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Acoustic emission signals associated with prebreakdown state in air high voltage insulating systems

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The paper presents the method of acoustic emission (AE) in the study of the state of insulation systems with air as the high-voltage insulation. The tested object was a planar system of electrodes made of aluminum. In addition, the analysis of AE signals and the impact on these signals the presence of dielectric coating on the electrode surfaces of aluminum was tested. We examined the influence of saturation (seal) these coatings on the dielectric strength of the insulation system. The study was conducted at an air pressure values 1·105, 3·105 and 5·105 Pa. The strength of the electrical systems were tested at alternating voltage with a frequency of 50 Hz.

Noted pros and cons of using the method of EA in the context of the assessment of high-voltage electric insulation devices. The presented results confirm the possibility of using acoustic emission method, not only for identifying vulnerable areas, but also to predict the time of of further use of high voltage device.

KEYWORDS: high voltage insulating system, breakdown voltage, acoustic emission method, dielectric coatings

1. Introduction

The increasing demand for electricity in large urban and industrial centers will use to supply their networks with higher and highest voltage ratings. Simultaneously, the increasing of these centers results in a decreasing quantity of undeveloped land, on which could be placed power equipment, and continuous increasing of land prices is an additional argument for miniaturization of these devices. Sticking it to seek better and better insulating materials insulating high voltage and eclipse electric arc. Type of high-voltage insulation-or rather its electric resistance has usually the greatest impact on the dimensions of the high voltage equipment.

The air and mineral oil are rarely used, instead of them are used better insulation mediums – compressed gases, particularly sulfur hexafluoride and vacuum.

Gases and vacuum are used in electrical and power devices as mediums of isolation due to their properties, in particular the poor electrical conductivity. Of course, with the increase in the value of electric field intensity they lose their insulating properties and eventually thrive in these electrical discharges causing material degradation, and eventually short circuit. Moreover, they can be sources of electromagnetic interference, which is why these devices are designed waist to minimize the intensity and time of disturbance.

It has been found that for most gases the Paschen's law, according to which the voltage jump of the gas in steady field is a function of product density (or pressure) of gas and the electrode distance is satisfied only at lower pressures, when the tension jump is low. After increasing the gas pressure, which leads to increase electrical resistance of gas deviation of measurement results from the Paschen curve is observed, showing the voltage versus the product of the hop pressure and distances of the electrodes (Figure 1).

If the electrode surfaces or only the surface of the cathode is applied to the dielectric coatings, the voltage of short circuit in the pressurized gas can be significantly increased so that the Paschen's law is fulfilled at much higher pressures than the uncoated electrodes. For example, increase in strength in the uniform due to the presence coatings was 50% for nitrogen and from 15% to 40% in the case of sulfur hexafluoride [5]. Unfortunately, reports in the literature as to the physical properties of coatings (type of material, resistivity, dielectric thickness) resulting in an increase in voltage jump in the compressed gases are not conclusive.

It is generally considered that the dielectric coatings on the electrode surfaces, resulting in increased electrical resistance pressurized gases insulate the electrode surfaces and thus microblades at the cathode. Therefore it prevents the flow of current emission and subsequent ionization of gas.

Obtaining information on the condition of high-voltage insulation, and hence the degree of risk incomplete discharge for the proper operation of the insulation system, it allows you to take the correct decision to exclude from the work defective item. Having this information allows you to perform elective, not forced by malfunction and at least costly and burdensome repairs.

Many different methods of identifying defects or damage to the electrical insulation devices is known. Among others: chemical, optical, acoustic and electric. Each of them is applicable to the specific properties and conditions of research and detection can be used only for certain types of defects. Chemical methods, for example based on an examination of oil permit infer about the local overheating, identified with the point defect. Thermal imaging method, as one of the optical methods, to detect high resistance transition in all kinds of devices, while the photographic method can detect only the fact of partial discharge in a prominent place [2]. Proper selection method leads to efficient diagnosis of the type of damage.

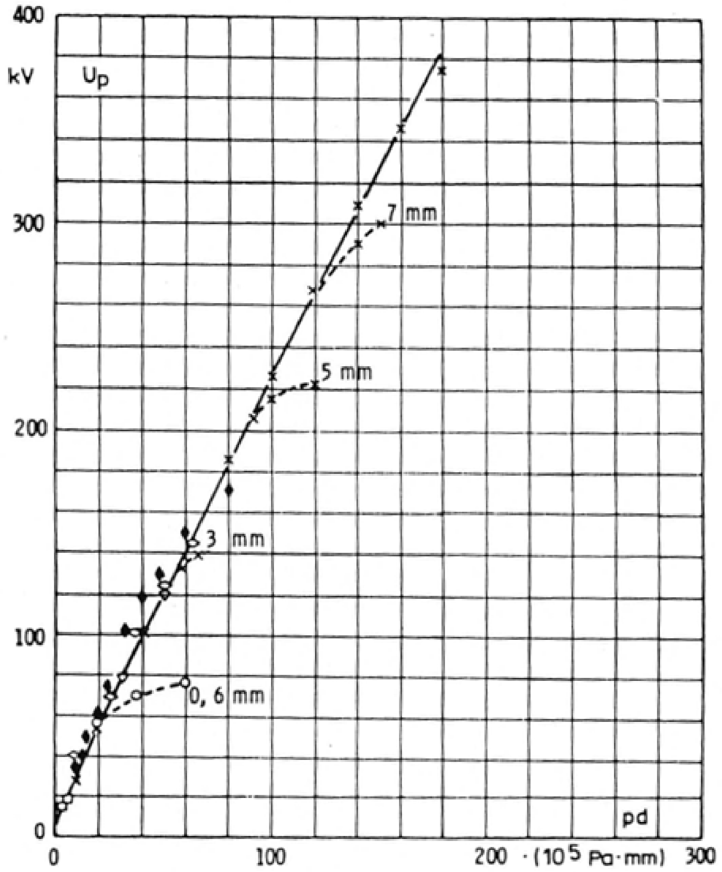

Fig. 1. The Paschen curve variation for nitrogen at a temperature of 25 °C; summary of the results of different authors obtained for systems with field uniform or close to uniform constant voltage or AC, 50 Hz or 100 Hz and electrode distance d equal to 0.6, 3, 5 and 7 mm [according to 1]

In any electrical device with high-voltage gas insulation there is a problem of surface dielectric strength constant. It is very important because the voltage of short circuit on the surface of solid insulation in the gases is significantly lower than the strength of cross-at the same distance between electrodes.

The most commonly used solution - other than the electrical method to assess the state of this type of electric insulation - for insulation of electrical equipment with gas and solid is the acoustic emission method, which uses acoustic signals generated by partial discharges.

Acoustic methods allow you to not only detect the prevalence of partial discharges, but also allow their location. The basis of the method of electroacoustic (AE) is an analysis of the acoustic signal generated by the partial discharge (PD) [6, 7, 8]. Most of incomplete discharge energy is converted into electricity, heat and chemical resistance. It is assumed that during discharge the incomplete conversion gates portion of the electrical energy to mechanical energy, with an efficiency of 1-5%. From the physical, individual partial discharge can be compared to microexplosion that takes place in the dielectric. Assuming that the partial discharge takes place in a homogeneous medium they can be treated as a point source of elastic disturbances.

This paper deals with the problem the application of acoustic emission method for testing the condition of a high-voltage solid insulation in the air.

2. Experimental apparatus and technique of measurement

Insulation system was formed with flat aluminum electrodes with a diameter of 50 mm with rounded corners according to the formula of Rogowski. The process of preparing the surface of the electrode, a method for producing oxide coatings on them are shown in [9]. In the present study, the aluminum oxide layer on the surfaces of the electrodes have a thickness of 5 ... 10 mm. After the process of applying a coating to the surface of the electrodes of the electrode Al_2O_3 repeatedly washed in distilled water and ethanol using ultrasonic scrubber. Then, the electrode was dried for 1 hour at 110°C, then their surfaces were coated with the spray technique further layer of insulating material. After these layers were hardened at 150°C for 10 to 60 minutes - depending on the instructions of the manufacturer. The thickness of the resulting layer applied to a coating Al_2O_3 was 30 ... 40 mm.

Prepared electrodes were placed inside a stainless steel cylindrical pressure vessel having a diameter of 40 cm and a height of 70 cm. Detailed Description of the chamber is shown in [9].

Electric strength were tested in systems with air at 1·105, 3·105 and 5·105 Pa. The distance between the electrodes was constant and was 3 mm.

High voltage obtained from the resonance system RS-700-30-50 (with a voltage of 700 kV and power 500 kVA) from Haefely Trench powered from the mains voltage of 0.4 kV via the autotransformer. One of the terminals of the test transformer was grounded and combined with the lower electrode insulation system under test, and the other via a resistor with a resistance of 40 kΩ and bushing in the lid of the chamber was connected to the high voltage electrode. High voltage were measured by electrostatic kilovoltometer. Figure 2 shows a block diagram of a system for measuring the acoustic emission signals and the electrical strength of the insulation test.

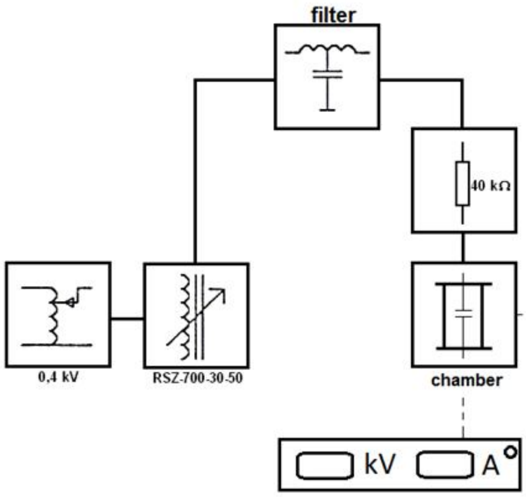

Fig. 2. Block diagram for measuring the acoustic emission and the dielectric strength of the insulation system

Figure 3 and 4 show photos of resonant system as well as a test to measure the acoustic emission and dielectric strength of the insulation system.

Fig. 3. Resonant Test System RS-700-30-50 made by Haefely Trench

Before the measurements the system was conditioning (by ESD). This was important in the case of electrodes with coatings, for avoiding destroying the coatings. This conditioning consisted of a very slow voltage increasing at a rate of about 1 kV/min. The voltage at which he performed the jump assumed to be the dielectric strength of the insulation system.

Fig. 4. Stand for measuring the acoustic emission and the dielectric strength of the insulation system

AE signals are obtained from a broadband acustoelectric type R3α made by PAC. They were transferred to a preamplifier integrated filter with a passband from 20 to 1000 kHz. After filtering signals were sent to the amplifier, and were recorded on the PC via a measuring card with a frequency of 1 MHz sampling rate and 16 bit resolution.

For signal recording computer program was created, allows you to configure operating parameters of measuring card, save data in binary format, and also a record, in the header measurement parameters.

The recorded signals were analyzed using a proprietary computer program [2], which allows you to:

- removal of noise from signals (using wavelet transform),
- calculation of selected parameters of AE signals (sum and the rate of counts, totals and pace of events, the effective value of the signal [4]),
- analysis of the frequency and time-frequency signals for the individual events and the calculation of the spectrum averaged for the entire measurement.

In the Figures 5 ÷ 7 are shown examples of the results of AE signal analyzed: registered signal, the pace of events and the amplitude spectrum of the recorded signal. The distance inter-electrode insulation system tested was 3 mm and the air pressure had a value of 3·105 Pa.

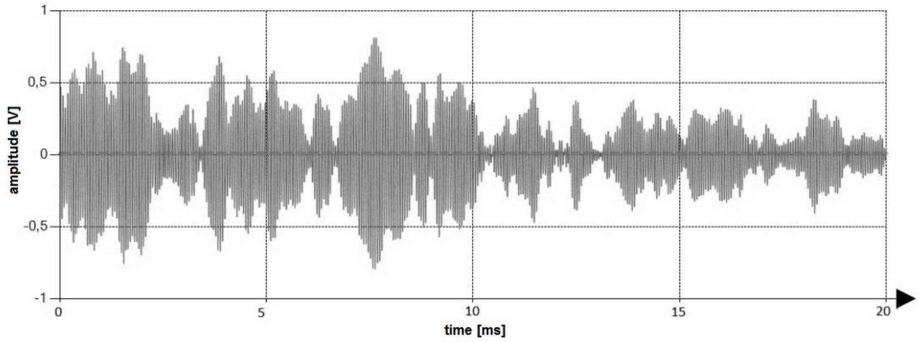

Fig. 5. Sample AE signal during the measurement

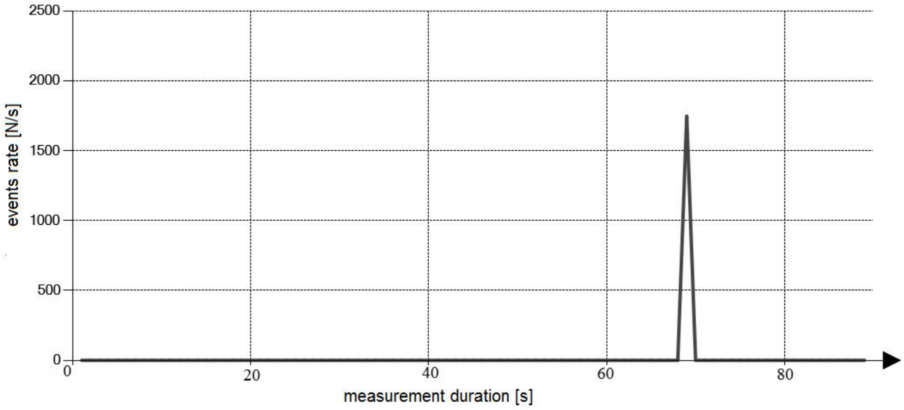

Fig. 6. The rate of AE events during the measurement

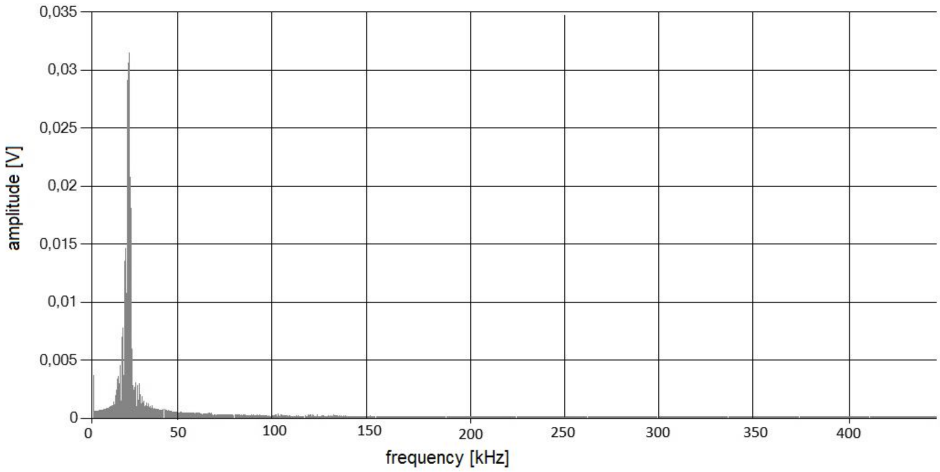

Fig. 7. The spectrum of recorded signal

During the tests AE signals did not appear until the final stage of raising the voltage, just before the short circuit. The results obtained indicate that the installation of the acoustic channel (fixing the transducer to the housing) lets the prediction of the appearance of the short circuit. At the same time it causes attenuation of acoustic signals, occurring well before the short circuit, the phenomenon of corona in the track supply.

Analyzing the rate of events , you will find that acoustic events appeared just before short circuit and it was characterized by a relatively high intensity. The analysis of the amplitude spectrum of the tested AE signals revealed that these signals are clearly dominant with a frequency of 20 to 30 kHz. The signals of different frequencies have very small amplitudes.

3. Summary

The paper presents the results of the use of acoustic emission method in the assessment of high-voltage gas insulated systems.

The measurements and analysis of signals associated with discharges in the air.

The research leads to the following conclusions:

- it is possible to measure and record AE signals associated with initiating the short circuit in the air, which allow its forecasting,
- in the recorded signals preceding short circuit is the dominant band of frequencies ranging from 20 to 30 kHz,
- AE method can be used for diagnostic and prognostic the short circuit in the high-voltage gas insulated systems.

We expect that our further work will concern on a detailed analysis of AE signals associated with initiating of the short circuit in the high-voltage insulating systems for gas-insulated switchgear for the various parameters of the electrodes: the distance between electrodes and the gas pressure. We assume that will be examined AE signals in systems with interelectrode different distance at different air pressure.

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