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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC)

Part 4-5 : Testing and measurement techniques - Surge immunity test

FOREWORD

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International Standard IEC 61000-4-5 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical Committee 77: Electromagnetic compatibility.

It forms part 4-5 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*..

This second edition cancels and replaces the first edition published in 1995 and its amendment 1 (2000), and constitutes a revision.

The text of this standard IEC 61000-4-5, is based on the following documents:

FDIS	Report on voting
77B/XX/FDIS	77B/XX/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.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annex A forms an integral part of this standard.

Annex B is for information only.

INTRODUCTION

This standard is part of the IEC 61000 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 6: Generic standards

Part 9: Miscellaneous

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

This part is an international standard which gives immunity requirements and test procedures related to surge voltages and surge currents.

ELECTROMAGNETIC COMPATIBILITY (EMC)

Part 4-5 : Testing and measurement techniques - Surge immunity test

1 Scope and object

This part of IEC 61000 relates to the immunity requirements, test methods, and range of recommended test levels for equipment to unidirectional surges caused by overvoltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment.

The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to surges. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

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

This standard defines:

- range of test levels;
- test equipment;
- test set-up;
- test procedure.

The task of the described laboratory test is to find the reaction of the EUT under specified operational conditions caused by surge voltages from switching and lightning effects at certain threat levels.

It is not intended to test the capability of the insulation to withstand high-voltage stress. Direct lightning is not considered in this standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61000. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61000 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 60050(161), *International Electrotechnical Vocabulary (IEV) - Chapter 161: Electromagnetic compatibility*

IEC 60060-1, *High-voltage test techniques - Part 1: General definitions and test requirements*

IEC 60469-1, *Pulse techniques and apparatus - Part 1: Pulse terms and definitions*

3 Definitions

For the purposes of this part of IEC 61000, the following definitions together with those in IEC 60050(161) apply, unless otherwise stated.

3.1 calibration: set of operations which establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement [IEV 311-01-09]

NOTE 1 - This term is based on the "uncertainty" approach.

NOTE 2 - The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

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

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

3.4 duration: The absolute value of the interval during which a specified waveform or feature exists or continues. [IEC 60469-1]

3.5 effective output impedance (of a surge generator): the ratio of peak open circuit voltage to the peak short circuit current.

3.6 electrical installation: An assembly of associated electrical equipment to fulfill a specific purpose or purposes and having co-ordinated characteristics. [IEV 826-01-01]

3.7 EUT: Equipment under test.

3.8 Front time

surge voltage: The front time T_1 of a surge voltage is a virtual parameter defined as 1,67 times the interval T between the instants when the impulse is 30 % and 90 % of the peak value (see figure 2).

surge current: The front time T_1 of a surge current is a virtual parameter defined as 1,25 times the interval T between the instants when the impulse is 10 % and 90 % of the peak value (see figure 3). [IEC 60060-1 modified]

3.9 high-speed communication lines consist of input/output lines which operate at speeds above 100 kb/s.

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

3.11 interconnection lines consist of I/O lines (input/output lines) and communication lines operating up to 100 kb/s;

3.12 primary protection: The means by which the majority of stressful energy is prevented from propagating beyond the designated interface.

3.13 rise time: The interval of time between the instants at which the instantaneous value of a pulse first reaches a specified lower value and then a specified upper value.

NOTE - Unless otherwise specified, the lower and upper values are fixed at 10 % and 90 % of the pulse magnitude. [IEV 161-02-05]

3.14 secondary protection: The means by which the let-through energy from primary protection is suppressed. It may be a special device or an inherent characteristic of the EUT.

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

3.16 symmetrical lines: A pair of symmetrically driven conductors with a conversion loss from differential to common mode of greater than 20 dB.

3.17 system: Set of interdependent elements constituted to achieve a given objective by performing a specified function.

NOTE - The system is considered to be separated from the environment and other external systems by an imaginary surface which cuts the links between them and the considered system. Through these links, the system is affected by the environment, is acted upon by the external systems, or acts itself on the environment or the external systems. [IEV 351-01-01]

3.18 time to half-value T_2: The time to half-value T_2 of a surge is a virtual parameter defined as the time interval between the virtual origin O_1 and the instant when the voltage or current has decreased to half the peak value. [IEC 60060-1 modified]

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

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

NOTE 1 - The methods used for verification may be different from those used for calibration.
NOTE 2 - The procedure of 6.1.2 and 6.2.2 is meant as a guide to insure the correct operation of the test generator, and other items making up the test set-up that the intended waveform is delivered to the EUT.
NOTE 3 - For the purpose of this basic EMC standard this definition is different of the definition given in the IEV (311-01-13)

3.21 virtual Origin O_1: The point in time where a straight line drawn between the 30 % and 90% amplitude values for the surge voltage waveform or 10 % and 90 % amplitude values for the surge current waveform crosses the time axis.

4 General

4.1 Power System Switching transients

Power System Switching transients can be separated into transients associated with:

a) major power system switching disturbances, such as capacitor bank switching;
b) minor switching activity near the instrumentation or load changes in the power distribution system;
c)) if the source of interference is not in the same circuit as are the ports of the victim equipment (i.e. indirect coupling), then the generator may simulate a higher impedance source;
d) various system faults, such as short circuits and arcing faults to the earthing system of the installation.

4.2 Lightning transients

The major mechanisms by which lightning produces surge voltages are the following:

a) direct lightning stroke to an external circuit (outdoor) injecting high currents producing voltages by either flowing through earth resistance or flowing through the impedance of the external circuit;

b) an indirect lightning stroke (i.e. a stroke between or within clouds or to nearby objects which produces electromagnetic fields) that induces voltages/currents on the conductors outside and/or inside a building;
c) lightning earth current flow resulting from nearby direct-to-earth discharges coupling into the common earth paths of the earthing system of the installation.

The rapid change of voltage and flow of current which can occur as a result of the operation of a lightning protection device can induce electromagnetic disturbances into adjacent equipment.

4.3 Simulation of the transients

a) The characteristics of the test generator are such that it simulates the above mentioned phenomena as closely as possible;
b) if the source of interference is in the same circuit, e.g. in the power supply network (direct coupling), the generator may simulate a low impedance source at the ports of the equipment under test;
c) if the source of interference is not in the same circuit as the victim equipment (indirect coupling) as the ports of the victim-equipment, then the generator may simulate a higher impedance source.

5 Test levels

The preferential range of test levels is given in table 1.

Table 1 - Test levels

Level	Open-circuit test voltage ± 10 % kV
1	0,5
2	1,0
3	2,0
4	4,0
X	Special
NOTE - x is an open class. This level can be specified in the product specification.	

The test levels shall be selected according to the installation conditions; classes of installation are given in B.3 of annex B.

All voltages of the lower test levels shall be satisfied (see 8.2).

For selection of the test levels for the different interfaces, refer to annex A.

6 Test Instrumentation

NOTE - The characteristics of surge generators given in clause 6 are meant as a guide to insure the correct operation of the test generator, coupling/decoupling networks, and other items making up the test set-up so that the intended waveform is delivered to the EUT.

Two types of surge generators are specified. Each has its own particular applications, depending on the type of port to be tested (see Clause 7).

6.1 Combination wave generator (1,2/50 µs - 8/20 µs)

This generator is intended to generate a surge having: an open circuit voltage front time of 1,2 µs; an open circuit voltage time to half value of 50 µs; a short circuit current front time of 8 µs; and a short circuit current time to half value of 20 µs.

A simplified circuit diagram of the generator is given in figure 1. The values are selected for the different components R_{S1}, R_{S2}, R_m, L_r, and C_c so that the generator delivers a 1,2/50 µs voltage surge (at open-circuit conditions) and a 8/20 µs current surge into a short circuit.

For convenience, the ratio of peak open-circuit output voltage to peak short-circuit current of a combination wave generator may be considered the effective output impedance. For this generator, the ratio defines an effective output impedance of 2 ohms.

Such a generator with 1,2/50 µs open-circuit voltage waveform 8/20 µs short-circuit current waveform is called a combination wave generator (CWG).

NOTE - The waveform of the voltage and current is a function of the EUT input impedance. This impedance may change during surges to equipment and due either to proper operation of the installed protection devices, or to flash over or component breakdown, if the protection devices are absent or inoperative. Therefore the 1,2/50 µs voltage and the 8/20 µs current waves have to be available from the same test generator output as instantaneously required by the load.

6.1.1 Characteristics and performance of the combination wave generator

Polarity	positive and negative
Phase shifting	in a range between 0° to 360° versus the phase angle of the ac line voltage to the equipment under test, with a tolerance of +/- 10 degrees
Repetition rate	1 per min or faster
Open-circuit peak output voltage:	Adjustable from 0,5 kV
Waveform of the surge voltage	see Table 2 and figure 2
Output voltage setting tolerance	± 10 %
Short-circuit peak output current	0,25kA to 2,0kA depending on peak voltage setting (see table 3), higher currents are possible with higher peak voltages
Waveform of the surge current	see figure 3
Short-circuit output current tolerance	± 10 %
Effective output impedance	2 Ω ± 10 %

Table 2 – Definitions of the waveform parameters 1,2/50µs

Definitions	Front Time µs	Time to Half Value µs
Open-circuit Voltage	1,2	50
Short-circuit Current	8	20
NOTE - In existing IEC publications, the waveforms 1,2/50 µs and 8/20 µs are generally defined according to IEC 60060-1 as shown in figures 2, and 3.		

Table 3 - Relationship between peak open-circuit voltage and peak short-circuit current

Open circuit peak voltage ± 10 %	Short circuit peak current ± 10 %
0,5 kV	0,25 kA
1,0 kV	0,5 kA
2,0 kV	1,0 kA
4,0 kV	2,0 kA

The peak short-circuit current shall be as shown in Table 3 when the peak open circuit voltage is as specified.

A generator with floating output shall be used.

6.1.2 Characteristics of the combination wave generator

In order to compare the test results from different test generators, the test generator shall be calibrated periodically. For this purpose, the following procedure is necessary to measure the most essential characteristics of the generator.

The test generator output shall be connected to a measuring system with a sufficient bandwidth and voltage capability to monitor the characteristics of the waveforms.

The characteristics of the generator shall be measured under *open-circuit* conditions (load greater than or equal to 10 kΩ) and under *short-circuit* conditions (load smaller than or equal to 0,1 Ω) at the same charge voltage.

All waveform definitions as well as the performance parameters stated in clauses 6.1.1 and 6.1.2 respectively shall be met at the output of the surge generator.

NOTE - When an additional internal or external resistance is added to the generator output to increase the effective source impedance from 2 Ω to e.g. 42 Ω according to the requirements of the test set-up, the duration of the test pulse at the output of the coupling network might be significantly changed.

6.2 10/700 µs surge generator

This generator is intended to generate a surge having: an open-circuit voltage front time of 10µs; and an open-circuit voltage time to half value of 700 µs. The simplified circuit diagram of the generator is given in figure 4. The values for the different components are selected so that the generator delivers a 10/700 µs surge.

6.2.1 Characteristics and performances of the 10/700 µs surge generator

Polarity	positive and negative
Repetition rate	1 per min or faster
Open-circuit peak output voltage	Adjustable from 0,5kV to 4,0kV
Waveform of the surge voltage	see figure 5
Output voltage setting tolerance	± 10 %
Short-circuit peak output current	12,5A to 100A (see table 4)
Tolerance of the short-circuit output current	± 10 %
Effective output impedance	40 Ω ± 10 %

Table 4 – Definitions of the waveform parameters of the 10/700 µs generator

Definitions	Front Time µs	Time to Half Value µs
Open-circuit Voltage	10	700
Short-circuit Current	5	320
Note - Voltage waveforms definitions are defined according to IEC 60060-1 as shown in figures 2, 3 and 5.		

Table 5 - Relationship between peak open-circuit voltage and peak short-circuit current

Open circuit peak voltage ± 10 %	Short circuit peak current ± 10 %
0,5 kV	12,5 A
1,0 kV	25 A
2,0 kV	50 A
4,0 kV	100 A

The peak short-circuit current shall be as shown in Table 4 when the peak open-circuit voltage is as specified.

6.2.2 Characteristics and performance of the 10/700 µs surge generator

In order to compare the test results from different test generators, the test generator shall be calibrated periodically. For this purpose, the following procedure is necessary to measure the most essential characteristics of the generator.

The test generator output shall be connected to a measuring system with a sufficient bandwidth and voltage capability to monitor the characteristics of the waveforms.

The characteristics of the generator shall be measured under *open-circuit* conditions (load greater than or equal to 10 kΩ) and under *short-circuit* conditions (load smaller than or equal to 0,1 Ω) at the same charge voltage.

All waveform definitions as well as the performance parameters of the test generator shall meet the specifications mentioned in 6.1.1 and 6.2.1 respectively at the output of the generator.

6.3 Coupling/decoupling networks, CDN

The coupling/decoupling network for the AC mains shall be designed so that the open circuit voltage wave and short circuit current wave meet the tolerance requirements of table 6 and 7. When coupling to interconnection lines, the waveforms may be distorted by the coupling mechanism as described in 6.3.2.1, 6.3.2.2 and 6.3.2.3.

Each coupling/decoupling network consists of a decoupling network and a coupling element as shown in the examples of figures 7 through 14.

On the AC mains, the decoupling network provides relatively high back impedance to the surge waveform but at the same time, allows a.c mains current to flow to the EUT. This back impedance allows the voltage waveform to be developed at the output of the coupling/decoupling network and prevents surge current from flowing back into the a.c source. High voltage capacitors are used as the coupling element, sized to allow the full waveform durations to be coupled to the EUT.

For I/O and telecom lines, the series impedance of the decoupling network will limit the available bandwidth for data transmission. Clause 6.3.3 describes a procedure to be used in the case where a test cannot be performed with a coupling/decoupling network in place. Coupling elements can be a capacitor, in cases where the line will tolerate the capacitive loading effects (6.3.2.1), or an arrestor (6.3.2.2, and 6.3.2.3).

Each coupling/decoupling network shall satisfy the following requirements:

6.3.1 Coupling-/decoupling networks for a.c./d.c. power supply circuits

(used with combination wave generator)

The front time and time to half value shall be verified for voltage under open circuit conditions and for current under short circuit conditions.

The test generator output or its coupling network shall be connected to a measuring system with a sufficient bandwidth and voltage capability to monitor the open circuit voltage waveform.

The open circuit voltage waveform at the output of the coupling/decoupling networks for AC or DC power supply circuits is selected as follows:

18 μF for “line to line coupling”
9 μF + 10 Ω for “line to ground coupling”

It is desirable that the open circuit voltage waveform at the output of the coupling/decoupling network meet the specifications given in figure 2; however, with higher current coupling/decoupling networks this may not be possible.
The decoupling inductance shall be selected by the simulator's manufacturer so that the a.c mains voltage drop at EUT connector of the coupling-/decoupling network is less than 10 % at the specified current rating, but should not exceed 1,5mH.
To prevent unwanted voltage drops in the coupling/decoupling networks, the value of the decoupling element generally must be reduced for coupling/decoupling networks rated at > 25 A. For this case the “time to half value” of the open-circuit voltage waveform may be reduced in accordance with Tables 6 and 7, below.

Table 6: Voltage waveform specification at the EUT output of the coupling/decoupling network, open loop condition with the input to the coupling decoupling network also open loop

Surge voltage parameters:	Coupling impedance	
	18 μF	9 μF + 10 Ω
Front time:	1,2 μs ± 30 %	1,2 μs ± 30 %
Time to half value:		
current rating < 25 A	50 μs +10μs/-10μs	50 μs +10μs/-20μs
current rating 25 - 60 A	50 μs +10μs/-15μs	50 μs +10μs/-25μs
current rating 60 - 100 A	50 μs +10μs/-20μs	50 μs +10μs/-30μs

Table 7: Current waveform specification at the EUT output of the coupling/decoupling network, short circuit condition with the input to the coupling decoupling network also open loop

Surge current parameters:	Coupling impedance	
	18 μF	9 μF + 10 Ω
Front time:	8 μs ± 20 %	2,5 μs ± 30 %
Time to half value:	20 μs ± 20 %	25 μs ± 30 %

Note: For EUT having a rated input current above 100 A (at 100 V), direct surge coupling of an un-powered EUT without the use of a coupling/decoupling network, may be the only viable test method. Partial testing of the EUT (e.g. of the control unit alone) is acceptable when it is not possible to surge test an entire system due to AC mains current requirements of greater than 100A.

The residual surge voltage on the power supply inputs of the decoupling network when the EUT is disconnected shall not exceed 15 % of the applied test voltage or twice the peak value of the power line voltage whichever is higher.

The residual surge voltage on unsurged lines shall not exceed 15% of the maximum applicable test voltage when the EUT is disconnected and the input is open circuit.

The above-mentioned characteristics for single-phase systems (line, neutral, protective earth) are also valid for three-phase systems (three-phase wires, neutral and protective earth).

6.3.2 Coupling/decoupling networks for interconnection lines

The coupling method shall be selected as a function of the circuits and operational conditions. This has to be specified in the product specification/standard.

Arrestor coupling is used in cases where the capacitive coupling is not possible because of functional problems or loading caused by attachment of capacitors to the interconnection line.

Testing using a coupling/decoupling network with capacitive coupling may not produce the same test results as with when arrestor coupling is used. If a particular coupling method is preferred, it should be specified in the product standards. In any case, the coupling method used should be documented in the test report.

6.3.2.1 Capacitive coupling for interconnection lines

The capacitive coupling is the preferred method for unshielded unsymmetrical I/O circuits if functional communications on that line can be maintained. An example of a coupling network is shown in figure 11.

Rated characteristics of the coupling/decoupling network:

Coupling element *R* = 40 Ω, *C* = 0,5 µF
Decoupling inductors *L* = 20 mH

6.3.2.2 Coupling via clamping devices

The method can also be used in cases where the capacitive coupling is not possible because of functional problems caused by attachment of capacitors to the EUT (see figure 11). Some clamping devices have a low parasitic capacitance and will allow connection to many types of I/O lines.

When coupling with a clamping device, the capacitor shown in figure 11 is replaced by a that clamping device.

The clamp voltage of the device must be selected to be as low as possible but higher than the maximum working voltage of the lines to be tested.

Rated characteristics of the coupling-/decoupling network:

Coupling impedance *R* = 40 Ω plus the impedance of the selected clamping device
Decoupling inductors *L* = 20 mH

The impulse shape at the EUT output is dependent on the impulse amplitude and the characteristics of the clamping device itself; therefore, it is not possible to specify waveform values and tolerances.

6.3.2.3 Coupling via avalanche devices

The method can also be used in cases where the capacitive coupling is not possible because of functional problems caused by attachment of capacitors to the EUT (see figure 11). Silicon avalanche devices or gas discharge arrestors have a low parasitic capacitance and will allow connection to most types of I/O lines.

Figure 12 shows an example of a coupler using arrestors.

The operating voltage of the arrestor must be selected to be as low as possible but higher than the maximum working voltage of the lines to be tested.

Rated characteristics of the coupling-/decoupling network:

Coupling impedance *R* = 40 Ω plus the arrestor impedance (gas-filled or solid state)
Decoupling inductors *L* = 20 mH

The impulse shape at the EUT output is dependent on the impulse amplitude and the characteristics of the avalanche device itself; therefore, it is not possible to specify waveform values and tolerances.

6.3.2.4 Coupling via arrestors to symmetrical lines

Coupling via arrestors is the preferred coupling method for unshielded symmetrical circuits (telecommunication), as shown in figure 13.

The coupling network also has the task of splitting the surge current into multiple pairs in multi-conductor cables.

Therefore the resistance *R*m2 in the coupling network shall be, for *n* composite conductors, *n x 40 Ω* (for *n* equal to or greater than 2). *R*m2 shall not exceed 250 Ω.

EXAMPLE 1: for 1,2/50 µs surges: *n* = 4, *R*m2 = 4 x 40 Ω. With the impedance of the generator the total value is approximately 42 Ω.

EXAMPLE 2: for 10/700 µs surges: n = 4, R_{m2} = 4 x 25 Ω. With the impedance R_{m1} (15 Ω) of the generator the total value is approximately 40 Ω while S1 in the generator is closed, see Figure 4.

Rated characteristics of the coupling-/decoupling network:

Coupling impedance *R*m2 plus the impedance of the arrestor
Decoupling inductors L = 20 mH

The impulse shape at the EUT output is dependent on the impulse amplitude and the characteristics of the avalanche device itself; therefore, it is not possible to specify waveform values and tolerances.

6.3.3 Coupling/decoupling networks for high-speed communication lines

Because of physical constraints, most coupling/decoupling networks are limited to handling data rates of up to about 100 kHz. In cases where no adequate coupling/decoupling network is commercially available, surges shall be applied to the high-speed communication data port directly.
The coupling method shall be selected as a function of the circuits and operational conditions. This has to be specified in the product specification.

High speed communication lines such as ISDN or xDSL require low impedance in the decoupling network path in order to operate and an example of a suitable coupling/decoupling network is given in figure 14. This will only work for the 1,2/50us combination wave since the inductors will likely saturate with the longer 10/700us telecom waveform.

7 Test set-up

7.1 Test equipment

The following equipment is part of the test set-up:

- equipment under test (EUT);
- auxiliary equipment (AE) when required;
- cables (of specified type and length);
- coupling/decoupling networks;
- test generator (combination wave generator, 10/700 µs surge generator);
- decoupling network/protection devices;
- earth reference in the form of a metal plate is allowed when high frequency events are likely (i.e., coupling via gas arrestors). Connection to an earth reference is only done when the EUT is normally installed with an earth reference connection.

7.2 Test set-up for tests applied to EUT power ports

The 1,2/50 µs surge is to be applied to the EUT power supply terminals via the capacitive coupling network (see figures 7, 8, 9 and 10). Decoupling networks are required in order to avoid possible adverse effects on equipment not under test that may be powered by the same lines and to provide sufficient decoupling impedance to the surge wave so that the specified wave may be applied on the lines under test.

If not otherwise specified the power cord between the EUT and the coupling/decoupling network shall not exceed 2 m in length.

To simulate the representative coupling impedance, coupling/decoupling networks may include additional specified resistors for the tests (explanations, refer to B.1 of annex B).

7.3 Test set-up for tests applied to unshielded unsymmetrical interconnection lines

In general, the surge is applied to the lines in accordance with figure 11 via capacitive coupling. The coupling/decoupling network shall not influence the specified functional conditions of the circuits to be tested.

An alternative test set-up (coupling via arrestors) is given in figure 12 for circuits with a higher signal transfer rate. Selection shall be made depending on the capacitive load with respect to the transmission frequency.

If not otherwise specified, the interconnection line between the EUT and the coupling/ decoupling network shall not exceed 2 m in length.

7.4 Test set-up for tests applied to unshielded symmetrical interconnections telecommunication lines

For symmetrical interconnection/telecommunication circuits (see figure 13), the capacitive coupling method can normally not be used. In this case, the coupling is performed via gas arrestors. Test levels below the ignition point of the coupling arrestor (about 300 V for a 90 V gas arrestor) cannot be specified.

NOTE - Two test configurations are to be considered:
1. For the equipment level immunity test with only secondary protection at the EUT at a low test level, e.g. 0,5 kV or 1 kV,
2. For the system level immunity test with additional primary protection at a higher test level, e.g. 2 kV or 4 kV.

If not otherwise specified the interconnection line between the EUT and the coupling/decoupling network shall not exceed 2 m in length.

7.5 Test set-up for tests applied to high speed communications lines

Once the port is determined to be functional, data lines are removed and the surge is applied directly to the telecom terminals with no coupling/decoupling network. After the surge, the data port must be re-tested to insure functionality. The EUT should be functional during the surge test with the port disconnected; however, it is noted that some EUTs may attempt to shut down or disconnect communications ports internally if the data/telecom line is removed. If possible, steps should be taken to keep the data/telecom port active during the test.

7.6 Test set-up for tests applied to shielded lines

In the case of shielded lines a coupling/decoupling network may not be applicable, in which case the set-up in 7.6.1 or 7.6.2 should be used.

7.6.1 Direct application

The EUT is isolated from earth and the surge is applied to its metallic enclosure; the termination (or Auxiliary Equipment) at the port under test is earthed. See figures 15 and 16.

NOTE - The earth reference mentioned in figure 15 or 16 represents a low impedance reference, preferably realized by either a dedicated cable or by a ground plane .

All connections to the EUT other than the port under test shall be isolated from earth by suitable means (such as safety isolation transformers or a suitable CDN).
The length of the cable between the port under test and the device attached to the other end of the cable (AUX in figures 15 and 16) shall be the lesser of: the maximum length permitted by the EUT’s specification, or 20 m. Where the length exceeds 1 m, the cable may be non-inductively bundled.

Rules for application of the surge to shielded lines:

a) *Shields earthed at both ends*

- the surge injection on the shield shall be carried out according to figure 15.

b) *Shields earthed at one end*

- the test shall be carried out according to figure 16. The capacitor *C* represents the cable capacity to earth and is not an additional component to be added to the test.. If cable lengths allow, the cable shall be on insulated supports 10cm above the ground plane or cable tray.

The test level applied on shields is the generator with a 2 Ω source impedance.

If the EUT does not have a metallic enclosure, apply the surge directly to the shield of the cable.

For products which do not have metallic enclosures, the surge is applied directly to the shielded cable.

7.6.2 Indirect application

Surges are applied in close proximity to the interconnection cable under test by a wire or metallic tube according to figure 17. This coupling method is useful for multiple shielded cable wiring with multiple earth connections, between two or more EUTs (or one EUT and AE) of a test configuration in order to apply the surge to a particular cable or bundle of cables. If individual cables are typically bundled in an installation, they should be tested in a bundle.

The length of the cable between the port under test and the device attached to the other end of the cable shall be the lesser of: the maximum length permitted by the EUT's specification, or 20 m. Where the length exceeds 1 m, the cable may be non-inductively bundled.

For system connected via unshielded lines, the test setup according to figure 16 is applicable except that the cable shield and cable capacitance are not present.

7.7 Test set-up to apply potential differences

In system level tests it may be necessary to apply potential differences which simulate voltages that can occur within a system. The tests may be carried out in accordance with figure 15 for systems with shielded lines, shields earthed at both ends, and in accordance with figure 16 for systems with unshielded lines or shielded lines earthed only at one end.

7.8 Other test set-ups

If one of the specified coupling methods in the test set-up cannot be used for functional reasons, alternative methods (suitable for the special case) shall be developed by product committees and the respective results shall be placed into product or product family standards. It may be necessary to specify a performance criterion as it is mentioned in item c) of clause 9, 2nd paragraph for high speed communication lines; see clause 6.3.3 and 9.

7.9 Test conditions

The operational test conditions and the installation conditions shall be in accordance with the product specification and shall include the:

- test configuration (hardware);
- test procedure (software).

8 Test procedure

8.1 Laboratory reference conditions

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

8.1.1 Climatic conditions

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

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

8.1.2 Electromagnetic conditions

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

8.2 Application of the surge in the laboratory

The performance of the test generators and CDN shall be checked prior to the measurement. This performance check can usually be limited to the existence of the surge pulse and its voltage and/or current.

The characteristics and performance of the test generators shall be as specified in 6.1.1 and 6.2.1; the calibration of the generators shall be performed on a regular basis according to 6.1.2 and 6.2.2. (typically once per year).

The test shall be performed according to the test plan that shall specify (refer also B.2 of annex B) the test set-up with :

- generator and other equipment utilized;
- test level (voltage) (refer to annex A);
- generator source impedance;
- polarity of the surge;
- number of tests:
    - Number of surge pulses as far as not otherwise specified by the relevant product standard:
        - for DC power ports and interconnection lines at least five positive and five negative surge pulses;
        - for AC power ports at least five positive and five negative pulses each at 0º, 90º, 180º and at 270º.
- time between successive pulses: one minute or less;
- representative operating conditions of the EUT;
- locations to which the surges are applied;
- actual installation conditions.

NOTE 1 - Power ports (AC or DC) can be input ports or output ports.

NOTE 2 - Product committees may select different phase angles if appropriate for their product.
Surges to output ports are recommended in applications where surges are likely to enter the EUT via that output port (e.g. switching of loads with large power consumption).

NOTE 3 - Surges to low voltage DC inputs ports (≤ 60 V) are not applied in the case, when the secondary circuits are not subject to transient overvoltages (i.e. reliably-earthed, capacitively-filtered DC secondary circuits where the peak-to-peak ripple is less than 10% of the DC component.)

NOTE 4 - In the case of several identical circuits representative measurements on a selected number of circuits may be sufficient.

NOTE 5 – Most protectors in common use have low average power capabilities even though their peak power or peak energy handling can deal with high currents. Therefore, the time between two surges depends on the built-in protection devices of the EUT.

Information on the mode to perform the tests is given in B.2 of annex B.

If not otherwise specified the surges on the ac mains shall be synchronized to the voltage phase at the respective angle and the peak value of the a.c. voltage wave (positive and negative).

When testing line to earth the test voltage has to be applied successively between each of the lines and earth, if there is no other specification.

The test procedure shall also consider the non-linear current-voltage characteristics of the equipment under test. Therefore the test voltage has to be increased by steps up to the test level specified in the product standard or test plan.

All lower levels including the selected test level shall be satisfied. For testing the secondary protection, the output voltage of the generator shall be adjusted to be just below the worst case voltage breakdown level (let-through level) of the primary protection.

If the actual operating signal sources are not available, they may be simulated. Under no circumstances may the test level exceed the product specification. The test shall be carried out according to a test plan.

To find all critical points of the duty cycle of the equipment, a sufficient number of positive and negative test pulses shall be applied. For acceptance test a previously unstressed equipment shall be used or the protection devices shall be replaced.

9 Evaluation of test results

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

a) normal performance within limits specified by the manufacturer, requestor or purchaser;
b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;
c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;
d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

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

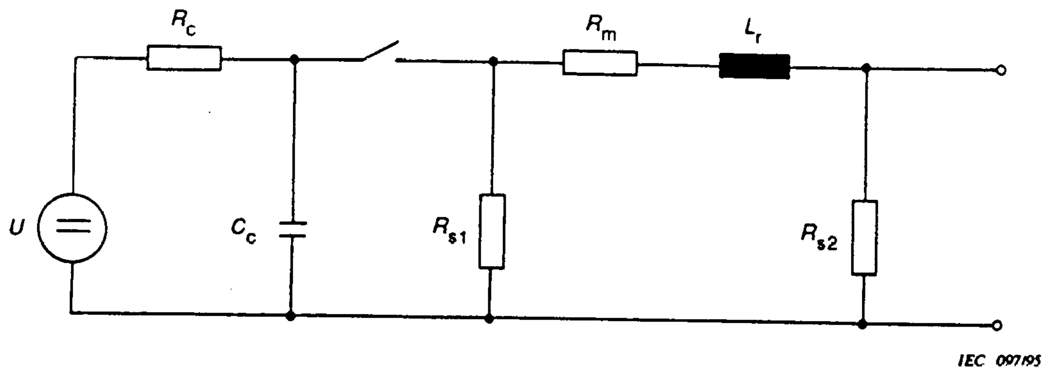
This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product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

10 Test report

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

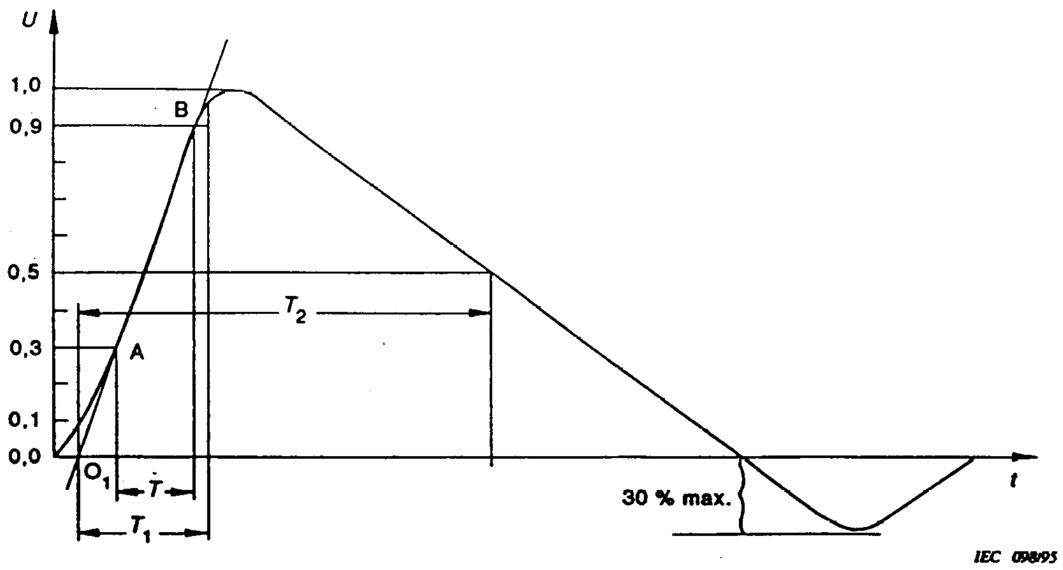
- the items specified in the test plan required by clause 8 of this standard;
- identification of the EUT and any associated equipment, e.g. brand name, product type, serial number;
- identification of the test equipment, e.g. brand name, product type, serial number;
- any special environmental conditions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

Equipment shall not become dangerous or unsafe as a result of the application of the tests defined in this part of IEC 61000.



U	High-voltage source
R_c	Charging resistor
C_c	Energy storage capacitor
R_s	Pulse duration shaping resistor
R_m	Impedance matching resistor
L_r	Rise time shaping inductor

Figure 1 - Simplified circuit diagram of the combination wave generator



Front time: T_1 = 1,67 x T = 1,2 µs ± 30 %
Time to half-value: T_2 = 50 µs ± 20 %.

Figure 2 - Waveform of open-circuit voltage (1,2/50 µs) (waveform definition according to IEC 60060-1)

Front time: T_1 = 1,25 x T = 8 µs ± 20 %
Time to half-value: T_2 = 20 µs ± 20 %.

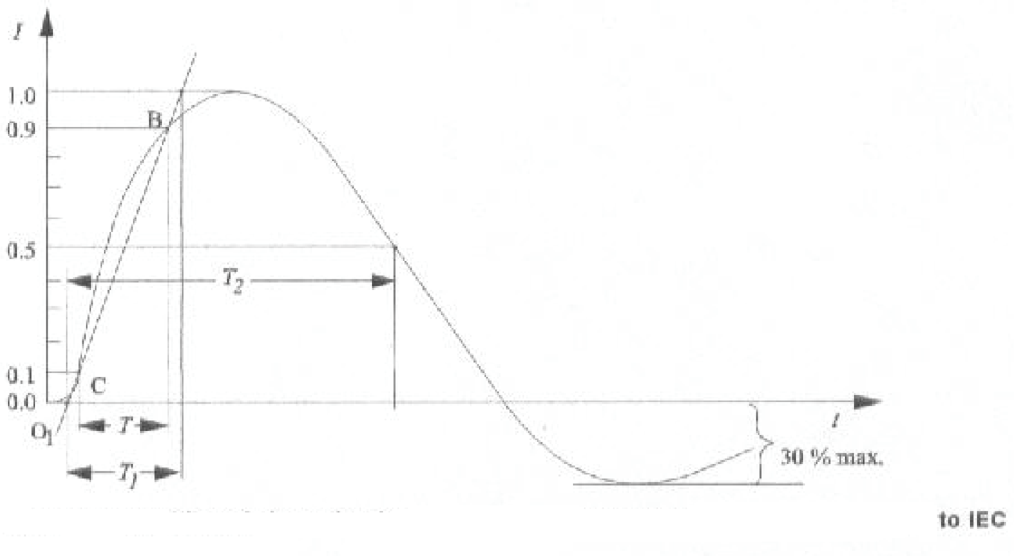
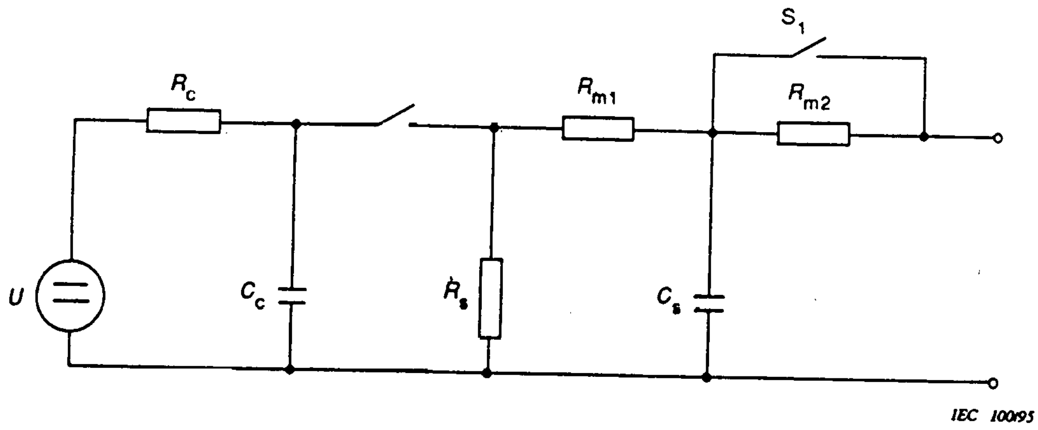
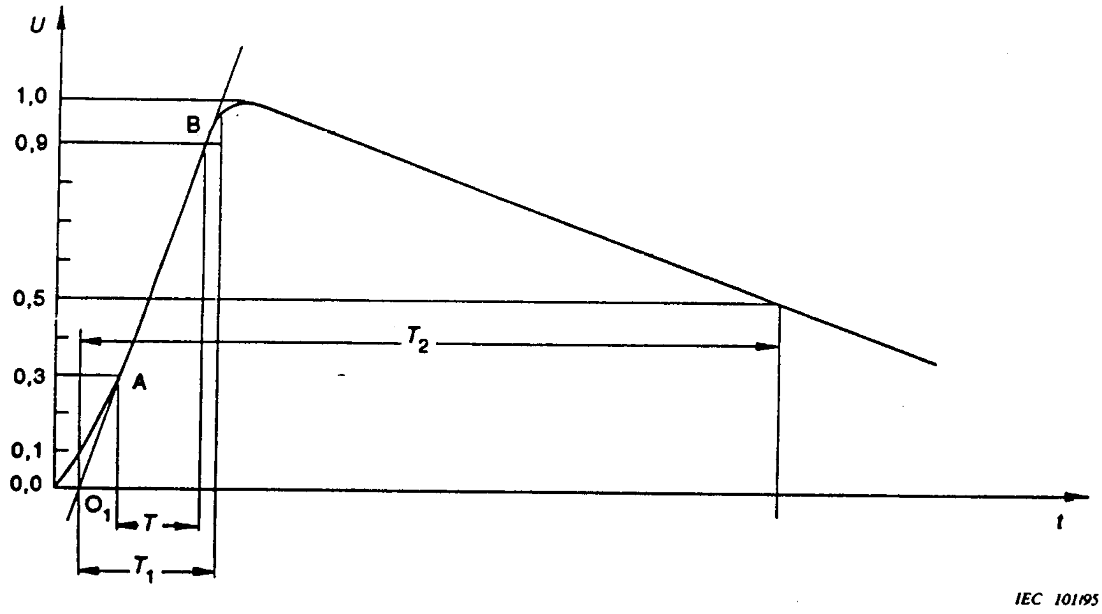


Figure 3. Waveform definition of short-circuit current (8/20us) (waveform definition according to IEC 60060-1)



U High-voltage source
R_C Charging resistor
C_C Energy storage capacitor
R_S Pulse duration shaping resistor
R_m Impedance matching resistors
C_S Rise time shaping capacitor
S_1 Switch closed when using external matching resistors

Figure 4 - Simplified circuit diagram of the 10/700 µs Surge generator



Front time: T_1 = 1,67 x T = 10 µs ± 30 %
Time to half-value: T_2 = 700 µs ± 20 %.

Figure 5 - Waveform of open-circuit voltage (10/700 µs) (waveform definition according to IEC 60060-1)

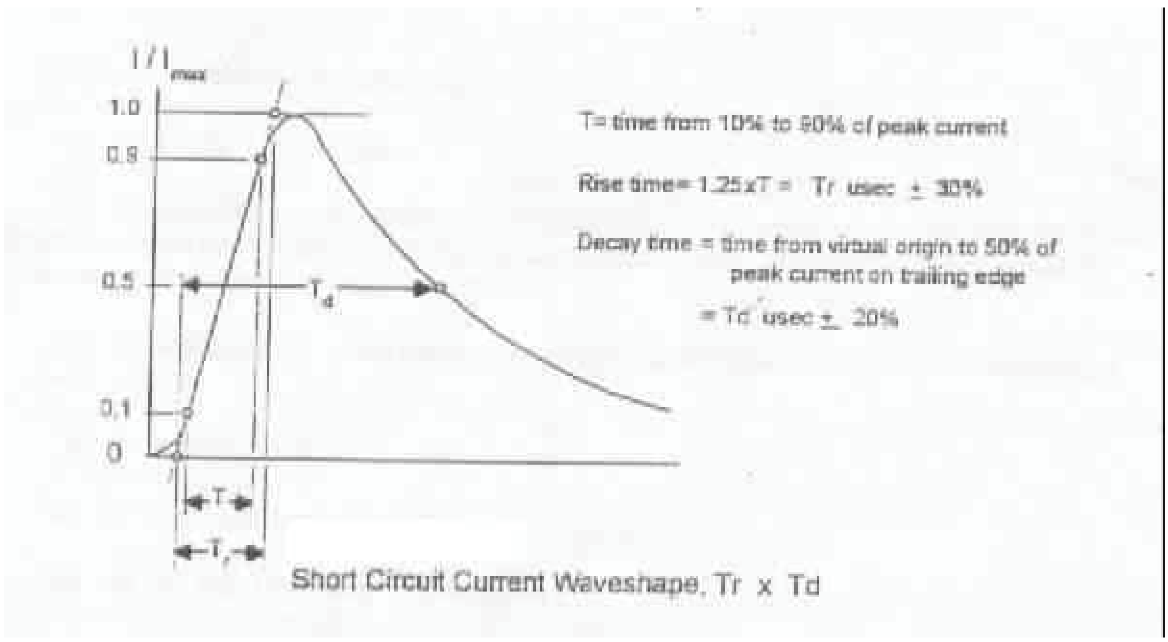


Figure 6 - Waveform of the 5 µs x 320 µs short-circuit current waveform (definition according to IEC 60060-1 and FCC Part 68)

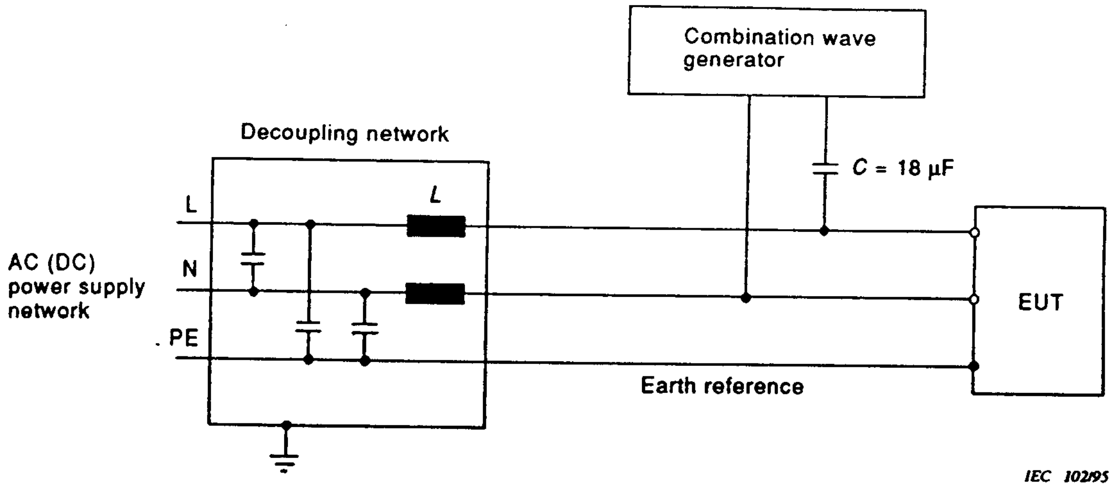


Figure 7 - Example of test set-up for capacitive coupling on a.c./d.c. lines; line-to-line coupling (according to 7.2)

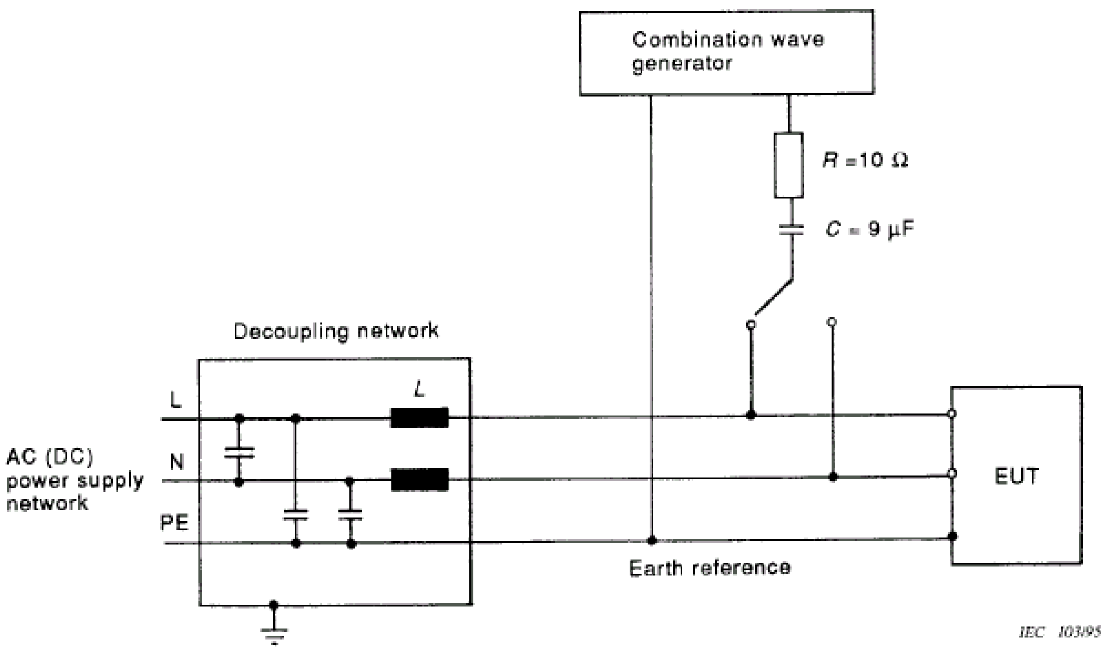


Figure 8 - Example of test set-up for capacitive coupling on a.c./d.c. lines; line-to-earth coupling (according to 7.2)

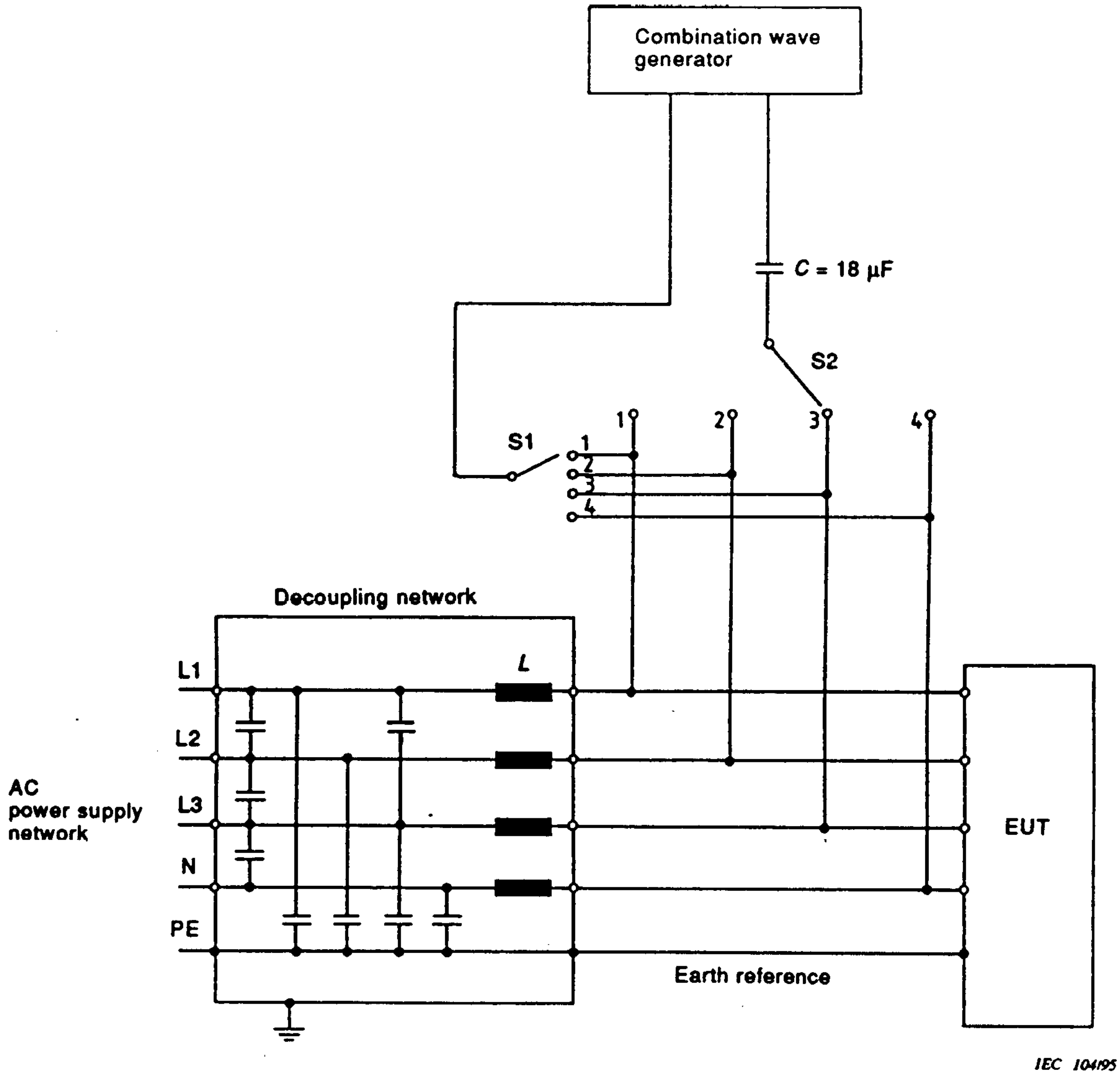
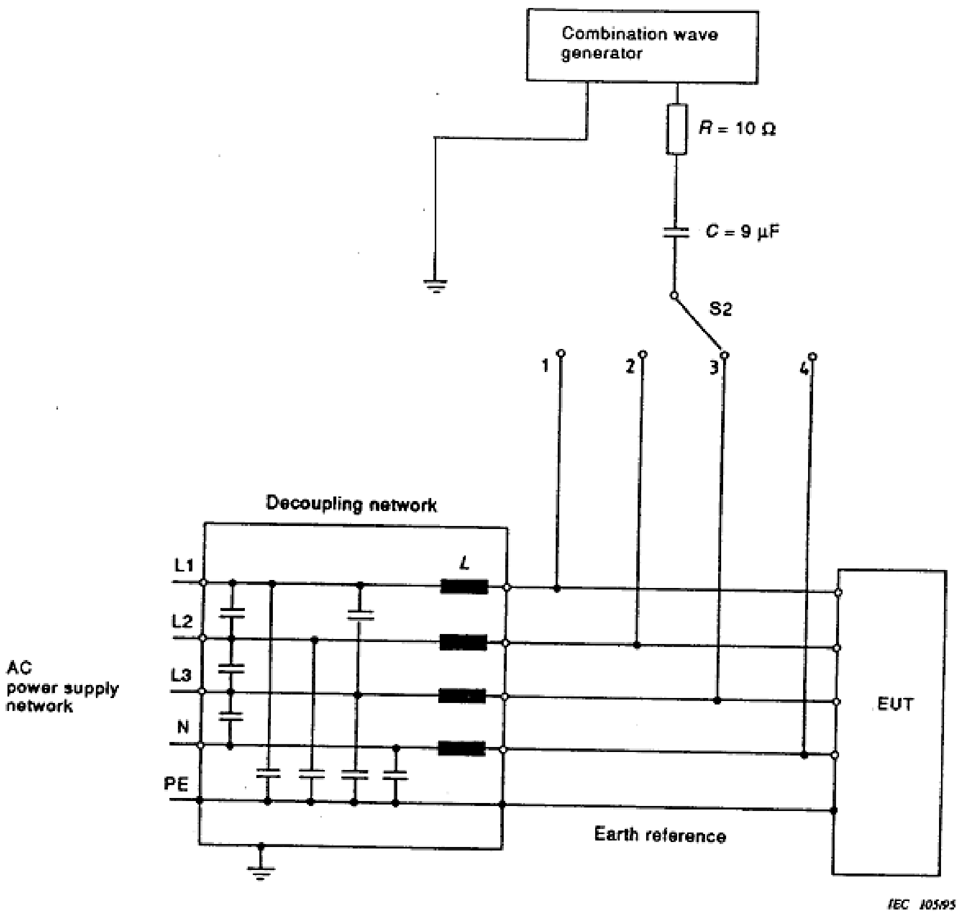
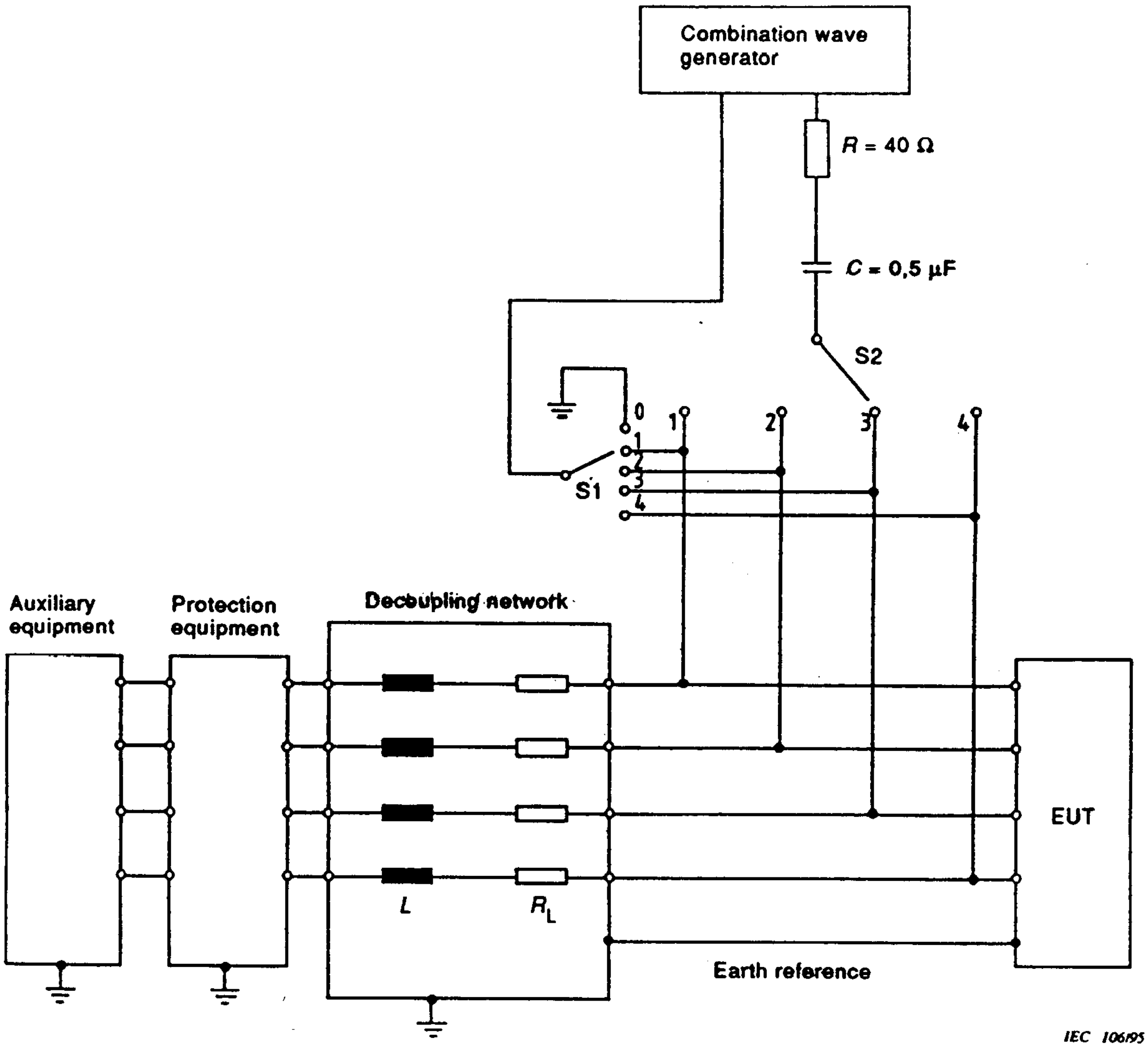


Figure 9 - Example of test set-up for capacitive coupling on a.c. lines (3 phases); line L3 to line L1 coupling (according to 7.2)



Switch S2
- during test positions 1 to 4

Figure 10 - Example of test set-up for capacitive coupling on a.c. lines (3 phases); line L3 to earth coupling (according to 7.2)

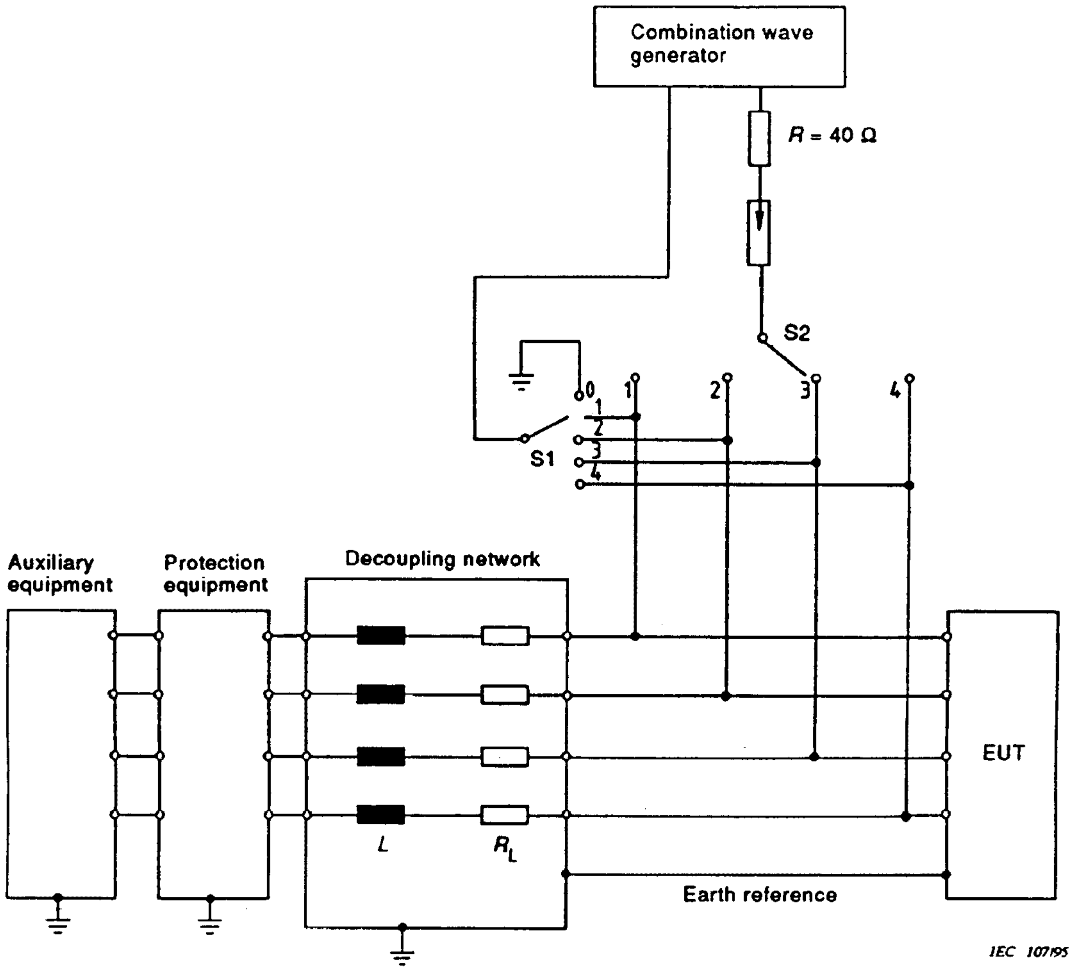


1) *Switch S1*
- line to earth: position 0
- line to line: positions 1 to 4

2) *Switch S2*
- during the test positions 1 to 4, but not in the same position with switch S1

3) L = 20 mH, R_L represents the resistive part of L

Figure 11 - Example of test set up for unshielded unsymmetrical interconnection lines; line-to-line and line-to-earth coupling (according to 7.3), coupling via capacitors

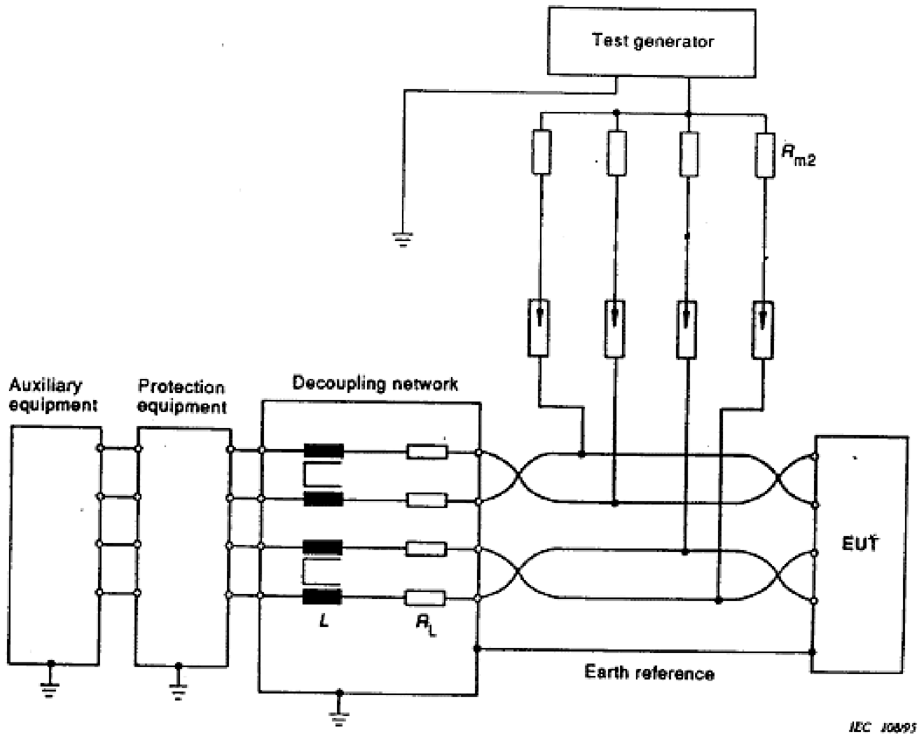


1) *Switch S1*
- line to earth: position 0
- line to line: positions 1 to 4

2) *Switch S2*
- during the test positions 1 to 4, but not in the same position with switch S1

3) L = 20 mH, R_L represents the resistive part of L

Figure 12 - Example of test set-up for unshielded unsymmetrical interconnection lines; line-to-line and line-to-earth coupling (according to 7.3), coupling via arrestors



Calculation of R_{m2} *when using CWG (1,2/50 µs generator)*

Example for n = 4:

R_{m2} = 4 x 40 Ω = 160, max. 250 Ω

Calculation of R_{m2} *when using 10/700 µs generator*

The internal matching resistor R_{m2} (25 Ω) is replaced by external R_{m2} = n x 25 Ω per

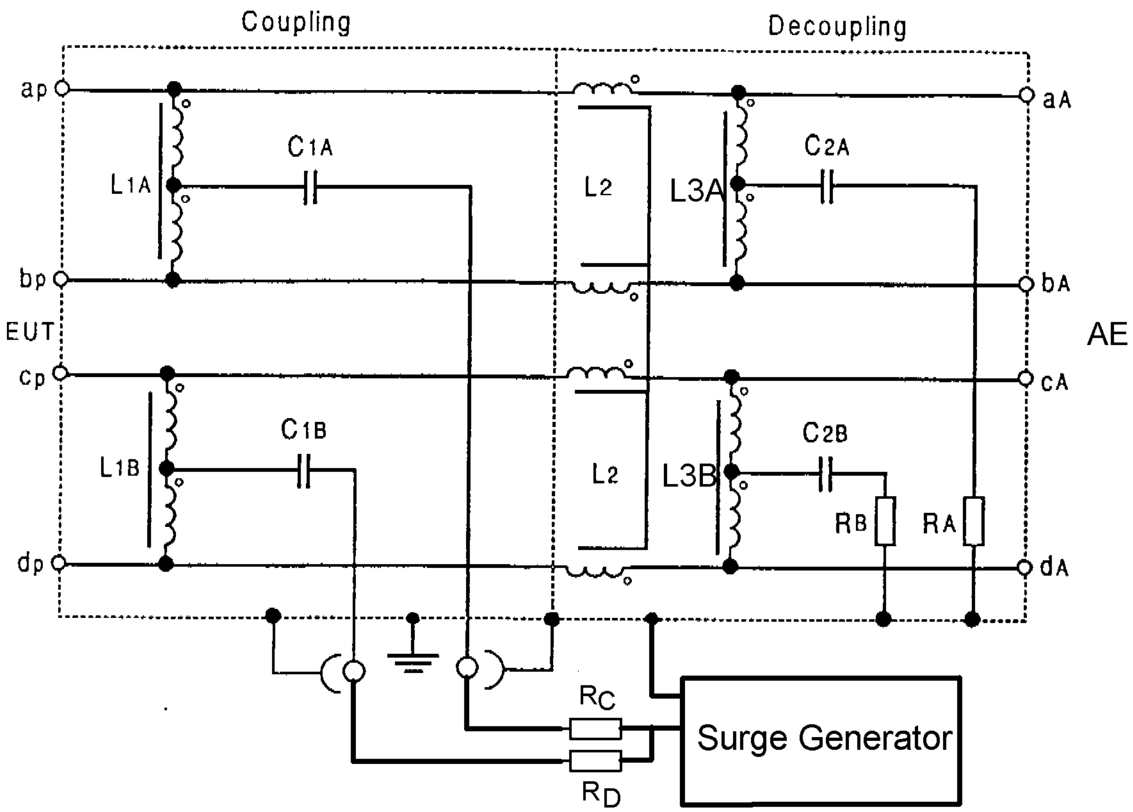
conductor (for n conductors with n equal or greater than 2).

Example for n = 4:

R_{m2} = 4 x 25 Ω = 100 Ω, R_{m2} shall not exceed 250 Ω

c) L = 20 mH, current compensation must include all 4 coils to be effective. R_L: value depending on negligible attenuation of the transmission signal

Figure 13 - Example of test set-up for unshielded symmetrical interconnection lines (telecommunication lines); lines-to-earth coupling (according to 7.4), coupling via arrestors



The socket-like symbols in the figure mean connection points.

Notes
1.) L2 shall be a 4-coil current compensated choke to avoid saturation of coil due to phantom power feeding. Further L2 shall have a low resistive impedance; i.e. << 1 Ω. Resistors connected parallel to L2 may lower the total resistance.
2.) RA and RB should have a value as low as possible to prevent oscillation or ringing.
3.) RC and RD are meant to be isolation resistors of 40 ohms.
4.) It is not recommended that this design be used with the 10/700 µs waveform since inductors will likely saturate.

Figure 14 - Example of a coupling/decoupling network for symmetrical high speed communication lines using the 1,2/50µs surge

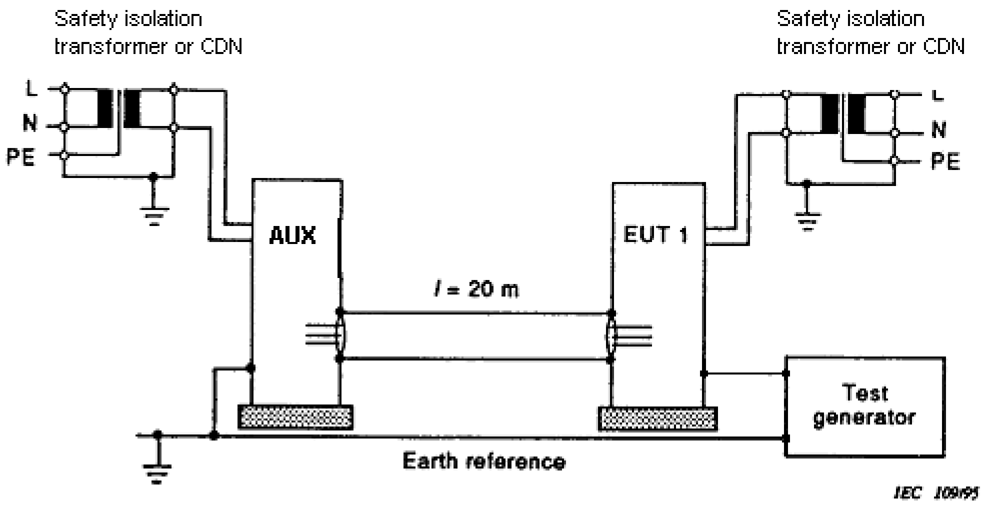
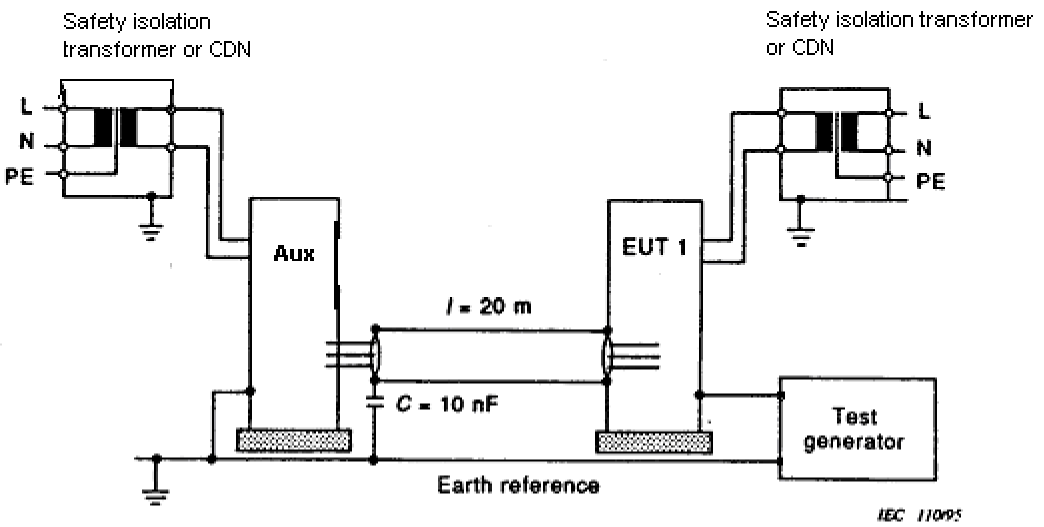


Figure 15 - Example of test set-up for tests applied to shielded lines (according to 7.6) and to apply potential differences (according to 7.7)



The 10nF capacitance is representative of the cable capacitance to ground and NOT and additional component to be added to the test.

Figure 16 - Example of test set-up for tests applied to unshielded lines and shielded lines earthed only at one end (according to 7.6) and to apply potential differences (according to 7.7)

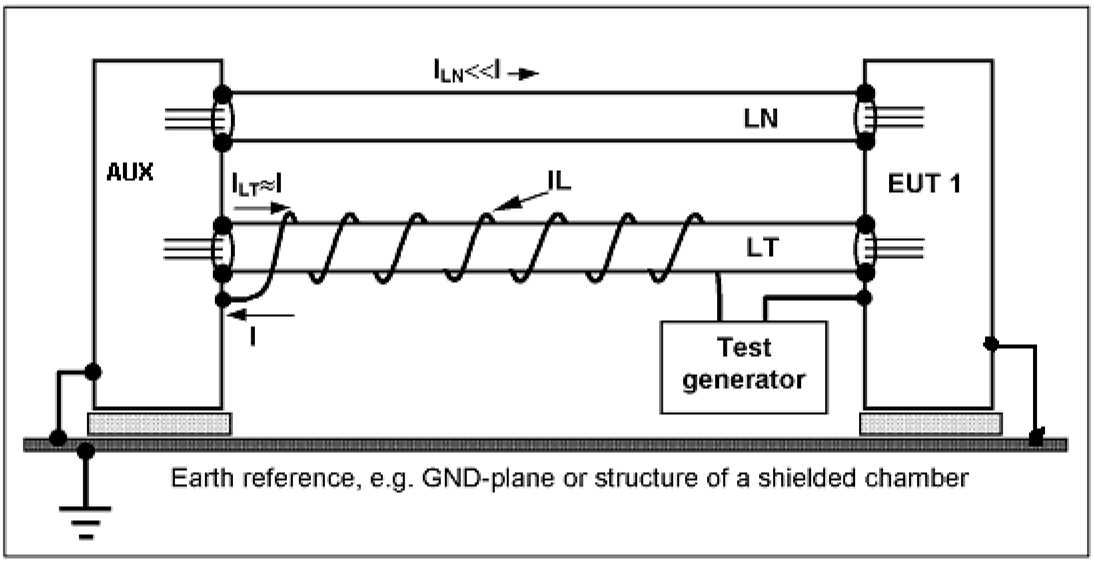


Figure 17 – Coupling method and test set-up for tests applied to shielded lines and to apply potential differences, especially in configurations with multiple shielded cable wiring.

Characteristics of the test set-up:(AUX shall be connected to GND.)

Test generator is located near EUT 1;

Common output of test generator is connected to structure of EUT 1;

Impulse output of test generator is routed to AUX via an insulated injection line extremely close to interface cable between EUT 1 and AUX (wrapped around tightly).

With $I_{LT} \approx I$ and $I_{LN} << I$, the bulk injected current will run over the shield of the cable under test (proximity effect).

Annex A
(normative)

Selection of generators and test levels

The selection of the test levels shall be based on the installation conditions. Unless otherwise specified in product- or product family standards, table A.1 should be used, together with information and examples given in B.3 of annex B where:

Class 0: Well-protected electrical environment, often within a special room.

Class 1: Partly protected electrical environment.

Class 2: Electrical environment where the cables are well separated, even at short runs.

Class 3: Electrical environment where cables run in parallel.

Class 4: Electrical environment where the interconnections are running as outdoor cables along with power cables, and cables are used for both electronic and electric circuits.

Class 5: Electrical environment for electronic equipment connected to telecommunication cables and overhead power lines in a non-densely populated area.

Class x: Special conditions specified in the product specification.

Additional information is given in figures B.1 to B.3 of annex B.

To demonstrate the system level immunity additional measures relevant to the actual installation conditions, e.g. primary protection, should be taken.

Table A.1 - Selection of the test levels (depending on the installation conditions)

Installation class	Test levels (kV)											
	AC Power supply and AC I/O directly connected to the mains network Coupling mode		AC Power supply and AC I/O not directly connected to the mains network Coupling mode		DC Power supply and DC I/O directly connected thereto Coupling mode		Unsymmetrical operated circuits/lines[4)] Coupling mode		Symmetrical operated circuits/lines[4)] Coupling mode		Shielded I/O and communication lines Coupling mode	
	Line to line	Line to earth	Line to line	Line to earth	Line to line	Line to earth	Line to line	Line to earth	Line to line	Line to earth	Line to line	Line to earth
0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	0,5	NA	NA	NA	NA	NA	0,5	NA	0,5	NA	NA
2	0,5	1,0	NA	NA	NA	NA	0,5	1,0	NA	1,0	NA	0,5
3	1,0	2,0	1,0[5)]	2,0[2) 5)]	1,0[5)]	2,0[2) 5)]	1,0[3)]	2,0[2) 3)]	NA	2,0[2) 3)]	NA	2,0[3)]
4	2,0	4,0[2)]	2,0[5)]	4,0[2) 5)]	2,0[5)]	4,0[2) 5)]	2,0[3)]	4,0[2) 3)]	NA	2,0[2) 3)]	NA	4,0[3)]
5	[1)]	[1)]	2,0	4,0[2)]	2,0	4,0[2)]	2,0	4,0[2)]	NA	4,0[2)]	NA	4,0[3)]

1) Depends on the class of the local power supply system.

2) Normally tested with primary protection.

3) The test level may be lowered of one level if the cable length is shorter or equal to 10 meters.

4) No test is advised at interconnection cables up to 10 m for data lines.

5) If protection is specified upstream from the EUT, the test level should correspond to the protection level when the protection is not in place.

The surges (and test generators) related to the different classes are as in the following:

Classes 1 to 4:	1,2/50 µs (8/20 µs).
Class 5:	1,2/50 µs (8/20 µs) for ports of power lines and short-distance signal circuits/lines.
Class 1 to 5:	10/700 µs for symmetrical telecom lines

The source impedance shall be as indicated in the figures of the test set-ups concerned.

Annex B
(informative)

Explanatory notes

B.1 Different source Impedance

The selection of the source impedance of the generator depends on:

- the kind of cable/conductor/line (a.c. power supply, d.c. power supply, interconnection, etc.);
- the length of the cables/lines;
- indoor/outdoor conditions;
- application of the test voltage (line to line or lines to earth).

The impedance of 2 Ω represents the source impedance of the low-voltage power supply network. The generator with its effective output impedance of 2 Ω is used.

The impedance of 12 Ω (10 Ω + 2 Ω) represents the source impedance of the low-voltage power supply network and earth. The generator with an additional resistor of 10 Ω in series is used.

The effective impedance of 42 Ω (40 Ω + 2 Ω) represents the source impedance between all other lines and earth. The generator with an additional resistor of 40 Ω in series is used.

In some countries (for instance, USA) other non-IEC standards for a.c. lines may require the tests according to figures 7 and 9 with a 2 Ω impedance; this is a more severe test. The general requirement is 10 Ω.

B.2 Application of the tests

Two different kinds of tests are to be distinguished: at equipment level and at system level.

B.2.1 Equipment level immunity

The test shall be carried out in the laboratory on a single EUT. The immunity of the EUT thus tested is referred to equipment level immunity.

The test voltage shall not exceed the specified capability of the insulation to withstand high-voltage stress.

B.2.2 System level immunity

The test carried out in the laboratory refers to an EUT, but immunity at the EUT does not necessarily assure the immunity of a larger system which contains that EUT. In order to ensure system level immunity, a test at the system level is recommended to simulate the real installation. This simulated installation shall be comprised of individual EUTs and shall also include protective devices (Surge Protective Devices – SPDs) if they are stipulated by the system application manual. The real length and type of interconnection lines will be used, all of which can affect the overall system protection level. The simple addition of an external SPD that is not co-ordinated with other internal SPDs, might have no effect, might reduce the effect on the overall system protection, or might improve overall system protection. Additional information can be found in IEC Surge Protective Devices Standards, IEC 61643 and IEC 61312 (Protection against lightning electromagnetic impulse).

This test is aimed at simulating as closely as possible the installation conditions in which the EUT or EUTs are intended to function.

In a real installation, higher voltage levels can be applied, but the surge energy will be limited by the installed protective devices in accordance with their current-limiting characteristics.

The system level test is also intended to show that secondary effects produced by the protective devices (change of waveform, mode, amplitude of voltages or currents) do not cause unacceptable effects on the EUT.

B.3 Installation classification

Class 0 Well-protected electrical environment, often within a special room

All incoming cables are provided with overvoltage (primary and secondary) protection. The units of the electronic equipment are interconnected by a well designed earthing system, which is not essentially influenced by the power installation or lightning.

The electronic equipment has a dedicated power supply (see table A.1).

Surge voltage may not exceed 25 V.

Class 1 Partly protected electrical environment

All incoming cables to the room are provided with overvoltage (primary) protection.

The units of the equipment are well interconnected by an earth line network, which is not essentially influenced by the power installation or lightning.

The electronic equipment has its power supply completely separated from the other equipment.

Switching operations can generate interference voltages within the room.

Surge voltage may not exceed 500 V.

Class 2 Electrical environment where the cables are well separated, even at short runs.

The installation is earthed via a separate earth line to the earthing system of the power installation which can be essentially subjected to interference voltages generated by the installation itself or by lightning. The power supply to the electronic equipment is separated from other circuits, mostly by a special transformer for the power supply.

Non-protected circuits are in the installation, but well separated and in restricted numbers.

Surge voltages may not exceed 1 kV.

Class 3 Electrical environment where power and signal cables run in parallel

The installation is earthed to the common earthing system of the power installation which can be essentially subjected to interference voltages generated by the installation itself or by lightning.

Current due to earth faults, switching operations and lightning in the power installation may generate interference voltages with relatively high amplitudes in the earthing system. Protected electronic equipment and less sensitive electric equipment are connected to the same power supply network. The interconnection cables can be partly outdoor cables, but close to the earthing network.

Unsuppressed inductive loads are in the installation and usually there is no separation of the different field cables.

Surge may not exceed 2 kV.

Class 4 Electrical environment where the interconnections are running as outdoor cables along with power cables, and cables are used for both electronic and electric circuits

The installation is connected to the earthing system of the power installation which can be subjected to interference voltages generated by the installation itself or by lightning.

Currents in the kA range due to earth faults, switching operations and lightning in the power supply installation may generate interference voltages with relatively high amplitudes in the earthing system. The power supply network can be the same for both the electronic and the electric equipment. The interconnection cables are running as outdoor cables even to the high-voltage equipment.

A special case of this environment is when the electronic equipment is connected to the telecommunication network within a densely populated area. There is no systematically constructed earthing network outside the electronic equipment, and the earthing system consists of pipes, cables etc.
only.

Surge voltage may not exceed 4 kV.

Class 5 Electrical environment for electronic equipment connected to telecommunication cables and overhead power lines in a non-densely populated area

All these cables and lines are provided with overvoltage (primary) protection. Outside the electronic equipment there is no widespread earthing system (exposed plant). The interference voltages due to earth faults (currents up to 10 kA) and lightning (currents up to 100 kA) can be extremely high.

The requirements of this class are covered by the test level 4 (see annex A).

Class x Special conditions specified in the product specifications

B.4 Equipment level immunity of ports connected to the power supply network

The minimum immunity level for connection to the public supply network is:

- Line-to-line coupling: 0,5 kV (test set-up see figures 6 and 8).

- Line-to-earth coupling: 1 kV (test set-up see figures 7 and 9).

B.5 Equipment level immunity of ports connected to interconnection lines

Surge tests on interconnection circuits are only required for external connections (outside of the cabinet/housing).

If it is possible to test at the system level (EUT with interconnection cables connected) it is not necessary to test at the equipment level especially in cases where the shield of the interconnection cable is part of the protection measure. If the installation of the plant is carried out by someone other than the manufacturers of the equipment, the admissible voltage for the inputs/outputs (especially for the process interface) of the EUT should be specified.

The manufacturer should test his equipment on the basis of the specified test levels to confirm the equipment level immunity, e.g. with secondary protection at the ports of the EUT for a level of 0,5 kV. The user of the plant or those responsible for the installation should then apply measures (e.g. shielding, bonding, earthing protection) necessary to ensure that the interference voltage caused by, for example, lightning strokes does not exceed the chosen immunity level.

B.6 Coupling of Surges to multiple shielded cable wiring

The following explanations are given related to figure B.1.

As for the test set-up:

- shielded cables in this case: coaxial cables RG142; length, each: 21 meters;
- generator: outputs: L - N (2 Ω); amplitude during tests: + 250 V;
- coaxial cable(s) contacted with a twin shielding case at peripheral end; load: 50 Ω;
- peripheral shielding case alternatively contacted with shielded chamber structure or floating.
- coaxial feed through at the measuring end; measurement with oscilloscope outside of the shielded chamber; load 50 Ω.
- the surge current flows from the measuring end to the peripheral end o fthe shielded cables via injection line that is tightly wrapped around the cable under test. -
- distance of tested cable to parallel shielded cable, if present: 15 cm.

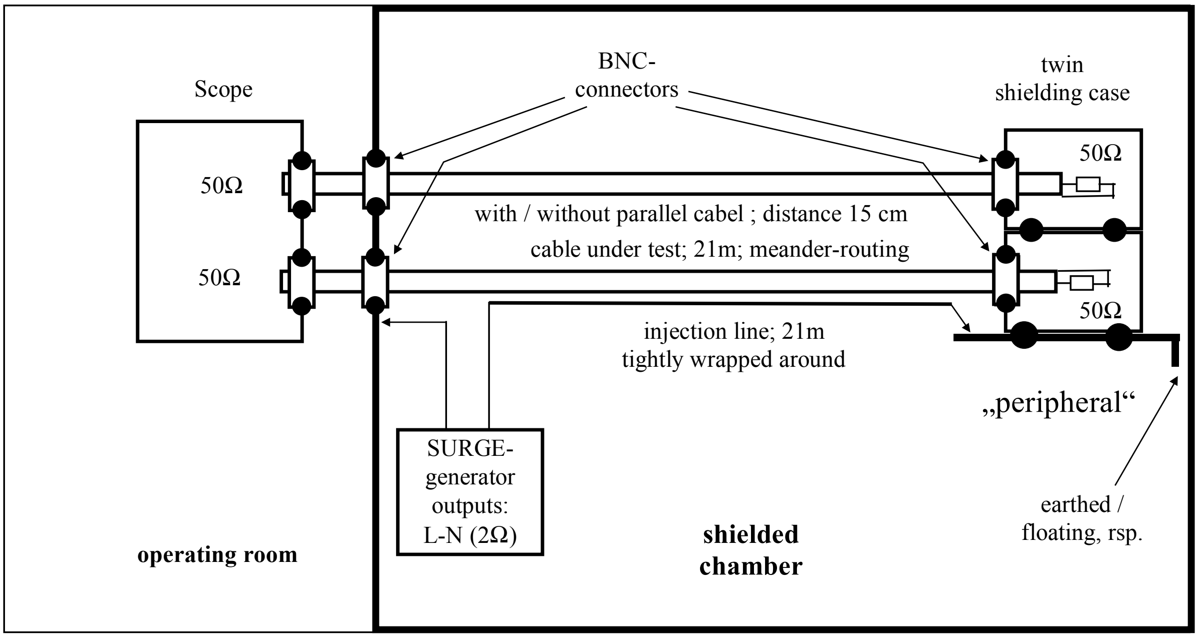


Figure B.1 - Surge injection via injection line extremely close to interface cable between EUT 1 and EUT 2.

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