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The measurement of partial discharges in voltage transformers using DDX 7000 instrument

Abstract. *The experiences of the author, gained during the measurements of partial discharges using DDX 7000 instrument, are presented in this article. The experiences concern the measurements carried out on the real electrical objects such the inductive voltage transformers. The measurement systems and procedures, and the methods of the visualization of the results obtained using DDX 7000 are also presented.*

Streszczenie. *W artykule przedstawione zostały doświadczenia autora związane z pomiarami wyładowań niezupełnych z użyciem detektora DDX 7000. Doświadczenia te dotyczą pomiarów wykonanych na rzeczywistych obiektach, którymi były indukcyjne przekładniki napięciowe. Zaprezentowano układy i procedury pomiarowe oraz metody wizualizacji wyników pomiarów uzyskanych z wykorzystaniem urządzenia DDX 7000.(**Pomiary wyładowań niezupełnych w przekładnikach napięciowych z użyciem detektora DDV 7000**)*

Keywords: partial discharges, voltage transformers, high voltage insulation.
Słowa kluczowe: wyładowania niezupełne, przekładniki napięciowe, izolacja wysokonapięciowa.

Introduction

Advance in the construction of high voltage insulating systems of electrical devices is connected with using much higher working stress and with introducing the synthetic materials, which are particularly sensitive on the action of such working stress. One of the basic kinds of stress of such systems, what has been confirmed by the experiments in service, are the partial discharges (PD), which are more dangerous when the rated voltage of device is higher [1]. Partial discharges are defined as the local electrical discharges, which take place only in the part of electro-insulating system and do not cause the loss of the insulating properties by the system. Such discharges do not transform in the conductive plasma channel breaking the electrodes. The appearance of partial discharges in the high voltage insulating system causes the step degradation of the insulation and also is the source of the other unfavorable phenomena, such energy and active power losses, noise and the radio-electrical disturbances [1-3]. Partial discharges may occur in the power transformers with the paper-oil insulation, electrical machines having the laminar and heat-hardening insulating systems, cables, current and voltage transformers (as result of appearances of gaseous microinclusions in the resinous or chemo-hardening parts of insulating system), electrical power capacitors, high voltage switchgears and in the insulators of high voltage power lines and substations. PD can appear in the new insulating system, but also in the devices in service, hence the measurement of PD intensity can be an important index speaking about the quality of production process or quality of operated insulating system of given electrical power devices [1, 4].

Measurement systems based on electrical method

Measurement of partial discharges can be performed as a product or type test. It can be realized as an individual test, but also within a framework of withstand voltage test [1-5]. There are two main methods of PD measurement: acoustic method and electrical method. This second allows on the quantitative assessment of the PD level and is used in the modern instruments (digital detectors with appropriate software) enabling the utilization of advanced analysis of the data acquired during the measurement, and on the basis of these data, the place and type of partial discharge can be determined. In the electrical method, the most commonly used index of partial discharges intensity, is the apparent charge. According to the standard IEC 60270 and CIGRE brochure 366, apparent charge (q) is defined as the charge, which delivered suddenly between the terminals of the investigated object would change steeply the voltage on these terminals on the same value as the discharges. The measurement of the apparent charge is based on the measurement of the voltage drop on the resistance (coupling quadripole), thus on the current pulse occurring in the circuit [1-3]. The apparent charge is measured in picocoulombs [pC], and according to the standard [3], the highest value (maximum apparent charge) registered within a period of the measurement, is given. The two basic circuits used for apparent charge measurement are described in details in [2, 3]. System with the serial (current) detection is characterized by the higher measurement sensitivity in comparison with the system with parallel (voltage) detection, because in the first one, all current, induced by the discharge, flows by the measuring impedance. For practical reasons (eg. when the grounding of the one electrode of the tested object is required) the serial system cannot be used always and opens the way, in most cases, for the parallel system [2, 3].

Partial discharge measurements, using electrical method based on the modern digital detectors, require directed knowledge and accuracy for preparing the test (realization of the connections, running and connecting the ground). The important problems are also the external disturbances which can influence on the measurement quality and the level of the measured charge. The other important aspect, which is connected with the measurements of partial discharges, is the proper calibration of the measuring system [1, 4, 6].

Digital detector DDX 7000

DDX 7000 Digital Discharge Detector is a computer controlled modern measuring instrument which thanks to installed measuring cards takes the small signals generated by partial discharge activity in an insulation of tested devices and processes them such that they can be measured and displayed. The device also contains facilities for measuring the applied high voltage and for generating calibration signals. DDX is equipped with a LCD screen on the front of the instrument on which, in the graphic form, the information about the registered processes, are displayed. The operator can select and control many operations by means of a standard mouse and keyboard. Most of the control and readout functions are implemented in the software, which also enables the deepened analysis of the

data collected by DDX [6]. DDX 7000 set together with its equipment and filters allows on the safe conducting of the measurement of PD apparent charge in the two configurations – using the direct or indirect calibration. The first one, based on the standard system to the PD measurement, with the coupling and injected high voltage capacitors, enables the direct calibration of the measuring system under high voltage and performs the measurements at the rms voltage up to 300 kV. In the second configuration, the portable coupling quadripole and low-voltage calibrator work well at the measurements performed outside the stationary laboratory when the indirect calibration is needed [5, 6].

Results of the measurements in voltage transformers

The goal of the PD measurements in the voltage transformers was the verification of the devices installed on the factory system of partial discharge measurement TE571 in one of the Polish factory. In order to verification, the measurement, both with the usage of factory devices and devices belong to the Institute of Electrical Power Engineering of Technical University of Lodz (DDX 7000), were done. The measurement was carried out in the special Faraday cage eliminating effectively all external disturbances. During the measurement both systems measured the level of PD intensity, and the testing voltage was measured by the factory system. For the calibration of the both PD detectors, the external calibration using low-voltage KAL 451 calibrator was adapted. The measurement circuit used during investigations is presented in Figure 1.

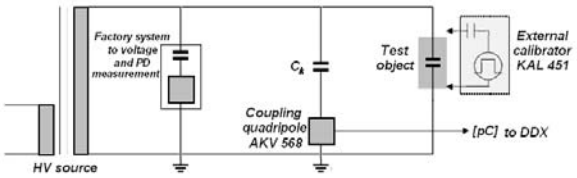

Fig.1. System for the PD detection used during the measurements realized for voltage transformers

The measurements were realized on the basis of the standard [5]. According to this standard PD measurement is performed as a product test using one of the following procedures. Procedure A says that the testing voltage of partial discharges is achieved during the decreasing the voltage after the measurement of insulation strength by the induced voltage. The measurement is carried out through the 30 seconds at the determined testing voltage. In the B procedure (used during the described measurements), the PD measurement is performed also after the measurement of insulation strength by the induced voltage. The delivered voltage is raised up to 80% of induced testing voltage and kept for 60 seconds. After that, the voltage is reduced to the PD testing voltage. The measurement of PD intensity lasts also 30 seconds [5]. The acceptable value of apparent charge is 50 pC for the testing voltage equals to the maximum working voltage U_m and 20 pC for $1.2U_m / \sqrt{3}$. The orderer of the transformers wished that the acceptable values equal to 50 pC should be fulfilled for the testing voltage $1.2U_m$ thus the PD measurement were performed for this voltage. The measurements were realized for the new-designed single-pole voltage transformers having the ratings:

- ratio: 30000/√3//100/√3/100/3 V;
- nominal insulation level: 36/70/170 kV.

Taking into account the above ratings, the apparent charge of partial discharges was observed for the following testing voltage:

1) $1.2U_m$: 1.2*36 kV = 43.2 kV (for a period of 30 seconds);
2) $1.2U_m/\sqrt{3}$: 43.2 kV /√3 = 24.9 kV (for a period of 30 seconds).

Acquired maximum values of apparent charge for the individual cases are shown in Table 1.

Table 1. Maximum values of apparent charge for the individual measurements

No	Type of transformer	Testing voltage [kV]	PD max [pC]	Required values [pC]
1	VT 1	43.2	28.4	< 50
2	VT 1	24.9	**6.6**	**< 20**
3	VT 2	43.2	13.9	< 50
4	VT 2	24.9	**6.4**	**< 20**
5	VT 3	43.2	28.3	< 50
6	VT 3	24.9	**6.5**	**< 20**

The results of the measurements were read using the functions of deepened analysis of the data collected by the DDX 7000 digital detector. The example of the visualization of such results, which allowed on the reading of the values of the maximum apparent charge, is presented in Figure 2.

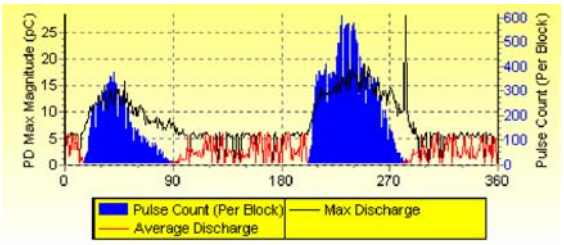

Fig.2. The values as a function of phase angle for the transformer VT1 at testing voltage 43.2 kV

On this picture, the pulses count versus phase angle is marked by blue color, the maximum intensity of discharges by black color and the average intensity by red [6].

Conclusions

The presented measurement results confirm the high quality of DDX 7000 instrument, which can be used with success as a portable apparatus to the measurement of partial discharges intensity and in the connection with the experiences and skills of the competent researchers, give the real chance on obtainment the reliable measurement results and their professional analysis.

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