BRITISH STANDARD

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IEC 1000-4-1 : 1992

Electromagnetic compatibility (EMC)

Part 4. Testing and measurement techniques

Section 1. Overview of immunity tests Basic EMC publication

The European Standard EN 61000-4-1 : 1994 has the status of a British Standard

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Cooperating organizations

The European Committee for Electrotechnical Standardization (CENELEC), under whose supervision this European Standard was prepared, comprises the national committees of the following countries:

Austria	Italy
Belgium	Luxembourg
Denmark	Netherlands
Finland	Norway
France	Portugal
Germany	Spain
Greece	Sweden
Iceland	Switzerland
Ireland	United Kingdom

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Contents

National foreword

This British Standard has been prepared under the direction of the Electrotechnical Sector Board and is the English language version of EN 61000-4-1 : 1994 *Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques Section 1: Overview of immunity tests — Basic EMC publication*, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 1000-4-1 : 1992 published by the International Electrotechnical Commission (IEC).

IEC 1000 has been designated a Basic EMC publication for use in the preparation of dedicated product, product family and generic EMC standards.

IEC 1000 will be published in separate Parts in accordance with 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 9. *Miscellaneous*

Each Part will be subdivided into Sections each of which may be published as either a standard or a Technical Report.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques Section 1: Overview of immunity tests Basic EMC publication

(IEC 1000-4-1 : 1992)

Compatibilité électromagnétique (CEM)
Partie 4: Techniques d'essai et de mesure
Section 1: Vue d'ensemble sur les essais d'immunité
Publication fondamentale en CEM
(CEI 1000-4-1 : 1992)

Elecktromagnetische Verträglichkeit (EMV)
Teil 4: Prüf- und Meßverfahren
Hauptabschnitt 1: Übersicht über Störfestigkeitsmeßverfahren
EMV Grundnorm
(IEC 1000-4-1 : 1992)

This European Standard was approved by CENELEC on 1994-07-05. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

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Foreword

The CENELEC questionnaire procedure, performed for finding out whether or not the International Standard IEC 1000-4-1 : 1992 could be accepted without textual changes, has shown that no common modifications were necessary for the acceptance as a European Standard.

The reference document was submitted to the CENELEC members for formal vote and was approved by CENELEC as EN 61000-4-1 on 5 July 1994.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1995-03-15
- latest date of withdrawal of conflicting national standards (dow) 1995-03-15

Annexes designated 'normative' are part of the body of the standard. Annexes designated 'informative' are given only for information. In this standard, annex ZA is normative and annexes A and B are informative.

CONTENTS

ELECTROMAGNETIC COMPATIBILITY (EMC)

Part 4: Testing and measurement techniques
Section 1: Overview of immunity tests
Basic EMC publication

1 Scope and object

This section of IEC 1000-4 is a basic EMC (electromagnetic compatibility) publication. It considers immunity tests for electric and/or electronic equipment (apparatus and systems) in its electromagnetic environment. Both conducted and radiated phenomena are considered, this includes immunity tests for equipment connected to power, control and communication networks.

The object of this section is:

- to give a general and comprehensive reference to the technical committees of IEC or other bodies, users and manufacturers of electrical and electronic equipment on EMC immunity specifications and tests;
- to give general guidance on selection and application of these tests.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 1000-4. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 1000-4 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 34-1: 1983, *Rotating electrical machines – Part 1: Rating and performance*

IEC 50(161): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 255-22-1: 1988, *Electrical relays – Part 22: Electrical disturbance tests for measuring relays and protection equipment – Part one: 1 MHz burst disturbance tests*

IEC 521: 1988, *Class 0.5, 1 and 2 alternating-current watt-hour meters*

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

IEC 801-2: 1991, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 2: Electrostatic discharge requirements*

IEC 801-3: 1984, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 3: Radiated electromagnetic field requirements*

IEC 801-4: 1988, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 4: Electrical fast transient/burst requirements*

IEC 801-5, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 5: Surge voltage immunity requirements* (under consideration)

IEC 801-6, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 6: Immunity to conducted radio frequency disturbances above 9 kHz* (under consideration)

IEC 816: 1984, *Guide on methods of measurement of short duration transients on low-voltage power and signal lines*

IEC 1000-1: 1992, *Electromagnetic compatibility (EMC) – Part 1: General*

IEC 1000-2-1: 1990, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 1: Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems*

IEC 1000-2-2: 1990, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 2: Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 1000-2-3: 1992, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 3: Description of the environment – Radiated and non-network-related conducted phenonema*

IEC 1000-4-X, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques* (under consideration)

IEC 1000-4-7: 1991, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 1000-4-8, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 8: Power frequency magnetic field immunity test* (under consideration)

IEC 1000-4-9, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 9: Pulse magnetic field immunity test* (under consideration)

IEC 1000-4-10, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 10: Damped oscillatory field immunity test* (under consideration)

IEC XXX *Static ripple control receivers for tariff and load control* (under consideration)

CCITT Recommendation K 20: 1985, *Resistability of telecommunication switching equipment to overvoltages and overcurrents*

CCITT Recommendation K 21: 1990, *Resistability of subscribers' terminals to overvoltages and overcurrents*

3 General

3.1 In the past, electromechanical devices and systems were generally not sensitive to electromagnetic disturbances (i.e. conducted electric, electrostatic and radiated electromagnetic disturbances). Susceptibility problems mostly arose from "low-frequency" phenomena such as harmonics or voltage interruptions. The electronic components and equipment now in use are much more sensitive to these disturbances, particularly to "high-frequency" and "transient" phenomena. The tremendous expansion in use of electronic components and equipment has increased the danger and importance of malfunctioning, damage, etc. which can arise from electric and electromagnetic disturbances.

In order to avoid or reduce the impact of this problem, numerous IEC product committees and users and manufacturers of electric and electronic equipment have to establish immunity levels that their equipment should withstand and develop corresponding immunity tests. However, these tests originating from various sources may often differ with regard to their characteristics and acceptance criteria.

The aim of this standard is to coordinate and standardize the immunity tests related to electromagnetic disturbances. It provides:

- an overview of the existing tests, or of the tests necessary in the near future;
- general guidance and recommendations concerning the choice of a relevant test and how to apply it, taking into account the type of equipment under test and its intended environment (site, level of the disturbances, required degree of immunity, etc);
- a short description of the tests: their field of application, test methods, test equipment and severity test levels.

3.2 *The following remarks should especially be noted:*

– the main aim of this standard is not to replace tests which already exist but to achieve the necessary coordination and standardization in the field of immunity tests. However, new tests are proposed when they appear to be necessary (as in this standard the tests are described only in a general, summarizing manner, these new tests will have to be specified in detail in further standards);

– neither does this standard intend to specify the tests to be applied to particular apparatus or systems. Its main aim is to give a general basic reference to all concerned product committees of the IEC. The product committees (or users and manufacturers of equipment) remain responsible for the appropriate choice of the tests and the severity level to be applied to their equipment;

– in order not to impede the task of coordination and standardization, the product committees or users and manufacturers are strongly recommended to consider (in their future work or revision of old standards) the adoption of the relevant immunity tests specified in this standard.

NOTE - This standard deals only with the tests related to electromagnetic immunity. For further information about the origin of the disturbances, compatibility levels, etc., see other reports of TC 77 or reports of other technical committees. See IEC 1000-1, IEC 1000-2-1, IEC 1000-2-2 and IEC 1000-2-3.

3.3 *This standard applies to:*

– electric and electronic equipment installed in the environment or connected to:

- LV – residential and commercial public power networks;
- LV – industrial power networks;
- LV – control networks in public and industrial plants (including control rooms);
- LV – power and control networks in electrical stations (including control rooms);
- telecommunication lines.

NOTE - This standard applies also to apparatus with dedicated power sources.

– conducted and radiated disturbances appearing as:

- electric disturbances;
- magnetic disturbances;
- electrostatic disturbances;
- electromagnetic disturbances;

and as:

- low-frequency disturbances (from d.c. to 10 kHz-20 kHz);
- high-frequency disturbances (up to several hundreds of megahertz – radiated up to the gigahertz range);
- transients (duration from a few milliseconds to a few nanoseconds)

due for example to:

- disturbing loads (e.g. non-linear loads, fluctuating loads, etc.);
- switching phenomena and faults in the network and equipment;
- atmospheric phenomena (e.g. lightning);
- static electricity;
- radio transmitters.

This section is intended to cover tests to be applied to a wide range of equipment and systems. However, certain equipment and systems may require different and/or additional tests (e.g. medical, military, maritime equipments, etc.).

3.4 Some immunity tests may be carried out with test waveforms similar to those used for insulation tests (however, generally with lower severity levels). Attention is drawn to the fundamental difference between these two kinds of tests:

- insulation tests are intended for the protection of persons, animals or equipment against the dangers or damages that may be caused by high voltages and concern insulation breakdown. These tests are always carried out with equipment not connected to the power supply;
- immunity tests are intended to check the operation of equipment under the influence of electromagnetic disturbances. During these tests the equipment is always powered and operating normally.

4 Definitions

For the purposes of this section of 1000-4, the following definitions apply. (Some notes comment on their practical application; figures 1 and 2 illustrate some of these definitions and comments.)

NOTE - For a complete terminology about EMC, see IEC 50(161). Where applicable, the references to the International Electrotechnical Vocabulary (IEV) are indicated.

electromagnetic disturbance: Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system. [IEV 161-01-05, modified]

electromagnetic interference: Degradation of the performance of a device, transmission channel or system caused by an electromagnetic disturbance. [IEV 161-01-06 modified]

NOTE - Disturbance and interference are respectively cause and effect.

electromagnetic compatibility: EMC (abbreviation): The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. [IEV 161-01-07]

(electromagnetic) compatibility level: The specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operated in particular conditions. [IEV 161-03-10]

NOTE - In practice the electromagnetic compatibility level is not an absolute maximum level but may be exceeded by a small probability.

immunity (to a disturbance): The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. [IEV 161-01-20]

immunity level: The maximum level of a given electromagnetic disturbance incident on a particular device, equipment or system for which it remains capable of operating at a required degree of performance. [IEV 161-03-14]

(electromagnetic) susceptibility: The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

NOTE - Susceptibility is a lack of immunity. [IEV 161-01-21]

EUT: Abbreviation for "Equipment Under Test"

severity Level: Value of an influencing electromagnetic quantity specified for an immunity test.

NOTE - A test standard can specify several severity levels according to different immunity levels.

transient: Pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest. [IEV 161-02-01]

NOTE - A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity.

voltage surge: A transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage. [IEV 161-08-11]

NOTE - The time parameters of a voltage surge are defined as follows:

- the rise time between 10 % and 90 % of the peak value (10 %/ 90 % rise time) according to IEV 161-02-05;
- the duration at 50 % of the peak value between increase and decrease of the wave (50 %/50 % duration).

power lines: Lines originating from the power supply (alternative or direct voltage).

control lines: In the context of this standard, all the lines for control, signalling and measurement purposes.

common mode voltage, asymmetrical voltage: The mean of the phasor voltages appearing between each conductor and a specified reference, usually earth or frame. [IEV 161-04-09]

differential mode voltage, symmetrical voltage: The voltage between any two of a specified set of active conductors. [IEV 161-04-08]

The theoretical relation between disturbance level, compatibility level, immunity level, susceptibility level is illustrated by figure 1.

However, attention should be drawn to the fact that, generally, the disturbance level is subject to a statistical distribution. In practice it is very difficult, often impossible, to determine the rare actual highest level of disturbance. Also, generally, it would not be economical to define the compatibility level for this highest value to which most devices would not be exposed most of the time.

For these reasons, it seems appropriate to certain technical committees to define the compatibility level not as the "maximum value" of a disturbance but as the level of the disturbance that would be exceeded by only a small or very small number of objects. Typical levels could be for example 95 %, 98 %, 99 % of the statistical distribution. The specification of this value should be set by TC 77 or in particular cases by the relevant product committee or by agreement between the involved parties.

It should be observed that the susceptibility level may also show a statistical distribution. A minimum limit of susceptibility can in practice be defined by a Go/NoGo immunity test level.

The relation between disturbance, compatibility, immunity (test), and susceptibility levels, taking into consideration the statistical distribution of the disturbance and the susceptibility levels, is illustrated by figure 2.

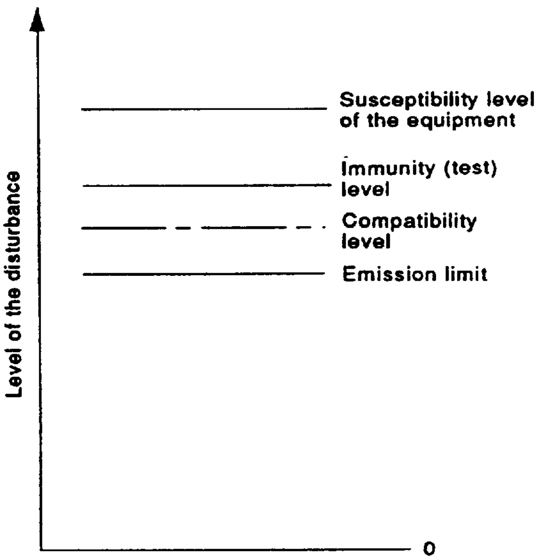


Figure 1 – Relation between different levels of an electromagnetic disturbance

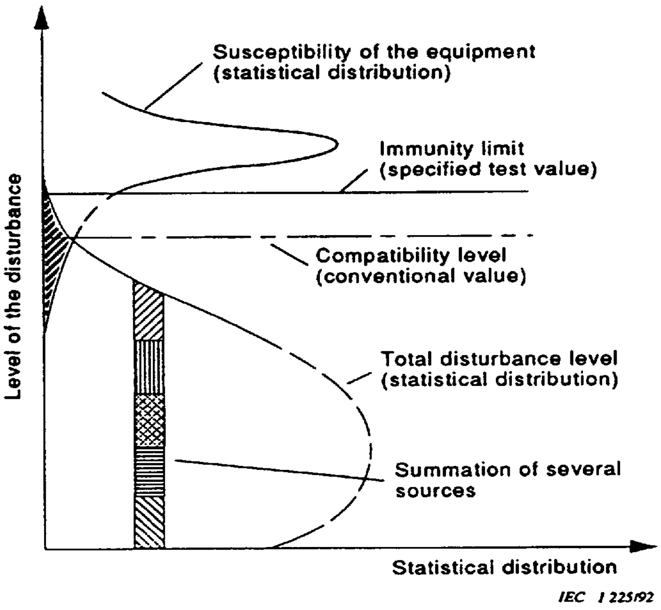


Figure 2 – Relation between the different levels of an electromagnetic disturbance, taking into consideration the statistical features

It can be noted from this that the compatibility level should not be considered as a definite disturbance level but more as a conventional reference value on which the coordination between disturbance level and the immunity/test level can be based.

5 List of immunity tests

Based on the general frame-work outlined in A.1.3, where these tests are briefly described, the following tests are considered to be adequate in order to cover the whole field of disturbances.

5.1 *Low-frequency disturbances*

Immunity tests concerning conducted low-frequency disturbances in low-voltage power supply networks:

1) harmonics;
2) interharmonics;
3) mains signalling systems (from 100 Hz to 150 [450] kHz);
4) voltage fluctuations;
5) voltage dips and short interruptions;
6) three-phase voltage unbalance;
7) power frequency variations;
8) d.c. component in a.c. networks.

5.2 *Conducted transients and high-frequency disturbances*

Immunity tests concerning conducted transients and HF-disturbances:

1) 100/1 300 µs voltage surges (fuse blowing);
2) 1,2/50 µs (voltage) – 8/20 µs (current) surges;
3) fast transients voltage bursts (n x 5/50 ns);
4) ring waves (0,5 µs/100 kHz);
5) damped oscillatory waves (0,1 and 1 MHz);
6) HF induced voltages (0,01 to 1 MHz);
7) conducted radio frequency disturbances;
8) 10/700 µs voltage surges.

5.3 *Electrostatic discharges*

Immunity tests concerning electrostatic disturbances:

1) electrostatic discharges (ESD).

5.4 *Magnetic disturbances*

Immunity tests concerning magnetic disturbances:

1) power frequency magnetic field;
2) pulse magnetic field;
3) damped oscillatory magnetic field.

5.5 *Electromagnetic disturbances*

Immunity tests concerning electromagnetic disturbances:

1) radiated electromagnetic field.

5.6 *Other immunity tests*

1) power frequency voltage on control and signal lines;
2) d.c. voltage on control and signal lines.

6 Environmental conditions

The selection of relevant tests and severity levels for a particular product generally depends on the environmental conditions. In the context of this clause "environmental conditions" include the electromagnetic environment and the conditions of installation. Because of the diversity of these influences, it is necessary to define specific environmental conditions for each group of disturbances.

Low-frequency disturbances in the power low-voltage supply network

Three types of environment are considered:

- public LV-distribution networks with a comparatively low level of disturbances;
- industrial LV-distribution networks with a comparatively high level of disturbances;
- LV networks in electricity stations.

Transients and high-frequency disturbances

The level of disturbances of this type depends:

- on the sources of electromagnetic disturbances;
- on the installation conditions such as shielding, earthing, overvoltage protection, etc.

Electrostatic discharges

The environmental conditions depend essentially on the installation conditions (particularly the type of floor) and on climatic conditions (air humidity). Four environmental classes have been defined, which are indicated in the short description of the electrostatic discharge test in A.3.1 of annex A.

Magnetic disturbances

The influencing magnetic field depends on the current flowing through the conductors in the vicinity of the equipment and the distance between them and the presence of neighbouring magnetic materials. A distinction can be made between equipment intended for LV distribution networks or for electricity stations.

A specification of different classes is under consideration.

Radiated electromagnetic field disturbances

The influencing electromagnetic field depends on the power of the transmitter and its distance from the equipment. The interferences due to hand-held transceivers are considered as being of particular concern. Four classes have been defined, which are indicated in the short description of the radiated electromagnetic test, in A.5.1 of annex A.

7 Guidance for the selection of immunity tests

Immunity tests can be applied to an equipment:

- for design tests during development;
- for type tests;
- for acceptance tests.

An equipment has to be subjected to all the tests necessary to provide the required reliability but, for obvious reasons, the number of tests has to be limited to a reasonable minimum. It is acceptable that the number of tests for acceptance production testing is reduced in comparison with type tests.

The selection of the immunity test to be applied to a particular equipment depends on numerous factors, mainly:

- kinds of disturbances affecting the equipment;
- environmental conditions;
- required reliability and behaviour;
- economic constraints.

With regard to the variety of equipment and environmental conditions to be considered, it is difficult to indicate exact rules concerning the selection of immunity tests. This selection is mainly the responsibility of the product committee concerned or should be fixed by agreement between manufacturer and user. Table 1 can serve as a guideline.

In this table three kinds of environment related to location are differentiated:

a) equipment for installation in the public LV distribution network:

- either for private applications (household and commercial applications) which may have the lowest level of requirements;
- or of utilities applications which, with regard to their particular functions and the long periods of operation without supervision, may have higher requirements to fulfil than the former class.

b) equipment for installation in industrial LV power networks and in industrial control networks, where high disturbances may be expected;

c) equipment for installation in electricity plants (e.g. HV/MV transformer substations) where, due to the special switching and fault phenomena, specific and extreme effects occur.

Particularly well-protected locations for information processing equipment (e.g. computer rooms, control rooms, etc.) and medical equipment have not been included in this table. They should be considered as special locations, characterized by their installation conditions, and by a specific selection of tests and severity levels.

8 Selection of severity levels

For most of the tests, several severity test levels are proposed. Because of the great variety of equipment, the different requirements for these various equipments and the diversity of the environmental conditions, it is not possible to establish precise criteria for the choice of the test level in each particular case. However the following most important factors can serve as guidelines:

- the degree of reliability required by the user under specified environmental conditions;
- the environmental conditions, which indicate the levels of the disturbances;
- the economical constraints: the selection of extreme test values could render the product uneconomical;
- the fact that these factors cannot generally be considered independantly of each other. They play a role together and may even react against each other, for example very high reliability requirements against economical constraints.

The selection of appropriate test levels is the task of the relevant product committee or is subject to an agreement between manufacturers and users; in all cases the technical-economical optimum is to be considered.

Tables in annex A give a survey of the recommended severity levels for the various tests.

9 Evaluation of test results

The variety and diversity of the equipment and systems to be tested make the task of establishing the effects of this test on equipment and systems difficult.

The test results shall be classified on the basis of the operating conditions and functional specifications of the equipment under test, as in the following, unless different specifications are given by product committees or product specifications.

1) Normal performance within the specification limits;
2) Temporary degradation or loss of function or performance which is self-recoverable;
3) Temporary degradation or loss of function or performance which requires operator intervention or system reset;
4) Degradation or loss of function which is not recoverable due to damage of equipment (components) or software, or loss of data.

In case of acceptance tests, the test program and the interpretation of the results have to be described in the specific product standard.

As a general rule, the test result is positive if the equipment shows its immmunity, for all the period of application of the test field, and at the end of the tests the EUT fulfils the functional requirements established in the technical specification.

The technical specification may define effects on the EUT that may be considered insignificant and therefore acceptable.

For these conditions, it shall be verified that the equipment is able to recover its operative capabilities by itself at the end of application of the test. The time interval during which the equipment has lost its full functional capabilities shall therefore be recorded. These verifications are binding for the definitive evaluation of the test results.

The test report shall include the test conditions and the test results.

Table 1 – Guidance for selection of immunity tests

	TESTS	EQUIPMENT LOCATION					
		Public networks including household, office and similar applications		Industrial installations and power plants		Medium-voltage and high-voltage stations	
		Power supply	Control and signal	Power supply	Control and signal	Power supply	Control and signal
	A.1.1 Harmonics	***		***		***	
	A.1.2 Interharmonics	**		**		**	
	A.1.3 Signal voltages	**		**		**	
	A.1.4 Voltage fluctuations	**		***		***	
	A.1.5 Voltage dips and short interruptions	***		***		***	
	A.1.6 Unbalance	*		*		*	
	A.1.7 Power frequency variations	*		*		*	
	A.1.8 D.C. in a.c. networks.	Under consideration		Under consideration		Under consideration	
	A.2.1 100/1 300 µs surge	**		**		**	
	A.2.2 1,2/50 - 80/20 µs surge	***		***	** 1)	***	** 1)
	A.2.3 Fast transient bursts	***	***	***	***	***	***
	A.2.4 Ring wave	**	*	**	** 2)	**	** 2)
	A.2.5 Damped oscillatory waves			**	**	*** 3)	*** 3)
	A.2.6 HF induced voltages			*	*	*	*
	A.2.7 Conducted radio frequency disturbances			Under consideration		Under consideration	
	A.2.8 10/700 µs surge	**		***		***	
	A.3.1 Electrostatic discharges	***		***		***	
	A.4.1 Power frequency magnetic field	**		**		***	
	A.4.2 Pulse magnetic field	*		*		**	
	A.4.3 Damped oscillatory magnetic field			*		**	
	A.5.1 Radiated electromagnetic field	**		***		***	
	A.6.1 Power frequency voltage on control and signal lines		*	***			***
	A.6.2 D.C. voltages on control and signal lines			*			**

Remarks

a) *Types of equipment*

– Public networks
LV equipment for utilities like electricity motors

– Household and office:
LV equipment for private use e.g. heating regulators, washing machines, office machines, etc.

– Industrial installations and power plants:
LV equipment for strongly disturbed networks

– MV and HV stations:
LV equipment in the vicinity of HV equipment

b) *Abbreviations and notes*

*** : Recommended
** : Possible
* : In special cases
Blank: Not relevant

1) Mainly applicable for equipment exposed to lightning (outdoor)

2) Mainly applicable for equipment not exposed to lightning (indoor)

3) Recommended for HV substations; for MV stations may not be necessary

c) *The selection of:*

– the relevant test
– the severity level
is the responsibility of the concerned product committee or is to be fixed by agreement between user and manufacturer

This table gives guidance in the selection of tests

Annex A
(informative)

Short description of immunity tests

The following test descriptions are short summaries of existing IEC standards or proposals for IEC standard tests not yet formally defined at the time of the preparation of this section of IEC 1000-4. These short descriptions are intended as general guidance and only the actual standards or draft standards are binding documents.

References are indicated for each test but only documents issued or under consideration by official bodies are mentioned. These documents should be consulted for more comprehensive information (test set-up, etc.).

The descriptions of tests concerning low-frequency disturbances are related only to 50/60 Hz systems. As for tests related to systems with other frequencies – for example 16 2/3 Hz railway networks – the tests have to be adapted accordingly.

A summary of different tests and possible severity levels are given in tables A.1a to A.1f.

Table A.1 – Guidance for selection of severity levels

Table A.1a – Networks frequency related disturbances

Test		Level	Test values	Application: power supply	Application: control signal
A.1.1 A.1.2 A.1.3	Harmonics Interharmonics Signal voltages		– Compatibility levels x Immunity factor (i.e. 1,2 ... 2,0)	x x x	
A.1.4	Voltage fluctuations		– Voltage steps of: $\Delta U = \pm 8$ % for public networks $\Delta U = \pm 12$ % for industrial networks	x	
A.1.5	Voltage dips and short interruptions		– Voltage dips of: $\Delta U_1 = 30$ % of U_n $\Delta U_2 = 60$ % of U_n – Short interruptions • $\Delta U = 100$ %	x	
A.1.6	Voltage unbalance		–Unbalance factor τi = 2 % $\tau i = \frac{\text{negative sequence voltage}}{\text{positive sequence voltage}}$	x	
A.1.7	Power frequency variations		– normally: + 2 % ... – 2 % – in special cases: + 4 % ... – 6 %	x	
A.1.8	D.C. in a.c. networks		(Under consideration)	x	

Table A.1b – Conducted transient and HF disturbances

Test		Level	Test values	Application: power supply	Application: control signal
A.2.1	100/1 300 µs voltage surge		1,3 x U_n 425 V for 230 V 735 V for 400 V	x	
A.2.2	1,2/50 µs – 8/20 µs voltage – current surge	 1 2 3 4 (x)	open circuit voltage: 0,5 kVp 1,0 2,0 4,0 short circuit current: a) power supply CM: Z = 12 Ω DM: Z = 2 Ω b) control signal CM: Z = 42 Ω subject to agreement	x	x
A.2.3	Fast transient bursts • 5/50 ns • 5/2,5 kHz over 15 ms • bursts period 300 ms	 1 2 3 4 (x)	open circuit voltage: 0,5 kVp 1,0 2,0 4,0 – power supply full values – control signal: half values subject to agreement	x	x
A.2.4	Ring wave test 0,5 µs/100 kHz	 1 2 3 4 (x)	open circuit voltage: 0,5 kVp 1,0 2,0 4,0 – CM: full values – DM half values subject to agreement	x	
A.2.5	Damped oscillatory wave • 0,1 MHz and/or 1 MHz • repetition rate 40 or 400 Hz	 1 2 3 (x)	open circuit voltage: 0,5 kVp 1,0 2/2,5 – CM: full values – DM: half values subject to agreement	x	x
A.2.6	HF induced voltage 1 kHz ... 1 MHz	1 2 3 4 (x)	subject to agreement	x	
A.2.7	Conducted RF disturbance		(Under consideration)	systems	
A.2.8	10/700 µs voltage surge		Open circuit voltage 1 kVp	Telecom/lines	

Table A.1c Electrostatic disturbances

Test		Level	Test values contact	Test values air	Application
A.3.1	Electrostatic discharges	1 2 3 4	2 kV 4 6 8	2 4 8 15	Apparatus and systems

Table A.1d Magnetic disturbances

Test		Level	Test values		Application
A.4.1	Power frequency magnetic field continuous or pulses	 1 2 3 4 5 (x)	Continuous 1 A/m 3 10 30 100	1 ... 3 s pulses - - - A/m - - - - - - 300 1 000 subject to agreement	Apparatus and cubicles
A.4.2	Pulse magnetic field	1 2 3 4 5 (x)	- - - - 100 A/m 300 1 000 subject to agreement		Apparatus and cubicles
A.4.3	Damped oscillatory magnetic field • 0,1 and 1 MHz • repetition rate 40 or 400 Hz	1 2 3 4 5 (x)	- - - - 10 A/m 30 100 subject to agreement		Apparatus and cubicles

Table A.1e Electromagnetic disturbances

Test		Level	Test values	Application
A.5.1	Radiated electromagnetic field 26 MHz to 1 000 MHz	1 2 3 (x)	1 V/m 3 10 subject to agreement	Apparatus and systems

Table A.1f Various tests

Test		Level	Test values	Application
A.6.1	Power frequency voltage on control and signal lines		Under consideration	
A.6.2	D.C. voltage on control and signal lines		Under consideration	

CM = common mode (line to ground)
DM = differential mode (line to line)

A.1 Immunity tests: low-frequency disturbances

A.1.1 *Harmonics (provisional test)*

A.1.1.1 *References*

See IEC 1000-2-1, IEC 1000-2-2 and future publications in the IEC 1000 series.

A.1.1.2 *Purpose of the test – Range of application*

The purpose of the test is to investigate the effects of harmonics in low-voltage supply networks on equipment that could be sensitive to such frequencies. These effects can be of two types:

- a short quasi-instantaneous effect, which may range from an occasional malfunctioning up to damage of an electronic component.
- a long-term effect such as excessive heating.

The tests apply to all types of equipment intended for low-voltage public distribution networks, industrial networks and electricity substations.

A.1.1.3 *Test voltage characteristics*

The test voltage consists of one or a combination of several continuous sine-waves superimposed on the power supply voltage.

Generally it is sufficient to consider only the harmonics up to the 40th rank (2 000 Hz at 50 Hz, 2 400 Hz at 60 Hz).

A.1.1.4 *Test equipment/Test generator*

Three arrangements are possible, depending on the 50/60 Hz power requirement:

a) for small power ratings, use can be made of an amplifier supplying the 50/60 Hz power and the harmonics (see figure A.1);

b) for higher power ratings, use can be made of a series injection circuit where the mains supplies the 50/60 Hz power and the amplifier delivers only the harmonics – see figure A.2 (this arrangement can be trebled for three-phase equipment);

c) for high frequencies, an arrangement with a parallel injection circuit and a back filter according to figure A.3, is also possible.

If the phase angle relationship of the harmonic to the power frequency voltage plays a role, means shall be provided to vary the phase angle, by using either a variable phase shifter or a harmonic source with a frequency deviating slightly from the exact harmonic frequency and producing a continuous phase variation.

NOTE - For long-duration tests and/or high power ratings when no harmonic generator of sufficient power is available, in certain cases use can be made of an equivalent power frequency voltage with a value of:

$$U'_n = [U_n^2 + \Sigma \alpha_h \times U_h^2]^{1/2}$$

(where α_h are factors to be defined by the relevant product committee).

A.1.1.5 *Recommended severity levels*

The test severity levels can be based on the compatibility levels for harmonic voltages enhanced by a factor to be specified by the relevant product committee. Table A.1.1 indicates the compatibility level specified in IEC 1000-2-2. Usually, the immunity factor will be chosen in the range between 1,2 and 2,0. When testing with several harmonics at the same time, the immunity factor may be reduced even below 1, because of the very low probability that all the harmonics will occur with the maximum value. Care should be taken not to exceed the permissible total distortion factor.

A.1.1.6 *Remarks on the test procedure*

The harmonics to be considered depend on the EUT characteristics:

- if the EUT is a frequency selective device (e.g. a ripple control receiver) the test can be carried out with the relevant disturbing harmonics;

- if the EUT is sensitive to the whole range of harmonics (e.g. capacitors), theoretically the test should be carried out with all the harmonics. However, this is not practicable and the whole range of harmonics can be replaced by one or a limited number of harmonics producing an equivalent disturbing effect;

- in certain cases – such as for heating tests for rotating machines or capacitors – the level of each considered harmonic should be weighted according to the influence of the frequency.

Table A.1.1 – Compatibility levels for individual harmonic voltages in low-voltage networks (IEC 1000-2-2)

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3		Even harmonics	
Rank *n*	U_n %	Rank *n*	U_n %	Rank *n*	U_n %
5	6,0	3	5	2	1 2,0
7	5,0	9	1,5	4	0,5 1,0
11	3,5	15	0,3	6	0,5
13	3,0	21	0,2	8	0,5
17	2,0	> 21	0,2	10	0,5
19	1,5			12	0,2
23	1,5			> 12	0,2
25	1,5	...			
> 25	0,2 + 0,5 25/*n*				
Admissible total distortion factor: 8 %.					

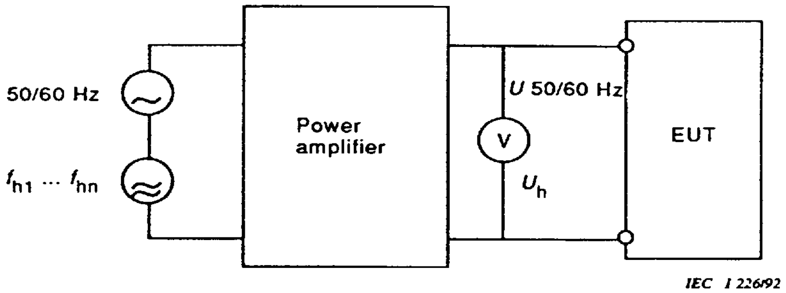
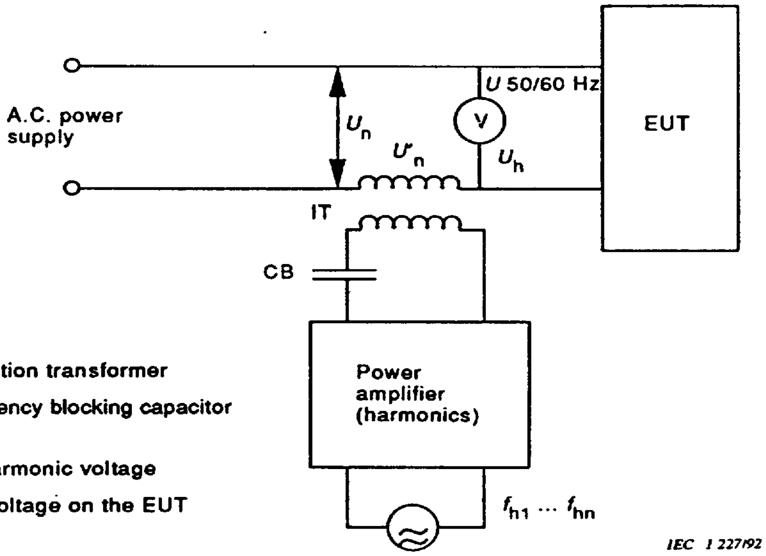


Figure A.1 – Schematic of a harmonics* test equipment for small power ratings



Legends:

IT is the series injection transformer

CB is the power frequency blocking capacitor

U'_n is the injection harmonic voltage

U_h is the harmonic voltage on the EUT

Figure A.2 – Schematic of a harmonics* test equipment for high power ratings (series injection)

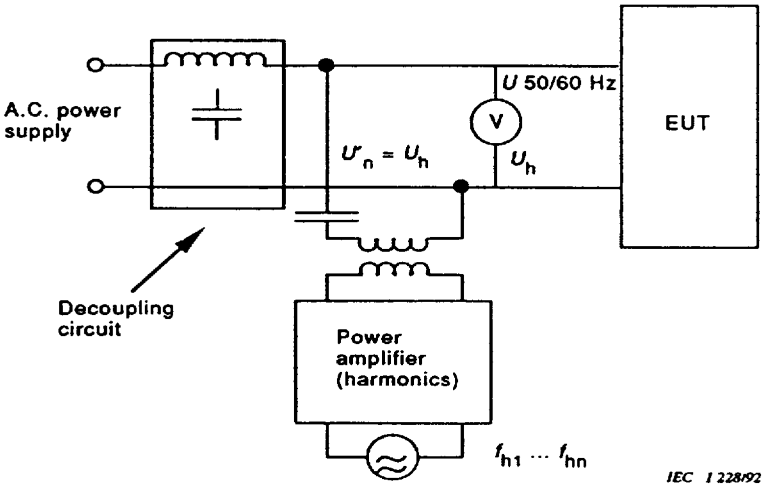


Figure A.3 – Schematic of a harmonics* test equipment for high frequencies (parallel injection with back filter)

* These schematics are also valid for tests with inter-harmonics and superimposed signals.

A.1.2 *Interharmonics (provisional test)*

A.1.2.1 *References*

See IEC 1000-2-1 and 1000-2-2.

A.1.2.2 *Purpose of the test – Range of application*

The purpose of the test is to investigate the effects of interharmonics in the low-voltage supply networks (voltages with a frequency between the harmonics) on equipment that could be sensitive to such frequencies. There are two types of interharmonic sources:

- discrete frequencies (e.g. static frequency converters, cyclo-converters);
- continuous spectrum (e.g. arc furnaces).

The effect of interharmonics on sensitive devices can be the same as of the harmonics: either short term effects causing possibly malfunctions or long-term effects e.g overheating.

A test for interharmonics should apply only in special cases e.g:

- for narrowband frequency selective equipment with a particular sensitivity to a specific interharmonic;
- for broadband sensitive equipment aimed to be installed in a location with a high interharmonic level (e.g. in the vicinity of large arc furnaces).

For the great majority of equipment, the test with harmonics should be sufficient to cover the requirements.

A.1.2.3 *Test voltage characteristics*

For discrete interharmonic frequencies, as for the harmonics, a continuous sine-wave of appropriate magnitude is superimposed on the power supply voltage.

For continuous spectra, it should be noted that, in practice, in the networks, such spectra have an amplitude varying with the frequency – depending on the source characteristics and the network impedance – and fluctuating continuously in the course of time. So far, no standard spectrum has been defined that can be reproduced unequivocally for test purposes. Until such a standard spectrum can be defined, it should be agreed from case to case on the test voltage characteristics. In particular, the possibility of using a representative equivalent single frequency should be considered.

A.1.2.4 *Test equipment/Test generator*

The test equipment is essentially the same as for the test with harmonics where the harmonic sources are replaced by a source of interharmonics (see figures A.1, A.2 and A.3).

In the case of a continuous spectrum, the source of interharmonics can consist of a noise generator the output of which passes through an appropriate filter producing the required amplitude versus frequency characteristic. Attention is drawn to the fact that series injection circuits like the ones in figures A.2 and A.3 may be very frequency dependant.

A.1.2.5 *Recommended severity levels*

The following information can serve as a guide for setting the compatibility level.

Discrete interharmonic the frequencies may have a level of 0,5 % of the fundamental frequency voltage U_n (in the absence of resonances) but must be reduced to less than 0,1 % of U_n when they could disturb ripple control systems.

Continuous spectra show usually a background level ≤ 0,02 % of U_n measured with a 10 Hz bandwidth. They show a higher level in the case of arc furnaces and similar equipment, depending on the circumstances.

The test levels have to be agreed upon from case to case: they may be set as equal to the compatibility level enhanced by an immunity factor chosen for example between 1,2 and 2,0.

A.1.2.6 *Comments on the test procedure*

The test with interharmonics can be carried out with or without the harmonics inside – or adjacent to – the considered frequency band.

The measurement of discrete interharmonics is similar to that of harmonics. The measurement of a continuous spectrum can be carried out in two ways:

- either measurement of the total r.m.s value in the considered frequency band;

- or measurement of the voltage density spectrum with a band filter (Δf = 3 Hz or 10 Hz).

A.1.3 *Signal voltages (provisional test)*

A.1.3.1 *References*

See IEC 1000-1 and IEC 1000-2-1.

A.1.3.2 *Purpose of the test – Range of application*

The purpose of the test is to investigate the effect of signal voltages in the low voltage supply networks or equipment that could be sensitive to such signals. Four types of signals are in use (or under consideration for new systems):

- "audio frequencies" in the range 110 Hz to 2 000 Hz (ripple control);
- "medium frequencies" in the range 3 kHz to 20 kHz (MF-power line carriers);
- "radio frequencies" in the range 20 kHz to 150 (500) kHz (RF-power line carriers);
- mark on the mains voltage curve (mains marks systems).

As the signals are transmitted intermittently in the form of pulses, only short-term effects should be investigated.

The test may be applied to equipment installed in low-voltage public distribution networks, in industrial networks or in electricity plants susceptible to be disturbed by short time pulses.

A.1.3.3 *Test voltage characteristics*

"Frequency-signals" are sine waves superimposed on the power supply voltages. "mains marks" signals should be sent with their specific shape.

A.1.3.4 *Test equipment/Test generator*

For "frequency signals" three different arrangements may be considered:

- for low power ratings of the EUT, the same amplifier arrangement as for harmonics, with an amplifier supplying the 50/60 Hz power as well as the signal (see figure A.1);
- for high power ratings and for low frequencies – for example up to 10 kHz – the same series injection arrangement as for harmonics (see figure A.2);
- for high power ratings and for medium and radio frequencies a parallel injection arrangement with back filter (see figure A.3).

In all of these arrangements, an impulsing device giving the signals according to the system code should be inserted.

For the mains marks signal a specific test equipment is necessary.

A.1.3.5 *Recommended severity levels*

In the audio-frequency range up to 2 000 Hz, the highest values of the compatibility levels for harmonics in the neighbourhood of the signals frequency (i.e. the odd harmonics non-multiple of 3) can be used for guidance. The severity levels should be enhanced by an appropriate immunity factor, i.e. 1,2 to 2,0, as in the harmonics.

NOTE - In countries where there exists a regulation concerning the maximum allowed ripple control signal levels (i.e. the so-called "Meister curve"), by agreement between user and manufacturer, these values, possibly enhanced by a small appropriate immunity factor, can also be considered.

As for the medium and radio frequency ranges, at the time this section of 1000-4 is being prepared, the compatibility levels are under consideration. Until definite results exist, immunity tests can be carried out with the maximum signal level as indicated by the manufacturer of the signalling system enhanced by an appropriate immunity factor.

With regard to mains marks signals, tests should also be carried out with the signal level indicated by the manufacturer, enhanced by an appropriate immunity factor.

A.1.3.6 *Comments on the test procedure*

Because the signals are coded according to different patterns, it is possible to check whether a certain appliance is more susceptible to coded signals than to continuous ones.

Some devices may also be sensitive to harmonics of the signal frequency; when this can be suspected, an immunity test at these frequencies should also be considered.

For the measurement of the signal levels, instruments appropriate to the coded pulses or type of signal are to be used.

A.1.4 *Voltage fluctuations (provisional test)*

A.1.4.1 *References*

See IEC 1000-1 and IEC 1000-2-1.

A.1.4.2 *Purpose of the test – Range of application*

Voltage fluctuations are defined as fast variations of the supply voltage within the normal (possibly contractual) variation range during normal operation of the network, i.e. ± 10 % U_n.

The purpose of the test is to verify the immunity of equipment which may be sensitive to fast voltage fluctuations in the LV-power supply network.

Such fluctuations are produced for example by:

- continuously but randomly varying large loads (e.g. arc furnaces);
- single on/off switching of loads (e.g. motors);
- step voltage changes (due to tap voltage regulators of transformers).

NOTE - These fast voltage fluctuations are to be differentiated from the normal slow voltage variations due to the normally increasing or decreasing loads.

Fast voltage fluctuations could possibly affect the operation of sensitive electronic equipment: electronic control devices, computers, etc.

NOTE - This type of interference should not be confused with the flicker effect which is a physiological phenomenon due to luminance fluctuations of the lighting.

This test may apply to all equipment intended for public networks, industrial networks and electricity plants likely to be sensitive to this type of disturbance.

A.1.4.3 *Test voltage characteristics*

It can be assumed that step voltage changes are the most disturbing type of voltage fluctuations.

The EUT is initially in operation at a steady mains voltage and is then subjected to repetitive step voltage changes according to figure A.4.

A.1.4.4 *Test equipment/Test generator*

A schematic of a possible arrangement is represented in figure A.5.

A.1.4.5 *Recommended severity levels*

The initial voltage is set to:

U_n (rated value), U_n + 10 %, U_n – 10 %

The magnitude of the voltage steps can be chosen as follows:

- ΔU = ± 8 % of U_n for equipment intended for public networks or other lightly disturbed networks;
- ΔU = ± 12 % of U_n for equipment utilized in heavily disturbed networks (i.e. industrial networks).

The repetition period T and the duration of the voltage fluctuations are to be specified; T = 5 s to 10 s, t = 2 s to 3 s can be taken as a general guide.

NOTE - The upper and the lower voltage operation limits defined by the product manufacturer should not, however, be exceeded.

A.1.4.6 *Comments on the test procedure*

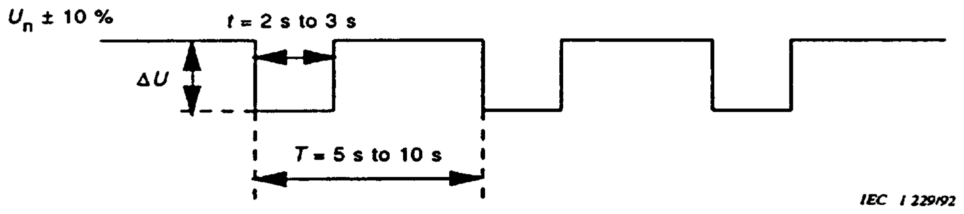


Figure A.4 – Example of a voltage fluctuation sequence

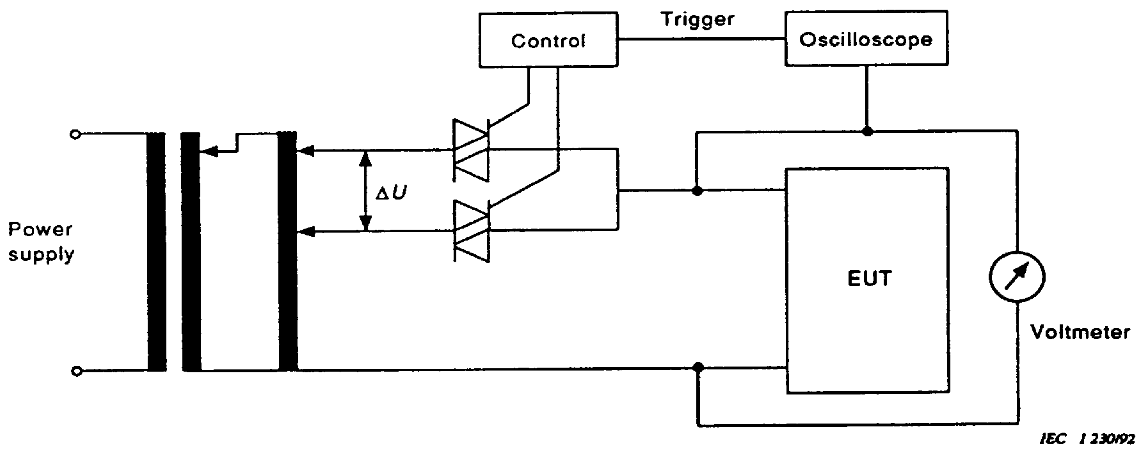


Figure A.5 – Schematic of a generator

- for voltage step changes
- for voltage dips and short voltage interruptions

A.1.5 *Voltage dips and short interruptions* (under consideration)

A.1.5.1 *References*

See IEC 1000-1, IEC 1000-2-2 and future publications in the series IEC 1000.

A.1.5.2 *Purpose of the test – Range of application*

Voltage dips are occasional voltage drops greater than 10 % to 15 % of U_n and of short duration (0,5 period to 50 periods). Short voltage interruptions are voltage dips of 100 % U_n.

The purpose of the test is to verify the immunity of equipment which may be sensitive to voltage dips and short voltage interruptions. Voltage dips and interruptions are caused by faults in the LV, MV or HV networks (short circuits or ground faults). In particular, dips or interruptions subsequent to fault switching with rapid reclosure with a duration of 0,5 s are to be considered.

The effects of voltage dips or interruptions can be of different types, for example:

- tripping of contactors;
- incorrect operation of regulating devices;
- commutation failures in converters;
- loss of data in computer memories, etc.

A.1.5.3 *Test voltage characteristics*

The EUT is initially in operation at its rated voltage and is then subjected to voltage dips or interruptions according to figure A.6.

A.1.5.4 *Test equipment/Test generator*

The same equipment as for the voltage fluctuation test may be used (see figure A.5).

A.1.5.5 *Recommended severity levels*

The following test values are recommended:

	U	Duration
Voltage dips	30 %	0,5 to 50 periods
	60 %	
Voltage interruptions	100 %	

The choice of the duration(s) depends on the type of process and/or of equipment (short durations particularly for devices with memories).

Further, in order to simulate the conditions in certain networks a test with a cycle of two consecutive dips/interruptions with a variable time interval may also be considered.

A.1.5.6 *Comments on the test procedure*

In the case of three-phase equipment, it may be necessary to apply voltage dips either on all the three phases simultaneously or on one or two phases only.

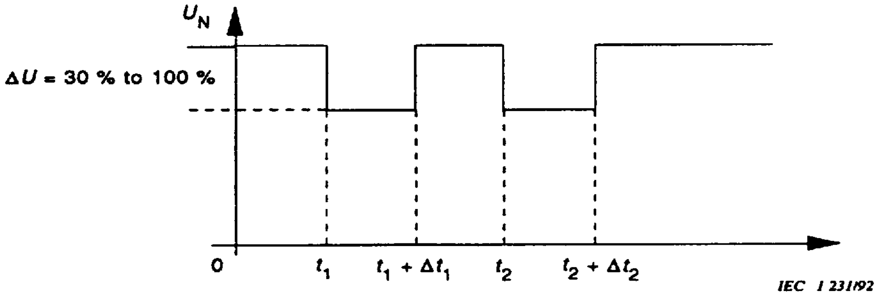


Figure A.6 – Example of a test cycle with two voltage dips

A.1.6 *Three-phase voltage unbalance (provisional test)*

A.1.6.1 *References*

See IEC 1000-1, IEC 1000-2-2 and IEC 34-1.

A.1.6.2 *Purpose of the test – Range of application*

The purpose of the test is to investigate the influence of unbalance in a three-phase voltage system on equipment which may be sensitive to this disturbance e.g.:

- overheating of a.c. rotating machines;
- generation of non-characteristic harmonics in electronic power converters.

The degree of unbalance is defined by the unbalance factor

$$i = \frac{U_i}{U_d} \quad \frac{\text{negative sequence voltage}}{\text{positive sequence voltage}}$$

The test applies only to three-phase equipment.

A.1.6.3 *Test voltage characteristics*

A power frequency three-phase voltage is applied to the EUT with the specified unbalance factor. In order not to falsify the test, this voltage should have only a very small harmonics content.

A.1.6.4 *Test equipment/Test generator*

The simplest test arrangement consists of three single-phase auto transformers, whose outputs are regulated individually.

A.1.6.5 *Recommended severity levels*

Unless otherwise specified, the test is to be carried out with an unbalance factor of 2 % (see IEC 1000-2-2).

A.1.7 *Power frequency variations (provisional test)*

A.1.7.1 *References*

See IEC 1000-1 and IEC 1000-2-2.

A.1.7.2 *Purpose of the test - Range of application*

The purpose of the test is to investigate the effects of power frequency variations on equipment which may be sensitive to this type of disturbance. The effects are generally instantaneous ones: measurement error, loss of synchronization, ...

As the power frequency in interconnected networks varies only in a very narrow frequency band around the rated frequency (50/60 Hz) this test applies only to special cases:

- equipment that has to operate particularly at large power frequency variations;
- equipment to be installed in small networks isolated from a large interconnected system.

A.1.7.3 *Test voltage characteristics*

The EUT is powered by a generator with an output frequency varying within a range of ±10 % for example.

A.1.7.4 *Test equipment/Test generator*

Any power frequency generator, power amplifier, frequency converter, diesel generator group, etc. may be used. The output voltage should not have a high harmonic content.

A.1.7.5 *Recommended severity levels*

The test values are to be specified for each particular case. The following indications can serve as a guide:

- normal frequency variation range:
  (f_n ± 2) % i.e. 51,0 Hz to 49,0 Hz, 61,2 Hz to 58,8 Hz;
- large frequency variation range (special cases)
  (f_n + 4/– 6) % i.e. 52 Hz to 47 Hz, 62,4 Hz to 56,4 Hz.

In cases where, for a particular equipment, the rate of frequency variation and the duration of the test may have an effect, these values should also be specified by the relevant product committee or by agreement between user and manufacturer.

A.1.8 *D.C. in a.c. networks* (under consideration)

A.1.8.1 *Purpose of the test – Range of application*

This test is intended to verify the immunity of equipment that may be sensitive to a direct voltage component superimposed on the supply voltage. Such d.c. components may be caused by asymmetrical loads with regard to the a.c. wave form, to unbalanced a.c.-d.c. converters, etc.

The range of application and the test specifications are under consideration.

A.2 Immunity tests: transients and high-frequency conducted disturbances

A.2.1 *100/1 300 μs voltage/current surge* (under consideration)

A.2.1.1 *Reference*

See the relevant section of IEC 1000-4.

A.2.1.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of equipment: single apparatus or systems against transients generated by the blowing of high rated fuses in LV-supply networks. These transients have the following general characteristics:

- unidirectional pulses or rapidly damped oscillatory waves;
- long duration (50 %/50 % duration up to 10 ms);
- long rise time of the unidirectional pulses (10 %/90 % up to 200 μs);
- low magnitude, only 2 U_n to 3 U_n;
- high energy content.

Because of their long duration and their high energy content, despite the low magnitude, such transients can influence the operation of electronic equipment or cause some damage.

The test may apply to sensitive electronic equipment intended to be connected to LV power distribution networks or to LV power networks of electricity stations. However, for high power electronic equipment, the test equipment may be too large and expensive, so that replacing the test in this case by a calculation method is envisaged.

A more precise specification of the range of application of this test is under consideration.

A.2.1.3 *Test wave characteristic*

It is considered that this type of transient can be represented by an unidirectional surge of approximately 100/1 300 μs superimposed on the positive and negative peak of the power frequency voltage curve (see figure A.7).

A.2.1.4 *Test generator/Test equipment*

Under consideration.

A.2.1.5 *Recommended severity levels*

The magnitude of the surge should be 1,3 $\hat{U}_n$

for example for U_n = 230 V; U_p = 425 V
= 400 V; U_p = 735 V

The test voltage is applied on the supply terminals of the equipment, between phases and neutral or between phases and is superimposed on the supply voltage sinusoid (see figure A.7).

A.2.1.6 *Comments on the test procedure*

The test is applied three times with each polarity, on the peak of the corresponding half-wave.

The time interval between the tests shall be long enough to allow protection devices to recover, i.e. 1 min. It is a test to be carried out generally in a laboratory, not on site.

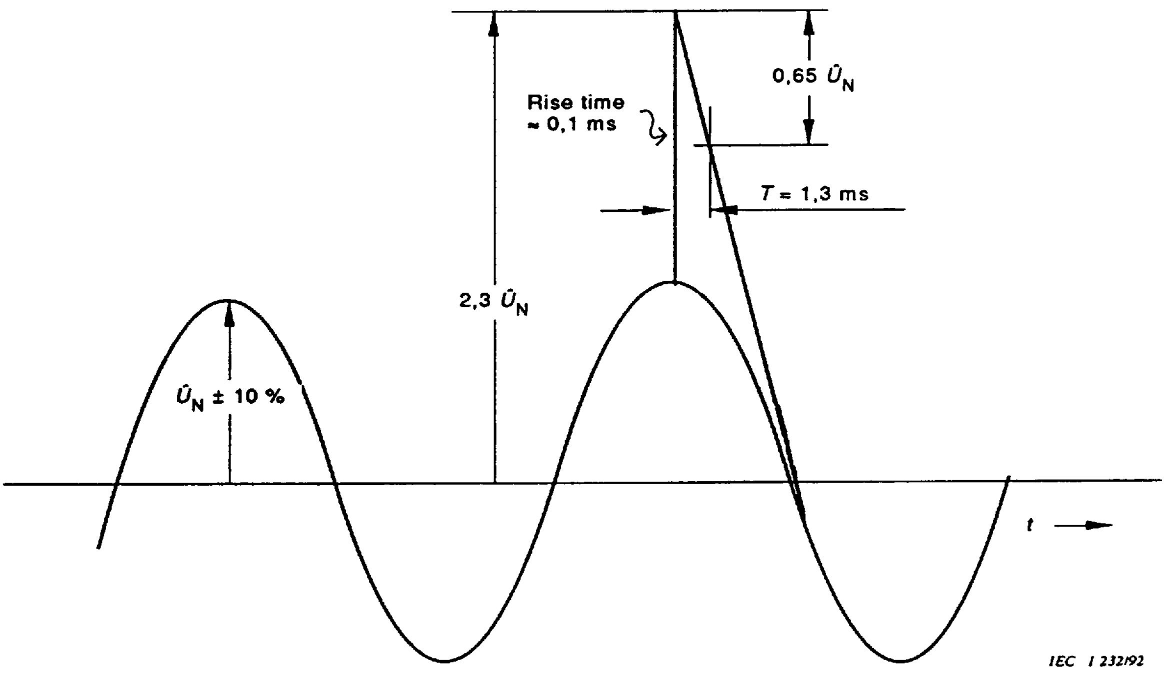


Figure A.7 – Shape of a representative long duration pulse

A.2.2 *1,2/50 µs (voltage) – 8/20 µs (current) surge* (under consideration)

A.2.2.1 *Reference*

See IEC 801-5 and IEC 1000-4-5 (under consideration).

A.2.2.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of equipment against unidirectional transients caused by the following phenomena:

- switching phenomena in the power network (e.g. switching of capacitor banks);
- faults in the power network;
- lightning strokes (direct or indirect strokes).

The induced voltage surge can produce different effects, depending on the relative impedance of the source and of the EUT:

- if the EUT has a high impedance relative to that of the source, the surge will produce a voltage pulse on the EUT terminals;
- if the EUT has a relatively low impedance, the surge will produce a current pulse.

This behaviour can be illustrated by an input circuit protected by an overvoltage suppressor: as long as the latter does not break down, the input impedance is high, when it breaks down the input impedance becomes very low. A realistic test shall correspond to this behaviour and the test generator shall be able to deliver a voltage pulse to a high impedance just as well as a current pulse to a low impedance (combination wave generator).

The test applies:

- to all types of equipment;
- to their a.c or d.c. power supply lines or terminals, to the input/output control and signal lines or terminals;
- between lines (line to line) or line(s) and ground.

Remarks

a) This combined test replaces previous separate tests by either voltage or current tests.

b) For equipment connected to LV public networks, this test is complementary to the ring wave test or the damped oscillatory wave test 0,1 MHz that cover mainly transients appearing in cable networks (see tests of A.2.4 and A.2.5).

c) This immunity test is not to be confused with the surge withstand test, that has another purpose (safety) and is carried out with higher voltages and without the equipment being energized.

A.2.2.3 *Test waves characteristics*

It is appropriate to consider the same wave for the surge voltage withstand test and the surge over current test because immunity and insulation effects are two different consequences of the same transients in the network.

Therefore the test surges should have the following basic characteristics:

- open-circuit generator – a voltage pulse 1,2/50 μs (see figure A.8);
- short-circuited generator – a current pulse 8/20 μs (see figure A.9).

Depending on the generator impedance and on the EUT impedance, which can vary during the test, the actual voltage or current waveform may significantly differ from the above characteristics (see also annex B).

The source impedance (i.e. the generator impedance for this test) may be chosen as follows:

- for a low-voltage supply network between two lines: approximately 2 Ω;
- for a low-voltage supply network between a line and ground: approximately 12 Ω;
- for all other lines (measure, control) between a line and ground: approximately 42 Ω.

Therefore the generator impedance must be variable.

A.2.2.4 *Test generator/test equipment*

The test generator shall be capable of delivering, in open circuit, a voltage pulse, as well as, in short circuit, a current pulse of the specified forms and magnitudes. Figure A.10 represents the schematic of such an "hybrid" generator.

The main characteristics shall be as follows:

- open circuit output voltage ±10 %: 0,5 kVp to 4 kVp;
- short circuit output current ±10 %: 0,25 kAp to 2 kAp, under consideration (presently in IEC 801-5 and future IEC 1000-4-5).

Generator impedance:

- generator itself: 2 Ω
- with additional resistances of 10 to 40 Ω: 12 Ω or 42 Ω.

Generator impedance for differential mode tests: 2 Ω.

Polarity: positive and negative.

Phase shifting in the whole range of 360°.

Maximum repetition rate: at least one per min.

The test equipment comprises also:

- a coupling circuit of one of the following types:
  - a capacitive coupling (parallel coupling) for power or control lines;
  - an inductive coupling (coupling through a series transformer) for power or control lines;
  - a gas arrester coupling for telecommunication lines;
- a decoupling circuit (back filter);
- an appropriate measuring instrument (oscilloscope) with a frequency range equal to or over 10 MHz.

A.2.2.5 *Recommended severity levels*

The selection of the test level for a particular apparatus or system depends on the environment and installation conditions where it will be used. The following classification gives general guidance (for industrial process measurement and control instrumentation, see IEC 1000-1).

Class 0:
- very well protected environments;
- surge voltage remains very low (i.e. ≤ 25 Vp);
- i.e. very well protected computer rooms;

Class 1:
- well protected environments, not strongly exposed;
- surge voltage may not exceed 500 Vp;
- i.e. control rooms of industrial plants or electrical stations;

Class 2:
- protected environments but less than class 1;
- surge voltage may not exceed 1 kVp;
- i.e. industrial plants not strongly disturbed;

Class 3:
- normally disturbed environments, no special measures of installation;
- surge voltage may not exceed 2 kVp;
- i.e. public distribution cable networks, industrial process areas, substation areas, etc.;

Class 4:
- heavily disturbed environments;
- surge voltage may reach 4 kVp;
- i.e. public distribution overhead networks, HV substations in unprotected locations;

Class X:
- special.

The following test levels may be applied:

Class	Line to line U_p (kV)	Line to ground U_p (kV)
0	No test	
1	–	0,5
2	0,5	1,0
3	1,0	2,0
4	2,0	4,0
x	Subject to agreement	
U_p is the open circuit voltage		

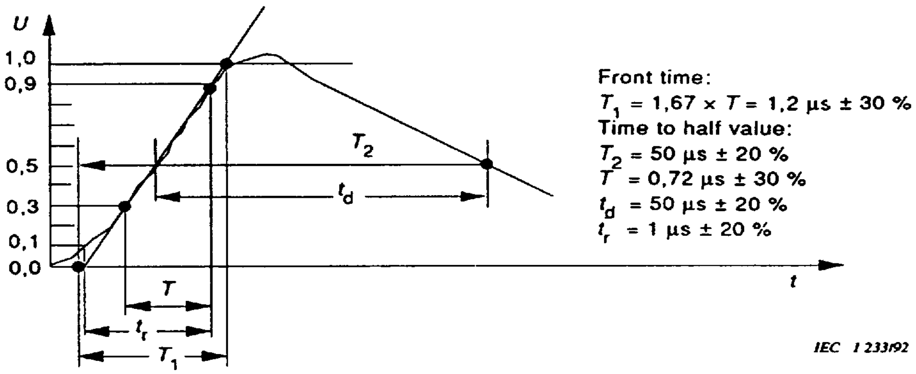
The same levels apply to power lines and input/outputs.

A.2.2.6 *Comments on the test procedure*

The test is to be carried out at least five times with each polarity, if possible each time at a different position on the mains voltage wave. The time between two surges depends on the recovery time of the (built-in) protection (e.g. repetition rate: one per minute).

It is essentially a laboratory test. Two types of tests may be considered:

- basic immunity tests on a single EUT;
- system/installation test on a whole system.



NOTE - 1 = 100 %

Figure A.8 – Open-circuit voltage waveform

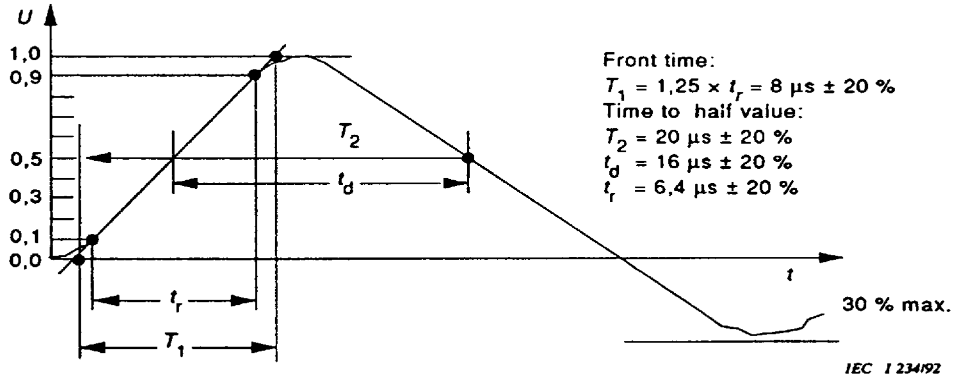
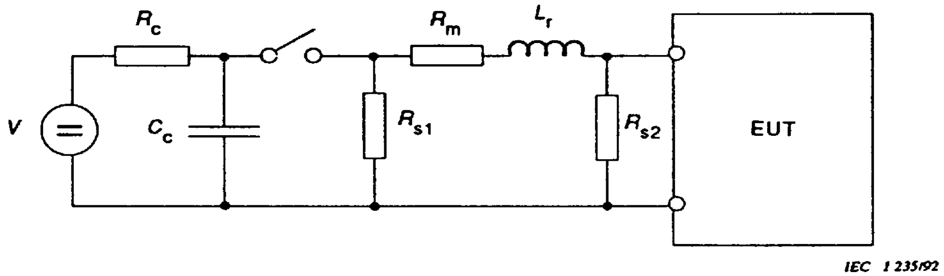


Figure A.9 – Short-circuit current waveform



V	is the high-voltage source
R_c	is the charging resistor
C_c	is the energy storage capacitor
R_s	is the pulse duration shaping resistor
R_m	is the impedance matching resistor
L_r	is the impedance matching inductor

Figure A.10 – Schematic of a combination wave generator

A.2.3 *Fast transient bursts* (publication)

A.2.3.1 *Reference*

See IEC 801-4 and IEC 1000-4-4 (under consideration).

A.2.3.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of the equipment: single device or systems, against bursts of very short transients generated for example by:

- the switching of small inductive loads, relay contacts bouncing (conducted interferences);
- the switching of HV-switchgear – particularly SF_6 or vacuum switchgear (radiated interferences).

The significant characteristics of these transients are fast rise time, short duration, low energy but with high repetition rate. They are likely to disturb electronic equipment but generally less likely to cause damage.

The test applies according to the following:

- to the a.c. or d.c. power supplies and the control and signal lines of the EUT;
- to equipment used by electricity suppliers and other utilities;
- to equipment used in industrial plants;
- to equipment for private use on LV public distribution networks.

A.2.3.3 *Test wave charateristics*

The test is performed with repetitive bursts of short pulses as represented in figures A.11 and A.12.

- rise time of a pulse 10 %/90 %: 5 ns ± 30 %;
- pulse duration 50 %/50 %: 50 ns ± 30 %;
- repetition frequency: 5 or 2,5 kHz;
- duration of a burst: 15 ms;
- burst period: 300 ms.

A.2.3.4 *Test generator/test equipment*

A schematic of the test generator is represented in figure A.13.

- open-circuit output voltage: 0,25 kVp to 4 kVp;
- dynamic impedance: 50 % ± 20 %;
- polarity: positive/negative;
- relation to power supply: asynchronous.

The test equipment also comprises (see IEC 801-4):

- for tests on the power ports of the EUT:
  - a coupling device, in practice a coupling capacitor of 33 nF;
  - for laboratory tests, in addition a decoupling (blocking) circuit;
  - for field tests this circuit is not used.
- for tests on the control and signal ports of the EUT:
  - a coupling device, either a capacitive coupling clamp;
  - or a conductive foil enveloping the lines;
  - or coupling capacitors of 100 pF for each line.
- an appropriate measurement equipment (oscilloscope) with a frequency range greater than 400 MHz.

A.2.3.5 *Recommended severity levels*

Level	Power supply earth terminal U_p kV	Repetition rate kHz
1	0,5	5
2	1	5
3	2	5
4	4	2,5
x	Subject to agreement	

Level	Input output U_p kV	Repetition rate kHz
1	0,25	5
2	0,5	5
3	1	5
4	2	5
x	Subject to agreement	

U_p (kV) is the open-circuit voltage of the generator.

The test voltage shall be applied to the different types of lines or terminals of the EUT.

- Power supply lines (a.c. or d.c.):

The test voltage is applied in common mode between each of the power supply terminals and the nearest protective earth point or reference ground plane.

- Control and signal lines and communication lines:

The test voltage is applied in common mode preferably with the capacitive coupling clamp or otherwise with one of the other methods.

- Protective earth terminals of cabinets:

The test voltage is applied between these terminals and the reference ground plane.

The appropriate test severity levels shall be specified independently for the power supply port and the control and signal ports. The two levels may be the same or different according to the operational conditions, the installation conditions and protection measures (i.e. for industrial process measuring and control equipment, the severity level on the control and signal ports of the EUT is half the severity level on the power port).

Level 1 could apply to equipment installed in a well-protected environment (e.g. computer room).

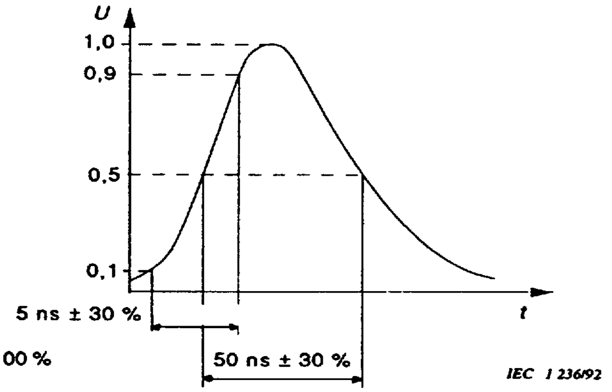
Level 2 could apply to equipment installed in a normally protected environment (e.g. computer and control rooms of industrial or electrical plants).

Level 3 could apply to equipment installed in an unprotected environment (e.g. public distribution networks, industrial process areas, substations areas, etc.).

Level 4 could apply to equipment for heavily disturbed environments (e.g. substations with gas insulated switchgear (GIS) or vacuum switchgears).

A.2.3.6 *Comments on the test procedure*

The minimum duration of the test is 1 min. The test applies to laboratory and field tests.



NOTE – 1 = 100 %

Figure A.11 – Waveform of a single spike into 50 Ω load

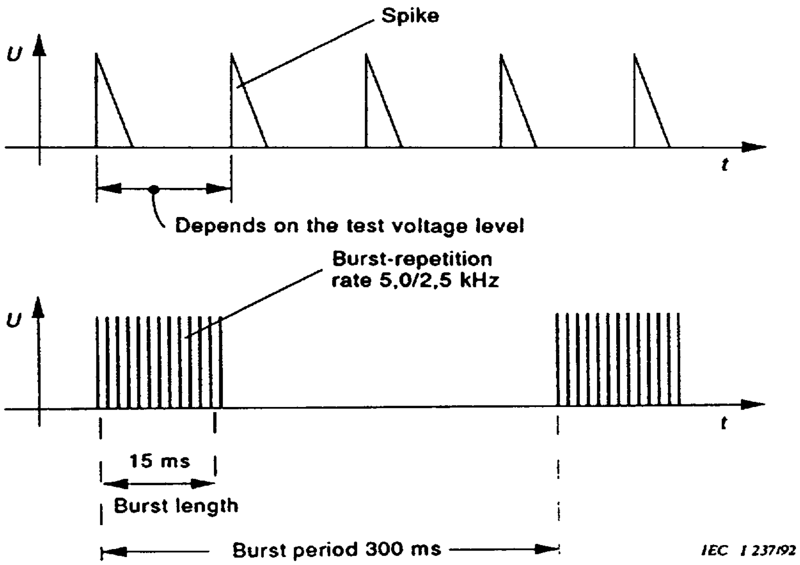
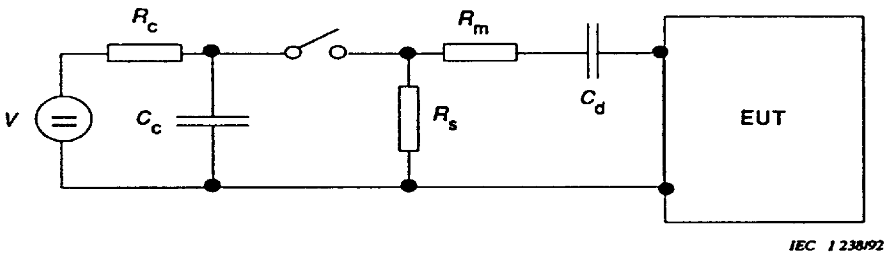


Figure A.12 – General graph of a fast transient



V is the high voltage source
R_c is the charging resistor
C_c is the energy storage capacitor
R_s is the pulse duration shaping resistor
R_m is the impedance matching resistor
C_d is the d.c. blocking capacitor

Figure A.13 — Schematic of a fast transients generator

A.2.4 *Ring wave* (under consideration)

A.2.4.1 *Reference*

See relevant future section of IEC 1000-4.

A.2.4.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of equipment to oscillatory transients – "ring waves" – that occur on residential and industrial LV underground cabling networks. These transients are caused mainly by switching phenomena.

This test is complementary to the 1,2/50 µs surge test that covers transients occurring on outdoor (overhead lines) networks (see test A.2.2) and is an alternative to the 0,1 MHz damped oscillatory wave both with less severe requirements (A.2.5).

The energy of the "ring waves" test is however less than that of the surges test; but the former may generate effects in the EUT due to the voltage polarity changes.

The test applies to equipment intended for LV residential and industrial networks and possibly for electrical substations.

A.2.4.3 *Test wave characteristics*

The waveform consists of a pulse with a rise time of 0,5 µs followed by an oscillation with an oscillation at 100 kHz with a decrement such that each peak is 60 % of the preceding peak. See figure A.14.

A.2.4.4 *Test generator/test equipment*

A schematic of the test generator is represented in figure A.15.

- open-circuit output voltage: 0,25 kVp to 4 kVp;
- dynamic impedance: under consideration;
  (presently): 12 or 30 Ω;
- polarity: positive/negative;
- relation to power supply: asynchronous;
- maximum repetition rate: 6/min.

The test equipment comprises also (see annex B, figure B.3):

- a coupling circuit;
- a decoupling circuit;
- an appropriate measuring instrument (oscilloscope) with a frequency range equal to or over 10 MHz.

A.2.4.5 *Recommended severity levels*

Level	Common mode A_p kV	Differential mode A_p kHz
1	0,5	0,25
2	1	0,5
3	2	1
4	4	2
x	Subject to agreement	

Recommendations for the choice of the severity level: under consideration.

A.2.4.6 *Comments on the test procedure*

- the number of tests shall be limited to: (under consideration);
- the interval between two tests shall be at least 10 s.

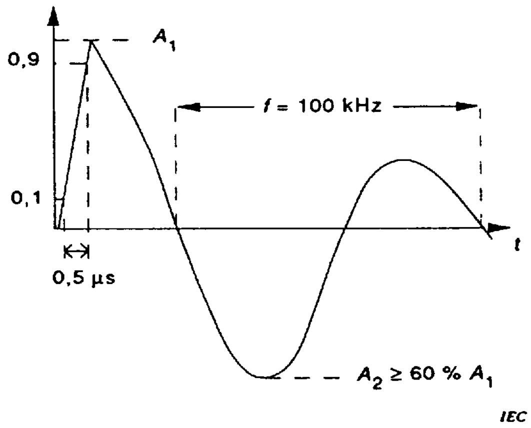
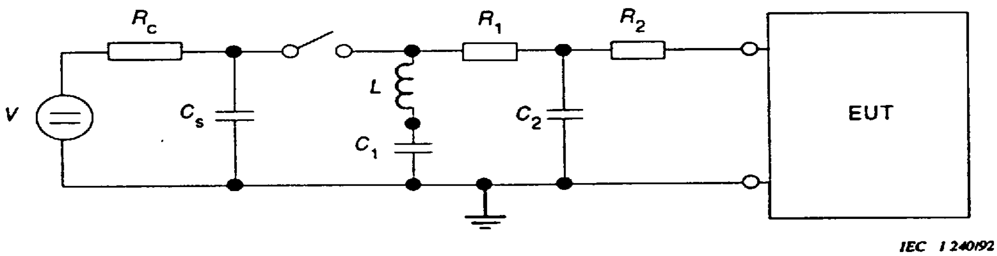


Figure A.14 – Ring wave characteristics (open-circuit voltage)



V	is the high-voltage source	C_2	is the matching capacitor (i.e. 0,005 µF)
R_c	is the charging resistor	R_1	is the time constant matching resistor (i.e. 2,5 Ω)
C_s	is the energy storage capacitor (i.e. 0,5 µF)	R_2	is the generator impedance matching resitor (i.e. 2,5 Ω to 25 Ω)
C_1-L	is the oscillatory circuit (i.e. 10 µF, 5 µF)		

Figure A.15 – Schematic of a ring wave generator 0,5 µs/100 kHz

A.2.5 *Damped oscillatory waves* (under consideration)

A.2.5.1 *References*

See relevant future section of IEC 1000-4 and IEC 255-22-1.

A.2.5.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of electrical or electronic equipment – particularly equipment installed in HV/MV electricity substations, or high reliability equipment – to oscillatory transients induced in the low-voltage circuits by phenomena in the HV or MV networks (switching phenomena, faults, etc). This type of transient is characterized by quite heavily damped oscillations in a frequency range between 30 kHz and 2 MHz.

The test applies essentially to equipment installed in electricity substations on the power supply port and on the control and signal ports of the EUT.

NOTE - This test can also be considered for equipment placed in other locations such as residential networks, with frequency 100 kHz. It is then similar to the ring wave test (see test A.2.4). (The latter has, however, a longer rise time.) Similarly it is complementary to the surge voltage test (see test A.2.2).

A.2.5.3 *Test wave characteristics*

The test voltage consists of a damped oscillation with a frequency between 30 kHz and 10 MHz, with the preferred values of 0,1 MHz and 1 MHz, with a crest value decaying to 50 % of the first peak after three to six periods and with a rise time of the first wave of 75 ns (see figure A.16). These oscillations are applied with a repetition rate of approximately 40/s at 0,1 MHz and 400/s at 1 MHz (preferred values).

A.2.5.4 *Test generator/test equipment*

A schematic of the test generator is represented in figure A.13:

– frequency:	0,1 MHz and 1 MHz;
– open-circuit peak output voltage:	0,25 kV to 2,5 kV;
– dynamic impedance:	under consideration;
(presently in IEC 255-22-1):	presently in 200 Ω ± 20 %;
– polarity of the first half wave:	positive/negative;
– relation to power supply:	asynchronous;
– repetition rate:	preferred values: 40/s or 400/s.

The test equipment comprises also (see annex B, figure B.3):

- a coupling circuit;
- a decoupling circuit;
- an appropriate measuring instrument (oscilloscope) with a bandwidth equal to or over 10 MHz.

A.2.5.5 *Recommended severity levels*

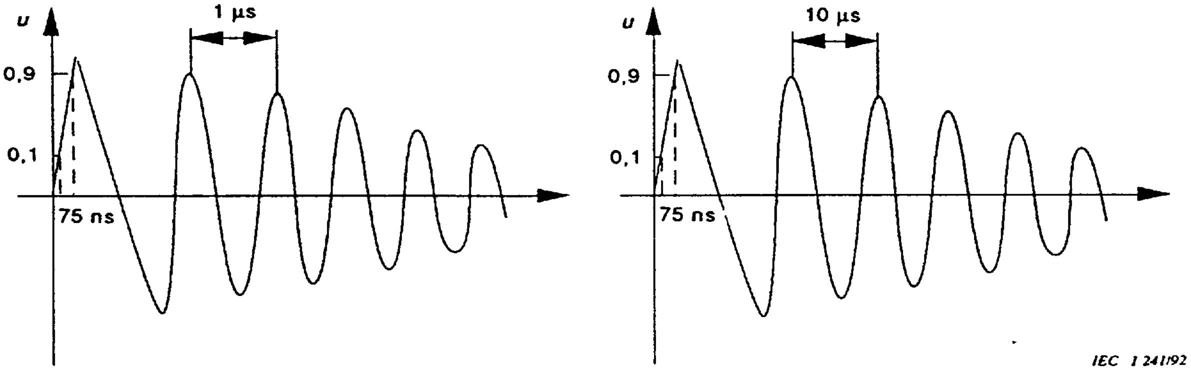
Level	Common mode U_p (kV)	Differential mode U_p (kHz)
1	0,5	0,25
2	1,0	0,5
3	2,0/2,5*	1,0
x	Subject to agreement	

Up is the open-circuit voltage
* 2,5 kVp in IEC 255-22-1.

The same test voltage is applied on all lines: power supply, or control and signal lines.

A.2.5.6 *Comments on the test procedure*

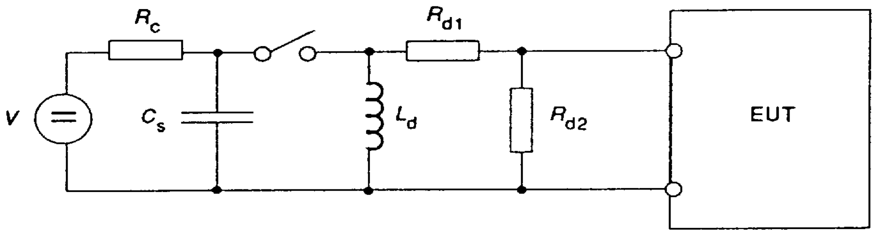
The minimum duration of each test is 2 s.
The test is carried out at 0,1 MHz and 1,0 MHz. Other values between 30 kHz and 10 MHz shall be recorded in the test plan.



Damped oscillatory wave 1 MHz

Damped oscillatory wave 0,1 MHz

Figure A.16 – Damped oscillatory wave characteristics



V	is the high-voltage source
R_c	is the charging resistor (200 KΩ)
C_s	is the energy storage capacitor (0,15 µF)
R_{d1}, R_{d2}	are the impedance matching resistors (300 Ω)
L_d	is the impedance matching inductor (0,75 µH)

Figure A.17 – Schematic of a 1 MHz generator

A.2.6 *High-frequency induced voltages (provisional test)*

A.2.6.1 *Reference*

See future section of IEC 1000-4.

A.2.6.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of electronic equipment to high-frequency voltages that appear on power, control and signal lines, for example as residual voltages on the screen of shielded cables. These disturbances may be continuous (or quasi continuous) voltages which originate from switching operations, or faults in the HV, MV, or LV networks. These disturbances induce oscillatory transients in the secondary circuits despite protective measures.

The interference appears as common mode voltage of limited amplitude. On the circuits of shielded cables, the shielding efficiency limits the voltage magnitude.

The test is essentially applicable to the control and signal ports of equipment to be installed in electrical substations and also possibly in industrial plants.

A.2.6.3 *Test wave characteristics*

The test voltage consists of a series of bursts, each of them consisting of 20 sinusoids of variable frequency. The frequency sweeps in the range 0,01 MHz to 1 MHz at a rate of 0,1 decade/s or lower and the interval between the bursts is 20 ms.

A.2.6.4 *Test generator/test equipment*

Specifications of the test generator (and associated amplifier if necessary):

- open circuit peak output voltage: maximum 100 V;
- generator impedance: 200 Ω;
- output current: ≥ 0,25 A_p;
- on/off modulation: pulses of 20 sinusoids with intervals of 20 ms;
- frequency sweeping 1 kHz to 1 MHz: < 0,1 decade/s.

The test equipment also comprises:

- a coupling circuit;
- a decoupling circuit;
- an appropriate measuring instrument (oscilloscope or selective voltmeter).

A.2.6.5 *Recommended severity levels*

Level	Peak test voltage V
1	10
2	20
3	50
4	100
x	Subject to agreement

The test voltage is applied in common mode on power supply and control terminals.

A.2.6.6 *Comments on the test procedure*

The duration of the test is to be limited to the time necessary to check the operating behaviour of the EUT as specified in the test plan.

A.2.7 *Conducted radio frequency disturbances* (under consideration)

A.2.7.1 *References*

See future sections of IEC 801-6, future sections of IEC 1000-4, IEC 1000-4-6 and 2nd edition of IEC 790 (under consideration).

A.2.7.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of electronic equipment: single devices or systems (including their cables) against radiated interferences by replacing a direct test with a disturbance field by an equivalent indirect test with a conducted disturbance. This current is the same that would be induced by the disturbance field.

Two tests are possible: continuous wave test and impulsive test.

The test specifications are under consideration.

A.2.8 *10/700 µs voltage surge* (under consideration)

A.2.8.1 *References*

See CCITT Recommendation K21.
See also Recommendation K20, IEC 801-5 and IEC 1000-4-5 (under consideration).

A.2.8.2 *Purpose of the test*

The purpose of the test is to verify the immunity of equipment connected to telecommunication lines against surge disturbances due for example to lightning discharges. In the context of this section, it applies to terminal equipment such as modems and similar equipment with control inputs/outputs, which send and receive information via telecom ports.

The test applies to the telecom ports of the EUT according to the specifications of the telecom authorities.

Comments:

a) for the other terminals other tests may apply (e.g. tests A.2.2, A.2.3, A.2.4, and A.2.5);

b) then Telecom authorities may also specify further very specific telecom tests, which are not within the general scope of the present document (i.e. a.c. induced voltage, see CCITT Recommendation K21).

A.2.8.3 *Test wave characteristics*

The test is performed with a voltage surge having the following specifications: (open circuit)

- rise time 10 %/90 % = 7 µs (front time 10 µs)
- duration 50 %/50 % = 700 µs

This surge is characterized by a relatively smooth front rise and a long duration and a relatively high energy content.

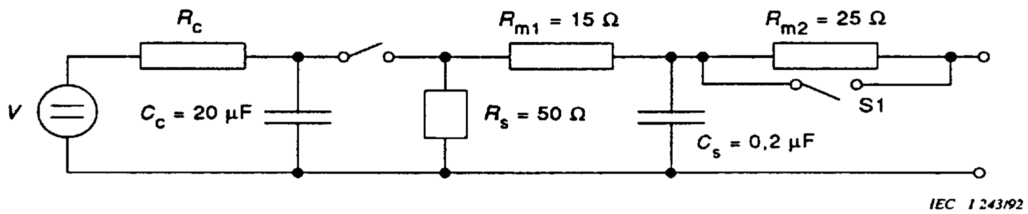


Figure A.18 – Schematic of the test generator

A.2.8.4 *Test generator/test equipment*

A schematic of the test generator is represented in figure A.18:

- open circuit peak output voltage: 0,5 kV to 4 kV;
- dynamic impedance: 40 Ω;
- polarity: positive/negative.

The test equipment also includes:

- a gas arrester coupling circuit;
- an appropriate measuring instrument, i.e. an oscilloscope with a minimum bandwidth of 2 MHz.

A.2.8.5 *Recommended severity level*

CCITT Recommendation K21 recommends a maximum voltage amplitude of:

- equipment for unexposed environments: $U_p \leq 1$ kV;
- equipment for exposed environments with agreed primary protection: $U_p \leq 4$ kV.

A.2.8.6 *Comments on the test procedure*

The test surge is applied 10 times, at intervals of 1 min, and the polarity is reversed between two consecutive pulses.

A.3 Immunity tests: electrostatic discharges

A.3.1 *Electrostatic discharges*

A.3.1.1 *Reference*

See IEC 801-2 and IEC 1000-4-2 (under consideration).

A.3.1.2 *Purpose of the test – Range of application*

The purpose of the test is to verify the immunity of equipments – single devices or systems in cubicles – against electrostatic discharges (ESD) generated, for example:

- by an operator or an object touching the equipment;
- by objects or persons coming into contact in the vicinity of the equipment.

Persons or objects can accumulate static electricity as a result of various phenomena. It should be particularly noted that people walking on synthetic carpets generate electrostatic charges. Depending on the circumstances the voltage can reach up to 15 kV (see clause A.5 below). The ESD can influence the operation of an equipment or damage its electronic circuitry, either by a direct effect or indirectly by inductive coupling or radiation.

The test applies to all electric and electronic equipment.

A.3 1.3 *Test voltage characteristics*

The waveform of the discharge current depends on the kind of load. Figure A.19 represents a typical waveform into a resistive load.

A.3.1.4 *Test generator/test equipment*

Figure A.20 gives a simplified diagram of the ESD generator.

A.3.1.5 *Recommended severity levels*

Level	Test voltage contact discharge kV
1	2
2	4
3	6
4	8
x	special

Level	Test voltage air discharge kV
1	2
2	4
3	8
4	15
x	special

Contact discharge is the preferred test method. Air discharge shall be used where contact discharge cannot be applied.

A.3.1.6 *Comments on the test procedure*

Direct application of the discharge.

The ESD shall be applied to all normally accessible points of the EUT. The test is performed:

- with single discharges;
- between these points and earth;
- with at least 10 discharges (positives or negatives);
- with intervals of at least 1 s between successive discharges.

Comment:

The points to which discharges are to be applied may be selected by an exploration with 20 discharges per second.

Simulation of discharges between objects in the vicinity of the EUT

The discharge is applied to the ground plane or on a metal plate of 50 cm x 50 cm around the EUT (at 10 cm from it).

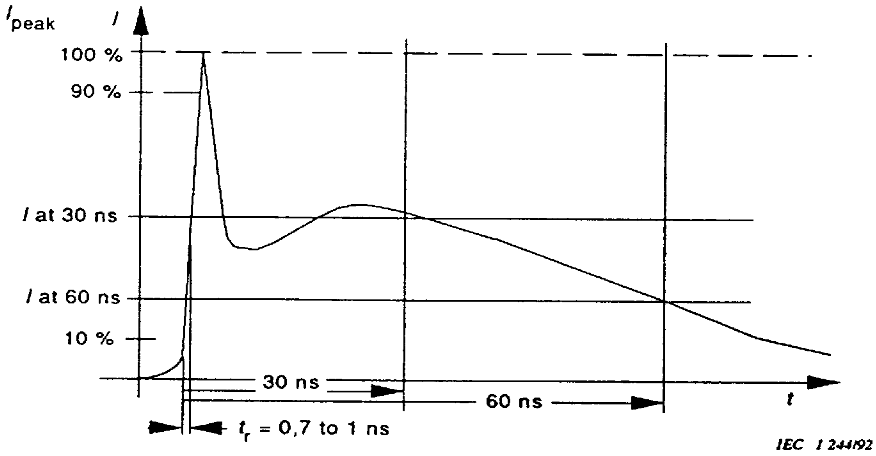
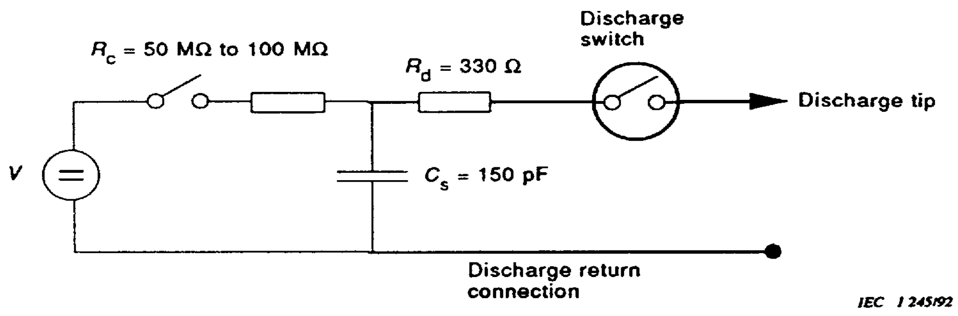


Figure A.19 – Typical waveform of the output current of the ESD generator



V	is the high-voltage source	(16,5 kV)
R_c	is the charging resistor	(50 MΩ to 100 MΩ)
C_s	is the energy storage capacitor	(150 pF)
R_d	is the discharge resistor	(330 Ω)

Figure A.20 – Simplified diagram of the ESD generator

A.4 Immunity tests: magnetic disturbances

A.4.1 *Power frequency magnetic field*

A.4.1.1 *References*

See IEC 1000-4-8 (in preparation) and 8.5.2 of IEC 521.

NOTE - IEC 1000-4-8 deals with magnetic fields at the power frequencies 50/60 Hz.
Tests for other magnetic fields are under consideration, e.g.:

- for power frequencies 16 2/3 Hz (railways);
  20-30 Hz (ships);
  400 Hz (avionic);
- for harmonic currents of the power frequency (100 Hz to 2 000 Hz);
- for higher frequencies up to 150 kHz (e.g. from mains signalling systems);
- for d.c. fields.

A.4.1.2 *Purpose of the test*

The purpose of the test is to verify the immunity of equipment, apparatus or systems in cubicles, to magnetic fields originating from power frequency currents in nearby conductors or, less often, from other devices (e.g. leakage of transformers).

A distinction should be made between the following:

- the current under normal operation conditions, which produces a steady magnetic field with a comparatively small magnitude;
- the current under fault conditions which can produce comparatively high magnetic fields but of short duration, until the protection devices operate (a few milliseconds with fuses, maximum 3 s to 5 s with protection relays).

The test with a steady magnetic field may apply to all types of equipment intended for public or industrial LV distribution networks and for electricity substations.

The test to short duration magnetic field (1 s to 3 s) applies mainly to equipment to be installed in exposed places in electricity substations.

A.4.1.3 *Test field characteristics*

The test field should be a power frequency field of specified magnitude, free of harmonics, reasonably homogeneous without the EUT (i.e. field strength variation –0 % to +50 %).

A.4.1.4 *Test equipment*

The test equipment includes:

- an induction coil to generate the magnetic field;
- a power frequency source to supply the induction coil;
- the necessary auxiliary test and measurement equipment.

A.4.1.4.1 *Three types of coils are recommended:*

a) a single induction coil (figure A.21) of square form – standardized side length: 1 m, for the testing of small apparatus – usable volume within 3 dB tolerance: 0,6 m x 0,6 m x 0,5 (h) m.

NOTE - For electrical meters, 8.5.2 of IEC 521 specifies a single coil of 1 m diameter.

b) a double induction coil (figure A.22) – [Helmoltz coil] of square form – standardized side length 1 m and distance between each half coil 0,6 m respectively 0,8 m, also for the testing of small apparatus but with a larger usable volume 3 dB tolerance: 0,6 m x 0,6 m x 1,0 m respectively 0,6 m x 0,6 m x 1,2 m.

c) dedicated single induction coils for large equipment for example cabinets (figure A.23). The coil shall be realized according to the dimensions of the EUT. In order to remain in the 3 dB area, the coil side should be at a distance of approximatively 25 cm to 30 cm from the EUT sides (e.g. for a cabinet 2,0 m x 0,5 m, the coil dimensions should be approximately 2,6 m x 1,0 m). It can be moved in steps of 0,5 m.

A.4.1.4.2 The current source consists of a voltage regulator (connected to the mains supply), a transformer supply/coil and a control circuit for short duration tests (figure A.25).

– output current range for continuous mode tests	1 A to 100 A divided by the coil factor
– output current range for short duration tests	300 A to 1 000 A divided by the coil factor
– time adjustment for short time tests	1 s to 3 s

NOTES

1 For preliminary investigations in order to discover the sensitive parts of an EUT, use of the "proximity method" can be made. This method consists of moving a small coil along the EUT side which also allows variation in the field direction.
This method is not applicable for acceptance tests.

2 For tests with power frequency the coils are normally supplied by the same network as the EUT.

A.4.1.5 *Recommended severity levels*

Level	Continuous field A/m	Short duration 1 s to 3 s A/m
1	1	–
2	3	–
3	10	–
4	30	300
5	100	1 000
x	Subject to agreement	Subject to agreement

NOTES

1 100 A/m generates a free space field of 0,125 mT ou 1,25 G.

2 The above field strengths are the values of the free field without EUT. For electricity meters, 8.5.2 of IEC 521 specifies 400 A/m.

A.4.1.6 *Comments on the tests procedure*

Magnetic field tests are mainly laboratory tests.

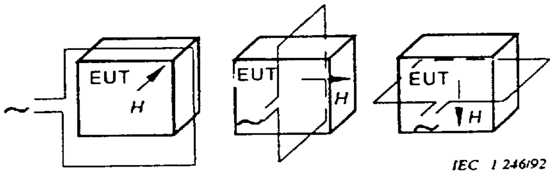


Figure A.21 – Example of an induction coil for the small EUT test

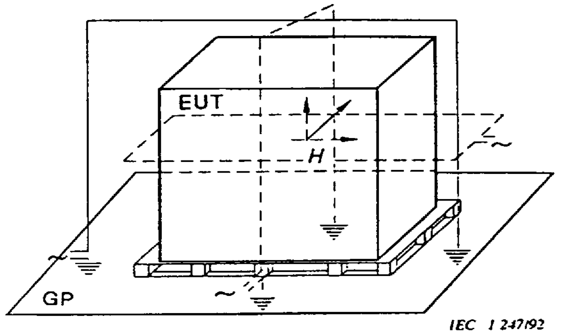


Figure A.23 – Example of an induction coil for the cubicles test

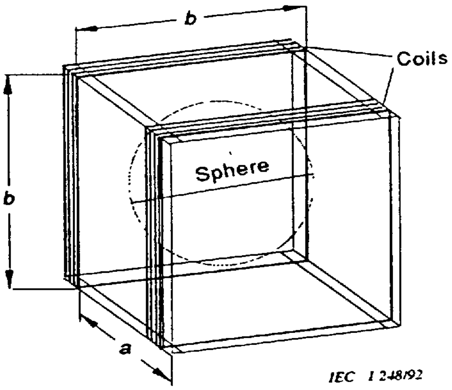


Figure A.22 – Helmolz coil for the small EUT test

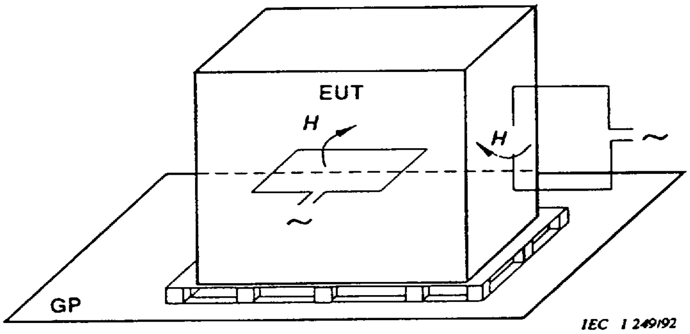
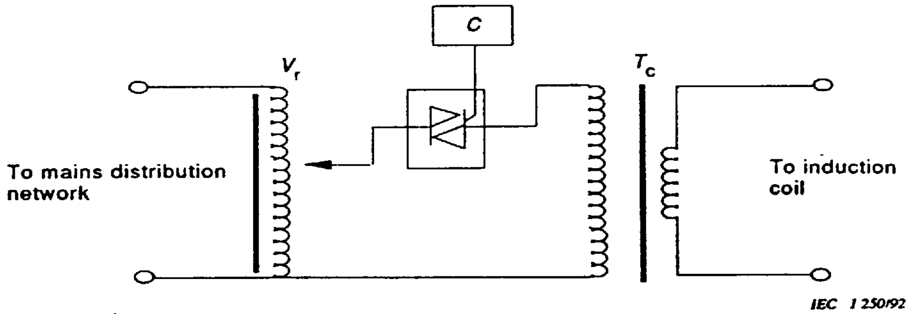


Figure A.24 – Example of an induction coil for a qualitative investigation of the magnetic sensitivity by the proximity method



V_r is the voltage regulator

C is the control circuit (continuous/short duration) source

T_c is the current transformer

Figure A.25 – Schematic of the current source

A.4.2 *Pulse magnetic field*

A.4.2.1 *Reference*

See IEC 1000-4-9 (in preparation).

A.4.2.2 *Purpose of the test*

The purpose of the test is to verify the immunity of equipment to magnetic fields generated by lightning strokes.

The test may be applied to electronic equipment to be installed in electricity plants. For distribution network equipment the test is applicable only in special cases.

A.4.2.3 *Test field characteristics*

The waveform of the magnetic field is that of the standard current wave 8/20 µs flowing through an induction coil.

A.4.2.4 *Test equipment/test generator*

The induction coils can be the same as for the test with the power frequency field (figures A.21 to A.23).

These coils are fed from a pulse generator with the current capability necessary for the required severity level; the generator is the same or similar to the one used for surge voltage tests (test A.2.2).

A.4.2.5 *Recommended severity levels*

Level	Maximum field magnitude* A/m
1	–
2	–
3	100
4	300
5	1 000
x	Subject to agreement

* Without EUT.

A.4.2.6 *Comments on the test procedure*

The EUT shall be tested with at least five pulses of each polarity in each of the orthogonal directions.

A.4.3 *Damped oscillatory magnetic field*

A.4.3.1 *Reference*

See IEC 1000-4-10 (in preparation).

A.4.3.2 *Purpose of the test*

The purpose of the test is to verify the immunity of equipment to damped oscillatory magnetic fields generated by the switching of H.V. circuits by isolators in electricity plants.

The test may be applied essentially to electronic equipment to be installed in electric plants. It is not relevant for distribution network equipment.

A.4.3.3 *Test field characteristics*

The waveform of the test field is that of a damped oscillatory wave flowing in an induction coil with the following characteristics:

- oscillatory frequency: 0,1 MHz and 1 MHz;
- damping: 50 % of the peak value after three to six cycles;
- repetition rate: 40/400 per s.

A.4.3.4 *Test equipment/test generator*

The induction coils can be the same as for the magnetic field test with the power frequency field (figures A.21 to A.23).

These coils are fed from an oscillatory current generator with the current capability necessary for the required severity level.

A.4.3.5 *Recommended severity levels*

Level	Maximum field magnitude* A/m
1	–
2	–
3	10
4	30
5	100
x	Subject to agreement

* without EUT.

A.4.3.6 *Comments on the test procedure*

Duration of the test: 1 s.

A.5 Immunity tests: electromagnetic fields

A.5.1 *Radiated electromagnetic field*

A.5.1.1 *Reference*

See IEC 801-3 and IEC 1000-4-3 (under consideration).

NOTE - The above part of IEC 801 covers the frequency 27 MHz to 500 MHz.
The revised edition will cover the frequency range 26 MHz or 80 MHz to 1 000 MHz modulation 1 kHz sinus 80 %.

A.5.1.2 *Purpose of the test*

The purpose of the test is to verify the immunity of equipments: single apparatus or systems, against electromagnetic fields generated by radio transmitters or any other device emitting continuous wave-radiated electromagnetic energy. The immunity of equipment to the radiation of hand-held transceivers (walkie-talkies) is the main concern but other sources of electromagnetic radiation are involved, such as fixed-station, radio and television transmitters, vehicle radio transmitters and various industrial electromagnetic sources or intermittent sources.

In order to obtain reproducible results, the test shall be carried out under laboratory conditions.

A.5.1.3 *Test field characteristics*

The test field generated in the test enclosure shall be, before the introduction of the EUT, an homogeneous field of the required frequency and strength (care should be taken to avoid standing waves and disturbing reflections).

A.5.1.4 *Test equipment/test generator*

The test equipment comprises basically the following items:

- the test enclosure (generating the homogenous field);
- the signal source with amplifier;
- the antenna;
- the measuring equipment.

Several types of test enclosures exist but one of them is particularly recommended for its uniform field:

- a shielded anechoic chamber with dimensions as large as necessary, suitable for large devices (cubicles, etc.).

Other test methods with limitations can be used:

- a strip line arrangement for small apparatus. It consists of two parallel plates enclosing – in a standard arrangement – a space of 80 cm x 80 cm x 80 cm and suitable for apparatus up to 25 cm x 25 cm x 25 cm.

The advantage of a strip-line circuit is that it is of a simple and low-cost design, the disadvantage is that the EM field spreads out beyond the open sides, it is used from d.c. to 150 MHz;

– A TEM cell (transverse electromagnetic cell) which is constituted by a closed metallic box with a rectangular cross-section. The advantage of the TEM cell compared to the strip line is that the EM field remains contained in the enclosure and is more homogeneous; the disadvantage is the higher cost. The utilisable volume is lower than that of a strip line of similar overall dimensions from d.c. to 200 MHz. Some devices can be used for EUT of 1 m x 1 m x 0,5 m from d.c. to 5 GHz.

The signal generator(s) should be capable of covering the prescribed frequency range, have a sweep capability and a modulation capability.

A.5.1.5 *Recommended severity levels*

Level	Test field strength V/m
1	1
2	3
3	10
x	Subject to agreement

The field strength is given prior to modulation.

The following classes may be considered as general guidelines for the selection of the appropriate levels:

Class 1 — Low-level electromagnetic radiation, such as fields produced by local radio/television stations located at more than 1 km and fields produced by low-power transceivers.

Class 2 — Moderate electromagnetic radiation, such as fields produced by portable transceivers that can be relatively close to the equipment but not closer than 1 m.

Class 3 — Severe electromagnetic radiation, such as fields produced by high-power transceivers in close proximity to the equipment.

Class 4 — Open class for situations involving very severe electromagnetic radiation environments. The level is subject to negotiations between the user and manufacturer or as defined by the manufacturer.

A.5.1.6 *Comments on the test procedures*

Modulation of the carrier is under consideration.

A.6 Other immunity tests

A.6.1 *Power frequency voltage on control and signal lines*

Under consideration.

A.6.2 *D.C. voltage on control and signal lines*

Under consideration.

Annex B
(informative)

Characteristics for conducted transient tests – Technical features concerning the tests with conducted transients

The immunity tests of equipment against conducted transient disturbances necessitate some specific comments related to the nature and characteristics of these transients and to the test equipment.

B.1 Nature and characteristics of the transients

Conducted transients can originate from various effects: switching operations, faults in the network, atmospheric phenomena, etc. and can be coupled into the sensitive equipment via different ways. Independently of their origin, these transients can be characterized and compared by some basic parameters or methods, either in the time domain representation or in the frequency domain representation (see IEC 816).

The most important characteristic features of transients in the time domain are:

- unidirectional or oscillating nature of the transient;
- amplitude;
- duration;
- damping factor of the oscillating transients;
- pulse strength (voltage x time) or energy content;
- rise time, respectively, the maximum voltage gradient dv/dt;
- repetition frequency.

Another feature – not related to the transient form – is the mode of appearance:

- in common mode between the conductors of a circuit and the reference level;
- in differential mode between the conductors of a circuit.

All these factors have to be indicated in the test specification.

B.2 Test equipment

The test equipment should simulate as well as possible and in a reproductible manner, the transients appearing in the networks or representative transients. It consists in principle of three elements (see figure B.1):

- test generator;
- coupling/decoupling circuits;
- measuring equipment.

The test generator shall produce the test voltage (or current). All the test generators have basically the same structure and consist of:

- a d.c. source charging a capacitor that serves as energy source for the transient;

- a triggering device, that initiates the transients.

It may be synchronized with the mains frequency and/or be able to adjust the position of the transient on the mains voltage wave.

- a circuit built-up of resistances, capacitors and inductances, that give the transient the required shape.

The coupling/decoupling circuits have several tasks:

- the coupling circuit shall allow the transients produced by the generator to be transferred on the power or control terminals of the EUT and to block a backward influence of the power frequency or of the signal voltage on the generator (it should be remembered that the EUT shall be in normal operation during the immunity tests);

- the decoupling circuit (back filter) has the task of preventing the injected transients from propagating into the network connected to the terminals of the EUT, on the one hand in order to limit the test to the EUT and protect the elements not being tested, on the other hand in order to avoid an influence of the network impedance on the transient shape and amplitude. This decoupling circuit is normally used for laboratory tests; however it may not be used for tests on site.

As for measuring equipment, see IEC 816.

An important feature of the test generator and its associated coupling/decoupling circuits is the source impedance.

In the networks, when a certain transient voltage is produced by a disturbing phenomenon, the actual voltage applied to the sensitive equipment results from a voltage sharing between the equipment impedance and the network impedance at the considered frequencies. The same should happen between the EUT impedance and the source impedance of the generator. In order to simulate correctly the network behaviour, the source impedance of the generator should be similar to the network impedance in the considered frequency range. For this reason, its source impedance is an important characteristic of the transient generator.

NOTE - It should be noted that at the time this section is written, the network impedances with regard to the transients where the equipment be connected are not sufficiently known, and that, anyway, a good simulation is quite difficult.

As for the decoupling device, it shall fulfil several severe conditions, for example:

- very small attenuation for the power frequency (max. 10 %);
- high backward attenuation for the transients (e.g. 40 dB);
- high dielectric strength (peak voltage up to 10 kV and more);
- small influence on the transient form;
- linearity up to maximum voltages and currents.

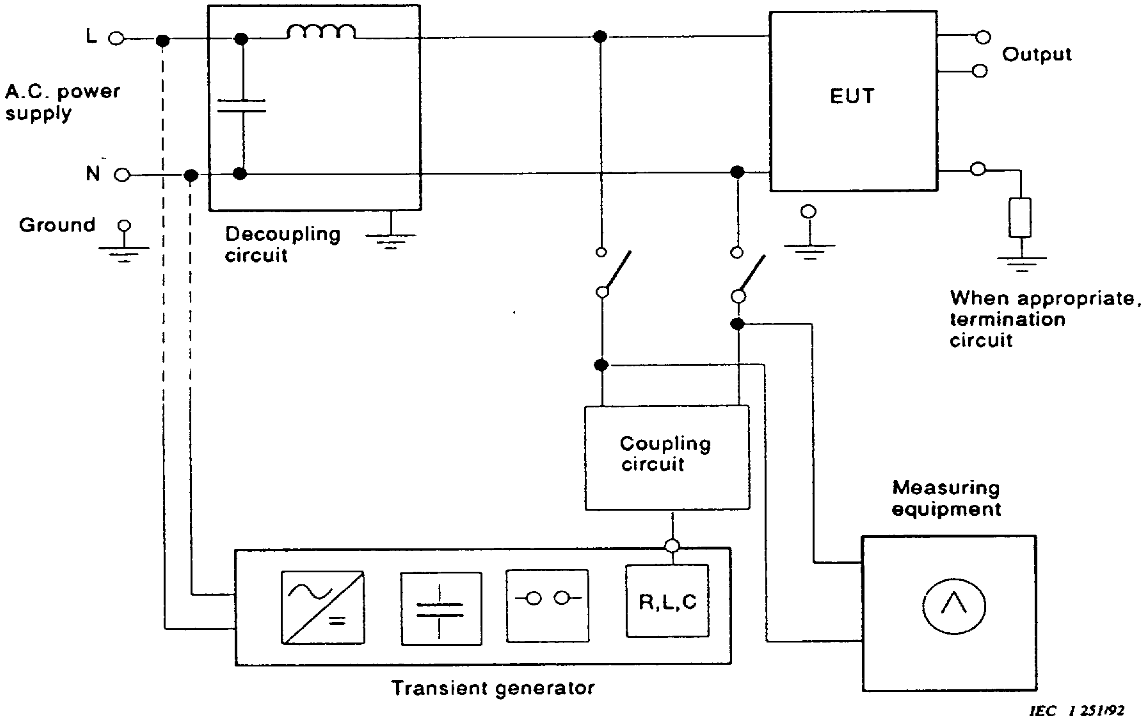


Figure B.1 – Transient generator – schematic of the test equipment for conducted transients

B.3 Amplitude-density spectrum

In the frequency domain, a transient can be described by an amplitude density spectrum obtained by a Fourier-Transform. Typical transients can be characterized by the envelopes of their amplitude density spectra:

– for unidirectional, described in the time domain by a double exponential equation, these envelopes can be approximated by three straight lines (see figures B.2a and B.2b):

- a horizontal line determined by the area under the voltage time curve (and therefore proportional to the amplitude of the surge);
- a line failing with a slope $1/f$ beginning at a frequency f_1 determined by the duration time T of the surge;
- a line failing with a slope $1/f^2$ beginning at a frequency f_2 determined by the rise time t of the surge.

– for damped oscillatory waves, the spectrum shows a "peak" at the specific oscillatory frequency and a line falling with a slope $1/f^2$ above the frequency f_2 (see figures B.2c and B.2d).

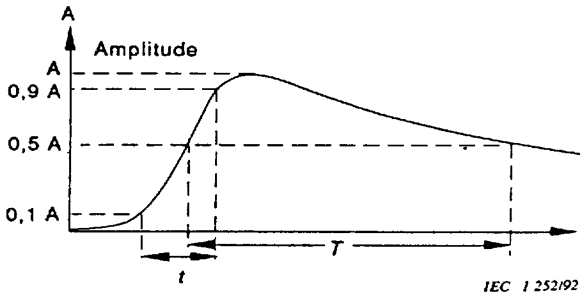


Figure B.2a

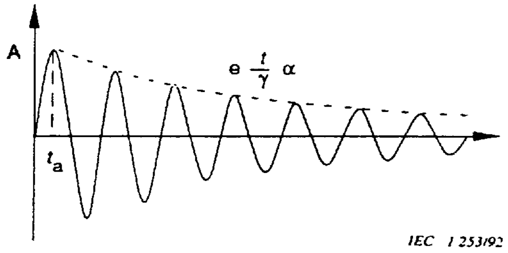


Figure B.2b

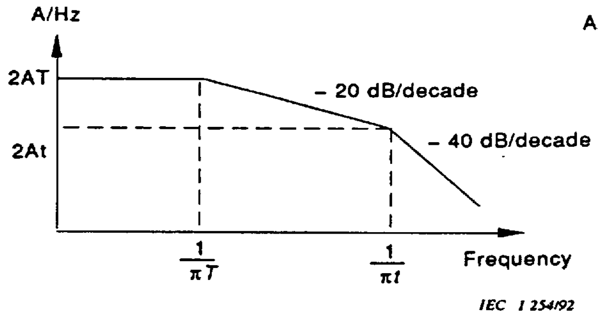


Figure B.2c

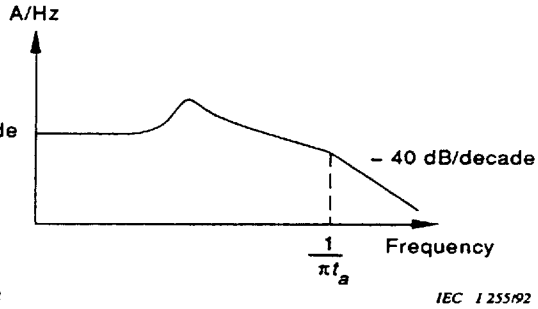


Figure B.2d

Figure B.2a	:	unidirectional surge
Figure B.2b	:	oscillatory surge
Figure B.2c	:	envelope of the amplitude density diagram of an unidirectional surge
Figure B.2d	:	envelope of the amplitude density diagram of an oscillatory surge

The frequency spectrum representation is particularly useful for several purposes, for example:

a) to compare different transients;

b) to analyze the influence of a given transient on an EUT taking into account the frequency response of the coupling path and the frequency response of the EUT (see figure B.3);

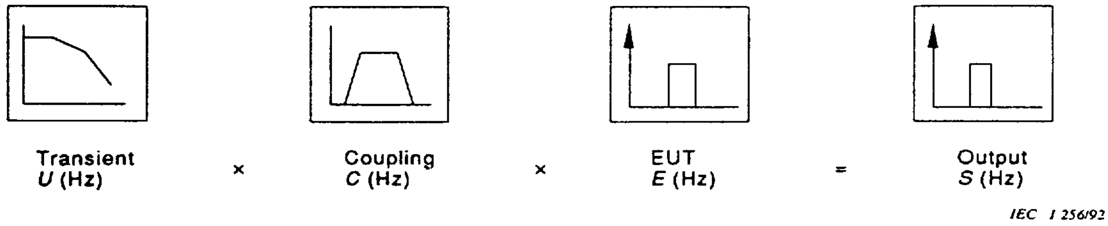


Figure B.3 – Transfer of a transient through a coupling element and a sensitive device (EUT)

c) accordingly, in general, to allow an appropriate design for all kinds of equipment with regard to the frequency characteristics (coupling filters, blocking filters, etc.);

d) and, in particular, to control if the frequency characteristics of a test equipment: coupling circuit, decoupling circuit, measurement equipment, does not unduly deform the transient. Care must be taken that the frequency response of the test equipment is suitable for the significant frequency spectrum of the transient.

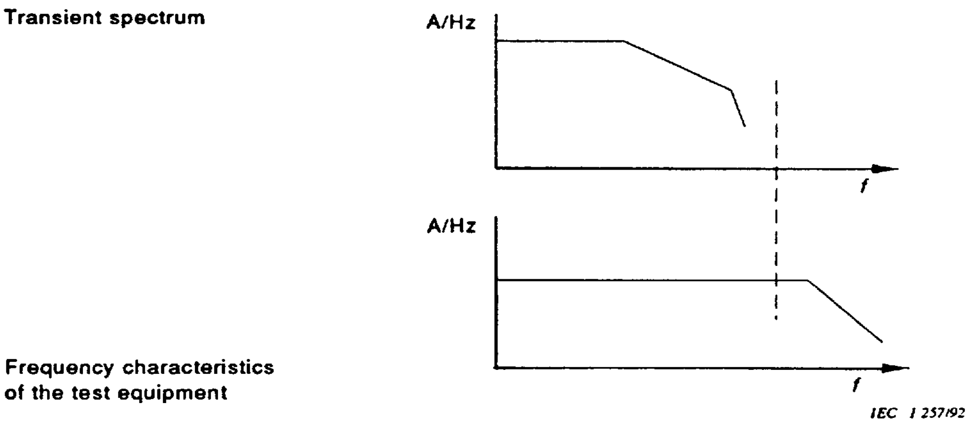


Figure B.4 – Example of the comparison of the amplitude density diagram of a transient and the frequency characteristic of a test equipment element (for example a coupling circuit)

Figures B.5a to B.5f represent the amplitude density diagrams of all the transients for which a test is recommended in this standard. Note that in order to allow the comparison of their frequency contents, all these diagrams are referred to a maximum amplitude of 1 kV peak.

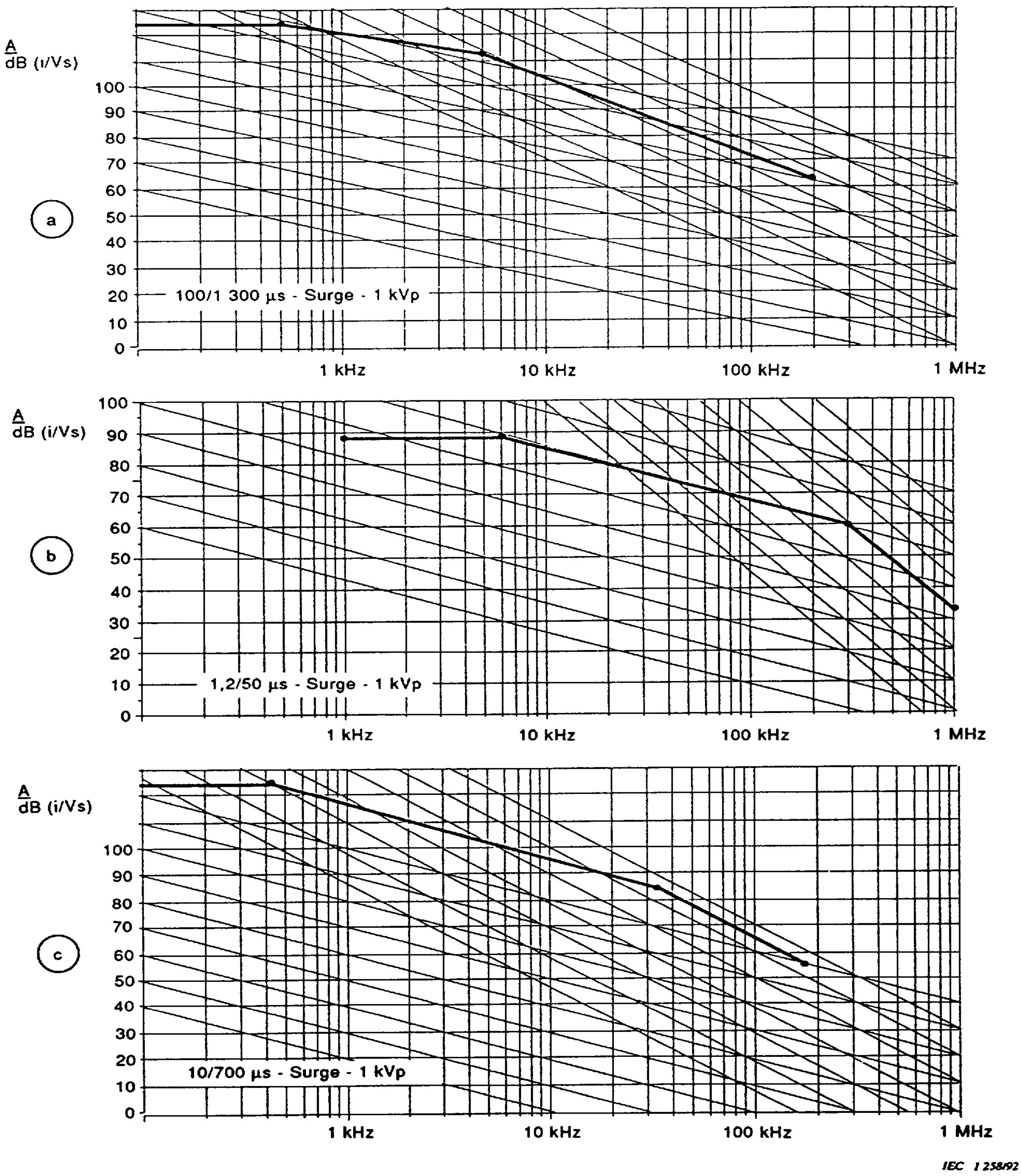


Figure B.5 a,b,c – Amplitude density spectra of test transients

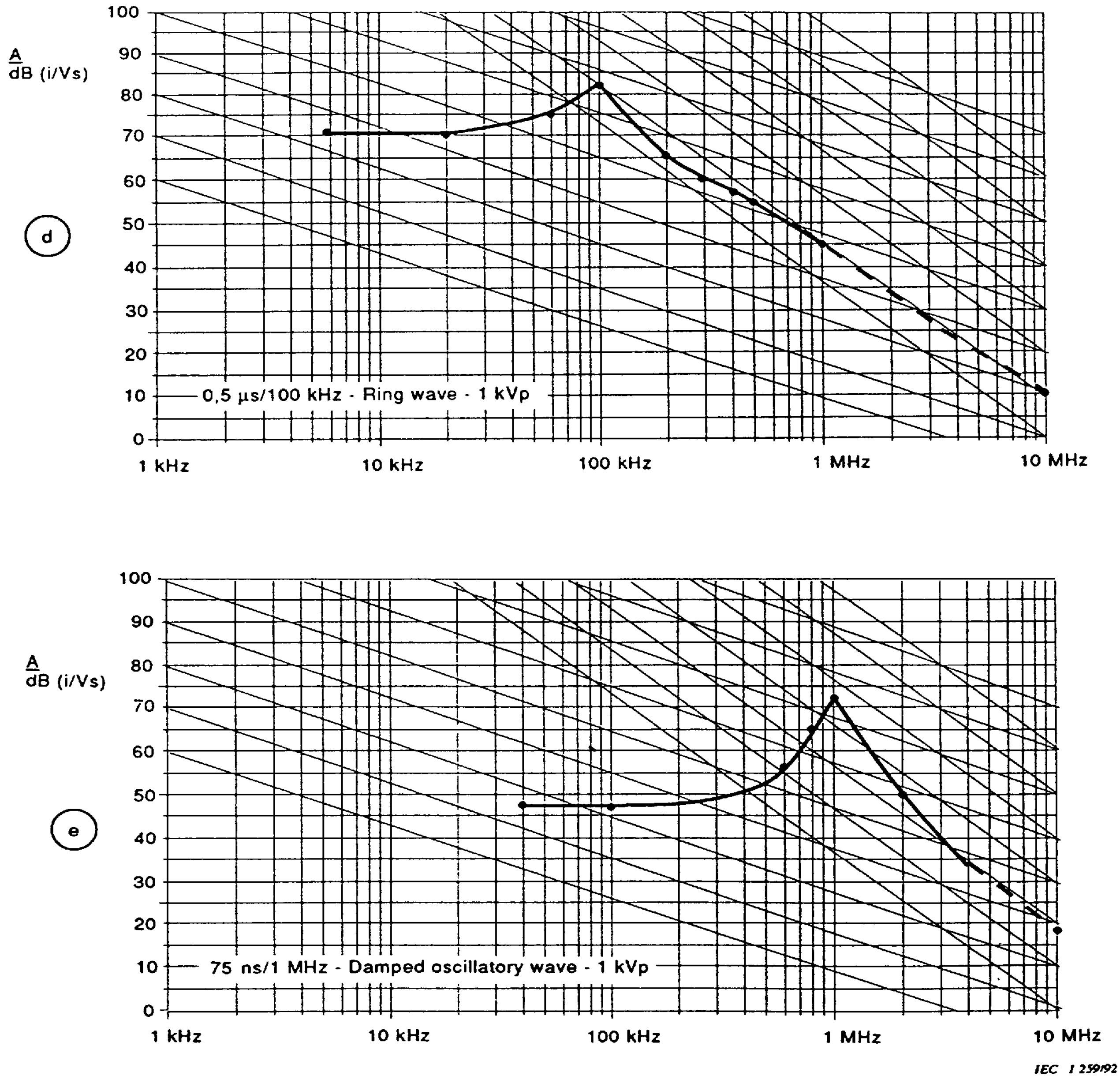


Figure B.5 d,e – Amplitude density spectra of test transients

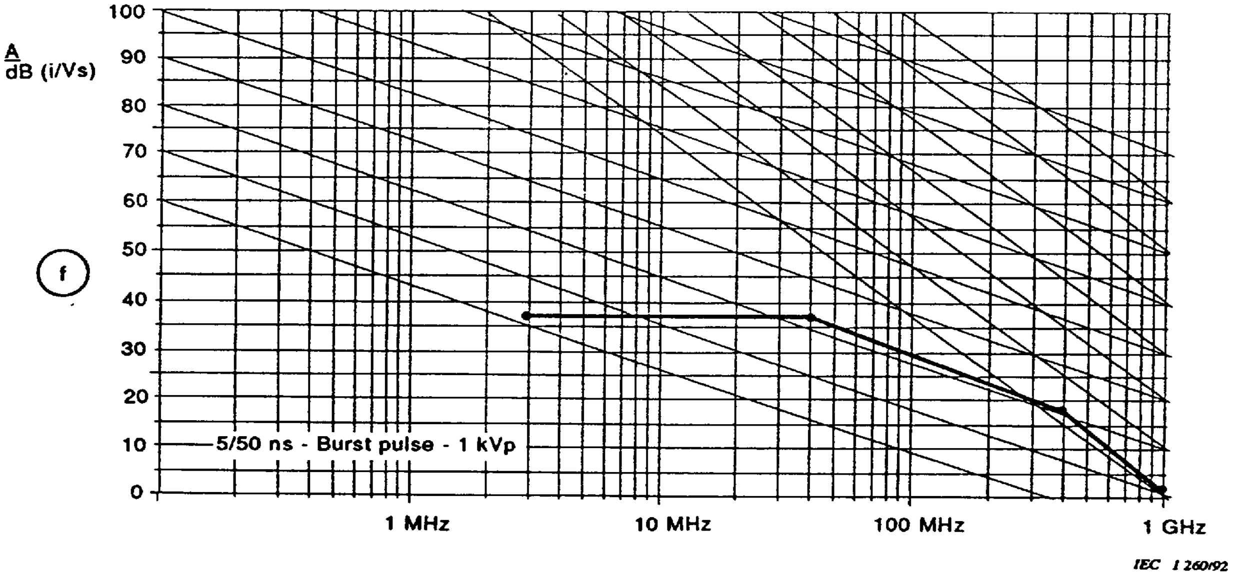


Figure B.5f – Amplitude density spectrum of fast transients

Annex ZA (normative)

Other international publications quoted in this standard with the references of the relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

NOTE. When the international publication has been modified by CENELEC common modifications, indicated by (mod), the relevant EN/HD applies.

IEC publication	Date	Title	EN/HD	Date
34-1 (mod)	1983	*Rotating electrical machines — Part 1: Rating and performance*	HD 53.1 S2	1985
50(161)	1990	*International Electrotechnical Vocabulary (IEV) — Chapter 161: Electromagnetic compatibility*	—	—
255-22-1	1988	*Electrical relays — Part 22: Electrical disturbance tests for measuring relays and protection equipment — Part one: 1 MHz burst disturbance tests*	—	—
521	1988	*Classes 0.5, 1 and 2 alternating-current watthour meters*	EN 60521	1994
790	1984	*Oscilloscopes and peak voltmeters for impulse tests*	HD 479 S1	1986
801-2	1991	*Electromagnetic compatibility for industrial-process measurement and control equipment — Part 2: Electrostatic discharge requirements*	EN 60801-2	1993
801-3	1984	*Part 3: Radiated electromagnetic field requirements*	HD 481.3 S1	1987
801-4	1988	*Part 4: Electrical fast transient/burst requirements*	—	—
801-5	—	*Part 5: Surge voltage immunity requirements* (under consideration)	—	—
801-6	—	*Part 6: Immunity to conducted radio frequency disturbances above 9 kHz* (under consideration)	—	—
816	1984	*Guide on methods of measurement of short duration transients on low voltage power and signal lines*	—	—
1000-1	1992	*Electromagnetic compatibility (EMC) Part 1: General*	—	—
1000-2-1	1990	*Part 2: Environment — Section 1: Description of the environment Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems*	—	—

1000-2-2 (mod)	1990	Section 2: *Compatibility levels for low frequency conducted disturbances and signalling in public low-voltage power supply systems*	ENV 61000-2-2	1993
1000-2-3	1992	*Section 3: Description of the environment — Radiated and non-network-frequency-related conducted phenomena*	—	—
1000-4-X	—	*Part 4: Testing and measurement techniques*	—	—
1000-4-7	1991	*Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*	EN 61000-4-7	1993
1000-4-8	1993	*Section 8: Power frequency magnetic field immunity test — Basic EMC Publication*	EN 61000-4-8	1993
1000-4-9	1993	*Section 9: Pulse magnetic field immunity test — Basic EMC publication*	EN 61000-4-9	1993
1000-4-10	1993	*Section 10: Damped oscillatory magnetic field immunity test — Basic EMC Publication*	EN 61000-4-10	1993
XXX	—	*Static ripple control receivers for tariff and load control* (under consideration)	—	—

Other publications:

CCITT Recommendation K 20 : 1985	*Resistability of telecommunication switching equipment to overvoltages and overcurrents*
CCITT Recommendation K 21 : 1990	*Resistability of subscribers' terminals to overvoltages and overcurrents*

National annex NA (informative)

Committees responsible

The United Kingdom participation in the preparation of this European Standard was entrusted by the Electrotechnical Sector Board to Technical Committee GEL/110, upon which the following bodies were represented:

Association of Consulting Scientists
Association of Control Manufacturers TACMA (BEAMA Ltd.)
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BEAMA Ltd.
BEAMA Metering Association (BMA)
British Industrial Truck Association
British Lighting Association for the Preparation of Standards (Britlaps)
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British Radio and Electronic Equipment Manufacturers' Association
Electrical Contractors' Association
Power Supply Manufacturers' Association PSMA (BEAMA Ltd.)
Professional Lighting and Sound Association

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National annex NB (informative)

Cross-references

Publication referred to	Corresponding British Standard
IEC 50 (161) : 1990	BS 4727 *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms* Part 1. *Terms common to power, telecommunications and electronics* Group 09 : 1991 *Electromagnetic compatibility*
IEC 255-22-1 : 1988	BS 142 *Electrical protection relays* Part 1. *Information and requirements for all protection relays* Section 1.4 *Specification for electrical disturbance tests* Subsection 1.4.1 : 1990 *1 MHz disturbance tests*
EN 60521 : 1994 (IEC 521 : 1988)	BS 5685 *Electricity meters* Part 1 : 1979 *Specification for Class 0.5, 1 and 2 single-phase and polyphase, single rate and multi-rate watt-hour meters*
HD 479 S1 : 1986 (IEC 790 : 1984)	BS 6647 : 1985 *Guide to oscilloscopes and peak voltmeters for impulse tests*
EN 60801-2 : 1993 (IEC 801-2 : 1991)	BS EN 60801-2 : 1993 *Electromagnetic compatibility for industrial-process measurement and control equipment* Part 2. *Electrostatic discharge requirements*
HD 481.3 S1 : 1987 (IEC 801-3 : 1984)	BS 6667 *Electromagnetic compatibility for industrial-process measurement and control equipment* Part 3 : 1985 *Method of evaluating susceptibility to radiated electromagnetic energy*
IEC 816 : 1984	BS 6662 : 1985 *Guide to methods of measurement of short duration transients on low voltage power and signal lines*
IEC 1000-2-1 : 1990	BS 7484 : 1991 *Guide to electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems*
ENV 61000-2-2 : 1993 (IEC 1000-2-2 : 1990)	DD ENV 61000-2-2 : 1993 *Electromagnetic compatibility (EMC)* Part 2. *Environment* Section 2. *Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*
EN 61000-4-7 : 1993 (IEC 1000-4-7 : 1991)	BS EN 61000-4-7 : 1993 *Electromagnetic compatibility (EMC)* Part 4. *Testing and measurement techniques* Section 7. *General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connnected thereto*
EN 61000-4-8 : 1993 (IEC 1000-4-8 : 1993)	BS EN 61000-4-8 : 1994 *Electromagnetic compatibility (EMC)* Part 4. *Testing and measurement techniques* Section 8. *Power frequency magnetic field immunity test. Basic EMC publication*
EN 61000-4-9 : 1993 (IEC 1000-4-9 : 1993)	BS EN 61000-4-9 : 1994 *Electromagnetic compatibility (EMC)* Part 4. *Testing and measurement techniques* Section 9. *Pulse magnetic field immunity test. Basic EMC publication*
EN 61000-4-10 : 1993 (IEC 1000-4-10 : 1993)	BS EN 61000-4-10 : 1994 *Electromagnetic compatibility (EMC)* Part 4. *Testing and measurement techniques* Section 10. *Damped oscillatory magnetic field immunity test. Basic EMC publication*

BS EN 61000-4-1 : 1995 IEC 1000-4-1 : 1992

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