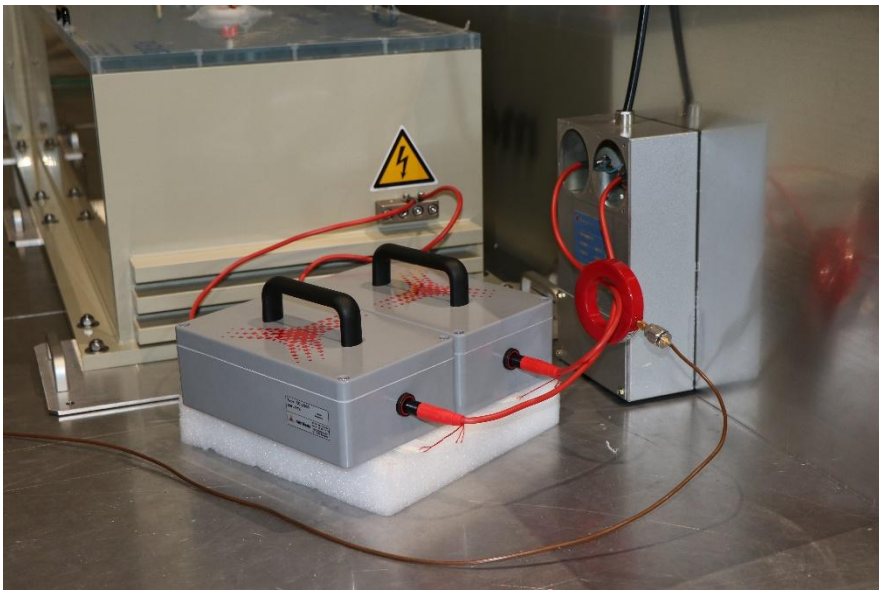
Pulsed Current Injection Test System MIL-STD-188-125/1&2



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1. Introduction

Montena PCI test system is designed to perform Pulsed Current Injection (PCI) tests according to MIL-STD-188-125-1 & 2.

“PCI acceptance testing is used to demonstrate that electrical POE (Point Of Entry) protective devices, as-installed, perform in accordance with the transient suppression / attenuation requirements of this standard. PCI verification testing confirms the transient suppression/attenuation performance in operational circuit configurations and demonstrates that mission-critical systems (MCS) are not damaged or upset by residual internal transient stresses.”

A typical test setup comprises following elements.

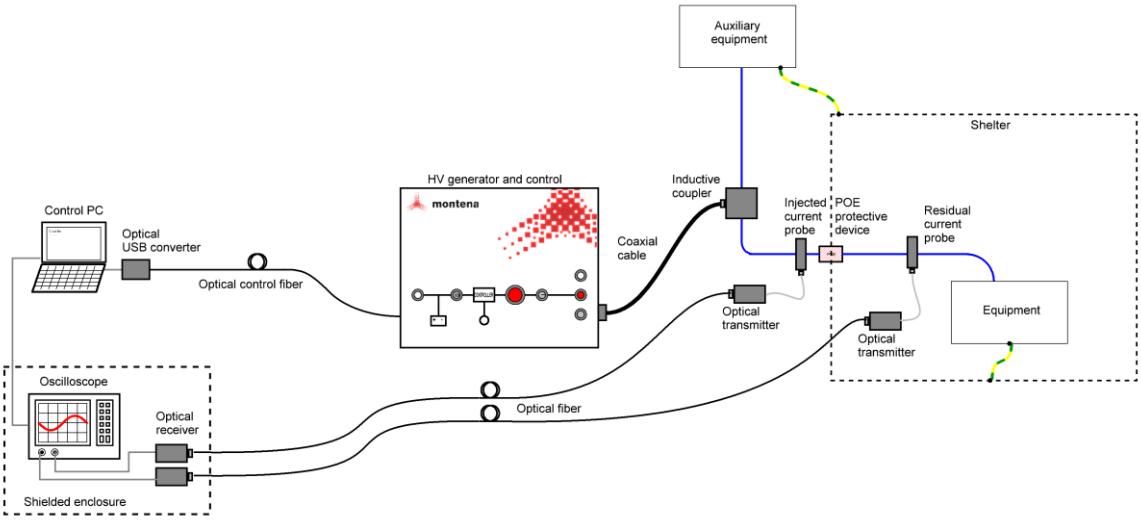


Figure 1: schematic of a typical PCI test setup installation

The high voltage pulse generator delivers the specified high current pulses either directly or through coupling devices into the wire attached to the protective device under test. The major part of the injected energy shall be shortcut to the grounded shielding. Only a small residual part of the pulse may enter the facility through the point of entry protective device. An oscilloscope measures the injected and residual pulse with current probes for display and eventually storage in the control PC. In order to ensure correct measurement, the current probes are connected using fibre optic links and the measurement equipment shall be installed in a shielded enclosure.

Montena PULSELab software application takes care of the configuration of the measurement oscilloscope. It directly provides the injected and residual current pulse shapes and parameters, what reduces to almost zero the risk of measurement errors.

Pulse shapes

Montena's PCI test system is able to perform pulsed current injection tests according to MIL-STD 188-125-1 & -2, short pulse (E1), intermediate pulse (E2) and charge line pulse tests.

	E1 - Short pulse	E2 - Intermediate pulse	Charge line pulse
Max. short circuit current (Isc)	≥ 5'000 Amp	≥ 250 Amp	≥ 400 Amp
Adjustable range of Isc	≤ 100 to ≥ 5'000 Amp	≤ 25 to ≥ 250 Amp	≤ 10 to ≥400 Amp
Waveform	Double exponential	Double exponential	Variable pulse width
Rise time (10%~90%)	≤ 20 ns	≤ 1.5 µs	≤ 5 ns
FWHM (50%~50%)	500 .. 550 ns	3 .. 5 ms	variable
Source impedance	≥ 60 Ω	≥ 10 Ω	≥ 50 Ω

MIL STD also specifies a long pulse (E3) test, which has only been done in the past by a couple of government organisations. It is technically very difficult to realise, and only makes sense for equipment connected to very long electrical lines. Such long electrical lines are no more used in telecommunication. In the power grid, the protection of such very long high voltage power line shall also consider other high energy effects as lightning, short cuts, and even solar storms.

Types of tests

MIL-STD 188-125-1 &-2 describes acceptance, verification and reverification tests.

The **acceptance tests** of a system, subsystem, or component are performed to ensure that specified HEMP performance characteristics have been met. They are conducted near the conclusion of a hardening production or installation contract, for the purpose of demonstrating that at least minimum performance requirements of the HEMP protection measures have been achieved before the unit is accepted by the Government from the contractor.

The **verification tests** are conducted for demonstrating that the installed HEMP protection measures provide the required HEMP hardness. These tests are performed after the production and acceptance testing are complete and after the equipment is installed and functioning, to determine if the operational system suffers mission-aborting damage or upset due to simulated HEMP excitations.

The **periodic reverification tests** are conducted at prescribed intervals during the operational phase of the system life cycle for evaluating whether the HEMP protection measures continue to provide the required HEMP hardness. The reverification test requirements are established in the technical manual. They typically require repetition of some or all of the test procedures from the original verification test program.

The periodic reverification test can be for instance reduced to a lower level E1 (short pulse) test. Such a test already can verify the reaction of the HEMP protective measures, but without too much stress and risk of alteration of the protecting devices. Montena has designed a portable E1 test setup optimized for these periodic reverification tests.

2. Portable low level short pulse test setup

This test setup shall be used for the injection of the short pulse (E1) with a peak current intensity of up to 1200 A. It has been designed to ease the onsite tests, especially for the periodic reverification campaigns.

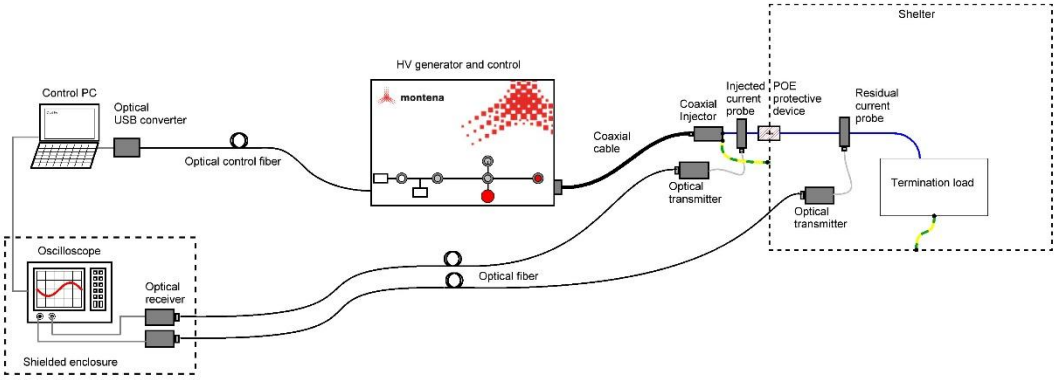


Figure 2: typical acceptance test setup with the PG-E1-1200 generator

1200 Amp Short Pulse Generator

The portable generator **PPG-E1-1200** generates output current pulse according to MIL STD 188-125, E1. It has an internal impedance of ≥60 ohm and its charging may be set between 3 kV and 80 kV to deliver short circuit current pulses in the range of 50 A to 1200 A.

The generator is compact, battery powered for easy deployment at customer site, where power is not always available. The power autonomy is up to one day and it can be charged from a 110V – 240V power plug directly.

The generator is remote controlled from a web-based software application through a USB over fibre link. The operator is thus electrically insulated from the high voltage elements.

The generator is delivered with a ruggedized transportation box on wheels for easy deployment on site.

SPECIFICATIONS	
Type	**PPG-E1-1200**
Standard	MIL-STD-188-125-1 and -2 / short pulse (E1)
Peak current (short circuit)	50 A to 1.2 kA
Peak voltage (open circuit)	3 kV to 80 kV
Output waveform	double exponential
Source impedance	≥ 60 ohms
Pulse rise-time (short circuit)	≤ 20 ns
Pulse length (FWHM, short circuit)	500 - 550 ns
Output interface	8 meters HV coaxial cable with a termination resistor
Insulation	oil
Interfaces	USB over fibre optic
Power rating	110 – 130 / 220 – 240 Vac, 50 / 60 Hz
Autonomy (on internal battery)	more than 24 hours
Generator dimensions	55 x 50 x 25 cm (L x W x H)
Weight	37 kg (with external HV cable), 67 kg (total incl. transport case and accessories)

Couplers for the PPG-E1-1200 generator

Couplers usually are required for verification or reverification tests, when the equipment is installed and functioning. The below schematic shows a typical setup for a verification test with a 3 wires common mode injection.

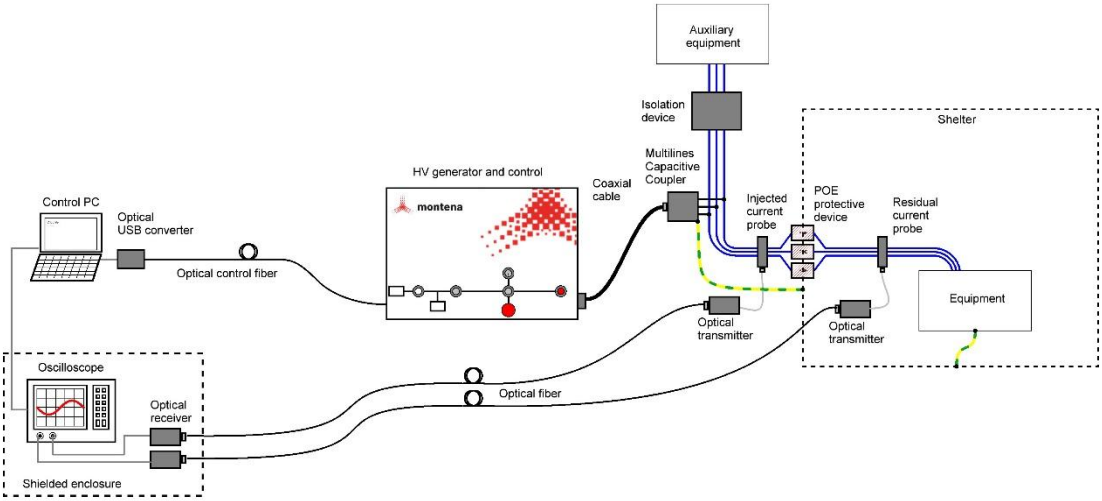
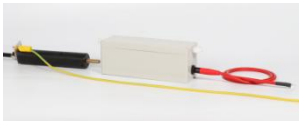


Figure 3: typical verification test setup with the PG-E1-1200 generator

Montena proposes 3 models of couplers to be used when performing verification or reverification tests with the **PPG-E1-1200** :



- CC-E1-1200-1 is a capacitive coupler for the current injection on one power or data wire.

- CC-E1-1200-4 is a capacitive coupler for the common mode current injection on one to four power or data wires.

- IC-E1-1200 is an inductive coupling clamp for the common mode current injection on a torch of wires

All these couplers can be easily connected to the generator output cable termination.

3. High level short pulse test setup

This test setup shall be used for the injection of the short pulse (E1) with a peak intensity between 1500 A and 5000 A.

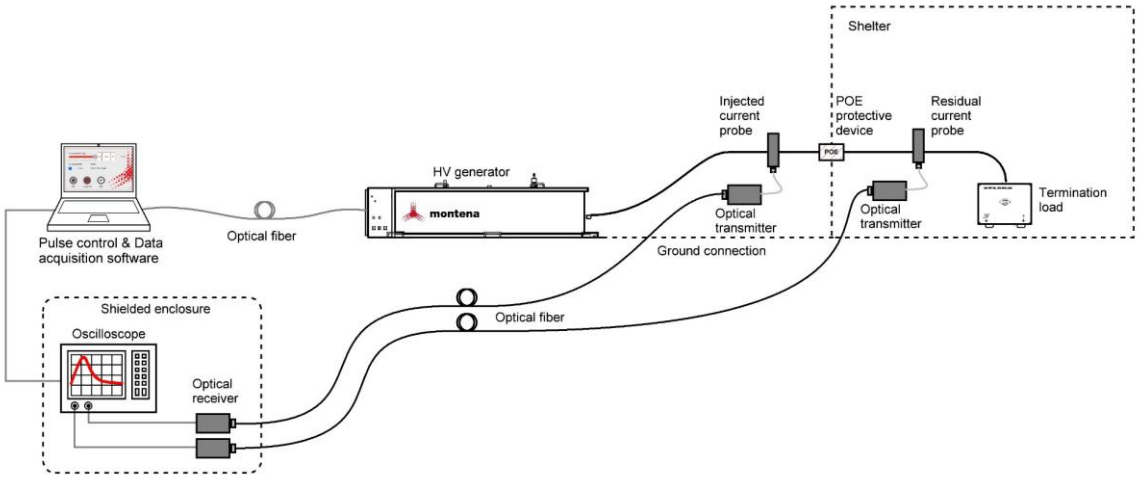


Figure 4: typical acceptance test setup with the EMP300K-5-500 generator

5000 Amp Short Pulse (E1) Generator

To fulfil the MIL-STD test specifications up to more than 5000 A peak current with a 60 Ohm internal impedance, this short pulse generator must be charged at over 300 kV. The generator is based on a Marx technology.

The generator is remote controlled from a web-based software application through a USB over fibre link. The operator is thus electrically insulated from the high voltage elements.

SPECIFICATIONS	
Type	**EMP300K-5-500**
Standard	MIL-STD-188-125-1 and -2 / short pulse (E1)
Peak current (short circuit)	≤ 1.5 kA to 5 kA
Peak voltage (open circuit)	100 kV to 350 kV
Output waveform	double exponential
Source impedance	≥ 60 ohms
Pulse rise-time (short circuit)	< 20 ns
Pulse length (FWHM, short circuit)	500 - 550 ns
Output interface	Bar with screws
Insulation	SF6
Interfaces	USB / optic fiber
Power rating	210 – 250 Vac, 50 - 60 Hz, 600 VA
Generator dimensions	188 x 60 x 42 cm (L x W x H)
Weight	about 175 kg

Couplers for the EMP300K-5-500

Couplers usually are required for verification or reverification tests, when the equipment is installed and functioning. The below schematic shows a typical setup for a verification test with a 2 wires common mode injection.

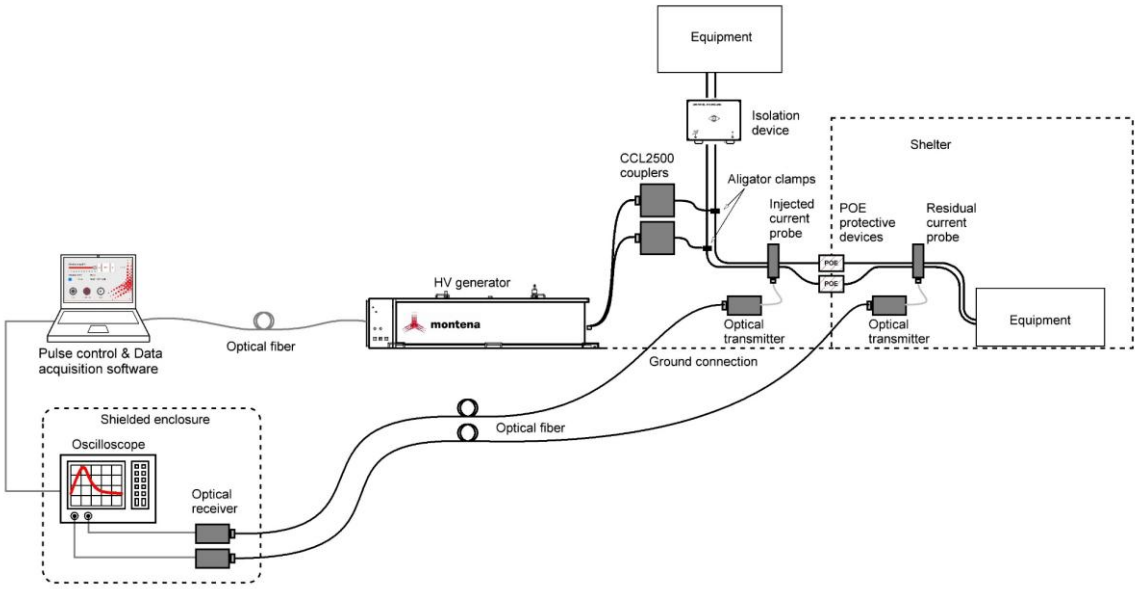
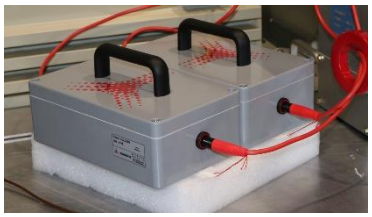


Figure 5: typical verification test setup with the EMP300k-5-500 generator

Montena proposes 2 models of couplers to be used when performing verification or reverification tests with the **EMP300K-5-500** :



- CCL2500 is a capacitive coupler for the current injection on one power or data wire.

- IC3B is an inductive coupling clamp for the common mode current injection on a torch of wires or on shielded cables.

4. Intermediate pulse test setup

This test setup shall be used for the injection of the intermediate pulse (E2) with a peak intensity up to 260 A.

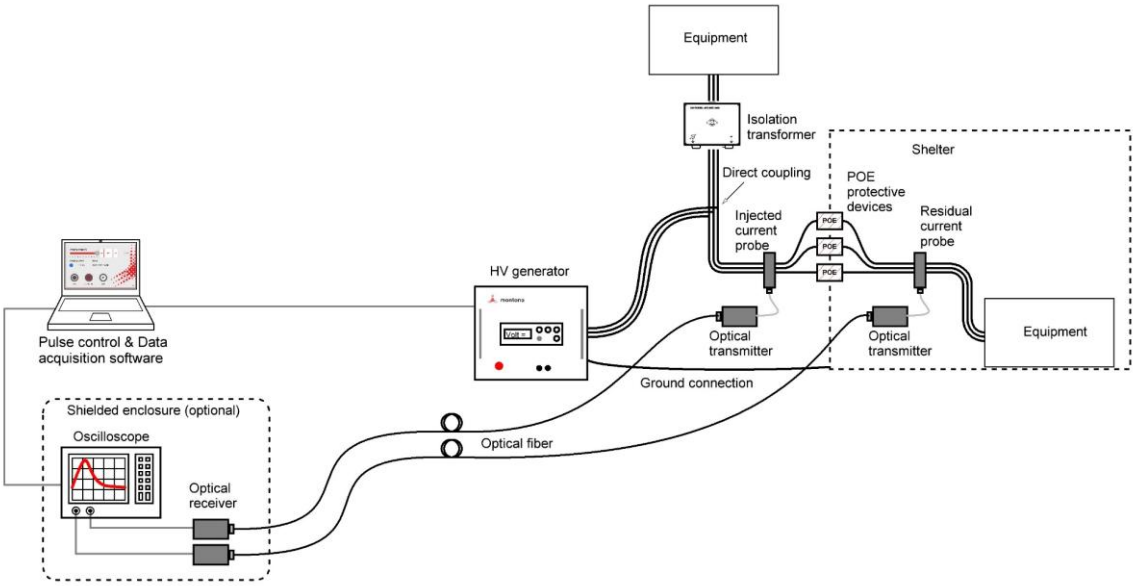


Figure 6: typical verification test setup with the IPP3K-4MS generator

Intermediate Pulse Generator

This generator is built using a direct discharge of high voltage capacitors.

SPECIFICATIONS	
Type	**IPP3K-4MS**
Standard	MIL-STD-188-125-1 and -2 / intermediate pulse (E2)
Technology	direct discharge
Peak short circuit current	25 A to 260 A
Peak voltage (open circuit)	3 kV max, positive only
Output waveform	double exponential
Source impedance	≥ 10 ohms (typ. 11 ohms)
Pulse rise-time (short circuit)	< 1.5 µs
Pulse length (FWHM, short circuit)	3 - 5 ms
Output interface	4 outputs, Multicontact (safety connectors)
Interfaces	RS 232 / USB
Power rating	90 – 264 Vac, 50 - 60 Hz, 1.6 kVA
Generator dimensions	51 x 40 x 55 cm (W x H x L)
Weight	42 kg

Couplers for the IPP3K-4MS

Because of the low frequency content of the intermediate pulse neither capacitive nor inductive coupling is possible. The IPP3K-4MS generator has 4 independent outputs which can be directly connected to 4 wires, even if those are carrying power or signals. Following methods are then recommended:

- On shielded cables: direct connection to the generator.
- On mains AC / DC supply connections: direct coupling to the pulse generator. The mains source or the auxiliary test equipment must be powered through an isolating transformer in order to force the current of the pulse to flow in the protective device. In this way, the "external load" is isolated. The intermediate pulse generator is equipped with 4 independent outputs which will allow the coupling on 4 lines. The pulse will be injected on 1 (wire-to-ground) or 2, 3 or 4 lines (common mode).
- On signal / data / telecom cables 1 A / 4 wires / 60 V_{dc} / 1 A a direct coupling is carried out through the 4 outputs of the generator.
  A transformer could also be used to isolate the connected equipment from the external world.

Summary: we recommend using direct coupling. No specific coupling device is proposed. Eventually a 60 A / 230 V_{ac} isolating transformer may be proposed as an option.

5. Charge line pulse test setup

This test setup shall be used for the injection of the variable length pulse into coaxial protective devices with a peak intensity of 400 A.

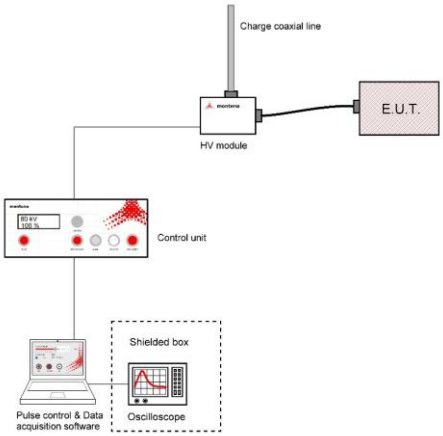


Figure 7: typical test setup with the CLP40K generator

Charge Line Pulse Generator

The CLP40K generator is based on a variable charge line. In order to adjust the length of the charge line to the quarter-wavelength of the applicable frequency, special coaxial plugs must be connected to the pulse generator. A set of 10 plugs are supplied with the generator to cover the frequency range of 30 to ~250 MHz.

For higher frequencies montena has developed the CLP5K, with lower voltage, but por up to 477 MHz tests.

SYSTEM SPECIFICATIONS		
Type	**CLP40K**	**CLP5K**
Standard	MIL-STD-188-125-2 / charge line	
Charging voltage	0.2 - 25 kV, positive only	0.05 - 5 kV, positive only
Peak short circuit current	≥ 400 A (with the 30 MHz charge line plug)	≥ 50 A (at 5 kV charging voltage)
Source impedance	50 ohm	50 ohm
Pulse rise time, on 50 ohm	< 5 ns	< 600 ps
Charging time	< 30 sec	< 10 sec
Number of charge line plugs	10	11
Charge line test frequencies	30, 40, 50, 75, 100, 125, 150, 175, 220 and ~250 MHz	30, 45, 50, 60, 90, 106.5, 140.5, 215, 300, 312.5 and 477.5 MHz
Charge line and output connectors	2 x HVM50K(f), montena proprietary	1 x N(f), 1 x N(m), other on demand
Triggering of the generator	manually or by the remote control	
Control interface	RS 232 and USB	
Power rating	85 - 264 Vac / 50 - 60 Hz / 150 VA	
Dimensions (control unit)	56 x 19 x 45 cm (L x H x W)	
Weight (control unit)	15.1 kg	
Dimensions (HV module)	30 x 12 x 20 cm (L x H x W)	21 x 6 x 4 cm
Weight (HV module)	3.2 kg	0.55 kg

The coupling of the charged line pulse is carried out by direct connection of the coaxial cable / connection to test to the pulse generator. No coupling device is proposed.

6. Pulse measurement equipment

Current probes

The injected and residual current pulses are monitored with off-the-shelf current probes. Attention has to be given to the possible saturation of the probe (i * t).

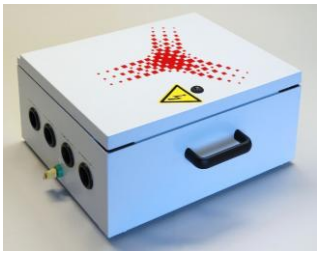
Fibre optic links

Montena has developed a range of broadband analogue signal transmissions over fibre, with highly shielded optical transmitter and receiver modules.

The model MOL2000T is particularly suited for monitoring fast pulses such as the Short Pulse (E1) while the MOL500T may be used for monitoring the Intermediate Pulse (E2).

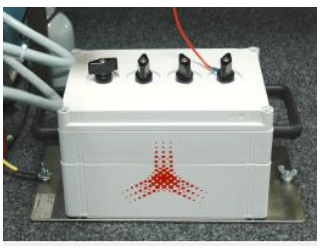
	MOL25T	MOL500T	MOL2000T
Frequency range	DC - 25 MHz	DC - 500 MHz	80 Hz - 3.5 GHz
Channel(s) per module	2	1	1
Input impedance	1 MΩ	50 Ω or 1 MΩ selectable	50 Ω
System attenuations / gain (remotely selectable)	1:1 / 10:1 / 100:1	1:1 / 10:1 / 100:1	-62.5 dB to +24 dB
Signal processing	12-bit AD/DA converters	100% analog (electro-optic)	100% analog (electro-optic)

7. Test accessories



During verifications tests, isolators, which are compatible with normal operation of the circuit, shall be installed on the conductors under test to direct the injected current toward the POE protective device.

Montena proposes the DL3 and DS3 which are multi lines isolators/decouplers based on a high energy low-pass filter that will block the major part of the E1 pulse.



During the acceptance test on protecting devices, the internal load shall be a dummy resistor of the value specified in the MIL STD document.

Montena proposes the TLB4, a dummy resistor box with multiple non inductive resistors to terminate the line under test.

8. PULSELab software

The system is delivered with PULSELab, montena pulse measurement software application.

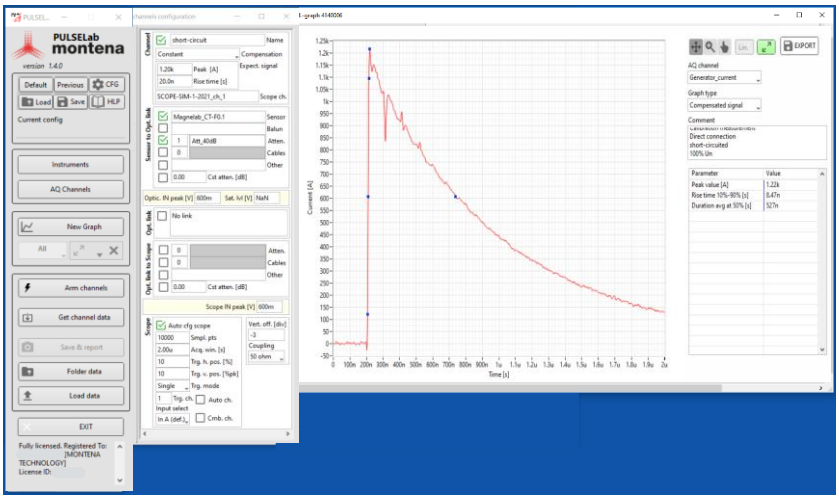


Figure 8: example of pulse measurement using PULSELab software

PULSELab has been especially developed to ease the measurement of electromagnetic, voltage or current pulses.

PULSELab

- Controls the measurement equipment
- Sets the needed attenuation of the optical transmission to avoid saturation of the transmission, based on the selected injected current and on the current probes
- Sets the oscilloscope parameters based on the expected signal
- Processes and displays the measurements
- Perform time and frequency domains compensation taking into account the different elements of the measurement chain (probes, cables, attenuators, fibre optic links ..etc)
- Display the measured current pulse in Amperes, based on the transfer function of the current probe and optical link transmission
- Display the pulse characteristics
- Display the test results : based on Pass & Fail criteria
- Generates a test report including all measurement results

9. Shielded enclosure and control room

Montena can propose additional equipment to facilitate the PCI test, as for instance :

Shielded tent

A shielded tent may be recommended to protect the surrounding electronic equipment from the electromagnetic disturbances during onsite PCI tests sessions.

Shielded enclosure

The SB3G is a shielded enclosure especially designed to protect measurement instrument in rash electromagnetic environment. The measurement oscilloscope must be protected from the electromagnetic disturbances to ensure a correct measurement of the current pulses.

Shielded mobile control room

It may be useful to have a mobile shielded control room for onsite test campaigns.

Montena can propose a shielded control toom installed in a maritime container, with air conditioning, diesel power supply, and equipped with shelves for the storage and the transportation of the test equipment.

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