the modelled PD source during about 200 periods of the supply voltage.

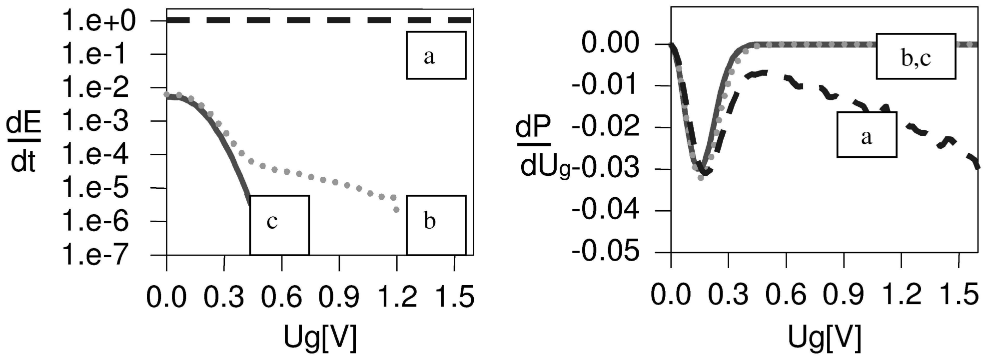

Fig. 10. The amplitude distributions of power of AE signal dE/dt and the first derivative of the amplitude distributions of power of AE signal dP/dU_g versus the discrimination threshold level U_g in the following measuring situations: a) PD source modeled with C, $U = 90$ kV, $q > 1600$ pC, 50 dB, b) PD source modeled with C, $U = 85$ kV, $q = 200$ pC, 50 dB, c) PD source modeled with C, $U = 74$ kV, $q =$ a few pC, 50 dB.

5. Analysis of the results

In order to apply the investigations, any AE descriptor should be found. Searching of such a descriptor, the following assumptions have been made: a) the descriptor can not be based directly on the measuring quantities (amplitudes, AE signal energies etc.), b) the descriptor should take into account the physical features related to the propagation of the AE signals. The first assumption results from the AE measuring technique (the AE signal generated by a source is changed during the propagation, registration and analysis). The second assumption should facilitate finding of any quantity dependences. According to these principles, such descriptors cannot be: the amplitude, RMS signal, and rate of AE counts. To this end some features of the amplitude distribution characteristics may be applied.

The amplitude distributions of the AE signal power (Figs. 8–10) are given in the logarithmic scale in order to distinguish better the physical processes connected with the PD. The linear fragments of the curves describe a single deformational process. For example, let the bottom end of the insulator to be placed inside the spherical electrode with a spike. There are AE sources of PD as in the case when the bottom end of the insulator is placed inside a spherical electrode with an additional "spike-source" activated when the supplying voltage reachs a level high enough. Let us consider the amplitude distribution of the power of the AE signal dE/dt from Fig. 10. Curve c describes the situation that occurs when PD sources are modeled in the way that the bottom end of the insulator is placed inside of the spherical electrode. Curve a represents the situation when the "spike-source" PD dominates. Curve b represents the situation that both types of PD sources occur. The first derivative of the power of the AE signal versus the discrimination threshold value shows the ranges of the discrimination threshold values connected with different physical processes.

Here, we propose as the AE descriptor the slope of the straight lines approximating the amplitude distributions of the power of the AE signal. The descriptor values result from the linear approximation of the curves of the amplitude distributions of the AE signal power (Figs. 8 – 10) within the discrimination threshold range higher than U_{g^*}. The U_{g^*} is defined as the value of the discrimination threshold for which the first derivative of the amplitude distributions of the power of the AE signal reachs its minimum. In Fig. 8 the value U_{g^*} for the curve a is additionally marked. We propose the name of the descriptor as: **ADP descriptor** (**A**mplitude **D**istribution of **P**ower of the AE signal). The values of the ADP descriptor are presented in Table 1.

Table 1.

Modeled PD source	U [kV]	Q [pC]	dB	ADP descriptor
C	74	a few	50	−15.4013
B	90	36	50	−03.2358
C	85	200	50	−01.7472∗
B	106	560	50	−02.6759
C	90	>1600	50	−00.0093
A	50	>1600	30	−31.1544
A	74	>1600	30	−04.8333
A	106	>1600	30	−00.9066
A	123	>1600	30	−00.6090

A — the bottom end of the insulator placed in oil,
B — the bottom end of the insulator placed inside the spherical electrode,
C — the bottom end of the insulator placed inside the spherical electrode with the spike,
ADP descriptor — **A**mplitude **D**istribution of **P**ower of the AE signal descriptor.

For the modeled source of type A, B and C the value of ADP increases with the increasing apparent charge value, except the modeled source type C with 85 [kV], 200 [pC], 30 [dB]. This exception is reasonable because the value of the apparent charge defines the medium PD source (no the maximum one), while the value of the ADP descriptor, because of the high energy "spike-source" of PD, describes the "spike-source" properties.

It should be stressed that the ADP descriptor in Table 1 distinguishes the properties of the AE impulses registered for several mountings of the AE sensor for differently modeled PD sources. The good correlation achieved between the values of the ADP descriptor and the value of the apparent electric charge is not a general one; the correlation is valid only for the measuring situation described.

It should also be stressed that any AE descriptor is connected with the properties of the AE signal. In these investigations we deal with the correlation between the apparent charge value and the AE signal. We hope to find good a correlation between the apparent charge value and the AE source of the PD properties. So the merit of the matter is the distinguishing of the properties of the AE source from the registered AE signal. The values of the ADP descriptor presented in Table 1 are a first approximation of that because the positions of the modeled PD sources and measuring point are fixed.

In the next paper we are going to deal with changes in the AE impulses caused by the propagation of the AE signal in oil (fixed position of modelled PD source, different positions of the measuring point).

6. Conclusions

Investigations of the partial discharge (PD) signals generated by different modelled PD sources based on the AE and resulting from the electric method have been carried out. PD sources have been modelled using different ends of the bushings:

A — the bottom end of the insulator placed in oil,

B — the bottom end of the insulator placed inside a spherical electrode,

C — the bottom end of the insulator placed inside a spherical electrode with a spike.

The acoustic images of the modeled PD were built basing on waveforms of the registered AE impulses, phase diagrams, frequency characteristics and amplitude distribution diagrams (the amplitude distributions of the power of the AE signal and the first derivative of the amplitude distributions of the power of the AE signal versus the discrimation threshold level U_g). The time functions of the registered AE impulses distinguish the periodic and random characters of investigated PD phenomena. The amplitude distributions in presented form distinguish the physical processes connected with the PD: the higher level of deformational process is characterized by a "flatter" distribution of the amplitude distribution of the power of AE signal (within a defined range of the discrimation threshold level).

The **ADP descriptor** — the **A**mplitude **D**istribution of **P**ower of the AE signal descriptor have been defined. It should be stressed that the calculated ADP descriptor distinguishes the properties of the AE impulses registered for several mountings of the AE sensor for different modeled PD sources. The calculated values of the ADP descriptor show good correlation between the values of ADP descriptor and those of the apparent electric charge. The correlation achieved is valid only for the measuring situation described (the positions of the modeled PD sources and the measuring point are fixed). That means that is the first approach of our investigations on the correlation between the apparent charge value and the AE signal.

Acknowledgements

The investigations reported in this paper were carried out within the frame of the research project 8 T10C 034 16 sponsored by the Committee of Scientific Research.

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