

Performance of Reference Partial Discharge Measurement System

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Abstract — Electrical insulation problems emerge while decreasing energy losses by the use of high voltage. Several tests are carried out in the laboratory to determine the electrical insulation problems such as partial discharge (PD) test. Due to the requirement of high accuracy of PD test, the reference measurement systems with low uncertainty are needed. Standard PD measurement system consists of two parts, PD detector, and calibrator. The most important role of the precise PD measurements belongs to the calibrator. This paper presents here the performance of reference measuring system developed in TÜBİTAK UME for the calibration of PD calibrators.

Index Terms — Calibration, charge measurement, partial discharges, PD measurement, uncertainty.

I. INTRODUCTION

High voltage equipment and apparatus used in power system networks such as insulators, rotating machines, cables, switchgear, transformers, capacitors, and bushings have to be good insulation conditions to prevent the possible breakdown failures. PD test aims to ensure to determine the quality and service life of insulation. Thus after manufacturing or repairing of high voltage equipment, PD tests are required as an acceptance test according to product's standards. PD measurements are performed by connecting the device under test to a high voltage supply. A measuring system with a suitable bandwidth permits the detection of the fast current pulses produced by the PD. The current pulses are measured to obtain the charge value. Systems equipped with both analog and digital measuring instruments can be employed in PD measurements [1].

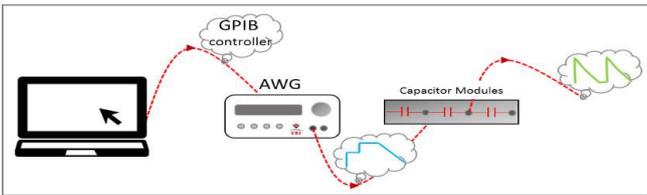


Fig. 1. Programmable reference PD calibrator graphical diagram.

There are some different measuring circuits in partial discharge measurements related to the testing object to ensure reproducible of PD measurements. In each separate circuit, it is used PD measuring instrument called as PD detector. PD detection consists typically of converting the PD pulse current to a voltage signal due to voltage sensitivity rather than current. The acceptance limit of discharges is the range of 5 pC and 500 pC. The rise time level of the current pulse is from some nanoseconds to microseconds

Standard PD measurement system consists of two critical parts, PD detector, and calibrator. The most important role of the precise PD measurement belongs to the calibrator.

II. DEFINITION OF PROGRAMMABLE REFERENCE PD CALIBRATOR (PDCAL)

The reference PD calibrators are able to produce sequences of current pulses to simulate the typical pulse distributions experienced with different kinds of PDs. Therefore for the characterization of PD measuring system, the programmable impulse charge calibrator is also developed in TÜBİTAK UME. The reference PD calibrator called as PDCAL has the features like precisely adjustable, wide-band charges value and remote control. PDCAL is a system that consists of a programmable arbitrary waveform generator, series capacitor modules, and specially designed software. PD pulses applied from PDCAL are characterized by measuring with a digital oscilloscope with the fast sampling rate and high resolution. Keysight VEE Pro 9.3 is used as a special tool to control the waveform generator via GPIB interface board [1, 2].

The design of reference PD calibrator system is given in Fig. 1. A programmable digital pulse generator used in PDCAL can apply various types of pulses. The capacitor modules with 1 pF, 10 pF, and 100 pF are used to generate the charges from 1 pC to 500 pC.

The characteristics of programmable digital pulse generator determine the performance and uncertainty of the reference calibrator. In PDCAL, Agilent 33220A is used as pulse generator with 14-bit vertical resolution, the sampling rate of 50 MSa/s, frequency range up to 20 MHz, ± 10 V output voltage and 256 KB memory. The rise time of generated waveform is 4 ns, and the range of the repetition frequency is between 1 Hz and 5 kHz. The system software that controls the digital pulse generator was developed using Keysight VEE Pro 9.3.

III. REFERENCE PD MEASURING SYSTEM

The reference PD measurement system consists of PDCAL, and PD detector. The definition of reference PD calibrator (PDCAL) was given in the previous section. The general diagram and hardware configuration of standard PD measuring system is shown in Fig. 2.

The pulse shape, charge value, rising time, and frequency of PDCAL can be selected using the software. The controlling and measuring software based on Keysight VEE automatically calculates the averages of charges, rise time and standard

deviations. With this software, more data are processed by the faster method, so that more accurate calibration can be performed. This system is software controlled with GPIB or Ethernet communication and data processing [3].

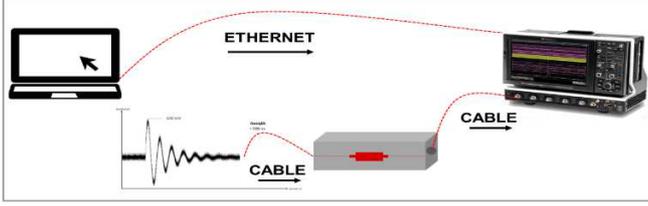


Fig. 2. Reference PD measuring system graphical diagram.

IV. PERFORMANCE OF PD MEASUREMENT SYSTEM

The model circuit of calibration setup includes the programmable pulse generator, capacitor module, measuring resistors and input impedances of a digital oscilloscope.

The uncertainty factor of the pulse generator can be defined as the accuracy of the output voltage and time accuracy of a digital oscilloscope. The model function of uncertainty is described as in (1),

$$\Delta Q = (V_s + \delta V_s') \cdot (C_0 + \delta C_0' + \delta C_0'') - \left(\frac{(V_n + \delta V_n') \cdot \Delta t}{R + \delta R' + \delta R''} \right) + \delta Q_r \quad (1)$$

The performance tests have been performed to determine the characteristic of PD measurement system with different capacitor modules. The required parameter values for the test results are given in Table 6. In Table 6, errors and standard deviation in different ranges values are calculated for 1 pF, 10 pF, and 100 pF capacitor modules. The most sensitive and reliable regions have been identified. According to the results of performance test described in Table 5, the region of the lowest uncertainty values is selected as the reference region.

The reference apparent charges from 50 pC to 1000 pC have been obtained using the capacitor module of 100 pF. The reference charges between 5 pC and 20 pC are taken from the capacitor module of 10 pF and the apparent charges from 1 pC to 20 pC are more reliable by using the capacitor module of 1 pF.

V. CONCLUSION

The reference partial discharge measurement system designed and constructed in TÜBİTAK UME is intended to be used in a high voltage metrology laboratory for the traceability of PD calibrators. The relative expanded uncertainty of partial discharge measurements is less than 2% with the confidence level of 95% that fulfills the requirements of IEC 60270.

For the characterization of PD measurement system designed, reference PD calibrator system (PDCAL) has also been constructed within $\pm 1\%$ relative uncertainty. The developed reference PD calibrator can be used for calibrating general PD calibrators and PD detectors used by electric

companies. The reference calibrator can be programmed by calculating the apparent charge value and rise time. The calibrator generates a current impulse with a delivered charge from 1 pC to 1000 pC. Pulse rising time is less than 4 ns.

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Table 1. Results of the measurement of PD measuring system

Capacitor Module 100 pF								
Applied Charge From Ref. Gen.	Measured Charge From Ref. Meas. Sys.	Error		Standard Dev.		Uncertainty		situation
		pC	%	pC	%	pC	%	
5.00	4.93	-0.07	-1.4	0.12	2.35	0.08	1.72	OK
10.00	10.07	0.07	0.7	0.10	1.00	0.11	1.04	OK
20.00	20.17	0.17	0.9	0.13	0.65	0.19	0.93	OK
50.00	50.37	0.37	0.7	0.19	0.38	0.43	0.86	OK
100.0	100.7	0.7	0.7	0.24	0.24	0.85	0.84	OK
500.0	501.6	1.6	0.3	1.77	1.77	4.32	0.86	OK
1000.0	1009.6	9.6	0.9	2.02	2.02	8.44	0.84	NO
Capacitor Module 10 pF								
Applied Charge From Ref. Gen.	Measured Charge From Ref. Meas. Sys.	Error		Standard Dev.		Uncertainty		situation
		pC	%	pC	%	pC	%	
1.00	1.01	0.01	1.1	0.06	6.28	0.04	4.10	OK
5.00	5.11	0.11	2.2	0.06	1.20	0.06	1.13	NO
10.00	10.04	0.04	0.4	0.07	0.69	0.10	0.95	OK
20.00	20.21	0.21	1.0	0.09	0.47	0.18	0.89	NO
50.00	49.54	-0.46	-0.9	0.12	0.25	0.39	0.79	NO
100.0	97.56	-2.44	-2.5	0.13	0.14	0.68	0.69	NO
Capacitor Module 1 pF								
Applied Charge From Ref. Gen.	Measured Charge From Ref. Meas. Sys.	Error		Standard Dev.		Uncertainty		situation
		pC	%	pC	%	pC	%	
1.00	0.96	-0.04	-4.1	0.03	2.63	0.02	1.99	NO
2.00	1.96	-0.04	-2.1	0.03	1.31	0.02	1.26	NO
5.00	5.02	0.02	0.4	0.06	1.17	0.06	1.15	OK
10.00	9.98	-0.02	-0.2	0.05	0.54	0.09	0.95	OK
20.00	20.00	0	0	0.09	0.45	0.19	0.93	OK

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