THE WAVELET ANALYSIS OF THE AE SIGNALS GENERATED BY SINGLE- AND MULTISOURCE PARTIAL DISCHARGES

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Abstract. The paper presents the results of the comparative analysis of the acoustic emission (AE) signals generated by single- and multisource partial discharges (PDs). The research tests were carried out in a model system, in which PDs were generated with spark-gaps. Two identical spark-gaps in the surface system were used due to the fact that this is the most often occurring PD form in power transformers. The AE signals were registered with a contact transducer placed on the external part of the tub. An analysis using continuous (CWT) and a discrete (DWT) wavelet transforms was carried out for the AE signals generated by both single- and multisource PDs. The CWT results are shown in the form of scaling graphs and the DWT results are shown in the form of time runs of the AE signals from PDs at seven decomposition levels and column diagrams visualizing the amount of energy transferred by the particular details. The comparison of the results obtained was carried out from the point of view of the form identification possibilities of the particular PD types. The aim of the research work carried out was also to confirm the usefulness of the AE method and the wavelet analysis for diagnosing the insulation condition of high-voltage power appliances in which multisource discharges occur.

1. Introduction

The introduction of a free electric power market in Poland caused the establishment of competing manufacture and distribution enterprises. With liberation of the energy market the requirements referring to the quality of the electric energy supplied and the reliability of its supply increased. The improvement of the electric power system reliability is connected, among others, with precise diagnostics of electric power transformers, which are one of the most sore points of electric power systems. The assessment of the insulation condition in respect of PD occurrence is an important element of a complex diagnostics of electric power transformers. Presently, diagnostic examinations of the transformer insulation condition are carried out by using a few non-destructive methods: the gas chromatography, electrical and AE methods [6, 7].

In recent years the development of the AE method was caused by introduction into the description of the AE signals generated by PDs a combined time-frequency analysis. Based on the frequency and time-frequency descriptions it is possible to detect PDs in single-source systems [1, 2, 3]. In electric power transformers being in use the occurrence of multi-source discharges is possible. Therefore it is necessary to carry out laboratory research tests on the possibilities of applying the AE method for detection of PDs in multi-source systems. The paper presents an excerpt from the research work on comparing the AE signals generated by single- and multi-source PDs.

2. Characteristics of the measuring system

Figure 1 presents a diagram of the measuring system for generation, registration and analysis of the AE signals generated by PDs.

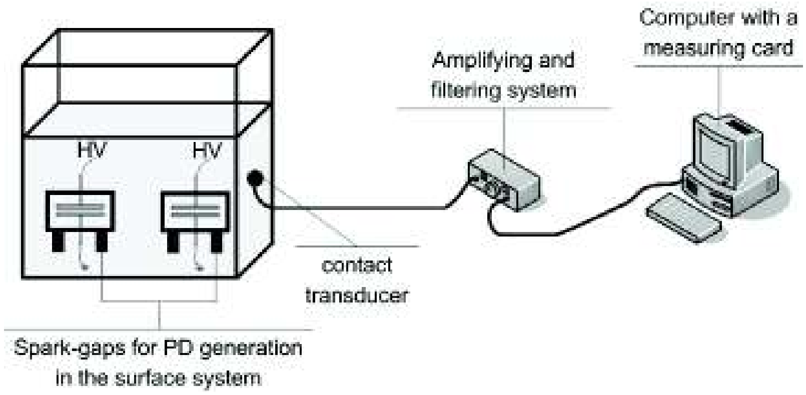


Fig. 1. Diagram of the measuring system

The measurement tub was filled with insulation oil and two indentical spark-gaps generating partial discharges in the sufarce system (SPDs) were immersed in it, due to the fact that it is the most often occuring PD form in real objects. The spark-gaps were supplied from two test transformers TP 10 with voltage 14.2 kV. The AE signals generated by PDs were registered with a contact transducer WD AH17 by the firm Physical Acoustics Corporation (PAC), placed on the external part of the tub. It is a transducer characteristic of high sensitivity (55 dB ± 1.5 dB in relation to V/ms^{-1}) and a wide transfer band from 100 kHz to 1 MHz in the range ± 10 dB. A piezoelectric transducer was connected with the amplifying and filtering system through a subamplifier. A band-pass filter of the cut-off frequencies of 10 and 700 kHz was used. The measurement signal was amplified by 35 dB. Time runs of the AE signals generated by PDs were registered with a four-channel measuring card CH 3160 by the Acquitec firm. Maximum sampling frequency of the card is 40 MHz at the resolution of 12 bits. During measurement taking a sampling frequency of 2.56 MHz was used ; 51 200 samples were registered, which enabled the signal registration in 20 ms [4].

The research tests were carried out in a measurement chamber, which is a specialized, silenced and electromagnetically screened place. The view of the measurement chamber, transducer, subamplifier and the amplifying and filtering system are shown in Fig. 2.

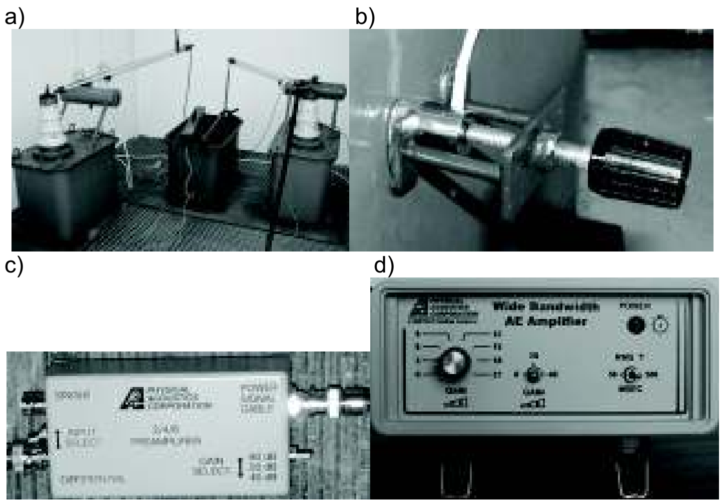


Fig. 2. View of the measuring system : a) measurement chamber, b) piezoelectric transducer, c) subamplifier, d) amplifying and filtering system.

3. Methodology of the research work carried out

In the first stage of the research work the registration of the AE signals from PDs, which were generated with the first spark-gap, was carried out. Next, this spark-gap was disconnected and the tests were carried out using the other spark-gap, at the same supply voltage. In the final stage of the measurements the registration of the AE signals from PDs generated with the two spark-gaps simultaneously was performed. The spark-gaps were supplied with identical sypply voltage.
The AE signals from PDs registered were subject to a wavelet analysis using CWT and DWT. The CWT results are shown in the form of scaling graphs, and the results of the DWT analysis are shown in the form of time runs on seven decomposition levels. The results obtained were supplemented by determining the amount of energy transferred by the particular details.

4. The analysis of the results obtained

A wavelet analysis is required for the description of the AE signals generated by PDs, which are characteristic of the low- and high-frequency component content. It makes the analysis of the AE signal from PDs using narrow observation windows at higher frequencies and adequately wide for low frequencies possible.

Fig. 3 shows CWT scaling graphs.

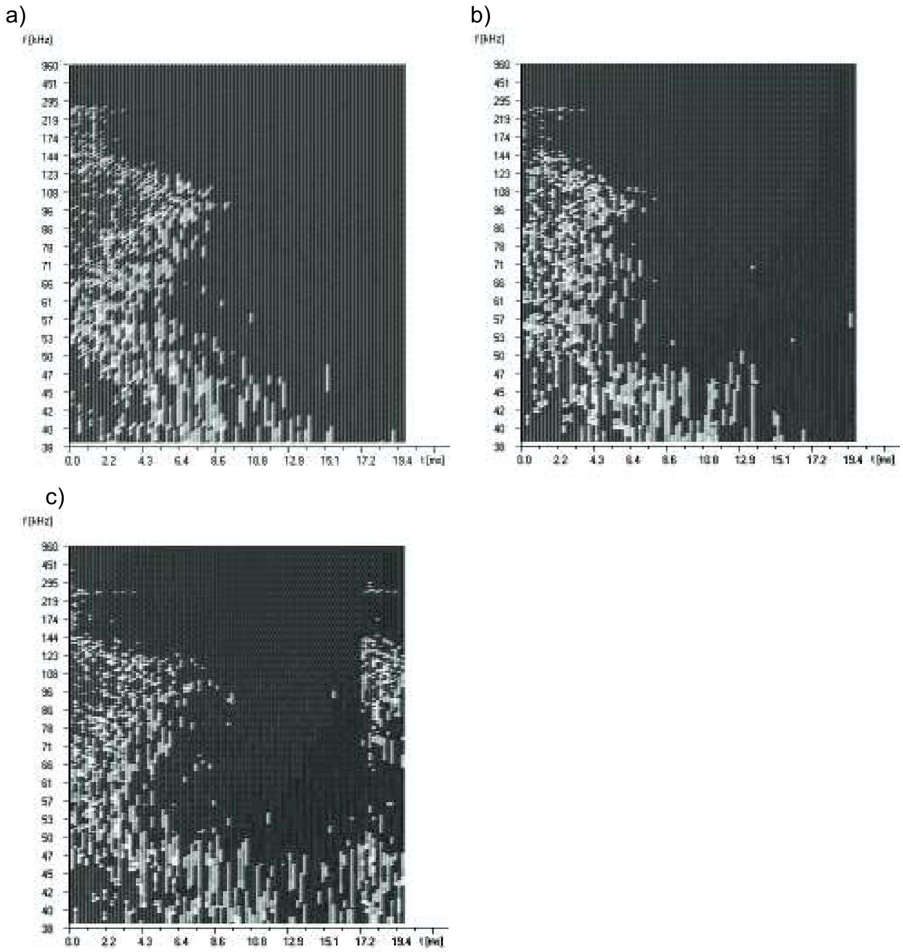


Fig. 3. CWT scaling graphs corresponding to the AE signals generated by PDs:
a) single-source (spark-gap 1), b) multi-source (spark-gap 2),
c) multi-source (spark-gap 1+2)

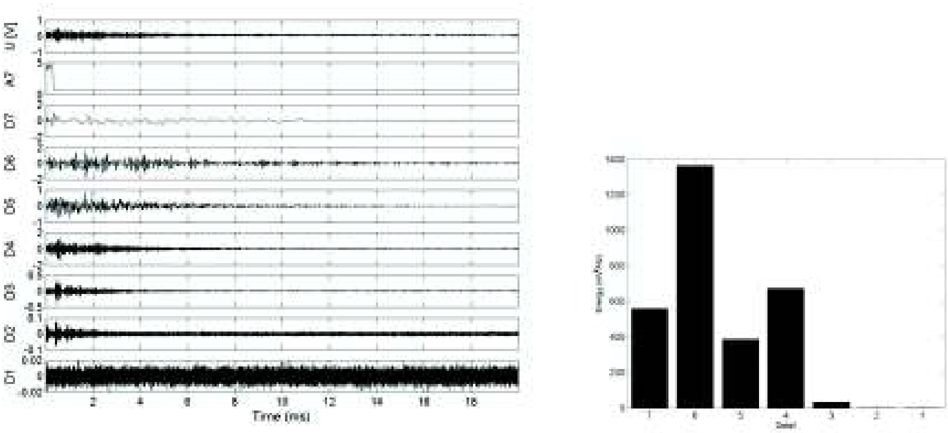
Time-frequency structures shown on CWT scaling graphs, describing the AE signals from PDs generated in single- and multi-source systems, are characteristic of a similar shape, amplitude and the range of dominant frequencies. The signals analyzed contain frequency components from the range from 20 to 300 kHz.. In this range of dominant frequencies, an area characteristic of a high amplitude value of the time-frequency structures determined can be determined. This area is contained within two frequency ranges (38 – 50) kHz and (71 – 150) kHz.

Analyzing the CWT scaling graphs determined it can be observed that in the case of single-source discharges there occurs only one time-frequency structure. Multi-source discharges are characteristic of a bigger intensity occurrence, which can be observed in Figs 3c and 4c. The occurrence of a bigger number of time-frequency structures does not influence, however, the range of dominant frequencies.

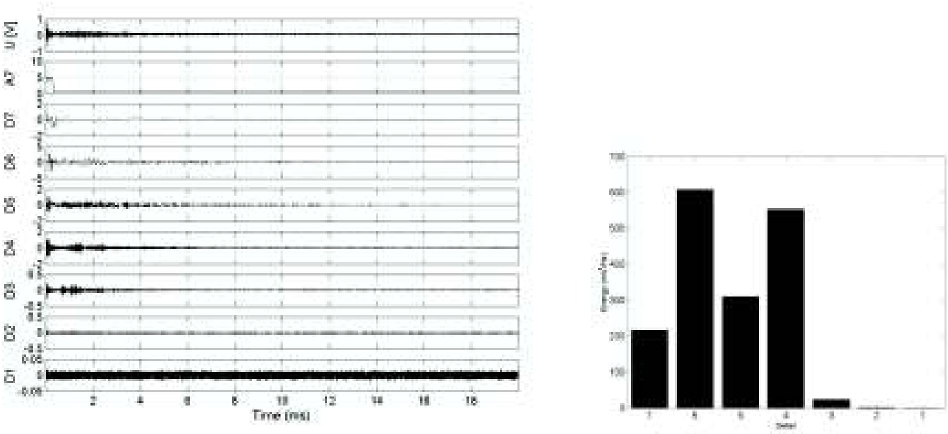
The time-frequency analysis using a CWT contains a large number of pieces of information, which is presented on scaling graphs. This cam limit the possibilities of CWT application as a parameter which can be used for building an expert system diagnosing insulation condition in electric power appliances. A much more synthetic time-frequency description is provided by the analysis carried out by using a DWT. The time-frequency analysis using a DWT can constitute a supplement of the results obtained by using a CWT [5, 8].

For the AE signals from PDs analyzed one by one, an original time run, approximation at the seventh decomposition level and the runs of seven details were determined. Moreover, the amount of energy transferred by each detail was determined in the form of column diagrams.

a)



b)



c)

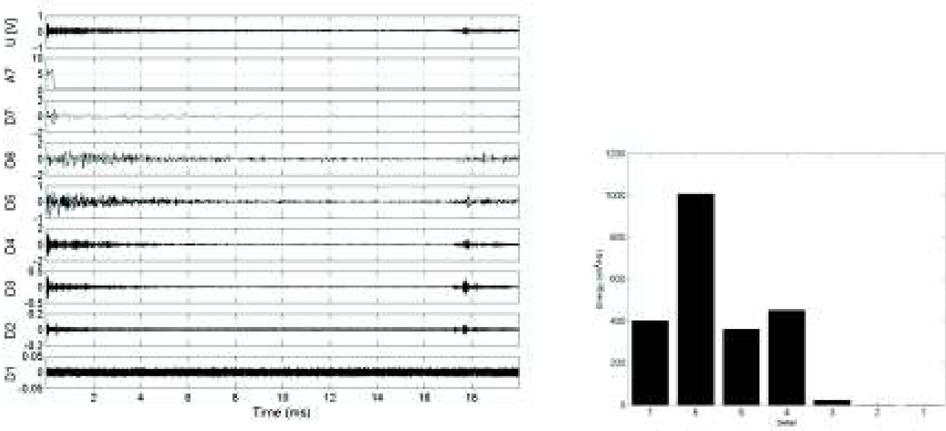


Fig. 4. Discrete wavelet decomposition and the amount of energy transferred by the particular details corresponding to the AE signals generated by PDs:
a) single-source (spark-gap 1), b) multi-source (spark-gap 2),
c) multi-source (spark-gap 1+2)

Table 1 shows the width of the frequency bands corresponding to the particular details

Table 1. The width of the frequency bands corresponding to the particular details

Details	Mid-band frequency [kHz]	Frequency band [kHz]
D1	960	640 – 1280
D2	480	320 – 640
D3	240	160 – 320
D4	120	80 – 160
D5	60	40 – 80
D6	30	20 – 40
D7	15	10 – 20

Analyzing the wavelet decomposition runs determined for the AE signals generated by single- and multi-source PDs it can be observed that the runs of details D4, D5, D6 and D7 are characteristic of the biggest amplitude. Detail D3, which is characteristic of a smaller amplitude, is also present in the signals analyzed. The runs of details D1 and D2 are of a noise character and do not significant information on the run analyzed. The power participation of the particular details in the measured AE signal from PDs is confirmed by the column diagram, attached to the decomposition runs, which visualizes the amount of the energy transferred by the details analyzed. Detail D6 has the biggest power participation in the analyzed AE signals from PDs.

The presence of details D3-D7 corresponds to the frequencies from the band from 10 to 320 kHz.
The content of the same details in the decomposition run of the accoustic event is confirmed by the fact that the number of the AE sources generated by PDs does not influence significantly the range of dominant frequencies.

5. Summing-up

The introduction of the wavelet analysis to the description of the AE signals generated by PDs constitutes a significant supplement of the processing methods, analysis and in consequence interpretation of the measurement results obtained, which have been used so far. The wavelet analysis carried out by using a CWT and DWT increases the assessment accuracy of PDs measured by the AE method.
The research work results presented in this paper confirm the possibility of PD detection in the case of occurrence of multi-source discharges. However, it is necessary to carry out laboratory investigations using other PD types and to determine recognition possibilities of basic PD forms in the case of occurrence of multi-source discharges.

The research work was financed from the means devoted to science as a research project No. R01 006 01 and No. N511 019 31/3638

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