

Australian Standard[®]

High-voltage test techniques

Part 2: Measuring systems

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Australian British Chamber of Commerce
Australian Chamber of Commerce and Industry
Australian Electrical and Electronic Manufacturers Association
Electricity Supply Association of Australia
Institution of Engineers, Australia
Railways of Australia
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High-voltage test techniques

Part 2: Measuring systems

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/7 on Power Switchgear. It is identical with and has been reproduced from IEC 60-2:1994, *High-voltage test techniques*, Part 2: *Measuring systems*, to supersede AS 1931.2 — 1977, *High-voltage testing techniques*, Part 2: *Application guide for measuring devices*.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard.

This Standard is Part 2 of AS 1931, *High-voltage test techniques*, which is published in Parts as follows:

- Part 1: General definitions and test requirements
Part 2: Measuring systems

The objective of this Standard, in addition to that stated in Clause 1, is to bring the superseded Standard into line with IEC 60-2.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the annexes to which they apply. A ‘normative’ annex is an integral part of a Standard, whereas an ‘informative’ annex is only for information and guidance.

As this Standard is reproduced from an international Standard, the following applies:

- Its number is shown only on the cover and title page, while the international Standard number appears only on the cover.
- In the source text, ‘this International Standard’ should read ‘this Australian Standard’.
- A full point substitutes for a comma when referring to a decimal marker.

References to international Standards should be replaced by equivalent Australian Standards, as follows:

<i>References to International Standard</i>		<i>Australian Standards</i>	
IEC		AS	
50	International Electrotechnical Vocabulary	1852	International Electrotechnical Vocabulary
50(301)	General terms on measurements in electricity	1852.301	General terms on measurements in electricity
50(302)	Electrical measuring instruments	1852.302	Electrical measuring instruments
50(303)	Electronic measuring instruments	1852.303	Electronic measuring instruments
50(321)	Instrument transformers	1852.321	Instrument transformers
51	Direct acting indicating analogue electrical-measuring instruments and their accessories	—	
52	Recommendations for voltage measurement by means of sphere-gaps (one sphere earthed)	2886	Voltage measurement — Sphere-gap method (one sphere earthed)
60	High-voltage test techniques	1931	High-voltage test techniques
60-1	Part 1: General definitions and test requirements	1931.1	Part 1: General definitions and test requirements
71	Insulation co-ordination	1824	Insulation co-ordination
71-1	Part 1: Definitions, principles and rules	1824.1	Part 1: Definitions, principles and rules

IEC 790	Oscilloscopes and peak voltmeters for impulse tests	AS —	
833	Measurement of power-frequency electric fields	3720	Measurement of power-frequency electric fields
1083	Digital recorders for measurements in high-voltage impulse tests	—	
1083.1	Part 1: Requirements for digital recorders		

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AUSTRALIAN STANDARD

**HIGH-VOLTAGE TEST TECHNIQUES—
Part 2: Measuring Systems****1 Scope**

This part of IEC 60 is applicable to complete Measuring Systems, and to their components, used for the measurement of high-voltages and currents during tests with direct voltage, alternating voltage, lightning and switching impulse voltages and for tests with impulse currents, or with combinations of them as specified in IEC 60-1.

The limits on measurement uncertainties stated in this International Standard apply to test levels stated in IEC 71-1. The principles of this International Standard apply also to higher levels but the uncertainty may be greater.

This standard:

- defines the terms used,
- states the requirements which the Measuring Systems shall meet,
- describes the methods for approving a Measuring System and checking its components,
- describes the procedure by which the user will show that a Measuring System meets the requirements of this standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(301, 302, 303): 1983, *International Electrotechnical Vocabulary (IEV)—Chapter 301: General terms on measurements in electricity; Chapter 302: Electrical measuring instruments; Chapter 303: Electronic measuring instruments*

IEC 50(321): 1986, *International Electrotechnical Vocabulary (IEV)—Chapter 321: Instrument transformers*

IEC 51, *Direct acting indicating analogue electrical-measuring instruments and their accessories*

IEC 52: 1960, *Recommendations for voltage measurement by means of sphere-gaps (one sphere earthed)*

IEC 60-1: 1989, *High-voltage test techniques—Part 1: General definitions and test requirements*

IEC 71-1: 1993, *Insulation co-ordination—Part 1: Definitions, principles and rules*

IEC 790: 1984, *Oscilloscopes and peak voltmeters for impulse tests*

IEC 833: 1987, *Measurement of power-frequency electric fields*

IEC 1083-1: 1991, *Digital recorders for measurements in high-voltage impulse tests—Part 1: Requirements for digital recorders*

3 Definitions and symbols

For the purposes of this part of IEC 60, the following apply.

3.1 *Measuring Systems*

3.1.1 Measuring System: Complete set of devices suitable for performing a high-voltage or impulse-current measurement.

NOTES

1 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 current circuit and the connections to earth, a transmission system connecting the output terminals of the device to the indicating or recording instruments with its attenuating, terminating and adapting impedances or networks, and indicating or recording instruments together with any connections 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 accuracy requirements specified in this standard. Components may be made of many elements or a single element, for example, a high-voltage capacitor of a capacitor divider may consist of many low-voltage capacitors or it may consist of a single gas capacitor.

2 The environment in which a Measuring System functions, its clearances to live and earthed structures and the presence of electric or magnetic fields may significantly affect its accuracy.

3.1.2 Record of Performance of a Measuring System: Detailed record, established by the user, describing the system and containing evidence that the requirements given in this standard have been met. This evidence shall include 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 which is shown to comply with one or more of the sets of requirements set out in this standard by:

- an initial Performance Test,
- successive Performance Checks and Performance Tests,
- inclusion of the results of these tests in the Record of Performance.

The system is approved only for the arrangements and operating conditions included in its Record of Performance.

3.1.4 Reference Measuring System: Measuring System 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 or current.

NOTE— A Reference Measuring System (maintained according to the requirements of this standard) can be used as an Approved Measuring System but the converse is not true.

3.1.5 IEC Standard Measuring Device: Device that can be used for measuring high voltage with the specified accuracy (for example a sphere-gap or a rod/rod gap used according to IEC 60-1).

3.2 *Converting devices*

3.2.1 converting device: Device for converting the quantity to be measured into another quantity, compatible with the indicating or recording instrument.

3.2.2 voltage divider: Converting device consisting of a high-voltage and a low-voltage arm such that the input voltage is applied across the complete device and the output voltage is taken from the low-voltage arm. [IEV 301-05-13, modified]

NOTE— The elements of the two arms are usually resistors or capacitors or combinations of these and the device is described by the type and arrangement of its elements (for example, resistor, capacitor or resistor-capacitor).

3.2.3 voltage transformer: Step-down transformer for the measurement of the parameters of high alternating voltages. [IEV 321-03-01, modified]

3.2.4 high-voltage measuring impedance: Device which carries a current proportional to the applied voltage.

3.2.5 current-measuring shunt: Resistor across which the voltage is proportional to the current to be measured. [IEV 301-06-05, modified]

3.2.6 compensated current-measuring device: Current-measuring device which includes a compensating circuit.

3.2.7 current transformer: Transformer which produces an output proportional to the input current. [IEV 321-02-01, modified]

NOTE— A Rogowski coil used with an integrating circuit is a wide-band current transformer.

3.2.8 electric-field probe: Converting device for the measurement of the amplitude and waveform of an electric field.

NOTE— An electric-field probe may be used to measure the waveform of the voltage producing the field provided that the measurement is not affected by corona.

3.3 transmission system: Set of devices which transfers the output signal of a converting device to an indicating and/or recording instrument.

NOTES

- 1 A transmission system generally consists of a coaxial cable with its terminating impedance, but it may include attenuators or other devices connected between the converting device and the instrument. For example, an optical link includes the transmitter, the optical cable and the receiver as well as related amplifiers.
- 2 A transmission system may be partially or completely included in the converting device.

3.4 indicating or recording instrument: Device intended to display or provide a record of the value of a measurand or a related value. [IEV 301-02-11 and 12, modified]

3.5 Scale factors

3.5.1 scale factor of a Measuring System: Factor by which the value of the instrument reading is to be multiplied to obtain the value of the input quantity.

NOTES

- 1 A Measuring System may have more than one scale factor, for example, it may have different scale factors for different frequency ranges or waveforms (see 3.6.1).
- 2 For some Measuring Systems the value of the input quantity is displayed directly (i.e., the scale factor of the Measuring System is unity).

3.5.2 scale factor of a converting device: Factor by which the output of the converting device is to be multiplied to obtain its input quantity.

NOTE— The scale factor of a converting device may be dimensionless (for example, the ratio of a divider) or may have dimensions (for example, the impedance of a high-voltage measuring impedance).

3.5.3 scale factor of a transmission system: Factor by which the output of a transmission system is to be multiplied to obtain its input quantity.

3.5.4 scale factor of an indicating or recording instrument: Factor by which the instrument reading is to be multiplied to obtain its input quantity.

3.5.5 Assigned Scale Factor: Scale factor of a Measuring System determined at the most recent Performance Test.

NOTE— A Measuring System may have more than one Assigned Scale Factor, for example, it may have several Nominal Epochs each with a different value (see 3.6.1)

3.6 Definitions related to the dynamic behaviour of a Measuring System

3.6.1 Nominal Epoch τ_N (Impulse measurements, front part of impulse only): Range of values between the minimum ($t_{\min}$) and the maximum ($t_{\max}$) of the relevant time parameter of impulses for which the Measuring System is to be approved. The relevant time parameter is:

the front time T_1 for full lightning and tail-chopped impulses and for current impulses

the time to chopping T_c for front-chopped impulses

the time to peak T_p for switching impulses

NOTES

- 1 A Measuring System may have one, two or more Nominal Epochs for different waveforms. For example, a particular Measuring System might be approved:

— for full lightning impulses with an Assigned Scale Factor F_1 over a Nominal Epoch τ_{N1} from $T_1 = 0,8 \mu\text{s}$ to $T_1 = 1,2 \mu\text{s}$

— 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 $T_p = 200 \mu\text{s}$ to $T_p = 300 \mu\text{s}$.

- 2 “Front-chopped impulse” is used to designate a chopped impulse with a time to chopping in the range $0,5 \mu\text{s}$ to $2 \mu\text{s}$ as distinct from a “tail-chopped impulse” which has a time to chopping greater than $2 \mu\text{s}$.

3.6.2 response of a Measuring System G : Output, as a function of time or frequency, when a specified voltage or current is applied to the input of the system.

3.6.3 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 (see figure 1).

3.6.4 step response $G(t)$: Output of a Measuring System as a function of time when the input is a step function.

3.7 Response parameters

3.7.1 response parameters: Parameters which are derived from the measured amplitude/frequency response or the measured step response by applying the specified procedure.

3.7.2 limit frequencies f_1 and f_2 : Lower and upper limits of the range within which the amplitude/frequency response is nearly constant. These limits are where the response first deviates by ± 3 dB from the constant value (see figure 1).

3.7.3 Reference Level I_R (impulse measurements only): Mean value of the step response taken over a Nominal Epoch (see figure 2).

NOTE— A Measuring System may have more than one Reference Level, for example, it may have different scale factors for different waveforms (see 3.6.1 and figure 2).

3.7.4 virtual origin of a step response O_1 : Intersection with the time axis of a straight line drawn as a tangent to the steepest portion of the front of the step response. In the case of a response with oscillations on the front, a mean curve is drawn through the oscillations and used to determine the tangent line. Any initial distortion is neglected when drawing the tangent line (see figure 3a).

NOTES

1 All time values are measured from the virtual origin O_1 .

2 For a smooth response, or for a smooth curve drawn through oscillations, the steepest portion will occur near the beginning of the response.

3.7.5 normalized step response $g(t)$: Step response normalized such that a Reference Level becomes unity.

NOTE— A Measuring System has a normalized step response for each Reference Level.

3.7.6 step response integral $T(t)$: Integral from O_1 to t of one minus the normalized step response $g(t)$, but with the initial portion of $g(t)$ replaced by the straight line drawn to determine O_1 (see 3.7.4).

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

3.7.7 experimental response time T_N : Value of the step response integral at $t_{\max}$ (see 3.6.1):

$$T_N = T(t_{\max})$$

3.7.8 partial response time T_α : Maximum value of the step response integral (see figure 3b).

NOTE— Usually $T_\alpha = T(t_1)$ where t_1 is the time when $g(t)$ first reaches unit amplitude.

3.7.9 residual response time $T_R(t_i)$: Experimental response time minus the value of the step response integral at some specific time t_i and $t_i < t_{\max}$.

$$T_R(t_i) = T_N - T(t_i)$$

3.7.10 overshoot β : Amount by which the maximum value of the normalized step response $g(t)$ exceeds unity.

3.7.11 initial distortion time T_O : Area bounded by the zero line, the normalized step response $g(t)$ and the straight line used to determine O_1 (see figure 3a).

3.7.12 settling time t_s : Shortest time for which the residual response time $T_R(t)$ becomes and remains less than 2 % of t :

$$|T_N - T(t)| < 0,02 t_s$$

for all values of t in the epoch from t_s to $t_{\max}$ (see figure 3b).

3.7.13 Equivalent Time T_E : Time parameter of calibration waveforms that:

- for direct voltage T_E is equal to 100 ms (arbitrary),
- for alternating voltage T_E is equal to one quarter of the period,
- for impulses T_E is equal to the time to peak T_p (for lightning impulses, use definition of T_p for switching impulses).

3.8 overall uncertainty e : Estimate characterizing the range of values around the result of a measurement within which the true value of the measurand could lie; it is the combination of many individual uncertainties due to the presence of many influence quantities.

NOTE— It is assumed that most of the sources of uncertainty considered in this standard have a random character and can be regarded as independent; the preferred estimate for the overall uncertainty e is:

$$e = \sqrt{\sum_{i=1}^n e_i^2}$$

where e and each e_i are expressed at the same confidence level.

3.9 *Rated values*

3.9.1 Rated Measuring Voltage or Rated Measuring Current: Maximum level of voltage or current of specified frequency or waveform at which a Measuring System can be used within the uncertainty limits given in this part of IEC 60.

3.9.2 operating voltage or current range: Range of voltage or current of specified frequency or waveform in which a Measuring System can be used within the uncertainty limits given in this part of IEC 60.

NOTE— The limits of the operating range are chosen by the user and verified by the Performance Tests specified in this part of IEC 60.

3.9.3 operating time (for direct or alternating voltages): Time during which the Measuring System can operate at its Rated Measuring Voltage within the uncertainty limits given in this part of IEC 60.

3.9.4 maximum rate of application (for impulses): Maximum rate of application of impulses with a specified waveform, at which the Measuring System can operate within the uncertainty limits given in this part of IEC 60 for a specified time at its Rated Measuring Voltage or Rated Measuring Current.

3.10 *Definitions related to tests*

3.10.1 acceptance test: Test on a device or Measuring System before it is accepted for use. The acceptance test includes type tests (performed on a device of the same design) and routine tests (performed on every device) to assess its specific characteristics, for example, measurement of temperature coefficient of an element, withstand test, etc. In addition, the acceptance test on a Measuring System includes the first Performance Test.

3.10.2 Performance Test: Test on a complete Measuring System to characterize it under operating conditions.

3.10.3 Performance Check: Simple procedure to ensure that the most recent Performance Test is still valid.

3.10.4 Reference Record (impulses 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 (see 9.3.2, 10.3.2, and 11.3.2).

4 Procedures for qualification and use of Measuring Systems

4.1 General principles

Approved Measuring Systems are required to undergo acceptance tests followed by tests and checks throughout their service lives.

The following are usually necessary:

- acceptance tests on system components (required once only),
- Performance Tests on the system (periodic, see 4.2),
- Performance Checks on the system (periodic, see 4.3).

A major requirement for converting devices, transmission systems and measuring instruments used in Measuring Systems is stability within their specified range of operating conditions so that the scale factor of the Measuring System remains constant over long periods.

The scale factor is determined in the Performance Tests.

Test facilities shall use the tests given in this part of IEC 60 to qualify their Measuring System(s). Alternatively, any test facility may choose to have the Performance Tests made by a National Laboratory or by an Accredited Calibration Laboratory: in this case the period of validity of each calibration is set by the National Laboratory or by the Accrediting Body.

Countries which choose to employ accreditation procedures to provide certified traceability in the implementation of this standard, shall meet the requirements given in annex A. Annex A is not applicable to the countries which do not choose to employ accreditation procedures.

Tables summarizing the tests to be performed on each type of Measuring System are given in annex F.

4.2 Schedule of Performance Tests

To maintain the quality of a Measuring System its Assigned Scale Factor(s) shall be determined by the Performance Tests of clause 6 repeated periodically: it is recommended that the tests of clause 6 should be repeated annually and in any case it shall be repeated at least once every five years.

Performance Tests shall be made after major repairs to the Measuring System and whenever a circuit arrangement which is beyond the limits already given in the Record of Performance is to be used.

When Performance Tests are required because a Performance Check shows that the Assigned Scale Factor has changed significantly, the cause of this change shall be investigated before the Performance Tests are 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.

Initially Performance Checks shall be made at short intervals to determine this stability.

Performance Checks are described in 7.4, 8.4, 9.4, 10.4, and 11.4.

No reference method is identified for the Performance Checks because the required accuracy is less than that required for Performance Tests: users requiring higher accuracies should repeat the Performance Test more frequently.

4.4 *Requirements for the Record of Performance*

4.4.1 *Contents of the Record of Performance*

The results of all tests and checks with the conditions under which the results were obtained shall be kept in the Record of Performance established and maintained by the user.

An outline of the Record of Performance is given in 4.4.3, the full format of the recommended Record of Performance is given in annex B (informative), clauses B.1 to B.6 and a minimal form is given in clause B.7.

4.4.2 *Exceptions*

In the case of apparatus or equipment manufactured before the date of issue of this standard, if the evidence required in some of the acceptance tests (for example, 5.6 and 5.9) is not available, then Performance Tests (in accordance with clause 6) and checks made in accordance with earlier standards are deemed to be 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 interchangeably, 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 instruments may be covered generically so that a range of cable lengths or similar instruments which meet the requirements of the relevant IEC standard may be indicated.

4.4.3 *Outline of a Record of Performance*

It is recommended that the format of each Record of Performance be as follows:

Chapters A: General descriptions of the Measuring System (see clause B.2)

Chapter B: Results of acceptance tests on converting devices, transmission systems and measuring instruments (see clause B.3)

Chapter C: Results of routine tests on the Measuring System, when performed (see clause B.4)

Chapters D: Results of Performance Tests on the Measuring System (see clause B.5)

Chapters E: Results of Performance Checks on the Measuring System (see clause B.6)

The successive chapters are identified by an ordinal number when needed (for example, Chapter A1 is the first general description of the system, Chapter A2 the description of the system after the first significant change, etc., Chapter D1 the initial Performance Test of the system, Chapter D2 the second one, etc. but Chapter B and Chapter C will not need repetition). For details see annex B.

The Assigned Scale Factor to be used shall be the one determined at the latest Performance Test and shall be filed under the latest Chapters D.

4.5 *Operating conditions*

An Approved Measuring System for voltages shall be connected directly to the terminals of the test object. The parasitic coupling between the test and measuring circuits should be minimized.

An Approved Measuring System for currents shall be connected in series with the test object.

An Approved Measuring System is usually designed for operating within the required limits of uncertainty in dry service conditions and in the absence of pollution.

Unless otherwise specified, Measuring Systems for direct and alternating voltages shall be designed for continuous operation.

Unless otherwise specified, the maximum rate of application for Measuring Systems for impulses shall be two per minute.

5 Acceptance tests on components for an Approved Measuring System

5.1 *Applicability*

The tests described in this clause are required for components of Measuring Systems. However these tests are not required for transmission systems which consist only of cables nor for instruments which meet the requirements of the relevant standard referenced in clause 2. Some of these tests cannot be performed on existing equipment (see 5.6 and 5.9): for these cases see 4.4.2.

For some of the tests described in this clause it is necessary to include the component in an appropriate Measuring System (whose other components have been shown to be linear), for example, the linearity test of 5.3.

5.2 *Determination of the scale factor*

The determination of the scale factor of a component may be made by one of the following methods:

- simultaneous measurements of its input and output quantities,
- a bridge method,
- calculation based on measured impedances.

The scale factor of a current-measuring shunt shall be measured by direct current methods.

5.3 *Linearity test*

Values of the scale factor of the Measuring System shall be measured at the minimum and maximum voltages (or currents) of the operating range and at three approximately equally spaced voltages or currents between these extremes. These five values shall not differ by more than ± 1 % from their mean value.

The reference method is by comparison with a Reference Measuring System according to 6.2 a).

Alternative methods are:

either comparison with an Approved Measuring System, the linearity of which has been established by the reference method

or one of the additional methods described in the relevant clauses of this standard.

These additional methods are provided to allow users alternative tests which may be economic. However, failure to meet the requirements of these tests does not necessarily show that a Measuring System is non-linear.

In such a case either the reference method or the method of comparison with an Approved Measuring System shall be used.

5.4 *Short-term stability test*

The full rated voltage or current shall be applied to the device continuously (or in the case of impulses, at the maximum rate) for a period appropriate to the anticipated use.

The scale factor shall be measured before and immediately after (within 10 min) the application of the voltage or current. The two values shall not differ by more than 1 %.

5.5 *Long-term stability of single elements*

The stability characteristics, voltage and current effects and temperature effects of each type of element, shall be such that the scale factor of a converting device does not change by more than 1 % between successive Performance Tests.

These characteristics may be taken from manufacturer's data or demonstrated by successive Performance Tests.

5.6 *Temperature effect*

The variations of the scale factor or of a parameter (for example, resistance or capacitance) of a device due to changes of the ambient temperature are determined by computation using the temperature coefficients of single elements or by making measurements at different temperatures.

The temperature coefficients shall be listed in the Record of Performance and may be taken from manufacturer's data.

Temperature correction factors may be used in cases where the ambient temperature varies over a wide range. Any temperature corrections to be used shall be listed in the Record of Performance.

In each case, it shall be shown that the scale factor is within 1 %, taking into account any temperature correction (see annex D).

5.7 *Proximity effect*

Variations of the scale factor or of a parameter to a device, due to proximity effects, can be determined by measurements performed for different distances of the device from an earthed wall or an energized structure, the distances from other earthed walls or energized structures remaining constant or so large there is no effect.

For each range of distances listed in the Record of Performance, it shall be shown that the scale factor is within 1 %.

For current measurements, the effects of off-centre paths (when relevant) and the effects of nearby paths for high currents can be determined by measurements performed for different paths and distances to current-carrying conductors.

NOTE— Some test facilities may choose to approve their Measuring Systems for only a single set of distances, or for a few sets or ranges of distances.

5.8 *Dynamic behaviour of a component*

The response of the component shall be determined in a Measuring System representative of its operating conditions, particularly clearances to earthed and energized structures. Either the amplitude/frequency response or the step response shall be measured.

5.8.1 *Determination of the amplitude/frequency response*

The system is subjected to a sinusoidal input of known amplitude, usually at low level, and the output is measured. This measurement is repeated for an appropriate range of frequencies.

5.8.2 *Determination of the step response*

The system is subjected to a voltage or current step and its output is measured (see annex C). The rise time of the applied step should be less than $1/10$ of the partial response time T_{α} .

5.9 *Withstand tests*

A converting device shall pass a dry withstand test performed with a voltage or current of the required frequency or shape at a level of 110 % of the Rated Measuring Voltage or Rated Measuring Current. For the procedures of withstand tests see IEC 60-1.

Wet tests and pollution tests, when specified, are performed as type tests.

The withstand tests shall be performed at the polarity or polarities at which the system is to be used.

NOTE— Design and construction of any component of an Approved Measuring System should be such that it can withstand a disruptive discharge at the test object without any change in its characteristics.

6 Performance Tests on Measuring Systems

6.1 General requirements

The Assigned Scale Factor of the Measuring System is determined by calibration using the specified Performance Tests. 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 disturbance is less than the specified limits.

In high-voltage tests, the size of the apparatus, the levels of voltage and current used, and the interaction between the test and measuring circuits often make it necessary to perform calibration tests in the test facility of the user.

However, Measuring Systems or their components may be transported to another laboratory for calibration in an arrangement which simulates the operating conditions, provided that the interference test, when specified, is performed in the test facility of the user. The simulated arrangement shall represent the operating conditions described in the Record of Performance and this simulated arrangement shall also be described in the Record of Performance.

Unless type tests show a converting device is not sensitive to proximity effects over a specified range of clearances the Assigned Scale Factor of any Measuring System based on that converting device shall be measured for each condition of use. Each set of clearances or range of clearances shall be entered in the Record of Performance.

The input voltage or current used for calibration should be of the same type, frequency or waveform as voltages or currents to be measured. When this condition is not fulfilled, evidence shall be given of the validity of the Assigned Scale Factor in the range of frequency or waveforms to be used.

The reference method of determining the Assigned Scale Factor is comparison with a Reference Measuring System at the Rated Measuring Voltage or Rated Measuring Current whenever possible. However, as Reference Measuring Systems are not always available at the highest voltages and currents, the comparison may be made at voltages or currents as low as 20 % of the Rated Measuring Voltage or Rated Measuring Current (see 6.2 a)).

For lightning impulses with peak values over 1 MV, it may be made at 200 kV. Alternatively, the Assigned Scale Factor may be determined by measuring the scale factor of each component, usually at low voltage, and taking the product of the scale factors of the components (see 6.2 b)).

The voltage or current used to determine the Assigned Scale Factor shall be included in the range covered by the linearity test.

All equipment used in establishing the scale factors of Measuring Systems and all instruments used in Measuring Systems shall have calibrations traceable to National Measurement Standards (Etalons).

The conditions under which the calibration has been performed shall be included in the Record of Performance.

6.2 Determination of the Assigned Scale Factor

a) Reference method: comparison with a Reference Measuring System

A Reference Measuring System shall be connected in parallel (voltage) or in series (current) with the Measuring System to be calibrated. 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 of its scale factor. The procedure is repeated to obtain n independent readings ($n \geq 10$) and the mean value F_m is taken as the Assigned Scale Factor of the system under test, provided that the experimental standard deviation s as calculated from:

$$s = \frac{\sqrt{\sum (F_i - F_m)^2}}{n - 1}$$

is less than 1 % of F_m .

NOTES

- 1 A rounded value F_o may be taken as the Assigned Scale Factor if, introduced in place of F_m in the formula for s , it gives the value of s less than 1 % of F_m .
- 2 For measurement of direct and alternating voltages, independent readings may 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.

The test shall be performed at a single voltage or current level (see 6.1). The setting of the measuring instrument may be changed or a different instrument may be used to achieve a suitable sensitivity, provided that this change does not alter the rest of the Measuring System and that the settings used on each instrument have been calibrated.

If only one measuring instrument is available (this measuring instrument is the instrument to be used in the Approved Measuring System and shall meet the relevant IEC standard) the test may be made by the repeated alternate connection of the instrument to each system to provide the n values F_i . A termination equivalent to the instrument shall be connected in the place of the instrument in the other system. All other parts of both systems shall remain unchanged.

A Measuring System with several scale factors (for example, the use of different low-voltage arms for a voltage divider) shall be calibrated for each scale factor. Measuring Systems with secondary voltage dividers 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 settings of the secondary divider shall be calibrated separately.

NOTE— For the use of oscilloscope probes see annex G.

b) *Alternative Method: component calibration*

The Assigned Scale Factor shall be determined as the product of the scale factors of its converting device, its transmission system and its measuring instrument.

For the converting device and the transmission system or their combination, the scale factor shall be measured by one of the methods given in 5.2 to assure a total uncertainty not larger than 1 % (care should be taken to ensure the appropriate “stray” capacitance or coupling and the mutual influence of the components are included in the measurement).

The scale factor of an instrument is determined according to the relevant IEC standard (see clause 2) or by performing the relevant tests given in this part of IEC 60.

6.3 *Dynamic behaviour test (for Impulse Measuring Systems)*

a) *Reference method: comparison with a Reference Measuring System*

The same records taken in the test of 6.2 a) can be used and the relevant time parameters of the measured impulses evaluated for each system and:

—the value of each time parameter shall be within ± 10 % of the corresponding value measured by the Reference Measuring System,

—for each time parameter, the experimental standard deviation of the ratio of the corresponding readings of the system under test and the Reference Measuring System shall be less than 5 % of the mean value of the ratio.

b) *Alternative Method: step response measurement*

The step response of the Measuring System shall be measured according to 5.8.2. The relevant response parameters shall be determined and shall meet the requirements given in the relevant clause of this part of IEC 60.

6.4 *Interference test (for Impulse Measuring Systems)*

The test shall be made on the Measuring System, with its cable or transmission system short-circuited at its input terminals without changing the earth connections of the cable or transmission system. An interfering condition shall be produced at the input of the Measuring System (for voltage measurements—by a disruptive discharge with an impulse representative of the waveform to be applied; for current measurements—by operation of an appropriate device) and the output shall be recorded. The test shall be made at the Rated Measuring Voltage or Rated Measuring Current.

The amplitude of the measured interference shall be less than 1 % of the output of the Measuring System when measuring the test voltage or current. Interference greater than 1 % is permitted provided it is shown that it does not affect the measurement.

7 Measurement of direct voltage

7.1 Requirements for an Approved Measuring System

The general requirement is to measure the value (arithmetic mean) of the test voltage with an overall uncertainty within $\pm 3\%$.

The uncertainty limits shall not be exceeded in the presence of ripple, the magnitude of which is within the limits given in IEC 60-1.

NOTE— Attention is drawn to the possible presence of alternating voltages coupled to the Measuring System and affecting the reading of the measuring instrument.

7.1.1 Stability of the scale factors

The scale factors of the converting device and the transmission system shall not vary by more than $\pm 1\%$ within the ranges of the ambient temperature and humidity given in the Record of Performance.

A converting device for direct voltage shall be constructed so as to conduct directly to earth all leakage current on its external surfaces and to keep internal leakage current negligible relative to the measuring current.

NOTE— To maintain a low ratio between the leakage and measuring currents, a measuring current as high as 0,5 mA at the rated voltage may be necessary.

Measuring instruments shall comply with the requirements of class 0,5 of IEC 51 or shall be tested according to this standard.

7.1.2 Dynamic behaviour for measuring rising voltages

The experimental response time T_N of an Approved Measuring System shall not be larger than 0,5 s. This will permit measurement with the accuracy required by 7.1 when the voltage is increased at the rate specified for dielectric tests in IEC 60-1.

NOTES

1 In some cases the response time of a converting device is kept much lower than 0,5 s to improve its behaviour in case of flashover in the test circuit. However, to avoid ripple on the high-voltage source affecting the measured value, the response time of the Measuring System (which includes the measuring instrument) should be greater than $5/f$ where f is the fundamental frequency of the ripple.

2 In certain cases, for example, in pollution tests, it may be necessary to detect and measure transient components. No requirements for this are given here, but some guidance may be obtained from clause 9.

7.2 Acceptance tests on components for an Approved Measuring System

The requirements of the type tests can be met by tests on a unit of the same type or sometimes from manufacturer's data. Routine tests shall be performed on each unit. See clause 5 for details and 4.4.2 for exceptions.