COMPARISON TEST OF TRANSDUCERS AND REFERENCE SYSTEM FOR IMPULSE CURRENT MEASUREMENT

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Abstract: A traceability system for impulse current measurements is under construction in Japan. A reference measuring system (RMS) for impulse currents has also been developed. Transducer comparison tests for impulse current measurement were conducted among principal laboratories in Japan. Two test wave shapes of 4/10 and 8/20 µs impulses were used for the comparison test. The peak values of the current were 10 and 20 kA, respectively. The device from each laboratory was connected in series with the RMS and the impulse current was measured simultaneously. The comparison test results and traceability system are described.

1 INTRODUCTION

The impulse current test is an important test that is used for the evaluation of lightning protection equipment. The quality of the test is significantly dependent on the measuring system. Some countries already have their own standard measuring systems; however, the standard measuring system is currently under construction in Japan. The system for impulse current is maintained by the Japan High voltage Impulse testing Laboratories Liaison (JHILL), established under the Japan Electric Machine Industry Association (JEMA).

According to the international standard on high-voltage test techniques, a comparison test is required to confirm the impulse parameters that have traceability or compatibility with the standard values. An international comparison test was carried out between Japan and the Korea Electrotechnology Research Institute (KERI) in 2010. Compatibility was confirmed, and a domestic comparison test of main laboratories in Japan was then conducted, and the traceability system was established.

In this paper, the comparison test procedure and its results, and the traceability system established in Japan are described.

2 OUTLINE OF COMPARISON TEST

A comparison test of the impulse current of measuring devices began in June, 2009 and involved nine main laboratories in Japan; MSA Co., Ltd., Otowa Electric Co., Ltd., Sankosha Corporation, Shoden Corporation, Central Research Institute of Electric Power Industry (CRIEPI), Toshiba Corporation, Japan AE Power systems Corporation, NGK Insulators, Ltd. and Mitsubishi Electric Corporation. Each current measuring device was compared with the reference measuring system (RMS).

For each laboratory, the same recorder (8 bits, 500 MS/s, Tektronix TDS744) was used. Test wave shapes of 4/10 and 8/20 µs were used for the comparison test with test current peaks of 10 and 20 kA, respectively.

The test was conducted by connecting two coaxial shunts in series, as shown in Figure.1 (a). In the figure, [A] represents a shunt of the rounded measuring system, and [B] the shunt of each laboratory. An impulse current was generated by the impulse current generator of each laboratory. The input terminals of the shunts were connected to the output terminal of the impulse current generator. The earth connection terminals of two shunts are mutually connected with the earth terminal of the impulse current generator. A voltage is charged to capacitor C, and when the discharge gap G is operated, the RLC circuit is discharged and an impulse current is generated. A current waveform of shunt A and a reverse-polarity is then caused in shunt B. The wave shapes are sent to the measurement room by coaxial cable to avoid interference. The power supplies of the recorders are respectively supplied via independent insulation transformers. Moreover, each recorder is separated electrically.

Figure 1(b) shows the arrangement used for comparison of the shunt and current transformer transducer (CT). In this circuit, CT is electrically insulated from the impulse current generator circuit. When it is not possible to use two recorders, it is possible to measure the signals with one recorder. Even in this case, the recorder should be supplied with power through an insulation transformer and each measurement circuit should be separated electrically. In addition, it is necessary to check the stability and interference to confirm the measuring system is under normal conditions before the comparison test. This is to exclude the influence of the circulation current, interference to the power line, and electromagnetic noise. When these checks were imperfect, the difference from the peak value was confirmed to be 35% or more. In addition, a problem with the GPIB that connects the recorder with the computer for control and evaluation caused communication errors. The common digital recorder may be connected to the ground from the outer case of the recorder. However, the recorder used a state of floating during this comparison test. Therefore, there were some problems where the recorder stopped suddenly and the earth potential of the recorder shifted. In that case, the measuring system was restarted, and re-calibration was conducted prior to the next comparison test.

The interference test of the measuring system was conducted prior to the comparison test. The recorder must be checked and calibrated before and after the test. To confirm the recorder performance, the output of a sine wave generator, which has traceability to the national standard in Japan, is input to the digital recorder. The peak value of the input voltage and the frequency are then read. Frequencies of 25 kHz, which corresponds to the 8/20 impulse, and 50 kHz, which corresponds to the 4/10 μs impulse were applied. The input voltages were 40 and 80 V_{pp}, of which the peak values and frequencies were evaluated using the least squares method from the measured waves. The sine wave voltage is applied to the recorder ten times and the average value and standard deviation are measured. These testing procedures are executed automatically. Moreover, the resistance value of the shunt of the RMS is measured before testing at each laboratory to confirm the stability of the reference shunt.

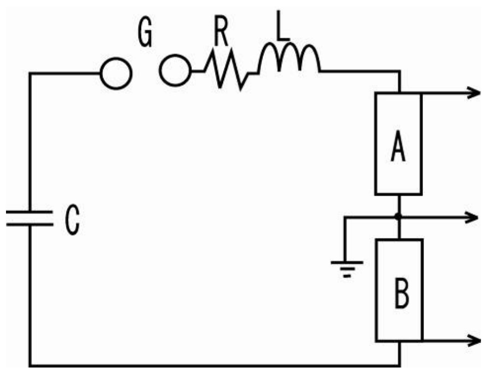
3 MEASURING SYSTEM UNDER TEST

3.1 Overview of RMS

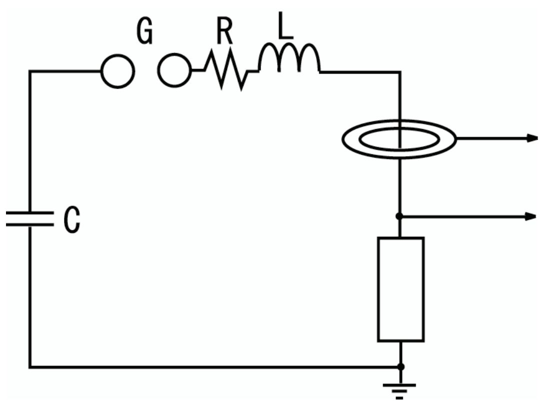
The impulse current measuring system is composed of a shunt and a digital recorder. The shunt is a coaxial shunt that is made from carmaroi with a resistance of 1 mΩ and the rated current is 200 kA. The reference shunt is shown in Figure 2(a). The resistance of the reference shunt was calibrated by the direct current voltage at Japan Electric Meters Inspection Corporation (JEMIC) to ensure that this RMS has traceability to the national standard of Japan.

The digital recorder screen capture shown in Figure. 2(b)) employs a general-purpose oscilloscope (8 bits, 500 MS/s) that was calibrated using 25 and 50 kHz sine wave voltages for traceability to the national standard. The estimated measurement uncertainty of the RMS was 2.1% for the peak- and time-parameter measurements.

The High Current Impulse Calculator (HiCIC) software was developed to calculate the wave parameters for the comparison test. HiCIC has functions such as automatic scaling, control of two digital recorders to electrically separate their circuits via wireless LAN, and automatic calculation of the scale factors from the measured impulse current parameters. The input range of the recorder was automatically set to be 80%f.s.d. The performance of the software for calculation of the impulse waveform parameters was confirmed through processing of the reference wave shapes generated by the software IEC-TDG defined by the IEC61083-2. The sine wave generator used to check the digital recorder consisted of a function generator (Wave Factory 1945, NF Corp.) and an amplifier (HSA4011, NF Corp.).

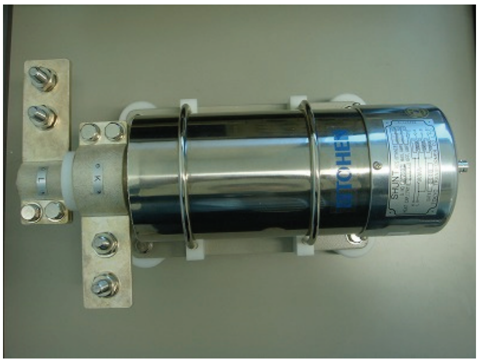


(a)



(b)

Figure 1: Test circuit for the comparison test.



(a)

(b)

(c)

Figure 2: Reference measuring system.

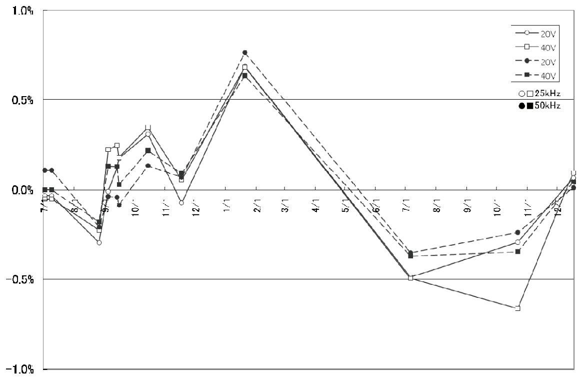
3.2 Domestic Measuring system

The laboratories that participated in the comparison test of the transducer impulse current used a common digital recorder (TDS 744, Tektronix) and software HiCIC, which were circulated with the RMS. The recorder was connected with the transducer under use according to the laboratory standard, as detailed in Figure 1. Among the measuring devices of participant laboratories, 6 were CTs and 5 were coaxial shunts (two laboratories used two transducers), so that 11 transducers were compared using the RMS, and are labeled from A to K in Table 1. 2 shunts were made by the Tokyo Transformer Corporation and 3 shunts were made by Haefely. The CTs were made by Pearson. The scale factor of each transducer was determined by each laboratory.

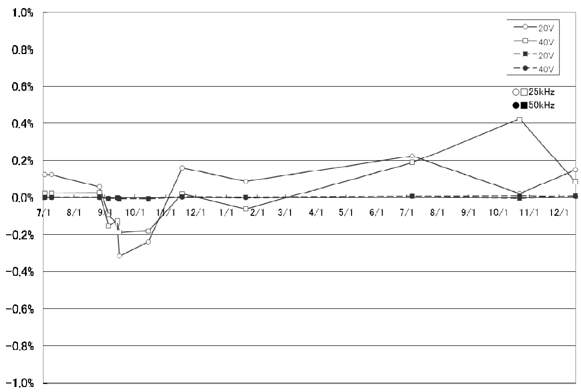
Each device was connected with the RMS in series and the impulse current was simultaneously measured.

Table 1: Measuring devices for the comparison test.

Device	Type	Model
Reference	Shunt	Tokyo Transformer
A	CT	Pearson 1423
B	CT	Pearson 1423
C	Shunt	Haefely SH-R
D	Shunt	Tokyo Transformer
E	CT	Pearson 4997
F	CT	Pearson 1423
G	Shunt	Tokyo Transformer
H	Shunt	Haefely SH-R
I	CT	Pearson 1330
J	CT	Pearson 6750
K	Shunt	Haefely SH-R

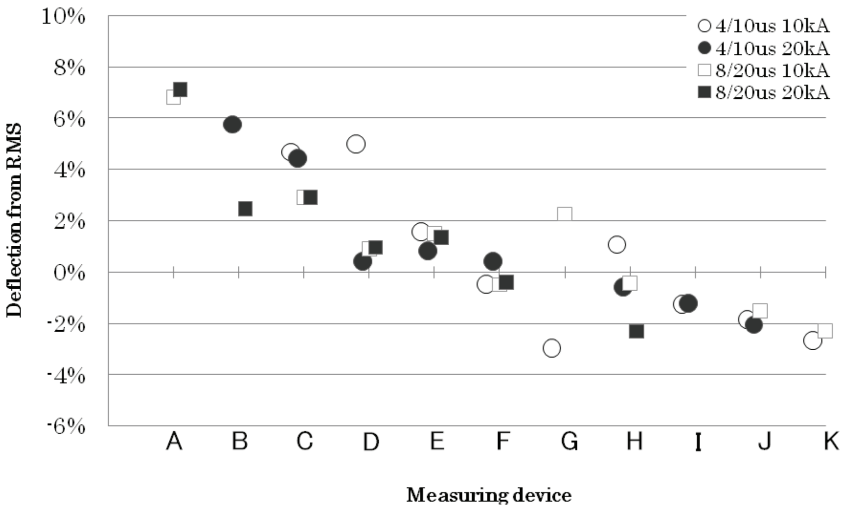


(a)

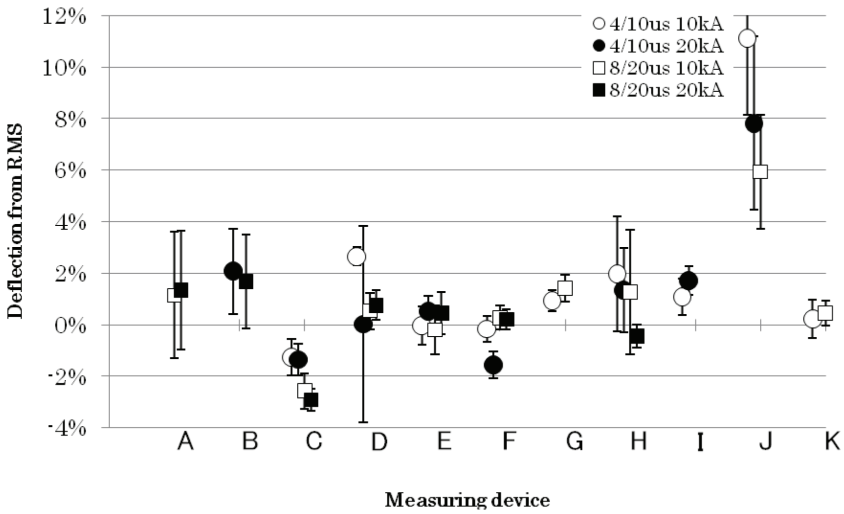


(b)

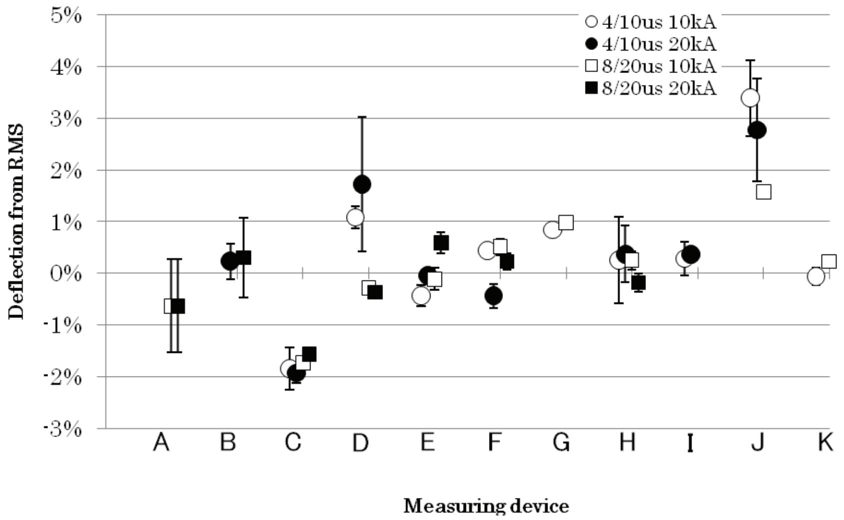
Figure 3: Calibration of the shunt for the RMS recorder.



(a) Peak value



(b) T1



(c) T2

Figure 4: Comparison of impulse current results.

4 COMPARISON TEST RESULT

4.1 Variation of Reference Recorder

To confirm the stability of the recorder, two different sine wave voltages were input to the digital recorder, and the peak value of the voltage and frequency were recorded. The variation of the RMS recorder from July, 2009 to November, 2010 is shown in terms of the peak value and frequency in Figure 3(a) and 3(b), respectively. The deflections from the mean value of all the measurement data are plotted to show the tendency of the relative characteristics. The maximum deviations are 0.77% for the peak voltage and 0.42% for the frequency. These values are in the ranges of the uncertainty of the digital recorder, and they also contain the differences of the signal generator.

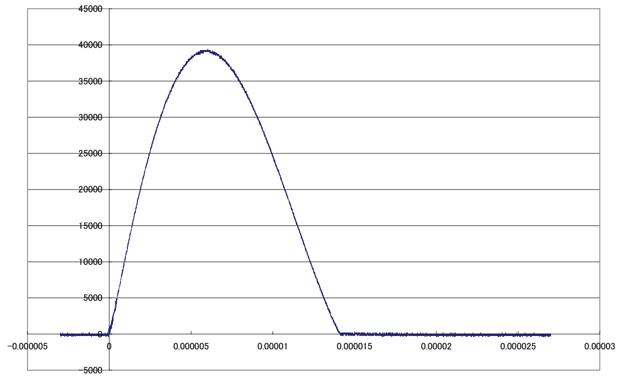
4.2 Comparison Test Result

Test results are shown in Figure 4. The maximum deviations of the wave parameters from those of RMS were 7.1% for the peak value measurement, and 11.1% for the time parameter measurement.

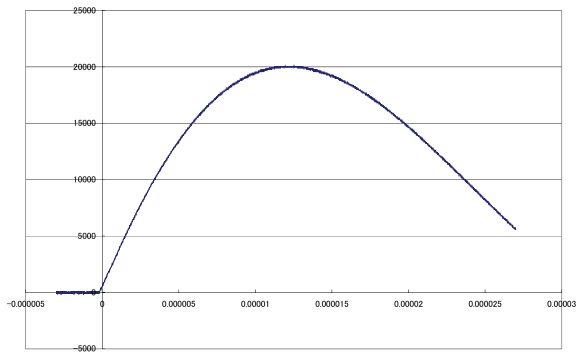
Figure 4 shows the peak value comparison result in (a), the front time comparison result in (b) and the time to half value comparison results in (c). These values are indicated as deflection from the RMS.

A typical curve for the comparison test in Figure 5 is a smooth curve, although some laboratories generated non-smooth curves. The differences of the particular points of the measurements influence the wave parameters; in the front time measurement, these were the peak value, and the 10% and 90% points of the peak value, of which the difference was approximately ±2% in standard deviation. In addition to the front time evaluation, the 50% point of the peak value of the tail part influences the wave parameter for the time to half value. However, the standard deviation of the time to half value is small compared with the difference of the front time, which is caused by the software algorithm that analyzes the wave parameters.

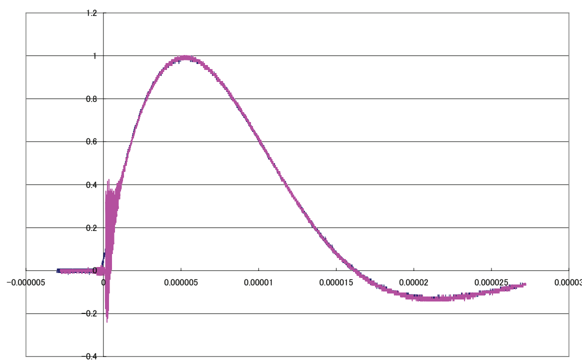
The large deflections to the peak value of laboratory devices A-C were due to using the wrong scale factor. The large deflection from the time parameters for laboratory device J was due to superimposed noise, because the rated current of the measuring system was too large to compare the current level. The wave shape is shown in Figure 5(c); the oscillations are superimposed until the vicinity of 40% of the peak on the front. The measurement waveform of the RMS at this time was very smooth.



(a) 4/10 impulse



(b) 8/20 impulse



(c) Wave shapes of Laboratory J

Figure 5: Impulse current waveform in the comparison test.

5 CONCLUSION

A comparison test between a RMS and transducers was carried out in Japan, of which the differences were within ±7.1% for the peak value comparison comprehensive evaluation.

An international comparison test of the impulse current measuring system was carried out by using this RMS and Korean standard measuring system. In the results of the comparison, very good agreement was observed. The measuring system in Korea is traceable to the national standard of Germany. Therefore, the compatibility and the traceability have been established among the standard measuring systems of the three countries. This means Japan's 11 transducers for impulse current measurement have traceability to the international standard.

Three complete measuring systems in Japan will be comparing with the reference measuring system that is used for the comparison test described in this paper. The traceability system for the impulse current in Japan will be established after then.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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