

Novità sulla IEC 61000-4-18

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11.06.2018

THE WORLD'S SPEED IS OUR BEAT

Content

Recently revised standards

IEC 61000-4-9	Ed. 2.0 2016-07	Impulse magnetic field
IEC 61000-4-10	Ed. 2.0 2016-07	Damped oscillatory magnetic field immunity test
IEC 61000-4-12	Ed. 3.0 2017-07	Ring Wave immunity tests
IEC 61000-4-18	Ed. 2.0 CDV 2018	Damped oscillatory wave immunity test

IEC 61000-4-18 Damped oscillatory wave Ed. 1.1 2011-03, (Ed.02 CDV 2018)



77B/xxx/CDV

COMMITTEE DRAFT FOR VOTING (CDV)

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DATE OF CIRCULATION: 2018-04-06	CLOSING DATE FOR COMMENTS: 2018-06-29
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IEC SC 77B : HIGH FREQUENCY PHENOMENA	
SECRETARIAT: France	SECRETARY: Mr Franck Gruffaz
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: <input type="checkbox"/> Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: <input checked="" type="checkbox"/> EMC <input type="checkbox"/> ENVIRONMENT <input type="checkbox"/> QUALITY ASSURANCE <input type="checkbox"/> SAFETY	

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Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE:
Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test



IEC 61000-4-18

Edition 1.1 : 2011-03

INTERNATIONAL STANDARD NORME INTERNATIONALE



BASIC EMC PUBLICATION
PUBLICATION FONDAMENTALE EN CEM

Electromagnetic compatibility (EMC) –
Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test

Compatibilité électromagnétique (CEM) –
Partie 4-18: Techniques d'essai et de mesure – Essai d'immunité à l'onde oscillatoire amortie

Phenomenon

The damped oscillatory waves are separated into two groups.

- **Slow oscillatory waves SDOW** with oscillations between 100 kHz and 1 MHz
- **Fast oscillating waves FDOW** with oscillations above 1 MHz

The **Slow Damped Oscillatory Wave** simulates the following specific phenomena:

Switching operations of isolators in free-field installations in **high and medium voltage distribution substations** and represents disturbances as they occur in busbars. The opening and closing of HS disconnectors generates transients, with rise times in the order of several tens of nanoseconds.

Due to reflections, oscillations occur in sub-stations in the free field, depending on the length of the conductor bars (several dozen meters to a few hundred meters). The oscillation frequency of 1MHz is recognized as representative, but can also be at 100kHz for large high-voltage systems.

The repetition frequency ranges from a few hertz to a few kHz, with the standard specifying repetition rates of 40/s and 400/s.

In **industrial plants**, oscillating transients can be caused by switching processes in the power grid and by transients from electrical devices.



Phenomenon

The “*Fast Damped Oscillatory Wave*” simulates the following two specific phenomena:

- **substations of the power network (produced by switchgear and control gear).**

For air insulated substations (AIS) these transients will radiate an electromagnetic field in the substation environment with frequencies higher than 1 MHz.

For gas insulated substations (GIS), these transients propagate inside the metallic enclosure, which contains the SF6 gas. Transient current is transferred to the external surface of the enclosure tube at any enclosure discontinuity. As a consequence, the enclosure potential rises and the current flowing on the enclosure surface radiates an electromagnetic field in the substation environment.

Measurements have shown that the maximum frequency can be as high as 30 MHz to 50 MHz

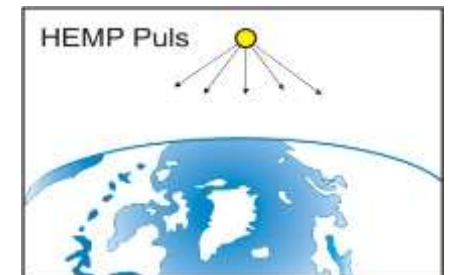
The repetition of these vibration packets at 5000/s was selected to depict the measured events.



SF6 Schaltstation EBM

- **all installations exposed to the high-altitude electromagnetic pulse (HEMP).**

These pulses are described in IEC 61000-2-9 and occur during atmospheric nuclear explosions, where pulses with rise times of 2.5 ns and 25 ns duration can occur. The high frequency field, up to 100 MHz, couples into exposed wires that become antennas. This results in oscillating voltages and currents in the connected devices.



Phenomenon

The formula of the ideal waveform of Figure 1, $w(t)$ (open circuit voltage), is as follows

$$w(t) = A \cdot K \cdot \frac{\left(\frac{t}{t_1}\right)^n}{1 + \left(\frac{t}{t_1}\right)^n} \cdot \exp\left(-\frac{t}{t_2}\right) \cdot \cos(2\pi f \cdot t + \phi)$$

Waveform	A	K	n	t_1	f	t_2	ϕ
Fast 30 MHz	$Pk1$	1,19	1,67	2,26 ns	30 MHz	126 ns	$-\pi/2$
Fast10 MHz	$Pk1$	1,04	2,65	1,69 ns	3 MHz	377 ns	$-\pi/4$
Fast 3 MHz	$Pk1$	1,07	2,3	2,89 ns	3 MHz	1,26 μs	0
Slow 1 MHz	$Pk1$	1,12	2,45	49,8 ns	1 MHz	3,77 μs	$-\pi/4$
Slow 100 KHz	$Pk1$	1,04	1,96	32,7 ns	100 kHz	37,7 μs	0

Table 1 – Values of the parameters of $w(t)$ for each standard oscillation frequency

Test Levels

The recommended ranges of test levels are shown in Tables 2 and 3.

**Table 2 – Test levels for the slow damped oscillatory wave
(100 kHz or 1 MHz)**

Level	Open circuit test voltage	
	Line to line kV	Line to ground kV
1	0,25	0,5
2	0,5	1
3	1	2 ^a
4 ^b	---	---
X ^c	Special	Special

- a The value is increased to 2,5 kV for substation equipment. .
- b This level is not applicable for slow damped oscillatory wave.
- c “X” can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification.

Table 3 – Test levels for the fast damped oscillatory wave (3, 10 und 30 MHz)

Level	Open circuit test voltage
	Line to ground
1	0,5
2	1
3	2
4	4
X ^a	Special

- a “X” can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification.

Amendment of terms:

Differential Mode → **Line to line**
 Common Mode → **Line to ground**

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

Impulsform Slow Damped

Specifications **open circuit voltage** :

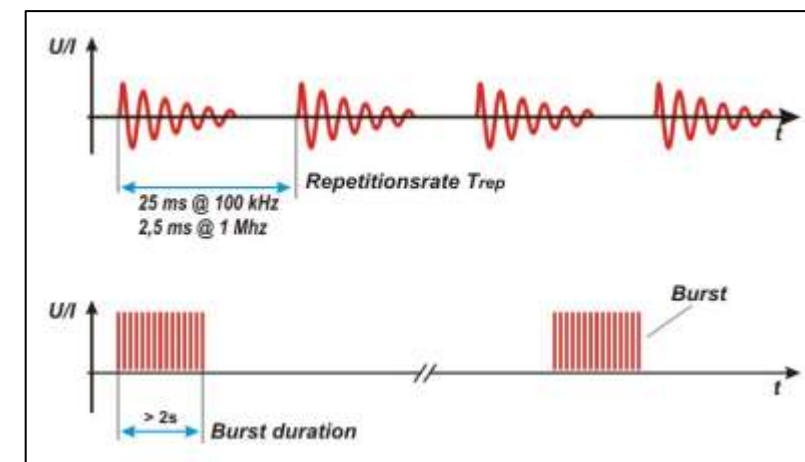
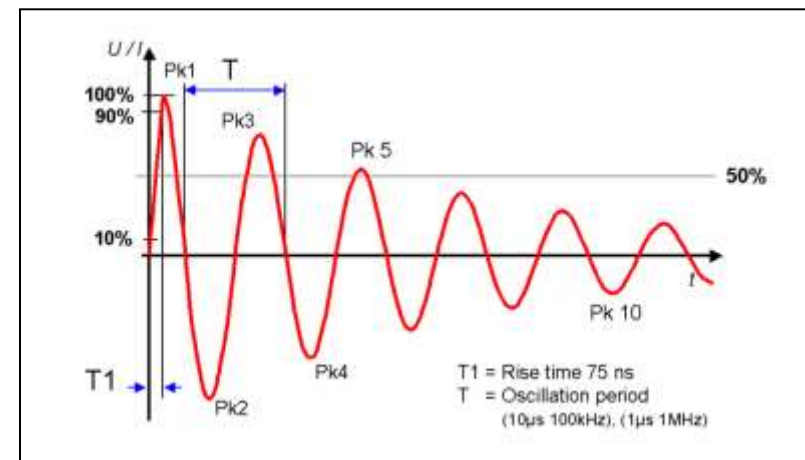
- Open circuit voltage CDN: Pk1 value, 250 V to 2.5 kV $\pm 10\%$
- Open circuit voltage direct: Pk1 value, 250 V to 3.0 kV $\pm 10\%$
- Voltage rise time T1 : 75 ns $\pm 20\%$
- Oscillation frequencies U: **100 kHz** and **1 MHz** $\pm 10\%$
- Repetition rate:

100kHz:	20/s – 50/s
1 MHz:	400/s
- Decaying:

Pk5 > 50 % of Pk1
Pk10 < 50 % of Pk1
- Burst duration: 0.1 to 99.9s (Norm ≥ 2 s)
- Burst period: 0s – 99.9s (0=const. burst)
- Output impedance: **200 Ω** $\pm 20\%$
- polarity of the 1st half-period: positive and negative

Specifications **short circuit current**:

- Short-circuit current Pk1 CDN : 1.25 A to 12.5 A $\pm 20\%$
- Short-circuit current Pk1 direct: 1.25 A to 15 A $\pm 20\%$



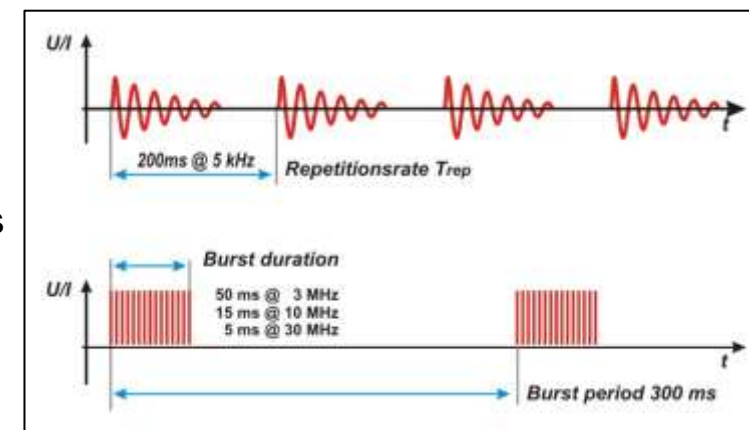
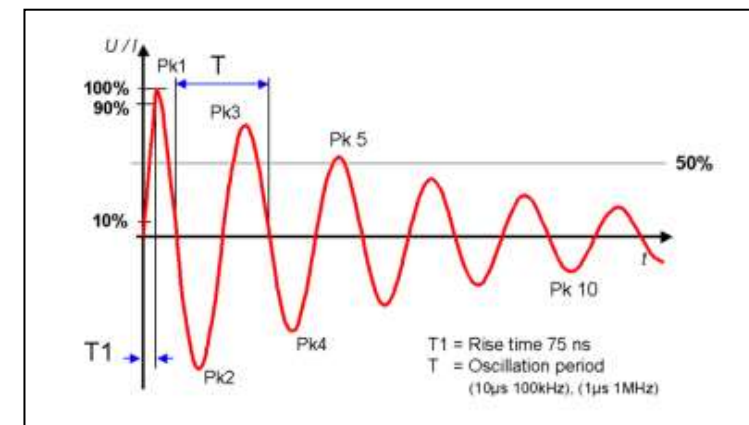
Impulsform Fast Damped

Specifications **open circuit voltage** :

- open circuit voltage: Pk1 value, **500 V** to 4.04 kV $\pm 10\%$
- Voltage rise time T1 : 5 ns $\pm 30\%$;
- Oscillation frequencies V: **3 MHz**, **10 MHz** and **30 MHz** $\pm 10\%$
- Repetition rate: 1 to 5000/s $\pm 10\%$
- Decaying: Pk5 > 50 % of Pk1
Pk10 < 50 % from Pk1
- Burst duration: 3 MHz: 1- 50 ms $\pm 20\%$
10 MHz: 1 - 15 ms $\pm 20\%$
30 MHz: 1- 5 ms $\pm 20\%$
- Burst period: 0.3-99.9s $\pm 20\%$ (Norm 300ms)
- Output impedance: **50 Ω** $\pm 20\%$;
- polarity of the 1st half-period: positive and negative

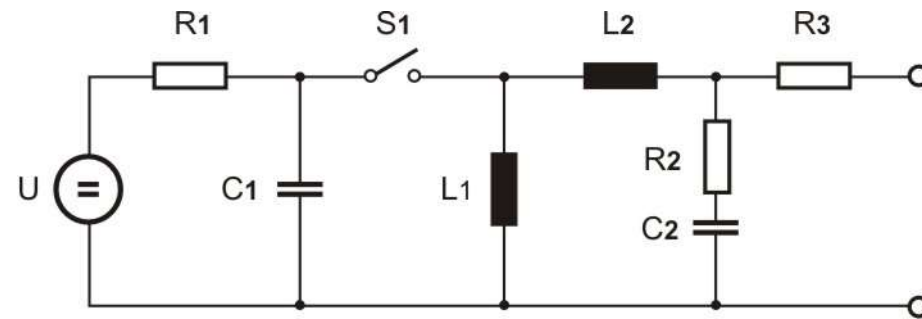
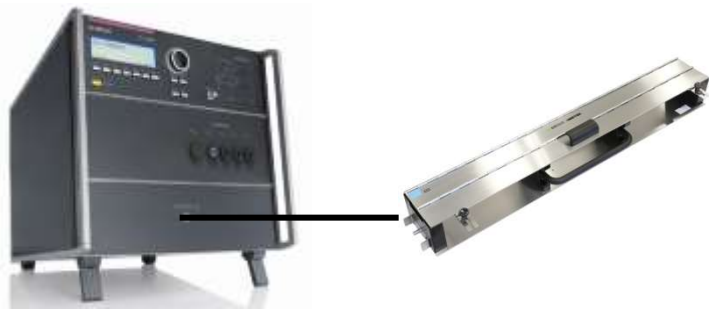
Specifications **short circuit current**:

- Current rise time T1: 3 MHz: < 330 ns, 10 MHz: < 100 ns, 30 MHz: < 33 ns
- Oscillation frequencies I: 3 MHz, 10 MHz and 30 MHz $\pm 30\%$;
- Current decaying: Pk5 > 25 % from Pk1
Pk10 < 25 % from Pk1
- Short-circuit current Pk1: 9 A to 88 A $\pm 20\%$



Generator

The generator output shall have the capability to operate under short-circuit conditions. The block diagram below shows the general design of the two generators.



Damped oscillating generator

The test generator generates a damped oscillating wave with the following characteristics:

- potential-free generator output with an asymmetry between the terminals and earth < 10 %. two outputs
- Common Mode output for both generators, coaxial for the fast damped generator
- Differential Mode (only 100 kHz, 1 MHz) to be connected to the mains, signal and control connections of the EUT.
- A decoupling network protects the auxiliary devices from the test pulse.

Generator characteristic

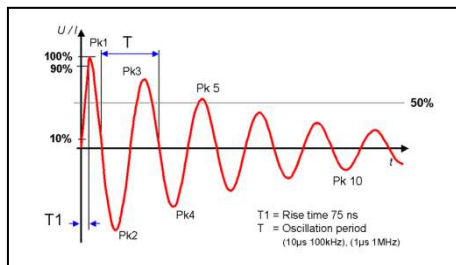
The waveform characteristics shall be verified directly at the output of the test generator.

Slow damped

- voltage rise time;
- oscillation frequency;
- repetition rate;
- decaying;
- burst duration;
- open-circuit voltage $UPk1$ ($Z_{oc} \geq 10 \text{ k}\Omega$);
- short circuit current $IPk1$ ($Z_{sc} \leq 0,1 \text{ }\Omega$);

Measuring instruments:

Oscilloscope: min. 40 MHz Bandwidth



Open circuit voltage measurement at the HV-COM output of the generator.

A differential high voltage probe is strongly recommended for waveform and amplitude measurement!

Calibration is also performed at the outputs of the coupling network.



Short circuit current, with current probe
Example: at the HV output of the generator

Calibration is also performed at the outputs of the coupling network.



Generator characteristic

The waveform characteristics shall be verified directly at the output of the test generator.

Fast damped

- rise time (voltage/current);
- oscillation frequency; (voltage/current)
- repetition rate;
- voltage waveform decaying (voltage/current);
- burst duration;
- open-circuit voltage UP_{k1} ($Z_{oc} = 1 \text{ k}\Omega \pm 2 \%$);
- current rise time IP_{k1} ($Z_{sc} = 0,10 \text{ }\Omega \pm 2 \%$)
- current oscillation frequencies;
- current waveform decaying

Measuring instruments:

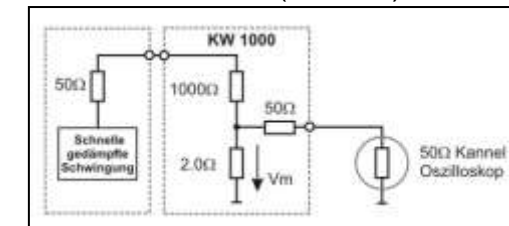
Oscilloscope: min. 400 MHz bandwidth

Current transformer: 3-dB, Bandwidth 400 MHz



Open circuit voltage

With coaxial load ($1000 \text{ }\Omega$)

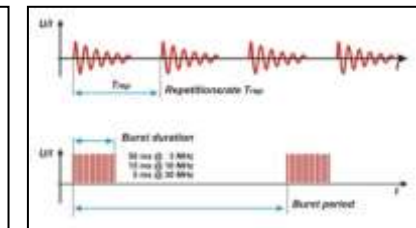
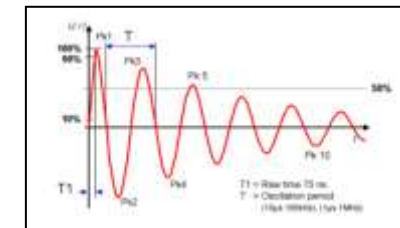


Abschwächung 1000:1

Short circuit current

With coaxial load ($0,1 \text{ }\Omega$)

The calibration is performed at the coaxial output and at each separate output of the switching network to earth.



Generator

Coupling network for AC/DC supply lines

The coupling/decoupling network is suitable for coupling the pulses (ring wave or damped oscillations) to AC/DC supply lines.

Coupling capacity

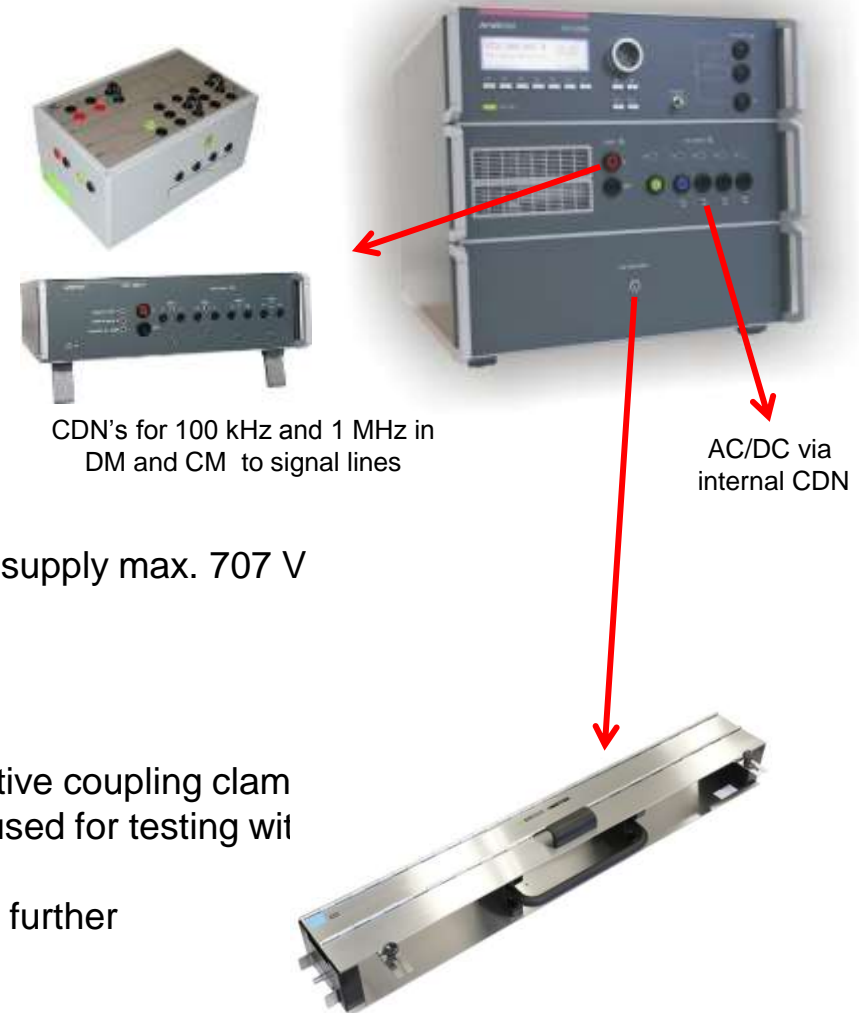
- slow-damped oscillation: **0,5 μ F**
 - fast oscillation: **33 nF**
- Damping by the coupling capacitance is <10%

Residual voltage at the input of the EUT power supply:

The residual voltage of the damped oscillation at the input of the EUT power supply max. 707 V

Coupling network for signal and data lines :

CDN's for 100 kHz and 1 MHz, as well as for 3, 10 and 30 MHz is the capacitive coupling clam CCI which is also used for burst testing according to IEC 61000-4-4, is also used for testing with Fast Damped Oscillatory Wave. Anmerkung:
The decoupling with the CCI to the AE port may not be sufficient, in this case further decoupling devices are necessary.



Coupling networks for slow-damped oscillations waves

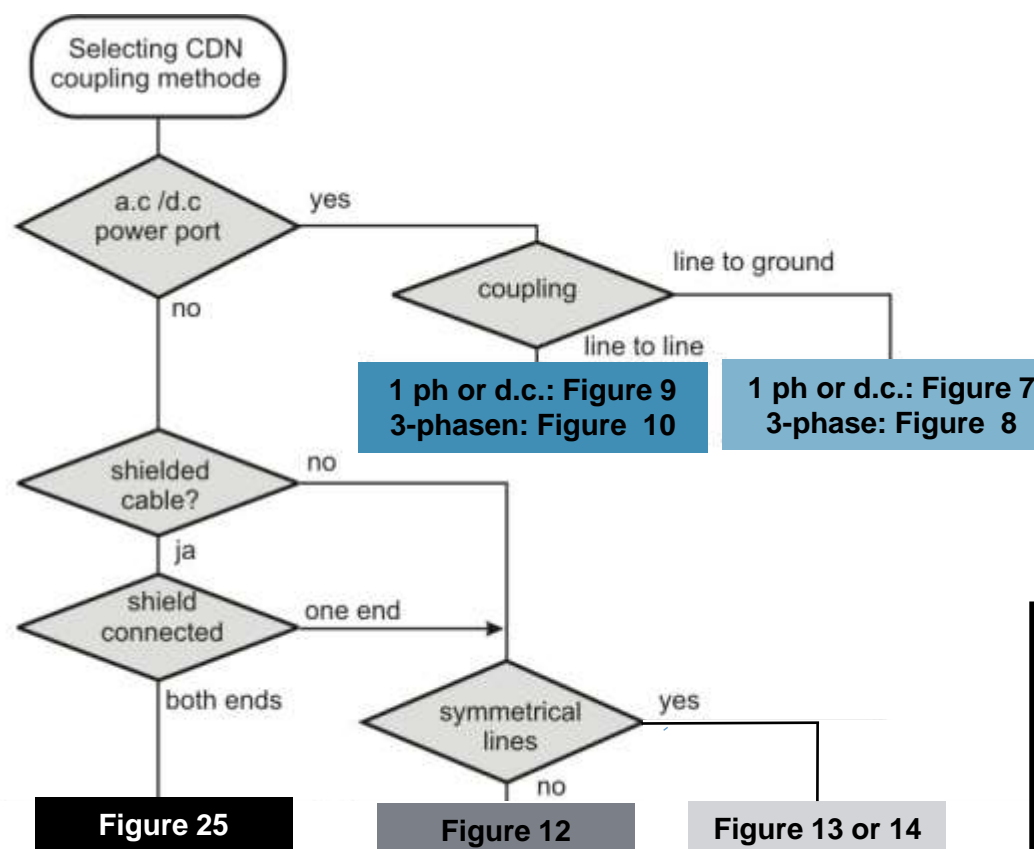


Figure 9

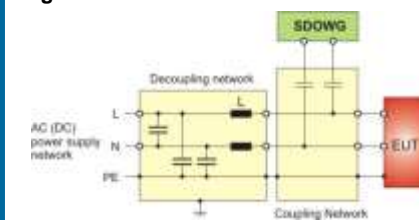


Figure 10

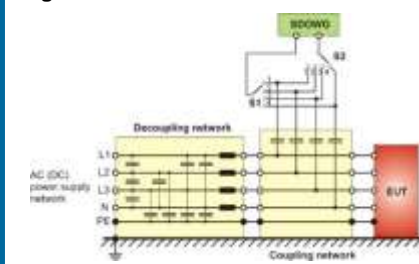


Figure 7

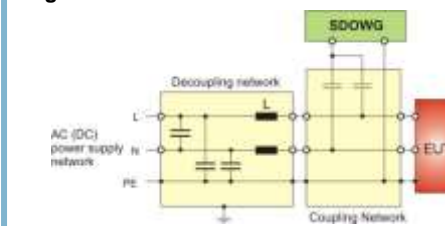


Figure 8

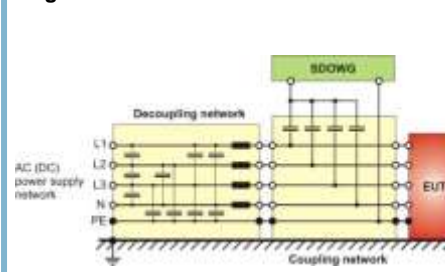


Figure 25

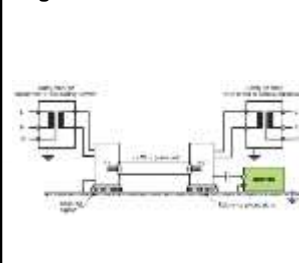


Figure 12

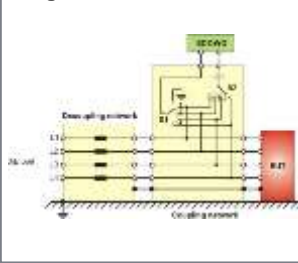
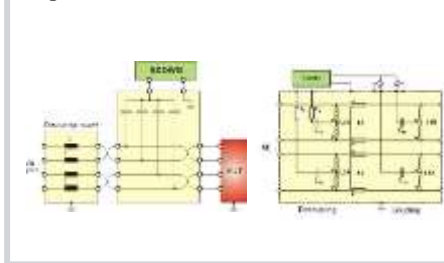


Figure 13 or 14



Coupling networks for fast damped oscillations

Various types of CDNs are used in combination with the SDOWG and the FDOWG to apply fast damped oscillations.

The following methods apply:

For a.c. /d.c. Power connections, as shown in Fig. 15 and Fig. 16;

For signal lines according to Fig. 17.

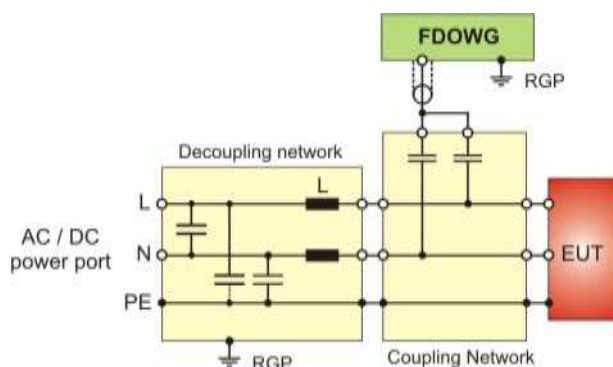


Fig. 15: CDN for a.c. /d.c. 1-ph supply

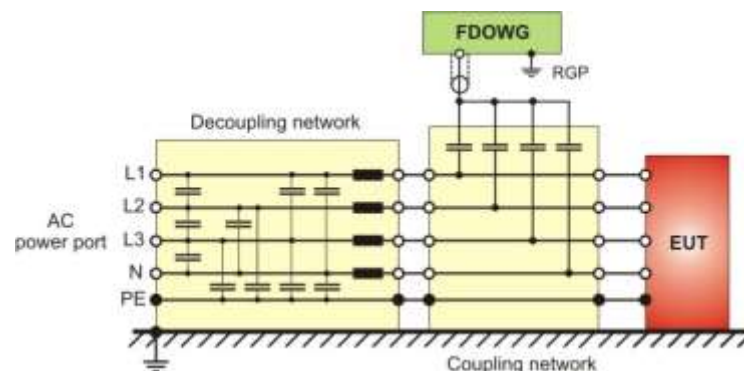


Fig. 16: CDN for a.c. 3-Ph

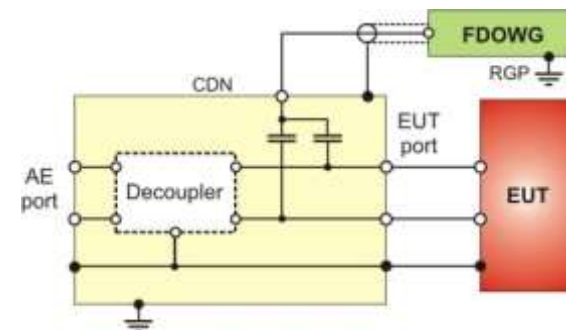


Fig. 17: CDN for Interconnection-lines.

For some applications the 33 nF coupling capacitors have to be replaced by other coupling types.

Devices, such as arresters or terminal circuits.

The decoupling part of the CDN is designed with inductors >100 μ H

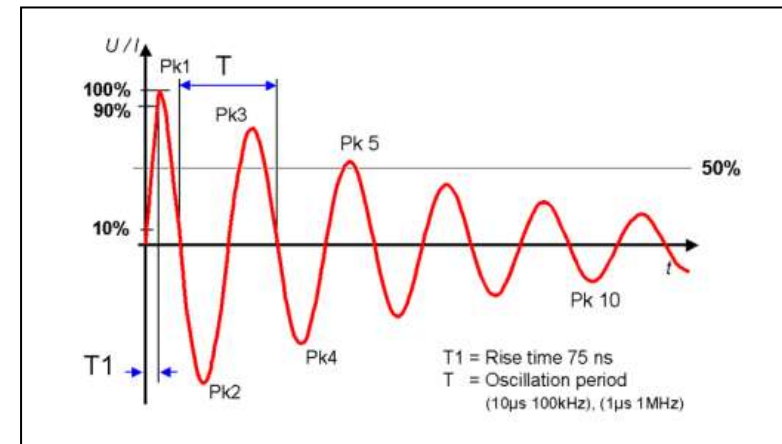
Verification of CDN's

The measuring equipment used for the calibration of the CDN shall satisfy the same requirements applicable to the calibration of the generator.

The calibrations are to perform port for port in **open circuit** and **short circuit** for $Pk1$ at the EUT- output of CDN ($\geq 10 \text{ k}\Omega$) .

- Both polarities must be calibrated.
- The open-circuit voltage $UPk1$, rise time and decay shall be measured under open circuit voltage conditions.
- Under short-circuit conditions, ($< 0,2 \text{ }\Omega$), the current $IPk1$ shall be measured.
- The residual damped oscillatory voltage measured between applied **lines and ground** on the a.c./d.c. input power port of the CDN with EUT and mains supply not connected shall not exceed 15 % of the maximum applied test voltage or twice the rated peak voltage of the CDN, whichever is higher.

The standard defines for all CDN the couplings and the values to be measured and their tolerances.



Verification of CDN's

Table 4 – Damped oscillatory waveform specifications at the EUT port of CDN's for slow damped oscillatory waves

Selection of CDN	Voltage oscillation frequencies ± 10 %	SDOWG Output voltage	UPk1 at CDN EUT port ± 10 %	Voltage rise time T1 ± 20 %	Voltage decaying UPk5	Voltage decaying UPk10	IPk1 at CDN EUT port ± 20 %
CDN (Figure 7, Figure 8) Common mode	100 kHz 1 MHz	0,5 kV 1,0 kV 2,0 kV ^a	0,5 kV 1,0 kV 2,0 kV ^a	75 ns	> 50 % of U _{pk1}	< 50 % of U _{pk1}	2,5 A 5 A 10 A ^a
CDN (Figure 9, Figure 10) Differential mode	100 kHz 1 MHz	0,5 kV 1,0 kV 2,0 kV ^a	0,5 kV 1,0 kV 2,0 kV ^a	75 ns	> 50 % of U _{pk1}	< 50 % of U _{pk1}	2,5 A 5 A 10 A ^a
CDN (Figure 11) Common mode	100 kHz 1 MHz	0,5 kV 1,0 kV 2,0 kV ^a	0,5 kV 1,0 kV 2,0 kV ^a	75 ns	> 50 % of U _{pk1}	< 50 % of U _{pk1}	2,5 A 5 A 10 A ^a
CDN (Figure 12) Differential mode	100 kHz 1 MHz	0,5 kV 1,0 kV 2,0 kV ^a	0,5 kV 1,0 kV 2,0 kV ^a	75 ns	> 50 % of U _{pk1}	< 50 % of U _{pk1}	2,5 A 5 A 10 A ^a
CDN (Figure 13, Figure 14) Common mode	100 kHz 1 MHz	0,5 kV 1,0 kV 2,0 kV ^a	0,5 kV 1,0 kV 2,0 kV ^a	75 ns	> 50 % of U _{pk1}	< 50 % of U _{pk1}	2,5 A 5 A 10 A ^a

NOTE The waveforms at the CDN output ports shall comply with the same tolerances than at the generator output port.
^a The value is increased to 2,5 kV / 12,5 A for substation equipment.

Table 5 – Damped oscillatory waveform specifications at the EUT port of CDN's for fast damped oscillatory waves

Selection of CDN	FDOWG Output voltage	IPk1 at CDN EUT port ± 20 %	Current oscillation frequencies ± 30 %	Current rise time T1	Current decaying I _{pk5}	Current decaying I _{pk10}
CDN (Figure 18, Figure 19) common mode	0,5 kV	10 A	3 MHz 10 MHz 30 MHz	< 330 ns < 100 ns < 33 ns	> 25 % of I _{pk1}	< 25 % of I _{pk1}
	1,0 kV	20 A				
	2,0 kV	40 A				
	4,0 kV	80 A				

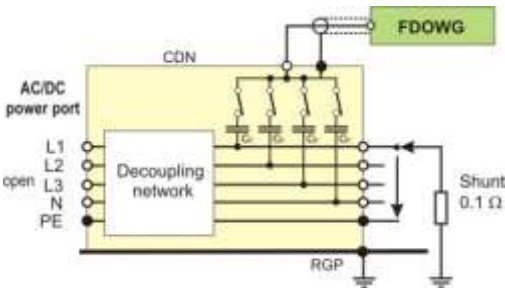


Figure 18 – Example of a calibration setup of CDNs for a.c./d.c. power ports

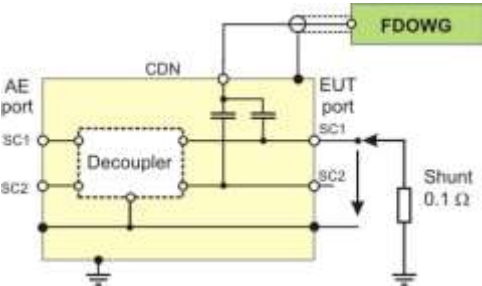


Figure 19 – Example of a calibration setup of CDNs for interconnection lines

Calibration of the capacitive coupling clamp

The calibration of the capacitive coupling clamp is done in the same way as for the burst according to IEC 61000-4-4 with the same transducer plate. Instead of the burst pulse, a fast damped oscillation is coupled to the coupling clamp.

Calibration is performed with the output voltage FDOWG set to **2 kV**.

The FDOWG is connected to the input of the coupling pliers. The **peak voltage** and **waveform parameters** are measured at the output of the clamp, which is on the opposite side.

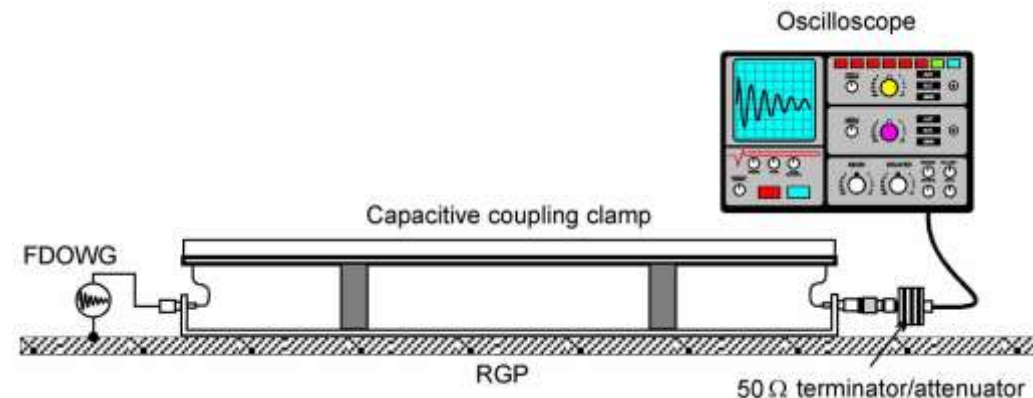
The waveform characteristics shall meet the following requirements:

Peak voltage: **1 000 V** ± 200 V

Oscillation frequencies: **3 MHz** $\pm 0,6$ MHz,

10 MHz ± 2 MHz,

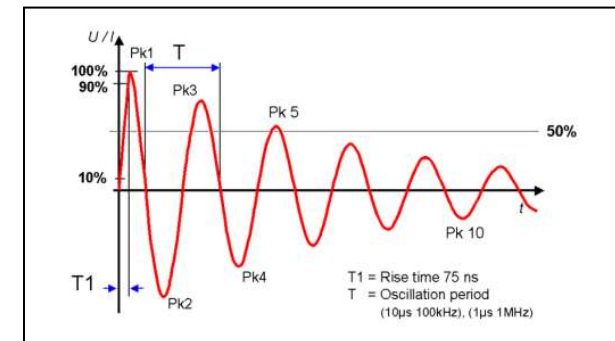
30 MHz ± 6 MHz.



Execution of the test

The test procedure includes:

- verification of the test equipment;;
 - pulse generator (SDOWG or FDOWG); CDN; capacitive coupling clamp; connection cable; measuring instruments;
 - to verify: Damped oscillation at the **CDN output** and at the **capacitive coupling clamp**
 - Check at each level without EUT. An internal laboratory **reference value** is permitted.
- the definition of **laboratory reference conditions**; with regard to climatic conditions
- confirmation that the **EUT is operating correctly**;
- the execution of the test according to the test plan;
 - Test level
 - Coupling method (CDN / coupling pliers)
 - type of **application** (line to earth, line to line, between the enclosures) ;
 - Sequence of application of the test voltage to the connections
 - Control of the **EUT operating behavior**
 - the test generators to be used for each test (SDOWG or FDOWG);
- the **evaluation** of the test results (see clause 9). .



7.3 Test setup

Device

Floor standing device
Table-top (wall/ ceiling)

Positioning

Floor
Table or floor

Isolation von GRP

(0,1 ± 0,05) m
(0,1 ± 0,01) m

Remark

when using GRP

Was

Generator & CDN

Distance EUT other metallic structure
Distance EUT – CDN table -top
Distance EUT – CDN floor standing

Remark

must be grounded
≥ 0.5 m

0.5 m -0/+0.1 m unless otherwise specified
1.0 m ± 0,1 m unless otherwise specified

The cables must be as short as possible, longer cables must be insulated and bundled at 0.1 m.

All cables to EUT
Cables not to be tested
Mains cable
Connection cables < 3 m

0.1 m isolated to GND
separated with max. distance to the cables to be tested
< 2 m, detachable power cables 1 m if not specified, fixed cables with actual length
Connecting cables not to be tested must be installed at 0.1 m insulated; Distance 0.5 m

Reference GND

Copper or aluminum ≥ 0.25 mm thickness, other metals 0.65 mm
Size min. 1.0 m (0.8 m) x 1.0 m should protrude the EUT at least 0.1 m

Connected to building ground

Examples test setup

NEW Ed.2

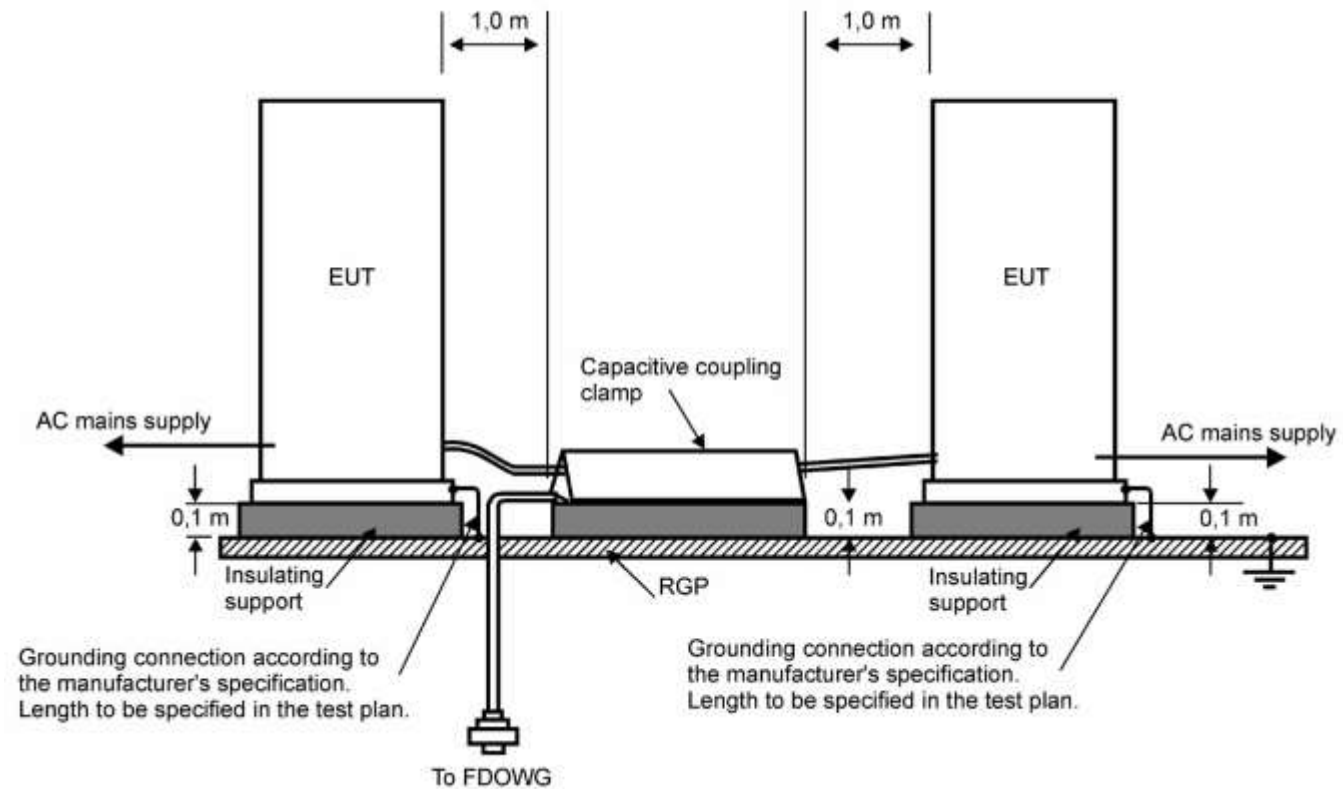


Figure 26 – Example of test setup using a floor standing system of two EUTs

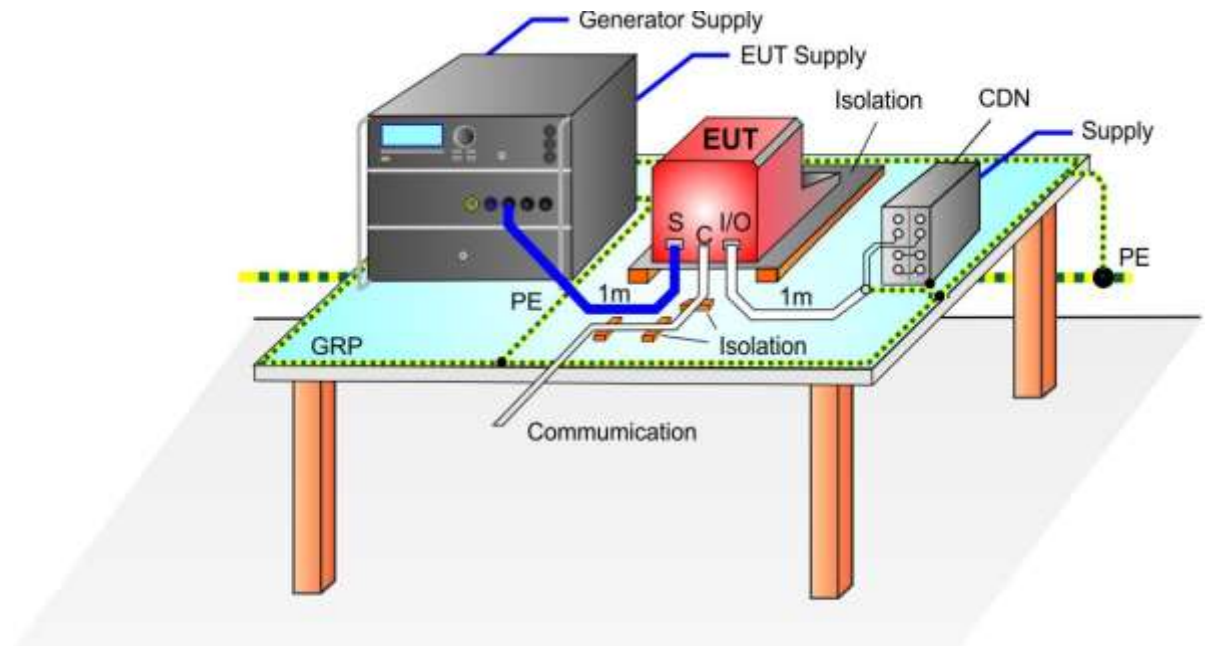
Carrying out the test

For safety reasons, the test setup must be grounded correctly. When using additional devices, the immunity of these devices must be ensured.

On shielded cables that are only earthed at one end, the unearthed side of the shield must be connected to the housing with a 0.5 μ F capacitor.

Test setup for table-top units

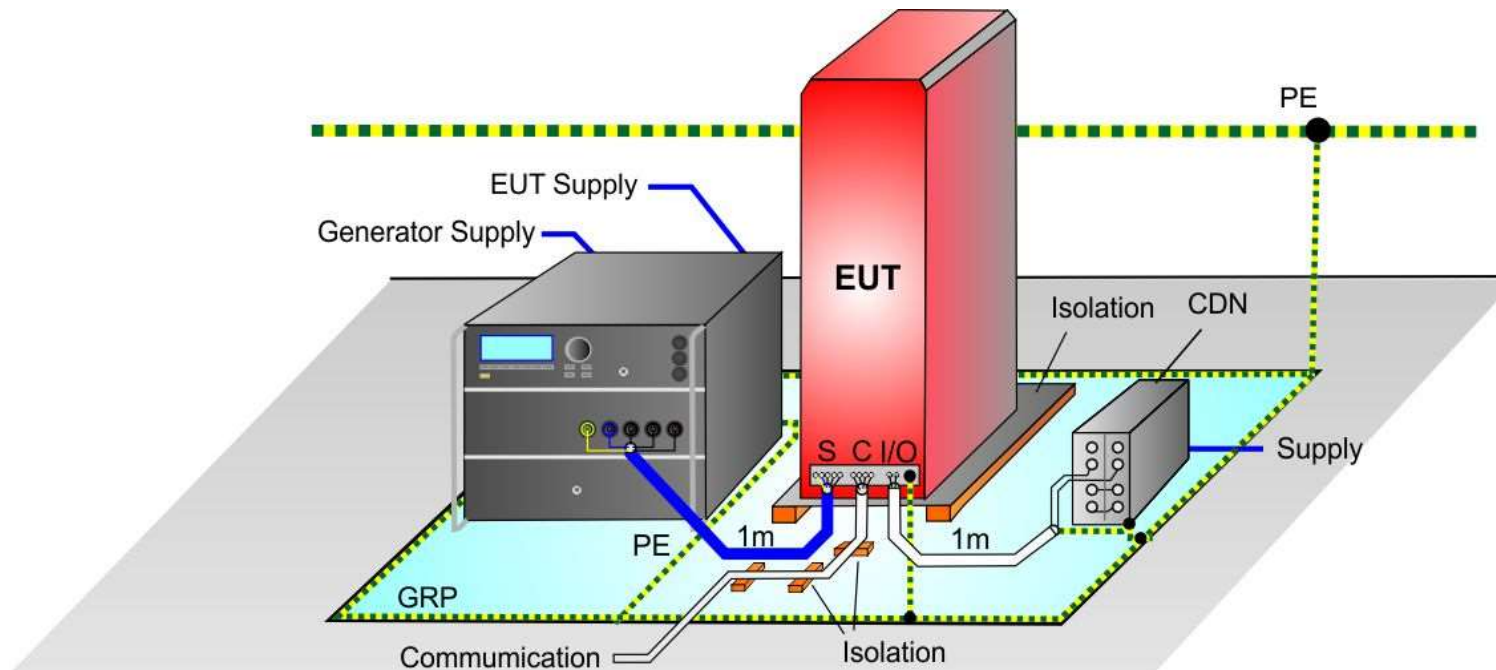
- Distance from EUT to metallic structures **>0.5 m**
- EUT isolated installed at **0.1 m \pm 1 cm**
- Distance from coupling network to EUT 1m
- I/O lines to AE ports must be decoupled using decoupling networks.
- Use the cables defined by the manufacturer or unshielded cables.
- Communication cables to the EUT must be routed at a distance of 0.1 m from the reference ground plate.



Example test setup IEC 61000-4-18 Ed 1

Carrying out the test

When using a reference ground plane, the EUT shall be placed on an insulation of **0.1 m ± 1 cm**.
The EUT must be earthed according to the manufacturer's instructions.
The housing must be connected to the reference ground plate as briefly as possible.



Measurement uncertainty MU (ANNEX B)

NEW Ed.2

Table B.1 – Example of uncertainty budget for the rise time of the open circuit voltage of the 3 MHz damped oscillatory wave ($T1$)

Symbol	Estimate	Unit	Error bound	Unit	PDF*	Divisor	$u(x_i)$	c_i	Unit	$u_i(y)$	Unit
$T10\%$	0,85	ns	0,100 0	ns	triangular	2,45	0,040 82	-1,015 03	1	0,041 44	ns
$T90\%$	6,1	ns	0,100 0	ns	triangular	2,45	0,040 82	1,015 03	1	0,041 44	ns
δR	0	ns	0,15	ns	normal (k=1)	1,00	0,150 00	1,015 03	1	0,152 25	ns
α	360	ns · MHz	40	ns · MHz	rectangular	1,73	23,094 01	-0,000 44	1/MHz	0,010 05	ns
B	400	MHz	30	MHz	rectangular	1,73	17,320 51	0,000 39	ns/MHz	0,006 78	ns
$uc(y) = \sqrt{\sum u_i(y)^2}$										0.16359	ns
$U(y) = 2 uc(y)$										0.33	ns
y										5.17	ns

Table B.2 – Example of uncertainty budget for the peak of the open circuit voltage of the 3 MHz damped oscillatory wave ($Pk1$)

Symbol	Estimate	Unit	Error bound	Unit	PDF*	Divisor	$u(x_i)$	c_i	Unit	$u_i(y)$	Unit
VPR	0,97	V	0,001 9	V	triangular	2,45	0,000 77	1000,11	1	0,773 52	V
A	1000	1	50	1	rectangular	1,73	28,867 51	0,970 11	V	28,004 58	V
δR	0	1	0,03	1	normal (k=1)	1,00	0,030 00	970,107	V	29,103 21	V
δV	0	1	0,02	1	rectangular	1,73	0,011 55	970,107	V	11,201 83	V
β	4,2	MHz	0,5	MHz	rectangular	1,73	0,288 68	0,050 94	V/MHz	0,014 70	V
B	400	MHz	30	MHz	rectangular	1,73	17,320 51	-0,000 53	V/MHz	0,009 26	V
$uc(y) = \sqrt{\sum u_i(y)^2}$										0,0419 2	kV
$U(y) = 2 uc(y)$										0,08	kV
Estimate y										0,97	kV

Thank you for your attention!