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Time-frequency Analysis of the Calibrating Signals Generated in the Hsu-Nielsen System

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This paper characterizes the idea of calibrating measurement paths, which make the measurement of the acoustic emission (AE) pulses generated by partial discharges (PDs) in insulation of power appliances possible, by using the Hsu-Nielsen method. It also presents the results of the analyses done in the time and frequency domains of the measured AE pulses generated by the Hsu-Nielsen calibrating source. The measurement and analysis of the AE pulses were performed on the lid of the distributive transformer tub.

Keywords: AE pulses, discharge, optical and acoustic signals, acoustic emission and optical spectrophotometry, gap modeling.

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Introduction

The results of the AE measurements provide electrical quantities (e.g. voltage) the values of which do not make it possible to determine the absolute value of a pulse registered. It often happens that it is not possible to measure the size of an AE signal in the place of its generation. It is usually so because the source of the AE is as a rule inside the dielectric under study, which causes that when a signal reaches a transducer it is suppressed and reflected many times. Moreover, the medium coupling a transducer with an insulation system under study can cause the suppression of the primary signal. Also the measuring system introduces some indeterminacy of the signal registered in relation to the signal in the place of generation. All these are incentives for taking quantitative measurements of the AE based on relative measurements. Quantitative measurements consist in comparing the pulses under study with model signals generated by artificial sources. A theoretical study of this issue was given by Breckenridge [1].

The calibration signal should be characteristic of the parameters determined in the time and frequency domains and be as close to the AE signal generated by PDs as possible. The most proper calibration methods are the methods that make it possible to produce a pulse of strictly determined and repeatable AE parameters, which are easy to produce in laboratory conditions. They provide the possibility to compare the results obtained in various laboratories dealing with measurements and analyses of the AE signals. Calibration of the apparatus also becomes vital when the AE measurements are taken in a costly or unrepeatable experiment.

Such a method is the method developed by Hsu-Nielsen. It is a simple and easy method to apply and it does not require any complex auxiliary apparatus or training people taking the measurements. The calibrating device comes down to making a proper head, automatic pencil and marking points of 2H hardness and the gauge of 0.5 mm. The calibration signal is generated in the Hsu-Nielsen system at the moment of breaking a sensitive graphite pin cased by a properly adapted tip put on the automatic pencil. The head and the marking point pulled out to 3 mm ensure the same breaking angle at each test, which also means generation of a repeatable acoustic surface wave. This method is classified as one of the pulse calibration methods.

This method found its application in calibration of the AE detectors in the process of their production. Owing to its simplicity it is used for calibration of measuring systems installed in technical conditions. It was also standardized.

The calibration head was made based on the data from the literature [3]. The photo of the head is shown in Fig. 1. Following the draft the head was made from methyl polymethacrylate. This material guaranties durability and constancy of the required shape and measurements of the head. The head was turned from a rod of the diameter of 7 mm. After giving the head the required shape and measurements, a concentric opening of the diameter of 0.9 mm was bored. Such calibration heads comply with the requirements described by the French standard NF – A 09-350, 'Non-destructive tests, vocabulary used in AE'. Fig. 2 shows an overall view of the transducer calibrated and installed on the transformer.

The scope of the research work carried out, the results of which are presented in this paper, comprised the measurements of the AE signals generated by

Fig. 1. Hsu-Nielsen calibration head.

Fig. 2. Overall view of the transducer calibrated by the Hsu-Nielsen method, installed on a transformer.

calibrating heads made according to the guidelines defined by Hsu-Nielsen and the analysis of the AE signals measured in the time and frequency domains.

I. The results of the time-frequency analysis of the AE pulses generated by the Hsu-Nielsen calibrating source

Figures 3 – 8 show the analysis results of the AE method generated by a Hsu-Nielsen calibrating source, carried out in the time, frequency and time-frequency domains. Fig. 3 shows a time run of the AE pulses registered, and Figs. 4 and 5 present the results of the frequency analysis in the form of amplitude (Fig. 4) and energy density (Fig. 5) spectra. The time-frequency analysis was carried out using a short time Fourier transform (STFT), and its results are shown in Figs 6-8. Fig. 6 shows a two-dimensional spectrogram, and Fig. 7 and 8 show three-dimensional spectrograms of the energy density spectrum (Fig. 7) and the amplitude spectrum (Fig. 8).

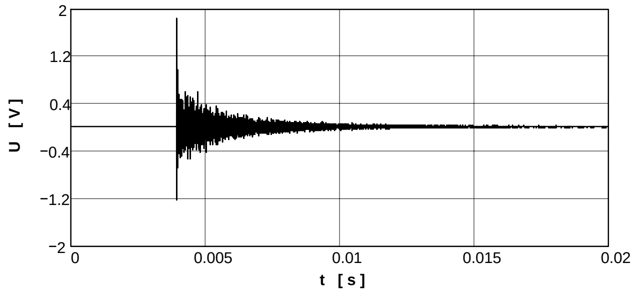


Fig. 3. Time run of the model AE pulses generated by the Hsu-Nielsen calibrating source.

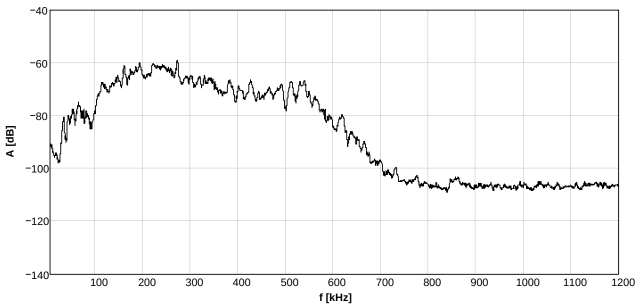


Fig. 4. Amplitude spectrum of the model AE pulses generated by the Hsu-Nielsen calibrating source.

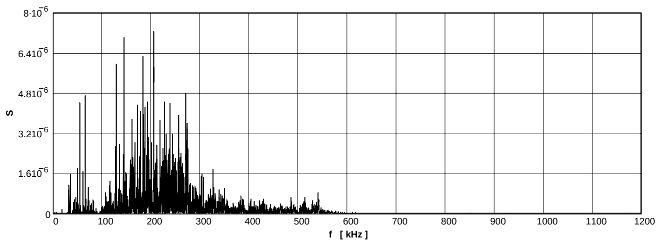


Fig. 5. Spectral energy density of the AE pulses generated by the Hsu-Nielsen calibrating source.

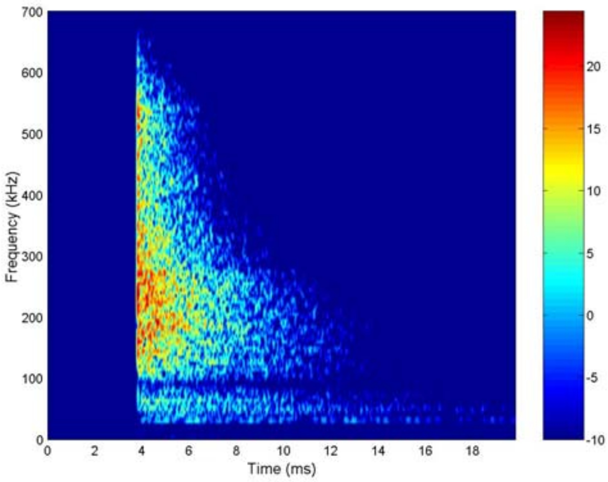


Fig. 6. Spectrogram calculated for the AE pulses generated by the Hsu-Nielsen calibrating source.

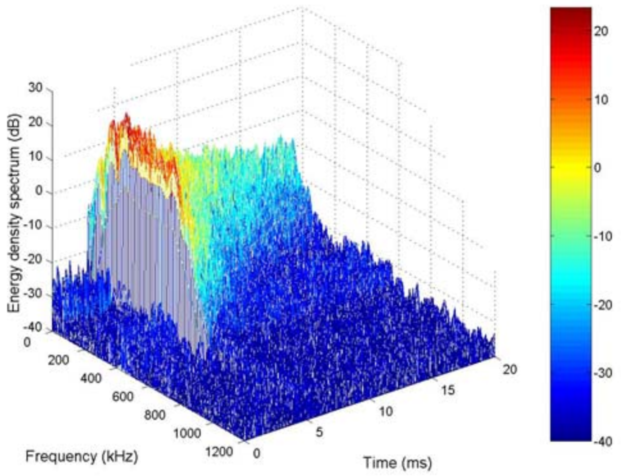


Fig. 7. Three-dimensional spectrogram of power spectrum density calculated for the AE pulses generated by the Hsu-Nielsen calibrating source.

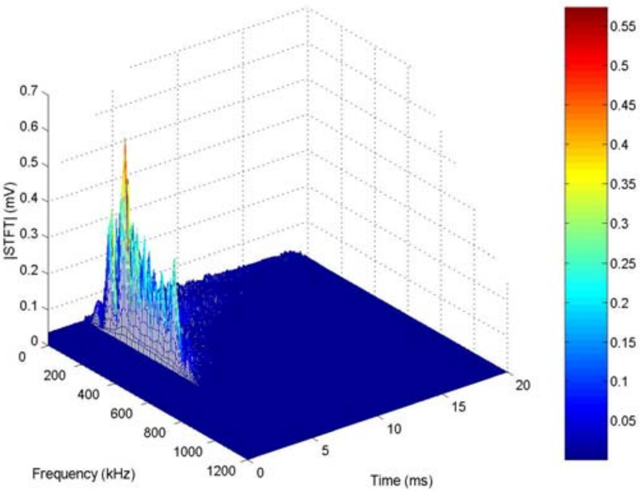


Fig. 8. Three-dimensional spectrogram of amplitude spectrum calculated for the AE pulses generated by the Hsu-Nielsen calibrating source.

Figure 9 shows a scalogram determined by using the continuous wavelet transform (CWT), of the AE pulses generated by the Hsu-Nielsen calibrating source.

The results of the multiresolution analysis obtained for the AE pulses generated by the Hsu-Nielsen calibrating source are shown in Fig. 10. This figure presents in order: original time runs of the AE pulses generated by the Hsu-Nielsen calibrating source, approximation A on the seventh decomposition level, and details D on the levels from 1 to 7, then power density spectra (PSD) runs and columnar diagrams visualizing the size of the energy transferred by the particular details.

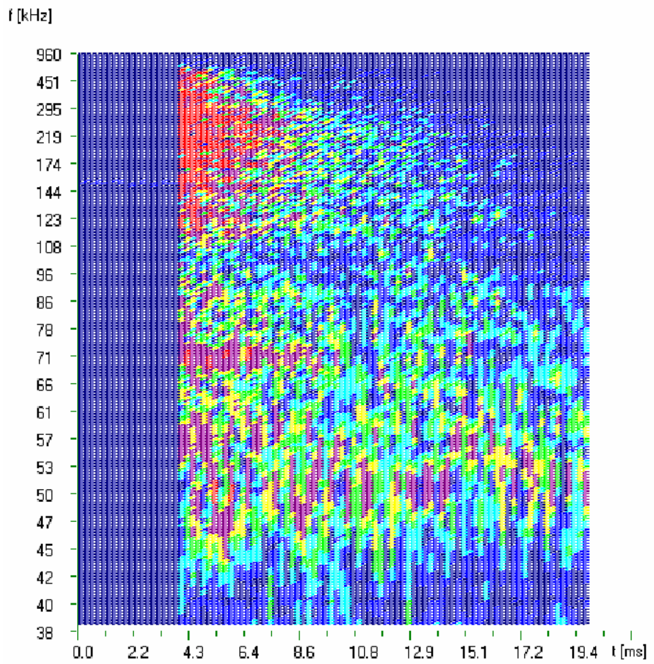
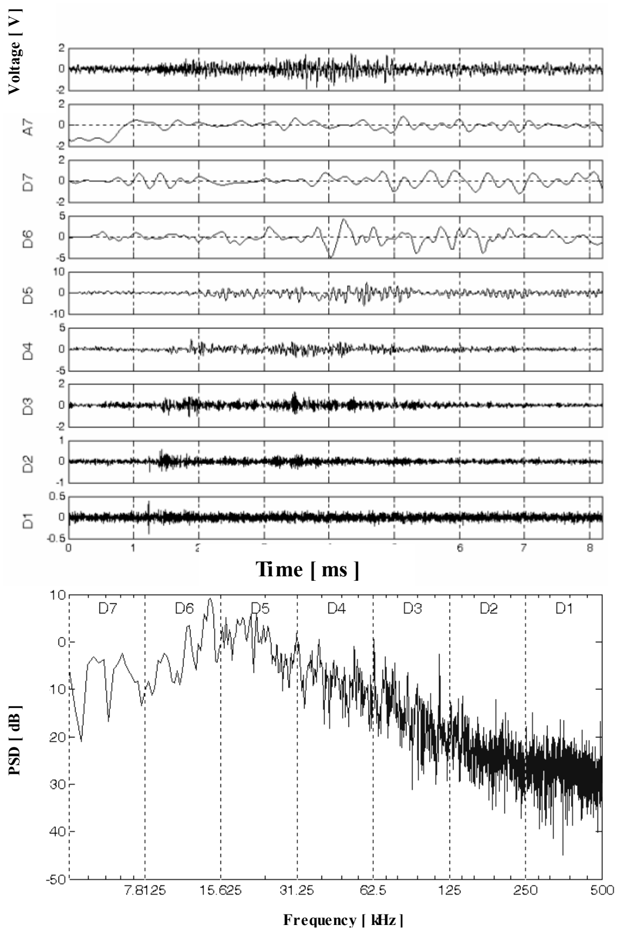


Fig. 9. CWT of a series of AE pulses generated by the Hsu-Nielsen calibrating source.



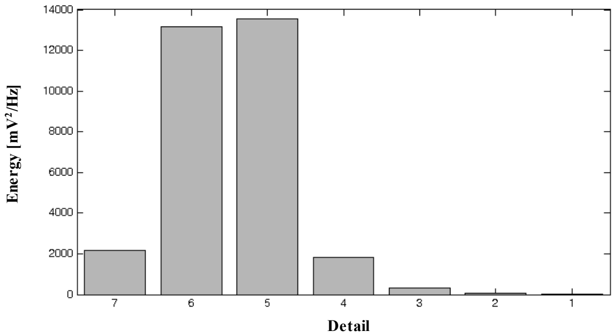


Fig. 10. DWT, PSD, the value of the energy transferred of a series of AE pulses generated by the Hsu-Nielsen calibrating source.

Summing-up

Analyzing the results of the time-frequency analysis of the AE pulses generated as result of breaking a draw point in the Hsu-Nielsen calibrating head it can be observed that: the frequency spectra obtained are of a wide band of dominant frequencies in the range from 40 kHz to 600 kHz (Figs 4-5), and the biggest energetic participation is that of the frequencies in the range (100-350) kHz for the first 4 ms of a signal (Figs 6-10). The results of time-frequency analyses obtained for acoustic calibrating signals generated in the Hsu-Nielsen system coincide with the results obtained for the AE pulses generated by basic PD forms in oil-paper insulation systems of power appliances. Therefore the Hsu-Nielsen method can be used for calibrating measuring paths that are used in the acoustic method of insulation system diagnostics.

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Т. Бохцар, М. Лоренс

Частотний аналіз калібрувальних сигналів, які вимірюють за методом Hsu-Нільсена

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В даній роботі досліджується ідея калібрування для вимірювання пульсів акустичної емісії (АЕ), вироблюваних частковими розвантаженнями (Фунти) в ізоляції енергетичних побутових приладів, використовуючи метод Hsu-Нільсена. Він також представляє результати аналізів, зроблених в часовій і частотні області вимірювальних пульсів АЕ, вироблюваних Hsu-Нільсена, калібруючого джерела. Вимірювання і аналіз пульсів АЕ виконувалися на кришці розподільчої ємності трансформатора.