The Application of Modern Signal Processing Methods in the Acoustic Emission Method for the Measurement of Insulation Systems of Power Transformers

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Abstract. The subject matter of this paper refers to the improvement of the use of the acoustic emission (AE) method in diagnostics of paper-oil insulation systems of power appliances. The paper will present modern processing methods of the AE signals registered during diagnostic measurements of power transformers. First of all, the results of the time-frequency analysis using a short-time Fourier transform and continuous and discrete wavelet transforms will be presented. Additionally, there will be presented power diagrams, autocovariance function runs and power density spectra for the wavelet decomposition levels calculated. In Summing-up there will be presented a comparative analysis of the results obtained by using a standard fast Fourier transform (FFT) and the results of the wavelet transformations of the AE pulses measured. Moreover, the advantages of the signal processing using time-frequency analyses will be brought into prominence and potential possibilities of their application in power engineering will be indicated.

1. Introduction

The subject matter of this paper refers to the improvement of the use of the acoustic emission (AE) method in diagnostics of paper-oil insulation systems of power appliances.

The paper will present modern processing methods of the AE signals registered during diagnostic measurements of power transformers. First of all, the results of the time-frequency analysis using a short-time Fourier transform and continuous and discrete wavelet transforms will be presented. Additionally, there will be presented power diagrams, autocovariance function runs and power density spectra for the wavelet decomposition levels calculated. In Summing-up there will be presented a comparative analysis of the results obtained by using a standard fast Fourier transform (FFT) and the results of the wavelet transformations of the AE pulses measured. Moreover, the advantages of the signal processing using time-frequency analyses will be brought into prominence and potential possibilities of their application in power engineering will be indicated.

2. Characteristics of the transformers, measuring apparatus and metrological conditions under study

The measurements of the AE pulses were taken during the voltage testing of a triphase distributive transformer type TAO 400/10 with oil insulation, which has been in operation since 1975. The rated power of the transformer was 400 kV·A, transformer voltage ratio 10.5 / 0.4 kV/kV, and the connection system Dyn5.

The scope of the research work carried out included the measurements of the AE signals taken with a wide-band contact piezoelectric transducer by the firm Brüel&Kjær, which was attached to the tub of the transformer analyzed with a special magnetic grip. Comparative measurements were also taken changing the place of the transducer attachment within the surface of all the sides, and also on the tub lid. Cup grease was used as a substance coupling the transducer with the tub surface. The AE pulsed measured were amplified and initially filtered; next they were registered with a measuring card working with a personal computer. A detailed characteristics of the measuring apparatus used is presented in works [4-8]. Numerical algorithms written in the programs Mathcad 2001 and Matlab 6.0 were used for the analysis of the AE signals measured and visualization of the results obtained. The AE signals registered were subject to the frequency analysis consisting in calculating a STFT and then determining two- and three-dimensional amplitude and power density spectrograms. The time-frequency analysis was supplemented with wavelet transformations using a continuous and discrete wavelet transform.

3. Results of frequency analysis

Amplitude and energy density runs for the AE signals, measured in the middle of a side wall of the transformer tub were selected for graphic presentation in this paper. For the transformer under study, regardless of the supplying voltage polarization, similar shapes of their frequency characteristics (minimum value of the mutual correlation coefficient was 0.96) were obtained for the AE pulses generated in both half-periods. Therefore in Figs 1-2 the results obtained only for the positive voltage polarization have been presented.

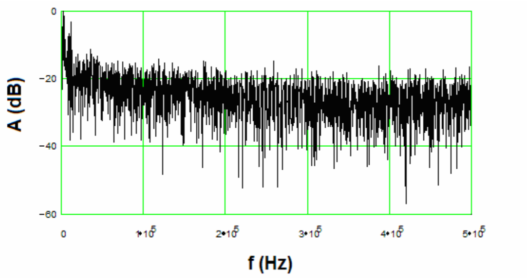

Figure 1. Amplitude spectrum of a series of AE pulses generated by the transformer

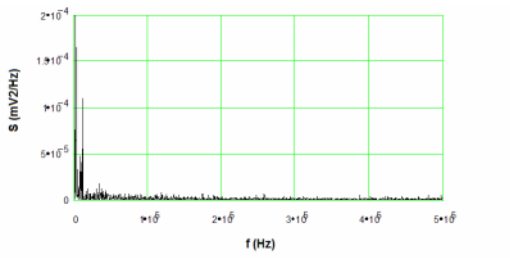

Figure 2. Energy density spectrum of a series of AE pulses generated by the transformer

4. Results of time-frequency analysis

Figs 3-7 show the results of the time-frequency analysis of the AE pulses registered for the conditions defined in Chapter 3. Fig. 3 shows a scaling graph calculated by using a CWT. Two- and three-dimensional spectrograms calculated by using a STFT are shown in

Figs 4-6. The wavelet decomposition results obtained by using a DWT are shown in Fig. 7, where, additionally, a power density spectrum and a column diagram visualizing the size of the energy transferred by the particular details have been included. Moreover, probability density function runs (Fig. 8) and the autocovariance diagram (Fig. 9) have been determined for each detail.

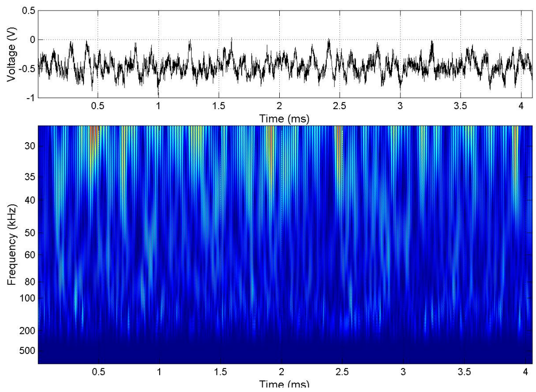

Figure 3. CWT of a series of AE pulses generated by the transformer

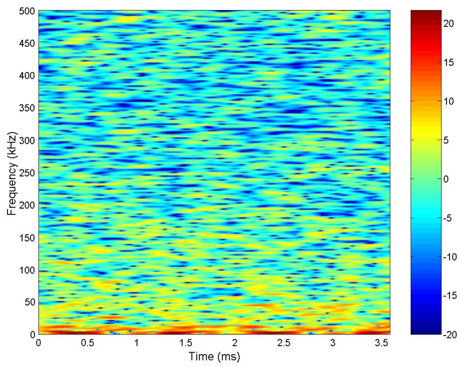

Figure 4. Spectrogram of a series of AE pulses generated by the transformer

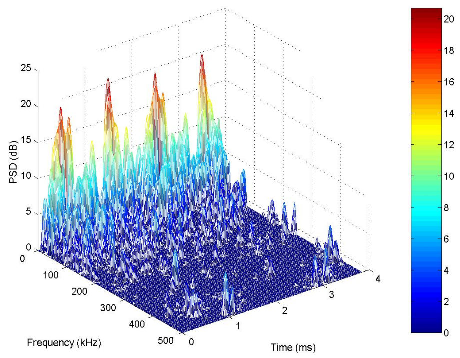

Figure 5. Three-dimensional spectrogram of power spectrum density of a series of AE pulses generated by the transformer

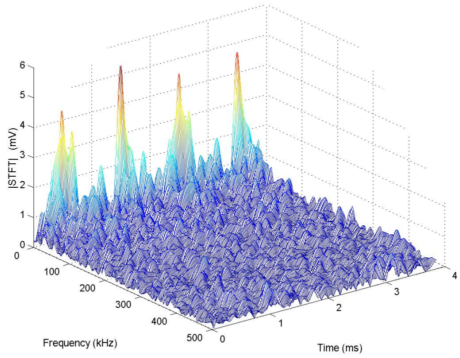

Figure 6. Three-dimensional spectrogram of amplitude spectrum of a series of AE pulses generated by the transformer

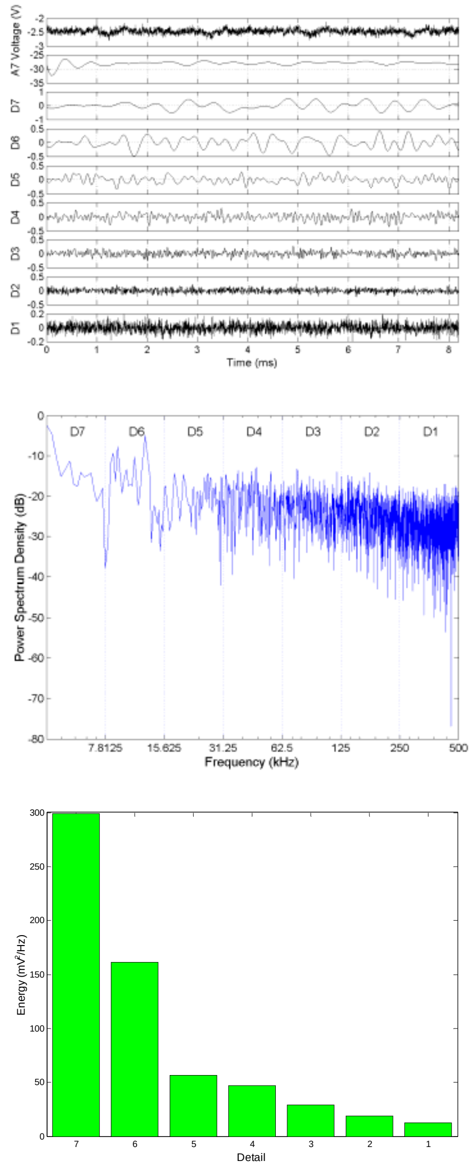

Figure 7. DWT, PSD, the value of the energy transferred of a series of AE pulses generated by the transformer

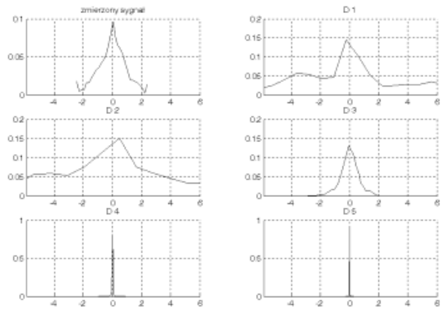

Figure 8. Probability Density Function (PDF) of a series of AE pulses generated by the transformer

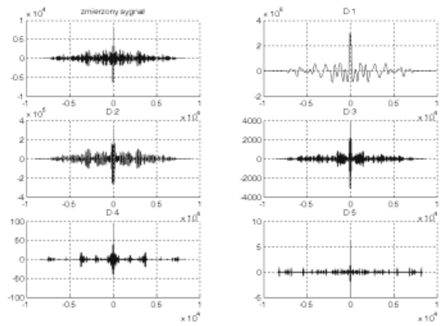

Figure 9. The autocorrelation function (ACF) of a series of AE pulses generated by the transformer

5. The analysis of the results obtained

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 [4-8]. 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.

6 . Summing-up

Within the research work carried out the AE pulses generated in a power transformer tub were measured and subjected to frequency and time-frequency analyses. The results obtained confirm the occurrence of the acoustic interfering signals, the dominant frequency bands of which overlapped the spectra of the AE pulses generated by PDs. Therefore it is necessary to eliminate the disturbances by using a properly selected analogue filter in the measuring path or using numerical procedures that enable a digital filtration of the AE signals measured. Modern computer programs, used for signal processing, contain bases of standard digital filters, which can be used for eliminating disturbances. Moreover, the occurrence of the AE pulses generated by PDs of a low intensity, the amplitude level of which was lower than the value of the given discrimination threshold, was observed. This was confirmed during examinations carried out by using the electrical and gas chromatography methods. The methods of digital processing of signals, presented in this paper, can be used for evaluating all processes that are accompanied by the acoustic emission generation.

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