INDICATION OF PARTIAL DISACHARGES BY MEANS OF THE ACOUSTIC EMISSION METHOD

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ABSTRACT

The present paper deals with a method of tracking the partial discharges using the acoustic emission method. The quantity under study was the overshoot counting rate in acoustic emission signals. The subject of the experiment was a high-voltage generator rod, which had been provided with RELANEX insulation.

KEYWORDS
Acoustic Emission (AE), High Voltage, Partial Discharges

EXPERIMENT SETUP

An automated measuring setup (see Fig. 1) was used to carry out the measurements. High voltage supplied by a 0 to 10 kV high-voltage DC power supply was applied to the specimen. Acoustic signals, which were generated in the RELANEX insulation layer, were picked up by B&K wide-band sensors. The sensor output signal was fed into an acoustic emission analyzer, to be amplified in a frequency range from 10 kHz to 1 MHz. The analyzer output signal was split into two branches. The first branch included BM 520 voltmeter and BM 640 counter, which recorded the AE overshoot counts exceeding the predefined level. The second branch included a DL 912 transient recorder, which was used to sample the AE time-domain realizations, whose magnitude exceeded the pre-set voltage level.

The experiment was controlled by a PC series computer. To control the measuring instruments, it was extended by an GPIB (IEEE – 488) bus securing the transmission of data (overshoot count during a preset time interval from the counter and time-domain realizations from the transient recorder) to the computer memory.

The experiment setup is shown in Fig. 2. The test specimen o dimensions 12 mm × 36 mm × 1000 mm was made of structural steel. A RELANEX 45750 insulating tape made by Elektroizola Tábor, was helically wound up on the test specimen with a half-pitch overlap, so that the resulting insulation layer thickness amounted to 1.9 mm. The insulation was cured in a mould in a pressing machine at a temperature of 165°C for two hours. During the curing temperature rise interval, the insulation was tightened at a temperature of 110°C, with a 22 % to 28 % compressibility. The insulated rod was further cured at a temperature of 130°C for 16 hours. A measuring electrode of a length of 100 mm, made of a SIB 643 grade semi-conducting varnish was deposited on the central part of rod. The B&K wide-band sensor was placed 12.5 cm apart from the rod center line.

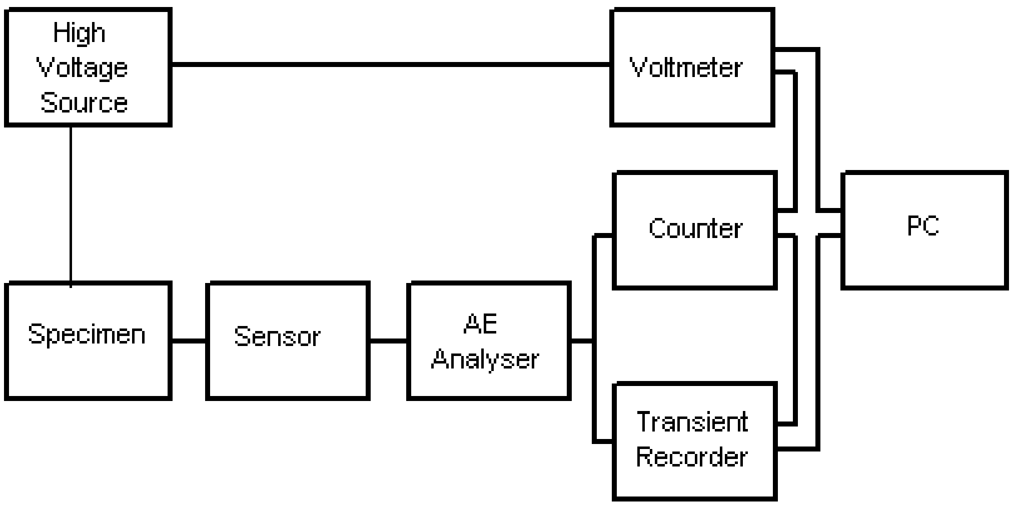

Fig. 1 Measuring apparatus diagram

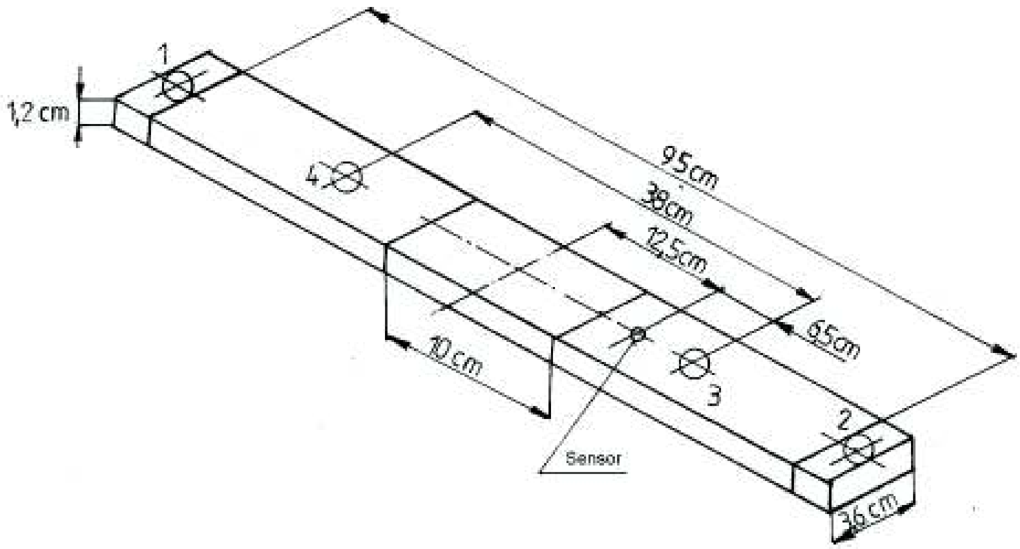

Fig. 2 Test specimen

MEASUREMENT RESULTS

It is evident from the measurement results that the shape of the AE signal overshoot count depends on the load voltage ramp time rate. The respective curve is shown in Fig. 3.

As is seen in the diagram, there is an abrupt growth in the overshoot count in the time interval from 10 s to 15 s. These acoustic signals are apparently due to the process of setting the high voltage to 10 kV (the *U* curve). A section with an exponential growth of the overshoot count follows. Another abrupt overshoot count growth occurs again in the time interval from 1080 s to 1095 s, which corresponds to the high voltage fall from 10 kV to zero. An exponential growth of the overshoot count continues up to the measurement end. The high voltage setting time interval being excluded, the obtained AE cumulative overshoot count versus time plot b can be approximated by the following exponential function:

$$N = 277.6 \cdot \exp(8.733 \cdot 10^{-4} \cdot t) \qquad (1)$$

where *N* is the overshoot count and *t* is the time in seconds.

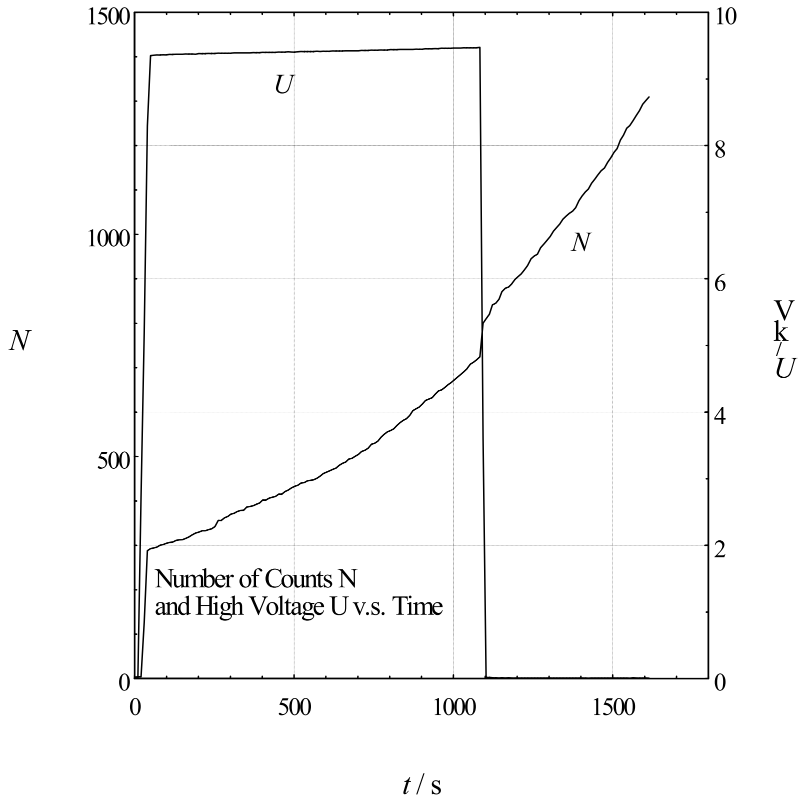

Fig. 3 Cumulative overshoot count versus time plot

A similar diagram is presented in Fig. 4, showing the measurement results for a slower growth of the load ramp voltage (the *U* curve).

The initial staircase-like growth of the overshoot count (the *N* curve) is apparently due to the high voltage growth process. After the maximum voltage of 10 kV is achieved, the growth of the overshoot count is smooth (exponential) up to the attainment of zero voltage. The local steep growth occurring in the time interval from 920 s to 950 s is apparently due to external interference.

The next Fig. 5 presents the AE signal versus time plots as sampled by the DL 912 transient recorder. The time-domain realization of Fig. 5a corresponds to a load voltage of 7 kV, that of Fig. 5b to 9.5 kV. It follows from the comparison of these diagrams that the pulse rise time is shorter for the higher load voltage. Rise times of 22 μs and 61 μs correspond to high voltage 9,5 kV and 7 kV, respectively.

Simultaneously with the above measurements, we addressed the AE signal source localization problem. To this end, we used LOCAN 320 measuring instrument, which has the capacity of processing four channel signals. Four B&K (f_{res} = 250 kHz) resonance sensors were used to pick up the acoustic emission response signals. They were positioned on the rod according to Fig. 2 (1 through 4). Sensors No 1 and 2 were installed at the metallic ends of the rod, whereas sensors No 3 and 4 at the insulated central part of the rod.

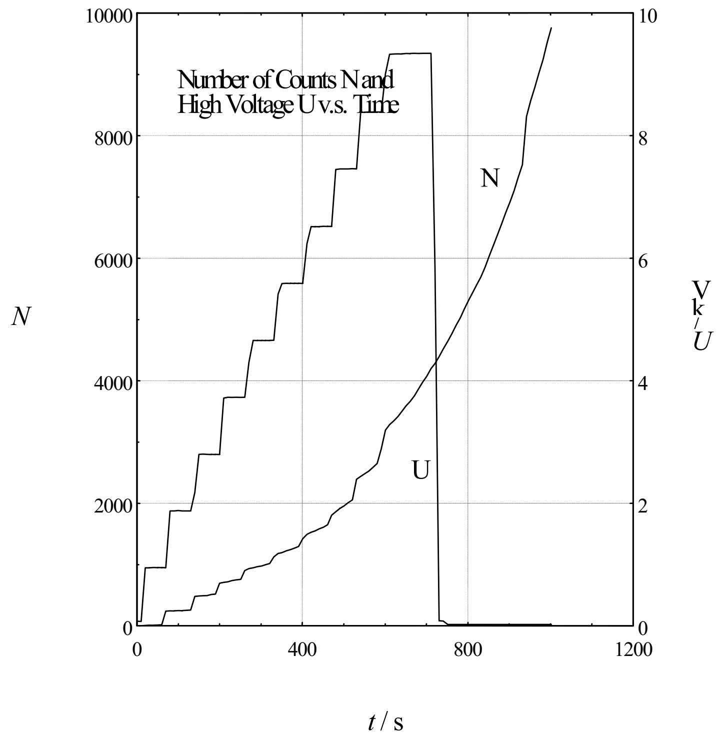

Fig. 4 Cumulative overshoot count versus time plot

The localized AE sources and the corresponding AE signal counts are shown in Fig. 6. The top curve corresponds to sensors No 3 and 4, which were mounted at the insulated central part of the rod. The bottom curve corresponds to sensors No 1 and 2 mounted at the rod metallic ends.

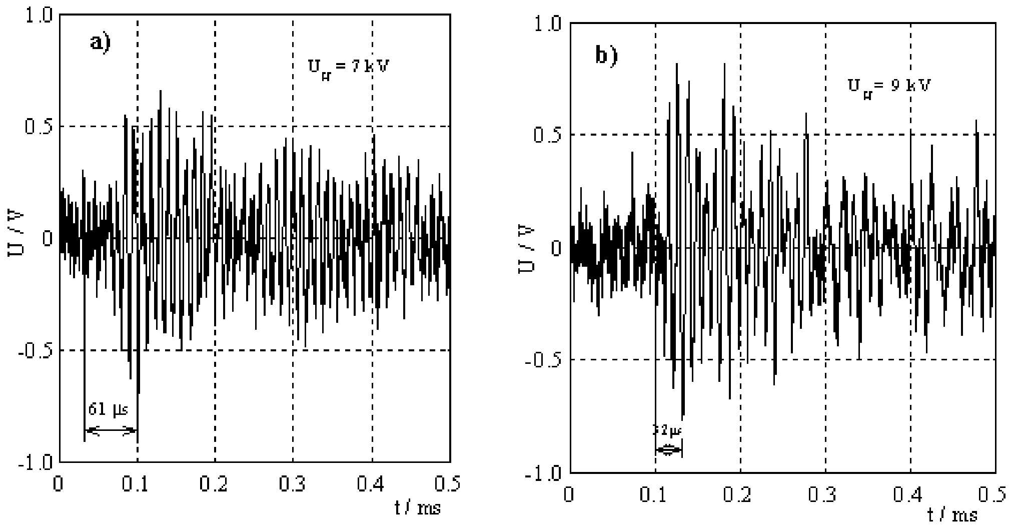

Fig. 5 AE signal time-domain realization

Fig. 7 shows the AE overshoot count versus time plot, the AE signals being picked up from all four resonance sensors simultaneously. It is seen in the Figure that the highest overshoot count is achieved for the load voltage changes which is in a good agreement with Fig. 3, corresponding to the wide-band sensor output.

Fig. 11 shows the duration of the analyzed acoustic signal at various time instants. It is seen that the duration of most signals is of the order of some tens of microsecond, the maximum duration is 1,6 ms.

The distribution of the acoustic phenomenon frequency, as recorded by the various channel sensors, is shown in Fig. 8. It is evident that the highest overshoot count was picked up by sensor No 2, which was placed at the metallic end of the rod.

Fig. 9 represents the amplitude of the acoustic signals as captured at various time instants. Maximum amplitudes were achieved when the high voltage was growing. The average frequencies of the captured acoustic signals are shown in Fig. 10. The channel frequency ranges from 3 kHz to 1 MHz. The maximum signal count corresponds to 300 kHz, which is the sensor resonance frequency.

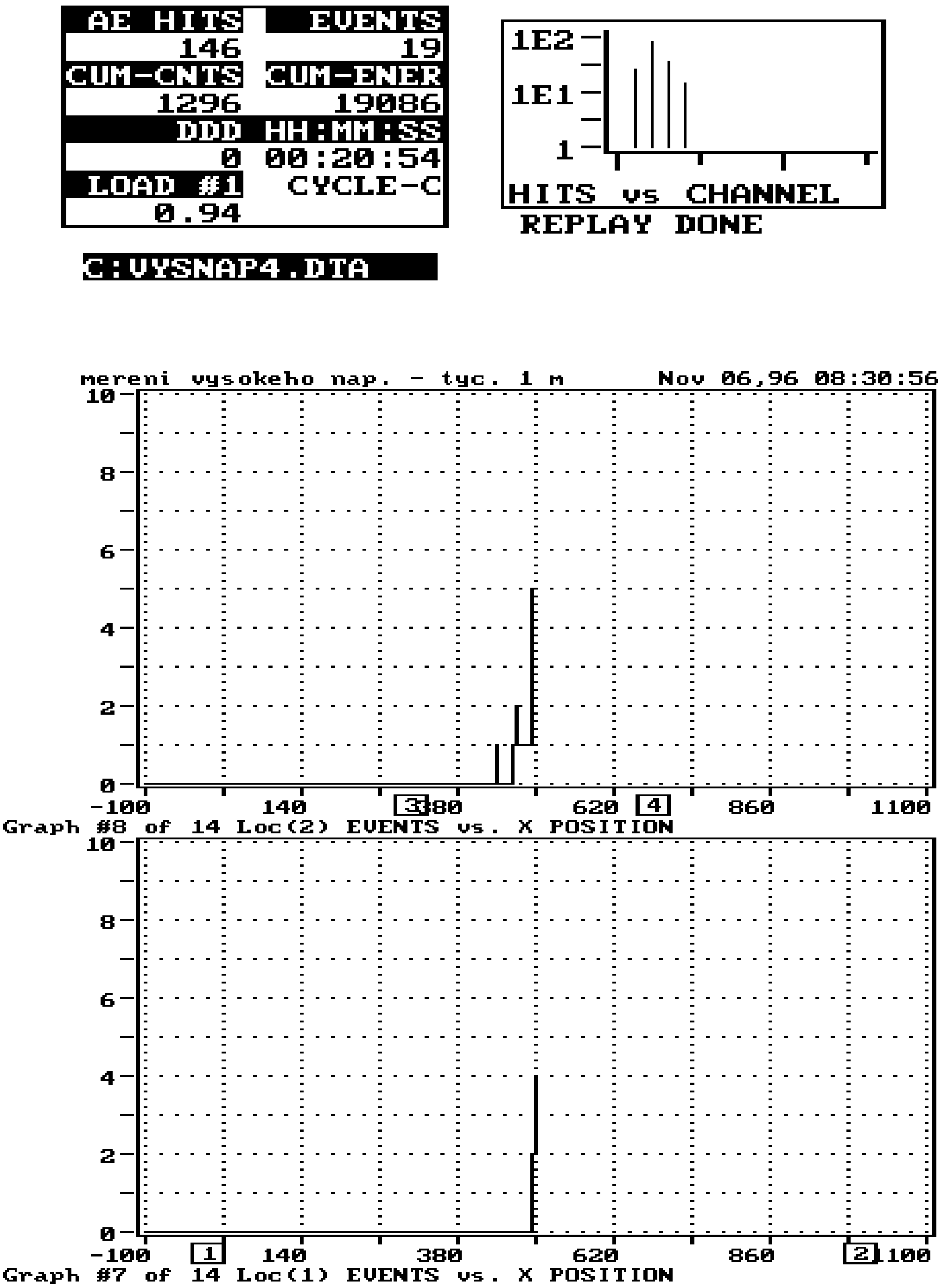

Fig. 6 AE source localization

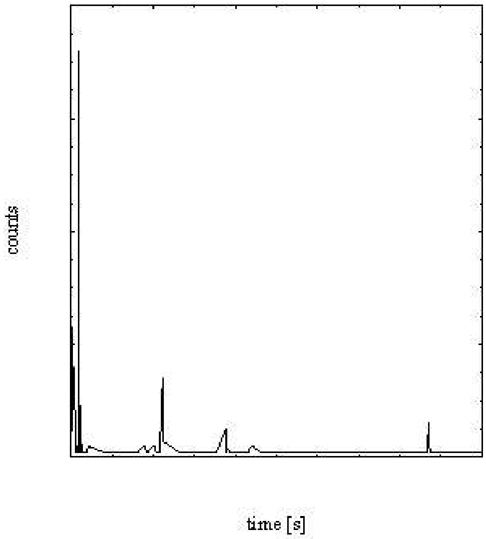

Fig. 7 Overshoot count versus time plot

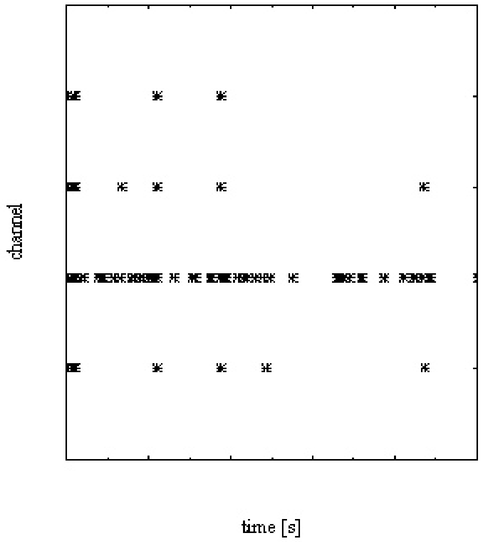

Fig. 8 Acoustic phenomenon counting rate for the different channels

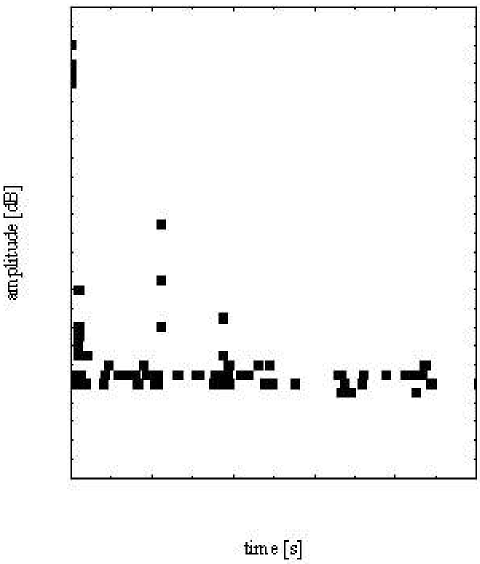

Fig. 9 Amplitude versus time plot

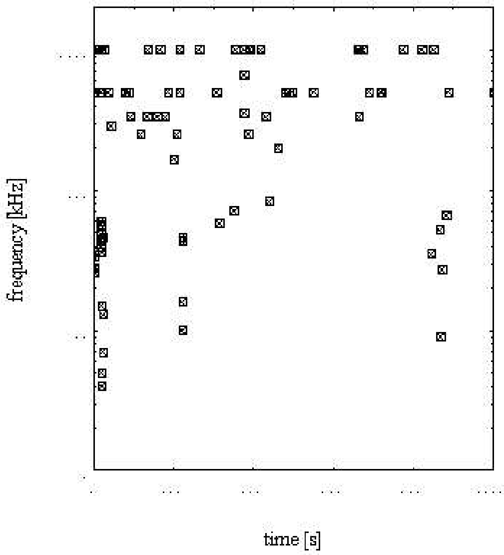

Fig. 10 Average frequencies

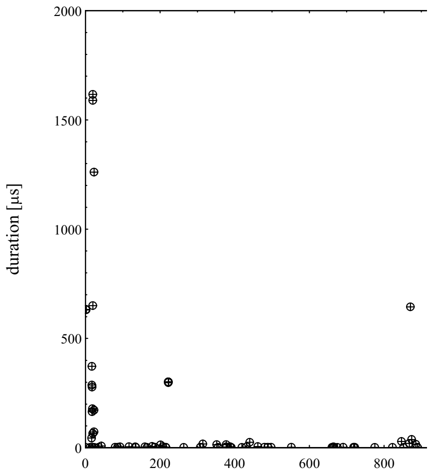

Fig. 11 Acoustic signal duration

CONCLUSION

Electric discharges in a cavity are accompanied by the generation of mechanical oscillations, which in turn act as a source of standing waves in the cavity and standing waves in the rod and the insulator. The frequency spectrum therefore extends from the rod fundamental oscillation mode (i.e., 3 kHz) up to the cavity eigenfrequencies (in the order of several MHz).

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