IEC 61000-4-4 Burst
Electrical fast transient / Burst immunity test

Accelonix EMC Workshop 18-6-2019
Phenomenon open a contact

Equivalent diagram of a switching circuit

Typical voltage waveform across an opening switch

230V Power relays
EMC Model for fast transients

- **Source of interference**
  - Circuit breaker in electric circuits
  - High voltage switchgears
  - 110/230V power supply systems
  - 24V control lines

- **Characteristics**
  - Impulse with rise time in nanoseconds
  - Broadband interference spectrum up to 400 MHz
  - Amplitudes up to some kV

- **Coupling**
  - Capacitive (du/dt) to parallel lines
  - Inductive by magnetic fields (di/dt) to earth leads
  - Radiation in the near field by arcs

- **Migration**
  - Conducted in the cable system
  - Asymmetrical resp. Line to Earth
Test level IEC 61000-4-4: Ed3.0 (2012-4)

The use of 5 kHz repetition frequency is traditional, however, 100 kHz is closer to reality. Product committees should determine which frequencies are relevant for specific products or product types. In Annex B1 you will find representative values from real installations for your assistance.

### Open circuit test voltage

<table>
<thead>
<tr>
<th>Level</th>
<th>Power line</th>
<th>I/O line</th>
<th>Repetition rate [kHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak voltage [kV]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0,5</td>
<td>0,25</td>
<td>5 or 100</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0,5</td>
<td>5 or 100</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>5 or 100</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5 or 100</td>
</tr>
<tr>
<td>X (1)</td>
<td>special</td>
<td>special</td>
<td></td>
</tr>
</tbody>
</table>

Table 1- Test levels
Components

- **U**  High-voltage source
- **Rc**  Charging resistor
- **Cc**  Energy storage capacitor
- **Rs**  Impulse duration shaping resistor
- **Rm**  Impedance matching resistor
- **Cd**  DC blocking capacitor
- **Switch**  High-voltage switch (electronic switch)

**NOTE:** The characteristics of the switch together with stray elements (inductance and capacitance) of the layout shape the required rise time.
**Characteristic waveform**

Output voltage range with 1000 Ω load:
- min. \(0.24\) kV up to \(3.8\) kV; Test level 1 to 4

Output voltage range with 50 Ω load:
- min. \(0.125\) kV up to \(2\) kV; Test level 1 to 4

Pulse repetition frequency:
- 5 kHz and 100 kHz ± 20 %

Burst duration (see 6.1.2 and fig. 2):
- \((15 \pm 3)\) ms at 5 kHz
- \((0.75 \pm 0.15)\) ms at 100 kHz

Burst period
- \((300 \pm 60)\) ms

**Pulse shape:**
- Termination at coaxial output
  - Rise time \(t_r = (5 \pm 1.5)\) ns
  - Pulse duration (50 %-value) \(t_d = (50 \pm 15)\) ns
  - Peak value of voltage; Table 2 ± 10 %

- Termination at coaxial output
  - Rise time \(t_r = (5 \pm 1.5)\) ns
  - Pulse duration (50 %-value) \(t_d = 50\) ns
  - with a tolerance of \(-15\) ns to \(+100\) ns
  - Peak value of voltage; Table 2 ± 20 %
Parameter of the actual interferences

**Single pulse**
Rise time \( t_r = 5 \text{ns} \)
Pulse duration \( t_d = 50 \text{ns} \)

**Pulse packet (Burst)**
Repetition time: \( T_r = 300 \text{ms} \)

As formerly:
Duration burst packet \( t_d = 15 \text{ms} \)
At spike frequency \( f = 5 \text{kHz} \)

Duration burst packet \( t_d = 0.75 \text{ms} \)
At spike frequency \( f = 100 \text{kHz} \)
Mathematical modeling of Burst waveforms

Figure 3 shows the ideal waveform of a signal pulse into a 50 Ω load with nominal parameters

\[ t_r = 5 \text{ ns} \] and

\[ t_w = 50 \text{ ns} \]

Formula of the ideal waveform per Figure 3, \( v_{EFT}(t) \)

\[
v_{EFT}(t) = k_v \left[ \frac{v_1}{k_{EFT}} \left( \frac{t}{\tau_1} \right)^{n_{EFT}} \cdot e^{-\frac{t}{\tau_2}} \right]
\]

where

\[ k_{EFT} = e^{-\frac{\tau_1}{\tau_2} \left( \frac{n_{EFT}}{\tau_1} \right)^{n_{EFT}}} \]

\( k_v \) is max. or peak value of the open-circuit voltage (\( k_v = 1 \) means normalized voltage)

\[ v_1 = 0,92 \quad \tau_1 = 3,5 \text{ ns} \quad \tau_2 = 51 \text{ ns} \quad n_{EFT} = 1,8 \]

Figure 3
New peak voltages for 1000Ω load with respect to the voltage divider Ratio with Ri =50 Ω in table 2

### Table 2 – Output voltage peak values and repetition frequencies

<table>
<thead>
<tr>
<th>Set voltage</th>
<th>$V_p$ (open circuit)</th>
<th>$V_p$ (1000 Ω)</th>
<th>$V_p$ (50 Ω)</th>
<th>Repetition frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kHz</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>0.24</td>
<td>0.125</td>
<td>5 or 100</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>0.48</td>
<td>0.25</td>
<td>5 or 100</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.95</td>
<td>0.5</td>
<td>5 or 100</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.9</td>
<td>1</td>
<td>5 or 100</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>3.8</td>
<td>2</td>
<td>5 or 100</td>
</tr>
</tbody>
</table>

Measures should be taken to ensure that stray capacitance is kept to a minimum.

**NOTE 1** Use of a 1 000 Ω load resistor will automatically result in a voltage reading that is 5 % lower than the set voltage, as shown in column $V_p$ (1 000 Ω). The reading $V_p$ at 1 000 Ω = $V_p$ (open circuit) multiplied times 1 000/1 050 (the ratio of the test load to the total circuit impedance of 1 000 Ω plus 50 Ω).

**NOTE 2** With the 50 Ω load, the measured output voltage is 0.5 times the value of the unloaded voltage as reflected in the table above.
Calibration at the coaxial output

In order to provide a common supply basis for all test simulators, the characteristics of the test simulators have to be proved.

The verification at **coaxial output** has to be carried out as follows:

1. The demanded test voltage is set at the simulator.

2. The curve progression is measured at the coaxial output of the simulator. The Peak value of the voltage has to be 50% of the set voltage at the simulator.

3. The curve progression is measured at constant simulator settings at 1000 Ω. The peak value of the voltage has to be Up (open circuit) corresponding (±20%)
Calibration routine no.: 1

Calibration at coaxial 50 Ohm output of the simulator with a 50 Ohm load

Ratio with KW50 -> 1:400
Example: 2000V Burst = 5V on scope
Calibration routine no.: 2

Calibration at coaxial 50 Ohm output of the simulator with a 1000 Ohm load

Ratio with KW1000 -> 1:1000
Example: 2000V Burst = 2V on scope
Coupling/Decoupling network for mains connectors (IEC 61000-4-4:2012)

Coupling capacitors: 33 nF
Insertion loss: asymmetric (all lines against reference earth)
Calibration of the CDN for mains supply

Proof of characteristics of coupling/decoupling network:

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 \( \Omega \)

The calibration has to be provided with a voltage setting of 4kV as follows:

<table>
<thead>
<tr>
<th></th>
<th>since EN 61000-4-4:2004</th>
<th>New: EN 61000-4-4:2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise time ( tr )</td>
<td>5 ns ± 30%</td>
<td>5,5ns ± 1,5ns</td>
</tr>
<tr>
<td>Pulse duration ( td )</td>
<td>50 ns ± 30%</td>
<td>45ns ± 15ns</td>
</tr>
<tr>
<td>peak value of voltage</td>
<td>± 10% of the voltage according to table</td>
<td></td>
</tr>
</tbody>
</table>
Calibration routine no.: 3

- The EFT transients are coupled to all CDN lines *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 50Ω load, while the other outputs are open.
- Each individual output must show the transients within the tolerances as specified.
Capacitive Coupling Clamp

Dimensions have now tolerances
Lower coupling plate height: (100 ± 5) mm
Lower coupling plate width: (140 ± 7) mm
Lower coupling plate length: (1000 ± 50) mm

New picture, the size of the clamp from 1050mm is no longer defined
In a new chapter the edition 3 describes the calibration method of the capacitive coupling clamp with a transducer plate.

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** $t_r$ \(5\text{ns} \pm 1.5\text{ns}\)
- **Pulse duration** $t_d$ \(50\text{ns} \pm 15\text{ns}\)
- **Peak value of voltage** \(1\text{kV} \pm 200\text{V}\)
Test setup and test execution

Coupling mode: „all lines against ground reference“
So, the coupling mode is a pure „Common Mode testing“. This means that the testing of single lines, line after line, is not demanded any more, but only all lines simultaneously have to be supplied with burst pulses.

Components
PE protective earth
N neutral
L phase
Z1 decoupling inductive
Cc coupling capacitor
General tests set-up acc. to EN 61000-4-4:2012

Figure 11: Example of a test setup for laboratory type tests (marked new in Ed3)
Test Setup coupling on lines

Coupling mode: Common mode “all lines to reference ground”
The coupling network has to be connected with the reference ground in low impedance manner!
Test setup: Coupling on supply lines

Burst to AC supply lines EUT on insulated support distance generator to EUT = 0.5m
Test setup: Coupling on supply lines (floor standing device)
Test setup: signal lines with capacitive coupling clamp

Example: Floor standing system of two EUTs
Test setup: capacitive coupling clamp

- EFT generator
- Ground reference plane
- Capacitive Coupling Clamp
- EUT
- Decoupling network to the AE port if required

EUT must placed on the same side as the burst simulator is connected.
Test setup: Capacitive coupling clamp

Figure 13 Example of a test setup for equipment with elevated cable entries
Example for in situ test on a.c./d.c. Power ports and PE

Figure 13 Example of a test setup for equipment with elevated cable entries
Alternative method for coupling to signal lines without a CCC

The capacitive coupling clamp is the preferred method for coupling the test voltage into signal and control ports. If the clamp cannot be used due to mechanical reasons (e.g. size, cable routing) in the cabling, it shall be replaced by,

a. a tape or a conductive foil enveloping the lines under test.
   or alternatively
b. via discrete (100 ± 20) pF capacitors
EFT Burst generators

Current EFT Burst generators from the AMETEK CTS product lines:

- Compact NX5
- Compact NX7
- EFT 500N8
- NSG 3040A
- NSG 3060A
Coffee break
IEC 61000-4-5 Surge
Inventory of revision of IEC 61000-4-5 Ed.3 : (2014)

Accelonix EMC workshop 18-6-2019
• **Atmospheric discharges**
  - Max current peak value
  - Rise of the current $\frac{di}{dt}$,
  - Rise of $\frac{dU}{dt}$ caused the tripping of arrestors in the primary loop who are transformed to the secondary part.

• **Switching events electromechanical events**
  - Switching of capacitive loads in high voltage circuits. Cables, capacitor banks etc.
  - Switching of loads in low voltage systems.
  - Switching of resonance circuits with thyristors.
  - Short circuits and flash-overs in installations.
  - Tripping of protection devices as varistors and fuses.
> EMC Model Surge

- **Coupling**
  - Capacitive to parallel lines (du/dt )
  - Induction in loops (di/dt )
  - Radiation in the near field
  - Direct coupling in case of direct impact

- **Propagation**
  - Conducted to supply-, signal-, data- and control lines
  - Symmetrical (line to line) or unsymmetrical to PE
No Change of:
• Test levels
• Generator specifications
• Phase angle
• Separation of pulse 1.2/50 and 10/700

Question: Can the old device still be used?
Answer: It depends...

Changes to Ed 3 :2014:
• Impulsform definition (only one definition)
• Add mathematical formula for wave shape
• Calibration for CDN and generator with a capacitor of 15 µF
• New definition for CDN up to 200A / phase with calibration
• New specification for CDN for signal and data-lines with calibration
• New specification for high speed communication CDN
• Move of 10/700 µs generator to Annex and Harmonization with ITU-TK series
• Measurement Uncertainty MU in annex D
> One Waveshape definition in the IEC 61000-4-5 Edition 3 (2014)

Previous edition 2 offers two methods for waveshape measurement
> IEC 61000-4-5  

**IMPULSE DEFINITION**

- **Open circuit voltage**: 1.2/50µs
  
  **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 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**: 8/20µs
  
  **Front Time**: $T_f = 1.25 \times T_r = 8\mu s \pm 20\%$
  
  **Duration**: $T_d = 1.18 \times T_w = 20\mu s \pm 20\%$
  
  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.

NOTE: The calculation as per IEC 60469-1 (10% - 90%) is deleted
Test Levels

Table 1 specifies in detail the test levels for the open circuit voltages for testing Line to Line and Line to ground

<table>
<thead>
<tr>
<th>Level</th>
<th>Open circuit test voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line to Line</td>
</tr>
<tr>
<td>1</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>0,5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>X&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Special</td>
</tr>
</tbody>
</table>

<sup>a</sup> "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification.

- All voltages of the lower test levels shall be satisfied
- For selection of the test levels for the different interfaces, refer to Annex A.
The characteristics of the test generator shall simulate the phenomena as closely as possible. Depending on the different arise and coupling mechanism of the sources, the standard defines different source impedances for surge testing.

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

If the source of interference is in another circuit as the victim equipment (indirect coupling) as the ports of the victim equipment, then the generator may simulate a higher impedance source.

### Generator Source Impedance

<table>
<thead>
<tr>
<th>2 Ohm</th>
<th>12 Ohm (2 Ohm + 10 Ohm)</th>
<th>42 Ohm (2 Ohm + 40 Ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power lines (acc. to IEC61000-4-5: low-voltage power supply)</td>
<td>All other Lines</td>
<td></td>
</tr>
<tr>
<td>symmetrical (L-N, L-L)</td>
<td>unsymmetrical (L-PE, N-PE)</td>
<td>Unsymmetrical</td>
</tr>
<tr>
<td>Source in the same circuit</td>
<td>Source in the other circuit</td>
<td>(symmetrical)</td>
</tr>
<tr>
<td>unsymmetrical Switching</td>
<td>indirect lightning</td>
<td>only indirect influences</td>
</tr>
<tr>
<td>direct lightning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>indirect lightning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>only indirect influences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IEC 61000-4-5 Edition 3 (2014)

Characteristics and performance of the generator:
The output impedance is controlled with the relationship between the open circuit peak voltage and the short circuit current.
New values for the 12 Ω output (10Ω + 2 Ω) impedance have been defined.

NOTE The time parameters are valid for the short circuit current at the generator output without 10Ω resistor. (New additional note)
Calibration of CDNs for a.c./d.c. mains supply rated up to 200 A per line (6.4.2)

The characteristics of the CDN shall be measured under open-circuit conditions (load greater than or equal to 10 kΩ) 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>
<thead>
<tr>
<th>Surge voltage parameters under open-circuit conditions</th>
<th>Coupling impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load &gt; 10kΩ</td>
<td>18 µF</td>
</tr>
<tr>
<td></td>
<td>(Line to Line)</td>
</tr>
<tr>
<td></td>
<td>9 µF + 10 Ω</td>
</tr>
<tr>
<td></td>
<td>(Line to ground)</td>
</tr>
<tr>
<td>Peak voltage</td>
<td></td>
</tr>
<tr>
<td>Current rating ≤ 16 A</td>
<td>Set voltage +10 %/-10 %</td>
</tr>
<tr>
<td>16 A &lt; Current rating ≤ 32 A</td>
<td>Set voltage +10 %/-10 %</td>
</tr>
<tr>
<td>32 A &lt; Current rating ≤ 63 A</td>
<td>Set voltage +10 %/-10 %</td>
</tr>
<tr>
<td>63 A &lt; Current rating ≤ 125 A</td>
<td>Set voltage +10 %/-10 %</td>
</tr>
<tr>
<td>125 A &lt; Current rating ≤ 200 A</td>
<td>Set voltage +10 %/-10 %</td>
</tr>
<tr>
<td>Front time</td>
<td>1.2 µs ± 30 %</td>
</tr>
<tr>
<td></td>
<td>1.2 µs ± 30 %</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
</tr>
<tr>
<td>Current rating ≤ 16 A</td>
<td>50 µs +10 µs/-10 µs</td>
</tr>
<tr>
<td>16 A &lt; Current rating ≤ 32 A</td>
<td>50 µs +10 µs/-15 µs</td>
</tr>
<tr>
<td>32 A &lt; Current rating ≤ 63 A</td>
<td>50 µs +10 µs/-20 µs</td>
</tr>
<tr>
<td>63 A &lt; Current rating ≤ 125 A</td>
<td>50 µs +10 µs/-25 µs</td>
</tr>
<tr>
<td>125 A &lt; Current rating ≤ 200 A</td>
<td>50 µs +10 µs/-30 µs</td>
</tr>
</tbody>
</table>

**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%
Measurements shall be performed with the impulse applied to one coupling path at a time. The peak amplitude, the front time and impulse duration shall be measured for the CDN rated impulse voltage under open-circuit conditions. The inputs of the DN at the auxiliary equipment (AE) side shall be short circuited to PE for the impulse voltage and impulse current measurement at the EUT output port. The residual voltage value depends on the protection requirements of the AE. Therefore no limits are given in this standard.

Calibration process for unsymmetrical interconnection lines

<table>
<thead>
<tr>
<th>Coupling</th>
<th>Measuring</th>
<th>AE side</th>
<th>EUT side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surge voltage at EUT side</td>
<td>Single Line to PE</td>
<td>Single Line</td>
<td>All lines shorted to PE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak voltage, front time, duration</td>
<td></td>
</tr>
<tr>
<td>Surge Current at EUT side</td>
<td>Single Line to PE</td>
<td>Single Line</td>
<td>All lines shorted to PE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak current, front time, duration</td>
<td></td>
</tr>
<tr>
<td>Surge voltage at EUT side</td>
<td>Single Line to Line</td>
<td>Single Line</td>
<td>All lines shorted to PE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak voltage, front time, duration</td>
<td></td>
</tr>
<tr>
<td>Surge Current at EUT side</td>
<td>Single Line to Line</td>
<td>Single Line</td>
<td>All lines shorted to PE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak current, front time, duration</td>
<td></td>
</tr>
<tr>
<td>Residual voltage on AE Side (with protection)</td>
<td>Single Line to PE</td>
<td>Line to PE at a time</td>
<td>Open Circuit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak voltage</td>
<td></td>
</tr>
</tbody>
</table>

Changes to Ed 3 :2014
## Waveform specification for unsymmetrical interconnection lines

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

<table>
<thead>
<tr>
<th>Coupling method</th>
<th>CWG Output voltage $V_1 \pm 10%$</th>
<th>Vec at CDN EUT output $T_f - 1.67 \times T_f \pm 30%$</th>
<th>Voltage Front time $T_{\text{f}}$ $T_d = T_w \pm 30%$</th>
<th>Current Front Time $T_f$ $T_d = 1.25 \times T_f \pm 30%$</th>
<th>Current Duration $T_d = 1.18 \times T_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line to PE</td>
<td>4 kV</td>
<td>4 kV</td>
<td>1.2 $\mu s$</td>
<td>38 $\mu s$</td>
<td>87 A</td>
</tr>
<tr>
<td>R = 40 $\Omega$</td>
<td>CD = 0.5 $\mu F$</td>
<td></td>
<td></td>
<td></td>
<td>1.3 $\mu s$</td>
</tr>
<tr>
<td>Line to PE</td>
<td>4 kV</td>
<td>4 kV</td>
<td>1.2 $\mu s$</td>
<td>42 $\mu s$</td>
<td>95 A</td>
</tr>
<tr>
<td>R = 40 $\Omega$</td>
<td>CD = GDT</td>
<td></td>
<td></td>
<td></td>
<td>1.5 $\mu s$</td>
</tr>
<tr>
<td>Line to Line</td>
<td>4 kV</td>
<td>4 kV</td>
<td>1.2 $\mu s$</td>
<td>42 $\mu s$</td>
<td>87 A</td>
</tr>
<tr>
<td>R = 40 $\Omega$</td>
<td>CD = 0.5 $\mu F$</td>
<td></td>
<td></td>
<td></td>
<td>1.3 $\mu s$</td>
</tr>
<tr>
<td>Line to Line</td>
<td>4 kV</td>
<td>4 kV</td>
<td>1.2 $\mu s$</td>
<td>47 $\mu s$</td>
<td>95 A</td>
</tr>
<tr>
<td>R = 40 $\Omega$</td>
<td>CD = GDT</td>
<td></td>
<td></td>
<td></td>
<td>1.5 $\mu s$</td>
</tr>
</tbody>
</table>

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 4 kV. 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 1 kV 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.
Measurements shall be performed with the impulse applied to one coupling path at a time. The peak amplitude, the front time and impulse duration shall be measured for the CDN rated impulse voltage under open-circuit conditions. The inputs of the CDN at the auxiliary equipment (AE) side shall be short circuited to PE for the impulse voltage and impulse current measurement at the EUT output port. The maximum allowed residual voltage value depends on application specific elements, which are not specified in this standard.

Table 9: Calibration process

Table 10: Waveform specification

> Calibration process for symmetrical interconnection lines (6.4.3.3)
> Calibration coupling network

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**

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

**Short circuit current with current probe**

- DM: L-N
- CM: L-PE
- CM: N-PE
Selecting the coupling/decoupling network method

Mains

Yes

No

Coupling

Line to GND

Line to line

coupling 18uF

1-phase

Fig. 5

3 phases

Fig. 7

coupling 9uF 10Ω

1-phase

Fig. 6

3 phases

Fig. 8

Symmetrical

Yes

No

shielded cable?

Yes

No

shield connected?

one end

Yes

No

Grounded each end

Fig. 12

Coupling 46

Coupling via arrestors, capacitor or clamping device

Fig. 9

Coupling

arrestors or clamping devices

capacitors or direct

Fig. 10

or

Fig. 11

Changes to Ed 3 :2014

> Coupling Network selection
New measurements method is defined including residual voltages at AE ports of data lines CDN. The inductance values for the decoupling inductance is removed from each figure.

> Example of test setup for capacitive coupling on a.c./d.c. lines

Fig. 5: Coupling Line to Neutral
Decoupling: L= 1.5mH

Fig. 6: Coupling L - PE and N – PE
Decoupling: L= 1.5mH
Example of test setup for capacitive coupling on 3-phase a.c. lines.

Fig. 7: Coupling Line to Line / Neutral

Fig. 8: Coupling Line - PE and Neutral - PE
Switch S1:
- Line to Earth: Position 0
- Line to Line: Position 1 to 4

Switch S2:
- during the test: Positions 1 to 4 but not in same position as switch S1

Switch S3:
- Position coupling with gas arrester to symmetrical I/O lines
- Position capacitive coupling 0.5uF asymmetrical I/O lines
- Position capacitive coupling 3.0uF Ringwave

Alternative coupling via clamping circuit
Example

Earth connector EUT

EUT

Generator connector
- red -> HV
- black -> COM

Grounding of the CDN

Example: Coupling line 1 to earth (PE)

Lines between the coupling network and the EUT must not exceed 2 m of length

> Coupling on I/O lines via CNV508N1 unshielded unsymmetrical
> Unshielded symmetrical interconnection lines

Line to Ground coupling

**IEC 61000-4-5 Ed2, Figure 14**

\[ R_{m2} = n \times 40 \, \Omega, \text{ max. } 250 \, \Omega \]

1.2/50us Generator

**10/700us Generator**

\[ R_{m2} = n \times 25 \, \Omega, \text{ max. } 250 \, \Omega \]

**IEC 61000-4-5 Ed3, Figure 10 and Figure A4**

\[ R_c = 40 \, \Omega \]

1.2/50us Generator

**10/700us Generator**

\[ R_c = 25 \, \Omega \]

Other coupling devices than gas arrestors (GDT) are allowed.

Changes to Ed 3 :2014
NOTE 1  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.

NOTE 2 D.C. supplied EUT and/or AE should be powered through the decoupling networks.

Test set-up for shielded lines ground at both sides
The EUT is isolated from ground and the surge ($2\Omega$) is applied to its metallic enclosure; the termination (or auxiliary equipment) at the port(s) under test is grounded.

Cable length:
- 20 m (preferred length) or
- the shortest length over 10 m, where the manufacturer provides pre-assembled cables used in actual installations

→ No test shall be required for cables which according to the manufacturer’s specification are $\leq 10$ m.
High voltage connector, To be connected at the central earthing point of EUT 1

Reference earth of high voltage source, that has to be connected as return conductor to reference earth.

20m shielded signal line laid in meandering manner

Auxiliary Equipment or EUT2

EUT1

Insulating transformer

Grounding of EUT 2 to the reference earth.
Rules for application of the surge to shielded lines:

a) Shields grounded at both ends:
   – the test shall be carried out according to Figure 12.
   The test level is applied on shields with a 2 Ω generator source impedance and with the 18 μF capacitor

b) Shields grounded at one end:
   – the test shall be carried out according to 7.4 or 7.5 (see Figure 4) because the shield does not provide any protection against surges induced by magnetic fields.

NOTE 2:
In this case, surge testing is not applied to the shield.

Changes to Ed 3:2014
> Test set-up for shielded lines grounded only at both and one end

Symmetrical

Yes

No

Coupling

40 Ω

Coupling via arrestors, capacitor or clamping device

Fig 9

Coupling

arrestors or clamping devices

capacitors or direct

Fig. 10 or Fig. 11
> Coupling on fast symmetrically operated I/O lines

Surge tests to high speed data-lines
Coupling as per figure 11 of IEC 61000-4-5 Ed. 3 :2014

Changes to Ed 3 :2014

EM Test up to 1GBit/s
CNI 508N2
Surge 1.2/50µ up to 3kV
Burst 5/50n up to 4kV
POE, POE+ compatible

HSC 4-8
Surge 1.2/50µ up to 3kV
Burst 5/50n up to 4kV
Ringwave (0.5µ/100kHz) up to 4kV
POE, POE+ compatible

Figure 11
Coupling on fast symmetrically operated I/O lines

Example for coupling as per figure 11 of IEC 61000-4-5 Ed. 3.0:2012

Coupling to unshielded lines

Coupling to shield with additional AE protection with SPN 508N1
Test procedure for Surge with 1-phase EUT

The test procedure includes:
- the verification of the test instrumentation according to 7.2.
- the establishment of the laboratory reference conditions;
- the confirmation of the correct operation of the EUT;
- the execution of the test;
- the evaluation of the test results (see Clause 9 ;Criteria A,B,C,D)

- 5 test-pulses for every setting (Level, Coupling, Angle, Polarity).
- Time between successive pulses: 1 min or less.
Testing of double-insulated products

No line to ground surges are applied for double-insulated products (i.e. products without any dedicated earth terminal).

NOTE 2  Product committees may decide if line to ground surge testing is applicable to double-insulated products with earthed connections other than PE.

Example: A product standard requires 4kV common mode and 2kV differential mode. For a single phase EUT it must be tested with 1kV between L and N and with 2kV between L and PE as well as between N and PE. According to the requirement for the coupling/decoupling network, the EUT may ‘see’ 1,5kV between L and N during the common mode tests. In the past some equipment failed the common mode tests with damages in the path between L and N, although the differential mode tests have been passed.
Annex A (Telecom Surge)

The surge testing for outdoor communication lines (telecom part) is moved to Annex A. The waveform definition is seen in the table blow.

Table A.1 – Definitions of the waveform parameters

<table>
<thead>
<tr>
<th></th>
<th>Front time µs</th>
<th>Duration µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-circuit voltage</td>
<td>10 ± 30 %</td>
<td>700 ± 20 %</td>
</tr>
<tr>
<td>Short-circuit current</td>
<td>5 ± 20 %</td>
<td>320 ± 20 %</td>
</tr>
</tbody>
</table>

Source impedance 40 Ohm

Table A.2 – Relationship between peak open-circuit voltage and peak short-circuit current

<table>
<thead>
<tr>
<th>Open-circuit peak voltage ± 10 % at generator output</th>
<th>Short-circuit peak current ± 10 % at generator output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 kV</td>
<td>12.5 A</td>
</tr>
<tr>
<td>1.0 kV</td>
<td>25 A</td>
</tr>
<tr>
<td>2.0 kV</td>
<td>50 A</td>
</tr>
<tr>
<td>4.0 kV</td>
<td>100 A</td>
</tr>
</tbody>
</table>

Waveform of open-circuit voltage (10/700 µs)

Waveform of short-circuit current (5/320 µs)
Surge generators

Current Surge generators from the AMETEK CTS product lines

- Compact NX5
- Compact NX7
- VCS 500Nx 8
- VCS 500N12 + CDN 100 A
- NSG 3040A
- NSG 3060A
- NSG 3150 (15 kV)
Thank you!

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Coffee break
Demo NX5