Comparison of Two Impulse Calibrators with a High Resolution Digitizer

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Abstract

The lightning impulse voltage calibrators, developed at NML and MIKES-HUT, and a recently developed commercial digitiser were compared. With this three-way comparison, not only the accuracies of the devices were compared, but also the linearity of both peak voltage and time parameters of the devices was investigated. The results demonstrated that the linearity of the calibrators is superior to that of the digitiser.

Measurement Arrangements

Calibrators for impulse voltages can be used for calibrating digital recorders and other components of impulse voltage measurement systems [1]. The NML calibrator [2] is a one stage impulse Marx generator of low output impedance, with MOSFETs used as the impulse switching devices. The peak voltage range of the calibrator is 30 to 1200 V. The output impedance is a 50 Ω non-inductive resistor (or attenuator) attached to the end of the output transmission cable to serve as the signal terminator. The output values of the calibrator are calculated using commercial circuit simulation software, with the DC input voltage and measured component values of the generation circuit being the inputs of the calculation. The estimated uncertainty (k=2) for the impulse peak value is 0.1%, and 1% for the time parameters.

The MIKES-HUT calibrator [3] is a single stage impulse Marx generator of high output impedance. The generation circuitry is housed in a compact box that can be attached directly to the input terminal of a digitiser. The analytical solutions of the circuit formulae are used to calculate the output values from the DC input voltage, component values of the generation circuit and the input impedance of the external load (e.g. the digitiser). The peak voltage range is 50 mV to 320 V. Output values of the calibrator are traceable to Finnish national standards of resistance, capacitance, and direct voltage. The estimated uncertainty (k=2) for the impulse peak value is 0.05% and for the time parameters 0.5%.

The digitiser used in the comparison has a 14-bit resolution and a sampling rate of 200 MS/s. The digitiser has its own in-build software to calculate the parameters of the applied impulses. The manufacturers default scale factors were used in the measurements. The scale factor of digitiser in the 10 V range was also measured at PTB using step voltages, and the scale factor in the 320 V range was calibrated against PTB's impulse voltage standards, with maximum uncertainty of 0.4 % and 1.5% for peak voltage and time parameters respectively.

The comparison measurements were performed at PTB, in an air-conditioned laboratory with its ambient temperature maintained between 22 and 23 °C. The measurements lasted two days, with the MIKES-HUT calibrator being compared with the digitiser first. Various impulse attenuators of 50 Ω input impedance were used with the NML calibrator to attenuate the output peak voltage to match the measurement range of the digitiser. The impulse waveform from the NML calibrator was 0.81/60 μs and that from the MIKES-HUT calibrator was 0.84/60 μs. In each comparison measurement, 10 impulses from the calibrator were applied to the input of the digitiser, and the digitiser calculated the average values of the measured impulses. The standard deviations were low, typically below 0.03% for the peak value and 0.2% for the time parameters.

Measurement Results

Figure 1 and Figure 2 show the peak voltage difference and front time difference, respectively, of the values measured by the 10 V range of the digitiser from the outputs of the calibrators. The impulses were applied at the 10 V input terminal of the digitiser. An attenuator with a scale factor of 12.6 was used for the output of the NML calibrator. No attenuators were used for the output of the MIKES-HUT calibrator. PTB's measurement points (step methods) are also shown in the Figures.

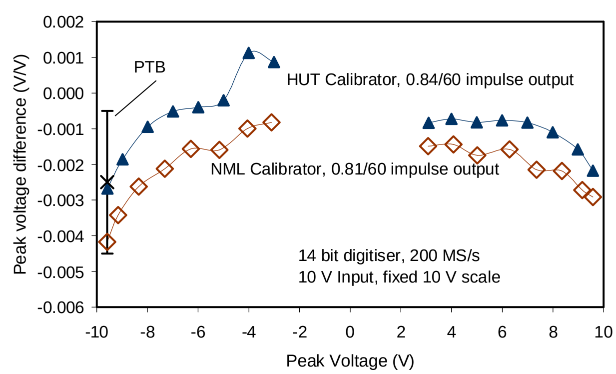

Figure 1 Peak voltage differences of the digitiser reading (10 V range) from the calibrators' outputs.

Figure 3 and Figure 4 show the peak voltage difference and front time difference, respectively, of the values measured by the 320 V range of the digitiser from the outputs of the calibrators. The impulses were applied at the 2000 V terminal of the digitiser. No attenuators were used for either the NML or the MIKES-HUT calibrator. Measurement points made by PTB against its impulse standards are also shown.

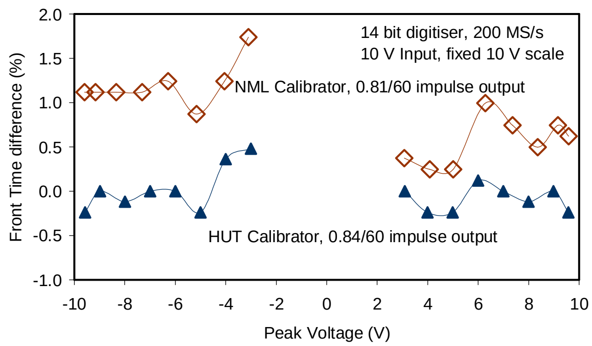

Figure 2 Front time difference of the digitiser reading (10 V range) from the calibrators' outputs.

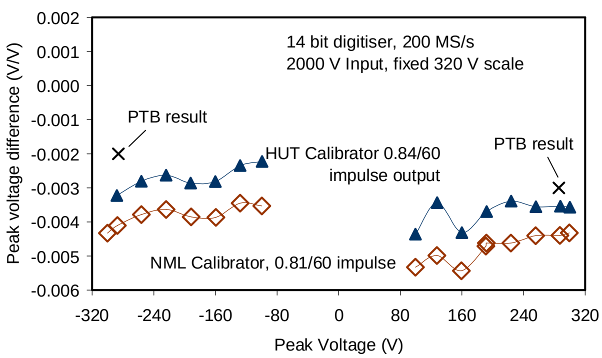

Figure 3 Peak voltage differences of the digitiser reading (320 V range) from the calibrators' outputs.

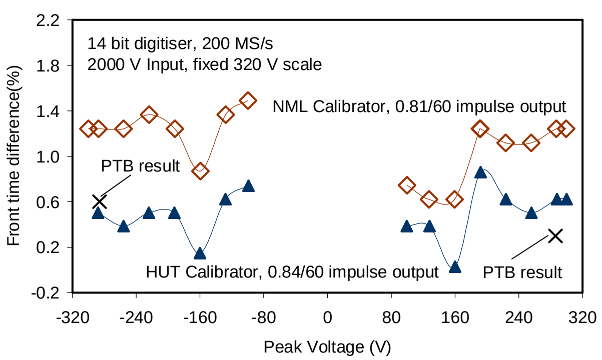

Figure 4 Front time difference of the digitiser reading (320 V range) from the calibrators' outputs.

Discussion

It should be noted that the 14-bit resolution of the digitiser enabled the impulse measurements to be performed at values between 30% to 95% of a fixed scale. It can be seen from Figure 1 and Figure 3 that, with the digitiser scale fixed, the voltage non-linearity behaviour of the digitiser was almost the same when the two different calibrators were used. Several conclusions about the digitiser and the calibrators can be drawn from these results. First, the measured non-linearity behaviour of the digitiser at these voltage scales should be quite accurate because they were the same and obtained with two different calibrators on different days. Secondly, the non-linearity behaviour of the digitiser is stable; and thirdly, the voltage linearity of the two calibrators has to be much better than that of the digitiser, otherwise the same non-linearity pattern of the digitiser would not be seen. Another conclusion is that the absolute peak voltage difference between the two calibrators was about 1 mV/V. This absolute difference includes both the voltage errors of the calibrators and the drift of the scale factor of the digitiser over two days.

It is most surprising to see (Figure 2 and Figure 4) that the non-linearity patterns of the front time were the same for impulses from the two calibrators. Although the non-linearity of the front time of the digitiser was about 1%, and the difference between the two calibrators was up to 1%, the pattern was constant within about 0.2%. This means that the non-linearity of the digitiser front time is repeatable to within 0.2 %, and that the front time linearity of calibrators is also within 0.2%.

Conclusions

The linearity of two calibrators was verified using a high resolution digitiser of stable but lower linearity. The voltage non-linearity of the digitiser investigated was about 4 mV/V for the 10 V range and 1.5 mV/V for the 320 V range. The non-linearity of the front time of the digitiser was about 1 %. The maximum voltage and front time non-linearity of the calibrators were approximately 1/10 to 1/5 of the corresponding non-linearity values of the digitiser.

The absolute peak voltage difference between the two calibrators was about 1 mV/V, and front time difference was about 1%.

References

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