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COMPARATIVE ANALYSIS OF THE AE SIGNALS GENERATED BY PARTIAL SINGLE- AND MULTI-SOURCE DISCHARGES

Andrzej CICHOŃ, Tomasz BOCZAR, Sebastian BORUCKI, Marcin LORENC

Technical University of Opole
Prószkowska 76, Building 2, 45-758 Opole, Poland
e-mail: a.cichon@po.opole.pl

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Within the research work carried out, the results of which are presented in this paper, a comparative analysis of the acoustic emission (AE) signals generated by partial single- and multi-source discharges (PDs) was carried out. The investigations were carried out in a model system, in which PDs were generated with two identical spark-gaps. In the work, spark-gaps in the surface system were used, due to the fact that this is the PD form occurring most often in power transformers. The AE signals were registered with a contact transducer placed on the external part of the tub. For the AE signals generated by both single-source PDs and multi-source PDs, a frequency analysis using a fast Fourier transform (FFT) and an analysis in the time-frequency domain using a short-time Fourier transform (STFT) were carried out. The results of the frequency analysis are presented in the form of power density spectra, and the time-frequency analysis results in the form of spectrograms. Analyzing the research results the signals registered were compared from the point of view of identification possibilities of the particular PD forms. The aim of the research work carried out is also proving the usefulness of the AE method for diagnosing the condition of high-voltage power appliance insulation, in which multi-source discharges occur.

Keywords: partial discharges (PDs), acoustic emission (AE), surface discharges (SPDs), stand-off insulator, bushing insulator.

1. Introduction

A widely-understood diagnostics of power transformers is a significant and dynamically developing in recent years area of activities of power enterprises and research centers. Maintaining a proper technical condition of power transformers is of great significance in the process of maintaining adequate customer service quality standards, the most important of which are continuity and reliability of electric energy supply. Statistically, power transformers are appliances of a high degree of reliability, however their failures result in serious technical and economic consequences. Therefore research work on improving diagnostic techniques is fully justified to assure the longest possible and failure-free operation of transformer units, especially high-power transformers [3, 4, 6].

Detection and location of partial discharges (PDs) are significant parts of a complex assessment of the technical condition of power transformers. In practice, the diagnostics of power transformers, from the point of view of PD occurrence possibility, has been carried out based on two measurement methods: the acoustic emission (AE) method and electrical method. In recent years the development of the AE method has been caused by the introduction of the combined time-frequency analysis for the description of the AE signals generated by PDs. Based on the frequency and time-frequency description the detection of PDs in single-source systems is possible. Multi-source discharges can occur in operating power transformers. Thus it is necessary to carry out laboratory research work on the application possibilities of the AE method for detecting PDs in multi-source systems. The paper presents a fragment of the research work relating to the comparison of the AE signals generated by single- and multisource 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.

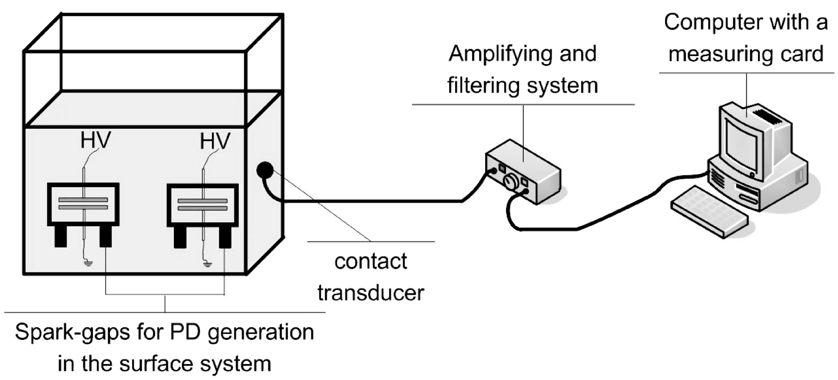

Fig. 1. Diagram of the measuring system.

The measurement tub was filled with insulation oil and two identical spark-gaps generating partial discharges in the surface system (SPDs) were immersed in it, due to the fact that it is the most often occurring 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 $\pm$ 1.5 dB in relation to V/ms^{-1}) and a wide transfer band from 100 kHz to 1 MHz in the range $\pm$10 dB. A piezoelectric transducer was connected with the amplifying and filtering system through a preamplifier. 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.

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, preamplifier and the amplifying and filtering system are shown in Fig. 2.

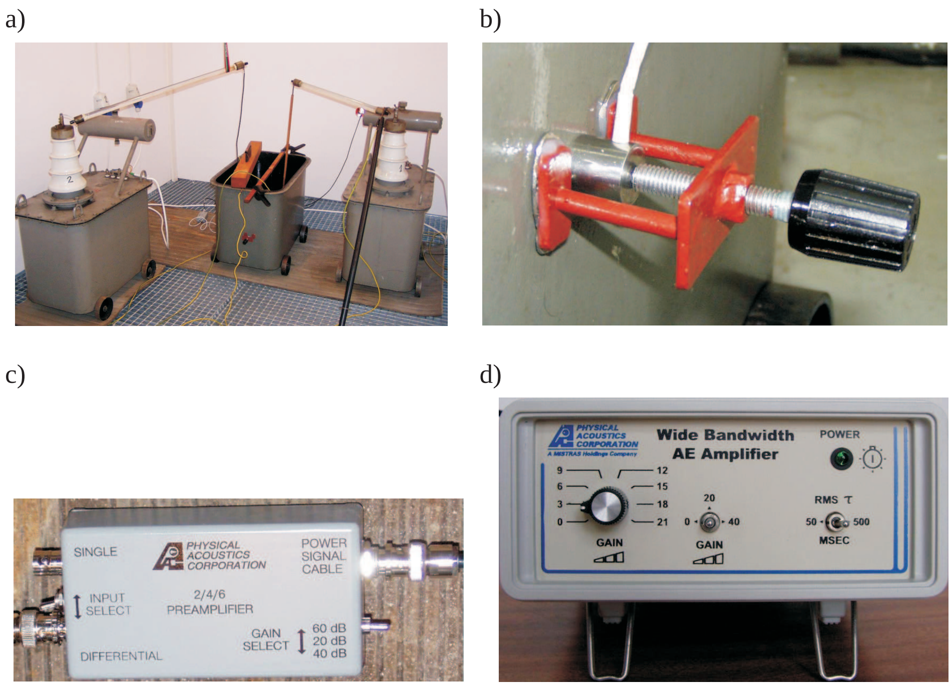

Fig. 2. View of the measuring system: a) measurement chamber, b) piezoelectric transducer, c) preamplifier, d) amplifying and filtering system.

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 supply voltage. The AE signals from PDs were subjected to the frequency analysis using a fast Fourier transform (FFT) and to time-frequency analysis using a short-time Fourier transform (STFT). The frequency analysis results were shown in the form of the amplitude spectrum, and the time-frequency analysis results were visualized with two- and three-dimensional power spectral density spectrograms.

4. The analysis of the results obtained

Figure 3 shows amplitude spectra corresponding to the AE signals from PDs in a single- and multisource systems. The single-source system was modeled for the two spark-gaps separately.

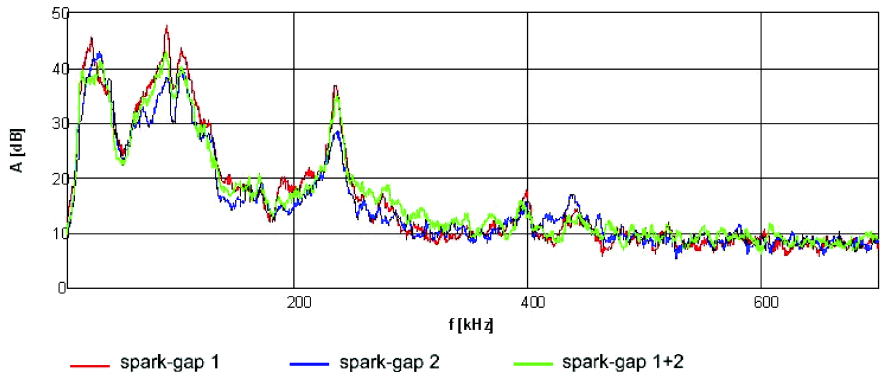

Fig. 3. Amplitude spectra of the AE signals generated in single- and multisource systems.

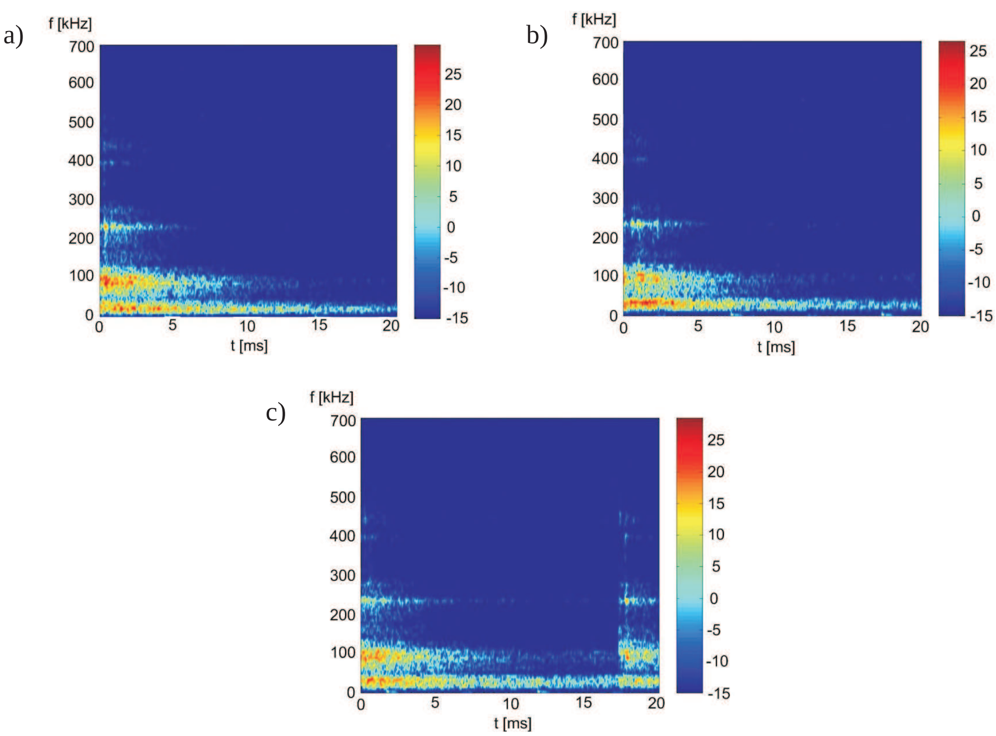

Fig. 4. Two-dimensional spectrograms of the power spectral density corresponding to the AE signals generated by PDs: a) single-source (spark-gap 1), b) multisource (spark-gap 2), c) multisource (spark-gaps 1+2).

The time-frequency analysis supplements the frequency analysis, the results of which are shown in Figs. 4 and 5.

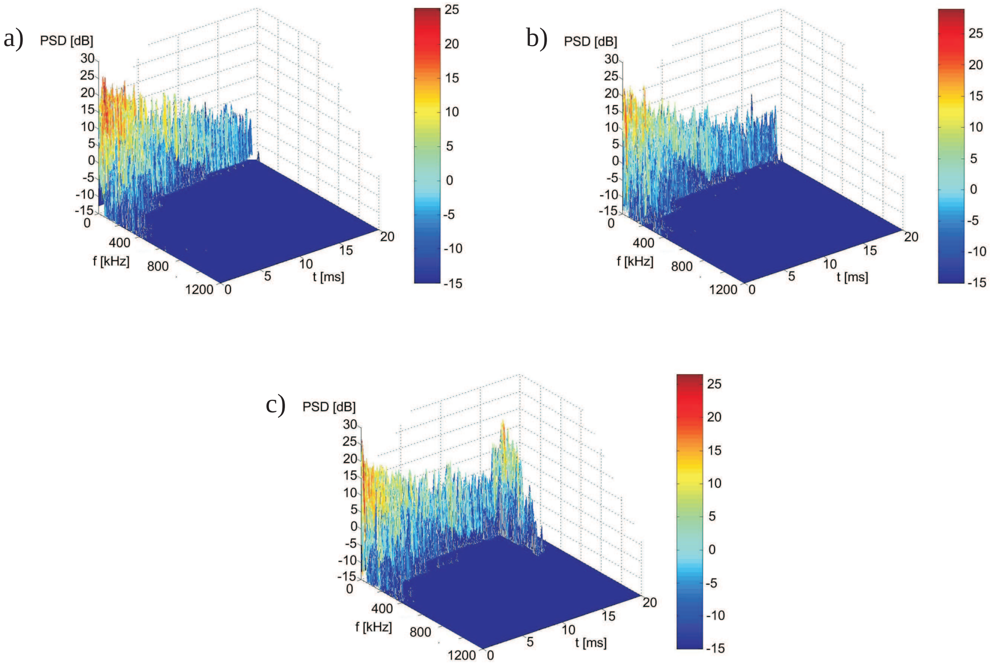

Fig. 5. Three-dimensional spectrograms of the power spectral density corresponding to the AE signals generated by PDs: a) single-source (spark-gap 1), b) multisource (spark-gap 2), c) multisource (spark-gaps 1+2).

The amplitude spectra describing the AE signals from PDs generated in single- and multisource systems, shown in Fig. 3, are characteristic of a similar shape, amplitude and the range of dominant frequencies. The signals analyzed contain frequency components from the range from 0 to 300 kHz.

During the time-frequency analysis using a STFT a Hamming time window was used, which is used most often for the analysis of high-frequency runs. The results of the time-frequency analysis are shown in Figs. 4 and 5 in the form of two- and three-dimensional power spectral density spectrograms. In order to set off time-frequency structures characteristic of a higher amplitude, the spectrograms were determined by using a threshold function cutting off the components below -15 dB. Analyzing the spectrograms determined it can be observed that in the case of single-source discharges, only one time-frequency structure occurs. Multisource discharges are characteristic of a bigger intensity of occurrence, which can be observed in Figs. 4c and 5c. The occurrence of a bigger number of time-frequency structures does not influence, however, the range of dominant frequencies and amplitude values. The longest duration time have structures from the range from 10 to 40 kHz. The participation of the time-frequency structures from the range 60–130 kHz, the duration time of which is about 15 ms, is also significant. Frequencies above 130 kHz are characteristic of a much smaller amplitude as well as duration time.

The spectrograms determined corresponding to single- and multisource discharges share many common features such as: the band of dominant frequencies, amplitude or duration time of the time-frequency structures determined. This confirms the usefulness of the time-frequency description for the analysis of the AE signals generated by multisource discharges.

5. Summing-up

A continuing development of the research work aiming at improving the AE method used for the assessment of the insulation condition of power transformers requires taking into account all factors that can influence the assessment of the measurement results. Modern digital technology enables to an accurate interpretation of the results obtained not only in the frequency domain but also, first of all, in the time-frequency domain. The research work results presented in this paper confirm the possibility of PD detection in the case of multisource discharge occurrence. However, it is necessary to carry out laboratory research using other types of PDs and to determine recognition possibilities of basic PD forms in the case of multisource discharge occurrence.

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References

[1] Boczar T., *Identification of a specific type of partial discharges form acoustic emission frequency spectra*, IEEE Transactions on Dielectrics and Electrical Insulation, **8**, 4, 598–606 (2001).

[2] Boczar T., Borucki S., Cichoń A., Lorenc M., *Objectivization of the electrical discharge measurement results taken by the acoustic emission method*, Journal de Physique IV Proceedings, 35-th Winter School on Wave and Quantum Acoustics, pp. 31–34, November 2006, ISSN: 1155-4339.

[3] Boczar T., Borucki S., Cichoń A., Lorenc M., *Time-frequency analysis of the AE signals generated by PDs on bushing and stand-off insulators*, Archives of Acoustics, **31**, 4S, 325–334 (2006).

[4] Praca zbiorowa: *Transformatory w eksploatacji*, Wyd. Energo – Complex, kwiecień 2007.

[5] Rak R., Majkowski A., *Czasowo-częstotliwościowa analiza sygnałów*, Przegląd Elektrotechniczny, R. 80, nr 5/2004.

[6] Skubis J., *Emisja akustyczna w badaniach izolacji urządzeń elektroenergetycznych*, PAN IPPT, Of. Wyd. PO, 1998.