Insights and best practice

EMC COMPLIANCE KNOW-HOW

TECHNICAL NOTE 0109

SURGE WAVEFORM VERIFICATION **FOR TRANSIENT GENERATORS**

Overview

Surge is caused by over-voltages from switching and lightning transients. IEC 61000-4-5 describes several tests which are intended to evaluate immunity from several natural phenomena and various equipment configurations.

The most frequent cause of damage in industrial electronic systems is over-voltages, caused either by switching actions in the equipment itself or by atmospheric discharges such as lightning. This paper will not discuss symmetrical communication lines that are intended to be directly connected to outdoor telecommunication networks (e.g. public switched telecommunications networks (PSTN) that typically have cable lengths in excess of 300 m or even many kilometers. This paper will be limited to calibrating surge waveforms for single-phase AC/DC power lines.

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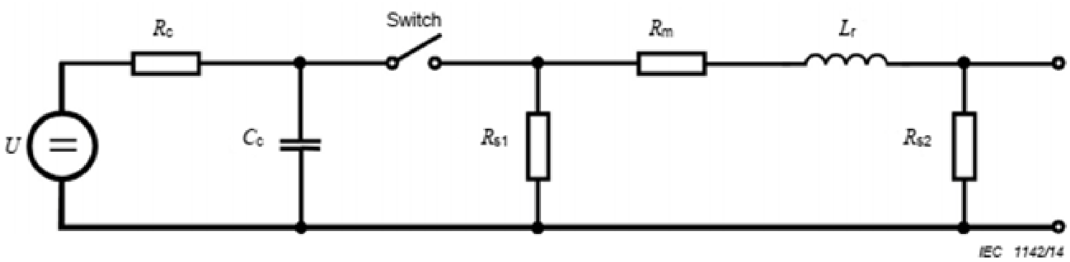
COMPLIANCE TEST SOLUTIONS

In order to generate the impulses necessary to meet the requirements of IEC 61000-4-5 Ed.3 a generator that can simulate conditions that may cause damage to the equipment under test (EUT). The most frequent cause of damage in industrial electronic systems is over-voltages; caused either by switching actions in the EUT or by atmospheric discharges such as lightning. If the interference source is in the same circuit as the EUT, the transfer impedance is low and the impulse takes a current form. If the interference is from some external source, the transfer impedance will be higher and a voltage impulse will result.

To simulate both these conditions, a Combination Wave Generator (CWG), such as the compact NX series or NSG 3000A series, available from AMETEK CTS, is designed to deliver both a voltage impulse into an open circuit and a current impulse into a short circuit. Combination Wave Generators have a virtual impedance (open circuit voltage / short circuit current) of 2 Ohms.



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

Calibration of the Combination Wave Generator

The waveform characteristics at the output of the CWG at its output are described in Figures 2 and 3 and Tables 1 and 2 below.

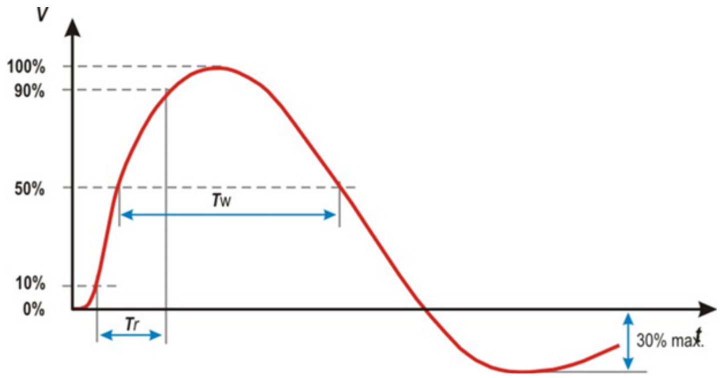


Figure 2

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

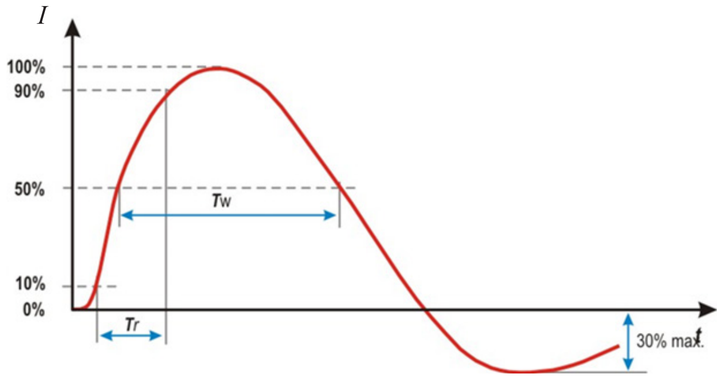


Figure 3

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

	Front time T_f (µs)	Duration Td (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 1:
Waveform parameters 1.2/50 µs and 8/20 µs

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

Table 2:
Relationship between peak open-circuit voltage and peak short-circuit current

To measure the waveform characteristics of a CWG, the CWG needs to be configured for an external CDN without its internal 18 µF coupling capacitor (Figures 4 and 5). The voltage and current waveforms then can be measured at the HV and COM ports on the rear panel. Figure 6 shows the rear panel of the Compact NX5. The external CDN configuration bypasses the internal 18 µF coupling capacitor.

Figure 4

Configuration of NSG 3000A series

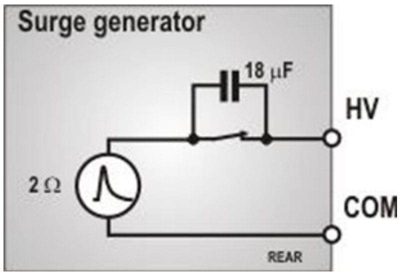


Figure 5

Surge verification configuration of NSG 3000A series

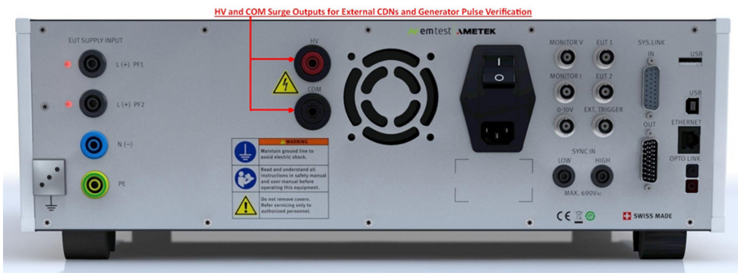


Figure 6

Rear panel of EM Test Compact NX5

A differential oscilloscope probe to measure the open-circuit pulse such as the Teseq MD 210, and a Surge Pulse Current Probe Set such as the MD 300 from Ametek CTS are recommended for measuring these high-voltage and high-current pulses. The current and voltage surge outputs on the NX5 (Figure 7) are only to monitor the pulse and not to be used for calibration.

Figure 7

Front panel of Compact NX5

Calibration of the Coupling / Decoupling Networks

After the open and short-circuit pulses have been calibrated, the impulses that will be delivered to the EUT will need to be calibrated as a CWG/CDN system. It is recommended to calibrate both the CWG and the CDN together as a system. In order to do this, measurement are to be taken at the output of the CDN (internal or external), with the power ports of the CDN open and the measurements for the open-circuit (≥ 10 kΩ) voltage surge and the short-circuit (< 0.1 Ω) current surge shall be measured at the EUT-side of the CDN. Both the line-to-line and line-to-ground coupling configurations are to be measured. Schematics of both configurations are shown below in Figures 8 and 9.

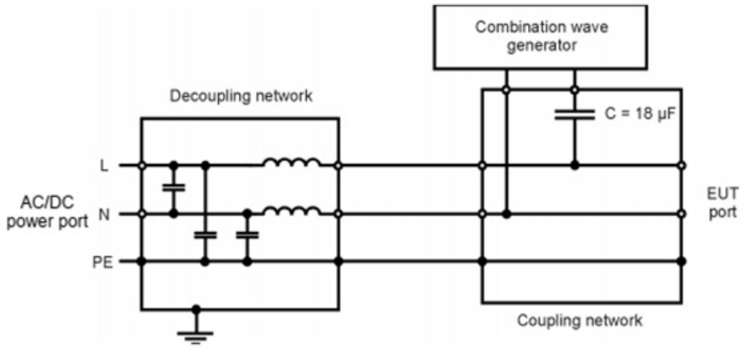


Figure 8

Example of coupling/decoupling networks for capacitive coupling on AC/DC lines (line-to-line coupling)

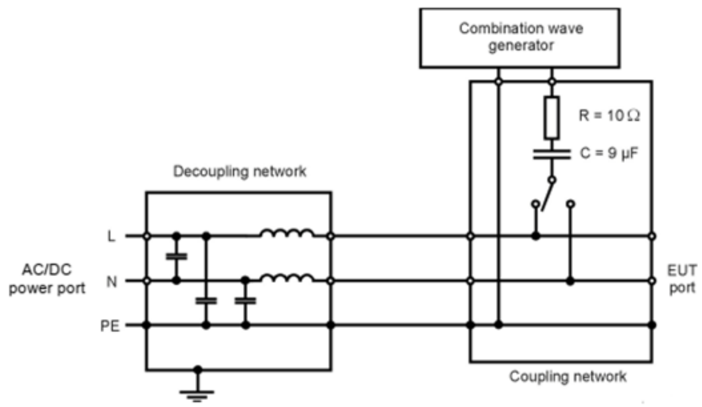


Figure 9

Example of coupling/decoupling networks for capacitive coupling on AC/DC lines (line-to-ground coupling)

When measuring the waveform characteristics at the output of the CDN, the waveform characteristics of the combined CWG/CDN system are still required to have the same as the CWG itself as shown in Figures 2 and 3, but with the relaxed tolerances described in Table 3 (open-circuit) and revised values for line-to-ground coupling in Table 4 (short-circuit) below. Note that the undershoot/overshoot limitations for the CWG noted in Figures 2 and 3 do not apply to the CWG/CDN combination.

To prevent unwanted voltage drops in the CDN, the value of the decoupling element shall be reduced for CDNs rated at > 16 A. Therefore, 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 3 and 4 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 3:
Voltage waveform specifications at the EUT port of the CDN

	Surge voltage parameters under open-circuit conditions [a, b]	**Coupling impedance**
	18 μF (line-to-line)	9 μF + 10 Ω (line-to-ground)
Peak voltage Current rating (of CDN) ≤ 16 A 16 A < current rating ≤ 32 A 32 A < current rating ≤ 63 A 63 A < current rating ≤ 125 A 125 A < current rating ≤ 200 A	Set voltage +10 %/-10 % Set voltage +10 %/-10 % Set voltage +10 %/-10 % Set voltage +10 %/-10 % Set voltage +10 %/-10 %	Set voltage +10 %/-10 % Set voltage +10 %/-10 % Set voltage +10 %/-15 % Set voltage +10 %/-20 % Set voltage +10 %/-25 %
Front time	1.2 μs ± 30 %	1.2 μs ± 30 %
Duration Current rating (of CDN) ≤ 16 A 16 A < current rating ≤ 32 A 32 A < current rating ≤ 63 A 63 A < current rating ≤ 125 A 125 A < current rating ≤ 200 A	50 μs +10 μs/-10 μs 50 μs +10 μs/-15 μs 50 μs +10 μs/-20 μs 50 μs +10 μs/-25 μs 50 μs +10 μs/-30 μs	50 μs +10 μs/-25 μs 50 μs +10 μs/-30 μs 50 μs +10 μs/-35 μs 50 μs +10 μs/-40 μs 50 μs +10 μs/-45 μs
NOTE: The current rating in the first column is that of the CDN used for that current range.		
[a] The measurement of the surge voltage parameters shall be performed with the AC/DC power port of the CDN open-circuit. [b] The values shown in this table are for a CWG with ideal values. Beware of cases where 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 4:
Current waveform specification at the EUT port of the CDNt

	Surge current parameters under open-circuit conditions [a, b]	**Coupling impedance**
	18 μF (line-to-line)	9 μF + 10 Ω (line-to-ground)
Front time	T_f = 1.25 × T_r = 8 μs ± 20 %	T_f = 1.25 × T_r = 2.5 μs ± 30 %
Duration	T_d = 1.18 × T_w = 20 μs ± 20 %	T_d = 1.04 × T_w = 25 μs ± 30 %
[a] The measurement of the surge current parameters shall be performed with the AC/DC power port of the CDN open-circuit. [b] The value 1.04 is derived from empirical data.		

The relationship between peak open-circuit voltage and peak short-circuit current values that are described in Table 2 for the CWG alone are supplemented to account for the CWG/CDN system's line-to-ground coupling configuration (9 µF + 10 Ω) in Table 5 below.

Open-circuit peak voltage ± 10 % at EUT port of the CDN	Short-circuit peak current ± 10 % at EUT port of the CDN (18 µF)	Short-circuit peak current ± 10 % at EUT port of the CDN (9 µF + 10 Ω)
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

Table 5:
Relationship between peak open-circuit voltage and peak short-circuit current at the EUT port of the CDN

Measuring the open-circuit waveform with an integrated CWG/CDN is shown below in Figure 10.

Figure 10

Test set-up to verify open-circuit CGW/CDN system

Measuring the short -circuit waveform with an integrated CWG/CDN is shown below in Figure 11.

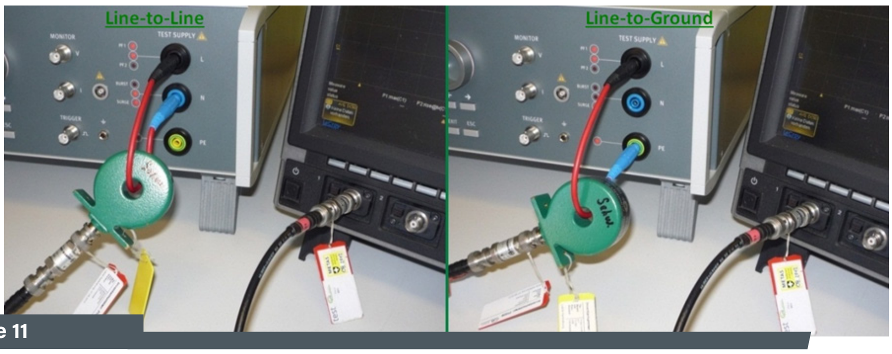


Figure 11

Test set-up to verify short-circuit CGW/CDN system

About AMETEK CTS

AMETEK CTS is a global leader in EMC compliance testing and RF power amplifiers. AMETEK has been designing and manufacturing precision instruments for more than 30 years. Under the brand names of EM Test, Teseq, IFI and Milmega the company produce a wide range of specialist solutions aligned to the individual needs of equipment manufacturers across a variety of industries. These include:

Automotive
Aerospace and Defense
Consumer electronics
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Medical devices
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From its design and manufacturing facilities in Switzerland, Germany, the United States and the UK, AMETEK CTS provides customers with innovative solutions to the complex requirements of EMC compliance standards.

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