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IEC 61000-4-4 AND IEC 61000-4-5 NEWS, TESTING ON HV LINES

DIPL.-ING. FRANK NIECHCIAL

HIGH VOLTAGE / HIGH CURRENT APPLICATIONS

THE AUTHOR

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IEC 61000-4-4

IMMUNITY TEST PROCEDURE

FOR BROADBAND INTERFERENCES

(BURST)

LATEST/IMPORTANT CHANGES IN ED. 3

CHANGES IN IEC 61000-4-4

- **IEC 61000-4-4:2012 (Ed. 3)**

- New version introduces calibration of capacitive coupling clamp. Procedure as well as impulse parameters are specified.

- Changes regarding calibration values at output of the coupling network:
  - Rise time (tr): 5,5 ns ± 1,5 ns
  - Pulse duration (td): 45 ns ± 15 ns

- Distance between DUT and coupling device, both coupling network and/or coupling clamp are:
  - Devices mounted on table: 0,5 m (-0/+0,1 m)
  - Floor Standing devices: 1,0 m (+/-0,1 m)

- Test setup for rack mounted equipment.

TEST SEVERITY LEVEL

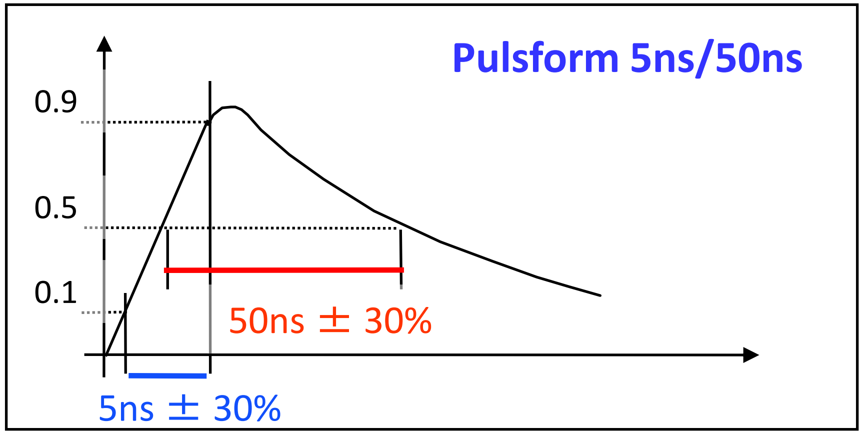
- **New repetition frequency of burst pulses introduced**

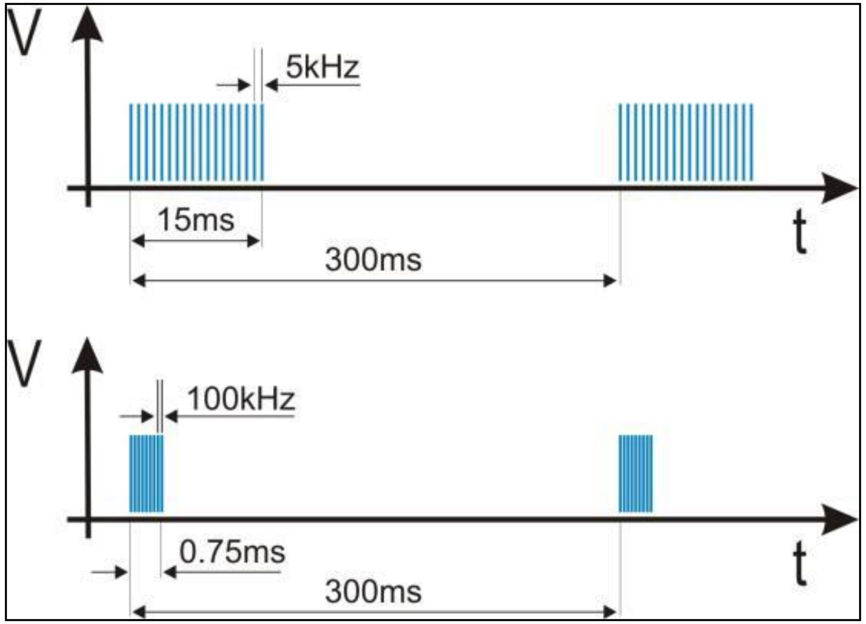
Open circuit test voltage			
Level	Power line	I/O line	
	Peak voltage in kV		Repetition rate in kHz
1	0,5	0,25	5 or **100**
2	1	0,5	5 or **100**
3	2	1	5 or **100**
4	4	2	**5 or 100**
X (1)	special	special	

- The 100 kHz are merely a guideline, that could be adjusted by product committees to a more relevant variable for their product lines or products.

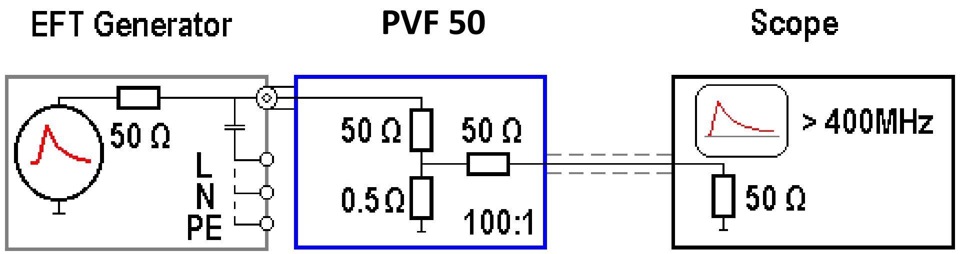
PARAMETER

- **Single pulse**
- Rise time tr = 5 ns
  Pulse duration td = 50 ns
- **Pulse package**
- Repetition time Tr = 300 ms
  As formerly:
  Duration burst package Td = 15 ms
  at spike frequency f = 5 kHz
- Newly added:
  Duration burst package Td = 0,75 ms
  at spike frequency f = 100 kHz





CALIBRATION 50 OHM OUTPUT WITH 50 OHM LOAD



MEASURING EXAMPLE USING THE PVF 50

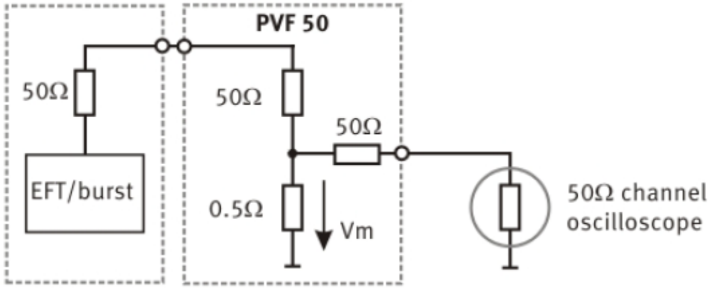
Open circuit voltage setting at the EFT/burst generator (50 ohm output): 2,000 V

Resulting output voltage across the 50 ohm matching resistor: 1,000 V.

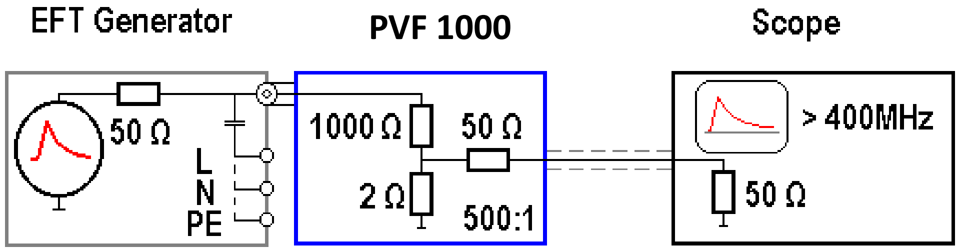
Measuring voltage Vm: 10 V

Measured voltage considering the 50 ohm input impedance of the oscilloscope: 5 V

Resulting attenuation (theoretical): 400:1



CALIBRATION 50 OHM OUTPUT WITH 1000 OHM LOAD



MEASURING EXAMPLE USING THE PVF 1000

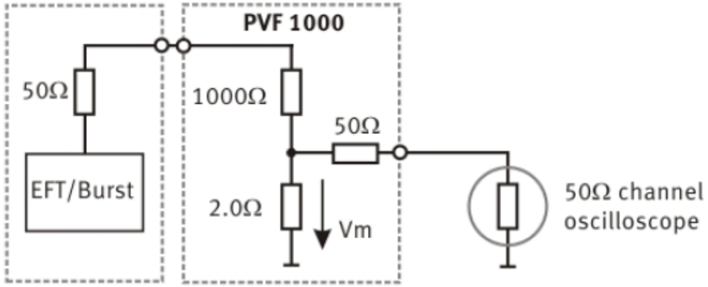
Open circuit voltage setting at the EFT generator (50ohm output): 2,000 V

Resulting output voltage across the 1,000 ohm matching resistor: 1,905 V

Measuring voltage Vm: 4 V

Measured voltage considering the 50 ohm input impedance of the oscilloscope: 2 V

Resulting attenuation (theoretical): 1,000:1



CALIBRATION OF CDN

- **Coupling/decoupling network for mains supply connectors**

  The pulse shape has to be proved at each output/path of coupling-/decoupling network

  - Therefore, all coupling paths are set simultaneously (Common Mode)
  - The output of the coupling network is terminated with a coaxial load of 50 Ohm

- The calibration must be provided with a voltage setting of 4kV as follows:

	since EN 61000-4-4:2004	**New:** EN 61000-4-4:2012
Rise time **tr**	5 ns ± 30%	5,5 ns ± 1,5 ns
Pulse duration **td**	50 ns ± 30%	45 ns ± 15 ns
peak value of voltage	± 10 % of the voltage according to table	

CALIBRATION AT CDN OUTPUT

- **Procedure since Amendment A1 of IEC 61000-4-4 ed.2, 01/2010**

- The calibration is performed with the generator output at a set voltage of 4 kV. Each individual output of the CDN (normally connected to the EUT) is terminated in sequence with a 50 Ω load while the other outputs are open. The peak voltage and waveform are recorded for each polarity.

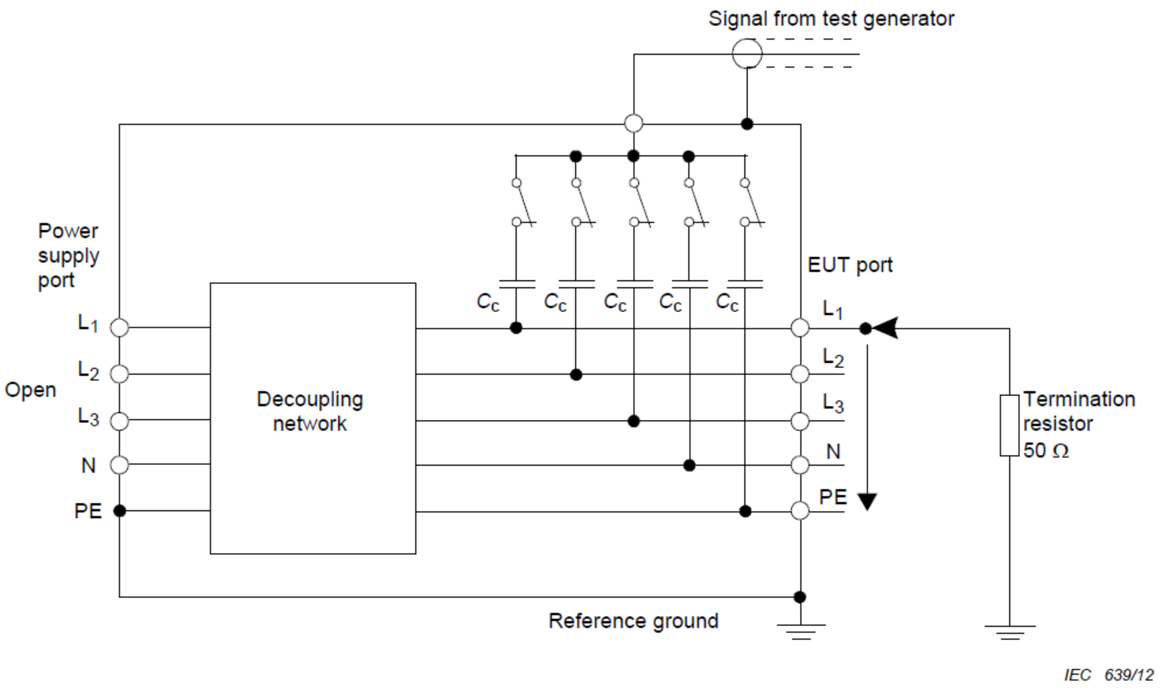
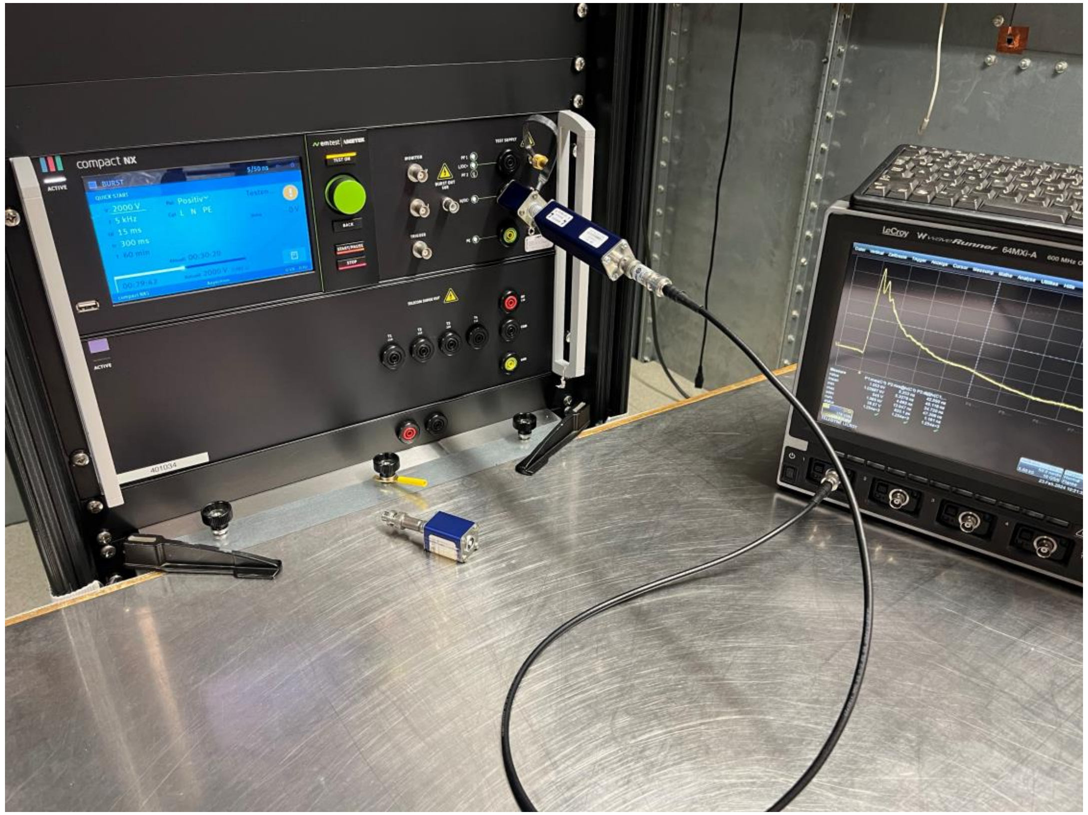
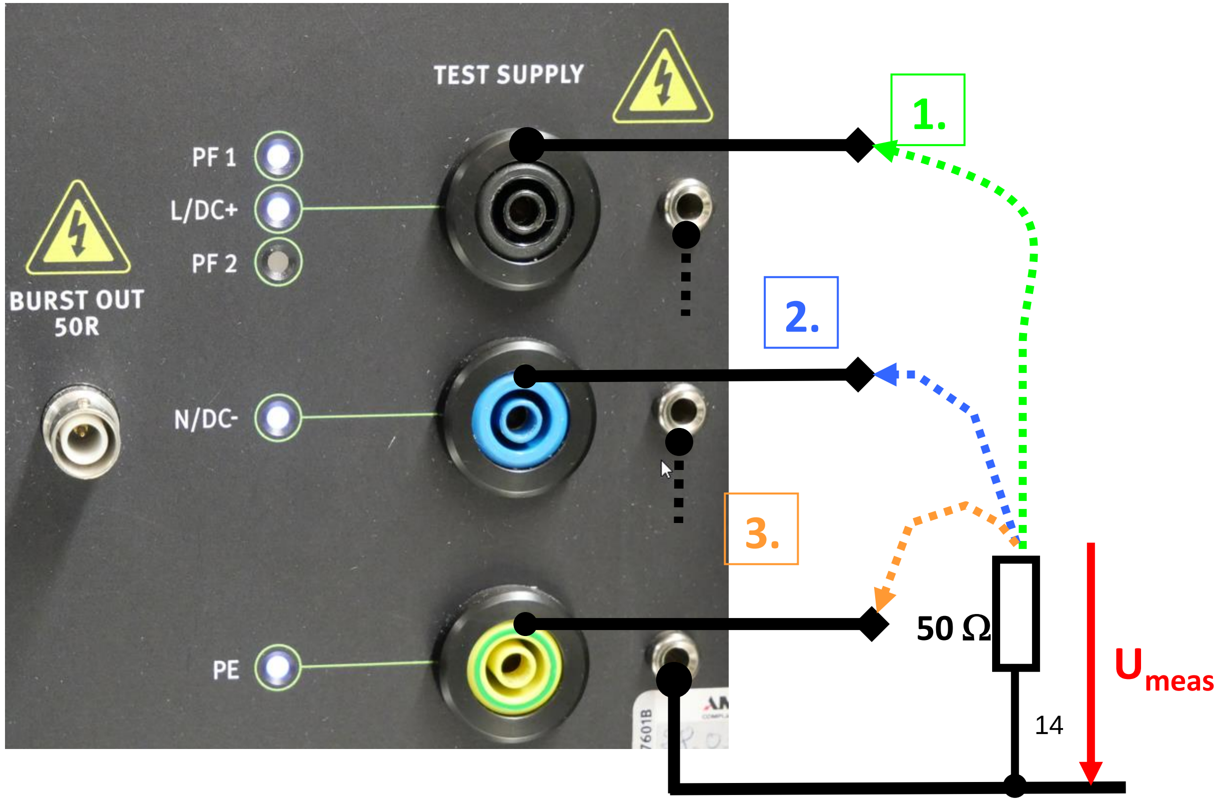


Figure 5 – Calibration of the waveform at the output of the coupling/decoupling network



CALIBRATION AT CDN OUTPUT WITH 50 OHM

- - The EFT transients are coupled to all lines of the CDN simultaneously (CM).
  - The output of the CDN shall not be short circuited.
  - The EFT transients shall be measured at each individual output of the CDN with 50 Ohm load, while the other outputs are open.
  - Each individual output must show the transients within the tolerances as specified.



1.

2.

3.

CALIBRATION OF COUPLING CLAMP

- The transducer plate consists in a metallic sheet of 120 mm x 1050 mm of max 0.5 mm thickness, isolated on top and bottom by a dielectric foil of 0.5 mm. Isolation for 2.5 kV on all sides must be guaranteed in order to avoid the clamp to contact the transducer plate.
- The transducer plate is to be inserted into the coupling clamp and must be terminated at the opposite end of the generator connection with a coaxial load of 50 Ω.
- The calibration is performed with the generator output voltage set to 2 kV. The calibration have to meet the following requirements:

Rise time **tr**	5ns ± 1,5ns
Pulse duration **td**	50ns ± 15ns
peak value of voltage	1kV ± 200V

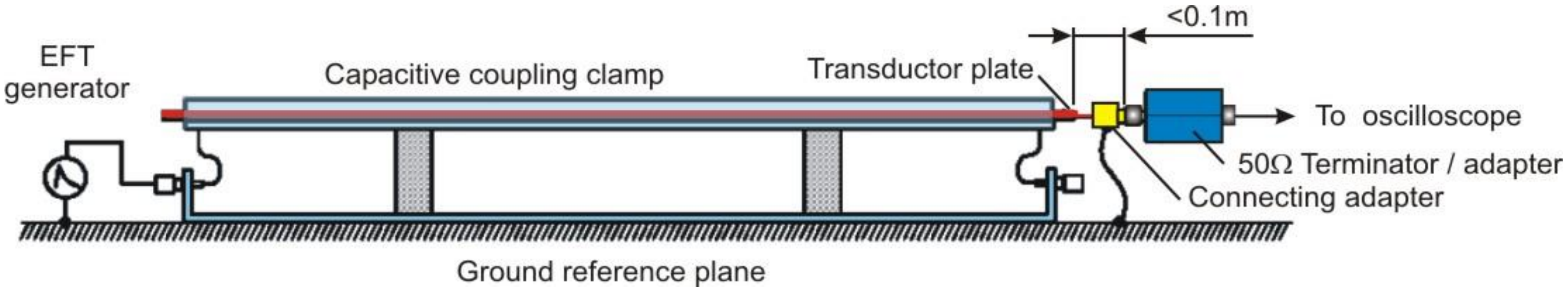
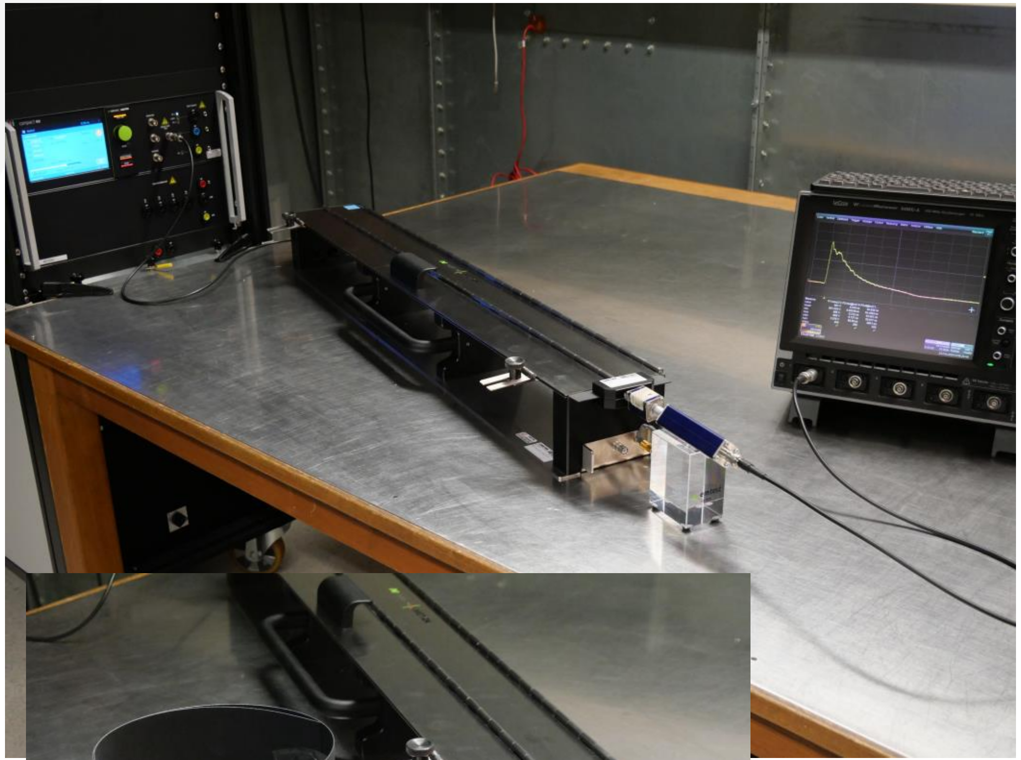
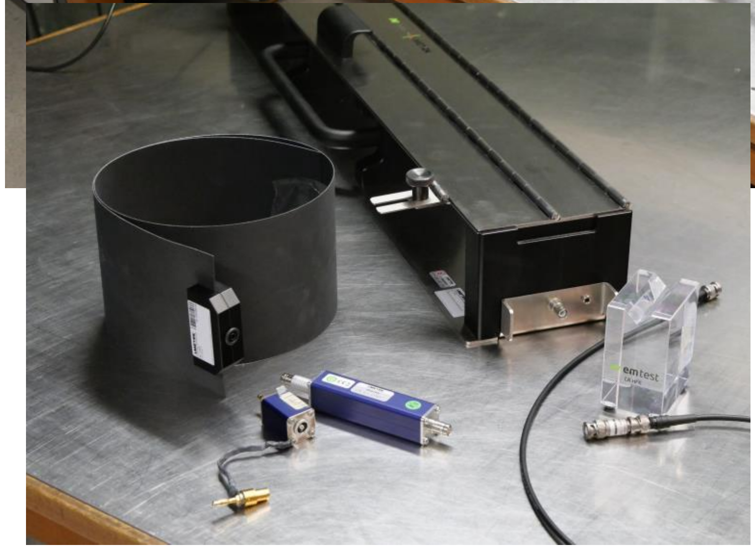


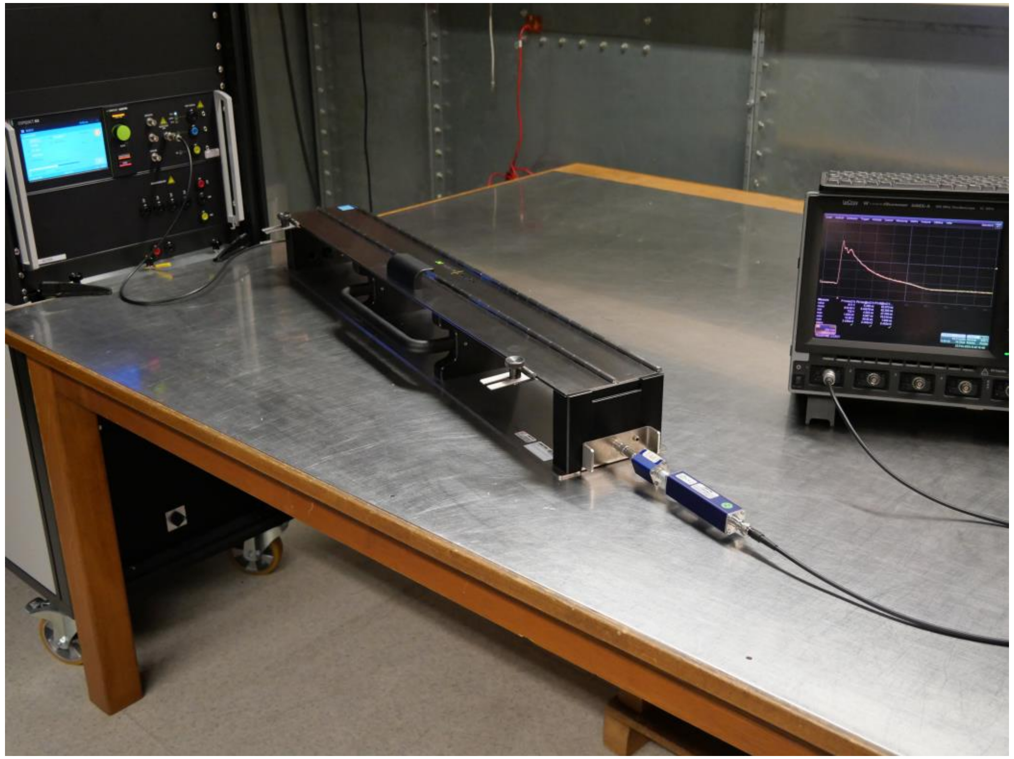
Figure 8 – Calibration of a capacitive coupling clamp using the transducer plate

CALIBRATION OF COUPLING CLAMP



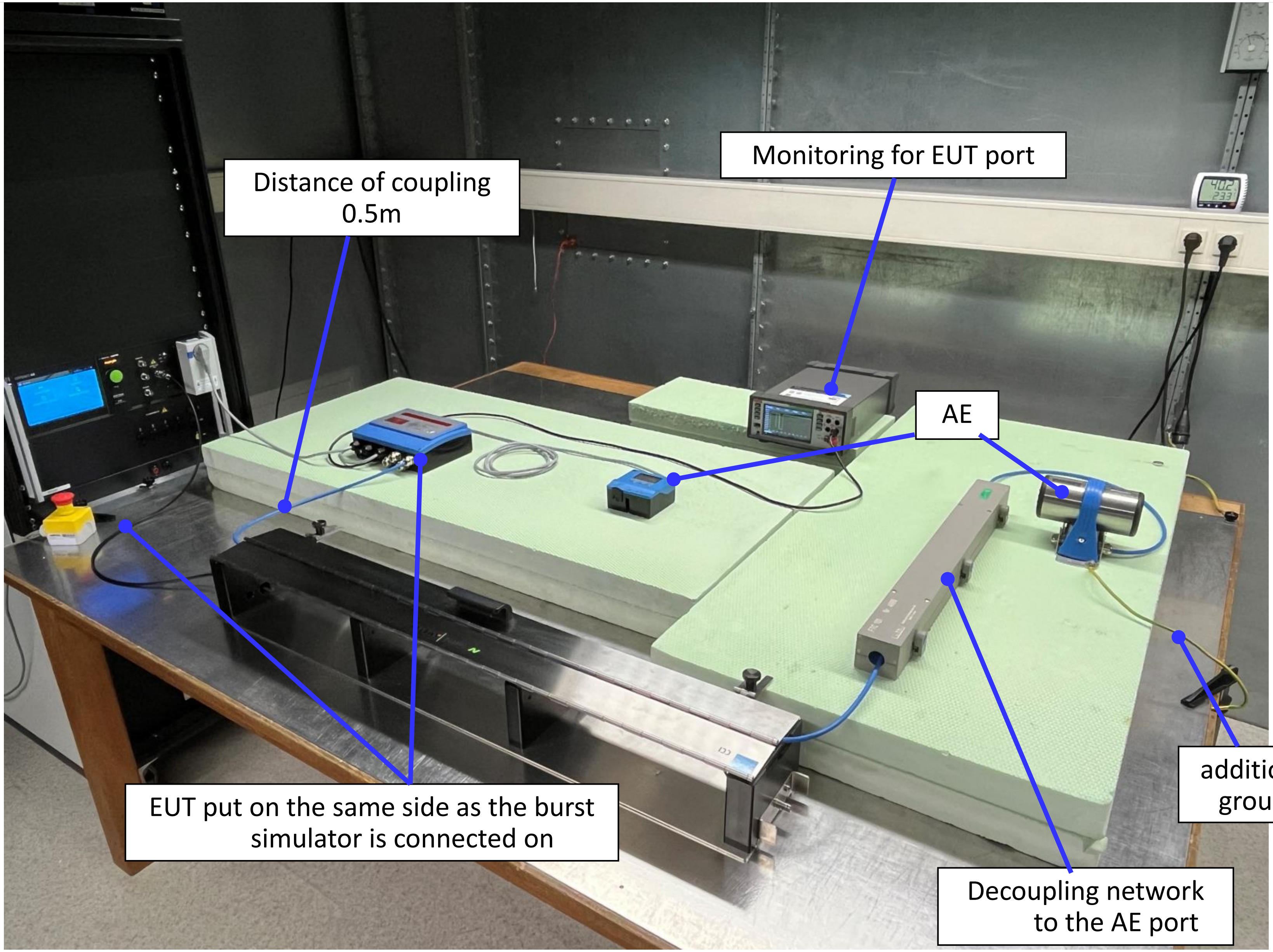


Calibration setup
of a capacitive coupling clamp using the transducer plate acc. to figure 8 of IEC 61000-4-4:2012



Setup for verification
of the capacitive coupling clamp
acc. to figure 10 of IEC 61000-4-4:2012

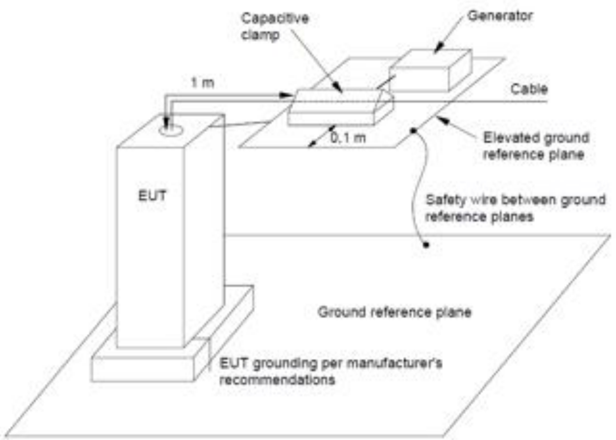
TEST SETUP COUPLING CLAMP



SPECIAL TEST SETUP FOR FLOOR STANDING EQUIPMENT

EN 61000-4-4:2004 and +A1:2010

- with coupling device elevated to the EUT intrance



NOTE The clamp may be mounted on the wall of a shielded room or any other grounded surface and bonded to the EUT. For large, floor standing systems with cables exiting at the top, the clamp could also be centred 10 cm above the EUT and have cables drop through the center of the plane.

Figure 8 – Example of a test set-up for rack mounted equipment

Source: IEC 61000-4-4 ed.2.0

EN 61000-4-4:2012

- with 1m between coupling device and EUT

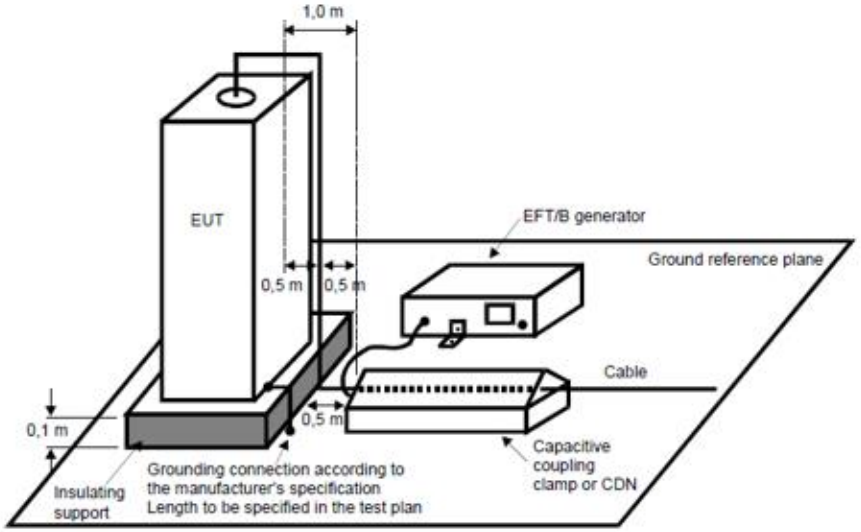
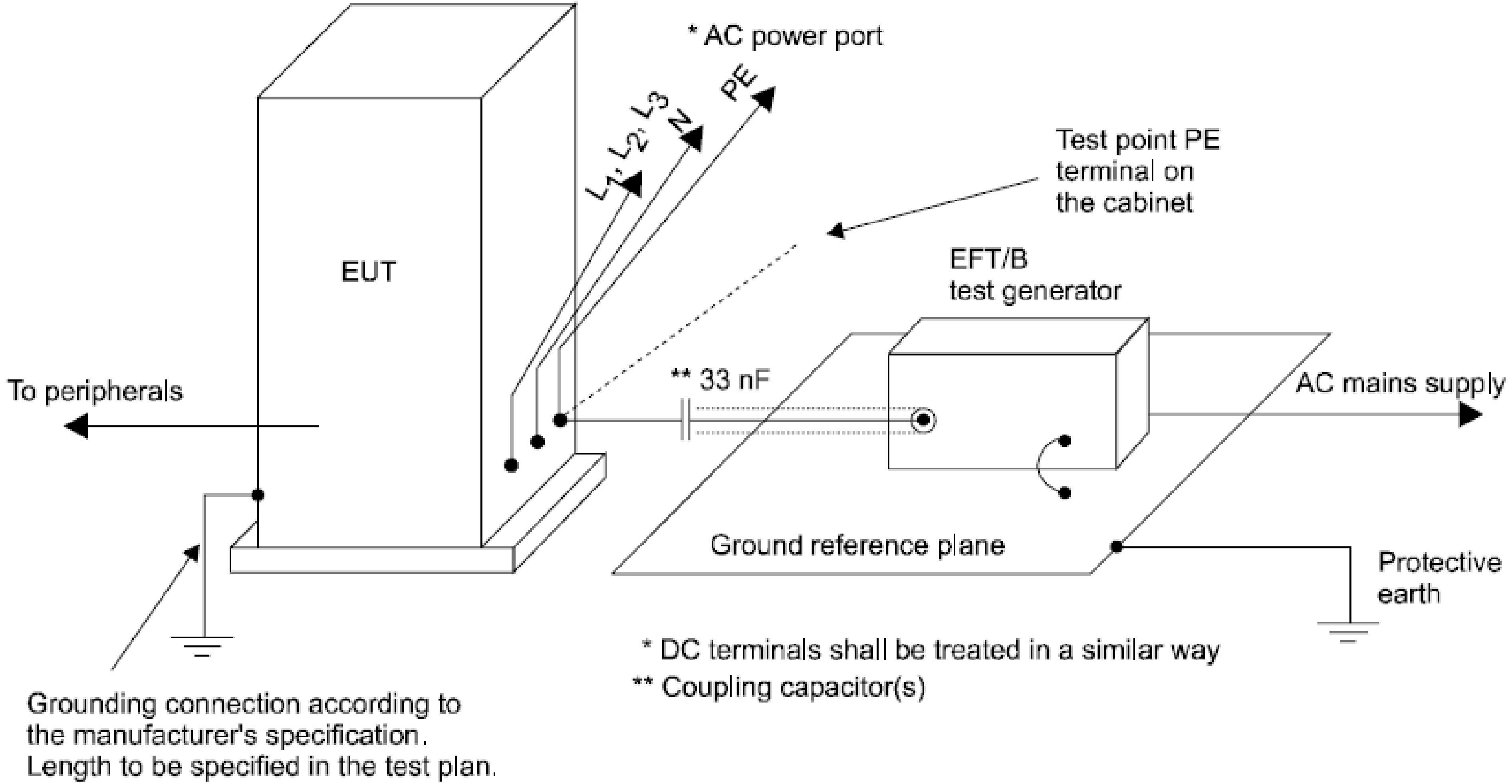


Figure 13 – Example of a test setup for equipment with elevated cable entries

Source: IEC 61000-4-4 ed.3.0

IN SITU TEST ON AC/DC POWER PORTS



IEC 61000-4-5

IMMUNITY TO HIGH-ENERGY SURGE VOLTAGES (SURGE)

LATEST/IMPORTANT CHANGES IN ED. 3

CHANGES IN IEC 61000-4-5

- **IEC 61000-4-5:2014 (Ed 3); consolidated version IEC 61000-4-5:2017 (Ed. 3.1)**
- Pulse parameters changed , now it is only one time definition of pulse shapes (front time Tf and pulse duration Td)
- Verification of the Waveforms have to made at the generator output (with 18 µF in serial), and at the output of the coupling/decoupling networks
- Harmonization of CDNs up to 200 A
- New verification procedure for data line CDN´s, new calibration table. For verification, the open-circuit voltage and the short-circuit current will measured. Additionally, the AE-port should be shortened.
- The impedance for tests on shielded lines are 2 Ohm + 18 µF

SURGE PULSE DEFINITION IEC 61000-4-5:2006 (OLD)

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

Definitions	In accordance with IEC 60060-1		In accordance with IEC 60469-1	
	Front time µs	Time to half value µs	Rise time (10 % – 90 %) µs	Duration time (50 % – 50 %) µs
Open-circuit voltage	1,2 ± 30 %	50 ± 20 %	1 ± 30 %	50 ± 20 %
Short-circuit current	8 ± 20 %	20 ± 20 %	6,4 ± 20 %	16 ± 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. Other IEC recommendations are based on waveform definitions according to IEC 60469-1 as shown in Table 2.

Both definitions are valid for this part of IEC 61000 and describe just one single generator.

Source: IEC 61000-4-5 ed.2.0

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

Source: IEC 61000-4-5 ed.2.0

SURGE PULSE DEFINITION IEC 61000-4-5:2014 (NEW)

The characteristics of the pulse shapes must be verified at the generator HV-output (2 Ω +18µF). If the 18µF capacitor is not integrated in the generator output, an external 18µF capacitor must be used.

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 × T = 1,2 ± 30 %	T_d = T_w = 50 ± 20 %
Short-circuit current	T_f = 1,25 × T_r = 8 ± 20 %	T_d = 1,18 × T_w = 20 ± 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

Source: IEC 61000-4-5 ed.3.0

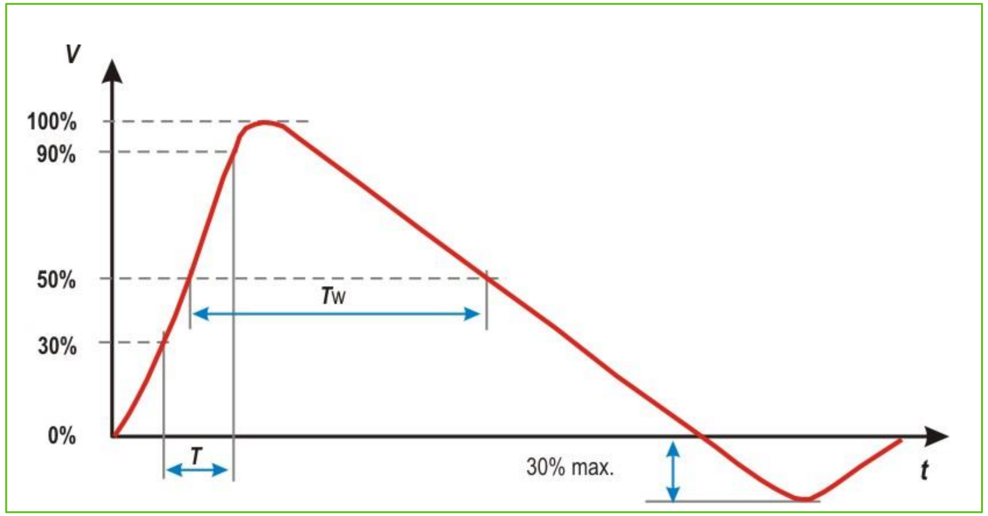
SURGE PULSE DEFINITION IEC 61000-4-5:2014

- **Open circuit voltage :** 1.2/50 µs

Front Time: T_f = 1.67 x T= 1.2µs ± 30 %

Duration: T_d = Tw = 50 µs ± 20 %

NOTE: The open circuit voltage waveform at the output of the coupling/decoupling network may have a considerable undershoot, in principle as the curve shown in Figure

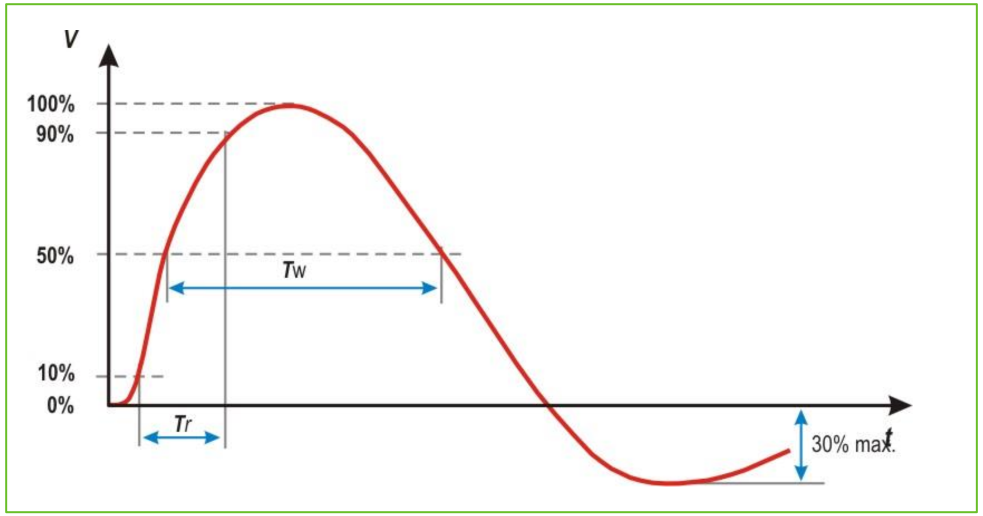


- **Short circuit current:** 8/20 µs

Front Time : T_f = 1.25xTr = 8 µs ± 20 %

Duration: T_d = 1.18 x Tw =20 µs ± 20 %

NOTE :The 30 % undershoot specification applies only at the generator output. At the output of the coupling/decoupling network there is no limitation on undershoot or overshoot.



CAPACITIVE COUPLING ON AC/DC LINES

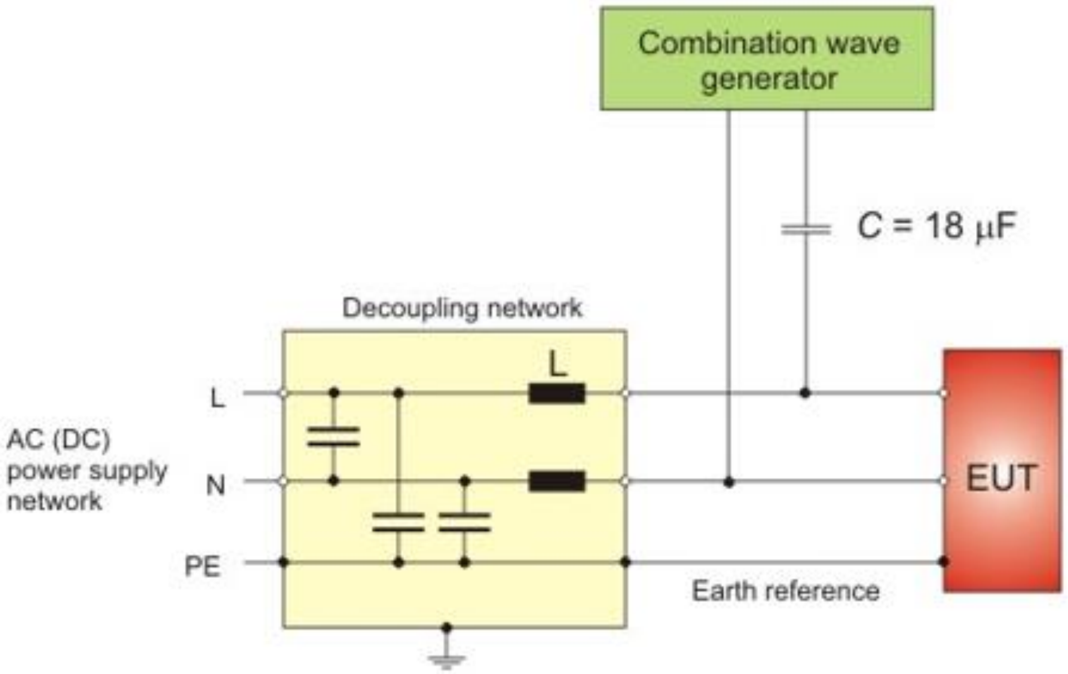


Fig. 5: Coupling Line to Neutral

Decoupling: L= 1.5mH

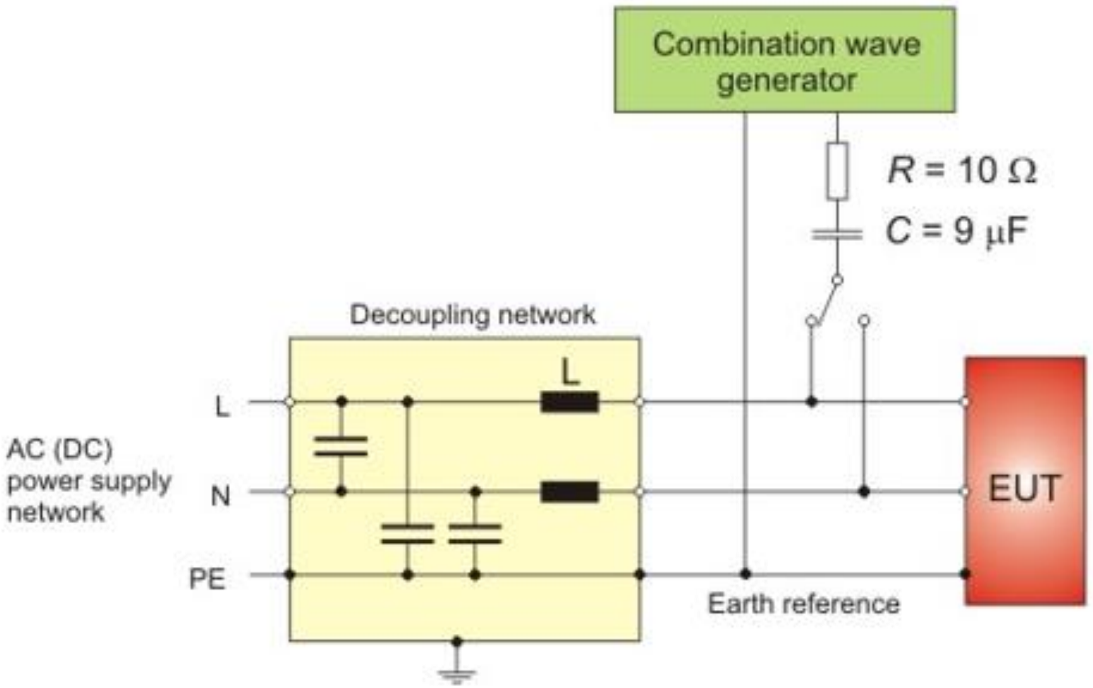


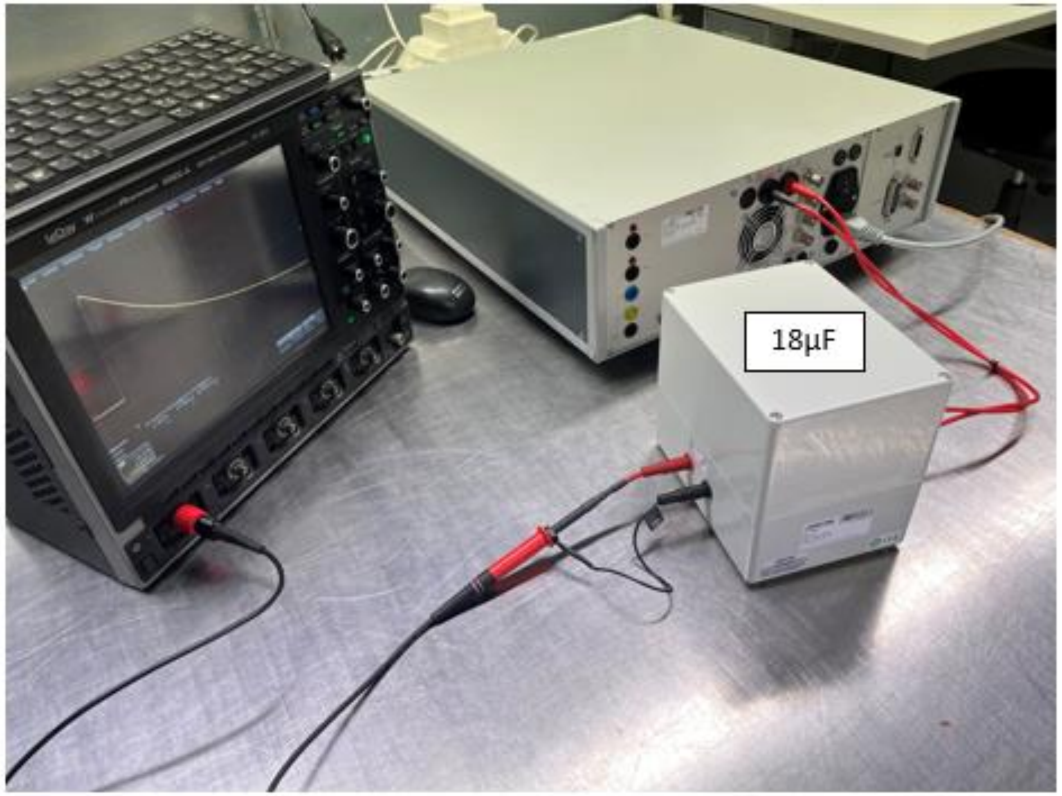
Fig. 6: Coupling L - PE and N – PE

Decoupling: L= 1.5mH

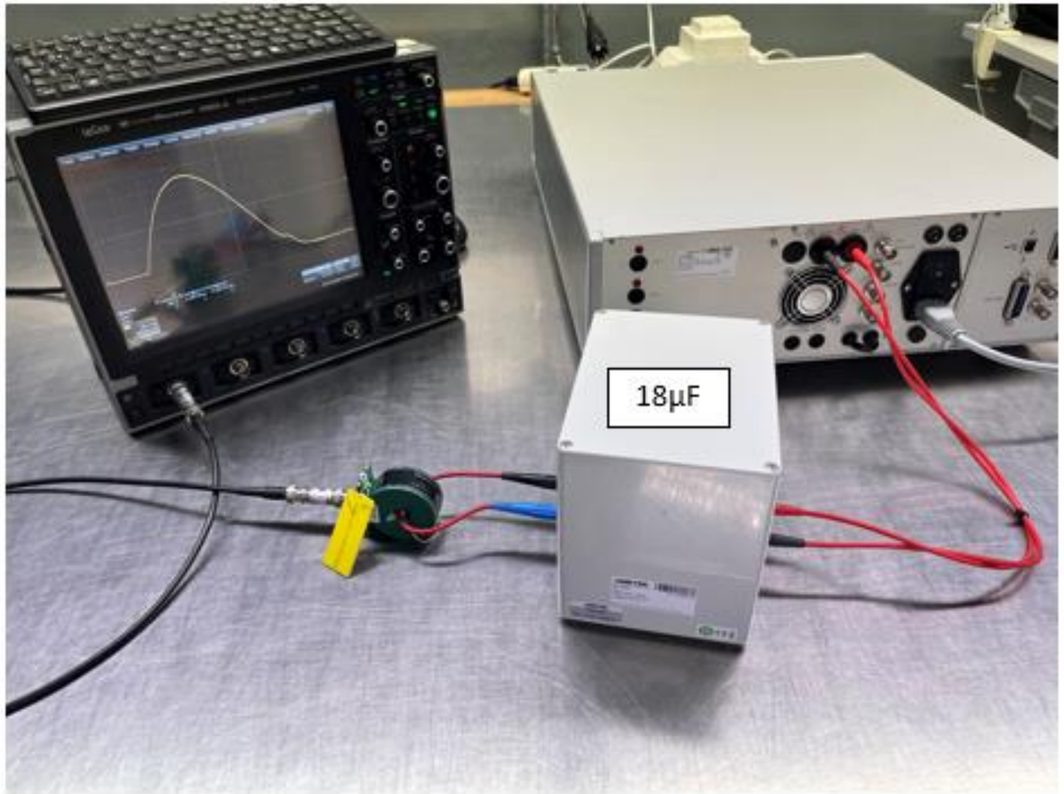
CALIBRATION AT THE HV OUTPUT VIA 18 UF

- If the generator does not have an 18 µF capacitor installed in the direct high-voltage output, it is mandatory to use an external capacitor.

Voltage calibration via 18 µF by using HV voltage probe:



Current calibration via 18 µF by using current probe:



CALIBRATION CDN SPECIFIED UP TO 200A

6.4.2 Calibration of CDNs for a.c./d.c. mains supply rated up to 200 A per line

The characteristics of the CDN shall be measured under *open-circuit* conditions (load greater than or equal to 10 kOhm) and under *short-circuit* conditions at the same set voltage.

All performance characteristics stated in 6.3.2 Tables 4 and 5 shall be met at the CDN output.

Table 4 – Voltage waveform specification at the EUT port of the coupling/decoupling network

Surge voltage parameters under open-circuit conditions [a]	Coupling impedance	
	18 µF	9 µF + 10 Ω
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 µs ± 30 %	1,2 µs ± 30 %
Duration		
Current rating ≤ 16 A	50 µs +10 µs/-10 µs	50 µs +10 µs/-25 µs
16 A < Current rating ≤ 32 A	50 µs +10 µs/-15 µs	50 µs +10 µs/-30 µs
32 A < Current rating ≤ 63 A	50 µs +10 µs/-20 µs	50 µs +10 µs/-35 µs
63 A < Current rating ≤ 125 A	50 µs +10 µs/-25 µs	50 µs +10 µs/-40 µs
125 A < Current rating ≤ 200 A	50 µs +10 µs/-30 µs	50 µs +10 µs/-45 µs

[a] The measurement of the surge voltage parameters shall be done with the a.c./d.c. mains supply port of the CDN open-circuit.

Source: IEC 61000-4-5 ed.3.0

New in Ed. 3

- Waveshape defined for common mode coupling to PE
- Tolerances are increased at higher current in the coupling network.

Decoupling inductivity:

- Maximum 1.5 mH
- Voltage Drop CDN < 10 %

CALIBRATION OF CDN

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. The characteristics of the generator shall be measured under:

Open circuit voltage with HV-Probe

each:
DM: L-N
CM: L-PE
CM: N-PE

Short circuit current with current probe

each:
DM: L-N
CM: L-PE
CM: N-PE

SPECIFICATION FOR UNSYMMETRICAL INTERCONNECTION LINES

Changes to Ed 3 :2014

Table 8 : Surge waveform specs. at the EUT port of the CDN

Coupling method	CWG Output voltage [1,2,3]	Voc at CDN EUT output ± 10 %	Voltage Front time T_f $T_f = 1,67 \times T_r$ ± 30 %	Voltage Duration T_d $T_d = T_w$ ± 30 %	I_{sc} at CDN EUT output ± 20 %	Current Front Time T_f $T_f = 1,25 \times T_r$ ± 30 %	Current Duration T_d T_d=1,18xT_w ± 30 %
Line to PE R = 40 Ω CD = 0,5 µF	4 kV	4 kV	1,2 µs	38 µs	87 A	1,3 µs	13 µs
Line to PE R = 40 Ω CD = GDT	4 kV	4 kV	1,2 µs	42 µs	95 A	1.5 µs	48 µs
Line to Line R = 40 Ω CD = 0,5 µF	4 kV	4 kV	1,2 µs	42 µs	87 A	1,3 µs	13 µs
Line to Line R = 40 Ω CD = GDT	4 kV	4 kV	1,2 µs	47 µs	95 A	1,5 µs	48 µs

[1]) It is recommended to calibrate the CDN at the highest rated pulse voltage, as this will minimise the effects of the switching noise generated by CLDs and GDTs. The value shown in the table is for a generator setting of 4kV. In case the CDN is rated for another maximum pulse voltage, the calibration shall be done at this maximum rated pulse voltage. The short circuit peak current specification shall be adapted accordingly. e.g. If the Maximum voltage is 1kV the short circuit current value shown in this table shall be multiplied by 1/4

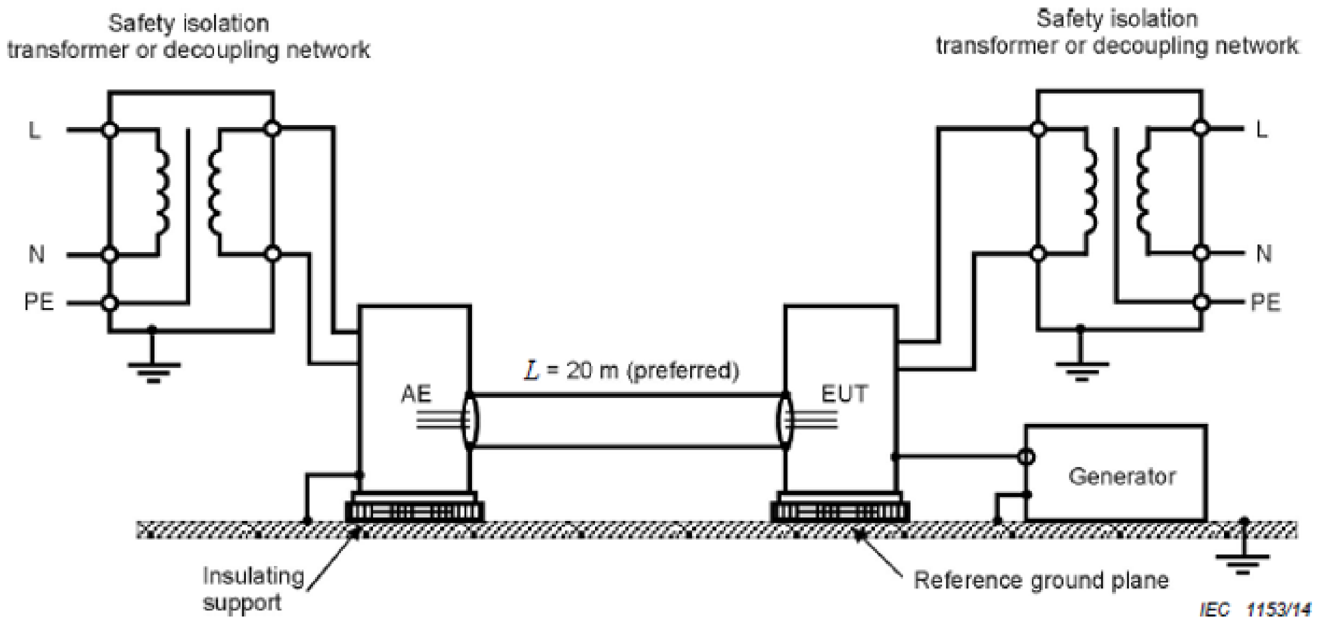
[2]) Coupling via gas arrestors, clamping or avalanche devices will show some switching noise on the pulse waveform. Working with the highest possible pulse voltage will minimise their impact on measurements; it is recommended to neglect the switching noise for the front times and duration values measurements.

[3]) 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.

Source: IEC 61000-4-5 ed.3.0

TEST SET-UP FOR SHIELDED LINES

For EUTs which do not have metallic enclosures, the surge is applied directly to the shielded cable at the EUT side.



Generator Impedance for tests on shielded lines:

IEC61000-4-5 Ed. 2

- **2 Ohm**

new: IEC61000-4-5 Ed. 3

- **2 Ohm + 18 µF**

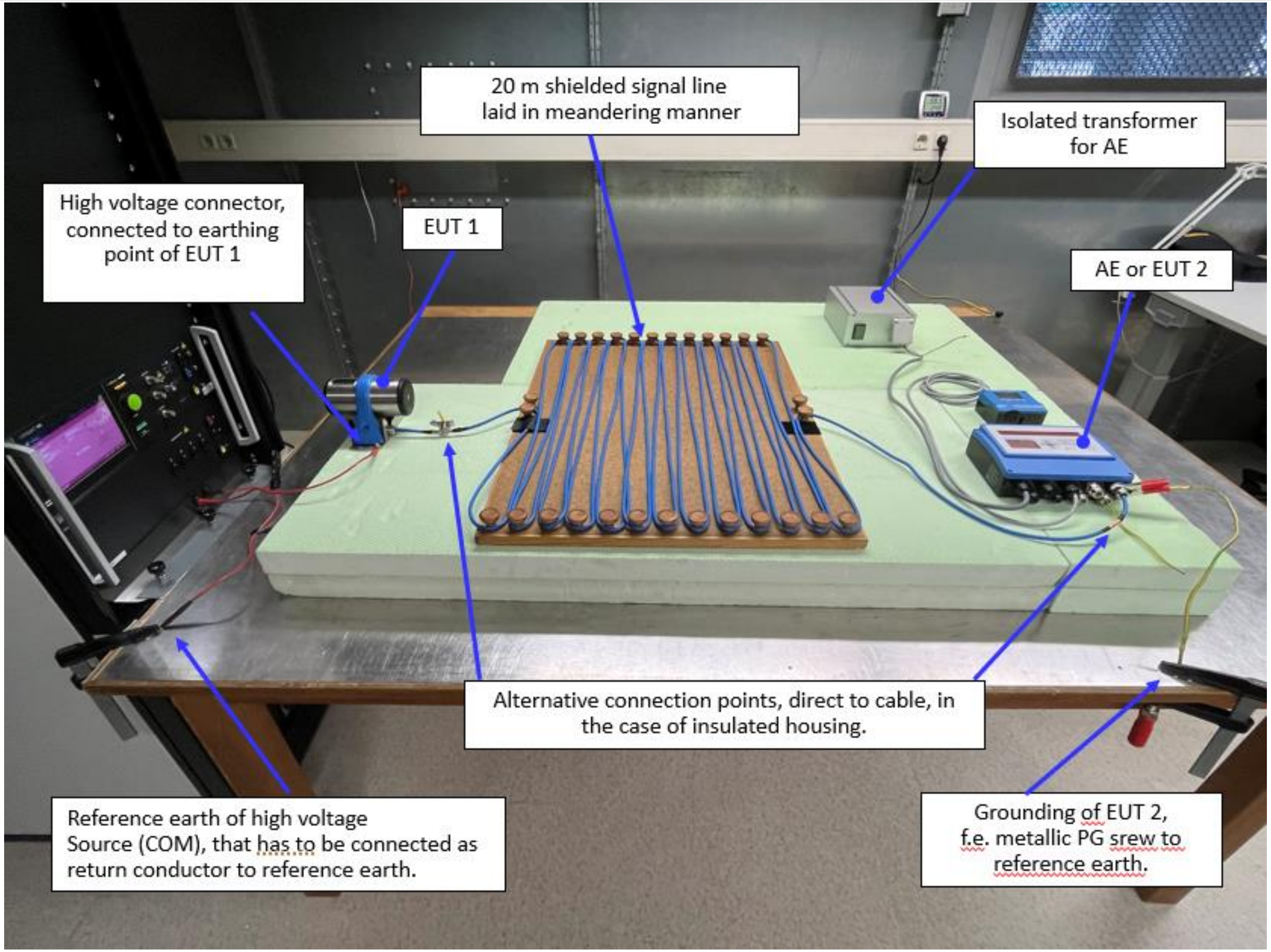
It is permissible for the power to the EUT and/or the AE to be provided via a decoupling network, rather than via the isolating transformer shown. In this case, the EUT's protective earth connection should not be connected to the decoupling network.

DC supplied EUT and/or AE should be powered through the decoupling networks.

Where it is necessary to isolate the AE equipment from the surge, the ground connection on the AE side of the cable under test may be achieved by connecting directly to the connector shield rather than the AE chassis. Where further insulation is required and the cable may be extended without impacting the integrity of the shield (e.g. using a coaxial barrel connector or a shielded Ethernet cable coupler) the connection to ground may be made to the shield of the extension coupler. In this case the length of the cable is measured between the EUT and the coupler and not between the EUT and AE. The cable length between the coupler and AE is not critical.

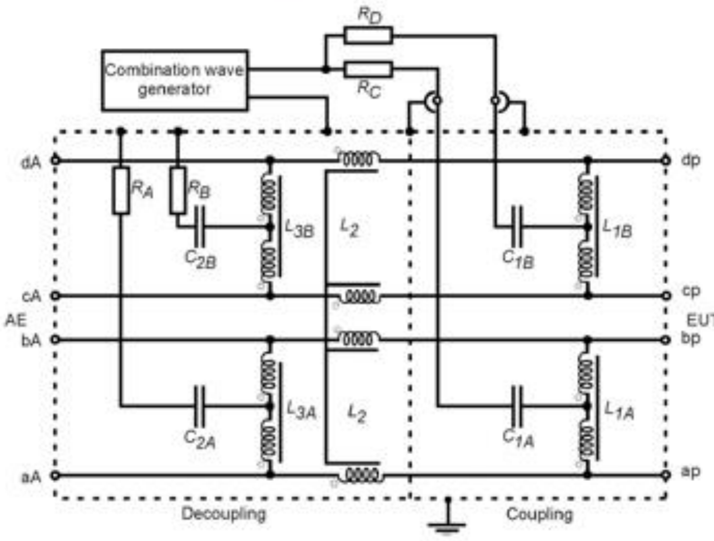
Source: IEC 61000-4-5 ed.3.0

TEST SET-UP FOR SHIELDED LINES



COUPLING ON FAST SYMMETRICALLY OPERATED I/O LINES

Figure 11 shows an example of a coupling and decoupling network for symmetrical interconnection lines allowing tests with interconnection speed up to 1000 Mbit/s.

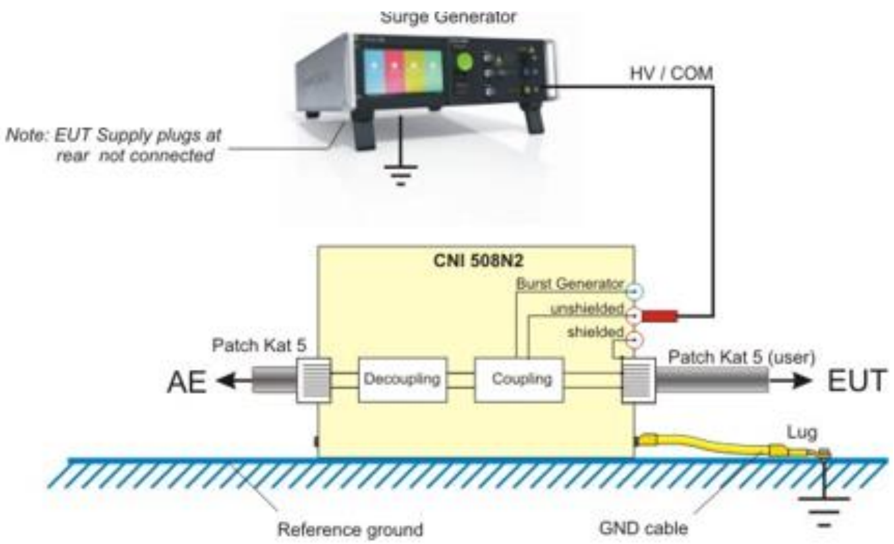


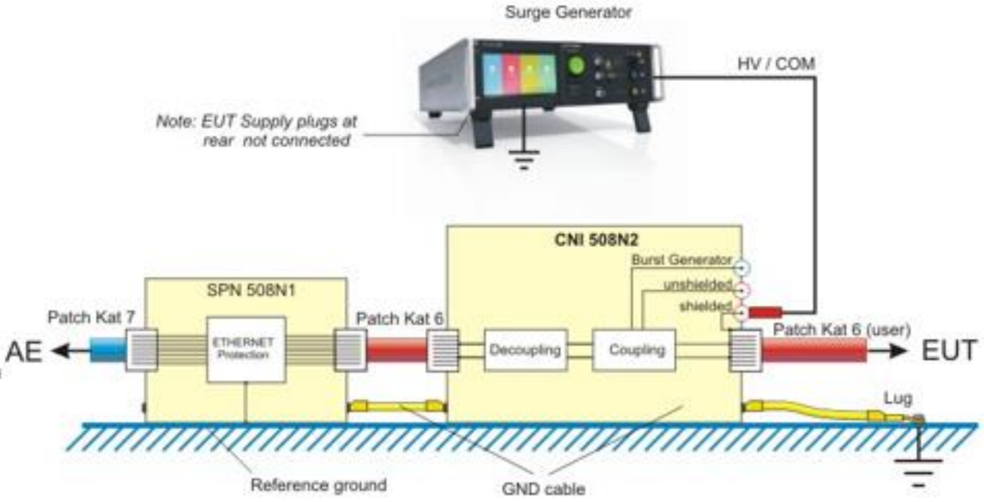
Calculation of coupling resistors and capacitors values:
R_C and R_D: The coupling resistors values are selected so that their resistance in parallel is equivalent to 40 Ω. So, a test on a two pairs port for example, requires two resistors each of 80 Ω, and a test on a four pairs port, requires four resistors each of 160 Ω.
R_A, R_B, C_1, C_2, L_1, L_2, L_3 : All components are selected so that the specified pulse parameters are met.

Figure 11: Example of coupling and decoupling network for unshielded symmetrical interconnection lines; lines-to-ground coupling via capacitors

Where normal functioning cannot be achieved because of the impact of the CDN on the EUT, product committees should specify appropriate operation or that no surge is required.

Source: IEC 61000-4-5 ed.3.0





COUPLING ON FAST SYMMETRICALLY OPERATED I/O LINES