



Electromagnetic compatibility (EMC)

Part 4.5: Testing and measurement techniques—Surge immunity test



This Australian Standard® was prepared by Committee TE-003, Electromagnetic Compatibility. It was approved on behalf of the Council of Standards Australia on 6 April 2017.

This Standard was published on 24 May 2017.

The following are represented on Committee TE-003:

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 - Australian Industry Group
 - Australian Information Industry Association
 - Consumer Electronics Suppliers Association
 - Curtin University of Technology
 - Department of Defence (Australian Government)
 - Electrical Compliance Testing Association
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-

This Standard was issued in draft form for comment as DR AS IEC 61000.4.5:2017.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

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Australian Standard[®]

Electromagnetic compatibility (EMC)

Part 4.5: Testing and measurement techniques—Surge immunity test

Originated as AS/NZS 61000.4.5:1999.
Previous edition AS/NZS 61000.4.5:2006.
Third edition revised in Australia and designated AS IEC 61000.4.5:2017.

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Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 1 76035 774 0

PREFACE

This Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee TE-003, Electromagnetic Compatibility, to supersede AS/NZS 61000.4.5:2006, *Electromagnetic compatibility (EMC), Part 4.5: Testing and measurement technique—Surge immunity test*. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this Standard is to provide guidance in relation to the immunity requirements, test methods, and range of recommended test levels for equipment with regard to unidirectional surges caused by over-voltages from switching and lightning transients.

This Standard is identical with, and has been reproduced from IEC 61000-4-5:2014 (ED.3.0), *Electromagnetic compatibility (EMC), Part 4-5: Testing and measurement techniques—Surge immunity test*.

As this Standard is reproduced from an International Standard, the following applies:

- (a) In the source text ‘this part of 61000’ should read ‘this Australian Standard’.
- (b) A full point substitutes for a comma when referring to a decimal marker.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the annex to which they apply. A ‘normative’ annex is an integral part of a Standard, whereas an ‘informative’ annex is only for information and guidance.

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INTRODUCTION

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

Part 1: General

- General considerations (introduction, fundamental principles)
- Definitions, terminology

Part 2: Environment

- Description of the environment
- Classification of the environment
- Compatibility levels

Part 3: Limits

- Emission limits
- Immunity limits (insofar as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

- Measurement techniques
- Testing techniques

Part 5: Installation and mitigation guidelines

- Installation guidelines
- Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

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

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

NOTES

AUSTRALIAN STANDARD

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 with regard to unidirectional surges caused by over-voltages 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 is 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 test levels for their products.

This standard defines:

- a range of test levels;
- test equipment;
- test setups;
- test procedures.

The task of the described laboratory test is to find the reaction of the equipment under test (EUT) under specified operational conditions to surge voltages caused by switching and lightning effects.

It is not intended to test the capability of the EUT's insulation to withstand high-voltage stress. Direct injections of lightning currents, i.e. direct lightning strikes, are not considered in this standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at www.electropedia.org)

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050 as well as the following apply.

3.1.1

avalanche device

diode, gas tube arrestor, or other component that is designed to break down and conduct at a specified voltage

3.1.2

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

Note 1 to entry: This term is based on the "uncertainty" approach.

Note 2 to entry: The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

[SOURCE: IEC 60050-311:2001, 311-01-09]

3.1.3

clamping device

diode, varistor or other component that is designed to prevent an applied voltage from exceeding a specified value

3.1.4

combination wave generator

CWG

generator with 1,2/50 μs or 10/700 μs open-circuit voltage waveform and respectively 8/20 μs or 5/320 μs short-circuit current waveform

3.1.5

coupling network

CN

electrical circuit for the purpose of transferring energy from one circuit to another

3.1.6

coupling/decoupling network

CDN

combination of a coupling network and a decoupling network

3.1.7

decoupling network

DN

electrical circuit for the purpose of preventing surges applied to the EUT from affecting other devices, equipment or systems which are not under test

3.1.8

duration

3.1.8.1

duration

T_d

<surge voltage> time interval between the instant at which the surge voltage rises to 0,5 of its peak value, and then falls to 0,5 of its peak value (T_w)

$$T_d = T_w$$

SEE: Figures 2 and A.2

3.1.8.2 duration

T_d

<surge current for 8/20 μ s> virtual parameter defined as the time interval between the instant at which the surge current rises to 0,5 of its peak value, and then falls to 0,5 of its peak value (T_w), multiplied by 1,18

$$T_d = 1,18 \times T_w$$

SEE: Figure 3.

3.1.8.3 duration

T_d

<surge current for 5/320 μ s> time interval between the instant at which the surge current rises to 0,5 of its peak value, and then falls to 0,5 of its peak value (T_w)

$$T_d = T_w$$

SEE: Figure A.3.

3.1.9 effective output impedance

<surge generator> ratio of the peak open-circuit voltage to the peak short-circuit current at the same output port

3.1.10 electrical installation

assembly of associated electrical equipment having co-ordinated characteristics to fulfil purposes

[SOURCE: IEC 60050-826:2004, 826-10-01]

3.1.11 front time

3.1.11.1 front time

T_f

<surge voltage> 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: Figures 2 and A.2.

3.1.11.2 front time

T_f

<surge current> virtual parameter defined as 1,25 times the interval T_r between the instants when the impulse is 10 % and 90 % of the peak value

SEE: Figures 3 and A.3.

3.1.12 high-speed communication lines

input/output lines which operate at transmission frequencies above 100 kHz

3.1.13**immunity**

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

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

3.1.14**interconnection lines**

I/O lines (input/output lines) and/or communication lines and/or low voltage d.c. input/output lines (≤ 60 V), where secondary circuits (isolated from the a.c. mains supply) are not subject to transient over-voltages (i.e. reliably-grounded, capacitively-filtered d.c. secondary circuits where the peak-to-peak ripple is less than 10 % of the d.c. component)

3.1.15**power port**

port, at which the conductor or cable carrying the primary electrical power needed for the operation (functioning) of an apparatus or associated apparatus is connected to the apparatus

3.1.16**primary protection**

means by which the majority of stressful energy is prevented from propagating beyond a designated interface

3.1.17**reference ground**

part of the Earth considered as conductive, the electrical potential of which is conventionally taken as zero, being outside the zone of influence of any earthing (grounding) arrangement

[SOURCE: IEC 60050-195:1998, 195-01-01]

3.1.18**rise time** **T_r**

interval of time between the instants at which the instantaneous value of an impulse first reaches 10 % value and then 90 % value

SEE: Figures 3 and A.3.

[SOURCE: IEC 60050-161:1990, 161-02-05, modified – the content of the note has been included in the definition and “pulse” has been changed to “impulse”.]

3.1.19**secondary protection**

means by which the let-through energy from primary protection is suppressed

Note 1 to entry: It may be a special device or an inherent characteristic of the EUT.

3.1.20**surge**

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

[SOURCE: IEC 60050-161:1990, 161-08-11, modified – “surge” here applies to voltage, current and power]

3.1.21**symmetrical lines**

pair of symmetrically driven conductors with a conversion loss from differential to common mode of greater than 20 dB

3.1.22**system**

set of interdependent elements constituted to achieve a given objective by performing a specified function

Note 1 to entry: 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.

3.1.23**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 to the time scale of interest

[SOURCE: IEC 60050-161:1990, 161-02-01]

3.1.24**verification**

set of operations which is used to check the test equipment system (e.g. the test generator and its interconnecting cables) to demonstrate that the test system is functioning

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

Note 2 to entry: For the purposes of this basic EMC standard this definition is different from the definition given in IEC 60050-311:2001, 311-01-13.

3.2 Abbreviations

AE	Auxiliary equipment
CD	Coupling device
CDN	Coupling/decoupling network
CLD	Clamping device
CN	Coupling network
CWG	Combination wave generator
DN	Decoupling network
EFT/B	Electrical fast transient/burst
EMC	Electromagnetic compatibility
ESD	Electrostatic discharge
EUT	Equipment under test
GDT	Gas discharge tube
MU	Measurement uncertainty
PE	Protective earth
SPD	Surge protective device

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 local switching activity or load changes in the power distribution system;
- c) resonating circuits associated with switching devices, e.g. thyristors, transistors;
- d) various system faults, such as short-circuits and arcing faults to the grounding 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 (outdoor) circuit injecting high currents that produce voltages by either flowing through ground resistance or flowing through the impedance of the external circuit;
- b) 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 ground current flow resulting from nearby direct-to-earth discharges coupling into the common ground paths of the grounding 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

The characteristics of the test generator are defined to simulate the above-mentioned phenomena as closely as possible.

If the source of interference is in the same circuit as the victim equipment, for example in the power supply network (direct coupling), the generator may simulate a low source impedance at the ports of the EUT.

If the source of interference is not in the same circuit as the victim equipment (indirect coupling), then the generator may simulate a higher impedance source.

5 Test levels

The preferred range of test levels is given in Table 1.

Table 1 – Test levels

Level	Open-circuit test voltage	
	kV	
	Line-to-line	Line-to-ground ^b
1	---	0,5
2	0,5	1
3	1	2
4	2	4
X ^a	Special	Special
^a "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification. ^b For symmetrical interconnection lines the test can be applied to multiple lines simultaneously with respect to ground, i.e. "lines to ground".		

The test levels shall be selected according to the installation conditions; classes of installation are given in Annex C.

The test shall be applied at all test levels in Table 1 up to and including the specified test level (see 8.3).

For selection of the test levels for the different interfaces, refer to Annex B.

6 Test instrumentation

6.1 General

Two types of combination wave generators are specified. Each has its own particular applications, depending on the type of port to be tested. The 10/700 μ s combination wave generator is used to test ports intended for connection to outdoor symmetrical communication lines (see Annex A). The 1,2/50 μ s combination wave generator is used in all other cases.

6.2 1,2/50 μ s combination wave generator

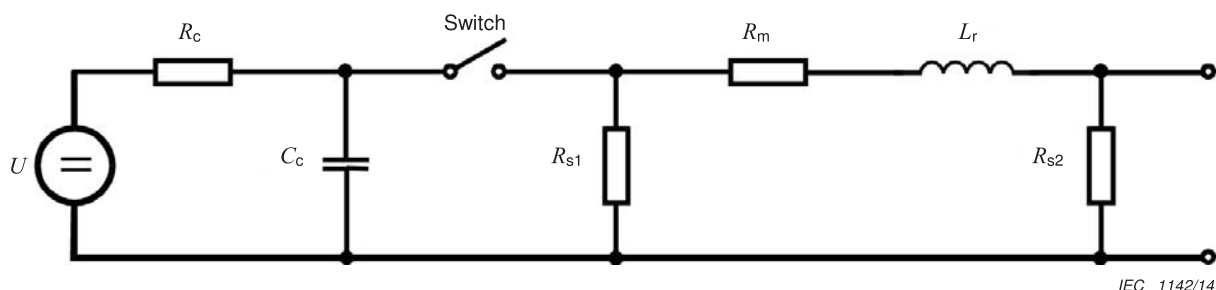
6.2.1 General

It is the intention of this standard that the output waveforms meet specifications at the point where they are to be applied to the EUT. Waveforms are specified as open-circuit voltage and short-circuit current and therefore shall be measured without the EUT connected. In the case of an a.c. or d.c. powered product where the surge is applied to the a.c. or d.c. supply lines, the output waveforms shall be as specified in Tables 4, 5, and 6. In the case where the surge is applied directly from the generator output terminals, the waveforms shall be as specified in Table 2. It is not intended that the waveforms meet specifications both at the generator output and at the output of coupling/decoupling networks simultaneously, but only as applied to the EUT.

This generator is intended to generate a surge having:

- an open-circuit voltage front time of 1,2 μ s;
- an open-circuit voltage duration of 50 μ s;
- a short-circuit current front time of 8 μ s;
- a short-circuit current duration of 20 μ s.

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



Key

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

Figure 1 – Simplified circuit diagram of the combination wave generator

The ratio of peak open-circuit output voltage to peak short-circuit current at the same output port of a combination wave generator shall be considered as the effective output impedance. For this generator, the ratio defines an effective output impedance of 2 Ω .

When the generator output is connected to the EUT, the waveform of the voltage and current is a function of the EUT input impedance. This impedance may change during surges to equipment 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 μ s voltage and the 8/20 μ s current waves should be available from the same generator output as required by the load.

6.2.2 Performance characteristics of the generator

Polarity	positive and negative
Phase shifting	in a range between 0° to 360° relative to the phase angle of the a.c. line voltage to the EUT with a tolerance of $\pm 10^\circ$
Repetition rate	1 per minute or faster
Open-circuit peak output voltage	adjustable from 0,5 kV to the required test level
Waveform of the surge voltage	see Table 2 and Figure 2
Output voltage setting tolerance	see Table 3
Short-circuit peak output current	depends on peak voltage setting (see Tables 2 and 3)
Waveform of the surge current	see Table 2 and Figure 3

NOTE The time parameters are valid for the short-circuit current at the generator output without a 10 Ω resistor (see 6.3).

Short-circuit output current tolerance see Table 3

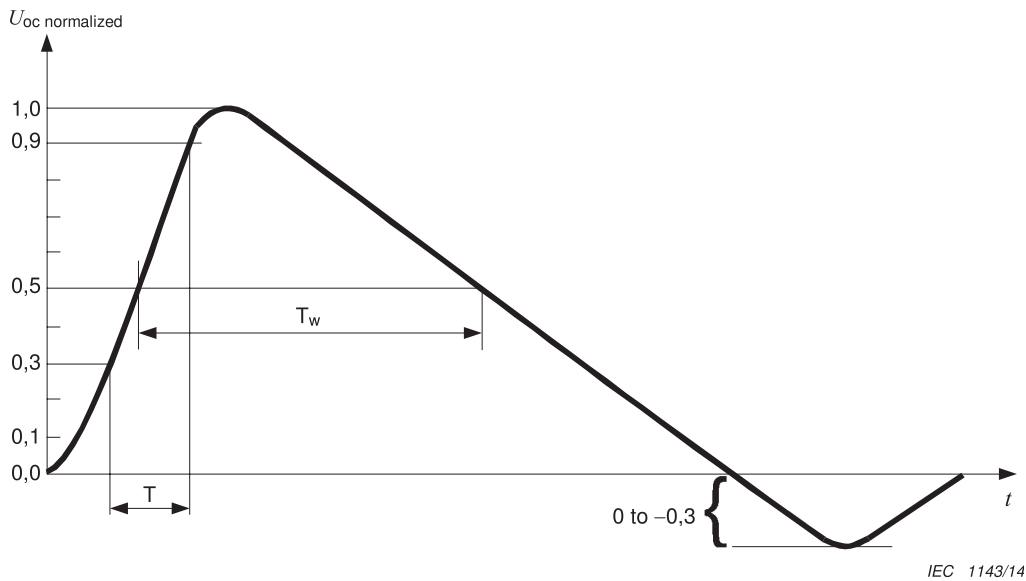
Table 2 – Definitions of the waveform parameters 1,2/50 μs and 8/20 μs

	Front time T_f μs	Duration T_d μs
Open-circuit voltage	$T_f = 1,67 \times T = 1,2 \pm 30 \%$	$T_d = T_w = 50 \pm 20 \%$
Short-circuit current	$T_f = 1,25 \times T_r = 8 \pm 20 \%$	$T_d = 1,18 \times T_w = 20 \pm 20 \%$

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

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

A generator with floating output shall be used.

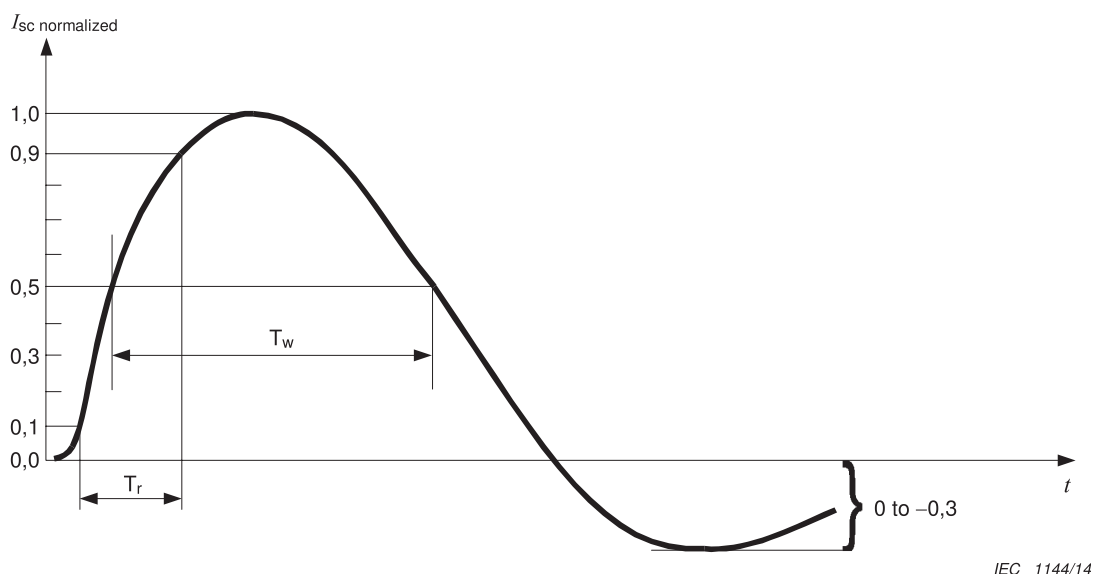


Front time: $T_f = 1,67 \times T = 1,2 \mu s \pm 30 \%$
Duration: $T_d = T_w = 50 \mu s \pm 20 \%$

NOTE The value 1,67 is the reciprocal of the difference between the 0,9 and 0,3 thresholds.

Figure 2 – Waveform of open-circuit voltage (1,2/50 μs) at the output of the generator with no CDN connected

The undershoot specification applies only at the generator output. At the output of the coupling/decoupling network there is no limitation on undershoot or overshoot.



Front time: $T_f = 1,25 \times T_r = 8 \mu\text{s} \pm 20 \%$
 Duration: $T_d = 1,18 \times T_w = 20 \mu\text{s} \pm 20 \%$

NOTE 1 The value 1,25 is the reciprocal of the difference between the 0,9 and 0,1 thresholds.

NOTE 2 The value 1,18 is derived from empirical data.

Figure 3 – Waveform of short-circuit current (8/20 μs) at the output of the generator with no CDN connected

The undershoot specification applies only at the generator output. At the output of the coupling/decoupling network there is no limitation on undershoot or overshoot.

6.2.3 Calibration of the generator

The test generator characteristics shall be calibrated in order to establish that they meet the requirements of this standard. For this purpose the following procedure shall be undertaken (see also Annex G).

The generator output shall be connected to a measuring system with a sufficient bandwidth, voltage and current capability to monitor the characteristics of the waveforms. Annex E provides information concerning the bandwidth of the surge waveforms.

If a current transformer (probe) is used to measure short-circuit current it should be selected so that saturation of the magnetic core does not take place. The lower (-3 dB) corner frequency of the probe should be less than 100 Hz.

The characteristics of the generator shall be measured through an external capacitor of 18 μF in series with the output, both under open-circuit (load greater than or equal to 10 k Ω) and short-circuit conditions at the same set voltage. If the 18 μF capacitor is implemented in the generator, no external 18 μF capacitor is required for calibration.

All performance characteristics stated in 6.2.2, with the exception of phase shifting, shall be met at the output of the generator. Phase shifting performance shall be met at the output of the CDN at 0°, 90°, 180° and 270° at one polarity.

NOTE When an additional internal or external resistor is added to the generator output to increase the effective source impedance from 2 Ω to e.g. 12 Ω or 42 Ω , according to the requirements of the test setup, the front time and the duration of test impulses at the output of the coupling network can be significantly changed.

6.3 Coupling/decoupling networks

6.3.1 General

Each coupling/decoupling network (CDN) consists of a coupling network and a decoupling network as shown in the examples of Figures 5 through 11.

NOTE The coupling resistors and/or capacitors can be part of the CDN or part of the generator or discrete external components.

On the a.c. or d.c. power lines, the decoupling network provides relatively high impedance to the surge waveform but at the same time, allows current to flow to the EUT. This impedance allows the voltage waveform to be developed at the output of the coupling/decoupling network and prevents the surge current from flowing back into the a.c. or d.c. power supply. High voltage capacitors are used as the coupling element, sized to allow the full waveform durations to be coupled to the EUT. The coupling/decoupling network for the a.c. or d.c. power supply shall be designed so that the open-circuit voltage waveform and short-circuit current waveform meet the requirements of Tables 4, 5 and 6.

For I/O and communication lines, the series impedance of the decoupling network limits the available bandwidth for data transmission. Coupling elements can be capacitors, in cases where the line tolerates the capacitive loading effects, clamping devices or arrestors. When coupling to interconnection lines, the waveforms may be distorted by the coupling mechanisms which are described in 6.3.3.

Each coupling/decoupling network shall satisfy the requirements of 6.3.2 and 6.3.3 and shall comply with the calibration requirements in 6.4. Their use is made according to the following flowchart:

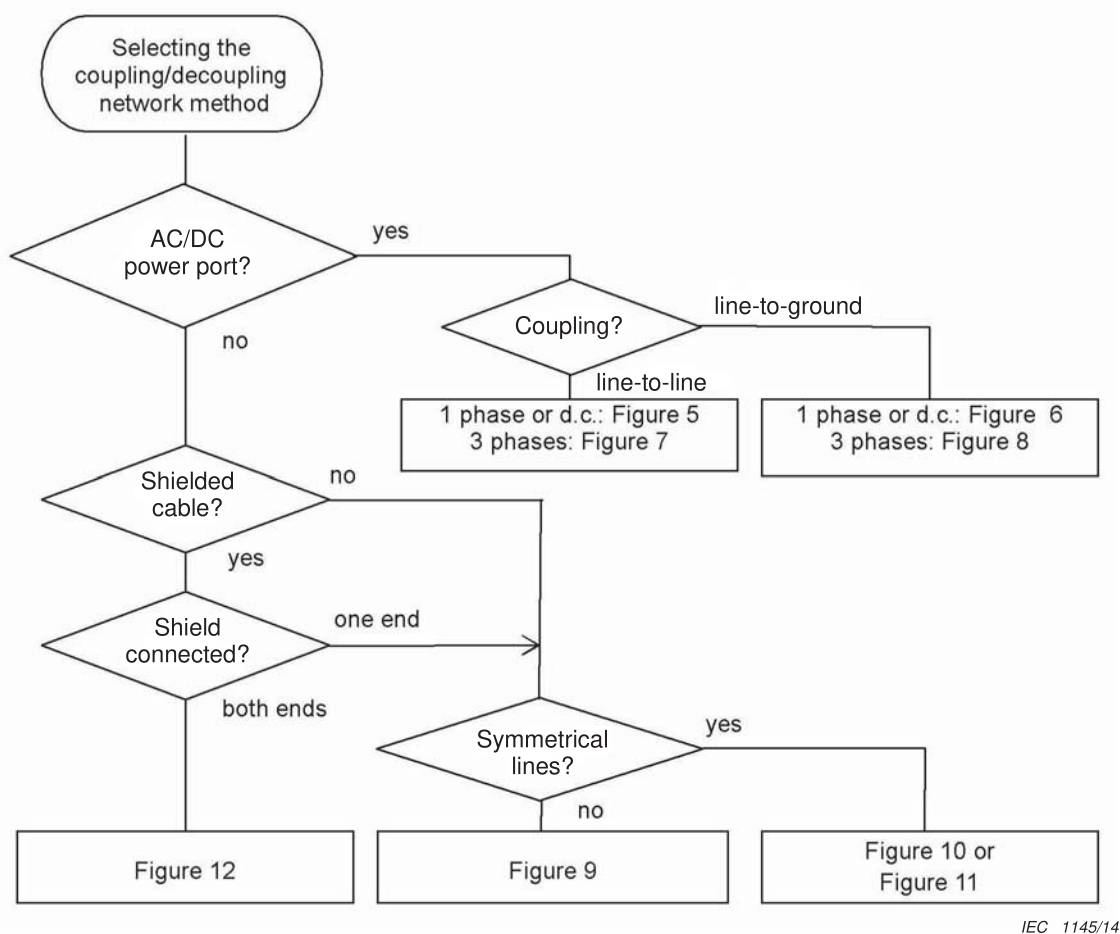


Figure 4 – Selection of coupling/decoupling method

6.3.2 Coupling/decoupling networks for a.c./d.c. power port rated up to 200 A per line

The peak amplitude, front time and duration shall be verified, for voltage under open-circuit conditions and for current under short-circuit conditions, at the EUT output port. The waveform parameters measured at the EUT port of the CDN are dependent upon the generator source and as such are only valid for the particular generator/CDN combination tested. The 30 % undershoot specification applies only at the generator output. At the output of the coupling/decoupling network there is no limitation on undershoot. The CDN shall be connected to a measuring system with a sufficient bandwidth, voltage and current capability to monitor the characteristics of the waveforms.

The decoupling inductance shall be selected by the CDN manufacturer so that the voltage drop across the CDN shall not exceed 10 % of the CDN input voltage at the specified current rating, but should not exceed 1,5 mH.

To prevent unwanted voltage drops in the CDN, the value of the decoupling element shall be reduced for CDNs rated at > 16 A. As a consequence, the peak voltage and the duration of the open-circuit voltage waveform which is measured with no load can vary within the tolerances given in Tables 4, 5 and 6 below. High current EUTs represent lower impedances and cause surges close to short-circuit conditions. Therefore, for high current CDNs it is the current waveform which is predominant. Large tolerances on the voltage definition are acceptable.

**Table 4 – Voltage waveform specification
at the EUT port of the CDN**

Surge voltage parameters under open-circuit conditions ^{a, b}	Coupling impedance	
	18 μ F (line-to-line)	9 μ F + 10 Ω (line-to-ground)
Peak voltage		
Current rating ≤ 16 A	Set voltage +10 %/-10 %	Set voltage +10 %/-10 %
16 A < current rating ≤ 32 A	Set voltage +10 %/-10 %	Set voltage +10 %/-10 %
32 A < current rating ≤ 63 A	Set voltage +10 %/-10 %	Set voltage +10 %/-15 %
63 A < current rating ≤ 125 A	Set voltage +10 %/-10 %	Set voltage +10 %/- 20 %
125 A < current rating ≤ 200 A	Set voltage +10 %/-10 %	Set voltage +10 %/- 25 %
Front time	1,2 μ s $\pm$ 30 %	1,2 μ s $\pm$ 30 %
Duration		
Current rating ≤ 16 A	50 μ s +10 μ s/-10 μ s	50 μ s +10 μ s/-25 μ s
16 A < current rating ≤ 32 A	50 μ s +10 μ s/-15 μ s	50 μ s +10 μ s/-30 μ s
32 A < current rating ≤ 63 A	50 μ s +10 μ s/-20 μ s	50 μ s +10 μ s/-35 μ s
63 A < current rating ≤ 125 A	50 μ s +10 μ s/-25 μ s	50 μ s +10 μ s/-40 μ s
125 A < current rating ≤ 200 A	50 μ s +10 μ s/-30 μ s	50 μ s +10 μ s/-45 μ s
NOTE The current rating in Table 4 is the CDN rating.		
^a The measurement of the surge voltage parameters shall be performed with the a.c./d.c. power port of the CDN open-circuit. ^b The values shown in this table are for a CWG with ideal values. In case the CWG generates parameter values close to the tolerances, the additional tolerances of the CDN may generate values out of tolerances for the CWG-CDN combination.		

**Table 5 – Current waveform specification at the EUT port
of the CDN**

Surge current parameters under short-circuit conditions ^a	Coupling impedance	
	18 μ F (line-to-line)	9 μ F + 10 Ω (line-to-ground) ^b
Front time	$T_f = 1,25 \times T_r = 8 \mu\text{s} \pm 20 \%$	$T_f = 1,25 \times T_r = 2,5 \mu\text{s} \pm 30 \%$
Duration	$T_d = 1,18 \times T_w = 20 \mu\text{s} \pm 20 \%$	$T_d = 1,04 \times T_w = 25 \mu\text{s} \pm 30 \%$
^a The measurement of the surge current parameters shall be performed with the a.c./d.c. power port of the CDN open-circuit. ^b The value 1,04 is derived from empirical data.		

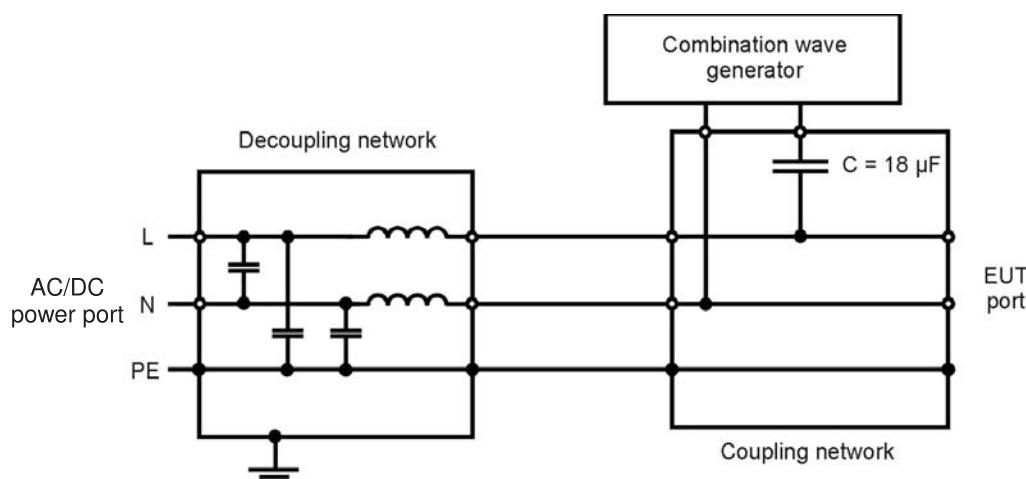
Table 6 – Relationship between peak open-circuit voltage and peak short-circuit current at the EUT port of the CDN

Open-circuit peak voltage $\pm 10\%$ at EUT port of the CDN	Short-circuit peak current $\pm 10\%$ at EUT port of the CDN ($18\ \mu\text{F}$)	Short-circuit peak current $\pm 10\%$ at EUT port of the CDN ($9\ \mu\text{F} + 10\ \Omega$)
0,5 kV	0,25 kA	41,7 A
1,0 kV	0,5 kA	83,3 A
2,0 kV	1,0 kA	166,7 A
4,0 kV	2,0 kA	333,3 A

Refer to Annex H for EUTs having a rated input current above 200 A per line.

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



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Figure 5 – Example of coupling network and decoupling network for capacitive coupling on a.c./d.c. lines line-to-line coupling

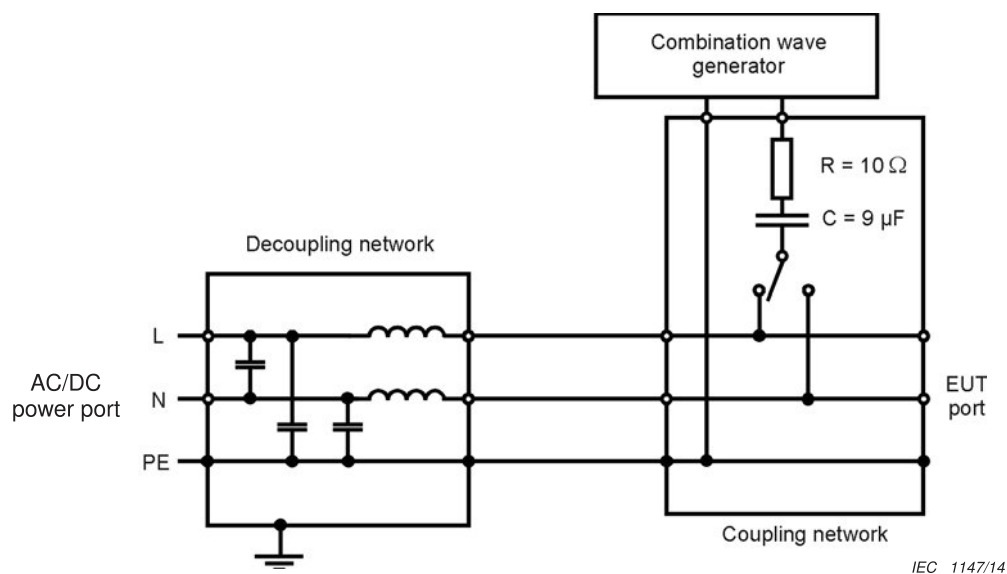
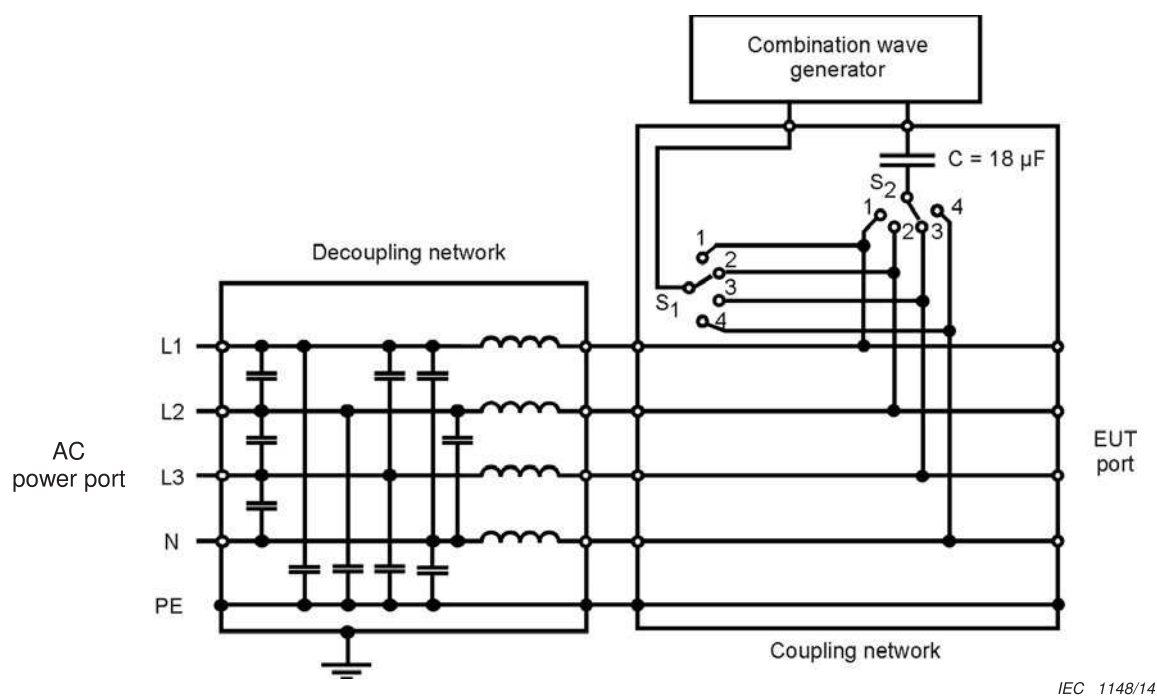


Figure 6 – Example of coupling network and decoupling network for capacitive coupling on a.c./d.c. lines: line-to-ground coupling



Switches S_1 and S_2 are used to select individual lines for test.

During testing, the position of switch S_2 is different from the position of switch S_1 .

Figure 7 – Example of coupling network and decoupling network for capacitive coupling on a.c. lines (3 phases): line L2-to-line L3 coupling