Application Note: Tests with Damped Oscillatory Waves according to IEC 61000-4-12 Ed. 1, IEC 60255-22-1 Ed. 1 and IEEE/ANSI C37.90.1

Introduction

The Basic EMC standard IEC 61000-4-12 edition 1.1 (2001) describes a transient immunity test involving "repetitive damped oscillatory waves occurring mainly in power, control and signal cables installed in high voltage and medium voltage stations".

These transients are representative of the switching of isolators and other background disturbances in MV and HV open air stations, and are therefore used primarily to test substation products such as protective relay devices. The following American and European product standards can also apply:

- IEEE/ANSI C37.90.1-2002: IEEE standard for Surge withstand Capability (SWC) Tests for Relays and Relays Systems Associated with Electric Power Apparatus.
- IEC 60255-22-1:1988: Electrical disturbance tests for measuring relays and protection equipment. Part 1: 1MHz burst disturbance tests.

This application note is intended to give a brief overview of the industry requirements for damped oscillatory surge generators, and a short description of the Haefely products in this range.

Basic requirements for the Damped Oscillatory Wave generator

The IEC 61000-4-12 Edition 1 standard specifies a series of damped oscillating pulses with 75ns rise time, oscillating frequencies of 100kHz and 1MHz and repetition rates of 40Hz and 400Hz respectively, as shown below:

Voltage Waveform	A damped oscillatory wave with 50% of the peak value between the third and the sixth periods
Current waveform	not defined
Voltage rise time:	75ns ±20%
Oscillation frequencies	100kHz and 1MHz ±10%
Peak open circuit voltage	250V (-10%) to 2.5kV (+10%)
Repetition rate	at least 40/s for 100kHz and 400/s for 1MHz optional repetition rate is $4*10^{-4}$ x oscillation frequency
Burst duration	not less than 2s
Output impedance:	200Ω ±20%
Phase relationship with the power frequency	no relation
Polarity of the first half-period	positive and negative
Coupling capacitor for the CDN:	0.5µF in both the high and the common path
Decoupling inductor for the CDN:	not defined.

The IEEE/ANSI C37.90.1-2002 standard was very closely harmonized with the European standard during its last revision in 2002. As you can see from the detailed specifications below, there are still some small differences between the American and European standards. These differences are very small, and all three sets of requirements may be met with the Haefely generator.

Voltage Waveform envelope:	A damped oscillatory wave, with the envelope decaying to 50% of peak value between the third and the sixth periods
Current Waveform	not defined
Rise time of first peak:	75ns ±20%, measured between 10% and 90% of the peak value
Frequency:	1MHz ±10%
Test voltage magnitude:	Initial crest of 2.5kV for common mode tests and for transverse tests, tolerance +0/-10%
Repetition rate:	6-10 bursts per period of power system frequency. Bursts shall be nonsynchronous with the power system frequency
Duration:	2 seconds +10/-0%. For relay with an operating time greater than 2 seconds, it is recommended that the test be carried out with a minimum time setting. In such cases, the period of application of the test signal shall be at least be as long as the operating time of the relay under test.
Source impedance:	200Ω resistive at 1MHz, tolerance ±20%
Coupling capacitor for the CDN:	≥33nF (common mode) or ≥66nF (differential mode) in both the high and the common path
Decoupling inductor for the CDN:	1.5mH

The IEC 60255-22-1:1988 also has very similar requirements:

Voltage Waveform:	A damped oscillatory wave, with the envelope decaying to 50% of peak value between the third and the sixth periods
Current Waveform:	not defined
Rise time of the first peak:	75ns ±20%
Frequency:	1MHz ±10%
Amplitude:	0.5 to 2.5kV +0/-10%
Repetition rate:	6-10 bursts per period of power system frequency, nonsynchronous with this frequency
Duration:	2s +10/-0%
Source impedance:	200Ω resistive at 1MHz, tolerance ±20%
Coupling capacitor for the CDN:	high frequency coupling capacitor 0.5μF
Decoupling inductor for the CDN:	high frequency blocking inductor 1.5mH

Waveform verification at the CDN output

The most important aspect in selecting a damped oscillatory wave generator is to ensure that the waveform requirements detailed above (specifically, rise time and damping) can be met not only at the output of the impulse circuit, but also at the output of the coupling / decoupling network (CDN) in all required coupling modes. This is important because of better reproducibility and to avoid overtesting or undertesting that can cause unnecessary costs in development and manufacturing. This is also an absolute requirement of both the IEC and the IEEE/ANSI standards, as clearly written in the following excerpts:

IEC 61000-4-12 edition 1.1 (2001)

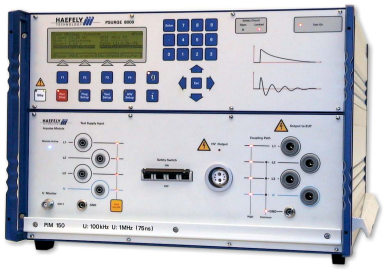
> *Section 6.3: Coupling/decoupling Network*
> *"**The network must not influence** the the specificed parameters of the test generator…"*
>
> *Section 6.3.1 Coupling/decoupling network for a.c./d.c. power supply ports*
> *"**The output waveforms from the coupling/decoupling network shall meet the same requirement**s set forth in 6.2 for the generator itself."*

IEEE/ANSI C37.90.1-2002

> *Section A.3 SWC test generator performance verification*
> *"All measurements in this section shall be preceded by conducting an SWC waveform validity test (see A.2). The addition of any components that are used during testing **shall be incorporated into the verification of the generator (i.e., coupling and isolation networks)."***
>
> *Section B.1 Waveform delivery principles*
> *"**The coupling network by itself shall not introduce additional waveform distortion** or rise time degradation."*
>
> *Section B.2 Verification of the waveform delivery system (CDN) characteristics*
> *"For common mode oscillatory and fast transient SWC tests, the measurements should be performed between the surge ground **and the surge output terminal of the coupling / isolating network assembly**. For a transverse mode oscillatory SWC test, the measurements should be performed between **the coupling / isolating network surge output** terminals, and between each of the terminals and the SWC generator ground (balance test). With the connections described above, **the wave shape measured on the output of the waveform delivery system [CDN] should comply with all specifications given in 4.1 and 4.2 [waveform definitions section]".***

This requirement applies to differential mode connections and to common mode connections including the simultaneous coupling of all lines to earth. At present, Haefely's PIM 150 impulse module is the only commercially available product which can meet these requirements.

The Surge Platform System – Haefely model PIM 150



Haefely originally conceived the damped oscillatory tester as a standalone impulse module with a separate external coupling / decoupling network. After much development and research, we concluded that due to the extremely strict waveform definition and the cost required to achieve it, the only way to reliably meet the waveform requirements at the CDN outputs was to actually integrate the CDN into the impulse module. As a result, the PIM 150 combines the impulse circuit and a three phase CDN into a single compact module. In this way, Haefely is able to guarantee waveform compliance in all coupling modes.

Future Developments

The IEC TC77B WG11 working group is responsible for maintenance and modification of the IEC 61000-4-12 standard. This working group decided to split the IEC 61000-4-12 Edition 1 into two parts. The future IEC 61000-4-12 Edition 2 contains the ring wave 100kHz only. The damped oscillatory waves are moved to the new IEC 61000-4-18 which contains also higher oscillation frequencies up to 30MHz to simulate HEMP. Both of these standards are in draft status and under consideration. They also clarify some damping requirements and tolerances on the waveform parameters. Much of the IEC 61000-4-18 draft is under debate, and it is unclear whether or not this draft will pass voting as written. However, Haefely's PIM 150 does meet the requirements of this draft.

We estimate it will take some time before a new IEC 61000-4-18 standard is published, so the current IEC 61000-4-12 edition 1.1 is valid for the near future. Haefely is represented on the IEC TC77B WG11 working group and on the Swiss national IEC committee, so we will of course update this document in the future as required to discuss any new developments.

Additional Tests:

The standards mentioned above require additional transient immunity tests, including the Electrical Fast Transient /Burst (EFT/B) and the 100kHz ring wave. These tests are not discussed in this document, but as always, please feel free to contact your Haefely representative for more information or to discuss your specific needs.

Ordering Information:

Article No.	Short Description
249939	PIM 150 impulse module, damped oscillatory wave 100kHz and 1MHz
249900	PSURGE 8000, surge platform system controller (required with PIM 150)
249130	IP4A capacitive coupling clamp
249525	Interconnect cable, PIM 150 (Fischer) to IP4A (HVBNC)
249967	Measuring connector for waveform verification
249804	PCD 150 Coupling Decoupling Network for control and data lines
249970	WinFEAT&R control and reporting software

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Haefely has a policy of continuous product improvement. Therefore we reserve the right to change design and specification without notice.