भारतीय मानक

Indian Standard

IS 15638 (Part 1) : 2023
IEC 61083-1 : 2021

हाई-वोल्टेज और हाई-करंट परीक्षण में मापन के लिए उपयोग किए जाने वाले उपकरण और सॉफ्टवेयर

भाग 1 आवेग परीक्षण के लिए उपकरणों के लिए अपेक्षाएँ

(पहला पुनरीक्षण)

Instruments and Software Used for Measurements in High-Voltage and High-Current Tests

Part 1 Requirements for Instruments for Impulse Tests

(First Revision)

ICS 17.220.20; 19.080

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High Voltage Engineering Sectional Committee, ETD 19

NATIONAL FOREWORD

This Standard which is identical to IEC 61083-1 : 2021 ‘Instruments and software used for measurements In high-voltage and high-current tests — Part 1: Requirements for instruments for impulse tests’ issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the High Voltage Engineering Sectional Committee and approval of the Electrotechnical Division Council.

This Standard was first published in 2001. This revision has been undertaken to align it with corresponding latest IEC standard.

The text of the IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appears referring to this standard, they should be read as ‘Indian Standard’; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60060-1 : 2010 High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 2016/ IEC 60060-1 : 2010 High-voltage test techniques: Part 1 General definitions and test requirements (*third revision*)	Identical
IEC 60060-2 : 2010 High-voltage test techniques — Part 2: Measuring systems	IS 60060-2 : 2010 High-voltage test techniques: Part 2 Measuring systems	Technical Equivalent
IEC 62475 : 2010 High-current test techniques — Definitions and requirements for test currents and measuring systems	IS 16828 : 2018/ IEC 62475 : 2010 High-current test techniques — Definitions and requirements for test currents and measuring systems	Identical

The Committee has reviewed the provisions of the following International Standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard.

International Standard	*Title*
ISO/IEC Guide 98-3 : 2008	Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurements (GUM : 1995)

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the International Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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INTRODUCTION

The electric power industry requires standardized tools to provide confidence in high-voltage and high-current testing results, and to prove equivalence between tests performed in different test facilities.

Analogue capture of test data has today been largely replaced by digital capture with recording instruments based on sampling technology. This part of IEC 61083 specifies requirements for the performance of digital recorders used for high-voltage and high-current impulse tests.

Since the last revision of this standard, significant improvements have been made in many aspects of digitising instruments used for high-voltage and high-current tests. In particular, digitising resolutions have improved several folds since the last revision, with 12-bit to 14-bit being typical resolutions for impulse measurement digitisers. Furthermore, the improvement of A/D converters has led to a situation where other aspects of the instruments, such as linearity of front-end amplifiers and performance of immunity to interference, have replaced performance of A/D converters as the main concern of measurement accuracy and instrument reliability.

The requirements in this edition of the standard have been revised to reflect these technological changes. For example, the number of type tests aimed for evaluating the performance of A/D converters has been reduced, and new requirements for the linearity of complete system (A/D converter and analogue components) have been added.

During preparation of the second edition of this standard in 2001, the need to keep analogue oscilloscopes and peak voltmeters was thoroughly discussed. Requirements for analogue oscilloscopes have now been removed, and only essential requirements for peak voltmeters have been kept.

Indian Standard

TESTS INSTRUMENTS AND SOFTWARE USED FOR MEASUREMENTS IN HIGH-VOLTAGE AND HIGH-CURRENT

PART 1: REQUIREMENTS FOR INSTRUMENTS FOR IMPULSE TESTS

(First Revision)

1 Scope

This part of IEC 61083 is applicable to digital recorders, including digital oscilloscopes, used for measurements during tests with high impulse voltages and high impulse currents. It specifies the measuring characteristics and calibrations required to meet the measuring uncertainties and procedures specified in IEC 60060-2 and IEC 62475.

This document

- defines the terms specifically related to digital recorders;
- specifies the necessary requirements for such instruments to ensure their compliance with the requirements for high-voltage and high-current impulse tests;
- establishes the tests and procedures necessary to demonstrate their compliance;
- covers digital recorders that permit access to raw data from permanent or temporary storage;
- covers peak meters used for measuring the extreme value of lightning impulses, the peak value of switching or current impulses.

It has the status of a horizontal standard in accordance with IEC Guide 108.

This horizontal standard is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 108. One of the responsibilities of a technical committee is, wherever applicable, to make use of horizontal standards in the preparation of its publications. The contents of this horizontal standard will not apply unless specifically referred to or included in the relevant publications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IE 60060-2:2010, *High-voltage test techniques – Part 2: Measuring systems*

IEC 62475, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurements (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General definitions related to digital recorders

3.1.1
digital recorder
digitiser
recording instrument in which the recording is made in digital form on a magnetic or optical medium, or on a solid-state memory medium

Note 1 to entry: The waveform of the digital record is usually displayed on a screen, plotted or printed. This process may change the appearance of the waveform due to the processing involved.

[SOURCE: IEC 60050-313:2001, 313-02-16, modified – "digitiser" and a note to entry have been added]

3.1.2
approved digital recorder
digital recorder that is shown to comply with the requirements set out in this document

3.1.3
assigned measurement range
range of input voltage for which the instrument can be used within the uncertainty limits given in this document

3.1.4
output of a digital recorder
numerical value recorded by a digital recorder at a specific instant

3.1.5
full-scale deflection
minimum input voltage, which produces the nominal maximum output of the instrument in the specified range

3.1.6
offset
output of an instrument for zero input

3.1.7
raw data
original record of sampled and quantized information obtained when a digital recorder converts an analogue signal into a digital form, with the correction of the output for offset and multiplying the record by a constant factor being permitted

3.1.8
processed data
data obtained by any processing (other than correction for offset and/or multiplying by a constant scale factor) of the raw data

Note 1 to entry: Digital recorders which do not allow access to the raw data are not covered by this document.

3.2 Definitions related to rated values

3.2.1
rated resolution
r
reciprocal of two to the power of the rated number of bits N of the A/D converter, namely $r = 2^{-N}$

3.2.2
sampling rate
number of samples taken per unit of time

Note 1 to entry: The sampling time interval is the reciprocal of the sampling rate.

3.2.3
record length
duration of the record expressed either in a time unit or as the total number of samples

3.2.4
warm-up time
time interval from when the instrument is first switched on to when the instrument meets operational requirements

3.3 Definitions related to scale factor

3.3.1
scale factor
factor by which the output corrected for offset is multiplied in order to determine the measured value of the input quantity

Note 1 to entry: The scale factor includes the ratio of any built-in or external attenuator and is determined by calibration.

3.3.2
static scale factor
scale factor for a direct voltage or a direct current input

3.3.3
impulse scale factor
scale factor for an input representing the shape of the relevant impulse

3.3.4
assigned impulse scale factor
impulse scale factor of a digitiser determined at the most recent calibration

3.3.5
base line
value of the output of the recorder during the initial flat part of the record of the impulse, with the value determined from the mean of at least 20 samples in the initial flat part

3.4 Definitions related to dynamic performance

3.4.1
nominal epoch
τ_N
range of values between the minimum (t_{min}) and the maximum (t_{max}) of the relevant time parameter of impulse voltage or impulse current for which the digitiser is to be approved, with the relevant time parameter being:

– the front time T_1 for full and tail-chopped lightning voltage impulse and exponential current impulse

– the time to chopping T_c for front-chopped lightning voltage impulse

– the time to-peak T_p for switching voltage impulses

– pulse rise time $0,5 \cdot (T_t - T_d)$ for rectangular current impulse

Note 1 to entry: Nominal epoch is applicable to the front part of an impulse only.

Note 2 to entry: A digitiser usually has one, two or more nominal epochs for different waveforms. For example, a particular digitiser is approved for:

- full and tail-chopped lightning impulses with an assigned impulse scale factor F_1 over a nominal epoch τ_{N1} from T_1 = 0,84 µs (t_{min}) to T_1 = 1,56 µs (t_{max}),
- full lightning impulses with an assigned impulse scale factor F_1 over a nominal epoch τ_{N1} from T_1 = 2,0 µs (t_{min}) to T_1 = 5,0 µs (t_{max}),
- front-chopped lightning impulses with an assigned impulse scale factor F_2 over a nominal epoch τ_{N2} from T_c = 0,5 µs (t_{min}) to T_c = 0,9 µs (t_{max}),
- and/or standard switching impulses with an assigned impulse scale factor F_3 over a nominal epoch τ_{N3} from T_p = 150 µs (t_{min}) to T_p = 500 µs (t_{max}).

3.4.2
step calibration epoch
time interval in which the impulse scale factor is determined with the step calibration method, with its lower limit being 0,5 times of the lower limit of the nominal epoch ($0,5t_{min}$) and its upper limit being 2 times the upper limit of the nominal epoch ($2t_{max}$), both of which are evaluated from the start of the recorded voltage step

3.4.3
rise time
time interval within which the response to an applied step passes from 10 % to 90 % of its steady-state amplitude

3.4.4
time base
unit of the digitiser horizontal scale against which a time interval is measured

3.5 Definitions related to uncertainties

3.5.1
error
measured quantity value minus a reference quantity value (VIM 2.16)

3.5.2
uncertainty (of measurement)
parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: Uncertainty is positive and given without sign.

Note 2 to entry: Uncertainty of measurement should not be confused with the tolerance of the test value.

[SOURCE: IEC 60050-311:2001, 311-01-02, modified – notes 1 and 2 to entry have been changed and note 3 to entry deleted]

3.5.3
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.1]

3.5.4
type A evaluation
method of evaluation of uncertainty by statistical analysis of a series of observations

3.5.5
type B evaluation
method of evaluation of uncertainty by means other than statistical analysis of a series of observations

3.6 Definitions related to tests

3.6.1
calibration
set of operations that establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement

[SOURCE: IEC 60050-311:2001, 311-01-09, modified – the notes to entry have been deleted]

3.6.2
type test
conformity test made on one or more items representative of the production

Note 1 to entry: For a measuring system, this is understood as a test performed on a component or on a complete measuring system of the same design to characterize it under operating conditions.

[SOURCE: IEC 60050-151:2001, 151-16-16, modified – the note 1 to entry has been added]

3.6.3
routine test
conformity test made on each individual item during or after manufacture

Note 1 to entry: This is understood as a test performed on each component or on each complete measuring system to characterize it under operating conditions

[SOURCE: IEC 60050-151:2001, 151-16-17, modified – the note 1 to entry has been added]

3.6.4
performance test
test performed on a complete measuring system to characterize it under operating conditions

3.6.5
performance check
a simple procedure to ensure that the most recent performance test is still valid

3.6.6
record of performance
detailed record, established and maintained by the user, describing the measuring system and containing evidence that the requirements given in this document have been met, which includes the results of the initial performance test and the schedule and results of each subsequent performance test and performance check

4 Operating conditions

The limits of operating conditions given in Table 1 are those under which the digitiser shall operate and meet the uncertainty requirements specified for this instrument.

Table 1 – Operating conditions

Condition	Range
Environment	
Ambient temperature	5 °C to 40 °C
Ambient relative humidity (non-condensing)	10 % to 90 %
Mains power supply	
Supply voltage	Rated voltage ±10 % (RMS)
	Rated voltage ±12 % (AC peak)
Supply frequency	Rated frequency ±5 %

Any exceptions to the values given in Table 1 shall be explicitly and clearly stated in the record of performance with an indication that they are exceptions.

NOTE The general requirements for testing electromagnetic compatibility of electrical equipment for measurement, control and laboratory use are described in IEC 61326-1.

5 Calibration and test methods

5.1 Calibration of scale factor and time base

The scale factor and time base shall be determined by either

– impulse calibration (5.2) with two waveforms covering the nominal epoch, or
– step calibration (5.3) with test of scale factor constancy (5.4) and calibration of time base (5.5), or
– an impulse calibration (5.2) with one impulse waveform within the nominal epoch with the constancy of scale factor test (5.4).

5.2 Impulse calibration

Impulse calibration is the reference method to establish the impulse scale factor of approved digital recorders. It is also the reference method to determine the errors of the impulse time parameters caused by the digital recorders. Requirements on reference calibration impulses for calibrating approved digital recorders are given in Table 2. The wave shapes shall be chosen from Table 2 according to the type and polarity of the high-voltage or high-current impulses that the digitiser is approved to measure. The uncertainties of the peak value and time parameters of the applied calibration impulses shall be within the limits given in Table 2, and the actual values shall be entered in the record of performance.

The number of calibration impulses to be applied shall be sufficient for obtaining sufficiently low type A uncertainties for all relevant parameters.

The impulse scale factor is the ratio of the peak value of the input calibration impulse and the peak value of its corresponding impulse recorded by the digitiser. The assigned impulse scale factor is the mean of impulse scale factors determined from a set of individual calibration impulses.

The error of a time parameter is the mean of the time parameter errors determined from individual calibration impulses.

This impulse calibration shall be made in each range of each channel that the digitiser is approved for use in impulse tests.

A digital recorder can be calibrated for exponential current impulses (IEC 62475) and the standard chopped (tail chopped) impulses using the full lightning impulse of a reference impulse generator.

Table 2 – Requirements for reference impulse generators

Impulse type	Parameter being measured	Value	Expanded uncertainty %	Short-term stability %
Full and standard chopped (tail chopped) lightning voltage impulse	Time-to-half value	55 µs to 65 µs	2	0,2
	Front time	0,8 µs to 1,0 µs	2	0,5
		or		
		0,8 µs to 1,0 µs and 1,5 µs to 1,7 µs	2	0,5
	Peak voltage	Within assigned measurement range	0,7	0,2
Front chopped lightning voltage impulse	Time-to-chopping	0,45 µs to 0,55 µs	2	1
	Peak voltage	Within assigned measurement range	2	0,2
Standard switching impulse	Time-to-peak	200 µs to 300 µs	2	0,2
	Time-to-half value	1 000 µs to 4 000 µs	2	0,2
	Peak voltage	Within assigned measurement range	0,7	0,2
Rectangular impulse current	Duration	0,5 ms to 3,5 ms	2	0,5
	Peak value	Within assigned measurement range	2	1
The short-term stability is the standard deviation of a sequence of at least 10 output impulses.				

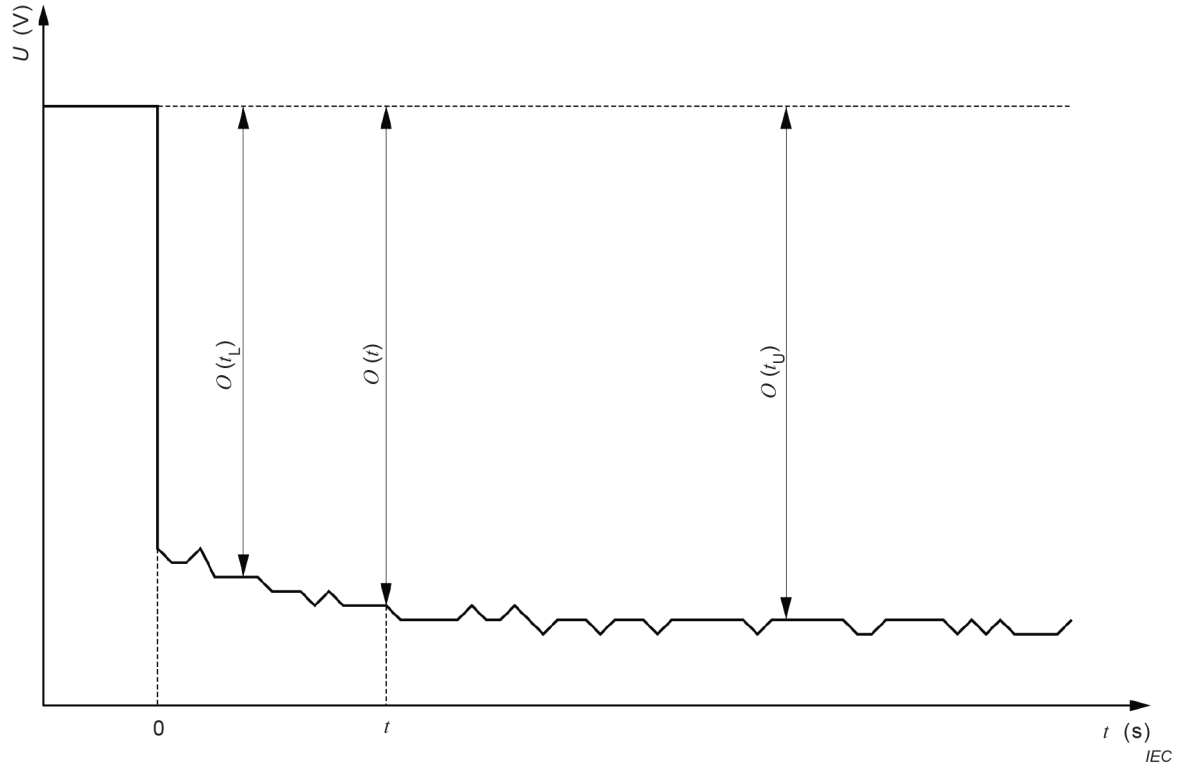
NOTE A digital recorder can be calibrated for exponential current impulses (IEC 62475) using either a lightning impulse generator or a switching impulse generator that best matches the waveform of the current impulse.

5.3 Step calibration

The step calibration is the alternative method for establishing the impulse scale factor of an approved digital recorder. To qualify an approved digitiser for measuring impulse time parameters, the scale factor constancy test specified in 5.4 and the calibration of time base as specified in 5.5 shall also be performed if the impulse calibration as specified in 5.2 is not performed.

A direct voltage V_{CAL}, with an uncertainty less than 0,1 % and within the assigned measurement range of the instrument, is applied to the input and then short-circuited to ground by an appropriate switching device, preferably based on a mercury-wetted relay. The resultant transition to zero level is recorded as the output $O(t)$ (an example is shown in Figure 1) and evaluated within the time interval of the step calibration epoch. A number of records (e.g. 10) of the response shall be averaged to reduce the random noise. The deviation of the sample values $O(t)$ in the time interval of the step calibration epoch from their mean O_{sm} shall be within the uncertainty limits specified for the assigned impulse scale factor. The value of O_{sm} shall be evaluated as the mean of all $O(t)$ values within the step calibration epoch (IEC 60060-2:2010). The impulse scale factor is the quotient of the input voltage V_{CAL} and O_{sm}. The rise time of the step shall be less than 10 % of the lower limit of the step calibration epoch.

This voltage calibration shall be made in each range of each channel that the digitiser approved for use in impulse tests. This test shall be performed using both voltage polarities. If the scale factors determined with the two polarities agree to within ± 0,5 %, then the impulse scale factor determined by this method is valid. Otherwise, impulse calibration according to 5.2 of appropriate polarity shall be used.



t_L and t_U are either the lower and upper limits of the step calibration epoch or the time interval of scale factor constancy test (see 5.4).

Figure 1 – Step calibration

5.4 Test of constancy of scale factor within time interval

A direct voltage within the measurement range of the digital recorder is applied to the input and then short-circuited to ground by an appropriate switching device, preferably based on a mercury-wetted relay. The resultant transition to zero level of the step response (see Figure 1) is recorded and evaluated within the following time intervals:

0,5 t_{min} to T_{2max} for full lightning impulses and exponential current impulses;

0,5 t_{min} to t_{max} for front-chopped impulses;

0,5 T_p to T_{2max} for switching impulses, and 10/350 µs current impulses;

0,5 (T_t – T_d) to T_t for rectangular current impulses;

where T_{2max} is the maximum time to half-value the digitiser is approved to measure for each of the corresponding impulse type.

Within these time intervals, the output magnitude $O(t)$ of the recorded step response shall be constant within the limits specified in this document.

It is permitted that several records of the response are averaged to reduce the random noise.

This scale factor constancy measurement shall be made in each range used for tests.

NOTE T_1, T_2 and T_c are defined in IEC 60060-1. t_{min} and t_{max} are as defined in 3.4.1. T_{2max} is the maximum value of T_2 that is to be measured by the approved digitiser.

5.5 Calibration of time base

Calibration of time base shall be performed if the errors of impulse time parameters are not determined by performing the impulse calibration as specified in 5.2.

Calibration of a time base shall be performed by comparison with a reference rectangular signal of known frequency. The period of the signal shall be T_2 of the impulse to be measured. The calibration shall be performed over the time interval of one full period.

5.6 Test of impulse scale factor non-linearity

The test is to assess the non-linearity of the scale factor obtained in accordance with 5.2 or 5.3, over the range settings within the assigned measurement range(s) of the digital recorder. Apart from being one of the qualifying tests of an approved digitiser, the test is for estimating contribution of non-linearity to the measurement uncertainty of the impulse peak voltage.

Ratios of the output of the digitiser and the input voltage of the digitiser shall be obtained with both voltage polarities. The input voltage shall cover the complete assigned measurement range. The non-linearity of the impulse scale factor is calculated as the maximum deviation of ratio values R_g, obtained at b different range settings of one channel of the digitiser, from the mean ratio, R_m. The maximum deviation shall be taken as a type B estimate of the standard uncertainty related to non-linearity of the scale factor:

$$u_{B1} = \frac{1}{\sqrt{3}} \cdot \max_{g=1}^{b} \left| \frac{R_g}{R_m} - 1 \right|$$

where

$R_1 \ldots R_b$ are ratios, scale factors or errors determined in the assigned measurement range, determined against a linear voltage source (or digitiser of a different model);

R_m is the mean of the values $R_1 \ldots R_b$;

b is the number of range settings at which the ratios $R_1 \ldots R_b$ are obtained, where one voltage level is tested in each range setting;

u_{B1} is the type B standard uncertainty due to non-linearity of the impulse scale factor.

NOTE If sufficiently low non-linearity is not obtained by using a particular voltage source, using a different voltage source can yield a lower value of impulse scale factor non-linearity.

5.7 Internal noise level

A direct voltage within the range of the digital recorder shall be applied. A sufficient number of samples at one voltage shall be taken at a specified sampling rate to acquire at least 1 000 samples. The standard deviation of these samples is taken as the internal noise level.

5.8 Interference test

Interference tests shall be performed according to Annex A of this document.

6 Requirements for impulse measurements

6.1 Requirements for digital recorders used in approved measuring systems

The expanded uncertainty of a digital recorder used in an approved measuring system according to IEC 60060-2 shall be not more than (at a level of confidence of not less than 95 %)

- 2 % in the voltage (current) measurement of full and standard-chopped (tail chopped) lightning voltage impulses, switching voltage impulses, exponential current impulses and rectangular current impulses;
- 3 % in the voltage measurement of front-chopped lightning impulses;
- 4 % in the measurement of the time parameters (front time, time to chopping, etc.) of the impulse.

Digitiser can be qualified for measurement of one, or more, or all types of impulses.

These uncertainties shall be estimated according to ISO/IEC Guide 98-3:2008.

NOTE The estimated uncertainty of the digitiser is used as a component of uncertainty of the complete measurement system according to IEC 60060-2 or IEC 62475.

The digital recorder shall allow storage of the raw data.

6.2 Individual requirements

6.2.1 General

In order to stay within the limits given in 6.1, the limits for individual contributions given in 6.2 should usually be met. In some cases, it is permissible that one or more of these limits be exceeded provided that it is demonstrated by estimation in accordance with ISO/IEC Guide 98-3:2008 that overall uncertainty specified in 6.1 is not exceeded.

6.2.2 Sampling rate

The sampling rate shall be not less than $30/T_x$ where T_x is the time interval to be measured.

NOTE T_x = 0,6 T_1 is the time interval between T_{30} and T_{90} of the lightning impulse to be measured. For a 1,2/50 lightning impulse, the permitted lower limit of front time T_1 is 0,84 µs. Therefore, a sampling rate of at least 60×10^6 s^{-1} is normally used for full and tail chopped lightning impulses. Similarly, a sampling rate of at least 100×10^6 s^{-1} is normally used for front chopped impulse and a sampling rate of at least $1,5 \times 10^5$ s^{-1} is normally used for the standard switching impulse.

6.2.3 Rated resolution

A rated resolution of 8-bit (0,4 % of the full-scale deflection) or better is required for tests where the impulse parameters are to be evaluated.

NOTE For tests which involve spectrum analysis or waveform transformation other than impulse parameter evaluation, a rated resolution of 9-bit (0,2 % of the full-scale deflection) or better is normally used.

6.2.4 Impulse scale factor

The impulse scale factor determined by one of the methods as specified in 5.1 shall be constant within ±1 % over the nominal epoch. The impulse scale factor, determined by either 5.2 or 5.3, shall be determined with an expanded uncertainty of not more than 1 %. If the impulse scale factor is only determined by the step calibration method specified in 5.3, the step response level shall be constant within ±1 % over the time intervals specified in 5.4.

The non-linearity of the impulse scale factor determined in 5.4 as the measure of an uncertainty component u_{B1}, either by the impulse voltage method or the step voltage method, shall not exceed 0,5 %.

6.2.5 Errors of time parameters

The errors of time parameters determined by the impulse calibration described in 5.2 shall be less than:

- 3 % for the front time T_1 of all relevant types of impulses,
- 2 % for the time to half-value T_2 of all relevant types of impulses,
- 3 % for the time to chopping T_c of the standard chopped (tail chopped) lightning voltage impulse,
- 5 % for the time to chopping T_c of the front chopped lightning voltage impulse,
- 3 % for the peak time T_p of switching voltage impulse,
- 3 % for T_d and T_t for the rectangular current impulse.

If the impulse calibration as specified in 5.2 is not performed, the digitiser is approved for measuring time parameters if the digitiser meets the requirement of constancy of impulse scale factor specified in 6.2.4 and the requirement for error of time base specified in 6.2.6.

6.2.6 Error of time base

The maximum value of the time base errors as measured in 5.5 shall be less than 0,1 %. The maximum relative standard deviation of measured mean period values shall be less than 10 %.

6.2.7 Rise time

The rise time shall not be more than 3 % of T_x where T_x is the time interval to be measured.

6.2.8 Interference voltage

The maximum amplitude of any deflection from the base magnitude in the interference test specified in Annex A shall be less than 1 % of the full-scale deflection in the ranges used for impulse tests.

NOTE An interference performance test is specified in IEC 60060-2 for the complete impulse measuring system.

6.2.9 Record length

The record length shall be sufficiently long to allow the required parameter (for example, T_2 or T_P) to be evaluated or a specific phenomenon to be observed.

6.2.10 Input impedance

The input resistance and capacitance of the digitiser shall be stated with their uncertainties.

6.2.11 Internal noise level

The internal noise level (RMS) shall be less than 0,4 % of the full-scale deflection for measurements of the waveform parameters and less than 0,1 % for other applications.

NOTE The noise level influences evaluation of LI extreme value or SI peak value, as well as evaluation of time parameters.

6.2.12 Assigned measurement range

The lower limit and upper limit of the assigned measurement range shall be established by proving that the performance of the digitiser meets the requirements of 6.2.3, 6.2.4, 6.2.5, and 6.2.6 when used within the range of the limits.

6.3 Requirements for digital recorders used in reference measuring systems

6.3.1 General requirements

These instruments are used in reference measuring systems specified in IEC 60060-2 for the calibration of approved measuring systems by comparison measurements. The peak and time parameters are in general determined as the mean of at least 10 measurements. The overall uncertainty of a digital recorder used in a reference measuring system according to IEC 60060-2 shall be not more than (at a confidence level of not less than 95 %)

- 0,7 % in the peak voltage (current) measurement of full and standard-chopped (tail chopped) lightning impulses, switching impulses and rectangular impulses;
- 2 % in the peak voltage measurement of front-chopped lightning impulses;
- 2 % for the front time T_1 of all relevant types of impulses;
- 1,5 % for the time to half-value T_2 of all relevant types of impulses;
- 2 % for the time to chopping T_c of the standard chopped (tail chopped) lightning voltage impulse;
- 4 % for the time to chopping T_c of the front chopped lightning voltage impulse;
- 2 % for the peak time T_p of switching voltage impulse;
- 2 % for T_d and T_t for the rectangular current impulse.

6.3.2 Sampling rate

The sampling rate shall be not less than $60/T_x$ where T_x is the time interval to be measured.

6.3.3 Rated resolution

A rated resolution of 9-bit (with peak amplitude at least 20 % of the full-scale deflection) or better is required for tests where the impulse parameters are to be evaluated.

6.3.4 Error of time base

The maximum value of the time base errors as measured in 5.5 shall be less than 0,1 %. The maximum relative standard deviation of measured mean period values shall be less than 10 %.

6.3.5 Rise time

The rise time shall not be more than 2 % of T_x where T_x is the time interval to be measured.

6.3.6 Interference voltage

The maximum amplitude of any deflection from the base magnitude in the interference test specified in Annex A shall be less than 0,5 % of the full-scale deflection in the ranges used for impulse tests.

6.3.7 Record length

The record length shall be sufficiently long to allow the required parameter (for example, T_2 or T_P) to be evaluated or a specific phenomenon to be observed.

6.3.8 Internal noise level

The internal noise level (RMS) shall be less than 0,4 % of the full-scale deflection for measurements of the waveform parameters and less than 0,1 % for other applications.

6.3.9 Scale factor

- The impulse scale factor of the transient recorder shall be determined with an expanded uncertainty of not more than 0,5 %.
- The impulse scale factor shall be constant within ±0,5 % over the time intervals given in 5.4.

6.4 Tests

6.4.1 General

To meet the requirements of this document, the digital recorder shall undergo tests specified in Table 3.

All calibration equipment shall be traceable, either directly or indirectly, to international or national standards. The calibration procedures shall be recorded.

Table 3 – Tests required for approved digital recorders

Type of test	Pass/fail	Reference to test method	Reference to test requirement		Test classification			
			Complete recorder at one input range	Complete recorder at each input range	Type test	Routine test	Per-form-ance test	Perform ance check
Impulse scale factor and time base		5.1		6.2.4		X	X	X
Scale factor non-linearity		5.6		6.2.4		X	X	X
Rise time	X	3.4.3		6.2.7	X			
Internal noise level	X	5.7	6.2.11		X			
Interference test	X	5.8, Annex A	6.2.8		X			

6.4.2 Type tests

Type tests shall be performed for one digital recorder of a model. These type tests are to be performed by the manufacturer of the digital recorder. If type test results are not available from the manufacturer, tests to verify the equipment shall be arranged by the user.

6.4.3 Routine tests

Routine tests shall be performed for each digital recorder. These routine tests are to be performed by the manufacturer of the digital recorder. If routine test results are not available from the manufacturer, tests to verify the equipment shall be arranged by the user.

Routine tests shall also be carried out after a repair of the digital recorder.

6.4.4 Performance tests

Performance tests (calibration) shall be performed on each new digital recorder. The interval between performance tests shall be based on evaluation of past stability of instrument. It is recommended that the performance test should be repeated annually, but the maximum interval shall be not more than five years.

A performance test shall be made after major repairs to the instrument.

A performance test on the instrument is also required if performance checks on the instrument indicate that the impulse scale factor has changed by more than 1 %.

6.4.5 Performance checks

Performance checks on the instrument are required only if performance checks on the complete measuring system indicate that the assigned impulse scale factor has changed significantly.

Performance checks shall be made for each setting of the instrument that is to be used in the impulse tests. This check shall include the possible external attenuator, if it was not calibrated with divider or shunt.

7 Requirements for peak voltmeters

The overall expanded uncertainty of a peak meter used in an approved measuring system according to IEC 60060-2 shall be not more than (at a level of confidence of not less than 95 %, see Annex A and Annex B of IEC 60060-2:2010)

- 2 % in the extreme value measurement of full and standard-chopped (tail chopped) lightning voltage impulses;
- 2 % in the peak value of switching voltage impulses, exponential current impulses and rectangular current impulse.

NOTE Peak voltmeters measures the extreme value (U_e), and they do not meet the requirements for measuring the test voltage (U_t) of standard lightning impulses, the peak voltage of front chopped lightning impulses or time parameters.

8 Uncertainty contributions for complete measuring systems

The uncertainty values determined in the tests specified in this document serve two purposes. The primary purpose is to set the measurement uncertainty limits for the approved digital recorder. The second purpose is to enable the estimation of measurement uncertainties of a complete measuring system as specified in other related international standards, such as IEC 60060-2 and IEC 62475, with the uncertainty values of the digital recorder as necessary contribution components.

Inclusion of uncertainties of an approved impulse digitiser as components in the combined uncertainties of a complete measuring system shall follow the procedure as specified in the relevant standard for the complete measuring system such as IEC 60060-2 and IEC 62475.

9 Record of performance

The record of performance shall include the following information (if applicable).

a) nominal characteristics
   1) identification (serial number, type, etc.),
   2) rated resolution,
   3) range of sampling rates,
   4) maximum record length,
   5) triggering capabilities,
   6) values of the maximum and minimum input voltages,
   7) input impedance,
   8) types of waveforms,
   9) warm-up time,

10) range of operating conditions,

b) results of type tests,

c) results of routine tests,

d) performance tests

1) date and time of each performance test,

2) results of each performance test,

e) performance checks

1) date and time of each performance check,

2) result – pass/fail (if fail, record of action taken).

NOTE Record of performance for the measuring instrument can be a part of the record of performance for the measuring system.

Annex A
(normative)

Electromagnetic interference in high-voltage and high-current laboratories and test fields

A.1 General

The shielding of general-purpose instruments may not be adequate for use in high-voltage or high-current laboratories and test fields. Interference may be induced by the transient electromagnetic field or conducted by either the signal or the supply lines.

Interference may attain high levels, especially in the case of signals such as flashovers or breakdowns. While such events are normally not a concern of the actual measurement, it shall be ensured that the instruments can handle such stress.

The following requirements for instruments and precautions will reduce such interference.

A.2 Precautions

A.2.1 Electromagnetic shielding

Interference due to electromagnetic fields penetrating directly into the instrument may be reduced by placing the instrument in a Faraday cage having sufficient attenuation in the frequency range of interest. Such a Faraday cage consists of a metal enclosure, which ensures conductivity across permanent and mobile joints. This metal enclosure may be a shielded control room or an instrument enclosure. The instrument enclosure may consist of two parts: one with high shielding efficiency (completely enclosing the instrument) which is required for real time recording or displaying of the signal, and the other to allow access to the computer, plotter, and printer which operate after the record.

A.2.2 Reduction of conducted interference from the supply line

Conducted interference on the mains supply can be reduced by inserting a filter (effective in the range from some tens of kilohertz to some tens of megahertz). An isolating transformer with low inter-winding capacitance should be interfaced between the instrument and the mains supply.

A.2.3 Reduction of interference on the signal line

Interference due to current flowing in the shield of the measuring cable may be reduced by an adequate earthing at the voltage divider side, by using tri-axial cable with the outer shield grounded at both input and instrument ends, and/or by cable running through a metallic conduit connected at both ends to the local grounds. Inner and outer shields should be bonded at the input end. Avoiding loops between the measuring cable and the earth returns can also reduce interference.

Interference due to potential differences, induced or applied between the terminals of the measuring cable, may be reduced by using an input voltage or input current as high as possible, namely by operating the instrument on its maximum range, or by inserting an external attenuator between the receiving end of the cable and the instrument.

A.2.4 Signal transmission by optical means

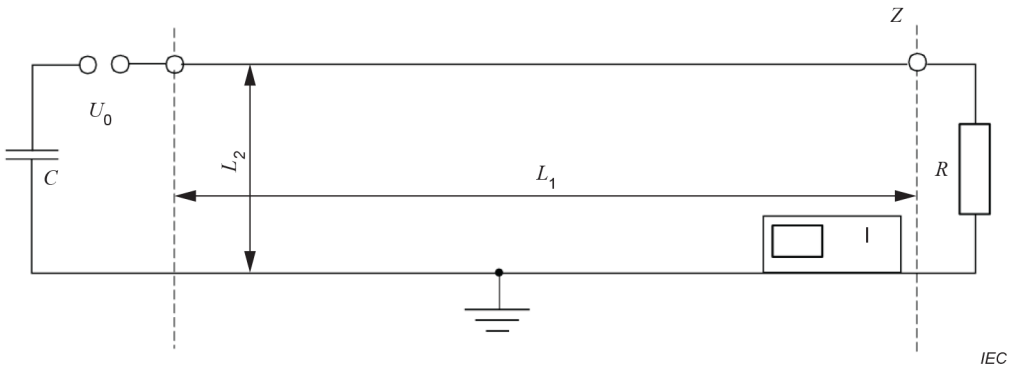
Signal transmission by optical means (either analogue or digital) may be used to reduce interference provided the characteristics of any such link are adequate to meet the requirements of IEC 60060-2.

A.3 Tests with transient induced electromagnetic fields

The instrument without measuring cable, including any additional shielding added to it, shall be subjected to rapidly changing electric and magnetic fields representative of those produced by high-voltage or high-current test circuits. Tests in these types of laboratories have indicated fields up to 100 kV/m and 1 000 A/m.

These fields may be obtained by the discharge of a capacitor via a sphere gap as shown in Figure A.1.

For tests with electric field, the line connected to the capacitor shall be terminated by its surge impedance (R = Z). For tests with magnetic fields, the line connected to the capacitor shall be short-circuited (R = 0). The corresponding transient characteristics are determined by the parameters of that test circuit and are, for the voltage, a step with a rise-time in the order of 50 ns and, for the current, a damped oscillation with a frequency in the order of 0,5 MHz.



Components

I instrument placed at the end of the line

Z characteristic impedance: C = 20 nF; L_1 = 5 m; L_2 = 1 m

For the electric field test, U_0 = 40 kV (R = Z)

For the magnetic field test, U_0 = 100 kV (R = 0)

Figure A.1 – Application of electric and magnetic fields

NOTE An oil or compressed gas immersed sphere gap can be used to check the instrument employed for impulse tests. The corresponding voltage and current transients will show a shorter rise time (of a few nanoseconds) and a higher frequency initial oscillation (a few tens of megahertz), respectively.

The tests are not applicable if the instrument is operated in a well-shielded area (for example, in a shielded control room).

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