

INTERNATIONAL STANDARD

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Instruments and software used for measurement in high-voltage and high-current tests –

Part 3: Requirements for hardware for tests with alternating and direct voltages and currents

Appareils et logiciels utilisés pour les mesurages pendant les essais à haute tension et à courant élevé –

Partie 3: Exigences relatives au matériel pendant les essais avec des tensions et des courants alternatifs et continus



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INSTRUMENTS AND SOFTWARE USED FOR MEASUREMENT
IN HIGH-VOLTAGE AND HIGH-CURRENT TESTS –****Part 3: Requirements for hardware for tests with alternating
and direct voltages and currents**

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International Standard IEC 61083-3 has been prepared by IEC technical committee 42: High-voltage and high-current test techniques.

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

FDIS	Report on voting
42/380/FDIS	42/387/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61083 series, published under the general title *Instruments and software used for measurement in high-voltage and high-current tests*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

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INTRODUCTION

The electric power industry requires standardized tools to provide confidence in testing results, and to prove equivalence between tests performed in different laboratories and test fields.

This part of IEC 61083 specifies requirements for the performance of digital recording instruments used for tests with alternating and direct voltages and currents.

The intention of this document is to provide recommendations on the digital recording instruments to be used in tests with alternating and direct voltages and currents.

Digital recording instruments are considered as black boxes (including hardware, firmware, and software). They are characterized for their intended application by physical calibration with the waveforms needed for that application.

This document does not apply to simple analogue or digital meters that do not have recording capability.

INSTRUMENTS AND SOFTWARE USED FOR MEASUREMENT IN HIGH-VOLTAGE AND HIGH-CURRENT TESTS –

Part 3: Requirements for hardware for tests with alternating and direct voltages and currents

1 Scope

This part of IEC 61083 is applicable to digital recording instruments used for measurements during tests with high alternating and direct voltages and currents. It specifies the measuring characteristics and calibrations required to meet the measuring uncertainties and procedures specified in the relevant IEC standards (e.g. IEC 60060-1, IEC 60060-2, IEC 60060-3, IEC 62475, IEC 61180).

This document is applicable to those digital recording instruments that will be designed and type tested according to this document.

This document

- defines performance requirements for digital recording instruments used during tests with alternating voltages and currents (AC) or direct voltages and currents (DC);
- specifies the necessary requirements for such instruments to ensure their suitability for use under the relevant standards;
- establishes the tests and procedures necessary to demonstrate their compliance;
- defines the terms related to digital recording instruments with recording function and access to raw data.

NOTE Examples of relevant alternating and direct voltages and currents to be measured are listed in Annex D.

This International Standard has the status of a horizontal standard in accordance with IEC Guide 108.

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

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

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 measurement (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 Digital recording instruments

3.1.1

approved instrument

measuring device that is shown to comply with the requirements set out in IEC 61083-3

3.1.2

digital recording instrument

device with digital output capability of the recorded input

Note 1 to entry: This definition includes digital recorders, digital oscilloscopes, digital peak voltmeters and other digital recording instruments if applicable.

Note 2 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.

3.1.3

assigned measurement range

range of input voltage for which the digital recording instrument can be used within the uncertainty limits given in IEC 61083-3

3.1.4

output

displayed (in any way) value of a digital recording instrument at a specific instant or the numerical value of a digital recording instrument recorded at a specific instant

3.1.5

full-scale deflection

minimum input value, which produces the nominal maximum output of the digital recording instrument in the specified range

3.1.6

offset

output of a digital recording instrument for zero input

3.1.7

raw data

original record of sampled and quantized information obtained when a digital recording instrument 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

test duration

range of a time interval in which the measurement is done

3.1.9

reading rate

rate with which the instrument displays or stores the readings of the measured AC or DC voltage or current

Note 1 to entry: In sampling instruments, readings are calculated e.g. by averaging (DC) or by calculating the RMS value (AC) of several samples.

3.2 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, defined as

$$r = 2^{-N}$$

3.2.2 sampling rate

number of samples taken per unit of time

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 an instrument is first switched on to when an instrument meets operational requirements

3.3 Factors

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: 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 non-linearity of amplitude

deviation of the actual output of a digital recording instrument from the nominal value, which is determined by dividing the input voltage or input current by the scale factor

Note 1 to entry: The static non-linearity for a DC input voltage or current is different from the non-linearity under dynamic conditions.

3.3.4 peak factor

numerical value calculated from the peak value divided by the RMS value of a measurement

3.4 Dynamic performance

3.4.1 integral non-linearity

$s(k)$

difference between corresponding points on the measured quantization characteristic and on the ideal quantization characteristic that is based on the static scale factor

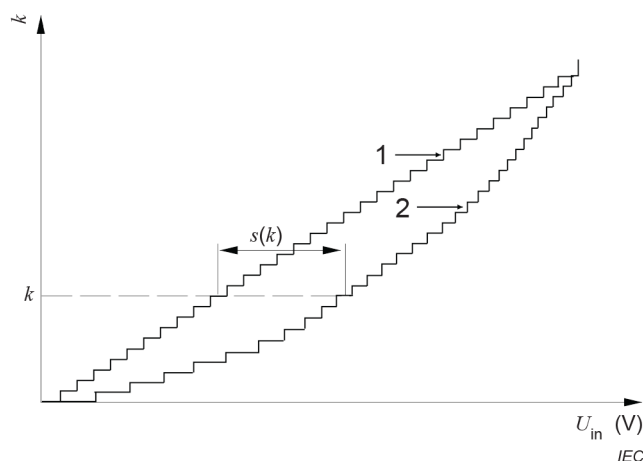
SEE: Figure 1.

3.4.2 quantization characteristic

characteristic showing the relationship between the output of the digital recording instrument and the direct voltage on the input which produces this output

SEE: Figure 1.

Note 1 to entry: The average slope of the quantization characteristic is equal to the reciprocal of the static scale factor of the A/D converter.



Curve 1: Quantization characteristic of an ideal 5-bit digital recording instrument.

Curve 2: Quantization characteristic of a non-linear 5-bit digital recording instrument (the low resolution of 5 bits has been chosen to clarify the illustration).

Figure 1 – Integral non-linearity $s(k)$ at code k

3.4.3 code k

integer used to identify a digital level

3.4.4 code bin width

$w(k)$

range of input voltage or input current allocated to code k

SEE: Figure 2.

3.4.5 average code bin width

w_0

product of the full-scale deflection and the rated resolution

SEE: Figure 2.

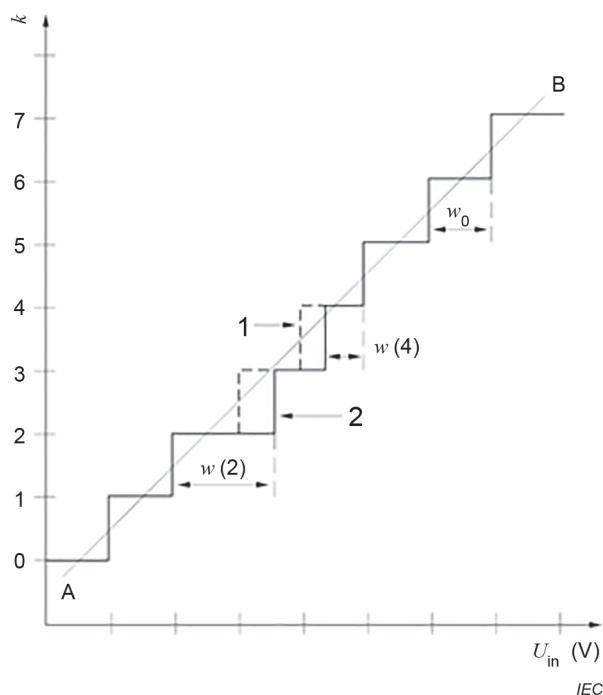
Note 1 to entry: The average code bin width is approximately equal to the static scale factor.

3.4.6 differential non-linearity

$d(k)$

difference between a measured code bin width $w(k)$ for code k and the average code bin width w_0 divided by the average code bin width w_0

$$d(k) = \frac{w(k) - w_0}{w_0}$$



Curve 1: Quantization characteristic of an ideal 3-bit digital recording instrument.

Curve 2: Quantization characteristic of a 3 bit digital recording instrument showing large $d(k)$ at codes $k = 2, 3$ and 4 .

Line AB: A straight line joining the midpoints of the code bins of an ideal instrument (the low resolution of 3 bits has been chosen to clarify the illustration).

Figure 2 – Non-linearity $d(k)$ and code bin width $w(k)$ under DC conditions

3.4.7 rise time

t_R

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

3.4.8 time base

unit of the digital recording instrument horizontal scale against which a time interval is measured

3.5 Uncertainties

3.5.1 uncertainty

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 measurement should not be confused with the tolerance of the test value.

3.5.2 standard uncertainty

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

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

3.6 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 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 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 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

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 IEC 61083-3 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 digital recording instrument 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.

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 Applicability

A digital recording instrument may be qualified for all requirements in this document, or for a suitable subset.

5.2 Qualification of digital recording instruments

Digital recording instruments for measurement of high voltage and/or high current are qualified by comparative measurements against known reference systems traceable to national standards, proving both requirements on accuracy and dynamic performance.

Qualifications are performed both as type tests performed once for each type of instrument and routine tests performed once for each instrument, and calibrations are performed regularly on each instrument.

For electromagnetic interference tests in high-voltage and high-current laboratories and test fields, see recommendations in Annex B.

5.3 Requirements for reference generators

A reference waveform generator is only necessary for calibration when the digital recording instrument contains a measurement device which is to be used as a reference instrument (see 6.3). Otherwise any waveform generator can be used if it fulfils general requirements for amplitude and frequency stability and noise.

NOTE An approved waveform generator can be considered qualified if the amplitude and the frequency are stable within 0,1 % of output and the noise is < 1 % of output.

5.4 Available methods for qualification of digital recording instruments

Calibration (scale factor determination) (5.5),

Dynamic performance tests (5.6.2),

Internal noise (5.6.3),

Interference tests (5.6.4),

Displaying performance (5.6.5).

5.5 Calibration

Calibration is the preferred method to establish the scale factor of approved digital recording instruments. It is also the preferred method to check the time parameter determination from the records of digital recording instruments. The actual values shall be entered in the record of performance.

In the case of direct voltages and currents (DC) the polarity of the calibration signal shall be that of the signal to be measured.

The output of a digital recording instrument corresponding to the applied calibration signal shall be evaluated for a sufficient number of values in each measurement range. The scale factor is the average of the values of the quotient of the input value and the output value. Different scale factors may be determined for different voltage and current parameters or for different waveform frequencies (e.g. peak values and derivations, RMS values).

The relevant frequency and time parameters of records shall be evaluated and compared with traceable reference values.

The calibration shall be performed on each range of use for tests. A calibration curve or table of scale factors may be developed to reduce the effects of non-linear converter characteristics.

5.6 Alternative test methods

5.6.1 General

Alternative test methods shall be applied if a calibration according to 5.5 is not possible. While the calibration is the recommended method, such test methods may be used if the type of instrument does not allow a calibration or they may be used in addition to the calibration.

5.6.2 Test of the rise time, step response

Apply a step with a rise time, which is less than 20 % of the specified rise time limit (see 6.2.5) required for the application. Measure the rise time of the output as the time from 10 % to 90 % of the settling level. The amplitude of the applied step shall be (95 ± 5) % of the full-scale deflection.

This rise time shall be determined at least at 5 levels (preferably with a constant quotient between levels, e.g. 1, 2, 5, 10 sequence), over the operating range.

NOTE A standard waveform generator up to a few kHz can be used for this task since usually the test frequencies are below 400 Hz (see Clause D.1).

5.6.3 Internal noise level

A direct voltage within the range of the digital recording instrument shall be applied.

Enough records shall be taken at a specified sampling rate to acquire at least 10 samples. The standard deviation of these samples is taken as the internal noise level.

5.6.4 Interference test

Annex A gives the requirements for interference tests.

5.6.5 Reading rate

The reading rate shall be sufficient to catch the voltage preceding the breakdown with required accuracy during tests.

NOTE The reading rate is not the sampling rate.

5.7 Uncertainty contribution

The manufacturer shall provide uncertainty estimates for quantities relevant to the intended application. The uncertainty contributions can then be used to evaluate the uncertainty according to IEC 60060-2, IEC 62475, IEC 61180 and IEC 61083-4¹.

5.8 Input impedance

Depending on the type of measuring system used, the input impedance of the instrument may influence the scale factor and response of a measuring system. For this reason, the input impedance of the digital recording instrument (resistance and capacitance) shall be stated.

6 Requirements for AC and DC measurements

6.1 Requirements for digital recording instruments used in approved measuring systems

The expanded uncertainty contribution for a measurement by digital recording instruments according to this document and used in an approved measuring system according to IEC 60060-2, IEC 61180 and IEC 62475, shall not be more than (at a confidence level of not less than 95 %)

- 1 % in the voltage (current) measurement,
- 1 % in the measurement of the time and frequency parameters.

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

NOTE The estimated uncertainty of the digitizer is used as a component of uncertainty of the complete measurement system according to IEC 60060-2, IEC 61180 or IEC 62475.

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, one or more of these limits may be exceeded provided the permitted overall uncertainty specified in 6.1 is not exceeded.

6.2.2 Scale factor

The scale factor shall be constant within ± 1 % over the time intervals or frequency range and shall be determined with an uncertainty of not more than 1 %.

6.2.3 Sampling rate

The sampling rate after signal processing shall be high enough for capturing the peak value with the required uncertainty (see Clause D.1).

The above requirement is met usually when the sampling rate is not less than N/T where N is the number of samples per period of the highest harmonic and T is the cycle duration of the highest harmonic to be measured with the specified uncertainty U_{SR} . N is given by $\pi/\arccos(1-U_{SR})$.

NOTE For a measurement with an uncertainty U_{SR} of 1 %, N will be 23 samples per period. This leads for AC ($f = 50$ Hz, without harmonics) to a minimal sampling rate = 1,2 kS/s and for AC ($f = 60$ Hz, without harmonics) to a minimal sampling rate = 1,4 kS/s.

¹ Under preparation. Stage at the time of publication IEC ACD 61083-4:2020.

For a measurement of an AC signal with up to 7th harmonics and with an uncertainty U_{SR} of 0,3 %, N will be 284 samples per period. This leads for AC ($f = 50$ Hz) to a minimal sampling rate = 14,2 kS/s and for AC ($f = 60$ Hz) to a minimal sampling rate = 17,0 kS/s.

6.2.4 Rated resolution

The rated resolution required depends on the parameters to be measured and the required uncertainty (see Clause D.1).

6.2.5 Rise time (bandwidth)

The necessary rise time of a digital recording instrument depends on the uncertainty requirements (6.1) and this relates directly to the analogue bandwidth of the digital recording instrument. The rise time t_R shall not be more than $1/(18 \cdot f_{MAX})$ where f_{MAX} is the highest frequency contained in the signal to be measured with an uncertainty of not more than 1 %. For more information refer to Clause D.3.

6.2.6 Noise level

The internal noise level shall be < 0,1 % of the low end of the specified measurement range for normal use.

6.2.7 Interference

The digital recording instrument (or the digital recording instrument and a suitable screening arrangement) is considered to be suitable for the electromagnetic environment if it fulfils the following requirements for electromagnetic compatibility.

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 tests.

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

6.2.8 Non-linearity of amplitude

The dynamic integral non-linearity and the differential non-linearity, for both static and dynamic tests, shall be so that the requirements of 6.1 are achieved. A procedure to determine the non-linearity of amplitude is shown in Annex C.

NOTE The requirements of 6.1 might be achieved when the dynamic integral non-linearity is within $\pm 0,5$ % of full-scale deflection and the differential non-linearity is within $\pm 0,8$ w_0 .

6.2.9 Record length of digital recording instruments

The record length shall be sufficiently long to allow the required parameter to be evaluated or a specific phenomenon to be observed (see Clause D.1).

6.3 Requirements for digital recording instruments used in reference measuring systems

Reference digital recording instruments are used in reference measuring systems specified in IEC 60060-2 for the calibration of approved measuring systems by comparison measurements. The overall uncertainty of digital recording instruments used in a reference measuring system according to IEC 60060-2 shall not be more than (at a confidence level of not less than 95 %):

- 0,3 % in the voltage (current) measurement;
- 0,3 % in the frequency measurement (if applicable).

No other individual requirements are necessary. All requirements of 6.2 apply.

6.4 Tests

6.4.1 General

The tests required for digital recording instruments are shown in Table 2.

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

Table 2 – Tests required for digital recording instruments

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	Performance test	Performance check
Dynamic integral and differential non-linearity ^a	X		6.2.8		X			
Scale factor, linearity		5.5		6.2.2		X	X	X
Rise time (bandwidth)	X	5.6.2		6.2.5	X			
Internal noise level	X	5.6.3		6.2.6	X			
Interference (EMC)	X	5.6.4		6.2.7	X			
Reading rate ^a		5.6.5	X ^b		X			
^a If applicable.								
^b No special requirements are given in this document.								

6.4.2 Type tests

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

6.4.3 Routine tests

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

Routine tests shall also be carried out after repair or modification of the digital recording instruments.

6.4.4 Performance tests

Performance tests (calibration) shall be performed on each new digital recording instrument and be repeated once a year. The date and results of each performance test shall be recorded in the record of performance.

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

6.4.5 Performance checks

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

Performance checks shall be made for each setting of the digital recording instrument that is to be used in the tests.

7 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 recording instrument. 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 recording instrument as necessary contribution components.

Inclusion of uncertainties of an approved digital recording instrument as a component 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.

8 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) value of the maximum and minimum input voltage,
 - 7) input impedance,
 - 8) type 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 digital recording 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 like flashovers or breakdowns. While such events are normally not a concern of the actual measurement, it shall be ensured that the digital recording instruments can handle such stress.

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

A.2 Precautions

A.2.1 Electromagnetic shielding

Interference due to electromagnetic fields penetrating directly into the digital recording instrument may be reduced by placing the digital recording 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 digital recording instrument) which is required for real time recording or displaying of the signal, and the other open to allow access to the computer, plotter, and printer which operate after the recording.

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 digital recording 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 triaxial cable with the outer shield grounded at both input and digital recording 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 digital recording instrument on its maximum range, or by inserting an external attenuator between the receiving end of the cable and the digital recording instrument.