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WAVELET ANALYSIS OF THE POWER TRANSFORMER TUB VIBRATIONS

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Abstract

The paper will present the wavelet analysis results using continuous and discrete wavelet transforms of vibrations of a power transformer tub installed on the block of a conventional, thermal condensation power station. The research tests were carried out during a regular transformer operation in industrial conditions. The measurements were taken from the point of view of the evaluation of the influence of the vibrations registered on the analysis results of the acoustic emission signals generated by partial discharges that can occur in paper-oil insulation systems of power transformers. Moreover, the analyses carried out were supplemented with the research results obtained in laboratory conditions during the measurements taken in the high-voltage testing station of high-voltage power appliances. The influence of the loosened screws fastening the lid of the transformer tub on the time-frequency analysis results obtained of the vibrations registered was investigated. Moreover, the range of the research work carried out referred to the evaluation of the influence of the changes of the pressure force of the metal plates forming the transformer core on the vibration measurement results were obtained. In summary, the evaluation of usefulness was presented and the range of the time-frequency analysis application possibilities, and especially wavelet transforms, in diagnostics of power transformers using the acoustic methods was characterized.

1. INTRODUCTION

The acoustic emission (AE) method, based on the analysis of the acoustic signals generated by partial discharges (PDs), is one of the measuring methods used in diagnostics of power appliance insulation. The particular merit of this method is the possibility of using it in industrial conditions, during a regular operation of the appliances, when the electromagnetic interfering signals occur. Moreover, it provides information on the existence, size, and first of all, the location of PD occurrence. It should be stressed that the AE method does not substitute the electric and gas chromatography methods, but it shows an additional indicator of an insulation under study and thus it is an important complement [1, 2, 8-10]. Due to the higher and higher requirements as to the information obtained by using the AE method it has to be constantly developed and improved. The research carried out so far has focused mainly on the mathematical analysis and explaining the physics of generation and propagation mechanisms of the AE signals in various dielectrics and insulation systems. Also the measuring apparatus has been improved taking advantage of the development of electronics and computer technology. The current research is connected with digital processing of the AE signals measured and with application of the tools of statistical analysis and advanced numerical algorithms in PD evaluation. It also refers to determining such parameters, called descriptors, which would make it possible to correlate the measurement results with the types of defects that are the sources of discharges, and which would characterize the mechanisms of occurrence and the particular stages of PD development [3, 6].

One of the significant issues that should be taken into account during the interpretation of the results obtained is the possibility of the occurrence of various types of disturbances of the acoustic and electric character, which can affect a correct evaluation of the condition of the insulation measured. The subject matter of this paper refers to acoustic disturbances that can accompany the measurements of PDs occurring in paper-oil systems of power transformers taken in industrial conditions using the AE method.

The paper presents the results of measurements and frequency and time-frequency analyses using a continuous and discrete wavelet transforms of the acoustic signals generated by vibrations caused by loosened screws fastening metal plates forming a magnetic core of a transformer and loosened screws of the transformer tub lid. The results obtained in laboratory conditions were compared with the results obtained in industrial conditions. Moreover, the influence of the disturbances analyzed on the measurement results of the AE pulses generated by basic PD forms that can occur in paper-oil insulation systems was determined.

2. CHARACTERISTICS OF THE MEASURING APPARATUS USED AND METROLOGICAL CONDITIONS

The measurements of the acoustic interfering signals were taken in laboratory conditions, during a voltage test of a three-phase distributive transformer type TNOSI 400/15 PNS. The transformer under study had oil insulation and was of the following nominal data: power 400 kV·A, transformer voltage ratio 15.75 ± 2.5% / 0.4 ± 7.5% kV/kV, idle loss 780 W, load loss 4200 W, short-circuit voltage 4.5% and scheme of connections Dyn5. The range of the research work carried out included the measurements of the acoustic interfering signals in the following cases: loosened screws fastening the tub lid and loosened screws clamping the metal plates constituting the magnetic core, on which the transformer windings were placed [6].

In the second part of the research work the measurements and analyses of the acoustic emission signals generated during a regular operation of a loaded distributing transformer, as described above, were performed. The transformer under study was installed in an overhead switching station and supplied nineteen farms.

Next, a comparative analysis of the results obtained during the measurements taken in laboratory conditions with the results obtained during a regular operation of the transformer under study was carried out.

A standard system by the firm Brüel&Kjær, consisting of the following elements: a wide-band contact piezoelectric transducer, an amplifier equipped with a linear filter, and a measuring card, was used for the measurement of the AE signals. A detailed characteristics of the measuring apparatus used and a description of the computational procedure have been shown, among others, in works [3, 6].

3. COMPARATIVE ANALYSIS OF THE FREQUENCY TRANSFORMATIONS OF THE INTERFERING ACOUSTIC SIGNALS GENERATED IN LABORATORY AND INDUSTRIAL

Figs 1-4 show the runs: of the amplitude spectra (Figs 1, 3) and energy density spectra (Figs 2, 4) of the acoustic signals generated by the interference sources under study, respectively. The characteristics in Figs 1-2 show the runs obtained for the interfering signals generated by the vibrations of the tub lid that occurred at loosened fastening screws. Figs 3-4 show the runs obtained for the disturbances of an acoustic character, generated by loosened sheet packs constituting the magnetic core of the transformer.

For the purpose of comparison, Figs 5-6 show the results of the frequency analysis of the acoustic signals emitted during a regular operation of the distributing transformer under study.

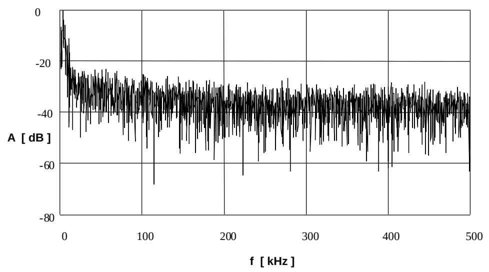


Figure 1 Amplitude spectrum run obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the cover of the tank.

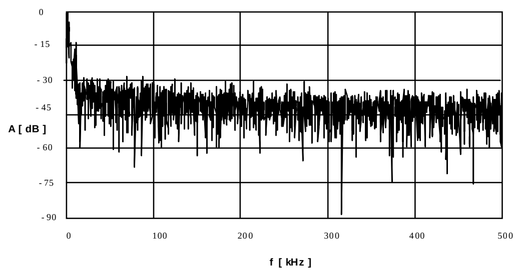


Figure 3. Amplitude spectrum run obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the core are loose.

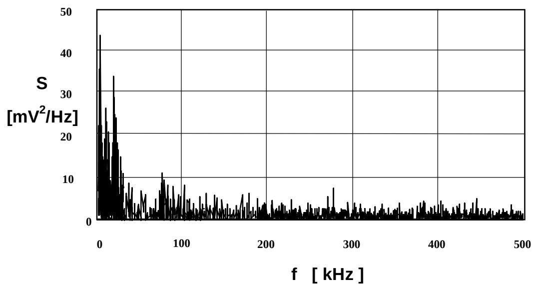


Figure 2. Energy density spectra run obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the cover of the tank.

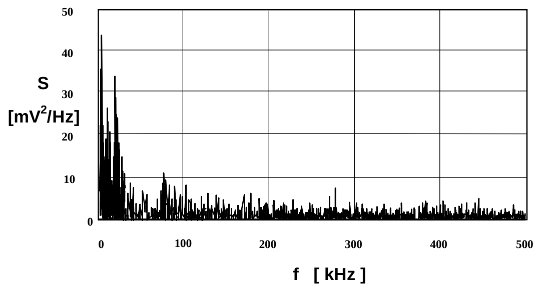


Figure 4. Energy density spectra run obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the core are loose.

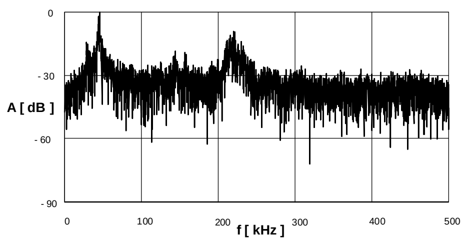


Figure 5. Amplitude spectrum of a series of AE pulses generated by the transformer.

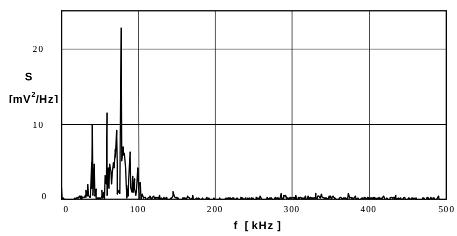


Figure 6. Energy density spectrum of a series of AE pulses generated by the transformer.

4. COMPARATIVE ANALYSIS OF THE WAVELET TRANSFORMATIONS OF THE INTERFERING ACOUSTIC SIGNALS GENERATED IN LABORATORY AND INDUSTRIAL CONDITIONS

Figs 7-10 show the results of the wavelet analysis of the interfering signals registered. Figs 7 and 8 show scaling graphs calculated by using a CWT for the acoustic interfering signals generated by the loosened screws fastening the lid of the transformer tub (Fig. 7) and by the loosened screws fastening the transformer core (Fig. 8). Figs 9 and 10 show the results of the wavelet decomposition obtained by using a DWT, which were supplemented with the power diagrams for the interfering signals analyzed.

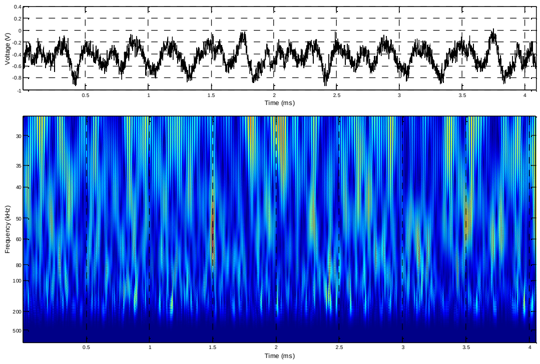


Figure 7. CWT obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the cover of the tank.

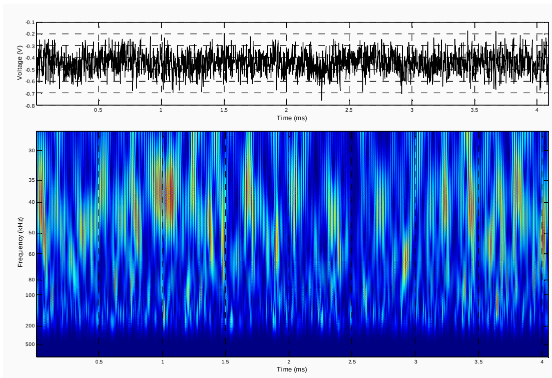
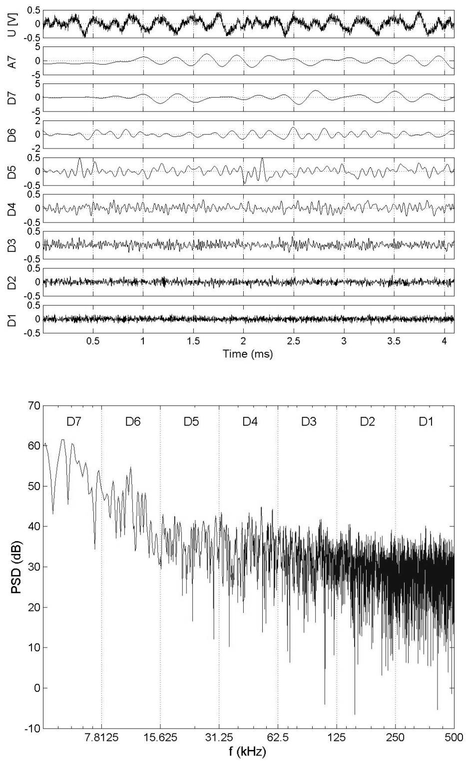
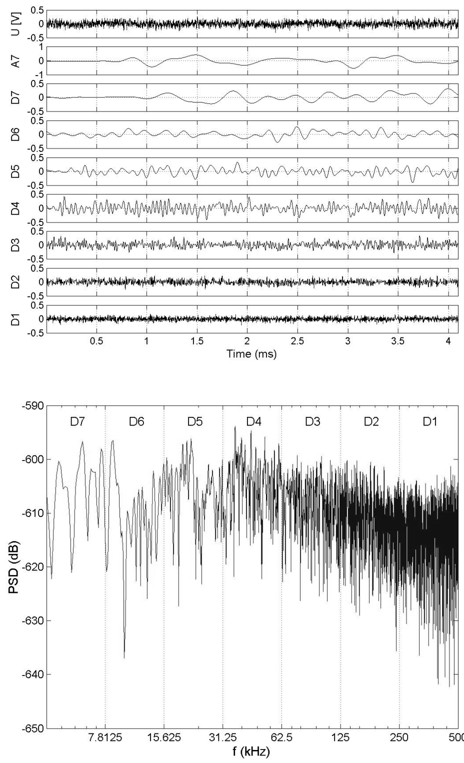


Figure 8. CWT obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the core are loose





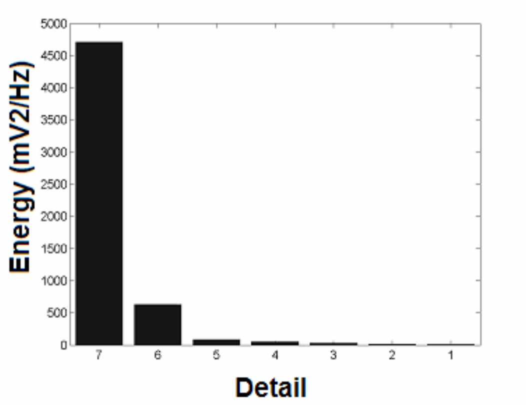


Figure 9. DWT, PSD and power diagrams obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the cover of the tank.

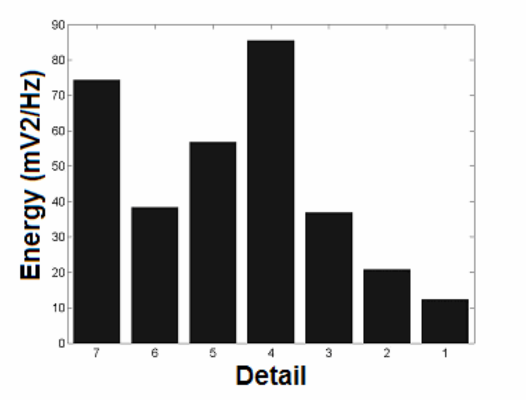


Figure 10. DWT, PSD and power diagrams obtained for the acoustic interfering signals generated by the distributive transformer when the screws fastening the core are loose.

Figs 11-12 show the results of the wavelet analysis of the acoustic emission signals generated during a regular operation of the distributing transformer under study.

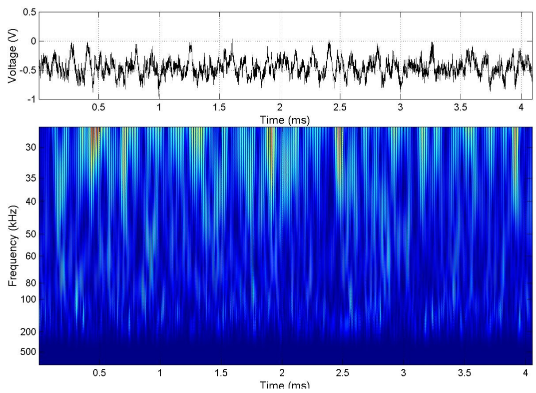
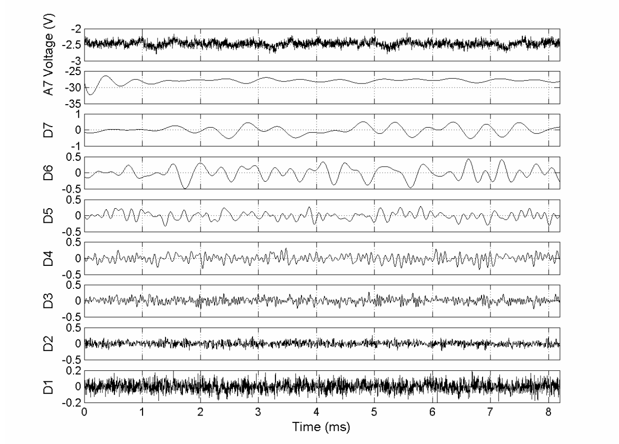


Figure 11. CWT of a series of AE pulses generated by the transformer.



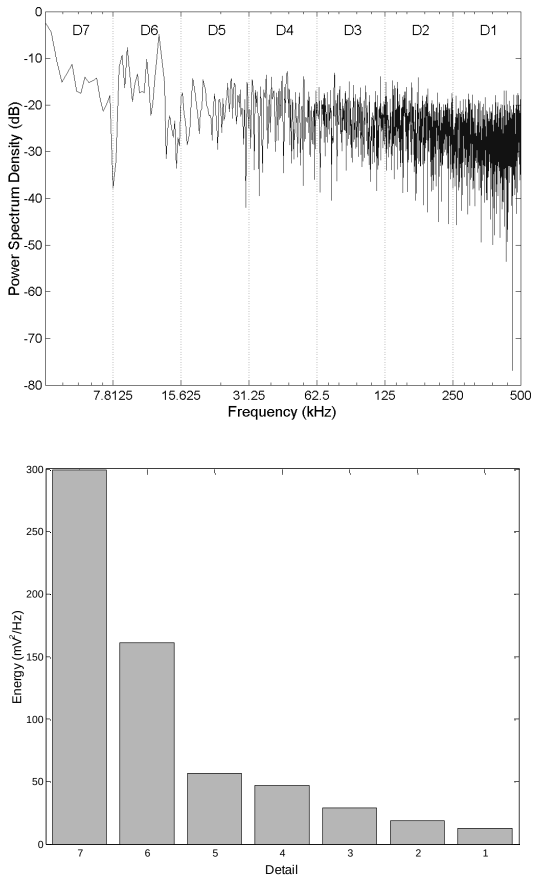


Figure 12. DWT, PSD, the value of the energy transferred of a series of AE pulses generated by the transformer.

Based on the results of the frequency and time frequency analyses carried out of the AE pulses generated in the insulation system of the transformer under study, the following conclusions can be drawn:

- the change of the location place of the transducer within the tub area of the transformer under study did not influence the AE results obtained. The value of the mutual correlation coefficient, calculated for the time runs, frequency characteristics and time-frequency structures of the AE pulses registered, at the changes of the location place of the transducer, for both transformers, was above 0.93;

- the ranges of dominant frequencies, determined for the discrimination threshold equal to 10 dB, were in the range (0÷40) kHz. Acoustic interfering signals coming from corona discharges and Barkhausen noises, caused by the transformer operation in the state of load, are contained within these frequency bands. Moreover, the increase of the values of the frequencies transferred in the range from 50 to 120 kHz can be observed for frequency characteristics and time-frequency images calculated for the AE pulses registered. This can testify to the increasing influence of the AE generated by PDs, since the ranges of dominant frequencies in the spectrum occur in this range for all basic PD forms [3, 6]. It also suggests that the transformer of a long operation time, which was subject to regular periodical check-ups, can be still operated from the point of view of PD occurrence in its insulation system. The allowable level of PDs generated in the transformer tub was confirmed additionally during the examinations carried out by using the electrical and gas chromatography methods [4].

5. COMPARATIVE ANALYSIS OF THE ACOUSTIC EMISSION PULSES GENERATED BY PARTIAL DISCHARGES AND THE INTERFERENCE SOURCES UNDER STUDY

Six basic PD forms that can occur in insulation oil were selected for the comparative analysis with the interference sources under study. The research work carried out referred to PDs generated in the systems that enable modeling of the following discharge types: point – plane, multipoint – plane, multipoint – plane with a layer of pressboard, surface, in gas bubbles, on particles of an indefinite potential. A detailed characteristics of the conditions in which the experiments were performed and the results of the frequency and time-frequency analyses carried out of the AE pulses generated by the PD forms have been presented, among others, in works [3, 6].

A comparative listing of the results of the frequency and time – frequency analyses of the AE pulses generated by the PD forms under study and the acoustic interfering signals and AE pulses generated by the transformer are shown in Fig. 13, on which the ranges of the dominant frequency bands have been shown in the form of columns. The dependencies in Fig. 13 have been determined for power density and energy spectra and for scaling graphs finlandia].

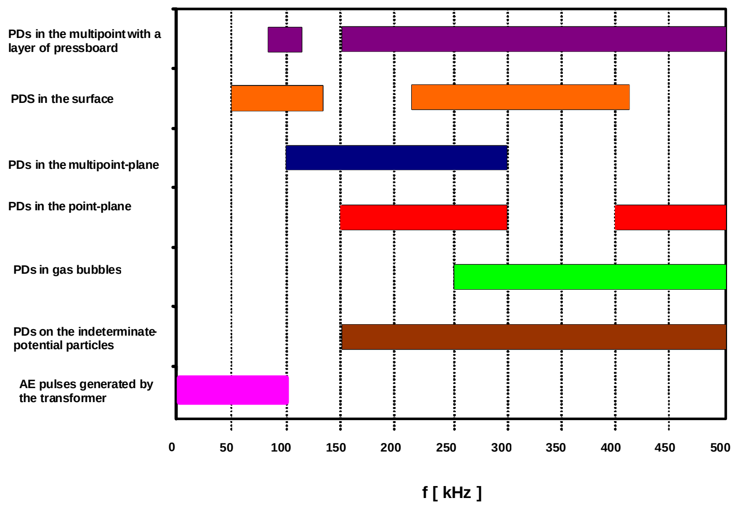


Figure 13. Comparative listing of dominant frequency bands for the AE pulses from PDs in oil and for the acoustic interfering signals and AE pulses generated by the transformer.

6. CONCLUSIONS

During the analysis of the results obtained at diagnostic measurements of insulation systems of power transformers taken by using the AE method, the influence of the interfering signals should be taken into account as their bands of dominant frequencies overlap the spectra of the measured AE pulses generated by PDs. The resultant interval of dominant frequencies for the interfering signals measured, for the discrimination threshold -20 dB, should be assumed in the range from 0 to 50 kHz. In order to eliminate the influence of the analyzed interference of the acoustic character, a high-pass filter of the low frequency equal to

50 kHz or numerical procedures making a digital filtration of the AE signals registered possible can be used [6]

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