Alfonsas MORKVĖNAS, Saulius GUDŽIUS, Linas Andronis MARKEVIČIUS, Povilas VALATKA, Audrius JONAITIS

Kaunas University of Technology

Investigation of the Partial Discharge Characteristic Parameters in Pressboard Insulation according to Experimental Results

***Abstract**. In the following paper the voltage influence on partial discharge characteristic parameters in the solid insulation is discussed. Partial discharge values in different size and shapes of solid insulation defects and under different voltage influence are evaluated.*

***Streszczenie.** W niniejszym artykule dyskutowany jest wpływ napięcia na parametry charakterystyki wyładowań niezupełnych w izolacji stałej. Wyznaczono wartości charakteryzujące te wyładowania w dielektrykach stałych z defektami o różnych kształtach i wymiarach oraz pod wpływem różnych napięć (**Badania parametrów charakterystyk wyładowań niezupełnych w izolacji stałej z defektami o różnych kształtach**).*

Keywords: partial discharge, partial discharge characteristics, overvoltage, dielectric, solid insulation.
Słowa kluczowe: wyładowania niezupełne, charakterystyki wyładowań niezupełnych, przepięcia, izolacja stała.

Introduction

High-voltage equipment insulation condition and the reliable duration of working time are determined by various factors of the power system: overvoltage, partial discharges, overcurrents, vibrations and so on. Insulation aging rate and the appearance of defects are mainly caused by overvoltages, heating, and partial discharges. Duration of the overvoltage and its amplitude can be various in the power system. Overvoltages and equipment operating temperature are the main factors of insulation aging speed [1, 2, 3].

Most insulation systems of high voltage electrical apparatus consist of cellulose paper and hydrocarbon oil. Partial discharge (PD) is one of the important indicators of insulation degradation. Therefore, measurements and diagnostic techniques of PD are helpful in finding defects in the electrical equipment. The detection of partial discharges in high voltage plant gives the indication of degradation in the insulation and can act as an early warning system to insulation failure. Wideband electromagnetic detection methods for online detection and localisation of partial discharge in cables and switchgear at distribution voltage levels have been available for more than 10 years [4]. Recently, these methods have been developed for on line testing of solid-insulated outdoor plants. The plant, that can be tested, includes current and voltage instrument transformers and cable sealing ends.

This work is aimed at studying the PD characteristics of pressboard system, which consists of a pressboard held between two electrodes. PD data are recorded according to their phase of occurrence with respect to the power frequency cycle and their magnitude.

Experimental set up

Partial discharge measuring and registration circuit of artificial defect as an air gap in a pressboard held between two electrodes is shown in Fig. 1

The air-gap discharge model consists of the cylindrical copper electrode, solid plate electrode and the test object. The test object BO is placed between these electrodes. The test object consists of two pieces of 0,4 mm (thickness) cellulose pressboards sandwiching a piece of 0,4 mm (thickness) cellulose pressboard which has a hole in the centre. These papers are agglutinated together by insulating glue. Four types of above described test objects were arranged: with Ø 0,5 mm, Ø 1 mm, Ø 2 mm hole in the middle of the pressboard and without a hole.

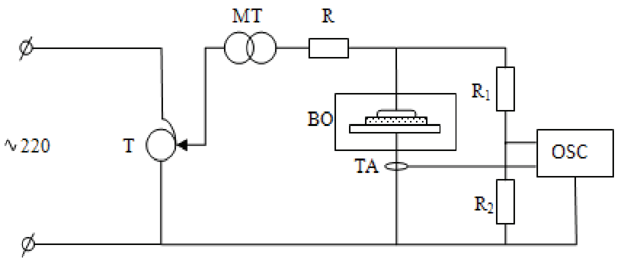


Fig. 1. Circuit arranged for experimental PD registration (T – autotransformer, MT – high voltage step-up transformer, R – protective resistance, BO – test object, TA – current transducer, R_1, R_2 – resistances for direct high voltage measurement, OSC – oscilloscope for data observation and recording)

During the experiments, five fixed voltage steps (8, 16, 24, 32, 40 kV) for the registration were determined. At the first step (8 kV) the discharge pulses are firstly sampled by the oscilloscope. The measurement system is based around a wide band digital storage oscilloscope to make high-resolution measurements of PD signals. After the collection of PD signals, a range of software is then used to categorise and analyse the collected data. During the investigation the entire 50 Hz power cycles could be sampled synchronously with the PD current measurements and the oscilloscope sampling frequency was set to 50 MHz. The time interval of each registration stored data is not less than 30ms. This detection and registration system has been used for short term spot test of around 10-20 minutes. It is assumed that site-permitting, short term monitoring with similar equipment can be carried out over a long time period.

A split-core high frequency current transformer TA (see. Fig. 1) is connected around the earth connection cable of the test object (BO) circuit in order to electromagnetically detect PD signals flowing to the earth. The measured current, corresponding to the solid-insulation internal PD, is very low, thus in order to enlarge this signal, earth connection wire was winded on the current transformers several tens of times.

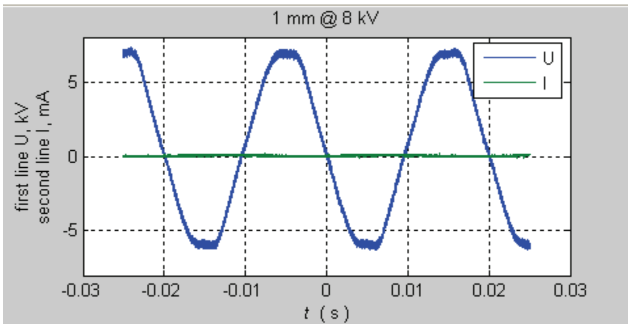
Corresponding to the IEC 60270 requirements for the measurements with digital PD-instruments, the instantaneous value of the test voltage, at the time instant of PD occurrence, was measured with direct high voltage measurement circuit- voltage divider R_1, R_2.

During the registration, raw data are captured from both channels synchronously with the power cycle. This ensures that all PD data will be captured for recovery in the later analysis stage and allows phase relationships of the pulses to be observed. Detailed analysis with the software allows investigating all the transient events that occur over the power cycle and divide them into PD events and noise.

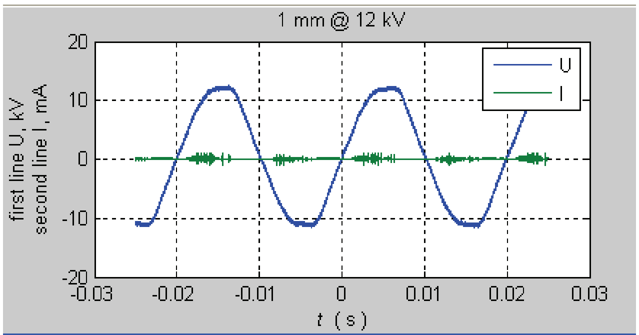
Experimental PD measurement results

The experimental measurement circuit described above has been applied in the laboratory. As an example, Fig. 2 shows typical measured PD activity across two and a half power cycle. The test object was selected with the 0,5 mm artificial defect inside and it was applied 8 kV. As it can be seen from Fig. 2 a, no PD was registered. When, for the same object, it was applied 12 kV, the PD activity was registered (see Fig 2 b).

a)



b)



c)

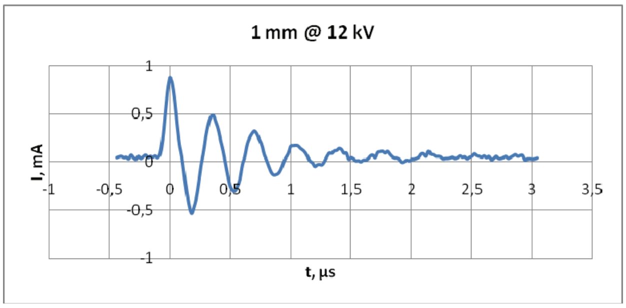


Fig. 2. Recorded data of a:
a. with no PD registered;
b. PD activity during initial PD activity stage;
c. one of the recorded transient processes of PD current.

The main parameters derived from the measured PD current curve are the maximum value of discharge current which for the case given in Fig. 2 c is equal to 0,817 µA and the duration of the PD process is 2µs.

As it can be seen from Fig. 2 c, the pattern of current caused by discharge in the sample is an oscillatory type. This is due to the oscillatory LCR type of measurement circuit.

The main object of registration curves analysis was the calculation of approximation curve which approximates PD current transient process. For the case shown in Fig. 2 c the approximation curve is given in Fig. 3

It was calculated that correlation coefficient calculated between registered data and calculated according approximation parameters is 0,977. So it can be assumed, that approximation curve and parameters are selected well. The same calculations were done for all the registration data.

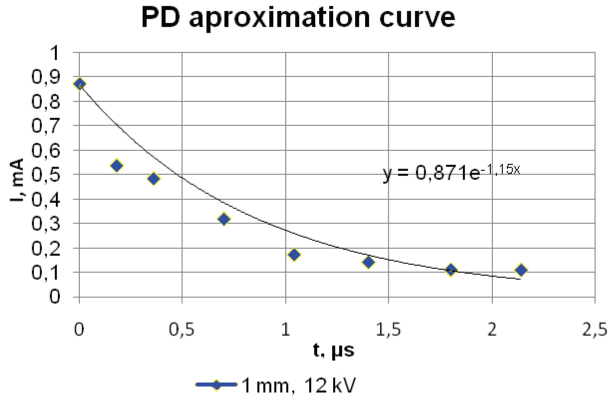


Fig. 3. Approximation curve of PD transient process

Test results and analysis

PD caused current patterns in accordance with the applied voltage were measured Experimental results revealed that the registered PD current impulse amplitude has a very wide range and does not always represent the size of the defect in the right way. The registered current impulse crest values for random selected cases are given in Table1.

Table 1. Crest values of registered current impulses

Voltage step, kV	Crest value of registered current impulse, mA			
	Size of artificial defect			
	0,5 mm	1 mm	2 mm	No
8			2,35	
16	4,24	0,871	5,017	0,99
24	3,591	-	4,2489	2,288
32	4,11	-	5,9	2,231
40	7,95	-	6,09	2,28

Graphically crest values of registered PD caused current impulses are given in Fig. 4.

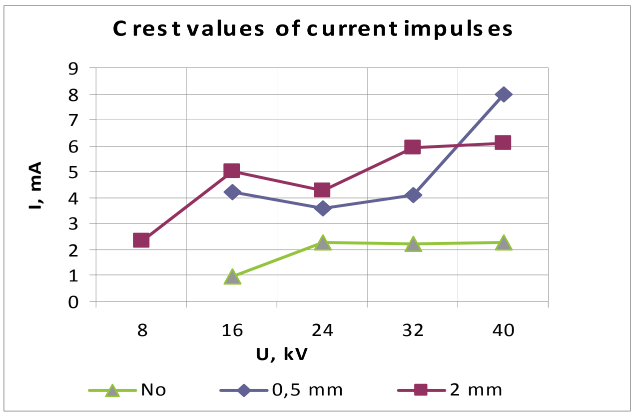


Fig. 4. Crest values of registered current impulses

From the Fig. 4 it can be seen, that for some cases (for example 0,5 mm at 40 kV) the PD caused current impulses crest values levels do not clearly represent the already known size of the defect. For this reason, the extinguishing time constants of currents were calculated.

Calculation data are given in table 2 and figure 5.

Table 2. Extinguishing time constants of current impulses

Voltage step, kV	Extinguishing time constants of current impulses, 1/μs			
	Size of defect			
	0,5 mm	1 mm	2 mm	No
8			-1,39	
16	-1,25	-1,15	-1,64	-0,83
24	-1,5	-	-1,75	-1,08
32	-1,38	-	-1,79	-0,77
40	-1,69	-	-2,09	-1,03

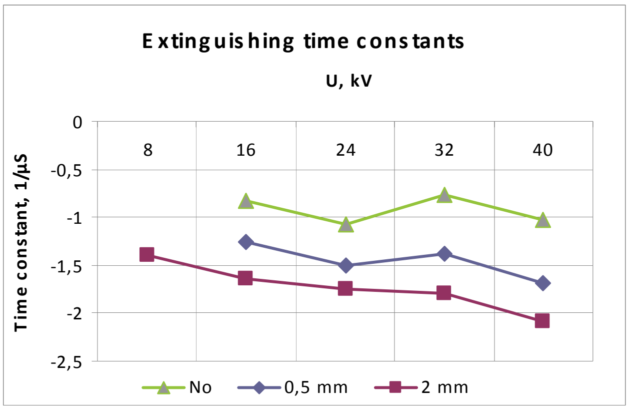


Fig. 5. Discharge caused current impulses extinguishing time constants

From Fig. 5 it could be seen that when artificial discharge increases, time constant for discharge current extinguishment decreases. If the current samples are selected correctly (with no extraneous noise), there are no cross-sections between different sizes of artificial defects extinguishing time constants curves.

The increase in extinguishing time constant, at the same registered voltage level, can give the indication of defect expansion. This parameter can be assumed as the warning factor for the insulation breakdown.

During the overvoltage in electrical network, measurement and registration of voltage levels and current impulses caused by discharges, calculation extinguishing time constants and evaluation methodology can be applied for the permanent active insulation coordination equipment arrangement.

Conclusions

The registration results show that discharge caused current impulses in pressboard insulation can be registered. The registration equipment and experimental set up require special preparation and arrangement according to the specific requirements.

When artificial discharge in pressboard solid insulation increases, time constant for discharge current extinguishment increases as well. If the current samples are selected correctly (with no extraneous noise), there are no cross-sections between different sizes of artificial defects extinguishing time constants curves.

The increase in extinguishing time constant, at the same registered voltage level, can give the indication of defect expansion. This parameter can be assumed as the warning factor for the insulation breakdown.

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REFERENCES

[1] Gerhards, J.; and Temkins, A. Prognostics of electrical insulation resources: Nordic Insulation Symposium Stockholm, 11-13 June 2001. P. 125-132

[2] Morais D. R.; and Rolim J. G. A hybrid tool for detection of incipient faults in transformers based on the dissolved gas analysis of insulating oil. IEEE Transactions on Power Delivery, April 2006, Vol.21, No.2. P.673-680

[3] Gudžius, S.; Markevičius, L. A.; Morkvėnas, A.; Navickas, A. S.; Stanionienė, R. The Analysis of the Integral Characteristics of the Overvoltages Effect Duration // EMD 2006: Proceedings of XVI International Conference on Electromagnetic Disturbances, September 27-29, 2006, Kaunas, Lithuania, Kaunas: Technologija. 2006. ISSN 1822-3249. P. 72-77

[4] Mackinlay, R.R. and Walton, C. “Some advances in PDmonitoring for high voltage cables” in Proc. IEE Colloquium on MW Paper Cables: Asset or Liability? Vol. 6, 21 April, 1998. P. 1-5

***Authors**: prof. dr Alfonsas Morkvėnas, Kaunas University of Technology, Studentų str. 48-144, Kaunas, Lituania, E-mail: alfonsas.morkvenas@ktu.lt; dr. Saulius Gudžius, Kaunas University of Technology, Studentų str. 48-144, Kaunas, Lituania, E-mail: saulius.gudzius@ktu.lt; prof. dr. Linas Andronis Markevičius, Kaunas University of Technology, Studentų str. 48-144, Kaunas, Lituania, E-mail: linas.markevicius@ktu.lt; Povilas Valatka, Kaunas University of Technology, Studentų str. 48-144, Kaunas, Lituania, E-mail: povilas.valatka@stud.ktu.lt; assoc. prof. dr. Audrius Jonaitis, Kaunas University of Technology, Studentų str. 48-144, Kaunas, Lituania, E-mail: audrius.jonaitis@ktu.lt.*