

Study on Charge Standard for calibrating PD Measurement Equipments

Na Liu¹, Shengyou Gao², Caijun Yang¹, Lu Huang¹

¹National Institute of Metrology, Beijing, P. R. China, liuna@nim.ac.cn

²Tsinghua University, Beijing, P. R. China, eeagsy@tsinghua.edu.cn

Abstract –The characteristics of a portable charge standard for calibrating partial discharge(PD) measurement equipments are discussed and investigated in this paper. A portable PD calibrator and measuring system was set up by NIM, China. This calibrator and two typical commercial ones are measured by NIM's digital system. The discharge impulses and the charge generated by the three calibrators are recorded and compared. The comparison results show that the portable PD calibrator is of good characteristic both in the range of charge and in the shape of its impulses and also in that of the repeatability.

Keywords – Charge, Partial discharge

I. INTRODUCTION

PD acceptance tests are required for every High Voltage(HV) apparatus to detect possible failures of the insulation, and rigid limits of apparent charge were specified in the standards of high voltage apparatus. However, the stochastic and unstable nature of partial discharges often led to the wrong conclusion. Therefore people paid much attention to the accuracy of their PD measuring equipments. PD calibrators are crucial components in PD measurements, by which the scale factor of the injected charge of the PD measuring system is determined. Many requirements on the PD calibrators and the measurement uncertainty were specified in IEC60270^[1-3].

Apparent charge(q) is the kernel parameter to be calibrated of PD calibrators. In 1999, with the framework of a European project there was an international comparison of thirteen laboratories for the apparent charge q of the PD impulses ranging between 1pC and 500pC^[4]. Charge generators different from conventional one for calibrating PD measuring equipments are investigated^[5,6]. In practice there are usually impulses up to thousands of pC generated in large-scale apparatus, such as power generators. Therefore the measurement range of PD measuring equipments is usually designed up to thousands of pC or higher. Besides these for the convenience of users a portable PD calibrators with wider

range of charge are more satisfactory and acceptable. In this paper, a portable partial discharge(PD) calibrator ranging between 1pC and 3000pC is developed by NIM, China.

II. DESCRIPTION OF THE MEASURING SYSTEM

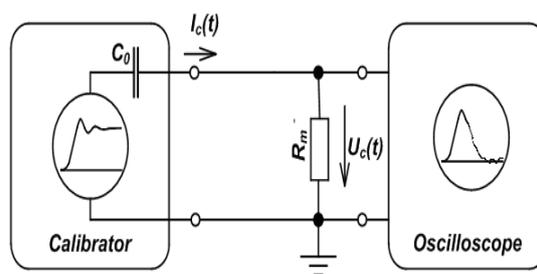


Fig.1 measuring circuit for charge of PD calibrators

Figure1 is the schematic diagram of PD calibrators and the measuring system of the output charge recommended in IEC60270. The PD calibrator is usually composed of a step voltage generator and a capacitor C_0 with small capacitance, such as a nominal value of 10pF and 100pF. The upper limit value of the rise time of the step voltage is 60ns.

To calculate the charge of the current impulse output by PD calibrator, a measuring resistor R_m with good frequency characteristics is applied. The impulse recorded by digital oscilloscope or digital recorder is in fact the voltage drop U_R across the measuring resistor R_m .

The output charge q of the calibrator is the integration of the impulse current i_R across the measuring resistor, and can be calculated by (1)

$$q = \int i_R dt = \frac{\int U_R dt}{R_m} \quad (1)$$

where R_m is the measuring resistor; i_R is the impulse current across the measuring resistor R_m ; U_R is the impulse voltage across the measuring resistor R_m .

According to Equation(1), theoretically the charge q is

irrelevant to the measuring resistor R_m . It is noted that in a practical measuring system the frequency bandwidth of the system and the accuracy of the measuring resistors are relevant to the measuring uncertainty, therefore these factors should not be neglected. A digital oscilloscope with high bandwidth and sampling rate is optimistic and expected. For example, a digital oscilloscope, with bandwidth of 500 MHz, and sampling rate of 40 GS/s are applied. On the other hand, measuring resistors with high accuracy and good frequency characteristics are necessities. resistors of 50Ω to 200Ω , with accuracy of $\pm 0.2\%$ and bandwidth of 100MHz is applied for this work.

III. CHARACTERISTICS OF A CHARGE STANDARD

The PD generators for the calibrating of PD measuring equipments can be as charge standard, such as that developed in this paper are different from the conventional or commercial calibrators. The characteristics of the charge standard are as followings:

(1) Charge: The repeatability of charge is as important as the accuracy of it. The output charge is the kernel parameters of a PD charge standard.

(2) Waveform: To obtain impulses with high quality in their waveform is the precondition of the measuring of charge. A charge standard should be a calibrator with low stray capacitance and series inductance so as to output good impulses with no obvious oscillation.

(3) Internal resistance: The charge standard should be a generator with low internal resistance to avoid the variation in the impulses with different PD measuring equipments of different impedances. The measuring resistor R_m used in this paper are of resistors of 50Ω to 200Ω , with accuracy of $\pm 0.2\%$ and bandwidth of 100MHz is applied for this work.

(4) Rise time t_r : The rise time of the step voltage in the calibrator is relevant to the frequency bandwidth of PD measuring equipments. For example, a conventional PD calibrator (Calibrator B in Section V) designed for a commercial PD measuring equipment with centre frequency up to MHz can generate the wave of step voltage with the rise time of about 10ns. We can indirectly estimate the rise time of the step voltage according to the measurement methods recommended in Ref[3] or Ref[7,8]. In this paper, the method to indirected measurement of t_r with the duration of the impulse current across the measuring resistor connected to PD calibrators as shown in Figure1.

(5) Range: With the development of digital technique, the measurement range of charge is getting wider. PD charge standards with the charge quantities up to thousands of

pCs or even much more are expected. In this paper, the charge up to 2000pC output by the calibrator of NIM (Calibrator A in Section IV) are measured.

(6) Power supply: To eliminate the interference from 220V power supply, most of the conventional calibrators are supplied by battery. However, as the battery capacity of a calibrator is consumed, the output amplitude of the step voltage will decrease as the ratio so as to that of the output charge. Therefore, the way to supply by battery is not suitable to a charge standard for the calibration PD measuring equipments. In this paper, that of the calibrator of NIM is an independent one to power line and not by an external battery.

(7) Portable: Besides these characteristics from the views of the users of PD measurement equipments, a portable PD charge standard is more satisfactory and acceptable to them so as to the application of on-site calibration. Unlike the charge standards in Ref[4], Ref[5] and Ref[6], the charge standards in NIM is designed to be a series of portable calibrators output between 1pC to 3000pC.

IV. RECOMPARISTION BETWEEN PD CALIBRATORS

(1) range

The output charge of 3 types of portable PD calibrators are listed in Table1 in which Calibrator A is the portable charge standard by NIM, and the others are two typical commercial calibrators. Calibrator B and Calibrator C are commercial calibrators with good characteristics in their waveform and repeatability. Calibrator C is the one designed for conventional PD measuring equipments with centre frequency lower than 500 kHz. Calibrator B is the one designed for PD measuring equipments with centre frequency up to MHz.

Table 1. Norminal value of PD calibrators.

NAME	TYPE	Charge q (pC)
Calibrator A	PDC_NIM	1,2,5,10,20,50,100...3000
Calibrator B	CAL542	1,2,5,10,20,50,100
Calibrator C	LDC-5	5,20,100,500

(2) power supply

To avoid the inference from power line and to make it easier to be used in user's lab, the power supply of conventional calibrators such as Calibrator B and Calibrator C are mostly supplied by battery. However, a new arising problem should be noticed that the amplitude of the step voltage is closely relevant to the output charge of the calibrators. Therefore, the voltage of its battery is an important uncertainty factor for the measurement of output charge. After working for no longer than one hour

or being put away for a long time, deviation of the output charge can be several percents, a value approaching its maximum permissible error ($\pm 5\%$).

Different from Calibrator B or Calibrator C but similar to the calibrator in Reference[3], by using a digital-to-analog converter(DAC) chip, we can obtain the calibrator A with better characteristic in its repeatability of charge as shown in Table1. The output charge of this calibrator is irrelevant to the voltage of its power supply. And the Calibrator A can work for several hours. It is longer than that of Calibrator B and Calibrator C. Thus, it is not necessary to check the indication of battery voltage frequently and worry about an unneglectable error introduced by the decay of its battery.

(3) Waveforms

The waveforms of different impulses with the charge from 1pC to 500pC output by the three calibrators in Table1 are shown in Fig1. to Fig8. The impulse with 3000pC output by Calibrator A is shown in Fig.9.

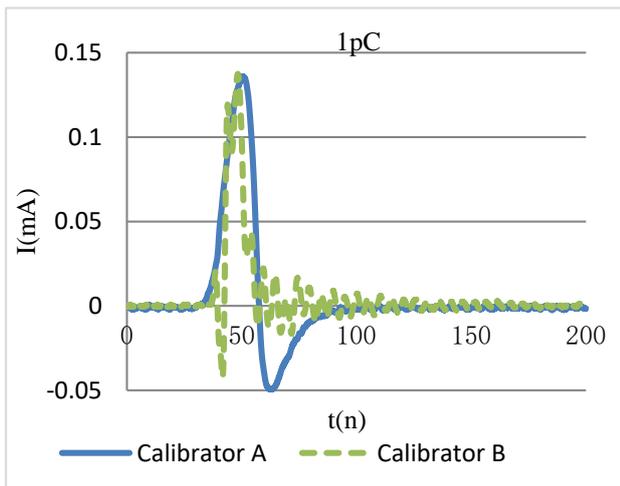


Fig. 1. 1pC :output by Calibrator A and Calibrator B

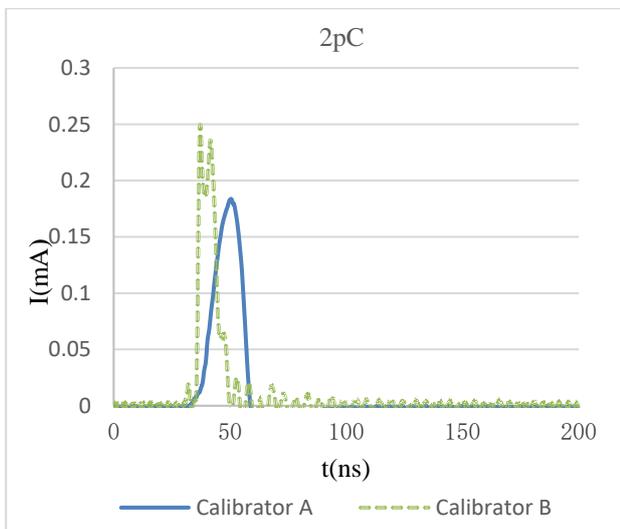


Fig. 2. 2pC :output by Calibrator A and Calibrator B

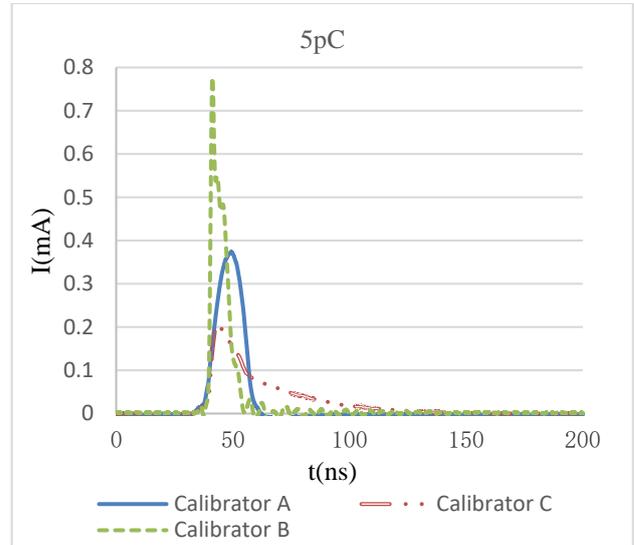


Fig. 3. 5pC :output by Calibrator A, Calibrator B and Calibrator C

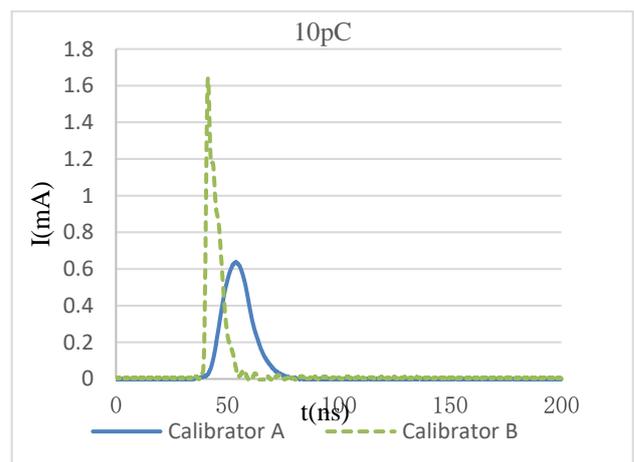


Fig. 4. 10pC :output by Calibrator A and Calibrator B

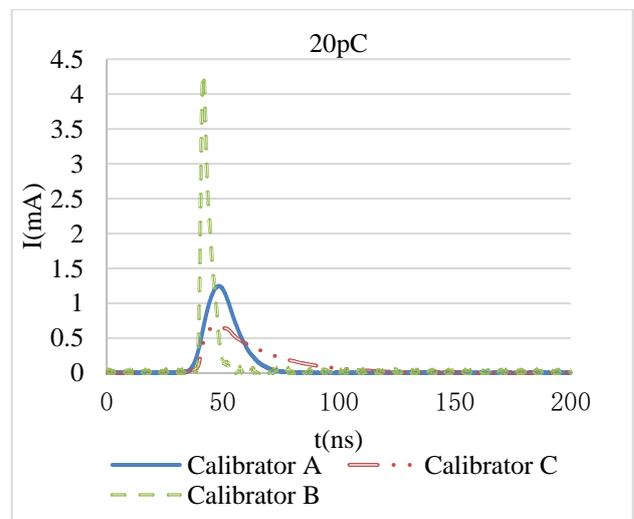


Fig. 5. 20pC :output by Calibrator A, Calibrator B and Calibrator C

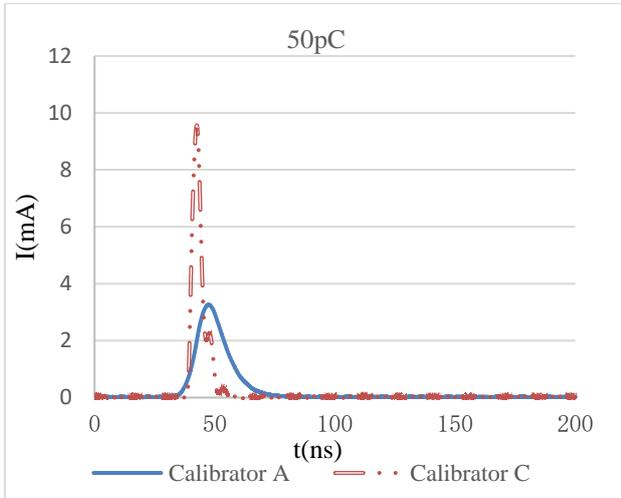


Fig. 6. 50pC :output by Calibrator A and Calibrator C

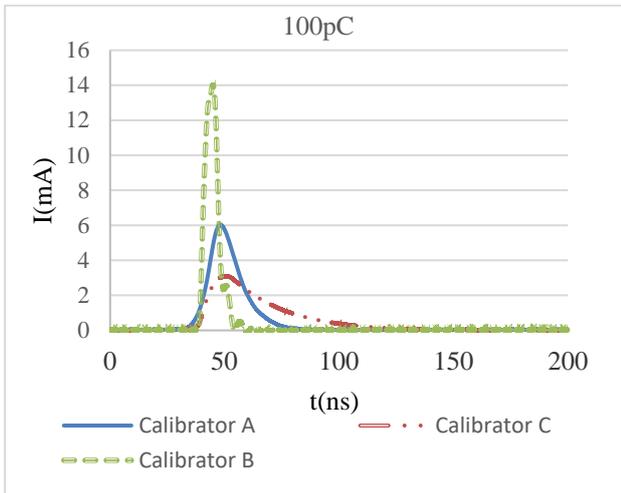


Fig. 7. 100pC :output by Calibrator A, Calibrator B and Calibrator C

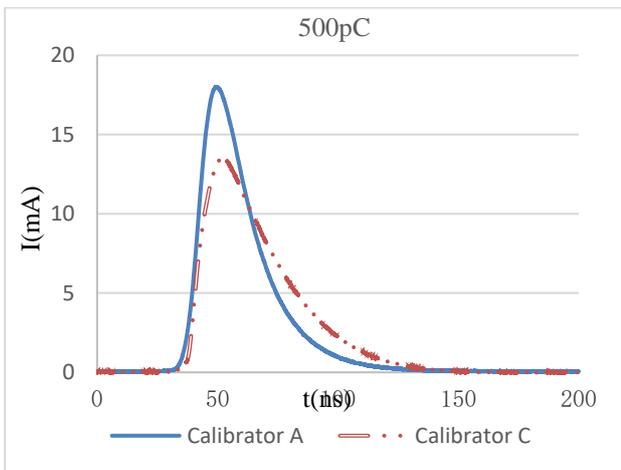


Fig. 8. 500pC :output by Calibrator A and Calibrator C

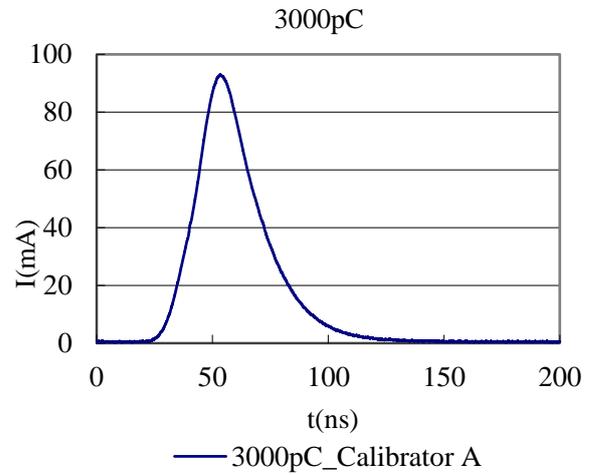


Fig. 9. 3000pC :output by Calibrator A

V. CONCLUSIONS AND DISCUSSION

Based on the comparison of the waveform of the three calibrators as shown in Fig.1 to Fig9, we can see that the shapes of the impulses output by the charge standard of NIM(Calibrator A) is better. The duration of the wave of the charge standard is also optimistic so as to there are ample frequency components are contained in their impulses.

In addition, the repeatability of the three calibrators has been tested and evaluated. The relative experimental standard deviation based on ten times of measurement data is not more than 0.5% between 10pC to 3000pC and not more than 1.5% of 1pC. The results show that there are good characteristics in the repeatability of the charge standard.

REFERENCES

- [1] IEC 60270: 2000: *Partial discharge measurements*
- [2] GB/T7354-2003 *High-voltage test techniques —Partial discharge measurements*
- [3] IEC 60270: 2015: *Partial discharge measurements*
- [4] Schon, K.; Lucas, W.; et al.: *Intercomparison on PD calibrators and PD instruments*. Proc. 11. ISH 99, London 1999, Bd. 1, S. 1.5.S1 - 1.8.S1
- [5] K. Schon, H.D Valentini, *Programmable impulse hcharge generator for calibrating PD*, Proc. of 10th Int. Symp. on Highvoltage Montreal, quebec, canada August 25-29, 1997, pp.33-36.Popescu, A., *Electrical machines and drives*, Politehnum, Iasi, 2011.
- [6] R.Gobbo, G. Pesavento, A. Scroccaro etal: *Calibration Reproducibility in partial discharge measuring systems*. Proc. XIVth. ISH 2005, Beijing, China 2005, J-42 1-4.
- [7] Na liu, Shengyou gao, Jiawei chen. *Research on Measurement of the rise time of the step voltage generated by PD calibrator*. Proc. the 18th Annual meeting of China Association for science and technology . September, 2016 Xi'an, China.S3
- [8] GB/T7354-2018 *High-voltage test techniques —Partial discharge measurements*