ประกาศกระทรวงอุตสาหกรรม
ฉบับที่ ๒๓๖๓ (พ.ศ. ๒๕๔๑)
ออกตามความในพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม
พ.ศ. ๒๕๑๑
เรื่อง กำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม
ความเข้ากันได้ทางแม่เหล็กไฟฟ้า
เล่ม ๔ เทคนิคการทดสอบและการวัด
ส่วนที่ ๑๒ การทดสอบภูมิคุ้มกันคลื่นแกว่ง

อาศัยอำนาจตามความในมาตรา ๑๕ แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. ๒๕๑๑ รัฐมนตรีว่าการกระทรวงอุตสาหกรรมออกประกาศกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ความเข้ากันได้ทางแม่เหล็กไฟฟ้า เล่ม ๔ เทคนิคการทดสอบและการวัด ส่วนที่ ๑๒ การทดสอบภูมิคุ้มกันคลื่นแกว่ง มาตรฐานเลขที่ มอก. ๑๔๖๑ - ๒๕๔๐ ไว้ ดังมีรายการละเอียดต่อท้ายประกาศนี้

ประกาศ ณ วันที่ ๕ กุมภาพันธ์ พ.ศ. ๒๕๔๑

สมศักดิ์ เทพสุทิน

รัฐมนตรีว่าการกระทรวงอุตสาหกรรม

มาตรฐานผลิตภัณฑ์อุตสาหกรรม
ความเข้ากันได้ทางแม่เหล็กไฟฟ้า
เล่ม 4 เทคนิคการทดสอบและการวัด
ส่วนที่ 12 การทดสอบภูมิคุ้มกันคลื่นแกว่ง

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นโดยรับ IEC 1000-4-12 (1995-05) Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques - Section 12: Oscillatory waves immmunity test มาใช้ในระดับเหมือนกันทุกประการ (identical) โดยใช้ IEC ฉบับภาษาอังกฤษเป็นหลัก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้เกี่ยวข้องกับคุณลักษณะที่ต้องการด้านภูมิคุ้มกันและวิธีทดสอบสำหรับบริภัณฑ์ไฟฟ้าและอิเล็กทรอนิกส์(เฉพาะภายใต้สภาวะการทำงาน) จากการรบกวนของคลื่นแกว่ง 2 ลักษณะคือ

ก. ภาวะชั่วครู่แกว่งแบบหน่วงไม่ซ้ำ(คลื่นสั้น) ที่เกิดขึ้นในสายไฟฟ้ากำลังแรงดันไฟฟ้าต่ำ สายควบคุม และสายสัญญาณซึ่งป้อนให้โดยเครือข่ายสาธารณะและไม่ใช่สาธารณะ

ข. คลื่นแกว่งแบบหน่วงซ้ำ ที่เกิดขึ้นในสายเคเบิลไฟฟ้ากำลัง สายเคเบิลควบคุม และสายเคเบิลสัญญาณที่ติดตั้งในสถานีไฟฟ้าแรงดันไฟฟ้าสูงและแรงดันไฟฟ้าปานกลาง

วัตถุประสงค์ของมาตรฐานนี้เพื่อจัดตั้งคุณลักษณะที่ต้องการต้านภูมิคุ้มกันและการอ้างอิงร่วมกัน สำหรับประเมินในห้องปฏิบัติการทดสอบเกี่ยวกับสมรรถนะของบริภัณฑ์ไฟฟ้าและอิเล็กทรอนิกส์ที่ประสงค์ให้ใช้ในสถานที่เพื่อการอยู่อาศัย สถานที่ทางการพาณิชย์ และวงการอุตสาหกรรมรวมทั้งบริภัณฑ์ที่ประสงค์ให้ใช้ในสถานีไฟฟ้าเท่าที่จะใช้ได้

จุดประสงค์ของมาตรฐานนี้เพื่อที่จะกำหนด

- รูปคลื่นแรงดันไฟฟ้าและกระแสไฟฟ้าทดสอบ
- พิสัยของระดับทดสอบต่าง ๆ
- บริภัณฑ์ทดสอบ
- สิ่งซึ่งจัดขึ้นเพื่อการทดสอบ
- วิธีดำเนินการทดสอบ

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้ไม่ได้ประสงค์เพื่อกำหนดการทดสอบซึ่งใช้สำหรับเครื่องสำเร็จหรือระบบเฉพาะ แต่เป้าหมายหลักเพื่อกำหนดข้ออ้างอิงพื้นฐานทั่วไปสำหรับคณะกรรมการทางเทคนิคที่เกี่ยวข้องทั้งหมด แต่คณะกรรมการทางเทคนิค (หรือผู้ใช้และผู้ผลิตบริภัณฑ์) ยังคงต้องรับผิดชอบในการเลือกการทดสอบและระดับความรุนแรงที่เหมาะสมสำหรับใช้กับบริภัณฑ์แต่ละชนิด รายละเอียดให้เป็นไปตาม IEC 1000-4-12 (1995-05)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4: Testing and measurement techniques – Section 12: Oscillatory waves immunity test

Basic EMC Publication

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 1000-4-12 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms section 12 of part 4 of IEC 1000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

The text of this standard is based on the following documents:

DIS	Report on voting
77B/141/DIS	77B/151/RVD

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

Annexes A, B, C and D are for information only.

INTRODUCTION

This standard is part of the IEC 1000 series, according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

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

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 9: Miscellaneous

Each part is further subdivided into sections which are to be published either as international standards or as technical reports.

These standards and reports will be published in chronological order and numbered accordingly.

This section is an international standard which gives immunity requirements and test procedures related to "oscillatory waves".

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4: Testing and measurement techniques – Section 12: Oscillatory waves immunity test

Basic EMC Publication

1 Scope

This section of IEC 1000-4 relates to the immunity requirements and test methods for electrical and electronic equipment, under operational conditions, to oscillatory waves represented by:

a) non-repetitive damped oscillatory transients (ring wave) occurring in low-voltage power, control and signal lines supplied by public and non-public networks;

b) repetitive damped oscillatory waves occurring mainly in power, control and signal cables installed in high voltage and medium voltage (HV/MV) stations.

NOTE – According to the frequencies considered in this standard, it is only relevant for an insulated switchgear.

Aie object of this basic standard is to establish the immunity requirements and a common reference for evaluating in a laboratory the performance of electrical and electronic equipment intended for residential, commercial and industrial application, as well as of equipment intended for electrical stations, as applicable.

The purpose of this standard is to define:

- test voltage and current waveforms;
- ranges of test levels;
- test equipment;
- test set-up;
- test procedure.

This standard does not 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 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.

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

IEC 68-1: 1988, *Environmental testing – Part 1: General and guidance*

IEC 1010-1: 1990, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

3 General

The oscillatory waves to which equipment is subjected may influence the reliable operation of equipment and systems.

The main parameters of the oscillatory waves are considered here, mainly the repetition rates: low repetition rate (single shot), or high repetition rate (bursts). The single-shot oscillatory transients are known by the term "ring wave" and the bursts of damped oscillatory transients by the term "damped oscillatory wave".

The ring wave appears at the terminals of equipment (equipment ports) as a consequence of switching in power and control lines, as well as a consequence of lightning. The single-event type and the decaying oscillatory waveform are the most significant parameters of this test.

The damped oscillatory wave appears at the terminals of equipment as a consequence of switching with restriking of the arc, typical of electrical plants, HV/MV stations, as well as of heavy industrial installations.

The relative fast rise time, the decaying oscillatory waveform, the high repetition rate and the duration of the burst are the most significant parameters of this test.

The test waveforms are defined in 6.1.1 and 6.1.2. Information on the primary phenomena and selection of the test is given in annex A.

It is the responsibility of the product committees to establish which phenomenon, among the ones considered in this standard, is relevant and to decide the applicability of the test.

4 Definitions

For the purpose of this section, the following definitions and terms apply. They are applicable to the restricted field of oscillatory transients; not all of them are included in IEC 50(161).

4.1 **EUT:** Equipment under test.

4.2 **port:** Particular interface of the EUT with the external electromagnetic environment.

4.3 **coupling:** Interaction between circuits, transferring energy from one circuit to another.

4.4 **coupling network:** Electrical circuit for the purpose of transferring energy from one circuit to another.

4.5 **decoupling network:** Electrical circuit for the purpose of preventing test voltage applied to the EUT from affecting other devices, equipment, or systems which are not under test.

4.6 **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]

4.7 **transient (adjective and noun):** 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]

4.8 **rise time:** The interval of time between the instants at which the instantaneous value of a pulse first reaches 10 % value and then the 90 % value. [IEV 161-02-05, modified]

4.9 **burst:** A sequence of a limited number of distinct pulses or an oscillation of limited duration. [IEV 161-02-07]

5 Test levels

The preferential range of test levels for the ring wave and the damped oscillatory wave tests, applicable to power, signal and control ports of the equipment, is given in table 1 and table 2 respectively.

Different levels may apply to power, signal and control ports. The level(s) used for signal and control ports shall not differ by more than one level from that used for power supply ports.

Table 1 – Test levels for ring wave

Level	Common mode kV	Differential mode kV
1	0,5	0,25
2	1	0,5
3	2	1
4	4	2
x [1)]	x	x

1) x is an open level. This level can be given in the product specification.

Table 2 – Test levels for damped oscillatory wave

Level	Common mode kV	Differential mode kV
1	0,5	0,25
2	1	0,5
3	2 [2)]	1
4	–	–
x [1)]	x	x

1) x is an open level. This level can be given in the product specification.

2) The value is increased to 2,5 kV for substation equipment.

The applicability of the two tests, respectively the ring wave and the damped oscillatory wave, shall refer to the product specification.

Specifications related to each test are given in 8.2.

Information on the selection of the test levels is given in annex B.

6 Test equipment

6.1 *Test generators*

The following features are common to the generators of ring waves and the generators of damped oscillatory waves; additional, unique features are given in 6.1.1 and 6.1.2.

The generators shall have the capability to operate in short-circuit conditions.

The generator output shall be floating and the stray capacity unbalance of the output terminals to earth shall be less than 10 %. This condition is recommended to test EUT control and signal ports in differential mode; it is not necessary for power ports and common mode tests of control and signal ports.

The provisions to be taken whenever the output of the test generator is not floating are given in item b) of 8.2.

The generators shall have provisions to prevent the emission of heavy disturbances that may be injected in the power supply network, or may influence the test results.

Information on the impedance of the test generators is given in annex C.

6.1.1 *Characteristics and performance of the ring wave generator*

The generator is a single-shot damped oscillatory wave generator with the following characteristics.

Specifications:

– voltage rise time (first peak):	0,5 µs ± 20 % (open-circuit condition);
– current rise time (first peak):	≤1 µs (short-circuit condition);
– oscillation frequency:	100 kHz ± 10 %;
– decaying (of each peak):	60 % of the preceding peak;
– transients' repetition:	1 to 60 transients per minute;
– output impedance:	12 Ω, 30 Ω and 200 Ω, ±20 % (switchable);
– open-circuit voltage (peak value):	250 V (–10 %) to 4 kV (+10 %);
– short-circuit current (minimum peak value):	333 A for 12 Ω generator setting; 133 A for 30 Ω generator setting; 20 A for 200 Ω generator setting;
– phase relationship with the power frequency:	synchronizable from 0° to 360° with 10° steps;
– polarity of the first half period:	positive and negative.

The waveform of the ring wave (open-circuit voltage and short-circuit current) is given in figure 1. An example of a schematic circuit of the generator is given in figure 2.

The impedance of the test generator to be used for the different tests is given in 8.2.

6.1.2 *Characteristics and performance of the damped oscillatory wave generator*

The generator is a repetitive damped oscillatory wave generator with the following characteristics.

Specifications:

- voltage rise time (first peak): 75 ns ± 20 %;
- oscillation frequencies; 100 kHz and 1 MHz ±10 %;
- repetition rate: at least 40/s for 100 kHz and 400/s for 1 MHz;
- optional repetition rate: $4 \cdot 10^{-4}$ x oscillation frequency;
- decaying: 50 % of the peak value between the third and sixth periods;
- burst duration: not less than 2 s;
- output impedance: 200 Ω ± 20 %;
- peak open-circuit voltage: 250 V (–10 %) to 2,5 kV (+10 %);
- phase relationship with the power frequency: no relation;
- polarity of the first half-period: positive and negative.

The waveform of the damped oscillatory wave is given in figure 3.

An example of a schematic circuit of the generator is given in figure 4.

6.2 *Verification of the characteristics of the test generators*

In order to make it possible to compare the results of different test generators, the most essential characteristics shall be verified.

The characteristics to be verified, according to the specifications given in 6.1.1 and 6.1.2, are the following:

- rise time (voltage and current);
- oscillation frequency;
- decaying;
- repetition frequency;
- open-circuit voltage;
- short-circuit current.

The verifications shall be carried out with voltage or current probes (as applicable) and with oscilloscope or other equivalent measurement instrumentation with 20 MHz minimum bandwidth.

The accuracy of the measurements shall be ±10 %.

The emission of disturbances by the generator shall be verified (see 6.1).

6.3 *Coupling/decoupling network*

The coupling/decoupling network (CDN) provides both the ability to apply the test voltage in either common or differential mode to the power supply, signal and control ports of the EUT, and for preventing test voltage from affecting the auxiliary equipment needed to perform the test. The network must not influence the specified parameters of the generator, for example, the current capability.

The specifications, common to the networks for power supply, as well as for the input/output ports, are given below; additional unique specifications are given in 6.3.1 and 6.3.2.

The coupling network shall be provided with coupling capability suitable for the selected impedance of the test generator (see 8.2), as follows:

- 0,5 μF for 200 Ω generator impedance;
- 3 μF (minimum) for 30 Ω generator impedance;
- 10 μF (minimum) for 12 Ω generator impedance.

These coupling capacitor values are suitable to give a coupling attenuation less than 1 dB.

For some applications, the coupling capacitors shall be replaced by other types of coupling devices (CD), such as gas tubes, silicon avalanche diodes, etc.

The coupling/decoupling network shall be provided with a dedicated earth terminal.

The verifications related to the specifications given in 6.3.1 and 6.3.2 shall be carried out with an oscilloscope, or equivalent measuring instrument, with 20 MHz minimum bandwidth.

The schematic circuit of the network is given in the figures related to the test procedures for carrying out the tests (see 8.2).

6.3.1 *Coupling/decoupling network for a.c./d.c. power supply ports*

The output waveforms from the coupling/decoupling network shall meet the same requirements set forth in 6.2 for the test generator itself.

Specifications:

– common mode decoupling (attenuation):	20 dB;
– differential mode decoupling (attenuation):	30 dB;
– insulation withstand capacity of the coupling capacitors with the 1,2/50 μs wave:	5 kV;
– current capability:	as for the current rating of the power supply port;
– number of phases:	one or three, as required.

6.3.2 *Coupling/decoupling network for signal and control ports*

The network has the same specifications given in 6.3.1, with the exception below:

- decoupling attenuation: 30 dB (common and differential modes).

The minimum decoupling attenuation may not be sufficient to protect auxiliary signal sources, and additional protection devices may be required.

The network may consist of single units in order to give the possibility of testing input/output ports with single circuits or grouping of circuits (for example, multi-wire with a common).

7 Test set-up

The test set-up includes the following components:

- earthing connections, ground (reference) plane (GRP);
- equipment under test (EUT);
- test generator;
- measurement instrumentation;
- coupling and decoupling network;
- auxiliary instrumentation.

Examples of test set-up are given in the following figures:

figure 5 – example of test set-up for table-top equipment;

figure 6 – example of test set-up for floor-standing equipment.

7.1 *Earthing connections*

In performing the tests, the safety earthing requirements of the manufacturer of the EUT and of the test equipment shall be observed.

In setting up the test configuration, the earthing of the test generator, of the coupling/decoupling network, of EUT and auxiliary equipment may be achieved by using an existing ground reference plane (GRP), or proper earthing connections.

The specifications are given in 7.1.1 and 7.1.2.

7.1.1 *Ground (reference) plane*

Where a ground reference plane (GRP) is used, it shall be a metal sheet (copper or aluminium) of 0,25 mm minimum thickness; other metals may be used, but in that case they shall have 0,65 mm minimum thickness.

If used, the EUT and auxiliary test equipment shall be placed on the GRP of the laboratory and connected to it.

The minimum size of the GRP is 1 m × 1 m; the final size depends on the dimensions of the EUT. The GRP shall be projected beyond the EUT and its auxiliary equipment by at least 0,1 m on all sides.

The GRP shall be connected to the safety earth system of the laboratory (see figures 7.a to 14.a).

7.1.2 *Dedicated earthing connections*

For table-top equipment, the tests may be performed without a GRP, in order to satisfy national safety regulations. In that case, the repeatability can be affected. However, when testing without the GRP is performed, it is important to ensure that all possible surge current paths do not include conductors (including protective earth conductors) which may be common with other equipment, not intended to be included in the testing configuration.

To accomplish this, it is necessary to derive the protective earth (PE) for all three units *(test generator, coupling/decoupling network and EUT)*, from the same point: specifically, from the PE input to the coupling/decoupling network (see figures 7.b to 14.b).

It is also necessary that the test generator case shall be connected to the PE, but the generator output terminals shall be floating.

7.2 *Equipment under test*

The equipment under test shall be arranged and connected according to the equipment installation specifications.

The minimum distance between the EUT and all other conductive structures (for example, the walls of a shielded room), except the GRP beneath the EUT, shall be 0,5 m.

The power supply, input and output circuits shall be connected to the sources of power supply, control and signals via the coupling/decoupling network.

The operating signals for exercising the EUT may be provided by auxiliary equipment, or by a simulator.

The input and output circuits to the simulator shall be provided with back filters, in order to prevent interference to that equipment.

The cables supplied or specified by the equipment manufacturer shall be used or, in their absence, unshielded cables shall be adopted, of the type suitable for the signals involved.

The coupling/decoupling network shall be inserted in the circuits at 1 m cable distance from the EUT and connected to the GRP.

The communication lines (data lines) shall be connected to the EUT by the cables given in the technical specification or standard for this application; they shall be elevated 0,1 m above the GRP for at least 1 m in length.

Particular prescriptions for table-top and floor-standing equipment are given below.

a) *Table-top equipment*

Table-top equipment shall be placed on a wooden table, approximately 0,8 m high. The EUT and cables shall be isolated from the GRP, if used, by an insulating support 0,5 mm thick.

Equipment (for example, terminals, monitors, etc.), for which the earthing is provided via the power supply cable (yellow-green wire), shall be connected to earth, for example, via the dedicated earth terminal of the coupling/decoupling network.

An example of the test set-up for table-top equipment is given in figure 5.

b) *Floor-standing equipment*

Where a GRP is used, floor-standing equipment shall be placed on the GRP with the interposition of a 0,1 m ± 0,01 m thickness insulating support, for example, dry wood.

The EUT shall be connected to the earthing system according to the manufacturer's installation specifications.

The equipment cabinets shall be connected to the safety earth directly on the GRP via a connection of minimum length starting from the earth terminal of the EUT; no additional connections are allowed.

An example of the test set-up for floor-standing equipment is given in figure 6.

7.3 *Coupling/decoupling network*

The coupling/decoupling network shall be arranged in close vicinity to the EUT and connected to the EUT through lines of 1 m in length. They shall be connected to the GRP, where used, through a connection as short as possible.

The EUT shall be tested with a power cable of 1 m in length, except in the following cases, where the excess length of the cable shall be gathered into a flat coil with 0,2 m diameter and situated at a distance of 0,1 m above the GRP.

EUT supplied with non-detachable moulded cable

It shall be tested with the actual length provided.

EUT supplied with detachable cable, moulded at both ends and specified in the manufacturer's authentic manual

It shall be tested with the specified cable; however, if the manufacturer specifies more than one length of such premoulded cable, then the shortest length shall be used for testing.

7.4 *Test generators*

The test generator shall be placed close to the coupling/decoupling network and connected to the latter through a line of 1 m length.

It shall be connected to the GRP, where used (see 7.1.1), or to the protection earth of the laboratory (see 7.1.2) through a connection as short as possible; in the case of testing of communication port, see prescriptions given in item c) of 8.2.1.

8 Test procedure

The test procedure includes:

- the verification of the laboratory reference conditions;
- the preliminary verification of the correct operation of the equipment;
- the execution of the test;
- the evaluation of the test results.

8.1 *Laboratory reference conditions*

In order to minimize the impact of environmental parameters on test results, the tests shall be carried out in the climatic and electromagnetic reference conditions as specified in 8.1.1 and 8.1.2.

8.1.1 *Climatic conditions*

The tests shall be carried out in standard climatic conditions in accordance with IEC 68-1:

- ambient temperature: 15 °C to 35 °C;
- relative humidity: 25 % to 75 %;
- atmospheric pressure: 86 kPa (860 mbar) to 106 kPa (1 060 mbar).

NOTE – Any other values are specified in the product specification.

The EUT shall be operated within its intended climatic conditions.

8.1.2 *Electromagnetic conditions*

The electromagnetic conditions of the laboratory shall not influence the test results.

8.2 *Execution of the test*

The test shall be carried out on the basis of a test plan, including verification of the performances of the EUT, as defined in the product standard, or in its absence, by the technical specification.

The EUT shall be in the normal operating conditions.

The test plan shall specify:

- type of test that will be carried out;
- test level;
- test generator and the internal impedance selected for each test;
- polarity of the test voltage (both polarities are mandatory);
- number of applications of the test voltage;
- duration of the test;
- EUT ports to be tested;
- mode of application of the test voltage (line-to-ground, line-to-line, between cabinets);
- sequence of application of the test voltage to the EUT ports;
- synchronization angle and phase for testing power supply (only for ring wave);
- representative operating conditions of the EUT;
- auxiliary equipment.

The power supply, signal and other functional electrical quantities shall be applied within their rated range. If the actual operating signal sources are not available, they may be simulated. Preliminary verification of equipment performances shall be carried out on the completed test set-up before applying the test voltage.

Before carrying out the test, the characteristics of the test generators shall be verified in order to satisfy the requirements of 6.1.

The test voltage shall be applied to the EUT, previously set-up as in 7.2.

The EUT shall be verified according to the product standard or, in its absence, by the technical specifications, which will specify the applicability of the ring wave, or of the damped oscillatory wave test, or both.

Under no circumstances shall the test level, the impedance of the generator and repetition rate exceed the product specification.

a) *Line-to-ground test (common mode)*

The test voltage shall be applied, through the coupling network, between each circuit and earth (GRP).

One of the terminals of the test generator shall be connected to earth (GRP). The other terminal of the generator shall be connected through a single line to all the input terminals of the coupling network, these terminals being interconnected.

To test circuits with more than two terminals (for example, grouping), the test voltage shall be applied simultaneously between all the terminals of the circuit and earth (GRP).

Examples of the application of the prescriptions related to the different types of EUT ports are given in the following figures:

figure 7 – a.c./d.c. power supply port, single phase, line-to-ground test;

figure 8 – a.c. power supply port, three phase, line-to-ground test;

figure 9 – input/output port, single circuit, line-to-ground test;

figure 10 – input/output port, group of circuits with common return, line-to-ground test.

Each figure refers to the set-up implemented with the GRP (figures 7.a, 8.a, 9.a and 10.a) and with dedicated earth connections (figures 7.b, 8.b, 9.b and 10.b) respectively.

b) *Line-to-line test (differential mode)*

The test voltage shall be applied, through the coupling network, between each representative combination of the terminals of the circuit under test.

The output of the test generator shall be floating.

Examples of the application of the prescriptions related to the different types of EUT ports are given in the following figures:

figure 11 – a.c./d.c. power supply port, single phase, line-to-line test;

figure 12 – a.c. power supply port, three phases, line-to-line test;

figure 13 – input/output port, single circuit, line-to-line test;

figure 14 – input/output port, group of circuits with common return, line-to-line test.

Each figure refers to the set-up implemented with the GRP (figures 11.a, 12.a, 13.a and 14.a) and with dedicated earth connections (figures 11.b, 12.b, 13.b and 14.b) respectively.

In the case of test generators without a floating output, the following shall apply:

– the power supply of the test generator, of the EUT and measurement instrumentation (for example, oscilloscope connected to the monitoring output), shall be provided via a low-capacity isolation transformer (about 10 pF);

– the generator shall be placed on a wood (or other insulating material) table, 0,8 m high;

– the generator shall not be connected to the safety earthing system, but it shall not be accessible to personnel.

An example of provisions for differential mode tests with test generator output not floating is given in figure 15.

Whenever the test generator is isolated in this way, particular provisions shall be taken in order to realize equivalent conditions in respect to the safety rules (clause 6 of IEC 1010-1).

8.2.1 *Test implementation with ring wave*

A minimum of five positive and five negative transients should be applied, at 1 s minimum time interval, depending on the generator impedance, as well as EUT and other transient protectors involved in the test.

The equipment specifications should define the impedance of the test generator to be used for the different EUT ports and the time interval.

The minimum time interval is:

- 10 s for tests with 12 Ω impedance;
- 6 s for tests with 30 Ω impedance;
- 1 s for tests with 200 Ω impedance.

Information on the maximum repetition rate is given in clause A.1 of annex A.

Other prescriptions may be given in the product standard or product specification.

a) *Test of power supply port*

The test voltage shall be applied through the coupling/decoupling network.

The impedance of the test generator shall be as follows:

- EUT ports connected to major feeders shall be tested with 12 Ω generator impedance;
- EUT ports connected to outlets shall be tested with 30 Ω generator impedance.

Other prescriptions may be given in the product standard or product specification.

The synchronization of the transients with the power frequency and phase relationship shall be stated; information on their possible effects is given in clause A.1 of annex A.

b) *Test of input/output port*

The test voltage shall be applied via the coupling/decoupling network, provided the network is suitable for the operating signal of the EUT ports.

Whenever the coupling/decoupling network may produce degradation of the operating signal, the method given in item c) shall be applied.

The impedance of the test generator shall be 200 Ω, unless the test shall involve protection devices or filters; in that case, the impedance of the test generator will be 12 Ω or 30 Ω, according to the product specifications.

Different impedance values shall be selected, therefore, whenever the test voltage at the EUT terminals (load condition) is reduced to 50 %, or less, of the selected test level.

c) *Test of a system with communication ports*

The test of communication ports of a system (fast operating signals involved) with the application of test voltage via the coupling/decoupling network may cause degradation of the operating signals; in that situation, the test voltage shall be applied between the cabinets of the equipment interconnected (EUT 1 and EUT 2), according to figure 16. The output impedance of the test generator shall be 12 Ω.

For cables with only one er d of the screen earthed, the unearthed side of the screen shall be connected to the cabinet through 0,5 μF coupling capacity.

The standard cable length for this test is 10 m.

The signal cables shall be connected according to the product specifications, which shall give information on any protection measure to be taken.

Whenever EUT 1 is an auxiliary equipment (simulator), a preliminary verification of the immunity of the simulator shall be made; in case of lack of immunity of the simulator, and whenever no provisions can be taken to avoid susceptibility, the test will be carried out with the following objectives:

- the communication port is not damaged;
- the communication is corrupted only during the application of the test voltage;
- the EUT performances, other than ones related to communications, are not affected.

8.2.2 *Test implementation with damped oscillatory wave*

The damped oscillatory wave test are carried out at 100 kHz and 1 MHz preferred oscillation frequencies.

The test voltage shall be applied to power supply, input/output and communication ports in both polarities, according to the product specifications.

The transients shall not be synchronized with the power supply.

The duration of the test shall not be less than 2 s.

The minimum time interval between two successive tests is 1 s.

Any other oscillation frequency in the range 30 kHz to 10 MHz, repetition rate and test duration, can be given by product committees or product specifications; a special test generator and coupling/decoupling network are necessary for this purpose. These shall be recorded in the test plan.

9 Test results and test report

This clause gives a guide to the evaluation of the test results and to the test report, related to this standard.

The variety and diversity of 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 the functional specifications of the equipment under test, as below, unless different specifications are given by product committees or product specifications:

a) normal performance within the specification limits;

b) temporary degradation or loss of function or performance which is self-recoverable;

c) temporary degradation or loss of function or performance which requires operator intervention or system reset;

d) degradation or loss of function which is not recoverable, due to damage to equipment (components) or software, or loss of data.

Equipment shall not become dangerous or unsafe as a result of the application of the tests defined in this standard.

In the case of acceptance tests, the test programme and the interpretation of the test results shall be described in the specific product standard.

As a general rule, the test result is positive if the equipment shows its immunity for all the period of application of the test; 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 those conditions, it shall be verified that the equipment is able to recover its operative capabilities by itself at the end of the test; the time interval during which the equipment has lost its functional capabilities shall be recorded therefore. These verifications are binding for the definitive evaluation of the test result.

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

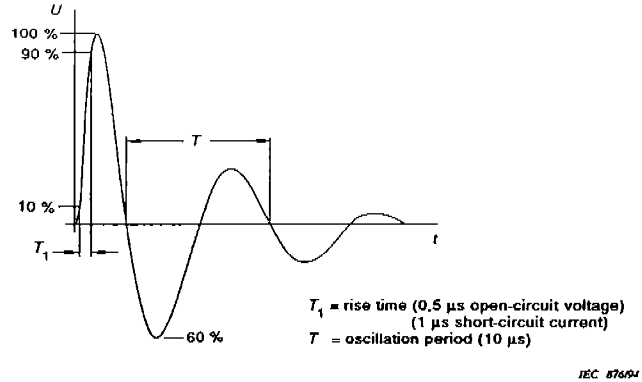
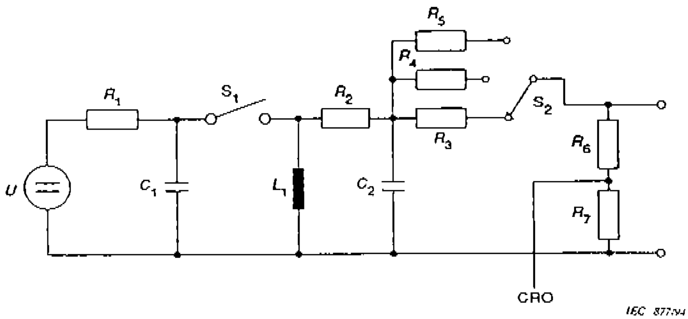


Figure 1 – Waveform of the ring wave (open-circuit voltage and short-circuit current)



U:	high-voltage source	C_2:	filter capacitor
R_1:	charging resistor	R_3:	200 Ω resistor
C_1:	energy storage capacitor	R_4:	30 Ω resistor
S_1:	high-voltage switch	R_5:	12 Ω resistor
L_1:	oscillating circuit coil	S_2:	output impedance selector
R_2:	filter resistor	R_6, R_7:	voltage divider resistors
		CRO:	monitoring signal

Figure 2 – Example of schematic circuit of the test generator for ring wave

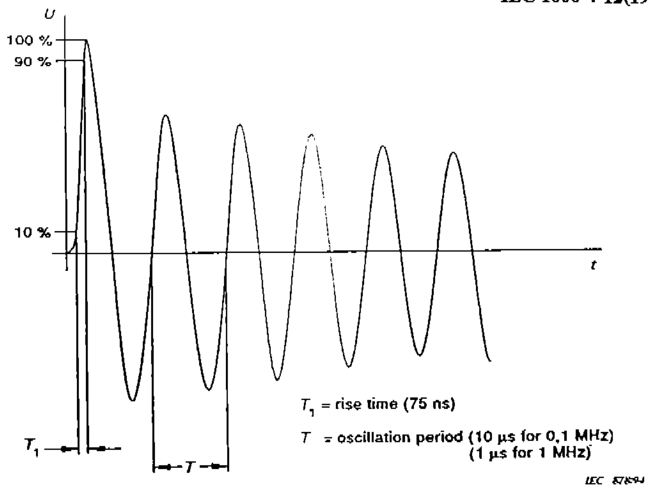
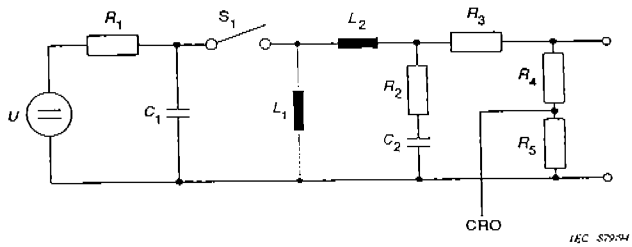
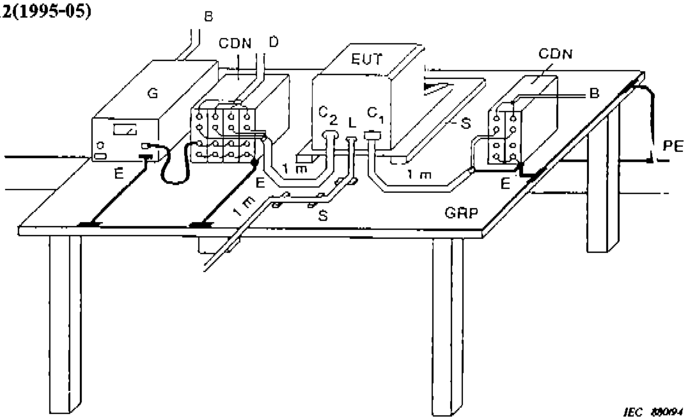


Figure 3 – Waveform of the damped oscillatory wave



U:	high-voltage source	L_2:	filter inductance
R_1:	charging resistor	R_2:	filter resistor
C_1:	energy storage capacitor	C_2:	filter capacitor
S_1:	high-voltage switch	R_3:	source resistor
L_1:	oscillating circuit coil	R_4, R_5:	voltage divider resistors
		CRO:	monitoring signal

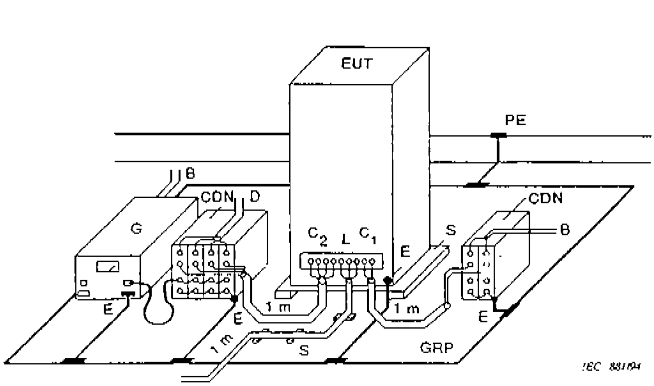
Figure 4 – Example of schematic circuit of the test generator for damped oscillatory wave



NOTE – Earth connections should be as short as practically possible.

PE:	protective earth	EUT:	equipment under test
B:	power supply source	G:	test generator
C_1:	power supply port	L:	communication port
C_2:	input/output port	GRP:	ground reference plane
D:	signal/control source	CDN:	coupling/decoupling network
E:	earth connection	S:	insulating support

Figure 5 – Example of test set-up for table-top equipment using the ground reference plane



NOTE – Earth connections should be as short as practically possible.

PE:	protective earth	EUT:	equipment under test
B:	power supply source	G:	test generator
C_1:	power supply port	L:	communication port
C_2:	input/output port	GRP:	ground reference plane
D:	signal/control source	CDN:	coupling/decoupling network
E:	earth connection	S:	insulating support

Figure 6 – Example of test set-up for floor-standing equipment using the ground reference plane

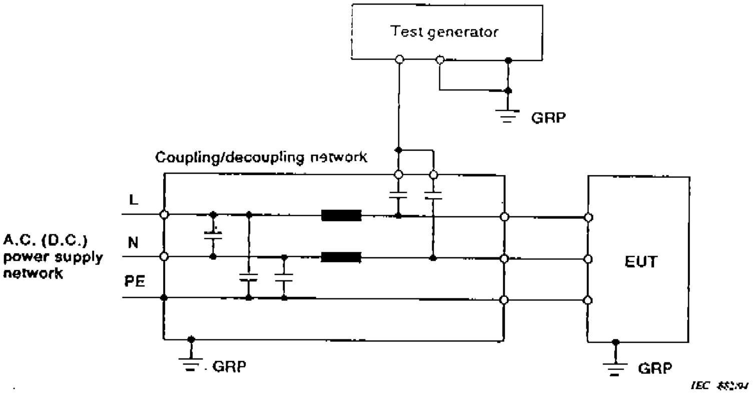


Figure 7.a – Set-up implemented with the ground reference plane (see 7.1.1)

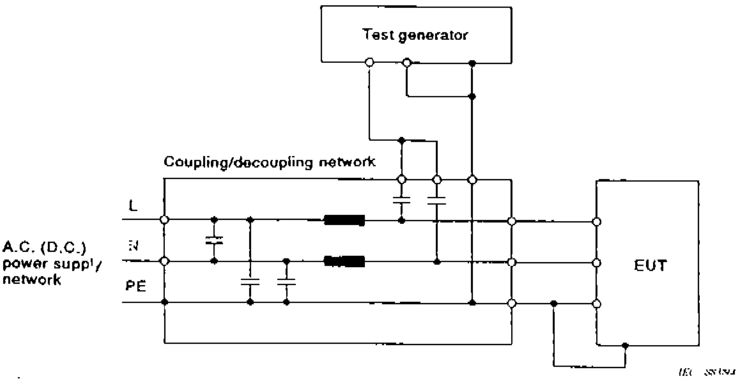


Figure 7.b – Set-up implemented with dedicated earth connections (see 7.1.2)

Figure 7 – A.C./D.C. power supply port, single phase, line-to-ground test

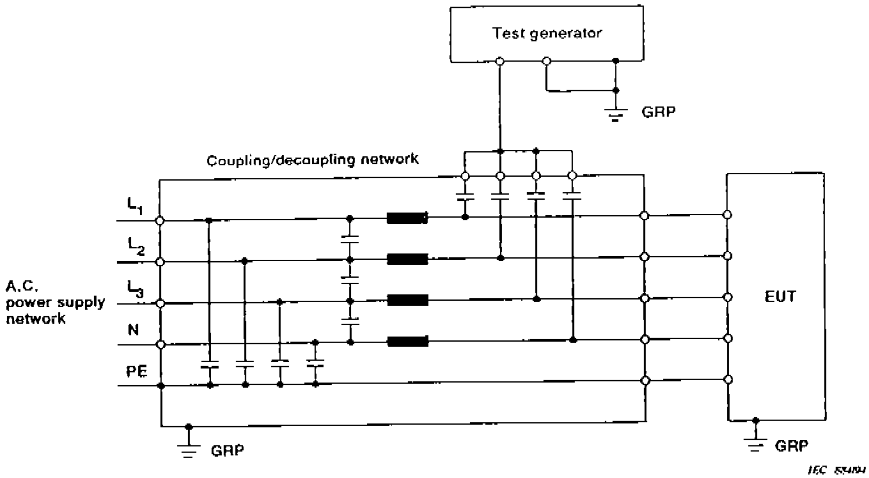


Figure 8.a – Set-up implemented with the ground reference plane (see 7.1.1)

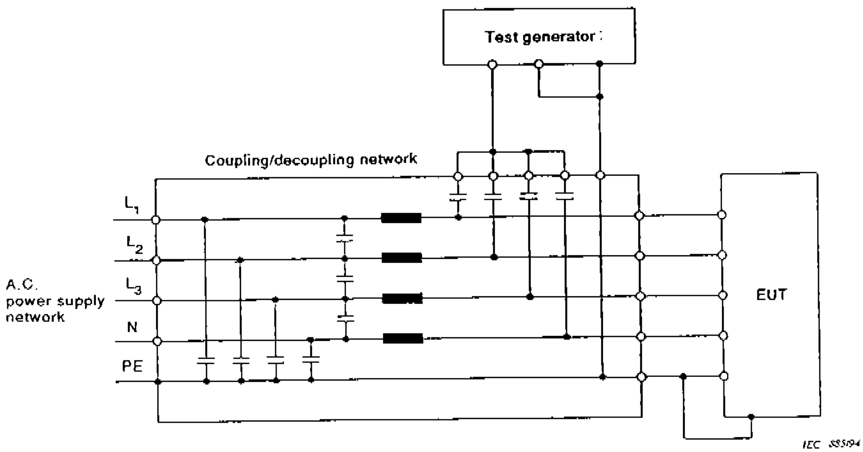


Figure 8.b – Set-up implemented with dedicated earth connections (see 7.1.2)

Figure 8 – A.C. power supply port, three phase, line-to-ground test

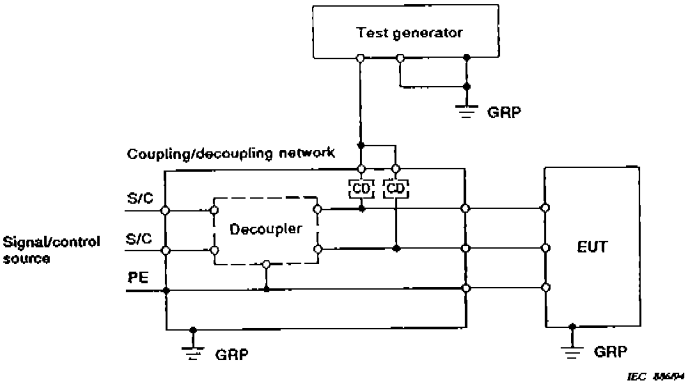


Figure 9.a – Set-up implemented with the ground reference plane (see 7.1.1)

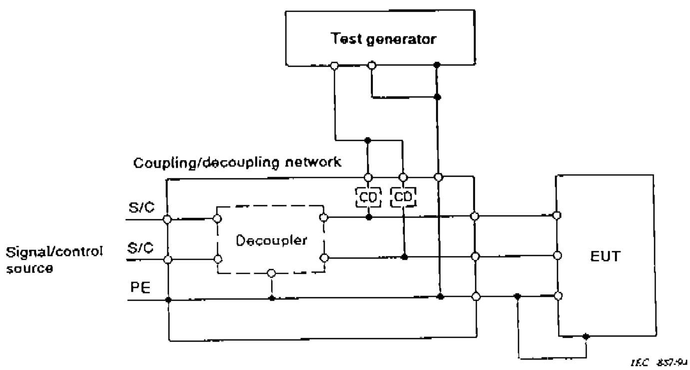


Figure 9.b – Set-up implemented with dedicated earth connections (see 7.1.2)

CD: Coupling devices. For some applications, the coupling capacitors have to be replaced by other types of coupling devices, such as gas tubes, silicon avalanche diodes, etc.

Figure 9 – Input/output port, single circuit, line-to-ground test

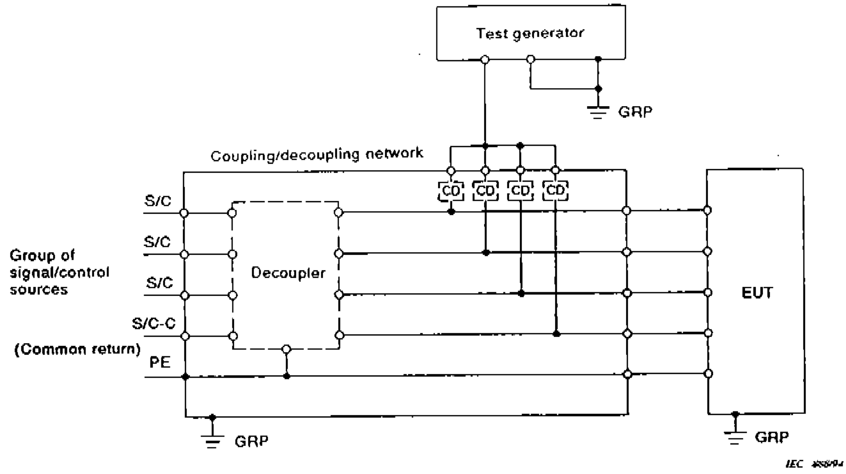


Figure 10.a – Set-up implemented with the ground reference plane (see 7.1.1)

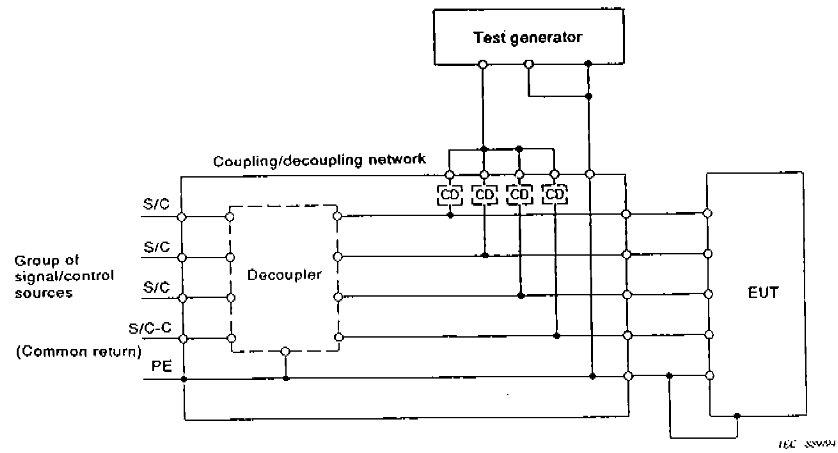


Figure 10.b – Set-up implemented with dedicated earth connections (see 7.1.2)

CD: Coupling devices. For some applications, the coupling capacitors have to be replaced by other types of coupling devices, such as gas tubes, silicon avalanche diodes, etc.

Figure 10 – Input/output port, group of circuits with common return, line-to-ground test

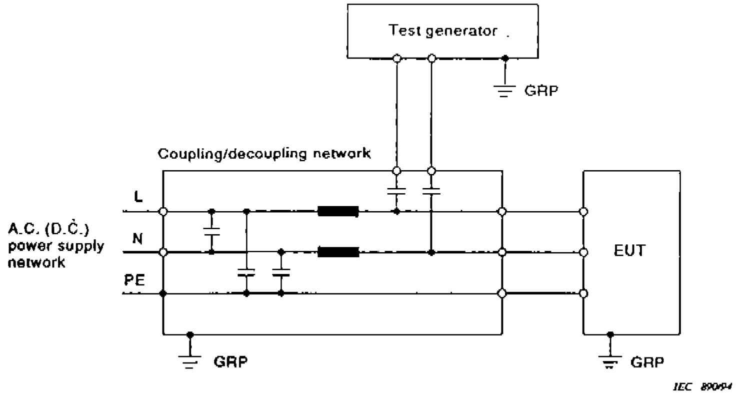


Figure 11.a – Set-up implemented with the ground reference plane (see 7.1.1)

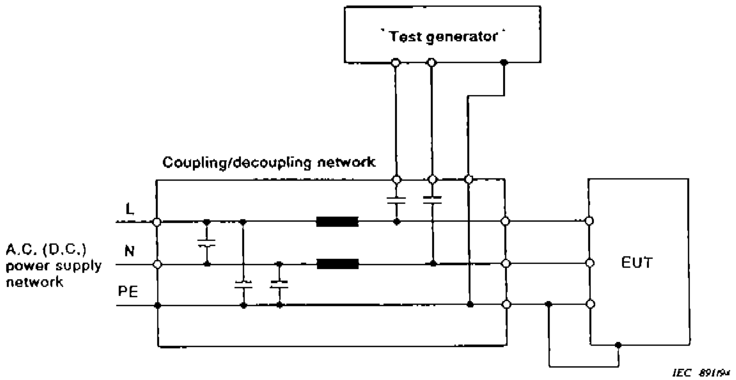


Figure 11.b – Set-up implemented with dedicated earth connections (see 7.1.2)

Figure 11 – A.C./D.C. power supply port, single phase, line-to-line test

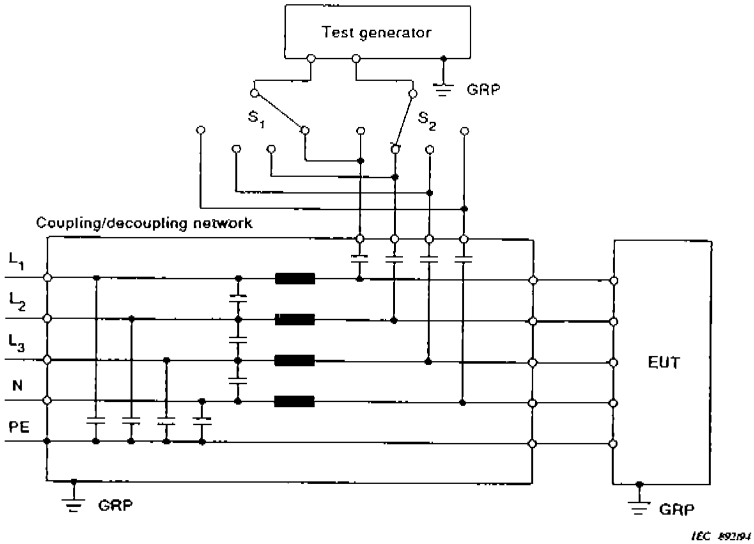


Figure 12.a – Set-up implemented with the ground reference plane (see 7.1.1)

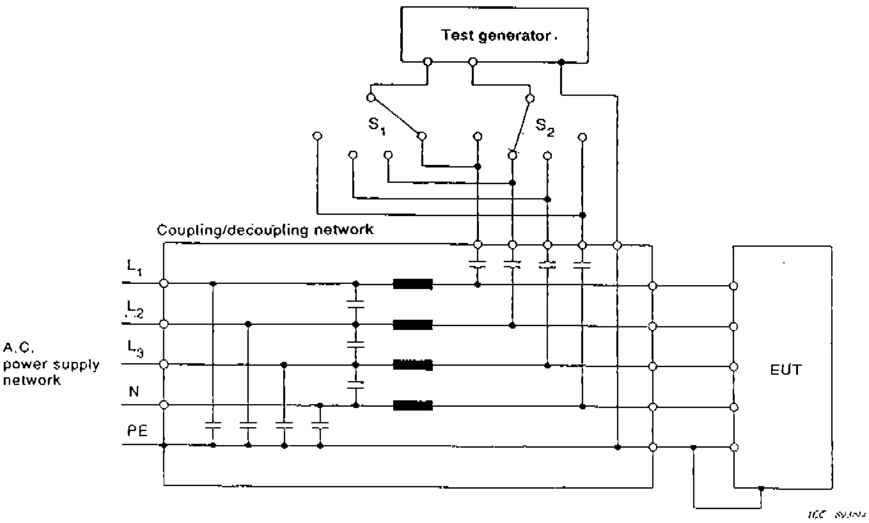


Figure 12.b – Set-up implemented with dedicated earth connections (see 7.1.2)

Figure 12 – A.C. power supply port, three phases, line-to-line test

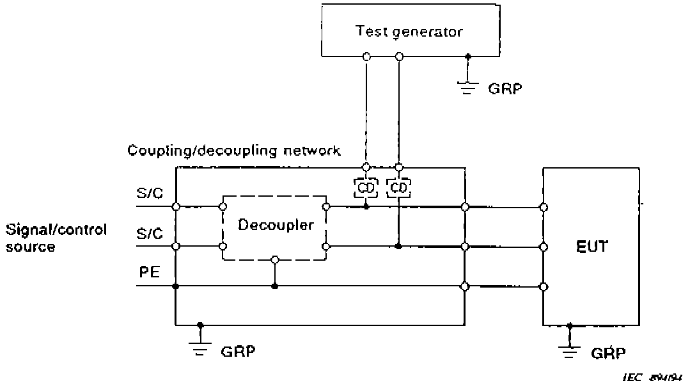


Figure 13.a – Set-up implemented with the ground reference plane (see 7.1.1)

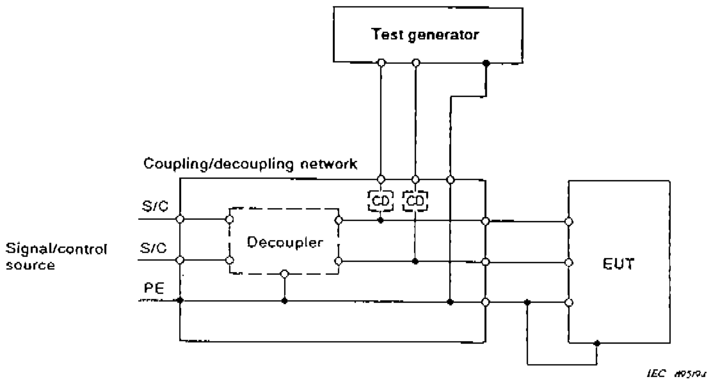


Figure 13.b – Set-up implemented with dedicated earth connections (see 7.1.2)

CD: Coupling devices For some applications, the coupling capacitors have to be replaced by other types of coupling devices, such as gas tubes, silicon avalanche diodes, etc.

Figure 13 – Input/output port, single circuit, line-to-line test

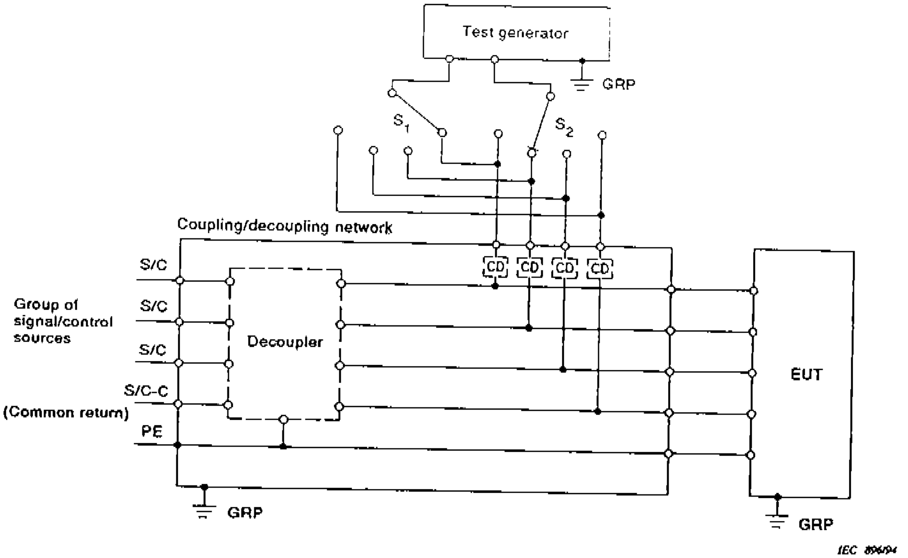


Figure 14.a – Set-up implemented with the ground reference plane (see 7.1.1)

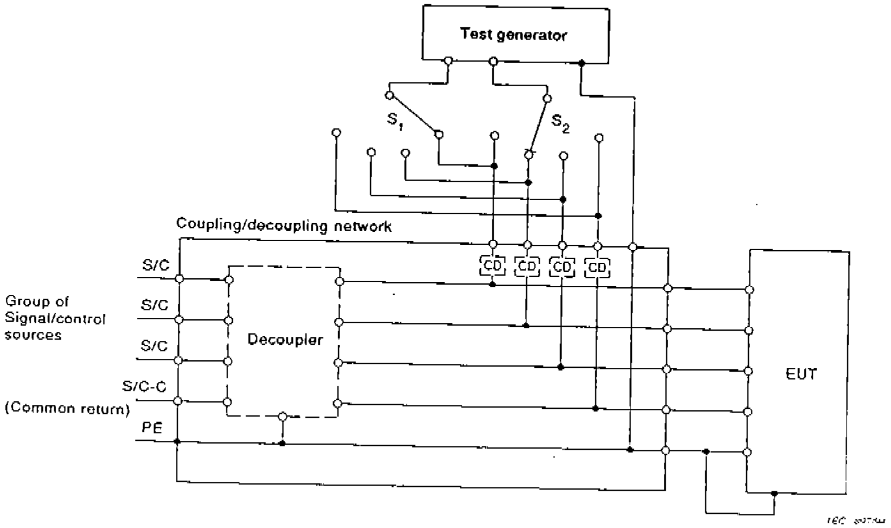
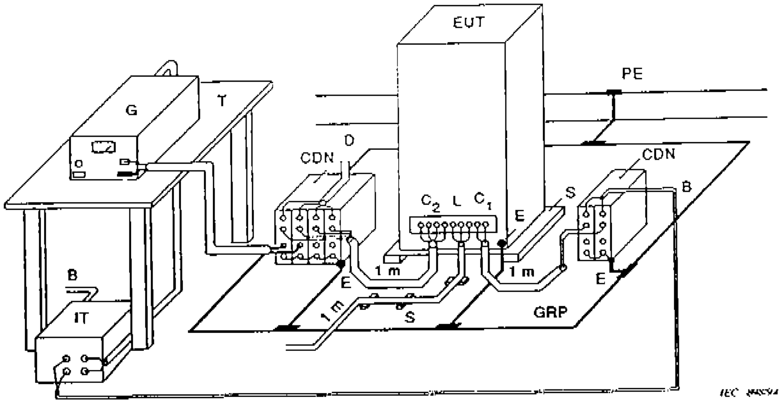


Figure 14.b – Set-up implemented with dedicated earth connections (see 7.1.2)

CD: Coupling devices. For some applications, the coupling capacitors have to be replaced by other types of coupling devices, such as gas tubes, silicon avalanche diodes, etc.

Figure 14 – Input/output port, group of circuits with common return, line-to-line test



NOTE – Earth connections should be as short as technically possible.

PE:	protective earth	EUT:	equipment under test
B:	power supply source	G:	test generator
C_1:	power supply port	L:	communication port
C_2:	input/output port	GRP:	ground reference plane
D:	signal/control source	CDN:	coupling/decoupling network
E:	earth connection	S:	insulating support
T:	insulating table	IT:	isolation transformer

Figure 15 – Provisions for line-to-line tests with test generator output not floating

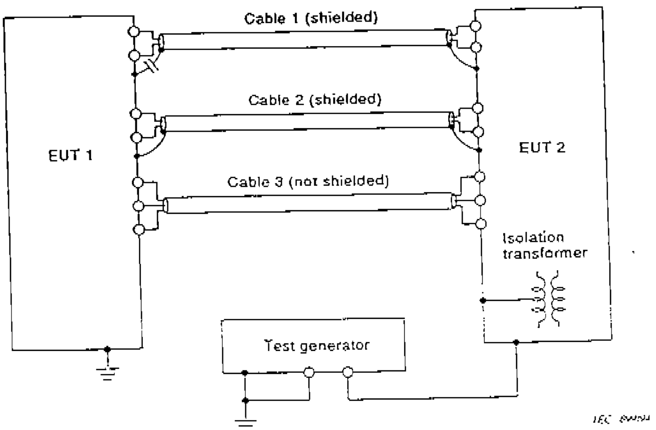


Figure 16 – Test of a system with communication ports with fast operating signals (generator output earthed)

Annex A
(informative)

Information on the phenomena, selection of the test

A.1 Ring wave

The ring wave is a typical oscillatory transient, induced in low-voltage cables due to the switching of electrical networks and reactive loads, faults and insulation breakdown of power supply circuits or lightning. It is, in fact, the most diffused phenomenon occurring in power supply (HV, MV, LV) networks, as well as in control and signal lines.

The ring wave is representative of a wide range of electromagnetic environments of residential, as well as industrial, installations; it is suitable for checking the immunity of equipment in respect of the above-mentioned phenomena which give rise to pulses characterized by sharp front-waves that, in the absence of filtering actions, are in the order of 10 ns to a fraction of µs; the duration may range from 10 µs to 100 µs.

The rise time and duration of the parameters are subject to modification, depending on the propagation media and path.

The propagation of the front-wave in the lines (power and signal) is always subject to reflections, due to the mismatching impedance (the lines are terminated on their own loads or connected to protection devices, input line filters, etc.). These reflections produce oscillations, whose frequency is related to the propagation speed. The presence of parasitic parameters (stray capacitance of components like motors, transformer windings, etc.) are other conditioning factors.

The rise time is generally subjected to slowing down, due to the low-pass characteristic of the line involved in the propagation; this modification is more relevant for the fast rise times (in the order of 10 ns), and less relevant for values in the range of a fraction of µs.

The resultant phenomenon at the equipment ports, representative of most actual situations, as the result of investigations in different types of installations, is an oscillatory transient with defined 0,5 µs rise time and 100 kHz oscillation frequency.

Another cause of the ring wave, lightning, is characterized by a unidirectional waveform (standard 1,2/50 µs pulse). The circuits subjected to its indirect effect (inductive coupling among lines) are mainly influenced by the derivative of the primary pulse. The coupling mechanism, from its original frequency spectrum, gives rise to oscillations, the characteristics of which depend on the reactive parameters of the ground circuits, on metal structures involved in the lightning current flow, in addition to the propagation in the low-voltage lines involved.

In respect of the primary phenomena considered here which generate the ring wave, other IEC standards refer to the 1,2/50 µs standard pulse; the tests with a low impedance generator and the test with the standard pulse may be considered complementary to each other.

It is the responsibility of the product committees to define the most appropriate test, according to the phenomenon considered as relevant.

Relevant parameters for testing

a) *Repetition rate*

The repetition rate of the transient is directly related to the frequency of occurrence of the primary phenomenon; it is higher whenever the primary cause is the load switching in control lines, and less frequent in the case of faults and lightning; the occurrence may range from 1/s to 1/month or 1/year.

For testing requirements, and not relying on the possible limit of the stresses applicable to the equipment under test, a repetition rate in the order of 1/s can be considered conservative in respect to switching phenomena which have a high probability of occurring.

The repetition rate may be increased in order to reduce the duration of the test; it should, however, be selected according to the characteristics of the transient protections involved in the test, as given in the equipment specifications.

b) *Phase angle*

Equipment failures related to ring wave on power supply sources can depend on the phase angle of the a.c. voltage sine wave at which the transients are applied. When a protection element sparks over during a ring-wave test, power-follow might occur. Power-follow is the current from the connected power source that flows through a protective element, or from any sparkover in the EUT, during and following the passage of test discharge current.

For semiconductors, the phenomenon appears related to the conduction state of the EUT semiconductor devices at the time the ring wave occurs. Semiconductor parameters that might be involved include forward and reverse recovery characteristics and secondary breakdown performance.

The devices most likely to fail in a phase-related way are semiconductors involved in the power input circuitry. Other devices, in different areas of the EUT, might also exhibit such failure modes in the EUT power-input circuits, if some or all of the transient pass through to them.

c) *Polarity reversal*

The sensitivity of semiconductors to the timing and polarity of a transient is one of the reasons for selecting an oscillatory waveform to represent the environment; it will be more likely to provoke undue semiconductor failures than a unidirectional wave.

The breakdown of semiconductors under various conditions of load and transient overvoltage applications has been investigated.

The results below are related to the effect of transient polarity reversal on diodes 1N679. The ring wave has been applied to the diode at the peak of the reverse voltage and the measured average breakdown voltage resulting being 1 800 V. The application of the ring wave at 30° and at 90° after start of conduction has given a reduction of the average breakdown voltage of about 33 % and 50 % respectively.

The same investigations put in evidence that reverse voltage applied during the conduction period of the power frequency produces lower breakdown voltage than the application of the same transient with no load or during blocking.

A.2 Damped oscillatory wave

This phenomenon is representative of switching of isolators in HV/MV open-air stations, and is particularly related to the switching of HV busbars, as well as of background disturbance in industrial plants.

In electrical stations, **the opening and closing operations of HV isolators give rise to sharp front-wave transients, with time of the order of some tens of nanoseconds.**

The voltage front-wave has an evolution that includes reflections, due to the mismatching of the characteristic impedance of HV circuits involved. In this respect, the resulting transient voltage and current in HV busbars are characterized by a fundamental oscillation frequency that depends on the length of the circuit and on the propagation time.

The oscillation frequency ranges from about 100 kHz to a few megahertz for open-air substations, depending on the influence of the parameters mentioned above and the length of the busbars, which may vary from some tens of metres to hundreds of metres (400 m may occur).

In this respect, the oscillation frequency of 1 MHz may be considered representative of most situations, but 100 kHz has been considered appropriate for large HV substations.

The repetition frequency is variable between some hertz and some kilohertz depending on the distance between the switching contacts: that is, with close contacts, there is a maximum repetition frequency, while for distances between the contacts near to the extinction of the arc, the minimum repetition frequency, in respect of each phase, is twice the power frequency (100/s per phase for 50 Hz and 120/s per phase for 60 Hz HV systems).

The repetition rates selected, 40/s and 400/s, represent therefore a compromise, taking into account the different durations of the phenomena, the suitability of the different frequencies considered and the problem related to the energy to which the circuits under test are subjected.

In industrial plants, repetitive oscillatory transients may be generated by switching transients and the injection of impulsive currents in power systems (networks and electrical equipment).

The systems have a local response in a frequency band well covered by the rise time and the fundamental frequency of oscillation of the damped oscillatory wave selected for testing purposes.

A.3 Selection of the test

The selection of the test waveform, *ring wave* or *damped oscillatory wave,* should be related to the disturbances which determine the electromagnetic environment of the installation.

The test with ring wave simulates single-shot transients with a low occurrence and repetition rate; this test has, therefore, the capability to verify the performances of the interfaces of the EUT ports with the environment, but limited capability to detect interference of the equipment.

The test with damped oscillatory wave simulates, with a high margin for the industrial environment, repetitive oscillatory transients; it makes easier the detection of interference of the EUT in different and specific operating conditions.

This test should therefore be preferred in appropriate cases (equipment of HV plants), or whenever high priority is given to the reliability of the equipment concerned.

Annex B
(informative)

Selection of the test levels

The test levels should be selected in accordance with the most realistic installation and environmental conditions. These levels are outlined in clause 5 of this standard.

The immunity tests are correlated with these levels in order to establish a performance level for the environment in which the equipment is expected to operate, taking into account the primary phenomena and the installation practices which determine the classes of the electromagnetic environment.

B.1 Ring wave

The selection of the test levels should be done on the basis of the applicability, for a given location or installation, of one or both the causes considered in this standard: the *switching* of power and/or control circuits and the indirect effect of *lightning.*

The relevance of the phenomena may determine the most appropriate test level selected on the basis of the following guide.

Level 1

Switching:
- power supply port connected to protected local power source (e.g. uninterruptible power system, power converter);
- input/output ports connected to cables running in parallel with power cables of the class under consideration.

Lightning:
- power supply, input/output ports of equipment in control room.

Level 2

Switching:
- power supply port directly connected to mains distribution systems of residential area;
- power supply port of equipment in industrial and electrical plants, decoupled from mains power distribution system through isolation transformers, protection devices, etc.;
- input/output ports connected to cables running in parallel with power cables of the class under consideration.

Lightning:
- power supply, input/output ports connected to shielded cables.

Level 3

Switching:
- power supply port connected to dedicated power distribution systems in electrical and industrial plants;
- input/output ports connected to cables running in parallel with the power cables of the class under consideration.

Lightning:
– power supply port connected to undershielded cables;

– power supply, input/output ports connected to outdoor cables provided with shielding provisions (for example, metallic cable trays).

Level 4

Switching:
– power supply port connected to power source characterized by heavy inductive loads in industrial or electrical plants;

– input/output ports connected to cables running in parallel with the power cables of the class under consideration.

Lightning:
– power supply, input/output ports connected to outdoor cables without shielding provisions.

Level x: Special situations to be analysed.

B.2 Damped oscillatory wave

The selection of the test levels should be done on the basis of the exposure to the primary phenomenon of the cables running in the installation.

The installations to which this selection of the test levels is applicable are mainly the high-voltage substations, as well as industrial plants provided with their own electrical plants (transformer stations).

In HV electrical plants, the degree and length of parallelism of the cables with the busbars, the operating voltage of these circuits, their shielding and earthing (grounding) will determine the level of induced voltages.

In order to reduce as much as possible these variables, and taking into consideration that equipment dedicated to this type of installation is used for a certain range of operating voltages of the plants (for example, from 150 kV to 800 kV), the definition of the test level is made considering mainly the equipment interconnected, its location, the quality of the cable shielding, and its earthing.

Based on common installation practices, which foresee the use of shielded cables with the screen earthed at both ends on the earth network, the recommended selections of test levels for damped oscillatory waves for the equipment ports are the following:

Level 1: Ports connected to cables running in a limited area of the control building.

Level 2: Ports connected to cables of equipment in the control building and relay house (kiosks). The equipment concerned is installed in the control building and relay house.

Level 3: Ports connected to cables of equipment installed in the relay house. The equipments concerned are those installed in the relay house. For these equipments, level 3 assumes the value of 2,5 kV.

Level 4: Not applicable to equipment for use in electrical plants, particularly HV substations. Whenever this level seems to be necessary, proper mitigation methods should be adopted.

Level x: Special situations to be analysed.

Annex C
(informative)

Impedance of the test generators

The impedance of the test generators should correspond, with close approximation, to the impedance values at the end of the line (power supply, signal and control, communication) towards the disturbance source; this concept is valid for both common and differential mode impedance.

The impedance of a line, however, depends on many factors (for example, type of cables), including the frequency spectrum of the disturbances and the length of the line, which vary in function of the type of installation, giving rise to a range of values which make it difficult to establish a single value valid for all cases.

On this subject, IEC 816 gives information related to power lines, applicable also to signal lines; it gives a diagram (see figure 5) with the measured impedance values (maximum, mean and minimum values) of power lines for United States of America and Europe, in the frequency range 20 kHz - 30 MHz. The measurements are made between phase and protective conductor (low-voltage distribution circuits).

The oscillatory transients considered in the present standard have a frequency in the range of some tens of kHz to several hundreds of kilohertz for the ring wave, and up to 5 MHz for the damped oscillatory wave.

For the frequency range 100 kHz - 5 MHz, IEC 816 gives the following mean values:

- 10 Ω to 30 Ω at 100 kHz;
- about 80 Ω at 1 MHz;
- 100 Ω to 150 Ω at 10 MHz.

The present basic standard considers the main parameters involved, including the rise time of the disturbance, the cable length, and therefore the characteristic impedance of the cables.

Information on the criteria adopted for the selection of the test generators impedance is given below.

Improvements in the choice of the output impedance of the test generators is possible, and a future solution could be the adoption of a single impedance value, for example the 50 Ω value. This value might cover the need to have standard coupling networks suitable for testing with different conducted disturbances, to avoid a complicated evaluation of installation conditions for the selection of different impedances of the test generators, and also for the majority of cases in which this choice is not so relevant.

C.1 Ring wave

Two values of impedance have been selected to test power supply ports: 12 Ω and 30 Ω. These values are applicable, respectively, to short and long branch circuits, corresponding to the relative distance of the power supply source from the main distribution network. They represent a technical compromise, because they include the need to test EUT ports normally interfaced with low impedance circuits, according to the values given in IEC 816; in addition, they cover the requirements to test the transients protection devices, such as the metal oxide varistors, Zener diodes, etc., installed in the EUT.

In this respect, the generator short-circuit current is suitable for non-destructive tests, according to their actual current and power rating.

For testing the input/output ports, the selection of the 200 Ω impedance is a compromise, which takes into account that the characteristic impedance of cables used for this purpose (twisted pairs) has a value ranging from 120 Ω to 150 Ω in the frequency range above 100 kHz and for a length of the order of 100 m.

As for the status of the diffusion of the similar test, the damped oscillatory wave test, for which the generator impedance is generally 200 Ω, a modification of the testing specifications has been considered not opportune. In fact, the application of the test voltage to EUT ports, having impedance values in the order of some hundreds or thousands of ohms or more, with a generator of 200 Ω instead of 120 Ω or 150 Ω, makes no difference.

In the case of testing input/output ports with groups of circuits, provided with transients protection devices, filters, etc., the 12 Ω and 30 Ω impedance of the test generator seems appropriate for the reasons given for the power supply ports, as applicable according to the equipment specifications.

C.2 Damped oscillatory wave

The output impedance of the test generator has been fixed at 200 Ω, although the actual impedance of the cables (twisted pairs) is nearer to 150 Ω. The reasons for which the 200 Ω impedance has been selected is not to modify an existing general status that would involve the technical specifications of a family of equipment, with applications mainly in high-voltage substations.

In addition, the cables in this category of electrical and industrial plants are mostly in the order of hundreds of meters in length, and therefore the impedance of the connections in the field is nearer the characteristic impedance of the cables, and not less than it.

Annex D
(informative)

Bibliography

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