# EVALUATION OF THE INFLUENCE OF THE PARAMETERS OF THE PROPAGATION PATH OF THE ACOUSTIC EMISSION PULSES GENERATED BY PARTIAL DISCHARGES ON THE RESULTS OF THEIR FREQUENCY ANALYSIS

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**SUMMARY**

*This paper presents the results of frequency analysis of the acoustic emission (AE) pulses generated in a setup modeling multisource partial discharges (PDs) of the multipoint – grounded plane type with a pressboard insulation layer placed between electrodes, which were obtained after the change of the parameters of the propagation path of the AE waves emitted and at the place changes of their registration. Within the research carried out, the influence of the insulation barrier made of melamine resin and additional transformer winding were analyzed, which were placed on the propagation path of the AE signals generated by PDs. The analysis carried out also included the evaluation of the mounting place and type change of the measuring transducer on the amplitude and energy density spectrum runs and the values of the descriptors connected with them. Finally, a comparative analysis of the descriptor values making the identification of basic PD forms possible, which were determined at the changes of the parameters under study, was carried out.*

***Keywords:*** *multisource partial discharges(PD), acoustic emission method (AE), the multipoint – grounded plane system*

## 1. INTRODUCTION

The subject matter of this paper is connected with the issues connected with the use of digital processing of signals for the frequency analysis of the acoustic emission (AE) pulses generated by partial discharges (PDs) occurring in insulation of power appliances. The results presented are a continuation of the research connected with determining the ranges and identification possibilities of basic PD forms occurring in oil insulation, based on the knowledge of frequency spectrum runs and the values of the descriptors that characterize them, determined for the AE pulses generated by them. The present research aims at creating models, i.e. fingerprints for the particular PD forms in such a way that if comparing with them the measurement results obtained it will be possible to identify the type of a PD measured uniquely.

The research carried out so far has proved that by simultaneously comparing the values of the peak factor and shape coefficient, median frequency, the range of dominant frequency bands in a spectrum, and the shape of frequency spectrum runs it is possible to identify basic PD forms occurring in insulation oil [1, 3].

The aim of the research carried out, the results of which are presented in this paper, was to determine the influence of the parameter change characterizing the propagation path of the acoustic waves propagating in insulation oil and the changes of the place of their measurement on the results of the frequency analysis of the AE pulses from PDs. First of all, it was tested whether the changes in the metrological conditions of the generation and propagation of acoustic waves from PDs and the changes in the place of mounting the measuring transducer decide about the shape and character of the frequency spectrum runs of the AE pulses measured. As a consequence, the influence of the changes of the parameters analyzed on the values of the criteria adopted making the identification of basic PD forms possible. Moreover, for comparison purposes, the measurements and frequency analysis of the AE pulses generated by PDs using three different types of measuring transducers were performed. The results presented in this paper are a continuation and ,to a high degree, broadening of the research work connected with the evaluation of the influence of the parameters of the path of AE wave propagation in oil insulation generated by PDs on the results of their frequency analysis, which were presented in the paper [2].

## 2. RANGE OF THE RESEARCH CARRIED OUT AND CHARACTERISTICS OF THE MEASURING SETUP APPLIED

The measurements and analysis of the AE pulses were carried out for PDs generated in a setup modeling multisource discharges of the multipoint – grounded plane type, in which a pressboard insulation layer was inserted between electrodes. The spark gap was placed in a special holder and immersed in a transformer tub sized 1.5 m x 1.5 m x 1 m, which was then filled with mineral insulation oil.

In order to determine the influence of the parameter change of the propagation path of acoustic signals on the results of their frequency analysis, there were placed successively: a 3 cm thick insulation barrier made of melamine resin and then a transformer core with primary and secondary winding which were not supplied, between the place of PD propagation and the wall of the transformer tub to which measuring transducers were attached. The AE pulses registered for these cases underwent a frequency analysis, and then they were compared with the results obtained for the AE signals registered without an insulation barrier.

The results of the frequency analysis obtained for the AE pulses generated by PDs of the multipoint – plane type using barriers made of seven different papers and insulation resins were presented in the work [2].

In order to determine the influence exerted on the results of the frequency analysis of the AE pulses registered by the changes of distance between the places of PD generation and their measurement, comparative measurements were taken by placing successively a measuring transducer on each of the for walls of the tub under study. Moreover, to compare the results obtained, the AE pulses generated by PDs were registered using three types of measuring transducers: piezoelectric wideband contact 8312 type by the firm Brüel&Kjær, piezoelectric brand accelerometer model ISOTRON 752-10 by the firm ENDEVCO, and piezoelectric accelerometer model ISOTRON 7259A-10 by the firm ENDEVCO, the parameters of which and frequency characteristics are presented in the works [1, 3].

The measurements of the AE pulses generated from PDs were taken every 1 kV, in the range from the striking voltage to the voltage of 0.8 $U_b$ (breakdown voltage). Next the frequency analysis of the AE pulses measured was carried out, which consisted in calculating a Fast Fourier Transform (FFT) and determining the runs of amplitude and energy density spectra. In calculations, the polarization of the supplying voltage was taken into consideration in which the AE pulses were measured and generated. For frequency spectra the following descriptor values that characterize them were selected and calculated: median frequency, peak factor and shape coefficient, maximum, mean and rsm values, ranges of dominant frequency bands in a spectrum for the adopted threshold, frequency for the maximum value in a spectrum. Next a comparative analysis of the measurement results obtained was carried out to determine the influence of the change of parameters of the propagation path and the place of measuring the AE pulses on the values of the identification criteria defined. The results of measurements and calculations presented in this paper were obtained at the same relative value of PD generation voltage of 0.8 $U_p$.

The characteristics of the measuring apparatus used, the setup for PD generation, metrological parameters and the way of carrying out the frequency analysis were presented, among others, in the works [1, 3].

## 3. DETERMINING THE INFLUENCE OF THE PARAMETER CHANGE OF THE PROPAGATION PATH OF THE AE PULSES FROM PDS ON THE RESULTS OF THEIR FREQUENCY ANALYSIS

In order that the measurement results obtained for the suppression barriers applied may be compared, in the first stage of research the AE pulses generated in the multipoint – plane setup, which were measured with three measuring transducers placed at the front of the tub, in a setup without barriers on the propagation path of the acoustic waves, were analyzed. The results obtained in this way constituted a comparative base of reference for the series of AE pulses measured when using a transformer winding and an insulation layer, and during the place change of the transducers with respect to the place of PD generation.

Since regardless of the polarization of the supplying voltage a similar shape and character of the frequency spectrum runs were obtained, only the measurement results obtained in the positive half-time of the supplying voltage were selected.

Fig. 1 - 3 present the runs of energy density spectra of the AE pulses generated by PDs of the multipoint – plane type, measured with a contact transducer type 8312, at the amplification of 10 dB, placed on the front wall of the tub, without using an insulation layer (Fig. 1), with a barrier of melamine resin (Fig. 2) and with a transformer core (Fig. 3).

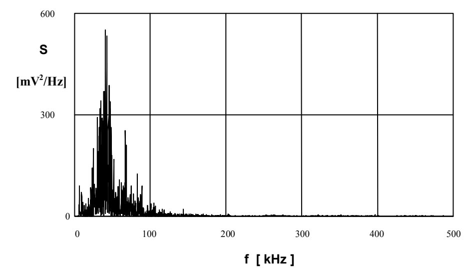


**Fig. 1** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with contact transducer type 8312 placed on the front side of the tub

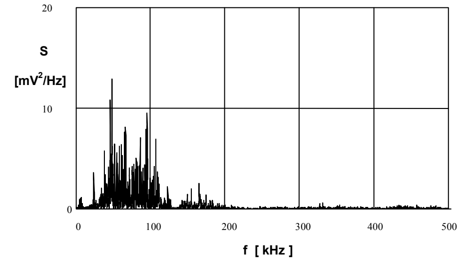


**Fig. 2** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type with the insulation barrier made of melamine resin. The measurement taken with contact transducer type 8312 placed on the front side of the tub

In order to compare the results of the frequency analysis that were obtained at changes of the measuring transducer placement, Fig. 4-6 present successively the runs of energy density spectra obtained for the AE pulses measured with a contact transducer, without insulation barriers, which was placed at the back of the tub (Fig. 4), on its left side (Fig. 5), and on its right side (Fig. 6).

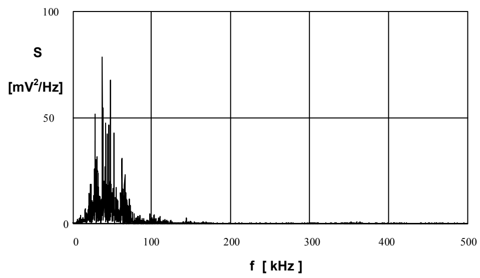


**Fig. 3** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type with the transformer core. The measurement taken with contact transducer type 8312 placed on the front side of the tub

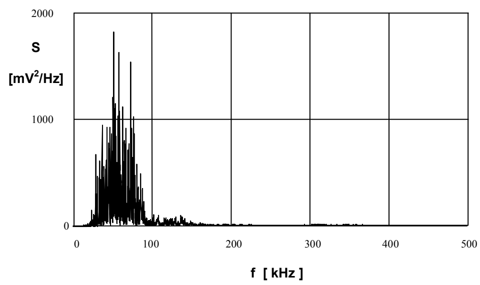


**Fig. 4** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with contact transducer type 8312 placed on the back side of the tub

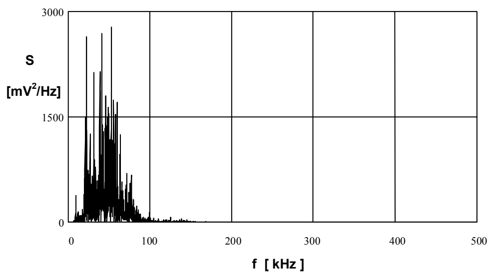


**Fig. 5** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with contact transducer type 8312 placed on the left side of the tub

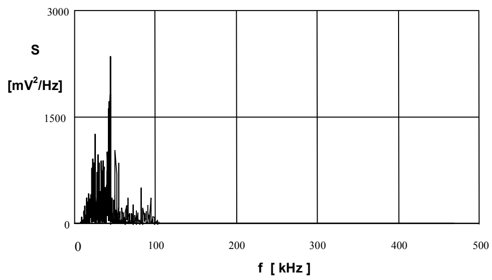


**Fig. 6** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with contact transducer type 8312 placed on the right side right side of the tub

Fig. 7 - 8 present the runs of energy density spectra calculated for the AE pulses generated by discharges of the multipoint – plane type measured for accelerometer type ISOTRON 752-10 (Fig. 7) and accelerometer type ISOTRON 7259A-10 which were place on the front wall of the tub. The results of comparing descriptors that make the identification of basic PD forms, determined for the propagation barriers under study, are presented collectively in Table 1. Table 2 presents a comparative listing of the descriptors analyzed, the values of which were determined at the changes of registration place of the AE pulses generated by the PDs under study.

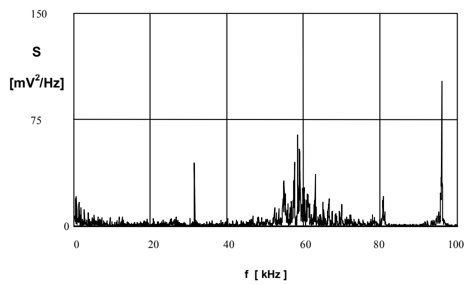


**Fig. 7** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with an accelerometer type 725-10 placed on the front side of the tub

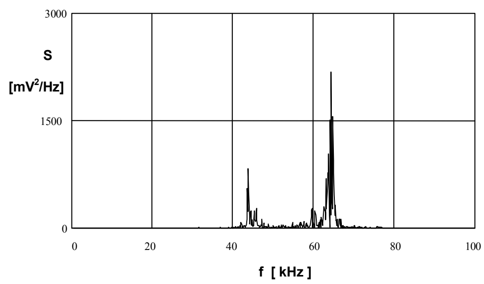


**Fig. 8** Energy density spectrum run for the AE pulses generated by PDs of the multipoint – plane type without suppression barriers. The measurement taken with an accelerometer type 7259A-10 placed on the front side of the tub

| Type of descriptor | AE pulses generated by multipoint – plane PDs | | | | | |
|---|---|---|---|---|---|---|
| | without insulation layers | | with an insulation barrier | | with a transformer winding | |
| | Spectrum type | | | | | |
| | amplitude | energy density | amplitude | energy density | amplitude | energy density |
| median frequency [kHz] | 73.9 | 43 | 70.7 | 41.7 | 69.9 | 45.2 |
| peak factor [ - ] | 3.9 | 15.2 | 3.7 | 14.4 | 4.2 | 17.9 |
| shape coefficient [ - ] | 3.6 | 3.9 | 3.4 | 3.7 | 3.6 | 4.0 |
| ranges of dominant frequencies [kHz] | (0-100) | (0-100) | (0-100) | (0-120)<br>(130-180) | (0-100) | (0-90)<br>(100-120) |

**Tab. 1** Comparative listing of the values of the selected descriptors calculated for the amplitude and energy density spectra of the AE pulses generated by PDs of the multipoint – plane type, measured without insulation layers, with and insulation layer and with a transformer winding

| Type of descriptor | AE pulses generated by multipoint – plane PDs registered | | | | | |
|---|---|---|---|---|---|---|
| | on the left side of the tub | | on the right side of the tub | | on the back side of the tub | |
| | Spectrum type | | | | | |
| | amplitude | energy density | amplitude | energy density | amplitude | energy density |
| median frequency [kHz] | 74.4 | 42.6 | 75 | 43.1 | 74.8 | 47.9 |
| peak factor [ - ] | 4.2 | 17.4 | 4.1 | 16.3 | 3.8 | 15.8 |
| shape coefficient [ - ] | 3.7 | 3.9 | 3.8 | 4.5 | 3.8 | 3.7 |
| ranges of dominant frequencies [kHz] | (0-100) | (0-100) | (0-100) | (0-100) | (0-100) | (0-100) |

**Tab. 2** Comparative listing of the values of the selected descriptors calculated for amplitude and energy density spectra of the AE pulses generated by PDs of the multipoint – plane type at the changes of a measuring transducer placement

## 4. CONCLUSION

The following conclusions can be drawn analyzing the measurement results obtained:

a) For the AE pulses measured, repeatable voltages and the runs of their frequency spectra of a similar shape and character were obtained for both voltage polarizations. The minimum value of their mutual correlation coefficient was 0.91;

b) suppression of the AE pulses measured of 97% on average in relation to the signals measured without suppression layers. The maximum, average and rsm values decreased by 83%, 95%, 98%, respectively, for an amplitude spectrum and by 89%, 97%, 99%, respectively, for an energy density spectrum in relation to their values calculated for the AE pulses generated by PDs without insulation barriers. The placement of a transformer core on the AE wave propagation path caused suppression of the AE pulses registered by 84% on average. Maximum, average and rsm values determined for the amplitude spectrum decreased by 81%, 86% and 84%, respectively, and for the energy density spectrum by 80%, 88% and 84%.

c) Extending the length of the AE wave propagation path from 40 cm (a transducer placed on the left or right wall of the tub) to 90 cm (front wall of the tub) caused a decrease in the amplitude and energy of the AE pulses registered by 80% on average. The placement of the transducer on the back wall of the tub (increase of the propagation path from 40 to 60 cm) caused suppression of the AE pulses measured by 33% on average.

d) The change of length and parameters of the AE signal propagation path did not influence the shapes of the runs of the frequency spectra and the values of the descriptors which are presented in Tables 1 and 2.

e) The application of accelerometers for measurements of the AE pulses generated by PDs enables a thorough analysis of frequency spectra in the range of low frequencies, i.e. in the band from 0 to 80 kHz.

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**Pawel Fracz** (MSc eng) was born in 1973 in Opole in Poland. He graduated from the Department of Electrical Engineering and Automatic Control, Technical University of Opole in 1993. In present time is engaged in different applications of the electrical method, optical spectral diagnostics and other nondestructive method especially in diagnostics of insulation setups of electric appliances. In these fields he published more than 15 journal and conferences papers. He is lecturer and research worker of Technical University of Opole.