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Contribution to measurement of discharge activity in acoustic range

Streszczenie. (Przyczynek do pomiaru aktywności wyładowań w paśmie akustycznym). *Artykuł przedstawia wyniki analizy sygnałów akustycznych uzyskanych podczas eksperymentów w niejednorodnym polu elektrycznym. Analizowano sygnały uzyskane z czujnika akustycznego pracującego w paśmie słyszalnym. Sygnał akustyczny transmitowany z obiektu jest charakterystyczny dla konkretnych warunków. Pomiary w paśmie słyszalnym na poziomie szumów zewnętrznych są trudne. Zaleta metody polega na łatwym przetwarzaniu wyników oraz tym, że nie są konieczne żadne połączenia galwaniczne z badanym obiektem.*

Abstract*. In this paper we introduce results from the analysis of the acoustic signal obtained from the experiments realized in non-homogeneous electric field. We analyzed the acoustic signal from the acoustic sensor in audible band. The acoustic signal transmitted from the object is unique for specific conditions. Exploitation of the audible band for the PD detection is difficult in outdoor bias level. The advantage of this method consists in simple results evaluation and also in the fact that it is not needful galvanic connection with the measured specimen.*

Słowa kluczowe: aktywność wyładowań, izolacja elektryczna, szum akustyczny.
Keywords: discharge activity, electric insulation, acoustic noise.

Introduction

The design of the energetic equipments is different but it consists of similar electrode systems. The differences are mainly in the electric field shape resulting in different electric stress of the insulating system. The insulation material should be stressed in the following environments:

1. homogeneous field,
2. slightly non-homogeneous field and
3. strongly non-homogeneous field.

The homogeneous field has constant electric field strength in all points. The typical example of the discharges originated in homogeneous electric field is so-called Townsend discharge and Reather-Meek discharge.

Slightly non-homogeneous field has only very small difference from the properties of the homogeneous field. The strong non-homogeneous field originates between systems with very high differences in the curve radius. Significant influence on the discharge processes has the space charge. During discharge processes in non-homogeneous electric field ionizing and de-ionizing processes exist. These have main influence on the formation of the discharge path and also on the properties of discharges. Ionization occurs in the form of elastic or non-elastic collision of the particles, photoionization and thermoionization. Deionizating processes are: recombination of particles, absorption of electrons and diffusion of ions. The discharge processes are ineligible during operation of the electric equipments because they effect progressive degradation of the insulating materials.

Discharge phenomena in non-homogeneous field

The discharge processes are classified according to their duration on the temporary and steady. The steady discharges are divided into independent and non-independent. The sort criterion results from the condition which leads to the generation and sustain of the discharge path. The category of the independent discharges include: silent discharge, corona discharge, spark discharge and arc discharge. Non-independent discharges require the source of the charge carrier or the source of the energy needed for ionization of the atoms.

The corona discharge exists surround the electrodes with small curve radius which create non-homogeneous electric field in the discharge path. On the interface solid-gas material the creeping discharge in non-homogeneous field is developed. This discharge acts on the surface of the insulation between electrodes. For these processes the best representation is Toepler model. The spark discharge is the temporary form of the electric discharge in the gas. This discharge manifests in the form of shined channel which has high temperature and high level of the thermal ionization.

Resources of the discharge activity detection

The discharge activity is coupled with different physical effects which can be used for the measurement and detection. These effects are electrical and non-electrical. The electrical effects result in electromagnetic impulse generation. Perspective is non-electrical effects: chemical, optical, thermal and acoustic.

For the diagnostic purpose different methods for the discharge activity are used. They are:

a) electrical methods,
b) gas chromatography of the oil,
c) measurement of the acoustic emission,
d) measurement of the optic emission.

The principle of the electric methods consists in the electromagnetic field detection or detection of the current impulses. The last mentioned method gives the possibility to quantify the magnitude of the detected apparent charge and determine the magnitude of the degrading energy.

In liquid insulating systems the presence of the discharge activity can be registered by change of the chemical properties. The results from gas chromatography can determine the presence of the gases due to ionizing processes in the oil or during decomposition of the solid dielectrics due to partial discharges.

The acoustic detection is effective for the evaluation of the partial discharge activity under operation without the galvanic coupling with the measured equipment. This method utilizes the detection and localization of the sources originated from the acoustic signals – acoustic waves caused by electric discharge in the dielectric or on its surface.

The acoustic detection of the partial discharge emission

The partial discharge in the combined insulation paper-oil generates the electromagnetic impulse which energy is transformed to the mechanical energy in the form of acoustic wave. It is impossible express the transformation from the one form of the energy to the other form of the energy by simple function because it depends on many parameters. It includes the nature and the intensity of the partial discharges, type of the dielectric, initial pressure conditions, mechanical stress a.o. These waves propagate through the insulating material until the wave front falls in the material with different acoustic properties. This case originates usually in transformer tank. Several methods can be used for the diagnostic purposes.

The pressure field generated by acoustic wave can be expressed by differential equation of the second order:

$$\nabla^2 p = \frac{1}{v^2}\cdot\frac{\partial^2 p}{\partial t^2}, \qquad (1)$$

where: p – pressure field, ∇ – Laplacian operator, v – acoustic speed, p – time.

After acoustic wave front fall in the transformer tank two kinds of waves are excited: transversal and longitudinal with different speeds of propagation.

Experiment

The technical insulation materials which are used in the area of the high voltage technique are realized from the solid, liquid and gas combination e.g. liquid-solid, gas-liquid, eventually gas-solid. On the interfaces of the particular materials under specific condition surface discharges originates which produces the noise. In the praxis following types of the interfaces exists:

a) homogeneous electric field with explicitly tangential action of field on interface,
b) homogeneous electric field rectangular affect on interface of two insulating material,
c) non-homogeneous electric field with tangential action of field and small normal part,
d) non-homogeneous electric field with tangential action with strong normal part.

For the operation the most dangerous is case (d). This case we have used for measurement and acoustic signal analysis. In the figure 1 the block diagram of the measuring system is shown. In the figure 2 the equipment for the optic coupling between measuring systems with different voltage potential is shown. Electrode arrangement applied in our experiment represents interfaces between solid and gas material. In the measurement according to Toepler different types of electrodes were applied.

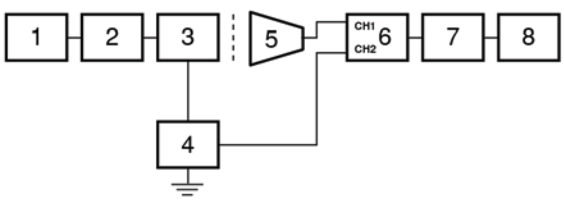

Fig.1. The block diagram of the measuring system

The autotransformer 1 supplies the hv transformer 2 with output a.c. voltage up to 80 kV. The electrode arrangement 3 is connected to the hv transformer and grounded through the measuring impedance 4 from which the measured signal is connected to the input amplifier with optic separation 6 to the channel 2. The signal obtained from the acoustic sensor 5 is connected to the channel 1.

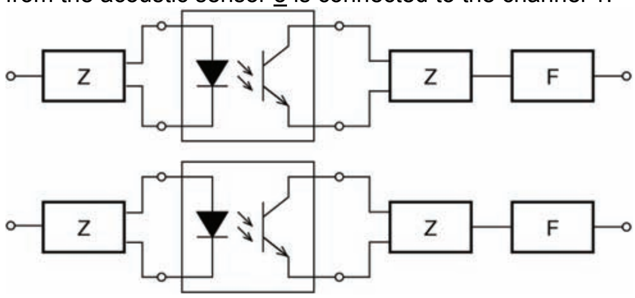

Fig.2. The block diagram for the optic coupling

The amplified signal from both channels is applied to the A/D converter 7 and then evaluated by PC 8. The measuring system enables to connect different kinds of sensors (optic, acoustic, electromagnetic a.o.) in order to compare the discharge activity by another physical effect point of view at the same time. The earphone can be connected to the measuring system in order to qualitative determination of the discharge activity by operating personnel. In the figure 2 the block diagram of the optic coupling is shown. The signal is amplified and converted to the optic signal which is converted back to the electric signal. This electric signal is amplified again and then converted by the filter F.

Experiment evaluation

The measured signal is highly deformed with the higher harmonics and the evaluation in the time domain is very difficult, see figure 3.

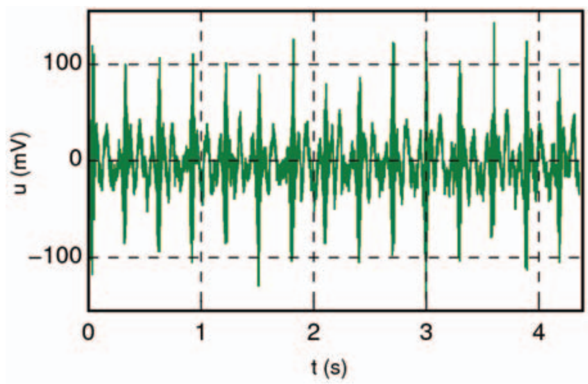

Fig.3. The block diagram of the measuring system

The recorded signals from the discharge activity were analyzed with Fourier transformation (FFT). The results show that the magnitude of the signal is relatively equally distributed over the acoustic band. However, it contains several extremes which vary in accordance with the shape of the electrode, its distance from the grounded electrode and amplitude of the appliedd voltage. The measured characteristics are nearly directly proportional with applied voltage.

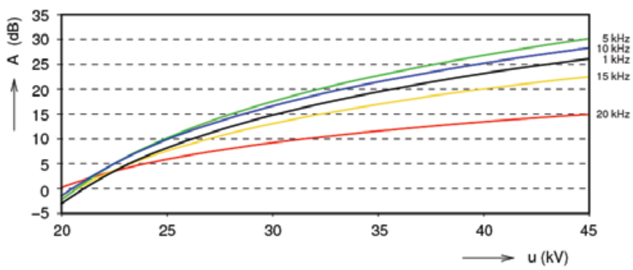

Fig.4. The increase in amplitudes of the particular frequencies for the given voltages

In the figure 4 the comparison of amplitude growth for frequencies 1 kHz, 5 kHz, 10 kHz, 15 kHz and 20 kHz is shown. From the figure it is clear that frequencies 5 kHz a 10 kHz dominate. 1 kHz frequency was compared with another frequencies because represent the ambient acoustic noise. Similar characteristics with other electrode systems and appropriate distances were measured.

Conclusion

The measurement of discharge activity in the acoustic band is strongly affected with the acoustic background of the surrounding environment and therefore its practical application is delimited on the objects with low ambient acoustic noise. The advantage of this method consists in simplicity of quantitative as well as ability of immediate qualitative evaluation. In the environments with strong noise it is better to orient on the measurement of the signals in the ultrasonic band.

The constructed device is suitable for the measurement in strong electromagnetic field for safe isolated coupling between sensor devices and measuring computer. In the next period by evaluation of measured data we will pay attention to the influence of the electrode shape, electrode configuration, frequency spectra of signal, amplitude of applied voltage, and kind of insulation.

The advantages of the acoustic emission measurement of the partial discharges are: resistance to the electromagnetic noise, on-line monitoring without galvanic coupling with measured equipment. In addition enables the location of the place of the discharge source and is suitable for the diagnostic purpose.

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