ACOUSTIC EMISSION OF SINGLE-SOURCE PARTIAL DISCHARGES OF VARIOUS TYPES GENERATED SIMULTANEOUSLY

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SUMMARY

The subject matter of this paper is connected with determining identification possibilities of partial discharge (PD) forms based on the analysis of frequency runs of the acoustic emission (AE) pulses generated. In the research carried out so far, the descriptors characterizing the AE pulses measured in the frequency domain were determined, and then their usefulness for the identification of basic PD forms was defined. The results presented here refer to the case when two various single-source PDs occur at the same time in oil insulation. This paper will present the results of frequency analysis of AE pulses generated separately in the setups modeling surface and single-source discharges of the multipoint – grounded plane type. Then, for comparison, the results obtained from simultaneous generation of the discharges of both types will be presented. In the Conclusion the results of the comparative analysis of the results obtained will be presented from the angle of determining identification possibilities in the case of generation of single-source PDs of various types.

Keywords: *partial discharges(PD), acoustic emission method (AE), frequency analysis, multipoint-plane gap, surface gap*

1. INTRODUCTION

The subject matter of this paper deals with improvement of the AE method used for measuring partial discharges (PDs) occurring in power appliance insulation. The application of the latest achievements of digital electronics and computer technology in measuring setups has resulted in a situation when registering AE pulses generated by PDs is no longer a problem, but their proper analysis and interpretation is. The results of the research on the possibilities of applying the AE method for measurements and PD evaluation, as presented in the literature, concentrate mainly on mathematical description and physical interpretation of mechanisms accompanying generation and propagation of AE signals in various dielectrics and compound insulation systems [4, 5].

In the research carried out so far, the authors concentrated on defining identification possibilities of basic PD forms based on the frequency analysis of the AE pulses generated. To do so, the measurements were taken and the frequency analysis was carried out of the AE pulses generated in the setups modeling the following PD forms: point – grounded plane, multipoint – grounded plane, surface, on particles of indefinite potential, and in gas bubbles. The above-mentioned PD forms were generated in insulation transformer oil. Based on the results of the research carried out, it was proved that based on the frequency spectrum runs, dominant frequency band ranges, peak factor, shape coefficient and median frequency, compared at the same time, it is possible to identify the defined PD forms. The comparative criteria designated make the identification of PDs possible, however, it refers only to single-source discharges, single discharges, of one type and at accurately defined measurement conditions [2, 3]. Moreover, it was proved that it is possible, based on the adopted comparative criteria, to identify basic PD forms for single-source and of one-type discharges. The research referred to point – plane and multipoint – plane discharges and the results were presented in a paper [1].

The aim of the measurements and analyses carried out for PDs of multipoint – grounded plane and surface types. For research purposes, spark gaps were made that model the above-mentioned PD forms. They were placed in a metal container in the shape of a rectangular prism of the following geometric measurements: 1.5 x 2.0 x 2.0 m^3, which was filled with transformer oil. Geometric measurements of the model setups were over 15 times smaller than the measurements of the object in which they were placed. High voltage of an adjustable value from a test transformer was applied to spark gaps. The spark gaps were supplied in such a way that PDs in both setups were generated in the same half-times of voltage at the same time. To be able to carry out a comparative analysis of the results obtained, the measurements were taken for the same relative value of the supplying voltage, which was 80% of the breakdown voltage value. Detailed characteristics of the spark gaps made, the object under study, the measuring apparatus used, metrological parameters, and the conditions in which the research was carried out were presented in the works [2, 3].

A Fast Fourier Transform (FFT) was calculated for the AE pulses measured, then the amplitude and energy density spectrum runs were drawn. For the determined frequency spectra the number values were calculated of the following descriptors that characterize them: maximum, mean and rms values, shape coefficient, peak factor, the ranges of dominant frequency bands in a spectrum for the adopted discrimination threshold, median frequency, standard deviation, variance, frequency for the maximum value in a spectrum. The calculation formulae applied and the procedures of digital processing of the AE pulses measured were presented, among others, in the works [2, 3]. The frequency analyses were carried out separately for the AE pulses generated by multipoint – plane and surface discharges at the positive and negative polarization of the supplying voltage. The length of the time interval, for which a FFT was calculated, was 8.192 ms and was selected in such a way that its range included the whole acoustic event occurring in a single half-time. In the Summery a comparative analysis of the results obtained was carried out for single-source surface PDS and multipoint-plane discharges generated separately and occurring simultaneously, in the same object under study, from the angle of evaluation of usefulness of the identification criteria adopted.

2. THE RESULTS OF A COMPARATIVE ANALYSIS OF THE AE PULSES GENERATED BY SINGLE-SOURCE DISCHARGES OF THE MULTIPOINT – PLANE AND SURFACE TYPES OCCURRING SIMULTANEOUSLY AND SEPARATELY

For the AE pulses measured generated by single-source discharges of the multipoint – plane and surface types, repeatable and characteristic shapes of their frequency spectrum runs and the values of the descriptors calculated for them were obtained. Regardless of the polarization of the supplying voltage, the amplitude and energy density spectra determined for the PD forms under study have their runs of characteristic and similar shapes. The values of the correlation coefficient of frequency characteristics calculated in the positive and negative half-times of the voltage for single-source discharges of a given type were 0.95 for multipoint – plane discharges, and 0.96 for surface discharges, respectively.

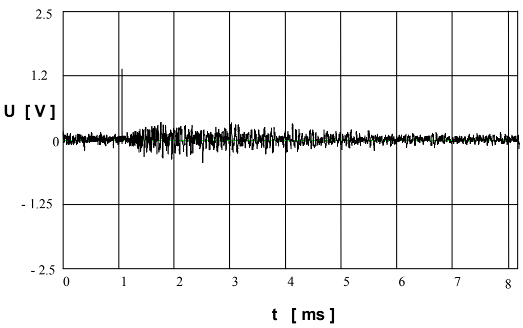

Fig. 1 Time run for AE pulse series generated by PDs in the multipoint - plane type at oil, in the positive voltage half-period

Fig. 1 - 9 present time runs (Fig. 1, 4, 6) amplitude spectrum runs (Fig. 2, 5, 7) and energy density runs (Fig. 3, 6, 9) determined for the AE pulses generated by single-source discharges of multipoint – plane type (Fig. 1 - 3), single-source surface discharges SPDs - (Fig. 4 - 6) and discharges of multipoint – plane and surface type generated simultaneously (Fig. 7 - 9).

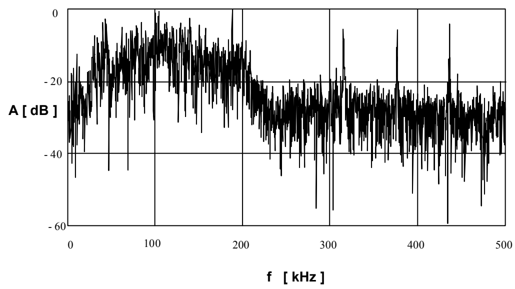

Fig. 2 Amplitude spectrum run for AE pulse series generated by PDs in the point - plane type at oil, in the positive voltage half-period

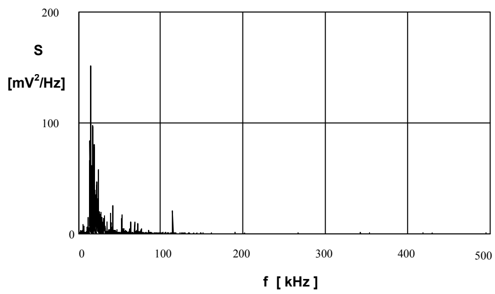

Fig. 3 Energy density spectrum run for AE pulse series generated by PDs in the point - plane system at oil, in the positive voltage half-period

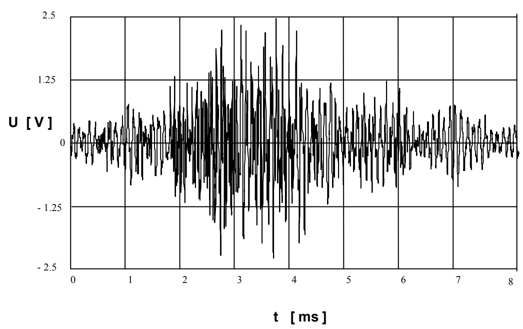

Fig. 4 Time run for AE pulse series generated by SPDs at oil in the positive voltage half-period

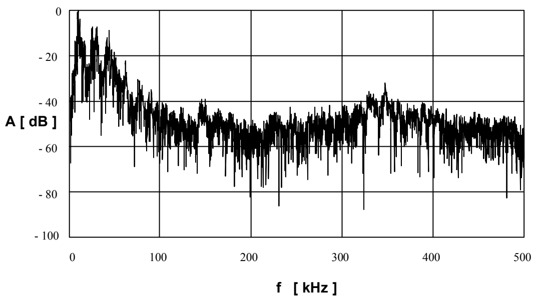

Fig. 5 Amplitude spectrum run for AE pulse series generated by SPDs at oil in the positive voltage half-period

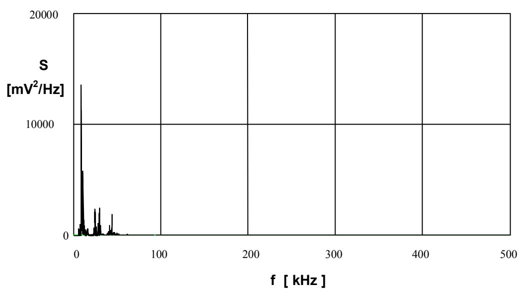

Fig. 6 Energy density spectrum run for AE pulse series generated by SPDs at oil in the positive voltage half-period

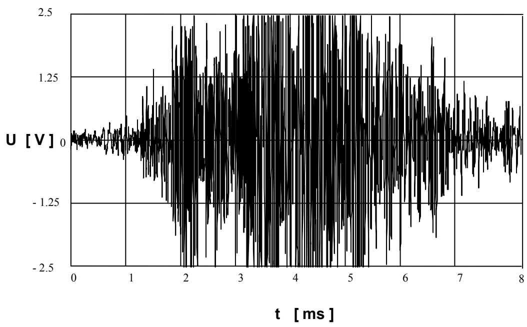

Fig. 7 Time run of the AE pulses generated by single-source PD of multipoint – plane and SPDs types in oil in the positive half-time of voltage

Table 1 presents a comparative listing of the values of the selected descriptors, which were determined for the amplitude and energy density spectra of the AE pulses generated by SPDs, multipoint – plane discharges and the both types under study occurring simultaneously.

For comparison purposes a frequency analysis was carried out of the datum series obtained as a result of digital subtraction of the time run of the AE generated by PDs of the multipoint – plane type from the time run of the AE pulses measured for both forms of PDs generated simultaneously. For the series of AE pulses obtained in this way, marked as run A, frequency characteristics were determined and the values of the descriptors used for identification of basic PD forms were calculated.

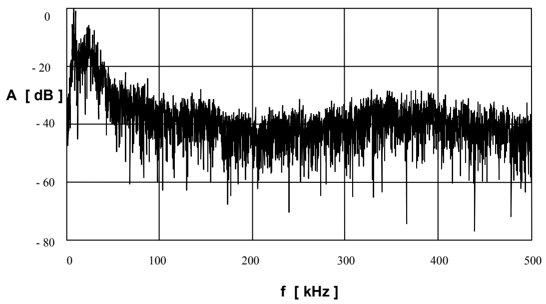

Fig. 8 Amplitude spectrum run of the AE pulses generated by single-source PD of multipoint – plane and SPDs types in oil in the positive half-time of voltage

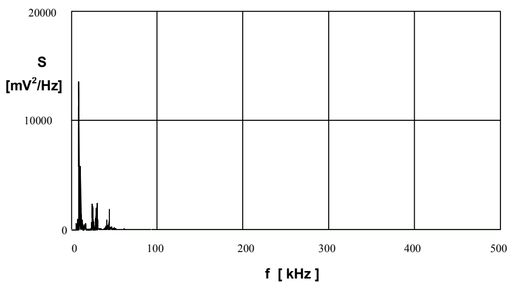

Fig. 9 Energy density spectrum of the AE pulses generated by single-source PD of multipoint – plane and SPDs types in oil in the positive half-time of voltage

Type of descriptor	PD type					
	single-source surface		single-source multipoint – plane		surface and multipoint -plane generated simultaneously	
	Type of frequency spectrum					
	amplitude	energy density	amplitude	energy density	amplitude	energy density
median frequency [kHz]	30.0	11.8	64.8	20.1	39.5	17.5
peak factor [-]	11.2	9.9	5.1	6.2	7.5	8.9
shape coefficient [-]	6.1	37.3	5.1	26.6	5.6	34.2
ranges of dominant frequencies [kHz]	(5-15) (20-30) (40-50)	(5-15) (20-30) (40-50)	(0-80)	(0-80)	(0-50)	(0-50)

Tab. 1 Comparative listing of the values of the selected descriptors determined for the amplitude and energy density spectra of the AE pulses generated by surface and multipoint – plane PDs and of both types occurring simultaneously

Type of descriptor	PD type			
	A		B	
	Type of frequency spectrum			
	amplitude	energy density	amplitude	energy density
median frequency [kHz]	30.0	11.8	64.8	20.1
peak factor [-]	11.2	9.9	5.1	6.2
shape coefficient [-]	6.1	37.3	5.1	26.6
ranges of dominant frequencies [kHz]	(5-15) (20-30) (40-50)	(5-15) (20-30) (40-50)	(0-70)	(0-70)

Tab. 2 Comparative listing of the values of the selected descriptors characterizing the amplitude and energy density spectra of the AE pulses obtained through digital subtraction from PDs of the surface and multipoint – plane types generated simultaneously, AE pulses generated by surface PDs (A) and multipoint – plane discharges (B)

Then the results obtained underwent a comparative analysis with the values determined for PDs of the surface type. The minimum value of the mutual correlation coefficient of the amplitude and energy density spectrum runs compared did not exceed the value of 0.76, and the maximum value of standard deviation for the descriptors determined was smaller than 15.6%.

In an analogous way a comparative analysis was carried out of the datum series (marked as run B) obtained after subtraction of the AE pulses generated by both PD forms analyzed occurring at the same time, time runs measured for surface discharges with the results obtained for single-source discharges of the multipoint – plane type from the time run. The value of the mutual correlation coefficient for the frequency characteristics calculated was smaller than 0.79. The value of the standard deviation determined for the descriptors analyzed did not exceed 14.8%.

A comparative listing of descriptors calculated for the series of data marked as A and B is presented in Table 2.

3. CONCLUSION

Based on the comparative analysis of the results obtained for single-source discharges of the multipoint – plane and surface types occurring separately and generated simultaneously, the following conclusions can be drawn:

- For single-source PDs analyzed, generated simultaneously at the same time and separately, frequency spectra of characteristic and repeatable for a given PD form shapes of their runs were obtained. The minimum value of the correlation coefficient determined for single PD forms under study and for PDs generated simultaneously two Pd forms under study was , respectively: for amplitude spectra 0.9, and for energy density spectra 0.83.

The value of the correlation coefficient calculated for surface PDs and multipoint – plane PDs was equal to 0.386, respectively. For surface PDs and the two PD forms analyzed, generated simultaneously, was 0.571. For multipoint – plane PDs and the two PD forms occurring at the same time was equal to 0.497.

- Based on the data listed in Table 1 significant differences in the values of the particular descriptors calculated for surface PDs, multipoint – plane PDs and the two PD forms generated simultaneously can be observed. Hence, They can be identified based on the value of the peak factor, shape coefficient, median frequency, range of the dominant frequencies in a spectrum and the shapes of the frequency spectrum runs compared simultaneously.

- Comparing the data listed in Table 1 with the values of the descriptors listed in Table 2 it can be stated that it is possible to identify single-source PDs of the surface and multipoint – plane types calculated from the runs of AE pulses generated by the two PD forms occurring simultaneously, at the same time, and in the same object under study.

The research carried out widened the identification possibilities of PDs based on the results of the frequency analysis of their AE in the case of occurring single-source PDs of various types. It is necessary to do comparable research for other types of single-source PDs generated at the same time and in the same object. Moreover, it seems useful to take measurements and carry out the analyses of the AE pulses generated in compound insulation systems and for other types of dielectrics.

REFERENCES

[1] Boczar, T.: "Acoustic emission of multisource partial discharges" International Conference on Advances in Processing, Testing and Application of Dielectric Materials, APTADM'2001, Wroclaw, 2001, pp. 221-224

[2] Boczar, T.: "Identification of a Specific Type of Partial Discharges form Acoustic Emission Frequency Spectra" IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 8, No 4 August 2001, pp. 598-606.

[3] Boczar, T.: „Widma emisji akustycznej generowanej przez wyładowania niezupełne w izolacji olejowej” Studia i Monografie Oficyna Wydawnicza Politechniki Opolskiej, z. 114, Opole, 2000.

[4] Kelen, A.: "Trends in partial discharges diagnostics. When new options proliferate, so do old and new problems", IEEE Trans. Electrical Insulation, Vol. 2, No. 4, pp. 529-534, 1995.

[5] Skubis, J.: „Emisja akustyczna w badaniach izolacji urzadzen elektroenergetycznych”, IPPT-PAN, Warszawa, 1993.

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Tomasz Boczar (Ph. D. eng.) was born in 1968 in Prudnik in Poland. He graduated from the Department of Electrical Engineering and Automatic Control, Technical University of Opole in 1993. In 1998 he was graduated PhD degree in Electrical Engineering Silesian University of Technology, Institute of Electrical Power Engineering in Katowice, Poland. In present time is engaged in different applications of the acoustic emission method and other nondestructive method especially in diagnostics of insulation setups of electric appliances. In these fields he published more than 50 journal and conferences papers and one monograph. He is lecturer and research worker of Technical University of Opole.

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