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BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 61000-4-11 has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-11 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second edition published in 2004 and Amendment 1:2017. This edition constitutes a technical revision.

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

a) rise time and fall time of transients are now defined terms in Clause 3;

b) the origin of voltage dips and short interruptions is now stated in Clause 4.

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

FDIS	Report on voting
77A/1039/FDIS	77A/1056/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 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of May 2020 have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

1 Scope

This part of IEC 61000 defines the immunity test methods and range of preferred test levels for electrical and electronic equipment connected to low-voltage power supply networks for voltage dips, short interruptions, and voltage variations.

This document applies to electrical and electronic equipment having a rated input current not exceeding 16 A per phase, for connection to 50 Hz or 60 Hz AC networks.

It does not apply to electrical and electronic equipment for connection to 400 Hz AC networks. Tests for these networks will be covered by future IEC documents.

The object of this document is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to voltage dips, short interruptions and voltage variations.

NOTE 1 Voltage fluctuation immunity tests are covered by IEC 61000-4-14.

The test method documented in this document describes a consistent method to assess the immunity of equipment or a system against a defined phenomenon.

NOTE 2 As described in IEC Guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and, if applied, they are responsible for defining the appropriate test levels. Technical committee 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

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 TR 61000-2-8, *Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*

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**~~
~~**basic EMC standard**~~
~~standard giving general and fundamental conditions or rules for the achievement of EMC, which are related or applicable to all products and systems and serve as reference documents for product committees~~

~~NOTE As determined by the Advisory Committee on Electromagnetic Compatibility (ACEC) – see IEC Guide 107.~~

3.1
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.2
voltage dip
sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval

Note 1 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 2 to entry: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.3
short interruption
sudden reduction of the voltage on all phases at a particular point of an electric supply system below a specified interruption threshold followed by its restoration after a brief interval

Note 1 to entry: Short interruptions are typically associated with switchgear operations related to the occurrence and termination of short circuits on the system or on installations connected to it.

3.4
residual voltage
<voltage dip> minimum value of RMS voltage recorded during a voltage dip or short interruption

Note 1 to entry: The residual voltage ~~may~~ can be expressed as a value in volts or as a percentage or per unit value relative to the reference voltage.

3.5
malfunction
~~the termination~~ breakdown of the ability of equipment to carry out intended functions or the execution of unintended functions by the equipment

3.6
calibration
method to prove that the measurement equipment is in compliance with its specifications

Note 1 to entry: For the purposes of this document, calibration is applied to the test generator.

3.7
verification
set of operations which are used to check the test equipment system (e.g. the test generator and the interconnecting cables) to demonstrate that the test system is functioning within the specifications given in Clause 6

Note 1 to entry: The methods used for verification ~~may~~ can be different from those used for calibration.

Note 2 to entry: The verification procedure of 6.1.~~2~~3 is meant as a guide to ensure the correct operation of the test generator and other items making up the test set-up so that the intended waveform is delivered to the EUT.

3.8
rise time
interval of time between the instants at which the instantaneous value of a transition first reaches a specified lower value and then a specified upper value

Note 1 to entry: The lower and upper values are fixed at 10 % and 90 % of the transition magnitude.

[SOURCE: IEC 60050-161:1990, 161-02-05]

3.9
fall time
interval of time between the instants at which the instantaneous value of a transition first reaches a specified upper value and then a specified lower value

Note 1 to entry: The lower and upper values are fixed at 10 % and 90 % of the transition magnitude.

Note 2 to entry: This definition is derived from IEC 60050-161:1990, 161-02-05.

4 General

Electrical and electronic equipment ~~may~~ can be affected by voltage dips, short interruptions or voltage variations of the power supply.

~~Voltage dips and short interruptions are caused by faults in the network, primarily short circuits (see also IEC 61000-2-8), in installations or by sudden large changes of load. In certain cases, two or more consecutive dips or interruptions may occur.~~ Voltage dips and short interruptions occur due to faults in a (public or non-public) network or in installations by sudden changes of large loads. In certain cases, two or more consecutive dips or interruptions can occur. Voltage variations are caused by continuously varying loads connected to the network.

These phenomena are random in nature and can be minimally characterized for the purpose of laboratory simulation in terms of the deviation from the rated voltage and duration.

Consequently, different types of tests are specified in this document to simulate the effects of abrupt voltage change. These tests are to be used only for particular and justified cases, under the responsibility of product specification or product committees.

It is the responsibility of the product committees to establish which phenomena among the ones considered in this document are relevant and to decide on the applicability of the test.

5 Test levels

5.1 General

The voltages in this document use the rated voltage for the equipment (U_T) as a basis for the voltage test level specification.

Where the equipment has a rated voltage range the following shall apply:

- if the voltage range does not exceed 20 % of the lower voltage specified for the rated voltage range, a single voltage within that range may be specified as a basis for the test level specification (U_T);
- in all other cases, the test procedure shall be applied for both the lowest and highest voltages declared in the voltage range;
- guidance for the selection of test levels and durations is given in IEC TR 61000-2-8.

5.2 Voltage dips and short interruptions

The change between U_T and the changed voltage is abrupt. The step can start and stop at any phase angle on the mains voltage. The following test voltage levels (in % U_T) are used: 0 %, 40 %, 70 % and 80 %, corresponding to dips with residual voltages of 0 %, 40 %, 70 % and 80 %.

For voltage dips, the preferred test levels and durations are given in Table 1, and an example is shown in Figure 1a) and Figure 1b).

For short interruptions, the preferred test levels and durations are given in Table 2, and an example is shown in Figure 2.

The rise and fall time are detailed in Figure 3.

The preferred test levels and durations given in Table 1 and Table 2 take into account the information given in IEC TR 61000-2-8.

The preferred test levels in Table 1 are reasonably severe, and are representative of many real world dips, but are not intended to guarantee immunity to all voltage dips. More severe dips, for example 0 % for 1 s and balanced three-phase dips, may be considered by product committees.

The generator specification for voltage rise time, t_r, and voltage fall time, t_f, during abrupt changes is indicated in Table 4.

The levels and durations shall be given in the product specification. A test level of 0 % corresponds to a total supply voltage interruption. In practice, a test voltage level from 0 % to 20 % of the rated voltage may be considered as a total interruption.

Shorter durations in Table 1, in particular the half-cycle, should be tested to ensure that the equipment under test (EUT) operates within the performance limits specified for it.

When setting performance criteria for disturbances of a half-period duration for products with a mains transformer, product committees should pay particular attention to effects which ~~may~~ can result from inrush currents. For such products, these ~~may~~ can reach 10 times to 40 times the rated current because of the magnetic flux saturation of the transformer core after the voltage dip.

High inrush currents can also occur in products with capacitors (e.g. EMC filters, bridge rectifiers connected to DC capacitors).

Table 1 – Preferred test levels and durations for voltage dips

Class[a]	Test levels and durations for voltage dips (t_s) (50 Hz/60 Hz)				
Class 1	Case-by-case according to the equipment requirements				
Class 2	0 % during ½ cycle	0 % during 1 cycle	70 % during 25/30[c] cycles		
Class 3	0 % during ½ cycle	0 % during 1 cycle	40 % during 10/12[c] cycles	70 % during 25/30[c] cycles	80 % during 250/300[c] cycles
Class X[b]	X	X	X	X	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels ~~must~~ shall not be less severe than class 2.

[c] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

Table 2 – Preferred test levels and durations for short interruptions

Class[a]	Test levels and durations for short interruptions (t_s) (50 Hz/60 Hz)
Class 1	Case-by-case according to the equipment requirements
Class 2	0 % during 250/300[c] cycles
Class 3	0 % during 250/300[c] cycles
Class X[b]	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels ~~must~~ shall not be less severe than class 2.

[c] "250/300 cycles" means "250 cycles for 50 Hz test" and "300 cycles for 60 Hz test".

5.3 Voltage variations (optional)

This test considers a defined transition between the rated voltage U_T and the changed voltage.

NOTE The voltage change takes place over a short period, and ~~may~~ can occur due to a change of load.

The preferred duration of the voltage changes and the time for which the reduced voltages are to be maintained are given in Table 3. The rate of change should be constant; however, the voltage may be stepped. The steps should be positioned at zero crossings, and should be no larger than 10 % of U_T. Steps under 1 % of U_T are considered as constant rates of change of voltage.

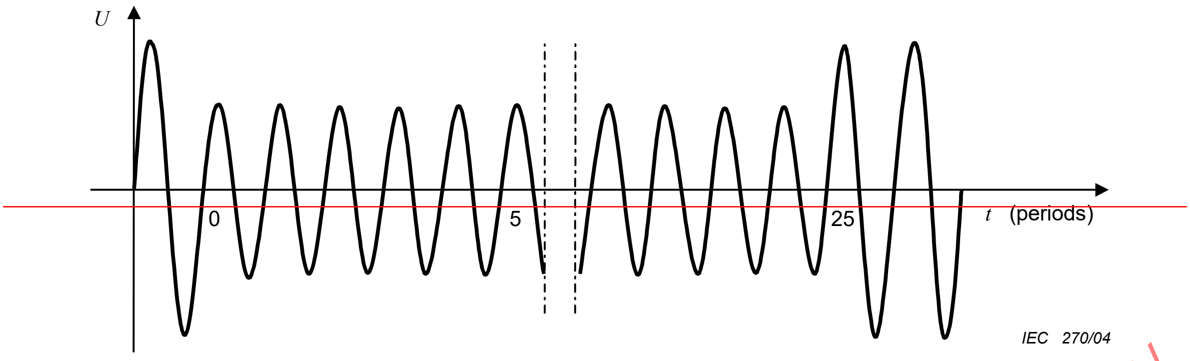
Table 3 – Timing of short-term supply voltage variations

Voltage test level	Time for decreasing voltage (t_d)	Time at reduced voltage(t_s)	Time for increasing voltage (t_i) (50 Hz/60 Hz)
70 %	Abrupt	1 cycle	25/30[b] cycles
X[a]	X[a]	X[a]	X[a]

[a] To be defined by product committee.

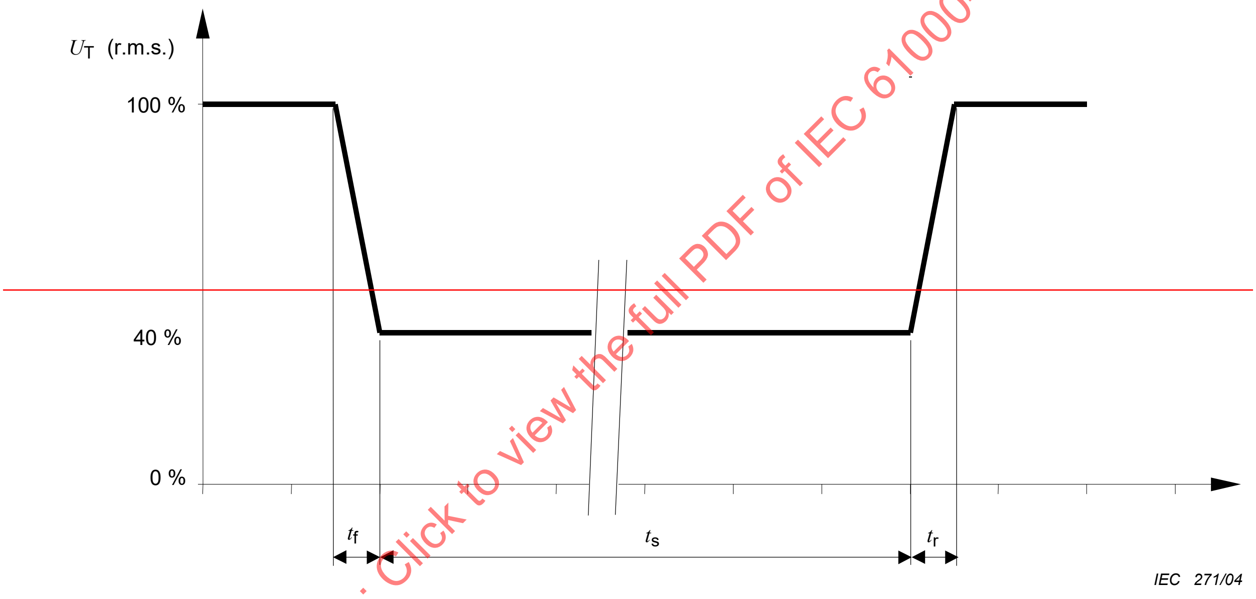
[b] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

This shape is the typical shape of a motor starting.



NOTE The voltage decreases to 70 % for 25 periods. Step at zero crossing.

Figure 1a) – Voltage dip – 70 % voltage dip sine wave graph



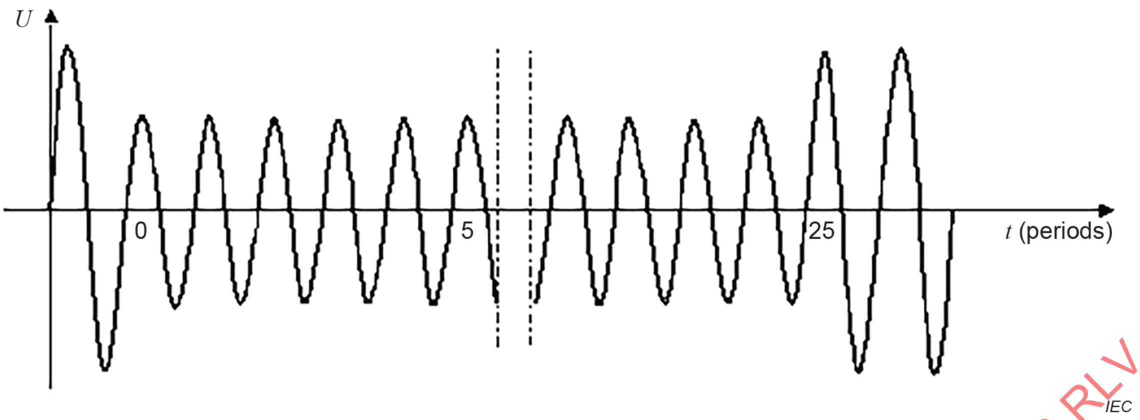
Key

t_r Voltage rising time

t_f Voltage fall time

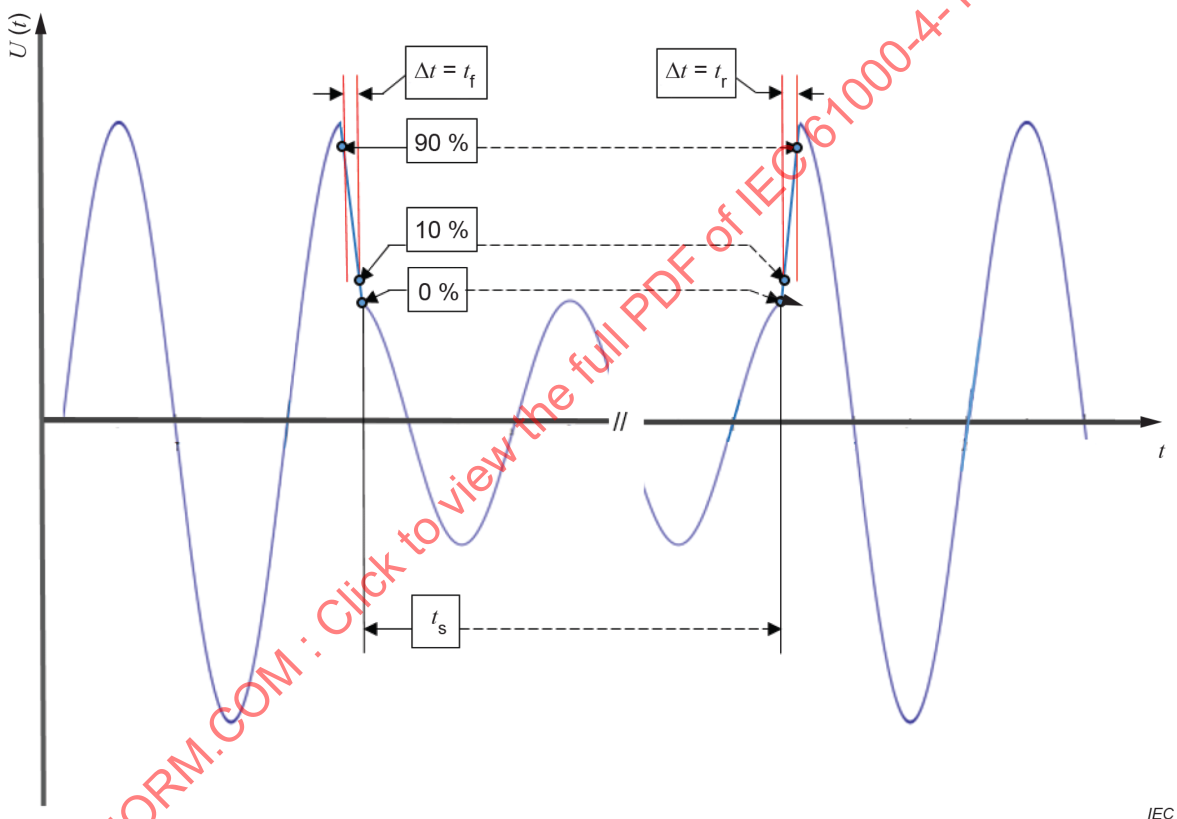
t_s Time at reduced voltage

Figure 1b) – Voltage dip – 40 % voltage dip r.m.s. graph



NOTE The voltage decreases to 70 % for 25 periods. Step at zero crossing.

a) Voltage dip: 70 % voltage dip sine wave graph at 0°



Key

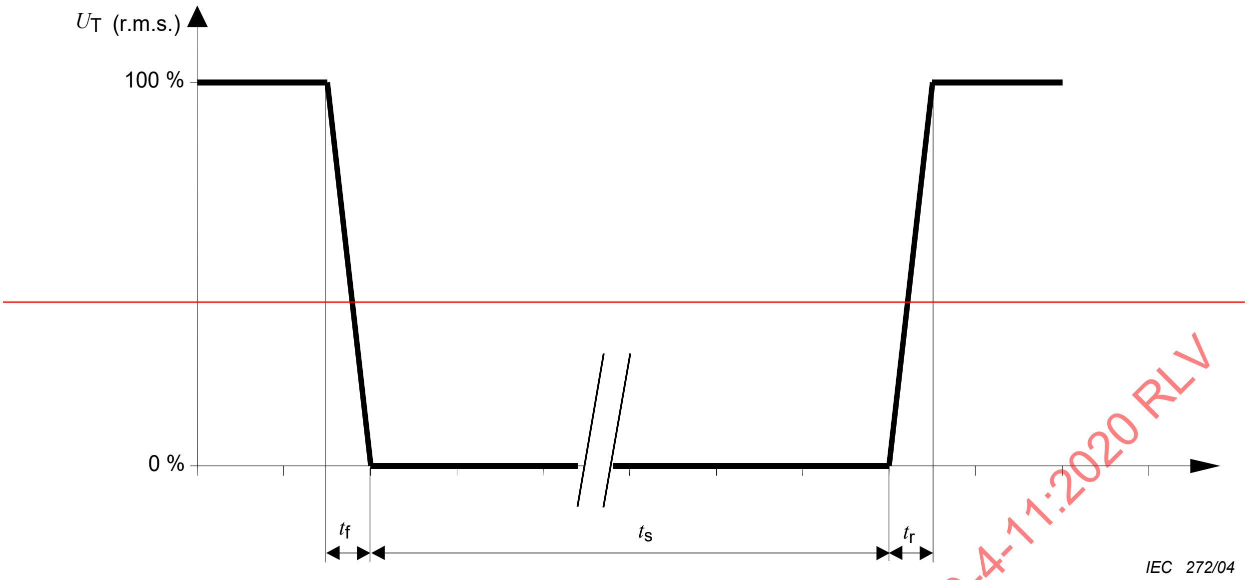
t_f fall time

t_r rise time

t_s duration of reduced voltage

b) Voltage dip: 40 % voltage dip sine wave graph at 90°

Figure 1 – Voltage dip - Examples

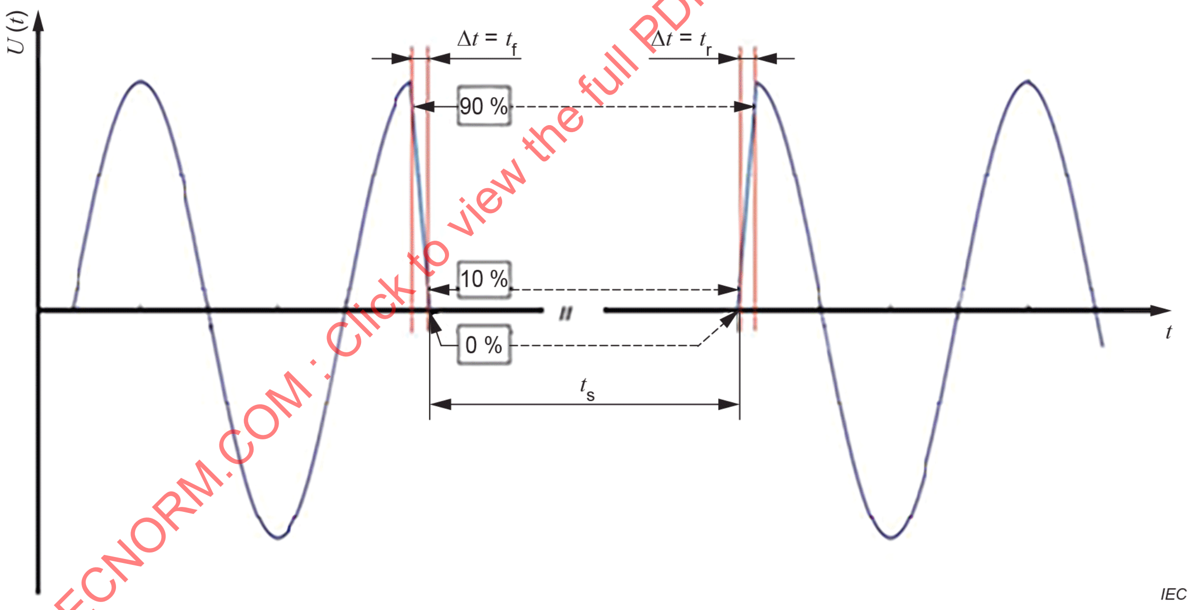


~~**Key**~~

~~t_r Voltage rising time~~

~~t_f Voltage fall time~~

~~t_s Time at reduced voltage~~



Key

t_f fall time

t_r rise time

t_s duration of reduced voltage

Figure 2 – Short interruption

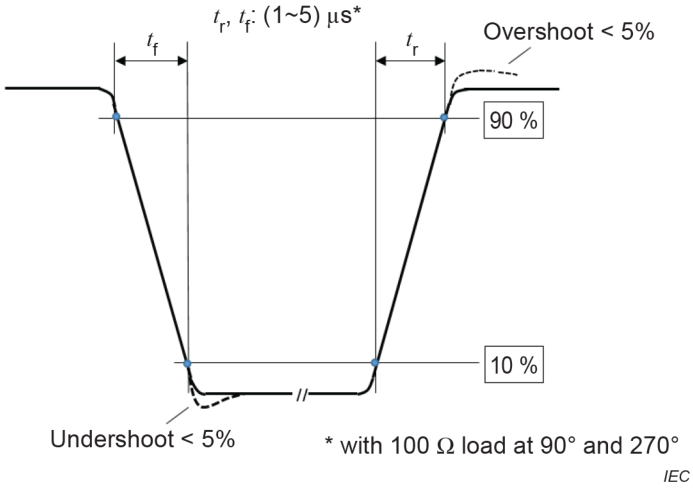
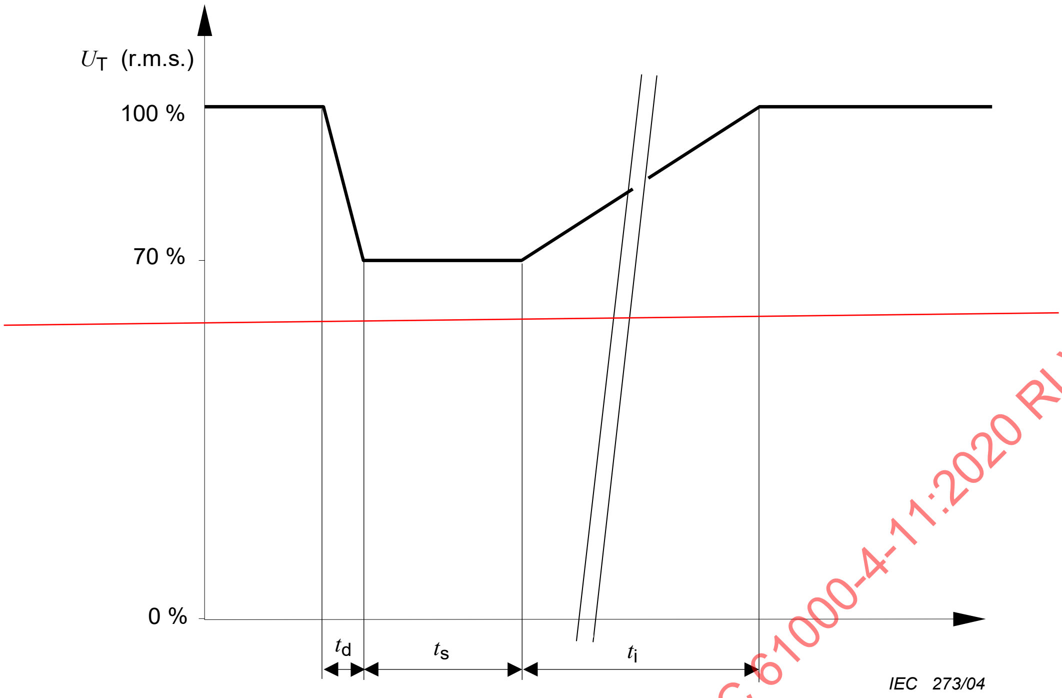
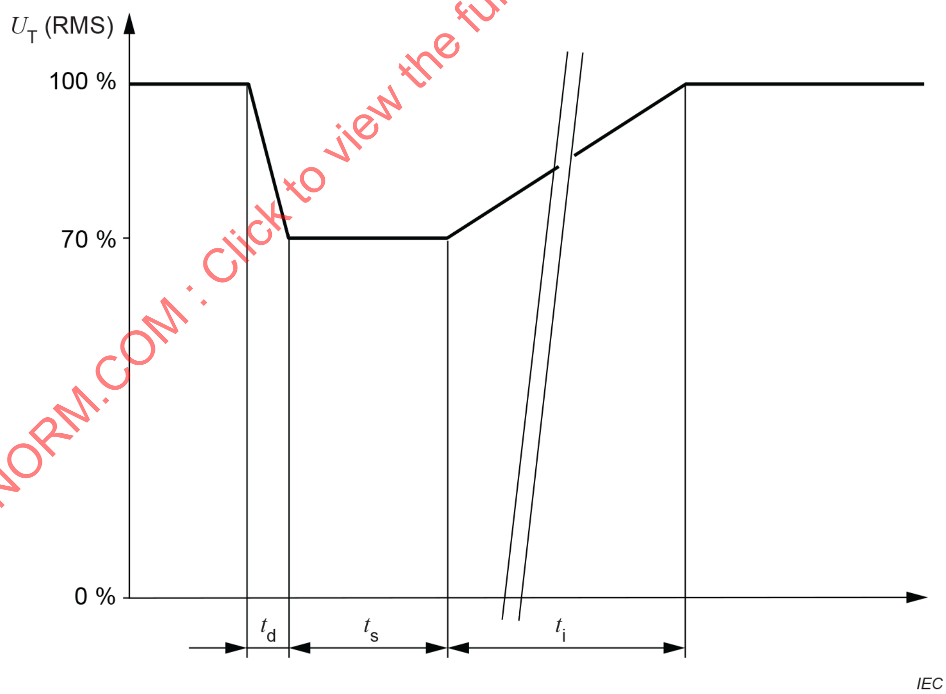


Figure 3 – Detailed view of rise and fall time

Figure 4 shows the RMS voltage as a function of time. Other values may be taken in justified cases and shall be specified by the product committee.



~~**Key**~~
~~t_d Time for decreasing voltage~~
~~t_i Time for increasing voltage~~
~~t_s Time at reduced voltage~~



Key

t_d Time for decreasing voltage

t_i Time for increasing voltage

t_s Time at reduced voltage

Figure 4 – Voltage variation

6 Test instrumentation

6.1 Test generator

6.1.1 General

The following features are common to the generator for voltage dips, short interruptions and voltage variations, except as indicated.

Examples of generators are given in Annex C.

The generator shall have provisions to prevent the emission of heavy disturbances, which, if injected in the power supply network, ~~may~~ can influence the test results.

Any generator creating a voltage dip of equal or more severe characteristics (amplitude and duration) than that ~~prescribed~~ specified by the present document is permitted.

6.1.2 Characteristics and performance of the generator

Table 4 – Generator specifications

Output voltage at no load	As required in Table 1, ±5 % of residual voltage value
Voltage change with load at the output of the generator	
100 % output, 0 A to 16 A	less than 5 % of U_T
80 % output, 0 A to 20 A	less than 5 % of U_T
70 % output, 0 A to 23 A	less than 5 % of U_T
40 % output, 0 A to 40 A	less than 5 % of U_T
Output current capability	16 A RMS per phase at rated voltage. The generator shall be capable of carrying 20 A at 80 % of rated value for a duration of 5 s. It shall be capable of carrying 23 A at 70 % of rated voltage and 40 A at 40 % of rated voltage for a duration of 3 s. (This requirement may be reduced according to the EUT's rated steady-state supply current, see Clause A.3.)
Peak inrush current capability (no requirement for voltage variation tests)	Not to be limited by the generator. However, the maximum peak capability of the generator need not exceed 1 000 A for 250 V to 600 V mains, 500 A for 200 V to 240 V mains, or 250 A for 100 V to 120 V mains.
Instantaneous peak overshoot/undershoot of the actual voltage, generator loaded with 100 Ω resistive load	Less than 5 % of U_T
Voltage rise (and fall) time t_r (and t_f), see Figure 1b), Figure 2 and Figure 3, during abrupt change, generator loaded with 100 Ω resistive load	Between 1 µs and 5 µs
Phase shifting (if necessary)	0° to 360°
Phase relationship of voltage dips and interruptions with the power frequency	Less than ±10 °
Zero crossing control of the generators	±10°

The output impedance shall be predominantly resistive.

The output impedance of the test voltage generator shall be low enough even during transitions ~~(for example, less than 0,4 + j0,25 Ω)~~.

~~NOTE 1~~ The 100 Ω resistive load used to test the generator should not have additional inductivity.

~~NOTE 2~~ To test equipment which regenerates energy, an external resistor connected in parallel to the load can be added. The test result ~~must~~ should not be influenced by this load.

6.1.3 Verification of the characteristics of the voltage dips, short interruptions generators

In order to compare the test results obtained from different test generators, the generator characteristics shall be verified according to the following:

- the 100 %, 80 %, 70 % and 40 % RMS output voltages of the generator shall conform to the percentages of the selected operating voltage: 230 V, 120 V, etc.;
- the 100 %, 80 %, 70 % and 40 % RMS output voltages of the generator shall be measured at no load, and shall be maintained within a specified percentage of the U_T;
- load regulation shall be verified at nominal load current at each of the output voltages and the variation shall not exceed 5 % of the nominal power supply voltage at 100 %, 80 %, 70 % and 40 % of the nominal power supply voltage.

For output voltage of 80 % of the nominal value, the above requirements need only be verified for a maximum of 5 s duration.

For output voltages of 70 % and 40 % of the nominal value, the above requirements need only be verified for a maximum of 3 s duration.

For output voltages of 40% of the nominal value it is acceptable to verify the load regulation requirements either at 200 V to 240 V nominal voltage or at 100 V to 120 V nominal voltage..

If it is necessary to verify the peak inrush drive current capability, the generator shall be switched from 0 % to 100 % of full output, when driving a load consisting of a suitable rectifier with an uncharged capacitor whose value is 1 700 μF on the DC side. The test shall be carried out at phase angles of both 90° and 270°. The circuit required to measure the generator inrush current drive capability is given in Figure A.1.

When it is believed that a generator with less than the specified standard generator peak inrush current ~~may~~ can be used because the EUT ~~may~~ can draw less than the specified standard generator peak inrush current (e.g., 500 A for 220 V to 240 V mains), this shall first be confirmed by measuring the EUT peak inrush current. When power is applied from the test generator, the measured EUT peak inrush current shall be less than 70 % of the peak current drive capability of the generator, as already verified according to Annex A. The actual EUT inrush current shall be measured both from a cold start and after a 5 s turn-off, using the procedure of Clause A.3.

Generator switching characteristics shall be measured with a 100 Ω load of suitable power-dissipation rating.

~~NOTE~~ The 100 Ω resistive load used to test the generator should not have additional inductivity.

Rise and fall time, as well as overshoot and undershoot, shall be verified for switching at both 90° and 270°, from 0 % to 100 %, 100 % to 80 %, 100 % to 70 %, 100 % to 40 %, and 100 % to 0 %.

Phase angle accuracy shall be verified for switching from 0 % to 100 % and 100 % to 0 %, at nine phase angles from 0° to 360° in 45° increments. It shall also be verified for switching from 100 % to 80 % and 80 % to 100 %, 100 % to 70 % and 70 % to 100 %, as well as from 100 % to 40 % and 40 % to 100 %, at 90° and 180°.

The voltage generators shall, preferably, be recalibrated at defined time periods in accordance with a recognized quality assurance system.

Annex D provides the rationale for generator specification regarding the voltage rise and fall time and the inrush current capability.

6.2 Power source

The frequency of the test voltage shall be within ±2 % of rated frequency.

7 Test set-up

The test shall be performed with the EUT connected to the test generator with the shortest power supply cable as specified by the EUT manufacturer. If no cable length is specified, it shall be the shortest possible length suitable to the application of the EUT.

The test set-ups for the three types of phenomena described in this document are:

- voltage dips;
- short interruptions;
- voltage variations with gradual transition between the rated voltage and the changed voltage (option).

Examples of test set-ups are given in Annex C.

Figure C.1a) shows a schematic for the generation of voltage dips, short interruptions and voltage variations with gradual transition between rated and changed voltage using a generator with internal switching. In Figure C.1b) a generator and a power amplifier are used.

Figure C.2 shows a schematic for the generation of voltage dips, short interruptions and voltage variations using a generator and a power amplifier for three-phase equipment.

8 Test procedures

8.1 General

Before starting the test of a given EUT, a test plan shall be prepared.

The test plan should be representative of the way the system is actually used.

Systems ~~may~~ can require a precise pre-analysis to define which system configurations ~~must~~ shall be tested to reproduce field situations.

Test cases ~~must~~ shall be explained and indicated in the test report.

It is recommended that the test plan include the following items:

- the type designation of the EUT;
- information on possible connections (plugs, terminals, etc.) and corresponding cables, and peripherals;
- input power port of equipment to be tested;
- representative operational modes of the EUT for the test;
- performance criteria used and defined in the technical specifications;
- operational mode(s) of equipment;

- description of the test set-up.

If the actual operating signal sources are not available to the EUT, they ~~may~~ can be simulated.

For each test, any degradation of performance shall be recorded. The monitoring equipment should be capable of displaying the status of the operational mode of the EUT during and after the tests. After each group of tests, a full functional check shall be performed.

8.2 Laboratory reference conditions

8.2.1 Climatic conditions

Unless otherwise specified by the committee responsible for the generic or product standard, the climatic conditions in the laboratory shall be within any limits specified for the operation of the EUT and the test equipment by their respective manufacturers.

Tests shall not be performed if the relative humidity is so high as to cause condensation on the EUT or the test equipment.

NOTE Where it is considered that there is sufficient evidence to demonstrate that the effects of the phenomenon covered by this document are influenced by climatic conditions, this ~~should be~~ is brought to the attention of the committee responsible for this document.

8.2.2 Electromagnetic conditions

The electromagnetic conditions of the laboratory shall be such as to guarantee the correct operation of the EUT in order not to influence the test results.

8.3 Execution of the test

8.3.1 General

During the tests, the mains voltage for testing shall be monitored within an accuracy of 2 %.

8.3.2 Voltage dips and short interruptions

The EUT shall be tested for each selected combination of test level and duration with a sequence of three dips/interruptions with intervals of 10 s minimum (between each test event). Each representative mode of operation shall be tested.

For voltage dips, changes in supply voltage shall occur at zero crossings of the voltage, and at additional angles considered critical by product committees or individual product specifications preferably selected from 45°, 90°, 135°, 180°, 225°, 270° and 315° on each phase.

For short interruptions, the angle shall be defined by the product committee as the worst case. In the absence of definition, it is recommended to use 0° for one of the phases.

For the short interruption test of three-phase systems, all the three phases shall be simultaneously tested according to 5.2.

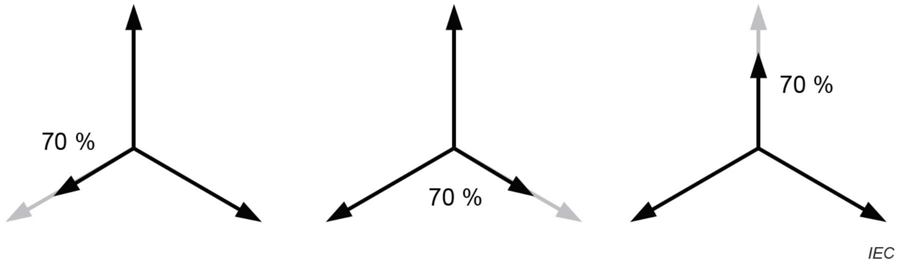
For the voltage dips test of single-phase systems, the voltage shall be tested according to 5.2. This implies one series of tests.

For the voltage dips test of three-phase systems with neutral, each individual voltage (phase-to-neutral and phase-to-phase) shall be tested, one at a time, according to 5.2. This implies six different series of tests. See Figure 5.

For the voltage dips test of three-phase systems without neutral, each phase-to-phase voltage shall be tested, one at a time, according to 5.2. This implies three different series of tests. See Figure 5b).

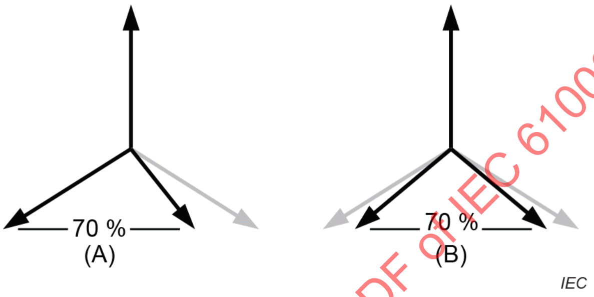
NOTE For three-phase systems, during a dip on a phase-to-phase voltage a change will occur on one or two of the other voltages as well.

For EUTs with more than one power cord, each power cord should be tested individually.



NOTE Phase-to-neutral testing on three-phase systems is performed one phase at a time.

a) Phase-to-neutral testing on three-phase systems



NOTE Phase-to-phase testing on three-phase systems is also performed one phase at a time. Both (A) and (B) show a 70 % dip. (A) is preferred, but (B) is also acceptable.

b) Phase-to-phase testing on three-phase systems

Figure 5 – Phase-to-neutral and phase-to-phase testing on three-phase systems

8.3.3 Voltage variations ~~(optional)~~

The EUT is tested to each of the specified voltage variations, three times at 10 s interval for the most representative modes of operations.

9 Evaluation of test results

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed between the manufacturer and the purchaser of the product. The recommended classification is as follows:

a) normal performance within limits specified by the manufacturer, requestor or purchaser;

b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;

c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;

d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which ~~may~~ can be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

NOTE The performance levels ~~may~~ can be different for voltage dip tests and short interruption tests as well as for voltage variations tests, if this optional test has been required.

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- the items specified in the test plan required by Clause 8;
- identification of the EUT and any associated equipment, for example brand name, product type, serial number;
- identification of the test equipment, for example brand name, product type, serial number;
- any special environmental conditions in which the test was performed, for example shielded enclosure;
- any specific conditions necessary to enable the test to be performed;
- performance level defined by the manufacturer, requestor or purchaser;
- performance criterion specified in the generic, product or product-family standard;
- any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;
- the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser);
- any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance.

Annex A
(normative)

Test circuit details

A.1 Test generator peak inrush current drive capability

The circuit for measuring generator peak inrush current drive capability is shown in Figure A.1. Use of the bridge rectifier makes it unnecessary to change rectifier polarity for tests at 270° versus 90°. The rectifier half-cycle mains current rating should be at least twice the generator's inrush current drive capability to provide a suitable operating safety factor.

The 1 700 µF electrolytic capacitor shall have a tolerance of ±20 %. It shall have a voltage rating preferably 15 % to 20 % in excess of the nominal peak voltage of the mains, for example 400 V for 220 V to 240 V mains. It shall also be able to accommodate peak inrush current up to at least twice the generator's inrush current drive capability, to provide an adequate operating safety factor. The capacitor shall have the lowest possible equivalent series resistance (ESR) at both 100 Hz and 20 kHz, not exceeding 0,1 Ω at either frequency.

Since the test shall be performed with the 1 700 µF capacitor discharged, a resistor shall be connected in parallel with it and several time constants (RC) ~~must~~ shall be allowed between tests. With a 10 000 Ω resistor, the RC time constant is 17 s, so that a wait of 1,5 min to 2 min should be used between inrush drive capability tests. Resistors as low as 100 Ω may be used when shorter wait times are desired.

The current probe shall be able to accommodate the full generator peak inrush current drive for one-quarter cycle without saturation.

Tests shall be run by switching the generator output from 0 % to 100 % at both 90° and 270°, to ensure sufficient peak inrush current drive capability for both polarities.

A.2 Current monitor's characteristics for measuring peak inrush current capability

Output voltage in 50 Ω load:	0,01 V/A or more
Peak current:	1 000 A minimum
Peak current accuracy:	± 10 % (3 ms duration pulse)
RMS current:	50 A minimum
$I \times T$ maximum:	10 A · s or more
Rise/fall time:	500 ns or less
Low-frequency 3 dB point:	10 Hz or less
Insertion resistor:	0,001 Ω or less

A.3 EUT peak inrush current requirement

When a generator peak inrush current drive capability meets the specified requirement (e.g., at least 500 A for a 220 V to 240 V mains), it is not necessary to measure the EUT's peak inrush current requirement.

However, a generator with less than this inrush current may be used for the test, if the inrush requirement of the EUT is less than the inrush drive capability of the generator. The circuit of Figure A.2 shows an example of how to measure the peak inrush current of an EUT to determine if it is less than the inrush drive capability of a low-inrush drive capability generator.

The circuit uses the same current transformer as the circuit of Figure A.1. Four peak inrush current tests are performed:

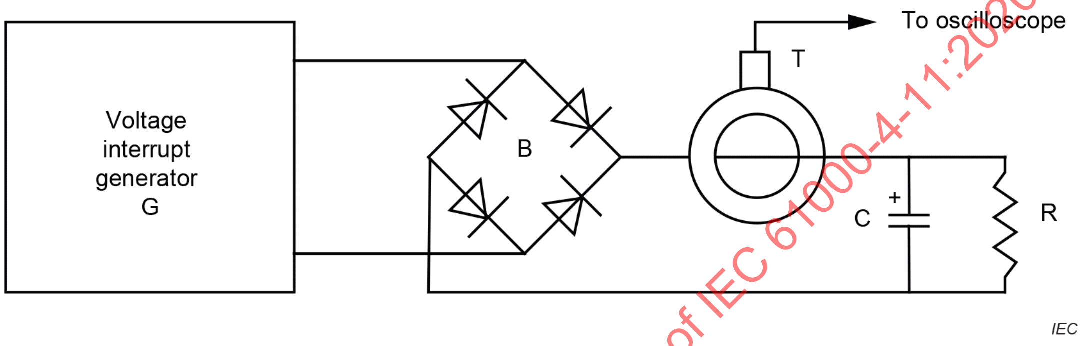
a) power off for at least 5 min; measure peak inrush current when it is turned back on at 90°;

b) repeat a) at 270°;

c) power on preferably for at least 1 min; off for 5 s; then measure peak inrush current when it is turned back on again at 90°;

d) repeat c) at 270°.

In order to be able to use a low-inrush drive current capability generator to test a particular EUT, that EUT's measured inrush current shall be less than 70 % of the measured inrush current drive capability of the generator.



Components

G voltage interrupt generator, switched on at 90° and 270°

T current probe, with monitoring output to oscilloscope

B rectifier bridge

R bleeder resistor, not over 10 000 Ω or less than 100 Ω

C 1 700 μF ± 20 % electrolytic capacitor

Figure A.1 – Circuit for determining the inrush current drive capability of the short interruptions generator

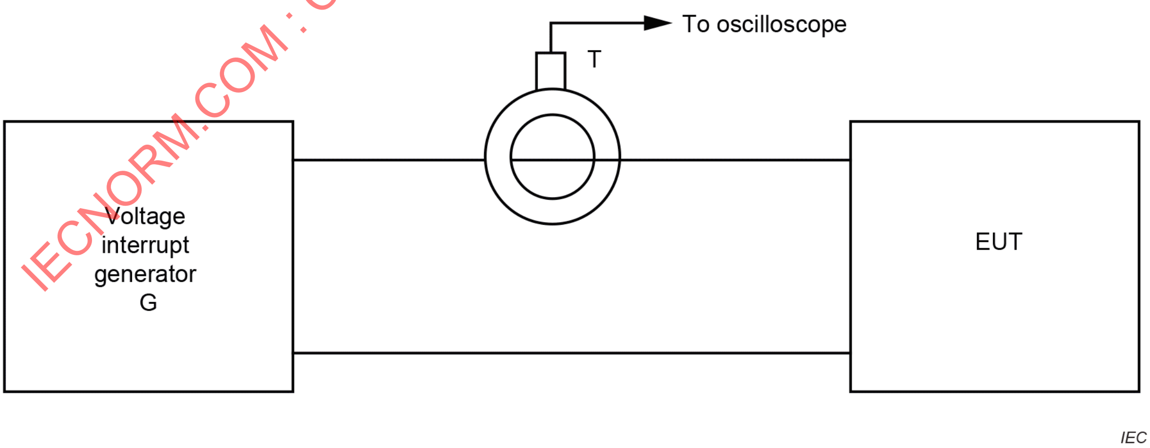


Figure A.2 – Circuit for determining the peak inrush current requirement of an EUT

Annex B
(informative)

Electromagnetic environment classes

~~B.1 Electromagnetic environment classes~~

The following ~~classes of~~ electromagnetic environment classes have been summarised from IEC 61000-2-4.

- **Class 1**

  This class applies to protected supplies and has compatibility levels lower than public network levels. It relates to the use of equipment very sensitive to disturbances in the power supply, for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.

  NOTE Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power supplies (UPS), filters, or surge suppressers.

- **Class 2**

  This class applies to points of common coupling (PCCs for consumer systems) and in-plant points of common coupling (IPCs) in the industrial environment in general. The compatibility levels in this class are identical to those of public networks; therefore components designed for application in public networks may be used in this class of industrial environment.

- **Class 3**

  This class applies only to IPCs in industrial environments. It has higher compatibility levels than those of class 2 for some disturbance phenomena. For instance, this class should be considered when any of the following conditions are met:

  – a major part of the load is fed through converters;

  – welding machines are present;

  – large motors are frequently started;

  – loads vary rapidly.

  ~~NOTE 1~~ The supply to highly disturbing loads, such as arc-furnaces and large converters which are generally supplied from a segregated bus-bar, frequently has disturbance levels in excess of class 3 (harsh environment). In such special situations, the compatibility levels should be agreed upon.

  ~~NOTE 2~~ The class applicable for new plants and extensions of existing plants should relate to the type of equipment and process under consideration.

Annex C
(informative)

Test instrumentation

~~C.1 Examples of generators and test set-ups~~

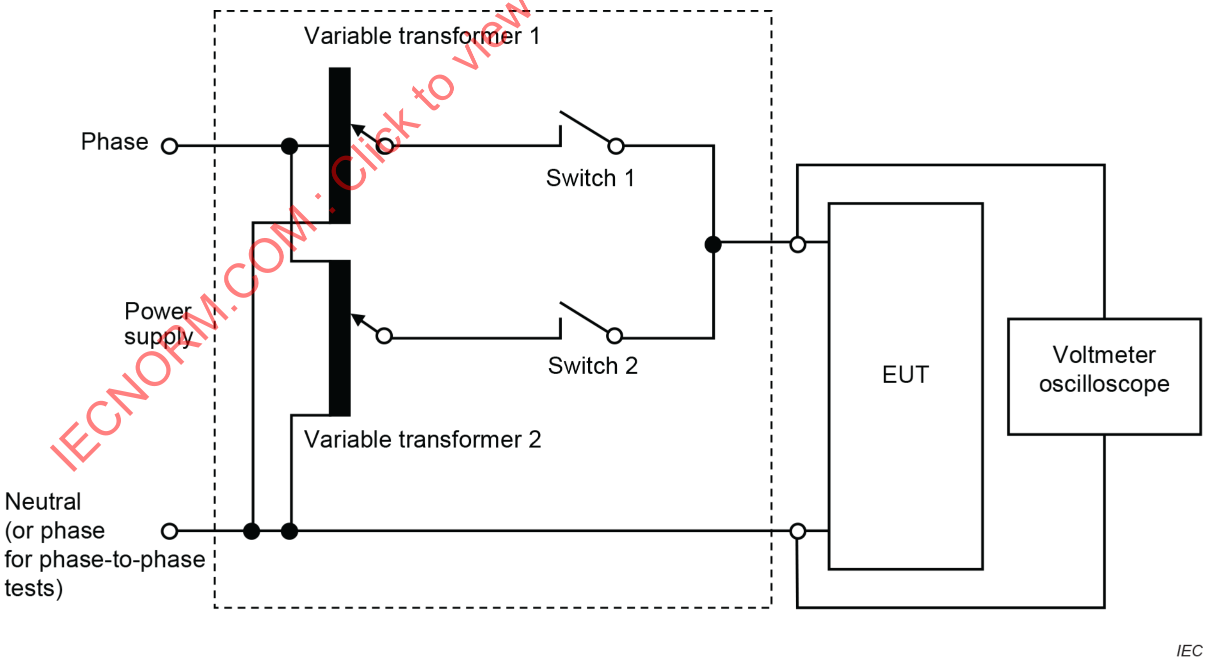
Figure C.1a) and Figure C.1b) show two possible test configurations for mains supply simulation. To show the behaviour of the EUT under certain conditions, interruptions and voltage variations are simulated by means of two transformers with variable output voltages.

Voltage drops, rises and interruptions are simulated by alternately closing switch 1 and switch 2. These two switches are never closed at the same time and an interval up to 100 µs with the two switches opened is acceptable. It shall be possible to open and close the switches independently of the phase angle. Semiconductors switches constructed with power MOSFETs and IGBTs can fulfil this requirement. Thyristors and triacs open during current zero crossing, and therefore do not meet this requirement.

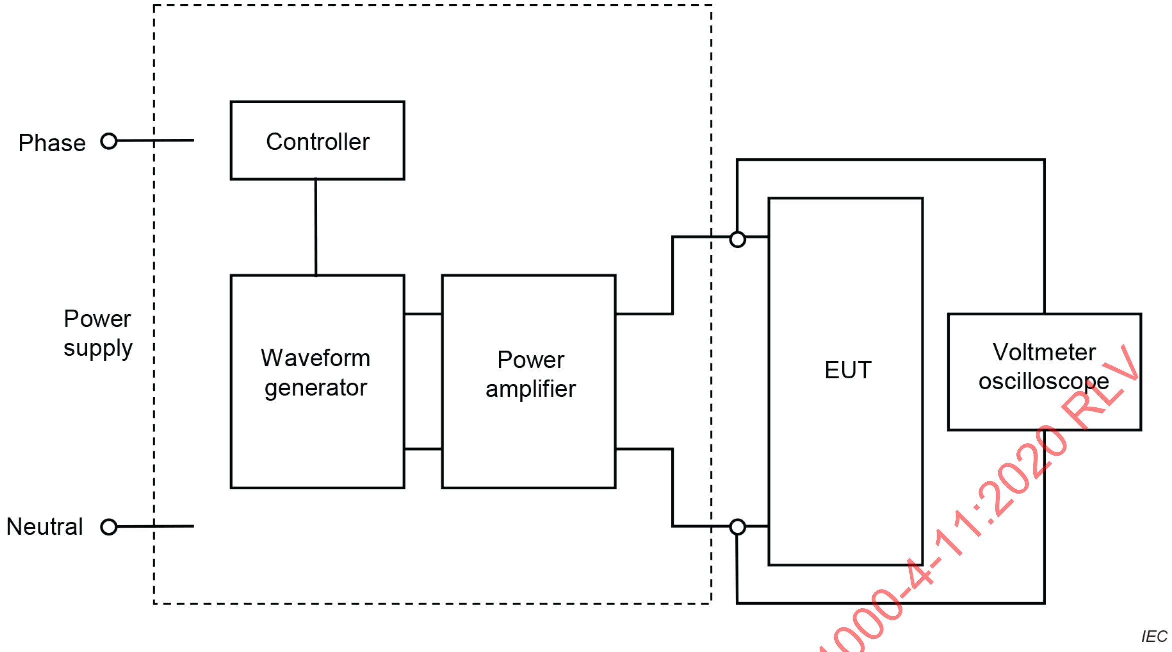
The output voltage of the variable transformers can either be adjusted manually or automatically by means of a motor. Alternatively, an autotransformer with multiple switch-selected taps may be used.

Waveform generators and power amplifiers can be used instead of variable transformers and switches (see Figure C.1b)). This configuration also allows testing of the EUT in the context of frequency variations and harmonics.

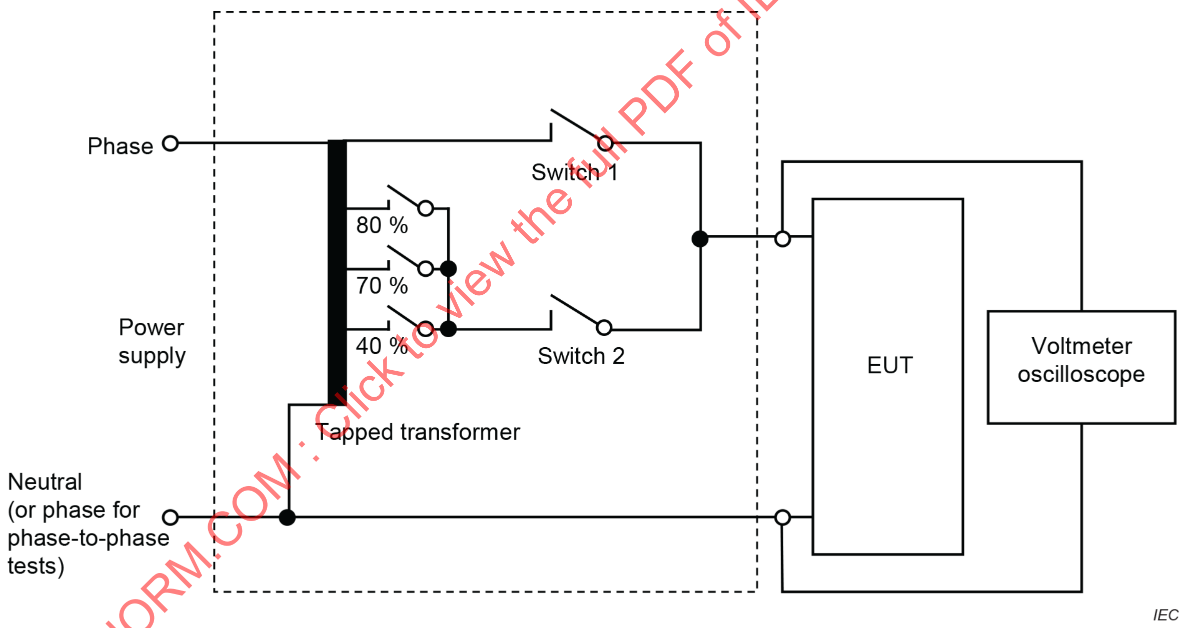
The generators described for single-phase testing (see Figure C.1a), Figure C.1b) and Figure C.1c)) can be also used for three-phase testing (see Figure C.2).



a) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using variable transformers and switches



b) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using a power amplifier



c) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using a tapped transformer and switches

Figure C.1 – Schematics of test instrumentation for voltage dips, short interruptions and voltage variations

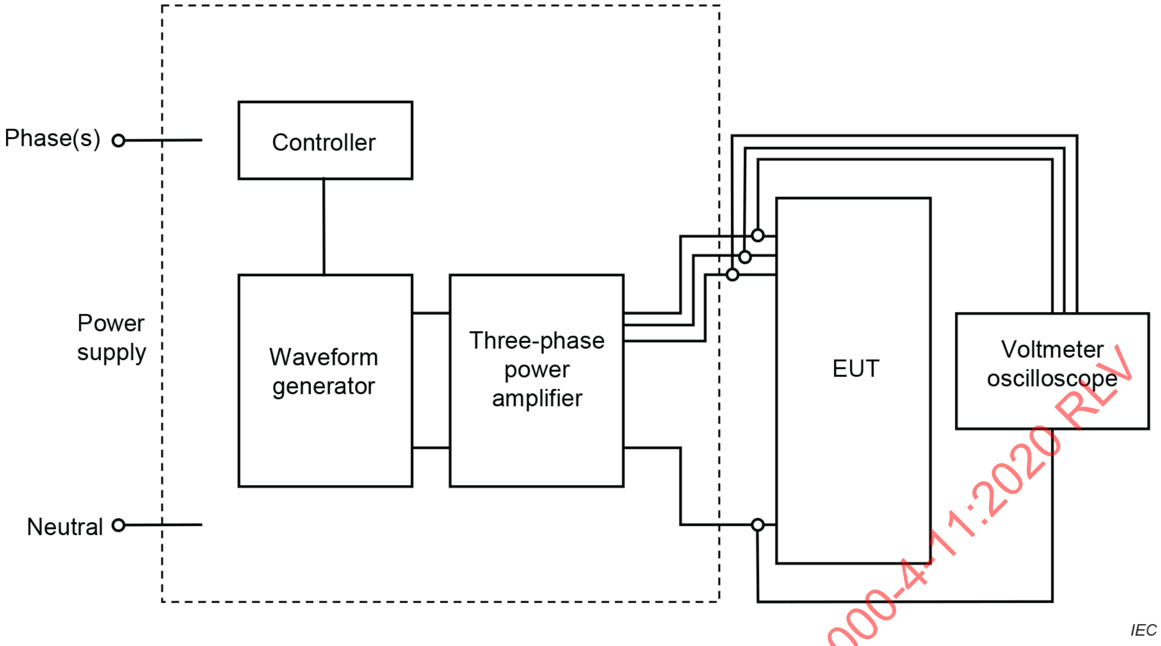


Figure C.2 – Schematic of test instrumentation for three-phase voltage dips, short interruptions and voltage variations using a power amplifier

Annex D
(informative)

Rationale for generator specification regarding voltage, rise-time and fall-time, and inrush current capability

D.1 Concept of basic standard

The immunity basic standards of the IEC 61000-4 series are based on the concept of defining a test system in one document representing typically one type of electromagnetic disturbance. The environmental description of the IEC 61000-2 series (which includes also compatibility levels), together with practical industry experience, is the basis for defining the disturbance source simulator, the necessary coupling and decoupling networks and the range of test levels.

Parameters in the basic standard are always compromises selected from a large amount of data derived from the disturbance source. The compromise is assumed to be correct if, once the immunity test is applied, only a few malfunctions occur in the real world.

To keep the immunity test as easy as possible, the generator output shall be verified in a calibration set-up and not with the EUT connected to the output of the generator. The purpose of the calibration is to guarantee comparable test results between different brands of generators.

D.2 IEC 61000-4-11:1994 (first edition)

Data from the UNIPEDE report was used which indicated short circuit in terms of voltage reduction and interruption duration. At that time, rare measurement results were available showing how equipment on the same phase was affected, in the public power network.

Based on this information, IEC 61000-4-11:1994 (first edition) was defined and published in 1994. For the switching time a value of 1 µs to 5 µs was chosen for representing the short circuit's worst case occurring at a distance of up to 50 m between the source and the affected equipment. For example, the equipment used in a laboratory or in an industrial plant has a greater risk of being affected by voltage dips and short interruptions within 50 m.

D.3 Rationale for the need of rapid fall-times

In case of short circuit in the line, the voltage at the input terminals of the equipment might go to zero in less than 5 µs.

If the short circuit originates from the public network, the fall-time will be relatively slow, in the order of hundreds of microseconds to some milliseconds. If, however, the short circuit is at the local premise, for example due to the failure of another equipment installed in close proximity, the mains voltage will go to zero within microseconds, with fall-times shorter than 1 µs reported for some cases.

In this case, the input rectifier diodes of the equipment will be commutated from conduction mode to blocking mode with a sudden high reverse voltage due to that very fast voltage rise-time. As those diodes are usually designed for natural line commutation with a rise-time of the voltage in the range of milliseconds, this event is an increased stress for the rectifier diodes. More generally, fast voltage transients can disturb electronics as well, leading to the damage of the equipment.

Tests performed with a fast fall-time in the range of a few microseconds emulating the short circuit condition can be used to test the robustness of equipment against fast transient short circuits of the line.

D.4 Interpretation of the rise-time and fall-time requirements during EUT testing

In 2010 an interpretation sheet for IEC 61000-4-11:2004 (second edition) was issued. The content of this sheet is as follows:

1) "In IEC 61000-4-11:2004, Table 4 does not apply to EUT (equipment under test) testing. Table 4 is for generator calibration and design only.
2) With reference to Table 1 and Table 2, there is no requirement in 61000-4-11:2004 for rise-time and fall-time when testing EUT; therefore, it is not necessary to measure these parameters during tests.
3) With reference to Table 4, all of the requirements apply to design and calibration of the generator. The requirements of Table 4 only apply when the load is a non-inductive 100 Ω resistor. The requirements of Table 4 do not apply during EUT testing."

D.5 Main conclusions

With respect to rise-time and fall-time, the main conclusions are the following:

- It is possible, for real-world voltage dips, to have fall-times faster than 5 µs in the case of short circuits close to the equipment. However, for the time being, this document does not consider the effects of voltage fall times shorter than 1 µs.
- Rise-time depends on several factors including the impedance of the network, cabling and equipment connected in parallel.
- The rise-time and fall-time requirements have remained unchanged and the document has been used worldwide since its first publication in 1994, but, as in the interpretation sheet, these rise-time and fall-time requirements do not apply during a test of an EUT. They only apply when calibrating a dip generator with a 100 Ω resistive load. These rise-times and fall-times do not necessarily occur during an actual EUT test.
- Most voltage dip and short interruption immunity tests begin and end at 0° or 180°. Published research generally concludes that these are the most severe phase angles for voltage ride-through tests. Note that at 0° and at 180° the instantaneous waveform voltage is zero, so rise-time and fall-time have no meaning.
- Pre-compliance testing could be considered using a dip generator with a longer rise-time and fall-time up to 200 µs for voltage dip and short interruption tests that begin and end at 0° or 180°, as rise-time and fall-time are not important at these angles. However, full compliance with the test methods of this document requires to use a generator that, when tested with a 100 Ω resistive load, meets the 1 µs to 5 µs requirement in 6.1.3.

D.6 Rationale for inrush current capability

During the connection of an equipment to a power line, an inrush current flows into it. This inrush current could conceivably damage parts of the equipment, for example an input rectifier with capacitive smoothing. In order to prevent damage, measures for inrush current limitation are usually incorporated inside the equipment.

An inrush current will also occur when the line voltage recovers after a voltage dip or interruption. In this case, the inrush current limitation measures might not be activated in the equipment with disabled pre-charge circuit, so it is possible for the post-dip inrush current to damage the equipment.

For this reason, it is necessary for the voltage dip generator to be capable of supplying sufficient current and that the post-dip inrush current is not limited by the dip generator.

Without this inrush current requirement, it would be possible for the equipment to pass the immunity test performed with the dip generator, but to fail in the real world due to inrush current damage.

In a real installation, this inrush current will be limited by the network impedance. If the short circuit is on the public supply, the network impedance is according to the line reference impedance of the public supply (796 µH according to IEC TR 60725), which is typical for rural low voltage networks, and it will limit the inrush current to about 15 A to 20 A. However, if the short circuit is inside the local premise, in a particular large installation such as an industrial plant, the impedance can be much lower and the inrush current much larger.

In order for the test generator to have adequate capabilities to properly stress the equipment under test, the document provides guidance in 6.1.3 to ensure that the equipment does not demand more current than 70 % of the generator capability, for example 500 A for 220 V to 240 V mains.

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1 This publication has been withdrawn.

2 An interpretation sheet was issued by IEC SC 77A for IEC 61000-4-11 in August 2010.

IEC 61000-4-11

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Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension pour les appareils à courant d'entrée inférieur ou égal à 16 A par phase

IEC 61000-4-11:2020-01(en-fr)

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-11: Testing and measurement techniques –
Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

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International Standard IEC 61000-4-11 has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-11 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second edition published in 2004 and Amendment 1:2017. This edition constitutes a technical revision.

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

a) rise time and fall time of transients are now defined terms in Clause 3;
b) the origin of voltage dips and short interruptions is now stated in Clause 4.

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

FDIS	Report on voting
77A/1039/FDIS	77A/1056/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 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of May 2020 have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

1 Scope

This part of IEC 61000 defines the immunity test methods and range of preferred test levels for electrical and electronic equipment connected to low-voltage power supply networks for voltage dips, short interruptions, and voltage variations.

This document applies to electrical and electronic equipment having a rated input current not exceeding 16 A per phase, for connection to 50 Hz or 60 Hz AC networks.

It does not apply to electrical and electronic equipment for connection to 400 Hz AC networks. Tests for these networks will be covered by future IEC documents.

The object of this document is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to voltage dips, short interruptions and voltage variations.

NOTE 1 Voltage fluctuation immunity tests are covered by IEC 61000-4-14.

The test method documented in this document describes a consistent method to assess the immunity of equipment or a system against a defined phenomenon.

NOTE 2 As described in IEC Guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and, if applied, they are responsible for defining the appropriate test levels. Technical committee 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

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 TR 61000-2-8, *Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*

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
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.2
voltage dip
sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval

Note 1 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 2 to entry: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.3
short interruption
sudden reduction of the voltage on all phases at a particular point of an electric supply system below a specified interruption threshold followed by its restoration after a brief interval

Note 1 to entry: Short interruptions are typically associated with switchgear operations related to the occurrence and termination of short circuits on the system or on installations connected to it.

3.4
residual voltage
<voltage dip> minimum value of RMS voltage recorded during a voltage dip or short interruption

Note 1 to entry: The residual voltage can be expressed as a value in volts or as a percentage or per unit value relative to the reference voltage.

3.5
malfunction
breakdown of the ability of equipment to carry out intended functions or the execution of unintended functions by the equipment

3.6
calibration
method to prove that the measurement equipment is in compliance with its specifications

Note 1 to entry: For the purposes of this document, calibration is applied to the test generator.

3.7
verification
set of operations which are used to check the test equipment system (e.g. the test generator and the interconnecting cables) to demonstrate that the test system is functioning within the specifications given in Clause 6

Note 1 to entry: The methods used for verification can be different from those used for calibration.

Note 2 to entry: The verification procedure of 6.1.3 is meant as a guide to ensure the correct operation of the test generator and other items making up the test set-up so that the intended waveform is delivered to the EUT.

3.8
rise time
interval of time between the instants at which the instantaneous value of a transition first reaches a specified lower value and then a specified upper value

Note 1 to entry: The lower and upper values are fixed at 10 % and 90 % of the transition magnitude.

[SOURCE: IEC 60050-161:1990, 161-02-05]

3.9
fall time
interval of time between the instants at which the instantaneous value of a transition first reaches a specified upper value and then a specified lower value

Note 1 to entry: The lower and upper values are fixed at 10 % and 90 % of the transition magnitude.

Note 2 to entry: This definition is derived from IEC 60050-161:1990, 161-02-05.

4 General

Electrical and electronic equipment can be affected by voltage dips, short interruptions or voltage variations of the power supply.

Voltage dips and short interruptions occur due to faults in a (public or non-public) network or in installations by sudden changes of large loads. In certain cases, two or more consecutive dips or interruptions can occur. Voltage variations are caused by continuously varying loads connected to the network.

These phenomena are random in nature and can be minimally characterized for the purpose of laboratory simulation in terms of the deviation from the rated voltage and duration.

Consequently, different types of tests are specified in this document to simulate the effects of abrupt voltage change. These tests are to be used only for particular and justified cases, under the responsibility of product specification or product committees.

It is the responsibility of the product committees to establish which phenomena among the ones considered in this document are relevant and to decide on the applicability of the test.

5 Test levels

5.1 General

The voltages in this document use the rated voltage for the equipment (U_T) as a basis for the voltage test level specification.

Where the equipment has a rated voltage range the following shall apply:

- if the voltage range does not exceed 20 % of the lower voltage specified for the rated voltage range, a single voltage within that range may be specified as a basis for the test level specification (U_T);
- in all other cases, the test procedure shall be applied for both the lowest and highest voltages declared in the voltage range;
- guidance for the selection of test levels and durations is given in IEC TR 61000-2-8.

5.2 Voltage dips and short interruptions

The change between U_T and the changed voltage is abrupt. The step can start and stop at any phase angle on the mains voltage. The following test voltage levels (in % U_T) are used: 0 %, 40 %, 70 % and 80 %, corresponding to dips with residual voltages of 0 %, 40 %, 70 % and 80 %.

For voltage dips, the preferred test levels and durations are given in Table 1, and an example is shown in Figure 1a) and Figure 1b).

For short interruptions, the preferred test levels and durations are given in Table 2, and an example is shown in Figure 2.

The rise and fall time are detailed in Figure 3.

The preferred test levels and durations given in Table 1 and Table 2 take into account the information given in IEC TR 61000-2-8.

The preferred test levels in Table 1 are reasonably severe, and are representative of many real world dips, but are not intended to guarantee immunity to all voltage dips. More severe dips, for example 0 % for 1 s and balanced three-phase dips, may be considered by product committees.

The generator specification for voltage rise time, t_r, and voltage fall time, t_f, during abrupt changes is indicated in Table 4.

The levels and durations shall be given in the product specification. A test level of 0 % corresponds to a total supply voltage interruption. In practice, a test voltage level from 0 % to 20 % of the rated voltage may be considered as a total interruption.

Shorter durations in Table 1, in particular the half-cycle, should be tested to ensure that the equipment under test (EUT) operates within the performance limits specified for it.

When setting performance criteria for disturbances of a half-period duration for products with a mains transformer, product committees should pay particular attention to effects which can result from inrush currents. For such products, these can reach 10 times to 40 times the rated current because of the magnetic flux saturation of the transformer core after the voltage dip.

High inrush currents can also occur in products with capacitors (e.g. EMC filters, bridge rectifiers connected to DC capacitors).

Table 1 – Preferred test levels and durations for voltage dips

Class[a]	**Test levels and durations for voltage dips (t_s) (50 Hz/60 Hz)**				
Class 1	Case-by-case according to the equipment requirements				
Class 2	0 % during ½ cycle	0 % during 1 cycle	70 % during 25/30[c] cycles		
Class 3	0 % during ½ cycle	0 % during 1 cycle	40 % during 10/12[c] cycles	70 % during 25/30[c] cycles	80 % during 250/300[c] cycles
Class X[b]	X	X	X	X	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels shall not be less severe than class 2.

[c] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

Table 2 – Preferred test levels and durations for short interruptions

Class[a]	Test levels and durations for short interruptions (t_s) (50 Hz/60 Hz)
Class 1	Case-by-case according to the equipment requirements
Class 2	0 % during 250/300[c] cycles
Class 3	0 % during 250/300[c] cycles
Class X[b]	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels shall not be less severe than class 2.

[c] "250/300 cycles" means "250 cycles for 50 Hz test" and "300 cycles for 60 Hz test".

5.3 Voltage variations (optional)

This test considers a defined transition between the rated voltage U_T and the changed voltage.

NOTE The voltage change takes place over a short period, and can occur due to a change of load.

The preferred duration of the voltage changes and the time for which the reduced voltages are to be maintained are given in Table 3. The rate of change should be constant; however, the voltage may be stepped. The steps should be positioned at zero crossings, and should be no larger than 10 % of U_T. Steps under 1 % of U_T are considered as constant rates of change of voltage.

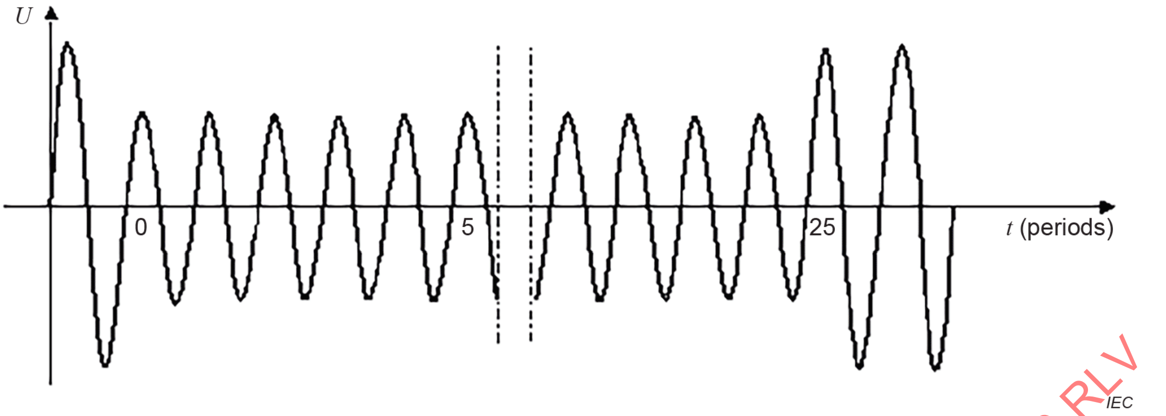
Table 3 – Timing of short-term supply voltage variations

Voltage test level	Time for decreasing voltage (t_d)	Time at reduced voltage(t_s)	Time for increasing voltage (t_i) (50 Hz/60 Hz)
70 %	Abrupt	1 cycle	25/30[b] cycles
X[a]	X[a]	X[a]	X[a]

[a] To be defined by product committee.

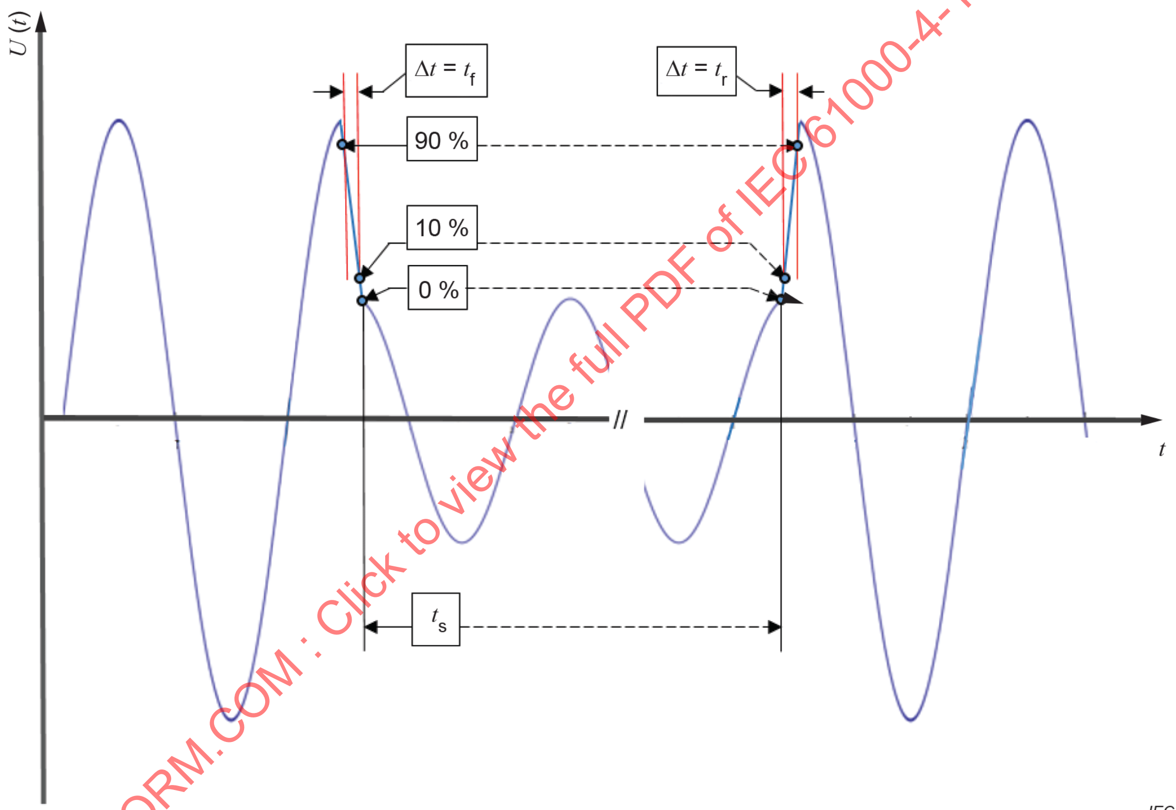
[b] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

This shape is the typical shape of a motor starting.



NOTE The voltage decreases to 70 % for 25 periods. Step at zero crossing.

a) Voltage dip: 70 % voltage dip sine wave graph at 0°



Key

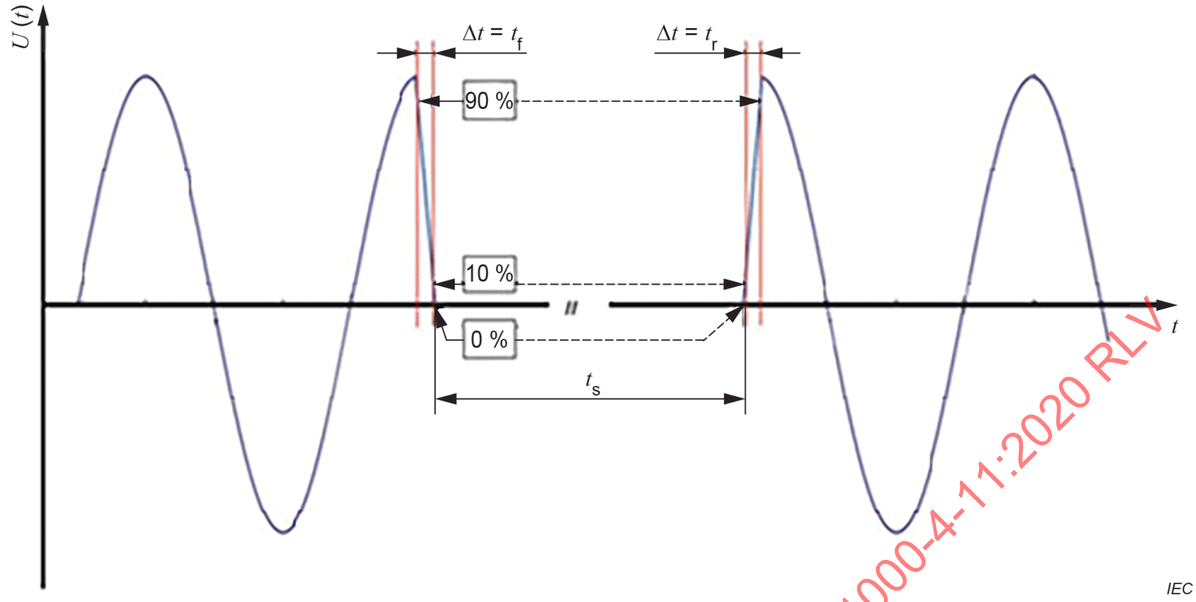
t_f fall time

t_r rise time

t_s duration of reduced voltage

b) Voltage dip: 40 % voltage dip sine wave graph at 90°

Figure 1 – Voltage dip – Examples



Key

t_f fall time

t_r rise time

t_s duration of reduced voltage

Figure 2 – Short interruption

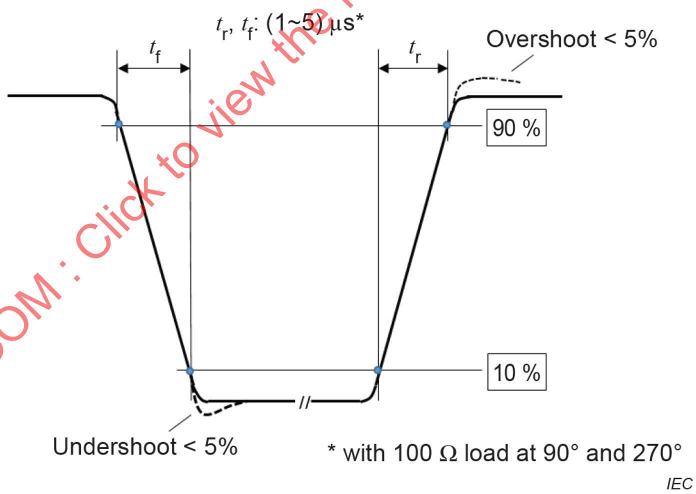
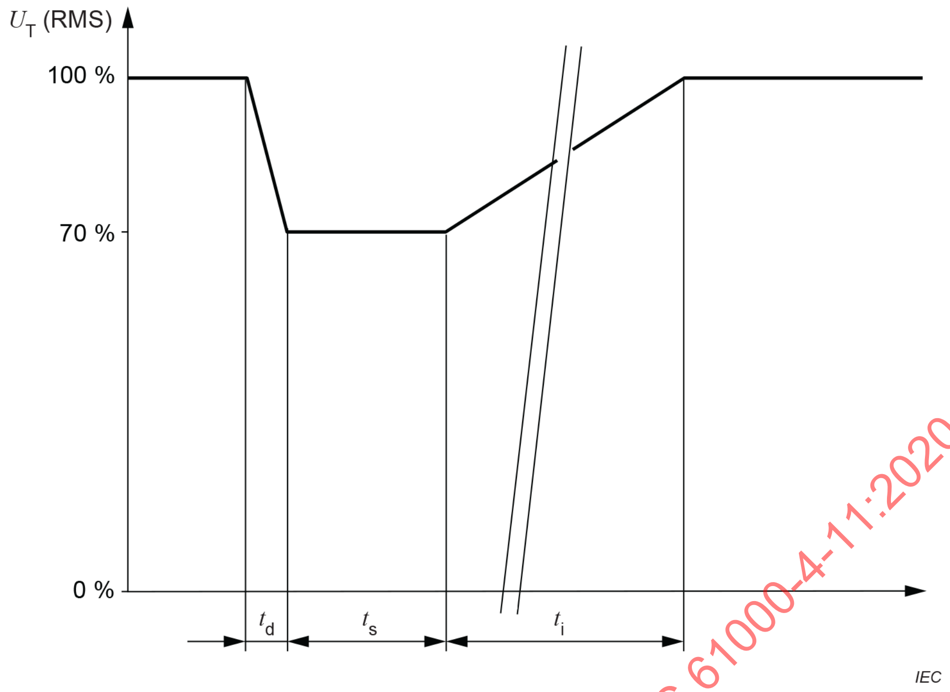


Figure 3 – Detailed view of rise and fall time

Figure 4 shows the RMS voltage as a function of time. Other values may be taken in justified cases and shall be specified by the product committee.



Key

t_d Time for decreasing voltage

t_i Time for increasing voltage

t_s Time at reduced voltage

Figure 4 – Voltage variation

6 Test instrumentation

6.1 Test generator

6.1.1 General

The following features are common to the generator for voltage dips, short interruptions and voltage variations, except as indicated.

Examples of generators are given in Annex C.

The generator shall have provisions to prevent the emission of heavy disturbances, which, if injected in the power supply network, can influence the test results.

Any generator creating a voltage dip of equal or more severe characteristics (amplitude and duration) than that specified by the present document is permitted.

6.1.2 Characteristics and performance of the generator

Table 4 – Generator specifications

Output voltage at no load	As required in Table 1, ±5 % of residual voltage value
Voltage change with load at the output of the generator	
100 % output, 0 A to 16 A	less than 5 % of U_T
80 % output, 0 A to 20 A	less than 5 % of U_T
70 % output, 0 A to 23 A	less than 5 % of U_T
40 % output, 0 A to 40 A	less than 5 % of U_T
Output current capability	16 A RMS per phase at rated voltage. The generator shall be capable of carrying 20 A at 80 % of rated value for a duration of 5 s. It shall be capable of carrying 23 A at 70 % of rated voltage and 40 A at 40 % of rated voltage for a duration of 3 s. (This requirement may be reduced according to the EUT's rated steady-state supply current, see Clause A.3.)
Peak inrush current capability (no requirement for voltage variation tests)	Not to be limited by the generator. However, the maximum peak capability of the generator need not exceed 1 000 A for 250 V to 600 V mains, 500 A for 200 V to 240 V mains, or 250 A for 100 V to 120 V mains.
Instantaneous peak overshoot/undershoot of the actual voltage, generator loaded with 100 Ω resistive load	Less than 5 % of U_T
Voltage rise (and fall) time t_r (and t_f), see Figure 1b), Figure 2 and Figure 3, during abrupt change, generator loaded with 100 Ω resistive load	Between 1 µs and 5 µs
Phase shifting (if necessary)	0° to 360°
Phase relationship of voltage dips and interruptions with the power frequency	Less than ±10 °
Zero crossing control of the generators	±10°

The output impedance shall be predominantly resistive.

The output impedance of the test voltage generator shall be low enough even during transitions.

The 100 Ω resistive load used to test the generator should not have additional inductivity.

To test equipment which regenerates energy, an external resistor connected in parallel to the load can be added. The test result should not be influenced by this load.

6.1.3 Verification of the characteristics of the voltage dips, short interruptions generators

In order to compare the test results obtained from different test generators, the generator characteristics shall be verified according to the following:

- the 100 %, 80 %, 70 % and 40 % RMS output voltages of the generator shall conform to the percentages of the selected operating voltage: 230 V, 120 V, etc.;
- the 100 %, 80 %, 70 % and 40 % RMS output voltages of the generator shall be measured at no load, and shall be maintained within a specified percentage of the U_T;
- load regulation shall be verified at nominal load current at each of the output voltages and the variation shall not exceed 5 % of the nominal power supply voltage at 100 %, 80 %, 70 % and 40 % of the nominal power supply voltage.

For output voltage of 80 % of the nominal value, the above requirements need only be verified for a maximum of 5 s duration.

For output voltages of 70 % and 40 % of the nominal value, the above requirements need only be verified for a maximum of 3 s duration.

For output voltages of 40% of the nominal value it is acceptable to verify the load regulation requirements either at 200 V to 240 V nominal voltage or at 100 V to 120 V nominal voltage..

If it is necessary to verify the peak inrush drive current capability, the generator shall be switched from 0 % to 100 % of full output, when driving a load consisting of a suitable rectifier with an uncharged capacitor whose value is 1 700 μF on the DC side. The test shall be carried out at phase angles of both 90° and 270°. The circuit required to measure the generator inrush current drive capability is given in Figure A.1.

When it is believed that a generator with less than the specified standard generator peak inrush current can be used because the EUT can draw less than the specified standard generator peak inrush current (e.g., 500 A for 220 V to 240 V mains), this shall first be confirmed by measuring the EUT peak inrush current. When power is applied from the test generator, the measured EUT peak inrush current shall be less than 70 % of the peak current drive capability of the generator, as already verified according to Annex A. The actual EUT inrush current shall be measured both from a cold start and after a 5 s turn-off, using the procedure of Clause A.3.

Generator switching characteristics shall be measured with a 100 Ω load of suitable power-dissipation rating.

The 100 Ω resistive load used to test the generator should not have additional inductivity.

Rise and fall time, as well as overshoot and undershoot, shall be verified for switching at both 90° and 270°, from 0 % to 100 %, 100 % to 80 %, 100 % to 70 %, 100 % to 40 %, and 100 % to 0 %.

Phase angle accuracy shall be verified for switching from 0 % to 100 % and 100 % to 0 %, at nine phase angles from 0° to 360° in 45° increments. It shall also be verified for switching from 100 % to 80 % and 80 % to 100 %, 100 % to 70 % and 70 % to 100 %, as well as from 100 % to 40 % and 40 % to 100 %, at 90° and 180°.

The voltage generators shall, preferably, be recalibrated at defined time periods in accordance with a recognized quality assurance system.

Annex D provides the rationale for generator specification regarding the voltage rise and fall time and the inrush current capability.

6.2 Power source

The frequency of the test voltage shall be within ±2 % of rated frequency.

7 Test set-up

The test shall be performed with the EUT connected to the test generator with the shortest power supply cable as specified by the EUT manufacturer. If no cable length is specified, it shall be the shortest possible length suitable to the application of the EUT.

The test set-ups for the three types of phenomena described in this document are:

- voltage dips;

- short interruptions;
- voltage variations with gradual transition between the rated voltage and the changed voltage (option).

Examples of test set-ups are given in Annex C.

Figure C.1a) shows a schematic for the generation of voltage dips, short interruptions and voltage variations with gradual transition between rated and changed voltage using a generator with internal switching. In Figure C.1b) a generator and a power amplifier are used.

Figure C.2 shows a schematic for the generation of voltage dips, short interruptions and voltage variations using a generator and a power amplifier for three-phase equipment.

8 Test procedures

8.1 General

Before starting the test of a given EUT, a test plan shall be prepared.

The test plan should be representative of the way the system is actually used.

Systems can require a precise pre-analysis to define which system configurations shall be tested to reproduce field situations.

Test cases shall be explained and indicated in the test report.

It is recommended that the test plan include the following items:

- the type designation of the EUT;
- information on possible connections (plugs, terminals, etc.) and corresponding cables, and peripherals;
- input power port of equipment to be tested;
- representative operational modes of the EUT for the test;
- performance criteria used and defined in the technical specifications;
- operational mode(s) of equipment;
- description of the test set-up.

If the actual operating signal sources are not available to the EUT, they can be simulated.

For each test, any degradation of performance shall be recorded. The monitoring equipment should be capable of displaying the status of the operational mode of the EUT during and after the tests. After each group of tests, a full functional check shall be performed.

8.2 Laboratory reference conditions

8.2.1 Climatic conditions

Unless otherwise specified by the committee responsible for the generic or product standard, the climatic conditions in the laboratory shall be within any limits specified for the operation of the EUT and the test equipment by their respective manufacturers.

Tests shall not be performed if the relative humidity is so high as to cause condensation on the EUT or the test equipment.

NOTE Where it is considered that there is sufficient evidence to demonstrate that the effects of the phenomenon covered by this document are influenced by climatic conditions, this is brought to the attention of the committee responsible for this document.

8.2.2 Electromagnetic conditions

The electromagnetic conditions of the laboratory shall be such as to guarantee the correct operation of the EUT in order not to influence the test results.

8.3 Execution of the test

8.3.1 General

During the tests, the mains voltage for testing shall be monitored within an accuracy of 2 %.

8.3.2 Voltage dips and short interruptions

The EUT shall be tested for each selected combination of test level and duration with a sequence of three dips/interruptions with intervals of 10 s minimum (between each test event). Each representative mode of operation shall be tested.

For voltage dips, changes in supply voltage shall occur at zero crossings of the voltage, and at additional angles considered critical by product committees or individual product specifications preferably selected from 45°, 90°, 135°, 180°, 225°, 270° and 315° on each phase.

For short interruptions, the angle shall be defined by the product committee as the worst case. In the absence of definition, it is recommended to use 0° for one of the phases.

For the short interruption test of three-phase systems, all the three phases shall be simultaneously tested according to 5.2.

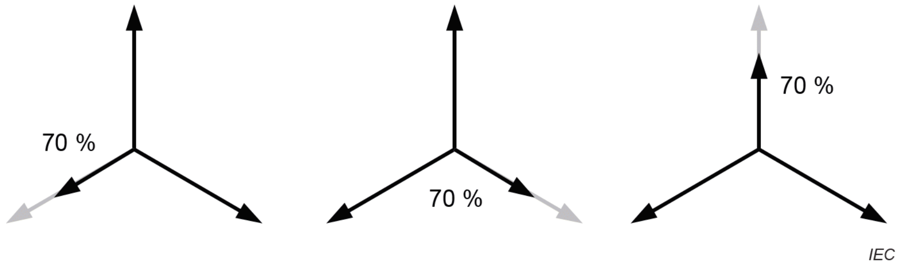
For the voltage dips test of single-phase systems, the voltage shall be tested according to 5.2. This implies one series of tests.

For the voltage dips test of three-phase systems with neutral, each individual voltage (phase-to-neutral and phase-to-phase) shall be tested, one at a time, according to 5.2. This implies six different series of tests. See Figure 5.

For the voltage dips test of three-phase systems without neutral, each phase-to-phase voltage shall be tested, one at a time, according to 5.2. This implies three different series of tests. See Figure 5b).

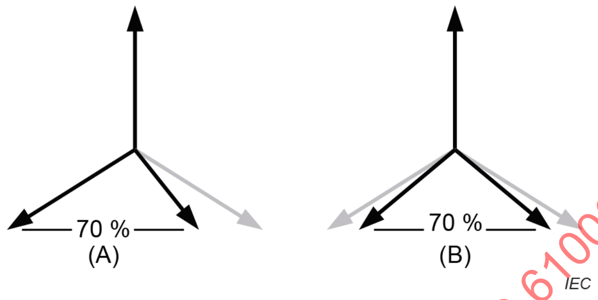
NOTE For three-phase systems, during a dip on a phase-to-phase voltage a change will occur on one or two of the other voltages as well.

For EUTs with more than one power cord, each power cord should be tested individually.



NOTE Phase-to-neutral testing on three-phase systems is performed one phase at a time.

a) Phase-to-neutral testing on three-phase systems



NOTE Phase-to-phase testing on three-phase systems is also performed one phase at a time. Both (A) and (B) show a 70 % dip. (A) is preferred, but (B) is also acceptable.

b) Phase-to-phase testing on three-phase systems

Figure 5 – Phase-to-neutral and phase-to-phase testing on three-phase systems

8.3.3 Voltage variations

The EUT is tested to each of the specified voltage variations, three times at 10 s interval for the most representative modes of operations.

9 Evaluation of test results

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed between the manufacturer and the purchaser of the product. The recommended classification is as follows:

a) normal performance within limits specified by the manufacturer, requestor or purchaser;

b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;

c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;

d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which can be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

NOTE The performance levels can be different for voltage dip tests and short interruption tests as well as for voltage variations tests, if this optional test has been required.

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- the items specified in the test plan required by Clause 8;
- identification of the EUT and any associated equipment, for example brand name, product type, serial number;
- identification of the test equipment, for example brand name, product type, serial number;
- any special environmental conditions in which the test was performed, for example shielded enclosure;
- any specific conditions necessary to enable the test to be performed;
- performance level defined by the manufacturer, requestor or purchaser;
- performance criterion specified in the generic, product or product-family standard;
- any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;
- the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser);
- any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance.

Annex A
(normative)

Test circuit details

A.1 Test generator peak inrush current drive capability

The circuit for measuring generator peak inrush current drive capability is shown in Figure A.1. Use of the bridge rectifier makes it unnecessary to change rectifier polarity for tests at 270° versus 90°. The rectifier half-cycle mains current rating should be at least twice the generator's inrush current drive capability to provide a suitable operating safety factor.

The 1 700 µF electrolytic capacitor shall have a tolerance of ±20 %. It shall have a voltage rating preferably 15 % to 20 % in excess of the nominal peak voltage of the mains, for example 400 V for 220 V to 240 V mains. It shall also be able to accommodate peak inrush current up to at least twice the generator's inrush current drive capability, to provide an adequate operating safety factor. The capacitor shall have the lowest possible equivalent series resistance (ESR) at both 100 Hz and 20 kHz, not exceeding 0,1 Ω at either frequency.

Since the test shall be performed with the 1 700 µF capacitor discharged, a resistor shall be connected in parallel with it and several time constants (RC) shall be allowed between tests. With a 10 000 Ω resistor, the RC time constant is 17 s, so that a wait of 1,5 min to 2 min should be used between inrush drive capability tests. Resistors as low as 100 Ω may be used when shorter wait times are desired.

The current probe shall be able to accommodate the full generator peak inrush current drive for one-quarter cycle without saturation.

Tests shall be run by switching the generator output from 0 % to 100 % at both 90° and 270°, to ensure sufficient peak inrush current drive capability for both polarities.

A.2 Current monitor's characteristics for measuring peak inrush current capability

Output voltage in 50 Ω load:	0,01 V/A or more
Peak current:	1 000 A minimum
Peak current accuracy:	± 10 % (3 ms duration pulse)
RMS current:	50 A minimum
$I \times T$ maximum:	10 A · s or more
Rise/fall time:	500 ns or less
Low-frequency 3 dB point:	10 Hz or less
Insertion resistor:	0,001 Ω or less

A.3 EUT peak inrush current requirement

When a generator peak inrush current drive capability meets the specified requirement (e.g., at least 500 A for a 220 V to 240 V mains), it is not necessary to measure the EUT's peak inrush current requirement.

However, a generator with less than this inrush current may be used for the test, if the inrush requirement of the EUT is less than the inrush drive capability of the generator. The circuit of Figure A.2 shows an example of how to measure the peak inrush current of an EUT to determine if it is less than the inrush drive capability of a low-inrush drive capability generator.

The circuit uses the same current transformer as the circuit of Figure A.1. Four peak inrush current tests are performed:

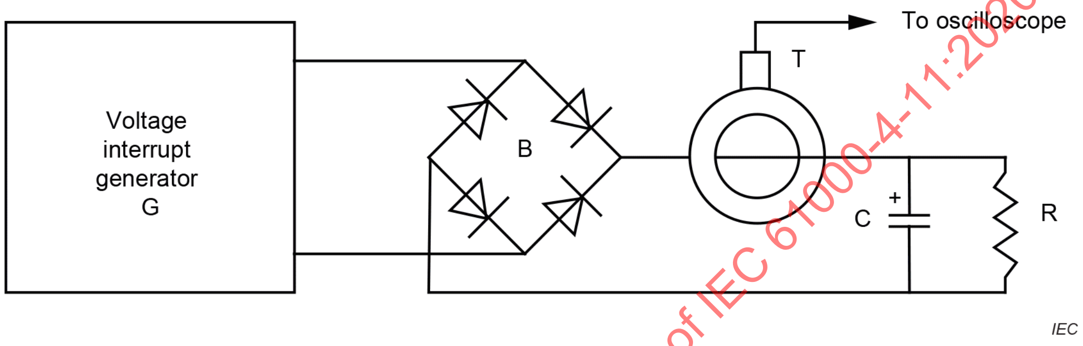
a) power off for at least 5 min; measure peak inrush current when it is turned back on at 90°;

b) repeat a) at 270°;

c) power on preferably for at least 1 min; off for 5 s; then measure peak inrush current when it is turned back on again at 90°;

d) repeat c) at 270°.

In order to be able to use a low-inrush drive current capability generator to test a particular EUT, that EUT's measured inrush current shall be less than 70 % of the measured inrush current drive capability of the generator.



Components

G voltage interrupt generator, switched on at 90° and 270°

T current probe, with monitoring output to oscilloscope

B rectifier bridge

R bleeder resistor, not over 10 000 Ω or less than 100 Ω

C 1 700 μF ± 20 % electrolytic capacitor

Figure A.1 – Circuit for determining the inrush current drive capability of the short interruptions generator

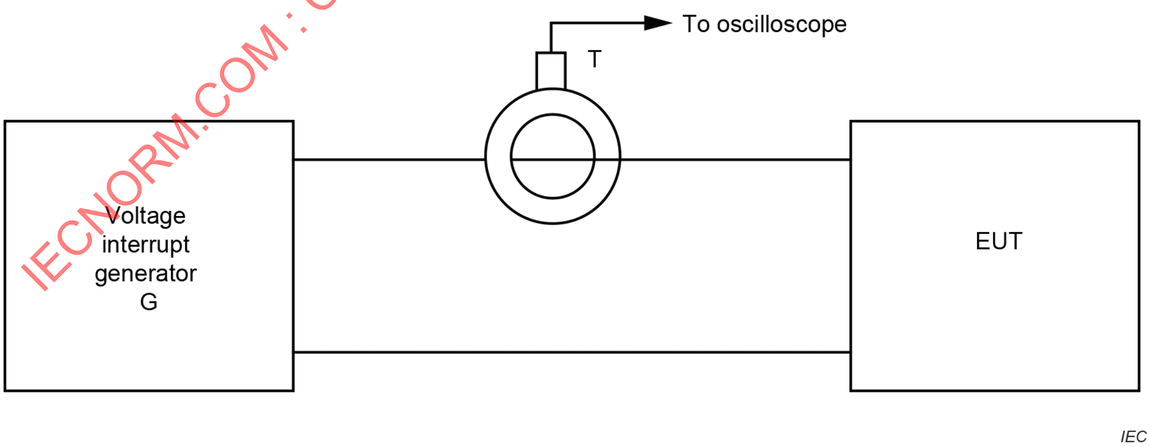


Figure A.2 – Circuit for determining the peak inrush current requirement of an EUT

Annex B
(informative)

Electromagnetic environment classes

The following electromagnetic environment classes have been summarised from IEC 61000-2-4.

- **Class 1**

  This class applies to protected supplies and has compatibility levels lower than public network levels. It relates to the use of equipment very sensitive to disturbances in the power supply, for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.

  NOTE Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power supplies (UPS), filters, or surge suppressers.

- **Class 2**

  This class applies to points of common coupling (PCCs for consumer systems) and in-plant points of common coupling (IPCs) in the industrial environment in general. The compatibility levels in this class are identical to those of public networks; therefore components designed for application in public networks may be used in this class of industrial environment.

- **Class 3**

  This class applies only to IPCs in industrial environments. It has higher compatibility levels than those of class 2 for some disturbance phenomena. For instance, this class should be considered when any of the following conditions are met:

  – a major part of the load is fed through converters;

  – welding machines are present;

  – large motors are frequently started;

  – loads vary rapidly.

  The supply to highly disturbing loads, such as arc-furnaces and large converters which are generally supplied from a segregated bus-bar, frequently has disturbance levels in excess of class 3 (harsh environment). In such special situations, the compatibility levels should be agreed upon.

  The class applicable for new plants and extensions of existing plants should relate to the type of equipment and process under consideration.

Annex C
(informative)

Test instrumentation

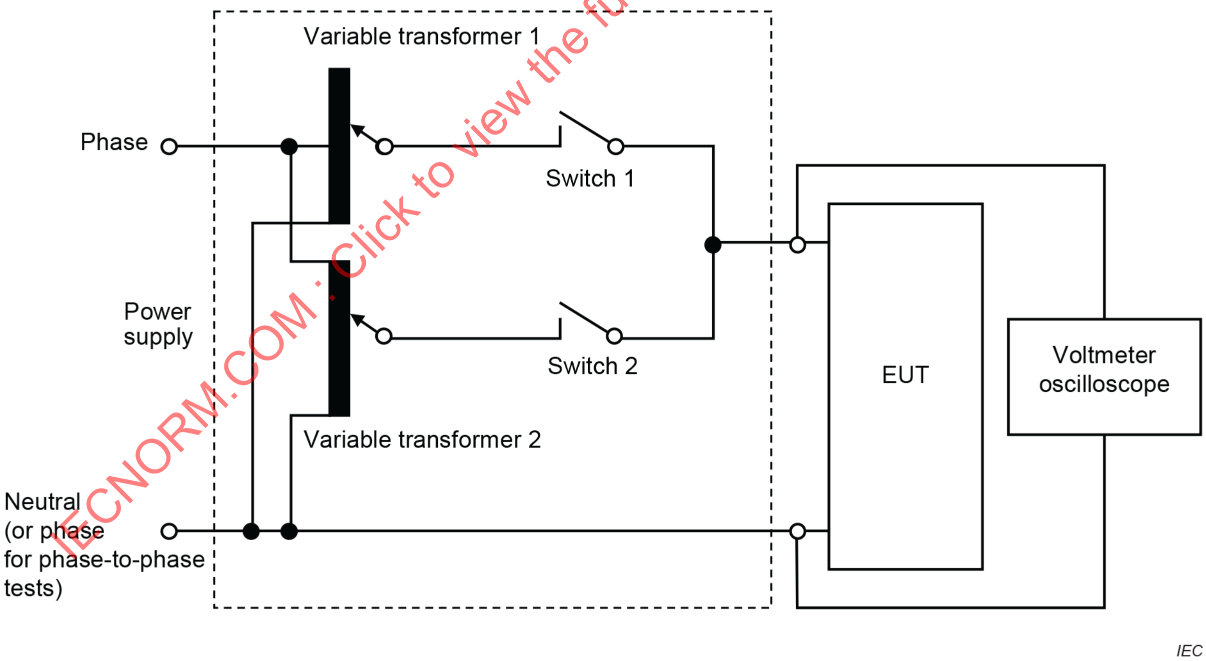
Figure C.1a) and Figure C.1b) show two possible test configurations for mains supply simulation. To show the behaviour of the EUT under certain conditions, interruptions and voltage variations are simulated by means of two transformers with variable output voltages.

Voltage drops, rises and interruptions are simulated by alternately closing switch 1 and switch 2. These two switches are never closed at the same time and an interval up to 100 μs with the two switches opened is acceptable. It shall be possible to open and close the switches independently of the phase angle. Semiconductors switches constructed with power MOSFETs and IGBTs can fulfil this requirement. Thyristors and triacs open during current zero crossing, and therefore do not meet this requirement.

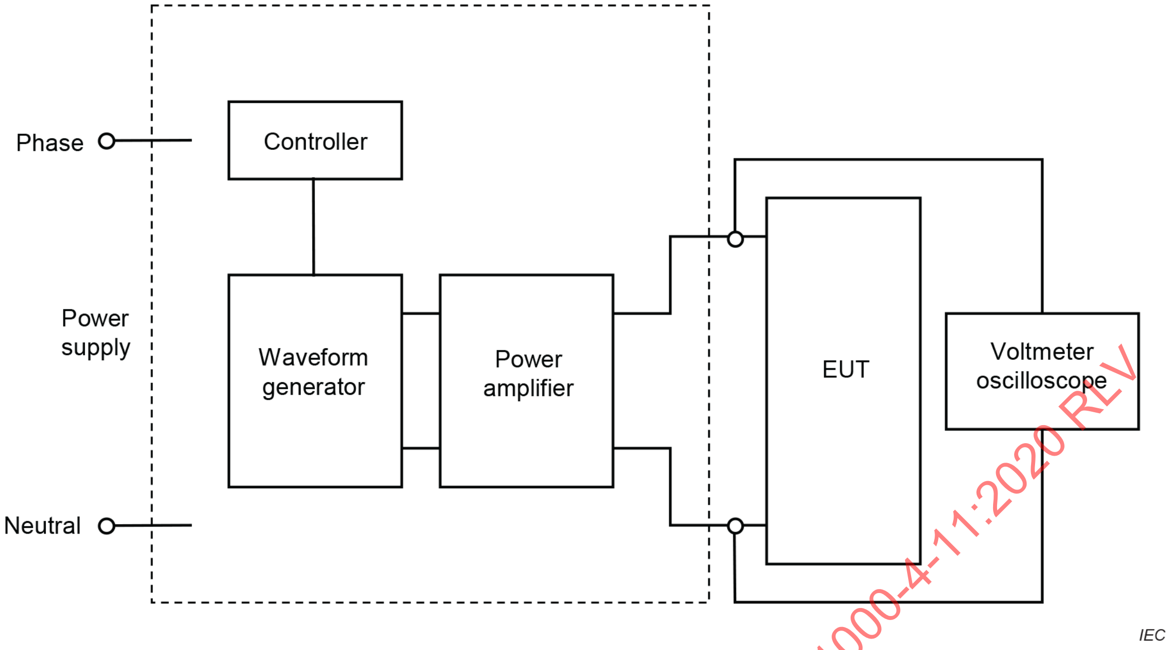
The output voltage of the variable transformers can either be adjusted manually or automatically by means of a motor. Alternatively, an autotransformer with multiple switch-selected taps may be used.

Waveform generators and power amplifiers can be used instead of variable transformers and switches (see Figure C.1b)). This configuration also allows testing of the EUT in the context of frequency variations and harmonics.

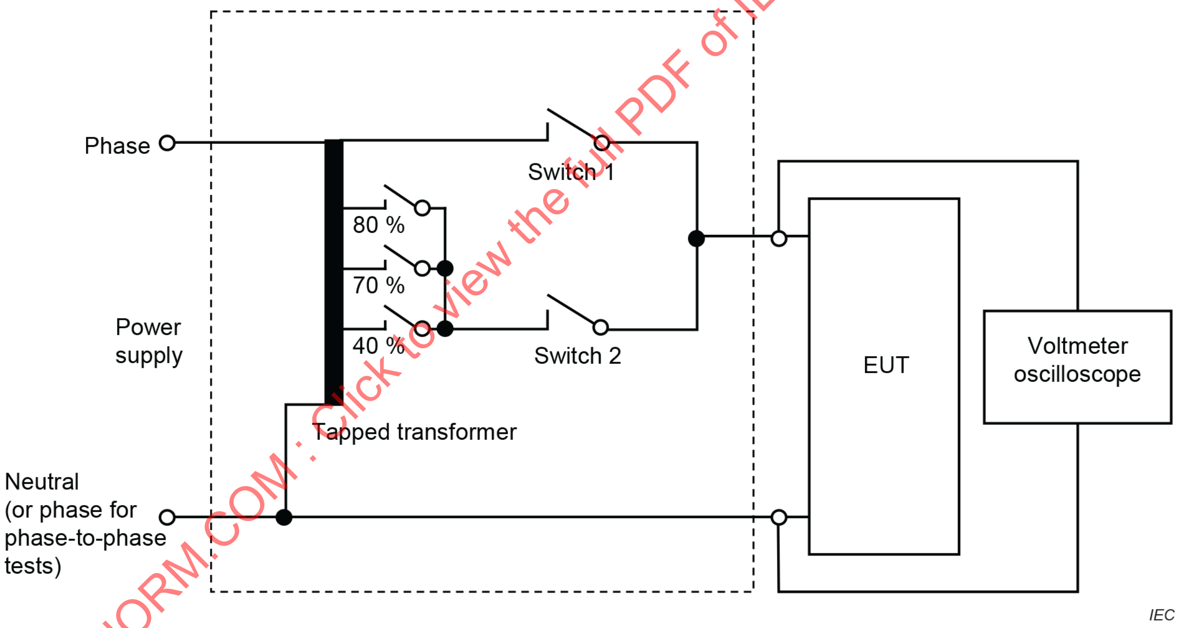
The generators described for single-phase testing (see Figure C.1a), Figure C.1b) and Figure C.1c)) can be also used for three-phase testing (see Figure C.2).



a) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using variable transformers and switches



b) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using a power amplifier



c) Schematic of test instrumentation for voltage dips, short interruptions and voltage variations using a tapped transformer and switches

Figure C.1 – Schematics of test instrumentation for voltage dips, short interruptions and voltage variations

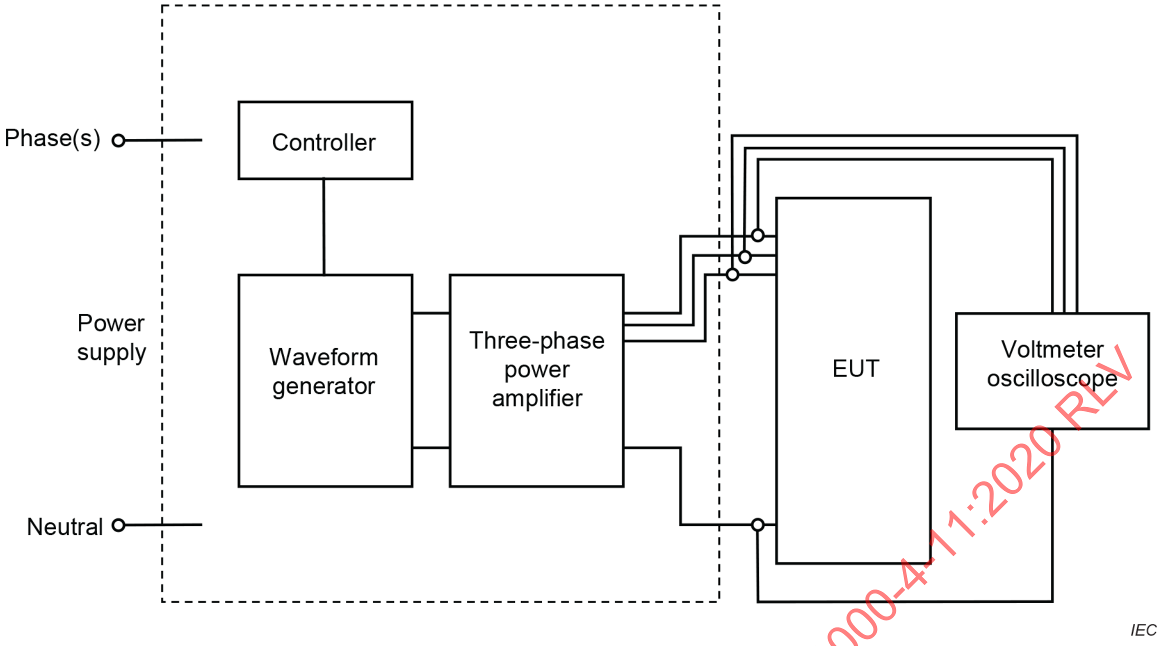


Figure C.2 – Schematic of test instrumentation for three-phase voltage dips, short interruptions and voltage variations using a power amplifier

Annex D
(informative)

Rationale for generator specification regarding voltage, rise-time and fall-time, and inrush current capability

D.1 Concept of basic standard

The immunity basic standards of the IEC 61000-4 series are based on the concept of defining a test system in one document representing typically one type of electromagnetic disturbance. The environmental description of the IEC 61000-2 series (which includes also compatibility levels), together with practical industry experience, is the basis for defining the disturbance source simulator, the necessary coupling and decoupling networks and the range of test levels.

Parameters in the basic standard are always compromises selected from a large amount of data derived from the disturbance source. The compromise is assumed to be correct if, once the immunity test is applied, only a few malfunctions occur in the real world.

To keep the immunity test as easy as possible, the generator output shall be verified in a calibration set-up and not with the EUT connected to the output of the generator. The purpose of the calibration is to guarantee comparable test results between different brands of generators.

D.2 IEC 61000-4-11:1994 (first edition)

Data from the UNIPEDE report was used which indicated short circuit in terms of voltage reduction and interruption duration. At that time, rare measurement results were available showing how equipment on the same phase was affected, in the public power network.

Based on this information, IEC 61000-4-11:1994 (first edition) was defined and published in 1994. For the switching time a value of 1 µs to 5 µs was chosen for representing the short circuit's worst case occurring at a distance of up to 50 m between the source and the affected equipment. For example, the equipment used in a laboratory or in an industrial plant has a greater risk of being affected by voltage dips and short interruptions within 50 m.

D.3 Rationale for the need of rapid fall-times

In case of short circuit in the line, the voltage at the input terminals of the equipment might go to zero in less than 5 µs.

If the short circuit originates from the public network, the fall-time will be relatively slow, in the order of hundreds of microseconds to some milliseconds. If, however, the short circuit is at the local premise, for example due to the failure of another equipment installed in close proximity, the mains voltage will go to zero within microseconds, with fall-times shorter than 1 µs reported for some cases.

In this case, the input rectifier diodes of the equipment will be commutated from conduction mode to blocking mode with a sudden high reverse voltage due to that very fast voltage rise-time. As those diodes are usually designed for natural line commutation with a rise-time of the voltage in the range of milliseconds, this event is an increased stress for the rectifier diodes. More generally, fast voltage transients can disturb electronics as well, leading to the damage of the equipment.

Tests performed with a fast fall-time in the range of a few microseconds emulating the short circuit condition can be used to test the robustness of equipment against fast transient short circuits of the line.

D.4 Interpretation of the rise-time and fall-time requirements during EUT testing

In 2010 an interpretation sheet for IEC 61000-4-11:2004 (second edition) was issued. The content of this sheet is as follows:

1) "In IEC 61000-4-11:2004, Table 4 does not apply to EUT (equipment under test) testing. Table 4 is for generator calibration and design only.
2) With reference to Table 1 and Table 2, there is no requirement in 61000-4-11:2004 for rise-time and fall-time when testing EUT; therefore, it is not necessary to measure these parameters during tests.
3) With reference to Table 4, all of the requirements apply to design and calibration of the generator. The requirements of Table 4 only apply when the load is a non-inductive 100 Ω resistor. The requirements of Table 4 do not apply during EUT testing."

D.5 Main conclusions

With respect to rise-time and fall-time, the main conclusions are the following:

- It is possible, for real-world voltage dips, to have fall-times faster than 5 μs in the case of short circuits close to the equipment. However, for the time being, this document does not consider the effects of voltage fall times shorter than 1 μs.
- Rise-time depends on several factors including the impedance of the network, cabling and equipment connected in parallel.
- The rise-time and fall-time requirements have remained unchanged and the document has been used worldwide since its first publication in 1994, but, as in the interpretation sheet, these rise-time and fall-time requirements do not apply during a test of an EUT. They only apply when calibrating a dip generator with a 100 Ω resistive load. These rise-times and fall-times do not necessarily occur during an actual EUT test.
- Most voltage dip and short interruption immunity tests begin and end at 0˚ or 180˚. Published research generally concludes that these are the most severe phase angles for voltage ride-through tests. Note that at 0˚ and at 180˚ the instantaneous waveform voltage is zero, so rise-time and fall-time have no meaning.
- Pre-compliance testing could be considered using a dip generator with a longer rise-time and fall-time up to 200 μs for voltage dip and short interruption tests that begin and end at 0˚ or 180˚, as rise-time and fall-time are not important at these angles. However, full compliance with the test methods of this document requires to use a generator that, when tested with a 100 Ω resistive load, meets the 1 μs to 5 μs requirement in 6.1.3.

D.6 Rationale for inrush current capability

During the connection of an equipment to a power line, an inrush current flows into it. This inrush current could conceivably damage parts of the equipment, for example an input rectifier with capacitive smoothing. In order to prevent damage, measures for inrush current limitation are usually incorporated inside the equipment.

An inrush current will also occur when the line voltage recovers after a voltage dip or interruption. In this case, the inrush current limitation measures might not be activated in the equipment with disabled pre-charge circuit, so it is possible for the post-dip inrush current to damage the equipment.

For this reason, it is necessary for the voltage dip generator to be capable of supplying sufficient current and that the post-dip inrush current is not limited by the dip generator.

Without this inrush current requirement, it would be possible for the equipment to pass the immunity test performed with the dip generator, but to fail in the real world due to inrush current damage.

In a real installation, this inrush current will be limited by the network impedance. If the short circuit is on the public supply, the network impedance is according to the line reference impedance of the public supply (796 µH according to IEC TR 60725), which is typical for rural low voltage networks, and it will limit the inrush current to about 15 A to 20 A. However, if the short circuit is inside the local premise, in a particular large installation such as an industrial plant, the impedance can be much lower and the inrush current much larger.

In order for the test generator to have adequate capabilities to properly stress the equipment under test, the document provides guidance in 6.1.3 to ensure that the equipment does not demand more current than 70 % of the generator capability, for example 500 A for 220 V to 240 V mains.

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1 This publication has been withdrawn.

2 An interpretation sheet was issued by IEC SC 77A for IEC 61000-4-11 in August 2010.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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COMPATIBILITÉ ÉLECTROMAGNÉTIQUE (CEM) –

Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension pour les appareils à courant d'entrée inférieur ou égal à 16 A par phase

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Elle constitue la Partie 4-11 de l'IEC 61000. Elle a le statut d'une publication fondamentale en CEM conformément au Guide IEC 107.

Cette troisième édition annule et remplace la deuxième édition parue en 2004 et l'Amendement 1:2017. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) le temps de montée et le temps de descente sont désormais des termes définis à l'Article 3;
b) l'origine des creux de tension et des coupures brèves est désormais décrite à l'Article 4.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
77A/1039/FDIS	77A/1056/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série 61000, publiées sous le titre général *Compatibilité électromagnétique (CEM)*, peut être consultée sur le site web de l'IEC.

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- supprimé,
- remplacé par une édition révisée, ou
- amendé.

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INTRODUCTION

L'IEC 61000 est publiée sous forme de plusieurs parties, conformément à la structure suivante:

Partie 1: Généralités

Considérations générales (introduction, principes fondamentaux)

Définitions, terminologie

Partie 2: Environnement

Description de l'environnement

Classification de l'environnement

Niveaux de compatibilité

Partie 3: Limites

Limites d'émissions

Limites d'immunité (dans la mesure où elles ne relèvent pas de la responsabilité des comités de produits)

Partie 4: Techniques d'essai et de mesure

Techniques de mesure

Techniques d'essai

Partie 5: Lignes directrices d'installation et d'atténuation

Lignes directrices d'installation

Méthodes et dispositifs d'atténuation

Partie 6: Normes génériques

Partie 9: Divers

Chaque partie est à son tour subdivisée en plusieurs parties, publiées soit comme Normes internationales, soit comme spécifications techniques ou rapports techniques, dont certaines ont déjà été publiées en tant que sections. D'autres seront publiées sous le numéro de la partie, suivi d'un tiret et complété d'un second chiffre identifiant la subdivision (exemple: IEC 61000-6-1).

COMPATIBILITÉ ÉLECTROMAGNÉTIQUE (CEM) –

Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension pour les appareils à courant d’entrée inférieur ou égal à 16 A par phase

1 Domaine d’application

La présente partie de l’IEC 61000 définit les méthodes d'essai d'immunité ainsi que la plage des niveaux d'essais préférentiels pour les matériels électriques et électroniques connectés à des réseaux d'alimentation à basse tension pour les creux de tension, les coupures brèves et les variations de tension.

Le présent document s’applique aux matériels électriques et électroniques dont le courant assigné d’entrée ne dépasse pas 16 A par phase et destinés à être reliés à des réseaux électriques à courant alternatif de 50 Hz ou 60 Hz.

Il ne s'applique pas aux matériels électriques et électroniques destinés à être reliés à des réseaux électriques à courant alternatif de 400 Hz. Les essais pour ces réseaux seront traités dans des documents IEC à venir.

Le but du présent document est d'établir une référence commune pour l'évaluation de l'immunité des matériels électriques et électroniques soumis à des creux de tension, à des coupures brèves et à des variations de tension.

NOTE 1 Les essais d’immunité aux fluctuations de tension sont traités dans l’IEC 61000-4-14.

La méthode d’essai décrite dans le présent document détaille une méthode sans faille pour évaluer l’immunité d’un matériel ou d’un système à un phénomène prédéfini.

NOTE 2 Comme cela est décrit dans le Guide 107 de l’IEC, ce document est une publication fondamentale en CEM destinée à l’usage des comités de produits de l’IEC. Comme cela est également mentionné dans le Guide 107, les comités de produits de l’IEC sont chargés de décider s’il convient d’utiliser ou non cette norme d’essai d’immunité et, si elle est utilisée, les comités sont responsables de la définition des niveaux d’essai appropriés. Le comité d’études 77 et ses sous-comités sont prêts à coopérer avec les comités de produits pour l’évaluation de la pertinence des essais particuliers d’immunité pour leurs produits.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu’ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l’édition citée s’applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC TR 61000-2-8, *Compatibilité électromagnétique (CEM) – Partie 2-8: Environnement – Creux de tension et coupures brèves sur les réseaux d’électricité publics incluant des résultats de mesures statistiques*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
immunité (à une perturbation)
aptitude d'un dispositif, d'un appareil ou d'un système à fonctionner sans dégradation en présence d'une perturbation électromagnétique

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.2
creux de tension
baisse brutale de la tension en un point particulier d'un système d'alimentation électrique qui devient inférieure à un seuil de creux spécifié, puis reprend une valeur supérieure au seuil après un court intervalle de temps

Note 1 à l'article: Typiquement, un creux est associé à l'apparition et à la disparition d'un court-circuit ou de toute autre cause de surintensité dans le système ou les installations connectées à celui-ci.

Note 2 à l'article: Un creux de tension est une perturbation électromagnétique en deux dimensions, dont le niveau est déterminé par la tension et la durée.

3.3
coupure brève
baisse brutale de la tension sur toutes les phases à un point particulier d'un système d'alimentation électrique qui devient inférieure à un seuil d'interruption spécifié, puis reprend une valeur supérieure au seuil après un court intervalle de temps

Note 1 à l'article: Les coupures brèves sont souvent liées aux dispositifs de commutation dont le fonctionnement est lié à l'apparition et à la disparition de courts-circuits dans le système ou les installations connectées à celui-ci.

3.4
tension résiduelle
<creux de tension> valeur minimale de la tension efficace enregistrée pendant un creux de tension ou une coupure brève

Note 1 à l'article: La tension résiduelle peut être exprimée en volts, en pourcentage ou en valeur unitaire par rapport à la tension de référence.

3.5
dysfonctionnement
cessation de l'aptitude d'un matériel à accomplir ses fonctions ou exécution de fonctions incorrectes par le matériel

3.6
étalonnage
méthode qui permet de démontrer que l'appareil de mesure est conforme à ses spécifications

Note 1 à l'article: Pour les besoins du présent document, l'étalonnage s'applique au générateur d'essai.

3.7
vérification
ensemble des opérations utilisées qui s'appliquent à l'ensemble des matériels d'essai (par exemple le générateur d'essai et les câbles d'interconnexion) pour démontrer que le système d'essai fonctionne conformément aux spécifications décrites à l'Article 6

Note 1 à l'article: Les méthodes de vérification peuvent ne pas être les mêmes que les méthodes d'étalonnage.

Note 2 à l'article: Les procédures de vérification décrites en 6.1.3 servent à vérifier que le générateur d'essai et les autres éléments constituant le montage d'essai fonctionnent correctement, pour que la forme d'onde correcte soit délivrée à l'EST.

3.8
temps de montée
durée de l'intervalle de temps entre les instants auxquels la valeur instantanée d'une transition atteint pour la première fois une valeur inférieure puis une valeur supérieure donnée

Note 1 à l'article: Les valeurs inférieure et supérieure sont fixées à 10 % et 90 % de l'amplitude de transition.

[SOURCE: IEC 60050-161:1990, 161-02-05]

3.9
temps de descente
durée de l'intervalle de temps entre les instants auxquels la valeur instantanée d'une transition atteint pour la première fois une valeur supérieure puis une valeur inférieure donnée

Note 1 à l'article: Les valeurs inférieure et supérieure sont fixées à 10 % et 90 % de l'amplitude de transition.

Note 2 à l'article: Cette définition est dérivée de l'IEC 60050-161:1990, 161-02-05.

4 Généralités

Les creux de tension, les coupures brèves et les variations de tension de l'alimentation électrique peuvent avoir une incidence sur les matériels électriques et électroniques.

Les creux de tension et les coupures brèves se produisent en raison de pannes sur un réseau (public ou non) ou dans des installations par suite de variations brusques de charges importantes. Dans certains cas, plusieurs creux ou coupures consécutifs peuvent survenir. Les variations de tension sont causées par des variations continues des charges connectées au réseau.

Ces phénomènes, aléatoires par nature, peuvent être caractérisés de manière minimale en vue d'être utilisés pour des simulations en laboratoire pour ce qui concerne l'écart par rapport à la tension assignée et la durée.

En conséquence, différents types d'essais sont spécifiés dans le présent document pour simuler les effets des variations brusques de tension. Ces essais doivent uniquement être utilisés pour des cas particuliers et justifiés, et relèvent de la responsabilité des comités de produits ou de spécifications.

Les comités de produits sont chargés d'établir les phénomènes concernés parmi ceux traités dans le présent document et de décider des conditions d'application de l'essai.

5 Niveaux d'essai

5.1 Généralités

Les tensions indiquées dans le présent document ont comme base la tension assignée du matériel (U_T) pour la spécification des tensions des niveaux d'essai.

Lorsque le matériel présente une plage de tensions assignées, les points suivants doivent s'appliquer:

- si la plage de tensions est inférieure à 20 % de la tension inférieure spécifiée pour la plage de tensions assignées, une tension unique dans cette plage peut être spécifiée comme base pour la spécification du niveau d'essai (U_T);
- dans tous les autres cas, la procédure d'essai doit s'appliquer à la fois aux tensions les plus élevées et aux tensions les plus faibles de la plage de tensions;
- l'IEC TR 61000-2-8 donne des recommandations concernant la sélection des durées et des niveaux d'essai.

5.2 Creux de tension et coupures brèves

Le passage de la tension U_T à la nouvelle tension est brusque. Cette variation peut commencer et se terminer à n'importe quel angle de phase de la tension du réseau. Les niveaux de tension d'essai suivants (en % de U_T) sont utilisés: 0 %, 40 %, 70 % et 80 %, ce qui correspond à des creux de tensions résiduelles de 0 %, 40 %, 70 % et 80 %.

Pour les creux de tension, les durées et les niveaux d'essai préférentiels sont indiqués dans le Tableau 1 et un exemple est représenté à la Figure 1a) et à la Figure 1b).

Pour les coupures brèves, les durées et les niveaux d'essai préférentiels sont indiqués dans le Tableau 2 et un exemple est représenté à la Figure 2.

Le temps de montée et le temps de descente sont représentés à la Figure 3.

Les durées et les niveaux d'essai préférentiels indiqués dans les Tableau 1 et Tableau 2 tiennent compte des informations indiquées dans l'IEC TR 61000-2-8.

Les niveaux d'essai préférentiels indiqués dans le Tableau 1 sont raisonnablement sévères et sont représentatifs de nombreux creux de tension réels, mais n'ont pas pour but d'assurer l'immunité à tous les creux de tension. Des creux de tension plus sévères, par exemple 0 % pendant 1 s et des creux de tension triphasés, peuvent être pris en considération par les comités de produits.

La spécification du générateur concernant le temps de montée en tension, t_r, et le temps de descente en tension, t_f, pendant les variations brusques est indiquée dans le Tableau 4.

Les durées et niveaux doivent être indiqués dans les spécifications des produits. Un niveau d'essai de 0 % correspond à une coupure totale de la tension d'alimentation. En pratique, un niveau de tension d'essai compris entre 0 % et 20 % de la tension assignée peut être considéré comme une coupure totale.

Il convient de vérifier par essai les durées plus courtes indiquées dans le Tableau 1, et en particulier la demi-période, pour confirmer que l'équipement soumis aux essais (EST) fonctionne conformément aux limites qui lui sont spécifiées.

Lors de la définition des critères de performances pour des perturbations dont la durée est une demi-période pour des produits équipés d'un transformateur de réseau, il convient que les comités de produits soient particulièrement attentifs aux effets qui peuvent être occasionnés par les courants d'appel. Pour de tels produits, ces courants peuvent être 10 fois à 40 fois plus élevés que le courant assigné en raison de la saturation du flux magnétique du noyau du transformateur après le creux de tension.

Des courants d'appel importants peuvent se produire également avec des condensateurs (par exemple, des filtres CEM, des redresseurs en pont connectés à des condensateurs en courant continu).

Tableau 1 – Durées et niveaux d'essai préférentiels pour les creux de tension

<table>
<tr><th>Classes [a]</th><th colspan="5">Durées et niveaux d'essai pour des creux de tension (t_s) (50 Hz/60 Hz)</th></tr>
<tr><td>Classe 1</td><td colspan="5">Au cas par cas en fonction des exigences du matériel</td></tr>
<tr><td>Classe 2</td><td>0 % pendant ½ période</td><td>0 % pendant 1 période</td><td colspan="3">70 % pendant 25/30 [c] périodes</td></tr>
<tr><td>Classe 3</td><td>0 % pendant ½ période</td><td>0 % pendant 1 période</td><td>40 % pendant 10/12 [c] périodes</td><td>70 % pendant 25/30 [c] périodes</td><td>80 % pendant 250/300 [c] périodes</td></tr>
<tr><td>Classe X [b]</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="6">[a] Classes selon l'IEC 61000-2-4; voir l'Annexe B.
[b] À définir par le comité de produits. Pour des matériels connectés directement ou indirectement au réseau public, les niveaux ne doivent jamais être moins sévères que ceux de la Classe 2.
[c] "25/30 périodes" signifie "25 périodes pour des essais à 50 Hz" et "30 périodes pour des essais à 60 Hz".</td></tr>
</table>

Tableau 2 – Durées et niveaux d'essai préférentiels pour les coupures brèves

Classes [a]	Durées et niveaux d'essai pour des coupures brèves (t_s) (50 Hz/60 Hz)
Classe 1	Au cas par cas en fonction des exigences du matériel
Classe 2	0 % pendant 250/300 [c] périodes
Classe 3	0 % pendant 250/300 [c] périodes
Classe X [b]	X

[a] Classes selon l'IEC 61000-2-4; voir l'Annexe B.

[b] À définir par le comité de produits. Pour des matériels connectés directement ou indirectement au réseau public, les niveaux ne doivent jamais être moins sévères que ceux de la Classe 2.

[c] "250/300 périodes" signifie "250 périodes pour des essais à 50 Hz" et "300 périodes pour des essais à 60 Hz".

5.3 Variations de tension (facultatif)

Cet essai porte sur une transition définie entre une tension assignée U_T et la valeur de la tension après la variation.

NOTE La durée de la variation de tension est courte et peut être causée par une variation de charge.

La durée préférentielle des variations de tension et la durée pendant laquelle les tensions réduites doivent être conservées sont indiquées dans le Tableau 3. Il convient que le taux de variation soit constant; toutefois, la tension peut être échelonnée. Il convient que les échelons se situent aux points de passage à zéro et qu'ils ne soient pas supérieurs à 10 % de U_T. Les échelons inférieurs à 1 % de U_T sont considérés comme des taux de variation de tension constants.

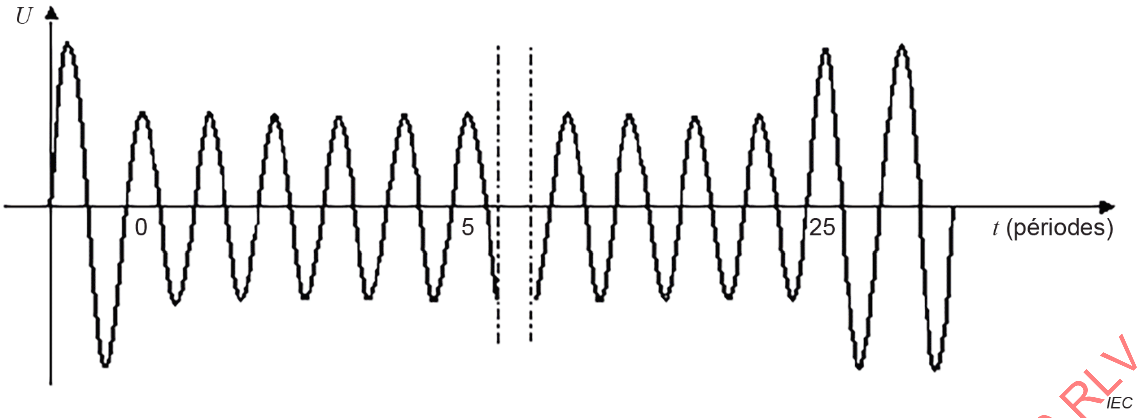
Tableau 3 – Durée des variations de tension d'alimentation de courte durée

Niveau d'essai de la tension	Temps de diminution de la tension (t_d)	Durée de la tension réduite (t_s)	Temps d'augmentation de la tension (t_i) (50 Hz /60 Hz)
70 %	Brusque	1 période	25/30 [b] périodes
X[a]	X[a]	X[a]	X[a]

[a] À définir par le comité de produits.

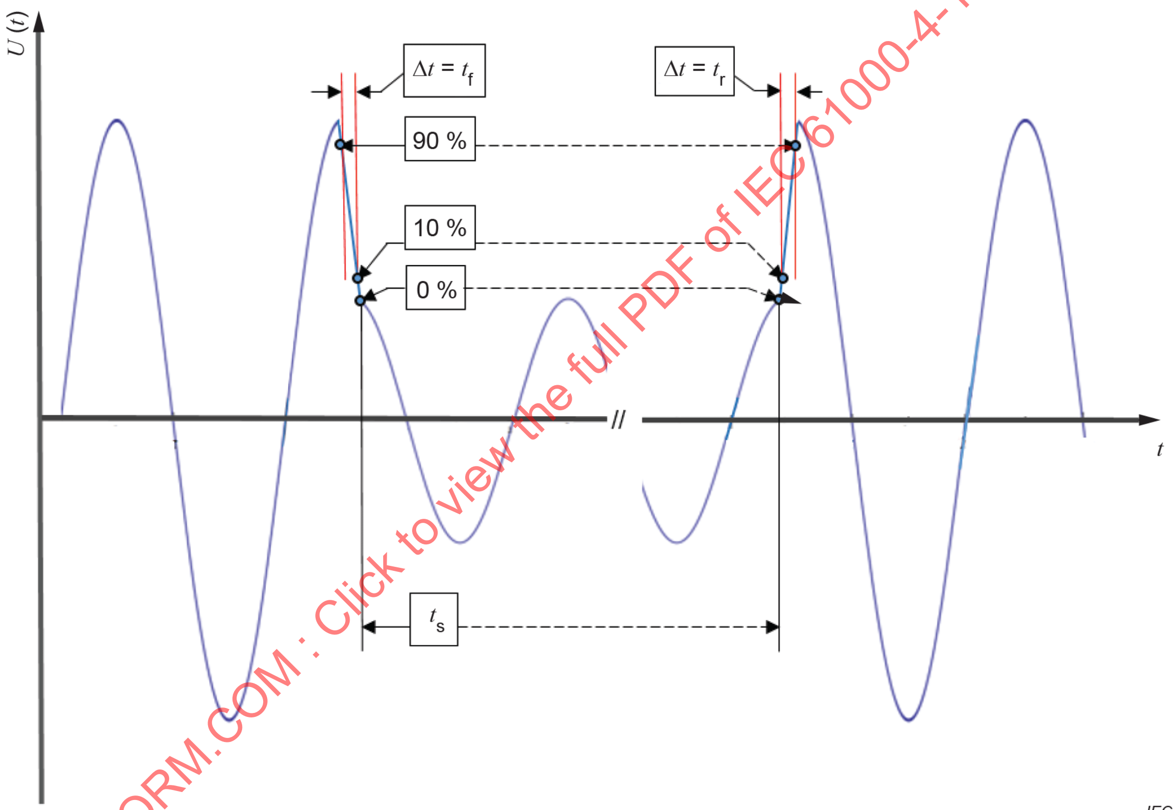
[b] "25/30 périodes" signifie "25 périodes pour des essais à 50 Hz" et "30 périodes pour des essais à 60 Hz".

Il s'agit de la forme typique du démarrage d'un moteur.



NOTE La tension diminue jusqu'à 70 % pour 25 périodes. Échelon au passage à zéro.

a) Creux de tension: Graphique indiquant la forme d'onde d'un creux de tension de 70 % à 0°



Légende

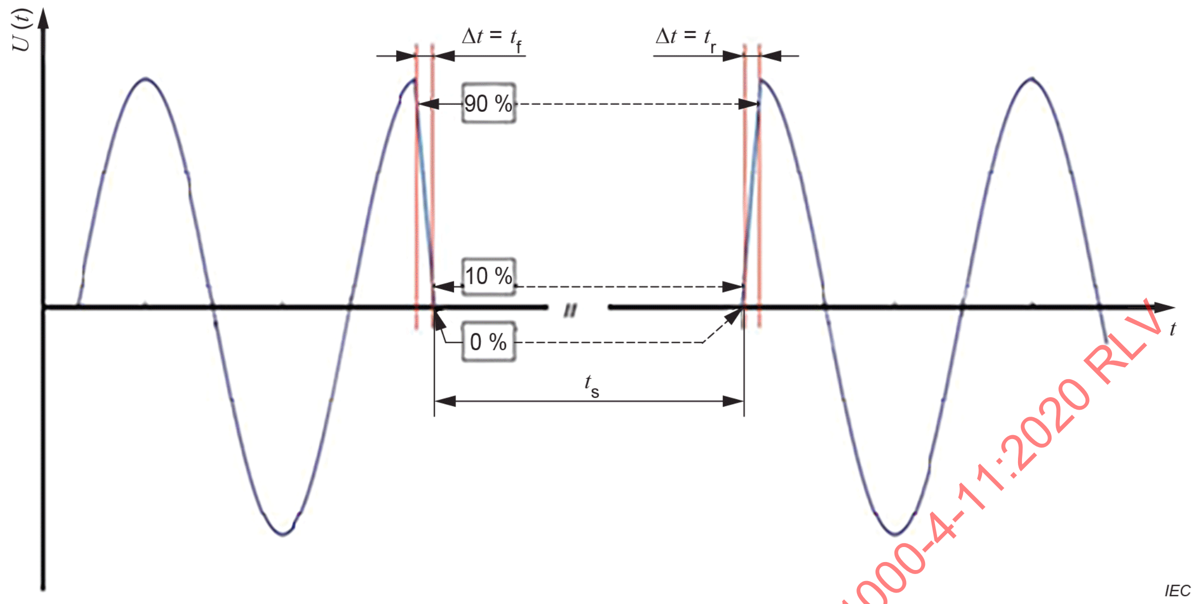
t_f temps de descente

t_r temps de montée

t_s durée de la tension réduite

b) Creux de tension: Graphique indiquant la forme d'onde d'un creux de tension de 40 % à 90°

Figure 1 – Creux de tension – Exemples



Légende

t_f temps de descente

t_r temps de montée

t_s durée de la tension réduite

Figure 2 – Coupure brève

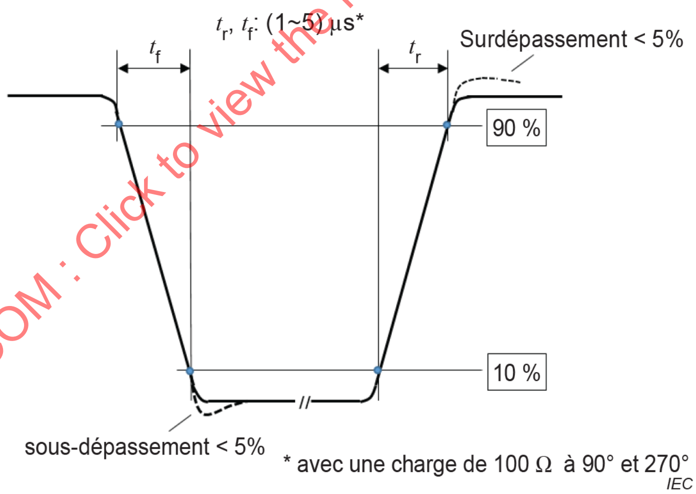


Figure 3 – Vue détaillée du temps de montée et du temps de descente

La Figure 4 représente la tension efficace en fonction du temps. D’autres valeurs peuvent être envisagées dans des cas justifiés et doivent être spécifiées par le comité de produits.