



BSI Standards Publication

High-voltage test techniques

Part 2: Measuring systems

National foreword

This British Standard is the UK implementation of EN IEC 60060-2:2025. It is identical to IEC 60060-2:2025. It supersedes BS EN 60060-2:2011, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/42, Testing techniques for high voltages and currents.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Date	Text affected
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Techniques des essais à haute tension - Partie 2: Systèmes
de mesure
(IEC 60060-2:2025)

Hochspannungs-Prüftechnik - Teil 2: Messsysteme
(IEC 60060-2:2025)

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 42/443/FDIS, future edition 4 of IEC 60060-2, prepared by TC 42 "High-voltage and high-current test techniques" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60060-2:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2026-06-30 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2028-06-30 document have to be withdrawn

This document supersedes EN 60060-2:2011 and all of its amendments and corrigenda (if any).

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The text of the International Standard IEC 60060-2:2025 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 60060-3	NOTE	Approved as EN 60060-3
IEC 60071-1	NOTE	Approved as EN IEC 60071-1
IEC 60270	NOTE	Approved as EN 60270
IEC 62475	NOTE	Approved as EN 62475
ISO/IEC 17025:2017	NOTE	Approved as EN ISO/IEC 17025:2017 (not modified)

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60052	-	Voltage measurement by means of standard air gaps	EN 60052	-
IEC 60060-1	-	High-voltage test techniques - Part 1: General terminology and test requirements	EN IEC 60060-1	-
IEC 61083	series	Instruments and software used for measurements in high-voltage and high-current tests	EN 61083	series
IEC 61083-1	-	Instruments and software used for measurements in high-voltage and high-current tests - Part 1: Requirements for instruments for impulse tests	EN 61083-1	-
IEC 61083-2	-	Instruments and software used for measurement in high-voltage and high-current tests - Part 2: Requirements for software for tests with impulse voltages and currents	EN 61083-2	-
ISO/IEC Guide 98-3	2008	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE TEST TECHNIQUES –

Part 2: Measuring systems

FOREWORD

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IEC 60060-2 has been prepared by IEC technical committee 42: High-voltage and high current test techniques. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) The general layout and text has been updated and improved to make the standard easier to use.
- b) This document has been revised to align it with the fourth edition of IEC 60060-1.
- c) The treatment of measurement uncertainty estimation has been expanded.

- d) This document is now applicable to measuring systems used in testing at all standard insulation levels specified in IEC 60071-1.
- e) The measurement uncertainty requirement for the front time of the standard lighting impulse voltage has been changed from 10 % to 15 %, for testing at all standard insulation levels specified in IEC 60071-1.
- f) The parameter "time-to-peak" of the switching impulse defined in the third edition of IEC 60060-1:2010 has been replaced by "front time" in the fourth edition of IEC 60060-1. Necessary changes have been made in this document to accommodate this change in IEC 60060-1.
- g) Clause 10, Measurement of combined voltages and Clause 11, Measurement of composite voltages have been added.
- h) Clause B.1 has been significantly revised to align more closely with the provisions of Clause 5, including using the same nomenclature.

The text of this International Standard is based on the following documents:

Draft	Report on voting
42/443/FDIS	42/447/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60060 series, published under the general title *High-voltage test techniques*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

HIGH-VOLTAGE TEST TECHNIQUES –

Part 2: Measuring systems

1 Scope

This part of IEC 60060 is applicable to complete measuring systems and to their components, used for the measurement of high voltages during laboratory and factory tests with direct voltage, alternating voltage and lightning and switching impulse voltages and combined and composite voltages as specified in IEC 60060-1. For measurements during on-site tests, see IEC 60060-3.

The limits on uncertainties of measurements stated in this document apply to test levels stated in IEC 60071-1. The principles of this document apply also to higher levels but the uncertainty can be greater.

This document:

- defines the terms used;
- describes methods to estimate the uncertainties of high-voltage measurements;
- states the requirements that apply to measuring systems;
- describes the methods for approving a measuring system and checking its components;
- describes the procedures by which the user demonstrates that a measuring system meets the requirements of this document, including the limits set for the uncertainty of measurement.

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 60052, *Voltage measurement by means of standard air gaps*

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

IEC 61083 (all parts), *Instruments and software used for measurements in high-voltage and high-current tests*

IEC 61083-1, *Instruments and software used for measurements in high-voltage and high-current tests – Part 1: Requirements for instruments for impulse tests*

IEC 61083-2, *Instruments and software used for measurement in high-voltage and high-current tests – Part 2: Requirements for software for tests with impulse voltages and currents*

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

3 Terms and definitions

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

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

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

3.1 Measuring systems

3.1.1

measuring system

complete set of devices suitable for performing a high-voltage measurement

Note 1 to entry: A measuring system usually comprises the following components:

- a converting device with the leads required for connecting this device to the test object or into the circuit and the connections to earth;
- a transmission system connecting the output terminals of the converting device to the measuring instruments with its attenuating, terminating and adapting impedances or networks;
- a measuring instrument together with any connection to the power supply. Measuring systems which comprise only some of the above components or which are based on non-conventional principles are acceptable if they meet the uncertainty requirements specified in this document;
- and in some cases the measuring system can include software to calculate the measurand.

Note 2 to entry: The environment in which a measuring system functions, its clearances to live and earthed structures and the presence of electric or magnetic fields can significantly affect the measurement result and its uncertainty.

3.1.2

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

Note 1 to entry: This evidence includes the results of the initial performance test and the schedule and results of each subsequent performance test and performance check.

3.1.3

approved measuring system

measuring system that is shown to comply with one or more of the sets of requirements set out in IEC 60060-2

3.1.4

reference measuring system

measuring system with its calibration conducted in conformity with relevant national or international standards of measurement, and having sufficient accuracy and stability for use in the approval of other systems by making simultaneous comparative measurements with specific types of waveform and ranges of voltage

Note 1 to entry: A reference measuring system (maintained in accordance with the requirements of this document) can be used as an approved measuring system but the converse is not true.

3.2 Components of a measuring system

3.2.1

converting device

device for converting the quantity to be measured (measurand) into a quantity compatible with the measuring instrument

3.2.2**voltage divider**

device comprising resistors, inductors, capacitors, transformer(s) or a combination of these components such that, between two points of the device, a desired fraction of the voltage applied to the device as a whole can be obtained

[SOURCE: IEC 60050-312:2001, 312-02-32]

3.2.3**voltage transformer**

instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections

[SOURCE: IEC 60050-321:1986, 321-03-01]

3.2.4**voltage converting impedance**

converting device which carries a current proportional to the applied voltage to be measured with a current measuring instrument

3.2.5**electric-field probe**

converting device for the measurement of the amplitude and waveform of an electric field

Note 1 to entry: An electric-field probe can be used to measure the waveform of the voltage producing the field provided that the measurement is not affected by corona or space charges.

3.2.6**transmission system**

set of devices that transfers the output signal of a converting device to a measuring instrument

Note 1 to entry: A transmission system usually consists of a coaxial cable with its terminating impedance, but it can include attenuators, amplifiers, or other devices connected between the converting device and the measuring instrument. For example, an optical link includes a transmitter, an optical cable and a receiver as well as related amplifiers.

Note 2 to entry: A transmission system can be partially or completely included in the converting device or in the measuring instrument.

3.2.7**measuring instrument**

device intended to be used to make measurements, alone or in conjunction with supplementary devices

[SOURCE: IEC 60050-311:2001, 311-03-01]

3.3 Scale factors**3.3.1****scale factor**

<of a measuring system> factor by which the value of the measuring-instrument reading is multiplied to obtain the value of the input quantity of the complete measuring system

Note 1 to entry: A measuring system can have multiple scale factors for different assigned measurement ranges, frequency ranges or waveforms.

Note 2 to entry: For measuring systems that display the value of the input quantity directly, the nominal scale factor of the measuring system is unity.

3.3.2

scale factor

<of a converting device> factor by which the output of the converting device is multiplied to obtain its input quantity

Note 1 to entry: The scale factor of a converting device can be dimensionless (e.g. the ratio of a divider) or can have dimensions (e.g. the impedance of a voltage converting impedance).

3.3.3

scale factor

<of a transmission system> factor by which the output of a transmission system is multiplied to obtain its input quantity

3.3.4

scale factor

<of a measuring instrument> factor by which the instrument reading is multiplied to obtain its input quantity

3.3.5

assigned scale factor

F

scale factor of a measuring system determined at the most recent performance test

Note 1 to entry: A measuring system can have more than one assigned scale factor; for example, it can have several ranges or nominal epochs or both, each with a different scale factor.

3.4 Rated values

3.4.1

operating conditions

specified ranges of conditions under which a measuring system will operate within the specified uncertainty limits

3.4.2

rated operating voltage

maximum level of voltage of specified frequency or waveform at which a measuring system is designed to be used

Note 1 to entry: The rated operating voltage can be higher than the upper limit of the assigned measurement range.

3.4.3

assigned measurement range

range of voltage of specified frequency or waveform, characterized by a single scale factor, in which a measuring system can be used

Note 1 to entry: The limits of the assigned measurement range are chosen by the user and verified by the performance tests specified in this document.

Note 2 to entry: A measuring system can have more than one assigned measurement range with different scale factors.

3.4.4

assigned operating time

longest time during which a measuring system for direct or alternating voltages can operate at the upper limit of the assigned measurement range

3.4.5

assigned rate of application

highest rate of specified voltage impulses for a specified time interval, at which the measuring system can operate at its upper limit of the assigned measurement range

Note 1 to entry: The rate is usually given as applications per minute and the time interval in minutes or hours.

3.5 Terms related to dynamic behaviour

3.5.1

response of a measuring system

G

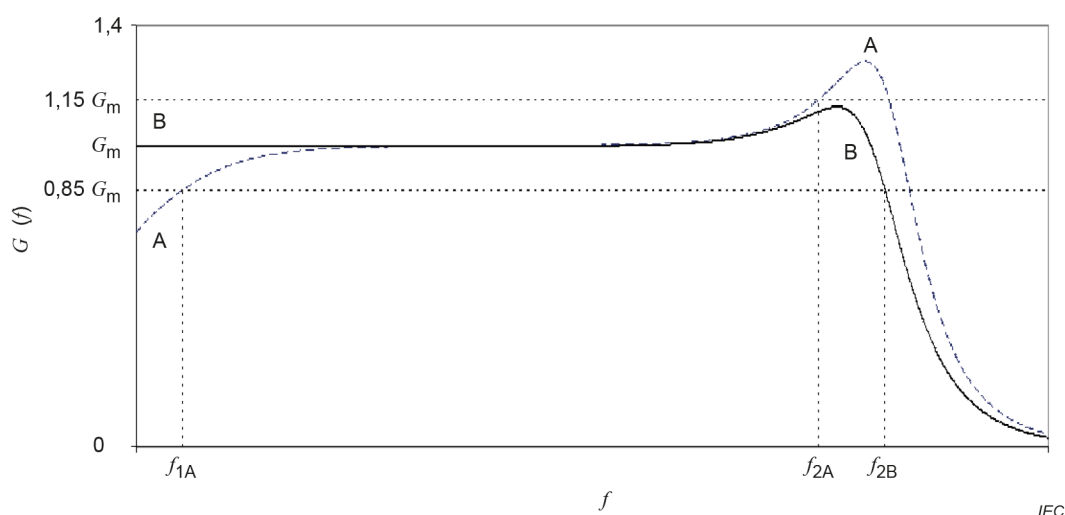
output, as a function of time or frequency, when a specified voltage is applied to the input of the system

3.5.2

amplitude-frequency response

$G(f)$

ratio of the output to the input of a measuring system as a function of frequency f , when the input is sinusoidal



Key

f_1 lower limit frequency

f_2 upper limit frequency

Figure 1 – Amplitude-frequency response with examples for limit frequencies (f_1 ; f_2)

Note 1 to entry: The lower and upper limit frequencies are shown on curve A. Curve B shows a constant response down to direct voltage, with G_m being the G_f value at nominal frequency.

3.5.3

step response

$G(t)$

output of a measuring system as a function of time when the input is a step function

Note 1 to entry: For more information on step response and step-response parameters see Annex C.

3.5.4

nominal epoch

τ_{N1}

<impulse voltage only> range of values between the minimum ($t_{\min}$) and the maximum ($t_{\max}$) of the relevant time parameter of impulse voltage for which the measuring system is approved

Note 1 to entry: The relevant time parameter is:

- the front time T_1 for full and standard chopped lightning impulses and for switching impulses;
- the time to chopping T_c for front-chopped impulses.

Note 2 to entry: A measuring system can have one, two or more nominal epochs for different waveforms. For example, a particular measuring system can be approved:

- for full and standard chopped lightning impulses with an assigned scale factor F_1 over a nominal epoch τ_{N1} from $T_1 = 0,8 \mu\text{s}$ to $T_1 = 1,8 \mu\text{s}$, even though the tolerance is $0,84 \mu\text{s}$ to $1,56 \mu\text{s}$;
- for front-chopped lightning impulses with an assigned scale factor F_2 over a nominal epoch τ_{N2} from $T_c = 0,5 \mu\text{s}$ to $T_c = 0,9 \mu\text{s}$;
- for switching impulses with an assigned scale factor F_3 over a nominal epoch τ_{N3} from $T_1 = 100 \mu\text{s}$ to $T_1 = 340 \mu\text{s}$.

Note 3 to entry: In Note 2 to entry, since time-to-peak has been replaced by front time, numerical values have been adjusted accordingly.

Note 4 to entry: "Front-chopped impulse" is used to designate a chopped impulse with a time to chopping that falls in the range $0,5 \mu\text{s}$ to the time of the extreme value. This is not a "standard chopped impulse", which has a time to chopping greater than the time of the extreme value.

3.5.5 reference level

I_R

<impulse measurements only> mean value of the step response taken over the reference level epoch, i.e., over the range of $0,5 t_{\min}$ to $2 t_{\max}$

Note 1 to entry: A measuring system can have more than one reference level, for example, it can have different scale factors for different waveforms due to the variation of the response level (see 3.5.4).

Note 2 to entry: Reference level epoch is defined in term 3.5.13 and shown in Figure 2

3.5.6 origin of a step response

O_1

instant when the response curve firstly starts a monotonic rise above the amplitude of the noise at the zero level of the (unit) step response

Note 1 to entry: The parameter is shown in Figure 2

Note 2 to entry: In some cases the unit step response starts with an initial distortion (Figure C.1). Then the origin O_1 should be determined at the crossing of the downward extension from the point of monotonic increase of the unit step response with the zero line. The initial distortion can be characterized by a parameter T_0 (initial distortion time) which corresponds to the partial area(s) between the zero line and the unit step response up to O_1 .

Note 3 to entry: All the time values (except T_0) are measured from the origin O_1 .

3.5.7 unit step response

$g(t)$

step response normalized such that a reference level becomes unity and the zero level remains zero

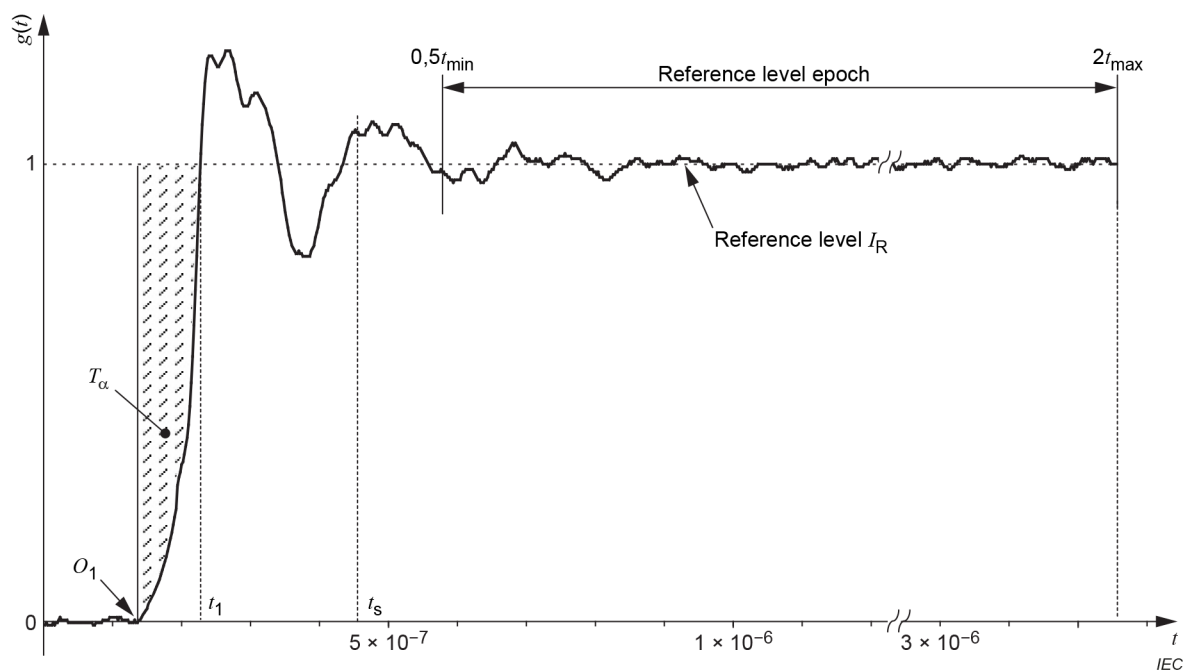


Figure 2 – Parameters for the unit step response $g(t)$

Note 1 to entry: A measuring system has a unit step response for each reference level. The origin O_1 of the step response is identical to that of the unit step response.

3.5.8

step-response integral

$T(t)$

integral from O_1 to t of one minus the unit step response $g(t)$

$$T(t) = \int_{O_1}^t (1 - g(\tau)) d\tau \quad (1)$$

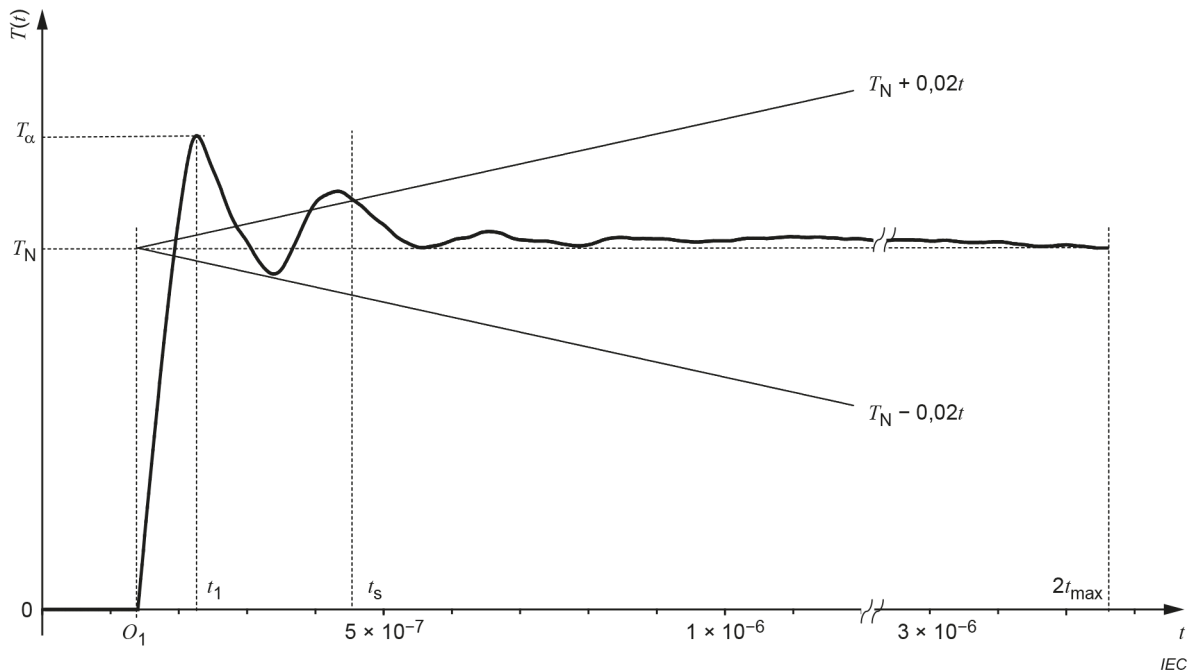


Figure 3 – Parameters for the step-response integral $T(t)$

3.5.9 experimental response time

T_N
value of the step response integral at $2 \cdot t_{\max}$

$$T_N = T(2 \cdot t_{\max}) \quad (2)$$

3.5.10 partial response time

T_α
maximum value of the step response integral for $t \leq 2 \cdot t_{\max}$ equal to the shaded area in Figure 2

Note 1 to entry: Usually $T_\alpha = T(t_1)$ where t_1 is the time when $g(t)$ first reaches the unit amplitude.

3.5.11 residual response time

$T_R(t_i)$
experimental response time T_N minus the value of the step response integral at some specific time t_i where $t_i < 2 \cdot t_{\max}$

$$T_R(t_i) = T_N - T(t_i) \quad (3)$$

3.5.12 settling time

t_s

time for which the residual response time $T_R(t)$ becomes and remains less than 2 % of t for all values of t in the epoch from O_1 to the longest time to half-value $T_{2\max}$ of the impulse voltage to be measured

$$|T_N - T(t)| < 0,02t \quad (4)$$

SEE: Figure 3.

3.5.13 reference level epoch

<impulse voltage only> time interval in which the reference level of the step response is determined with its lower limit being equal to 0,5 times the lower limit of the nominal epoch ($0,5 t_{\min}$) and its upper limit being equal to two times the upper limit of the nominal epoch ($2 t_{\max}$)

3.5.14 limit frequencies

f_1 and f_2

lower and upper limits of the range within which the amplitude-frequency response is nearly constant

SEE: Figure 1.

Note 1 to entry: These limits are where the response first deviates by a certain amount (e.g. $\pm 15\%$) from the constant value. The permissible deviation should be related to acceptable uncertainties of a measuring system.

3.5.15 voltage dip

sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time from a few cycles to a few seconds

[SOURCE: IEC 60050-161, 161-08-10]

3.6 Terms related to uncertainty

3.6.1 tolerance

permitted difference between the measured value and the specified value

Note 1 to entry: This difference should be distinguished from the uncertainty of measurement.

Note 2 to entry: The measured value is required to lie within the stated tolerance of the specified value.

3.6.2 error

measured quantity value minus a reference quantity value

[SOURCE: ISO/IEC Guide 99:2007, 2.16, modified – The preferred terms "measurement error" and "error of measurement" and the Notes to entry have been deleted.]

3.6.3

uncertainty

<of measurement> parameter, associated with the result of a measurement, that characterizes 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 voltage measurement should not be confused with the tolerance of a specified test voltage.

Note 3 to entry: For more information see Annex A and Annex B.

[SOURCE: IEC 60050-311:2001, 311-01-02, modified – The three Notes to entry have been replaced with three new Notes to entry.]

3.6.4

standard uncertainty

u

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

Note 1 to entry: The standard uncertainty associated with an estimate of a measurand has the same dimension as the measurand.

Note 2 to entry: In some cases, the relative standard uncertainty of a measurement can be appropriate. The relative standard uncertainty of measurement is the standard uncertainty divided by the measurand and is therefore dimensionless.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.1, modified – The symbol and the Notes to entry have been added.]

3.6.5

combined standard uncertainty

u_c

standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.4 modified – The symbol has been added.]

3.6.6

expanded uncertainty

U

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: Expanded uncertainty is the closest match to the term "overall uncertainty" used in earlier editions of this document.

Note 2 to entry: The true, but unknown test voltage value can lie outside the limits given by the uncertainty because the coverage probability is < 100 %.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5, modified – The symbol has been added and the two Notes have been replaced with two new Notes to entry.]

3.6.7**coverage factor***k*

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: For 95 % coverage probability and normal (Gaussian) probability distribution the coverage factor is approximately $k = 2$.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.6, modified – The symbol has been added and the Note has been replaced with a new Note to entry.]

3.6.8**type A evaluation**

method of evaluation of a standard uncertainty by statistical analysis of a series of observations

3.6.9**type B evaluation**

method of evaluation of a standard uncertainty by means other than statistical analysis of a series of observations

3.6.10**traceability**

property of the result of a measurement or of the value of a standard such that it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties

Note 1 to entry: The concept is often expressed by the adjective traceable.

Note 2 to entry: The unbroken chain of comparisons is called a traceability chain.

Note 3 to entry: In French, the way in which the relationship with the standards is determined is called "raccordement aux étalons".

[SOURCE: IEC 60050-311:2001, 311-01-15]

3.6.11**national metrology institute**

institute designated by national decision to develop and maintain national measurement standards for one or more quantities

3.6.12**measurand**

specific quantity subjected to measurement

[SOURCE: ISO/IEC Guide 98-3:2008, B.2.9, "subject to" has been replaced with "subjected to" and the note and example have been deleted.]

3.6.13**variance**

expectation of the square of the deviation of the centered random variable

[SOURCE: ISO/IEC Guide 98-3:2008, C.2.11, modified – The domain and formula have been deleted.]

3.6.14

correlation

relationship between two or several random variables within a distribution of two or more random variables

[SOURCE: ISO/IEC Guide 98-3:2008, C.2.8, modified – The note has been deleted.]

3.6.15

coverage probability

fraction, usually large, of the distribution of values that as a result of a measurement can reasonably be attributed to the measurand

3.7 Terms related to tests on measuring systems

3.7.1

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

Note 1 to entry: The determination of the scale factor is included in the calibration.

[SOURCE: IEC 60050-311:2001, 311-01-09, modified – The two Notes have been replaced with a new Note 1 to entry.]

3.7.2

type test

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

Note 1 to entry: For a measuring system, the type test 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 to entry has been added.]

3.7.3

routine test

conformity test made on each individual item during or after manufacture

Note 1 to entry: The routine test 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 to entry has been added.]

3.7.4

performance test

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

3.7.5

performance check

simple procedure to ensure that the result of the most recent performance test is still valid

3.7.6

reference record

<impulse measurements only> record taken under specified conditions in a performance test and retained for comparison with records to be taken in future tests or checks under the same conditions

Note 1 to entry: Reference records are often called "fingerprints" and used as characteristics of dynamic behaviour. In impulse voltage measurements they are usually taken from step-response measurements (Annex C).

4 Procedures for qualification and use of measuring systems

4.1 General principles

Every approved measuring system shall undergo initial testing, followed by performance tests (periodic, see 4.2) and performance checks (periodic, see 4.3) throughout its service life. The initial tests consist of type tests (performed on a component or system of the same design) and routine tests (performed on every component or system).

The performance tests and checks shall demonstrate that the measuring systems can measure the intended test voltages within the uncertainties given in this document. The system is approved only for the arrangements and operating conditions included in its record of performance.

A major requirement for a converting device, a transmission system, and a measuring instrument used in a measuring system is stability within the specified range of operating conditions so that the scale factor of the measuring system remains constant over long periods.

The assigned scale factor is determined in the performance test by calibration. The user shall apply the tests given in this document to qualify their measuring system(s). Any calibration should be conducted in conformity with national or international standards of measurement.

In all cases, the test results shall be kept in the record of performance.

4.2 Schedule of performance tests

To maintain the quality of a measuring system, its assigned scale factor(s), and for impulse systems also the relevant time parameters, shall be determined by periodic performance tests. The interval between performance tests shall be based on evaluation of past stability of the measuring system. It is recommended that the performance test should be repeated annually, but the maximum interval shall not be longer than five years.

NOTE Long intervals between performance tests can increase the risk of an undetected change in the measurement system.

A performance test shall be made after major repairs to the measuring system and whenever a circuit arrangement that is beyond the limits given in the record of performance is to be used.

When a performance test is required because a performance check shows that the assigned scale factor is no longer valid, the cause of this change shall be investigated before the performance test is made.

4.3 Schedule of performance checks

Performance checks shall be made at intervals based on the recorded stability of the measuring system as shown in the record of performance. The interval from the last performance test or the last performance check shall not be longer than one year.

For a new or repaired measuring system, performance checks shall be made at short intervals to demonstrate its stability.

No reference method is identified for the performance checks because the required accuracy is lower than that required for performance tests.

4.4 Requirements for the record of performance

4.4.1 Contents of the record of performance

The results of all tests and checks, including the conditions under which the results were obtained, shall be kept in the record of performance (stored in paper format or electronically) established and maintained by the user. The record of performance shall uniquely identify the components of the measuring system and shall be structured so that performance of the measuring system can be traced over time.

The record of performance shall comprise at least the following information:

- general description of the measuring system;
- Information on important aspects as for example the transmission system or high-voltage and earth-return arrangements;
- results of type and routine tests on the converting device, transmission system(s) and measuring instrument(s) and, if performed, on the measuring system;
- results of subsequent performance tests on the measuring system;
- results of subsequent performance checks on the measuring system.

NOTE The general description of the measuring system usually comprises main data and capabilities of the measuring system, such as the rated operating voltage, waveform(s), range(s) of clearances, operating time, or maximum rate of voltage applications.

4.4.2 Exceptions

For measuring systems or components manufactured before the date of issue of the second edition of IEC 60060-2, i.e. 1994, the required evidence can be unavailable for some part(s) of the type and routine tests. Then performance tests and checks made in accordance with earlier versions of this document are deemed adequate provided they show the scale factor is stable. The results of these previous checks shall also be entered in the record of performance.

Approved measuring systems comprising several pieces of equipment used inter-changeably may be covered by a single record of performance including all the combinations possible with the least amount of duplication possible. Specifically, each converting device shall be covered individually, but transmission systems and measuring instruments may be covered generically.

4.5 Operating conditions

A measuring system shall be connected directly to the terminals of the test object, or in such a way that the voltage difference between test object terminals and the measuring system is negligible. The parasitic coupling between the test and measuring circuit should be minimized.

NOTE 1 It can often be necessary to investigate parasitic coupling.

An approved measuring system shall have an uncertainty within the specifications of this document throughout the ranges of operating and environmental conditions given in the record of performance.

The assigned operating time for measuring systems for direct and alternating voltage shall be specified.

NOTE 2 The typical minimum value for the assigned operating time is 1 h.

The maximum rate of application for impulse voltages shall be specified.

NOTE 3 The typical minimum value for the maximum rate of application is one or two impulses/min.

The range of environmental conditions, under which the components of the measuring system fulfil the requirements of this document, shall be stated.

4.6 Uncertainty

The uncertainty of all measurements made under this document shall be evaluated in accordance with ISO/IEC Guide 98-3.

The procedures for evaluating uncertainties have been selected from ISO/IEC Guide 98-3 and presented in this document. These simplified procedures given in Clause 5 are considered sufficient for the instrumentation and measurement arrangements commonly used in high-voltage testing. However, users may select other appropriate procedures from ISO/IEC Guide 98-3, some of which are outlined in Annex A and Annex B.

In general, the measurand to be considered is the scale factor of the measuring system, but in some cases other quantities, such as the time parameters of an impulse voltage and their associated errors, should also be considered.

NOTE 1 Other measurands for specific converting devices are in common use. For example, a voltage divider is characterized by the voltage ratio and its uncertainty in the assigned measurement ranges used. A voltage transformer is characterized by the ratio error, the phase displacement and the corresponding uncertainties.

According to ISO/IEC Guide 98-3, the uncertainty of a measurement is determined by combining the uncertainty contributions of Type A and Type B (see 5.10, 5.11 and Annex A). The contributions are obtained from measurement results, from manufacturers' handbooks, calibration certificates and from estimating reasonable values of the influence quantities during the measurement. For example, influence quantities mentioned in Clause 5 include temperature and proximity effects. Others, such as limited resolution of the measuring instrument, can be added if necessary.

NOTE 2 The resolution of a measuring instrument, e.g. one with few significant digits, can be a significant source of uncertainty.

During the actual high-voltage test, it is usually necessary to consider additional influence quantities, apart from the calibration uncertainty of the scale factor stated in the calibration certificate, in order to obtain the uncertainty of measurement of the test voltage value.

Some guidance on determining uncertainty contributions, that are required to be considered, and on their combination is given in Clause 5 and Annex A and Annex B. The uncertainty shall be given as the expanded uncertainty for a coverage probability of approximately 95 % corresponding to a coverage factor $k = 2$ under the assumption of a normal distribution.

NOTE 3 In this document, the uncertainties of the scale factor and of voltage measurement (5.2 to 5.10) are expressed by the relative uncertainties instead of the absolute uncertainty normally considered in ISO/IEC Guide 98-3. The direct application of ISO/IEC Guide 98-3 and consideration of the absolute uncertainties are shown in 5.11 for time parameters as well as in Annex A and Annex B.

5 Tests and test requirements for an approved measuring system and its components

5.1 General requirements

The assigned scale factor of the measuring system shall be determined by calibration according to the specified performance tests. The assigned scale factor is a single value for the assigned measurement range. If necessary, several assigned measurement ranges with different scale factors may be defined.

For an impulse measuring system, the performance tests also show that its dynamic performance is adequate for the specified measurements and that the level of any interference is less than the specified limits.

Owing to the large size of the equipment and the real environmental conditions, the calibration should preferably be performed on site by comparison with a reference measuring system.

Smaller size measuring systems or their components may be transported to another laboratory for calibration in an arrangement that simulates the operating conditions, provided that the interference test, when specified, is performed in the test facility of the user.

If a converting device is sensitive to proximity effects, the range of clearances where the assigned scale factor is valid shall be determined and entered in the record of performance. One or more ranges of clearances and respective scale factors may be assigned.

The scale factor of a measuring system shall be determined in the assigned measurement range, preferably by comparison with a reference measuring system. However, as reference measuring systems are not always available at higher voltages, the comparison may be made at voltages as low as 20 % of the assigned measurement range, provided that linearity has been determined from this point up to the limit of the assigned measurement range. One of the methods given in 5.3 shall be used for this extension.

All equipment used in establishing the scale factors of measuring systems should have calibrations conducted in conformity with national or international standards of measurement.

Conditions significant for the result of the calibration of the approved measuring system shall be included in the record of performance.

5.2 Calibration – Determination of the scale factor

5.2.1 Calibration of measuring systems by comparison with a reference measuring system (preferred method)

5.2.1.1 Comparison measurement

Scale factor(s) is (are) determined for a complete measuring system by comparison with a reference measuring system.

The input voltage used for calibration should be of the same type, frequency or waveform for which the measuring system is intended. If this condition is not fulfilled, the related uncertainty contributions shall be estimated.

For the comparison, a reference measuring system shall be connected in parallel with the measuring system to be calibrated. Influence of ground loops between the converting device(s) and measuring instrument(s) shall be avoided. Simultaneous readings shall be taken on both systems. The value of the input quantity obtained for each measurement by the reference measuring system is divided by the corresponding reading of the instrument in the system under test to obtain a value $F_{i,g}$ of its scale factor. The procedure is repeated n times to obtain the mean value F_g of the scale factor of the system under test at one voltage level U_g . The mean value is given by:

$$F_g = \frac{1}{n} \sum_{i=1}^n F_{i,g} \quad (5)$$

The relative standard deviation s_g of F_g is given by:

$$s_g = \frac{1}{F_g} \sqrt{\frac{1}{n-1} \sum_{i=1}^n (F_{i,g} - F_g)^2} \quad (6)$$

and the Type A relative standard uncertainty u_g of the mean value F_g is given by (Annex A):

$$u_g = \frac{s_g}{\sqrt{n}} \quad (7)$$

NOTE 1 Usually, $n = 10$ independent readings are sufficient.

NOTE 2 For the measurement of direct and alternating voltages, independent readings can be obtained either by applying the test voltage and taking n readings or by applying the test voltage n times and taking a reading each time. For impulses, n impulses are applied.

A measuring system with several assigned measuring ranges (e.g. a voltage divider with several low-voltage arms) or different transmission systems shall be calibrated for each range or transmission system. Measuring systems with secondary attenuators may be calibrated on one setting only, provided that the load on the output of the converting device can be shown to be constant for all settings by other tests. For such cases the full range of secondary attenuators shall be calibrated separately.

The scale factor shall be determined over the assigned measurement range by one of the following methods described in 5.2.1.2 (preferred), 5.2.1.3 or 5.2.2.

5.2.1.2 Comparison over the full assigned measurement range

This test includes both the determination of the assigned scale factor and the determination of linearity. The scale factor determination shall be made by direct comparison with a reference measuring system at the minimum and maximum levels of the assigned measurement range and on at least three approximately equally spaced intermediate levels (Figure 4). The assigned scale factor F is taken as the mean value of all scale factors F_g recorded at h voltage levels:

$$F = \frac{1}{h} \sum_{g=1}^h F_g \text{ for } h \geq 5 \quad (8)$$

The standard uncertainty of the determination of the assigned scale factor F is obtained as the largest of the single standard uncertainties of Type A (Figure 5):

$$u_A = \max_{g=1}^h (u_g) \quad (9)$$

The effect of a non-linearity in F is estimated as a Type B standard uncertainty expressed by

$$u_{B0} = \frac{1}{\sqrt{3}} \cdot \max_{g=1}^h \left| \frac{F_g}{F} - 1 \right| \quad (10)$$

NOTE A rounded value F_o can be taken as the assigned scale factor if the difference between F_o and F is introduced as an uncertainty contribution of Type B in the estimate of the expanded uncertainty of the scale factor F_o .