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

System Description

Version 5.2

montena technology sa

montena technology sa - 1728 Rossens - Switzerland - phone +41 26 411 84 84 - fax +41 26 411 17 79
www.montena.com e-mail: products@montena.com

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1. PCI test system description

Montena's EMP PCI test system is designed to perform Pulsed Current Injection (PCI) tests according 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."*

The test setup comprises following elements.

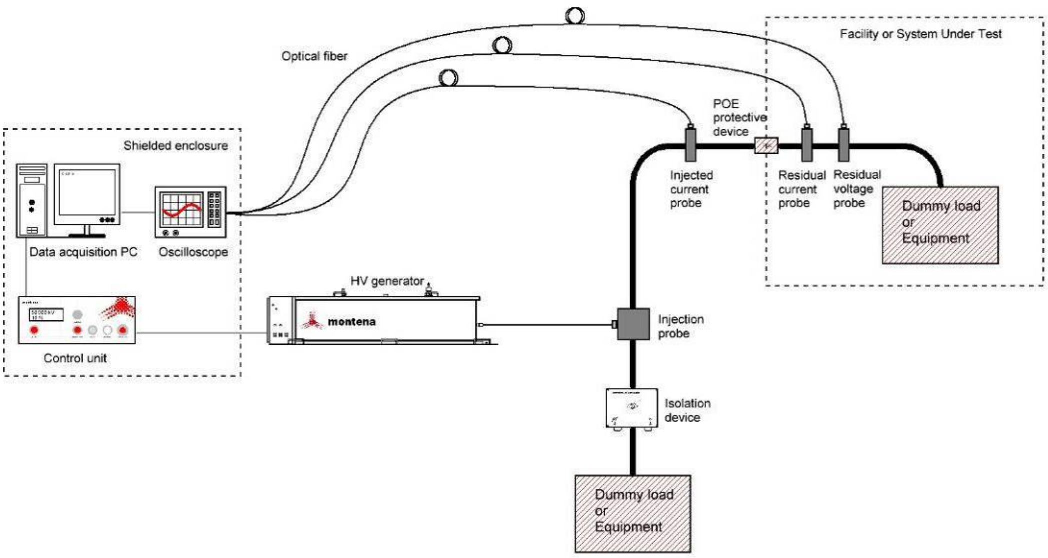

Figure 1 : Schematic of a typical PCI test setup installation

The pulse generators deliver the high energy pulses either directly or through coupling devices in the cable under test. The pulse enters the facility under test through the point of entry protective devices.

An oscilloscope collects the measurements from the current and voltage sensors for display and eventually storage in the control PC. In order to ensure correct measurement the sensors are connected using fibre optic links. The measurement and control systems are installed in a shielded measurement container.

Pulse shapes

Montena's PCI test system is able to perform pulsed current injection tests according MIL-STD 188-125-1 & 2, except for the long pulse. The long pulse is practically not used as it is technically almost impossible to realise and as it does only make sense for very long electrical lines which are no more used in telecommunication.

	Short pulse	**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

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2. Pulse generators and control units

The test system described in this document comprises four pulse generators designed and built by Montena. Each generator can be either directly controlled or remotely controlled via its RS232 or USB interface.

2.1 Short pulse generators & control units

To fulfil the MIL-STD test specifications (>5000 A with 60 Ohm), the short pulse generator has to deliver more than 300 kV. Additionally, to be able to test different type of POE protecting devices, it should be possible to perform tests at lower voltage (some tens of kV).
It is physically not possible to design a Marx generator for the whole required voltage range (10 kV – 300 kV). Two generators are proposed:

- EMP80K-5-500 : a 80 kV direct discharge pulse generator (10 kV – 80 kV)
- EMP300K-5-500 : a 350 kV high voltage Marx generator (~80 kV – 350 kV)

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80kV Short Pulse Generator

This generator is built around one single stage of high voltage capacitors directly charged from a high voltage power supply. The system comprises the high voltage unit and the control unit.

Figure 2 : Picture of an EMP80K-5-500 with its control unit

Specifications

Type	**EMP80K-5-500**
Standard	MIL-STD-188-125-1 and -2 / short pulse
Peak open circuit voltage	≤ 5 kV to 80 kV, positive only
Source impedance	≥ 60 ohm
Peak short circuit current	80 A to > 1 kA
Current pulse rise time (short circuit)	< 20 ns
Current pulse length (short circuit)	500 - 550 ns (FWHM)
Charging time	< 1 min
Output connectors	connecting bar with different drilling diameters
Insulation	oil
Interface	RS 232 / USB on the control unit
Power rating	85 - 264 V_{ac} / 50 - 60 Hz / 150 VA
Storage / working temperature	5 - 50 °C / 15 - 45 °C
Dimensions (control unit / generator)	56 x 19 x 45 cm / 92 x 38 x 55 cm (L x H x W)
Weight (control unit / generator)	~11 kg / ~80 kg (with oil)

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350 kV Short Pulse Generator

This generator is built around a Marx generator delivering up to 350 kV in open circuit and more than 5 kA in short circuit. It comprises the high voltage Marx unit and the control unit.

Figure 3 : Picture of an EMP300K-5-500 with its control unit

Specifications

Type	**EMP300K-5-500**
Standard	MIL-STD-188-125-1 and -2 / short pulse
Type	Marx + peaking
Peak erected voltage	100 to 350 kV, positive only
Peak short circuit current	<1.5 kA to 5 kA
Source impedance	≥ 60 ohm
Current rise time (short circuit)	< 20 ns
Current pulse length (short circuit)	500 - 550 ns (FWHM)
Charging time	< 1 min
Insulation	SF_6 and N_2
Output connector	custom (connecting bar)
Interface	RS 232 and USB on control unit
Power rating	210 - 250 V_{ac} / 50 - 60 Hz / 600 VA
Storage / working temperature	5 - 50 °C / 10 - 45 °C
Dimensions (control unit / generator)	45 x 19 x 56 cm / 60 x 42 x 188 cm (W x H x L)
Weight (control unit / generator)	~13 / ~175 kg

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2.2 Intermediate pulse generator & control unit

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

Figure 4 : Picture of an IPP3K-4MS pulse generator

Specifications

Type	**IPP3K-4MS**
Standard	MIL-STD-188-125-1 and -2 / intermediate pulse
Charging voltage	3.0 kV max, positive only
Peak short circuit current	25 A - 260 A
Source impedance	> 10 Ω (typically 11 Ω)
Pulse shape	double exponential waveform
Typical current rise time (short circuit)	0.6 µs
Typical current pulse length (short circuit)	3.4 ms (FWHM)
Charging time	< 45 sec
Output connectors	4 outputs, safety connectors
Interface	RS 232 / USB
Power rating	200 V to 264 V / 50 / 60 Hz / 1.6 kVA peak
Storage / working temperature	5 - 50 °C / 10 - 45 °C
Dimensions (L x H x W)	55 x 40 x 51 cm
Weight	42 kg

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2.3 Charge line pulser

This 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 cables must be connected to the pulse generator. A set of 9 cables are supplied with the generator to cover the frequency range of 30 to 300 MHz.

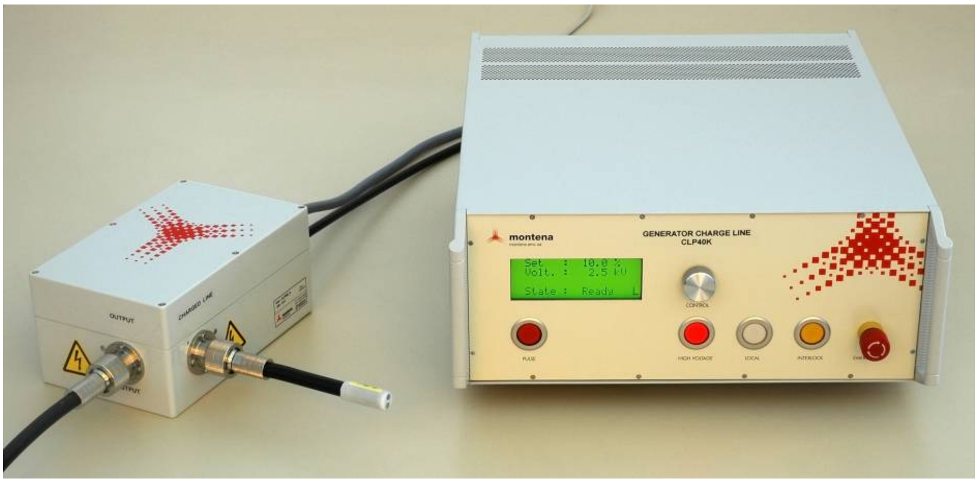

Figure 5 : Picture of an CLP40k pulse generator

Specifications

Type	**CLP40K**
Standard	MIL-STD-188-125-2 / charge line
Charging voltage	0.2 - 25 kV, positive only
Peak short circuit current	40 A to 400 A
Provided lines (electrical lengths)	6, 15, 18, 23, 31, 50, 67, 100, 125, 167 cm
Source impedance	50 ohm
Rise time of the current, on 50 ohm	< 5 ns
Charging time	< 30 sec
Charge line and output connectors	HVM50K-S (montena proprietary)
Interface	RS 232 / USB
Power rating	85 - 264 Vac / 50 - 60 Hz / 150 VA
Storage / working temperature	5 - 50 °C / 10 - 45 °C
Dimensions (control unit / HV unit)	56 x 19 x 45 cm / 30 x 12 x 20 cm (L x H x W)
Weight (control unit / HV unit)	~15 / ~3.2 kg

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3. Pulse coupling devices

The pulse generator have to be somehow connected to the cable under test as shown in *Figure 1 : Schematic of a typical PCI test setup installation*.

In this document we propose some solutions for a coupling on following typical types of cables / connexions:

- shielded cables
- mains AC / DC supply, 2 wires, 50 A, 230 V_{ac} or 60 V_{dc}
- signal / data / telecom cables, 4 wires, 1 A, 60 V_{dc}.

A) Short pulse coupling

The coupling can be direct, inductive or capacitive, depending from the type of cable to be tested and if the cable has to be tested when in-service.

The output of the short pulse generators (EMP300K-5-500 and EMP80K-5-500) are acting as mechanical switches. This means the output can be connected to any kind of cable even if this cable is carrying a signal or power.

See the different types of proposed couplers in the next paragraphs.

B) Intermediate pulse coupling

Because of the low frequency content of the intermediate pulse neither capacitive nor inductive coupling is possible. Very high capacitance / inductance would be required for the coupling efficiency. And these very high capacitance / inductance would drain high current from the device or from the source connected to the line under test.

The intermediate pulse generator (IPP3K-4MS) has 4 independent outputs which can be connected to 4 independent 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 to use direct coupling. No specific coupling device is proposed. Eventually a A 60 A / 230 V_{ac} isolating transformer could be proposed as an option.

C) Charge line pulser coupling

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.

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3.1 Inductive coupler

The inductive coupler shown below can be used for the short pulse common mode coupling on any type of cable bundle. It allows the injection of the pulsed current without interrupting the cable bundle to test.

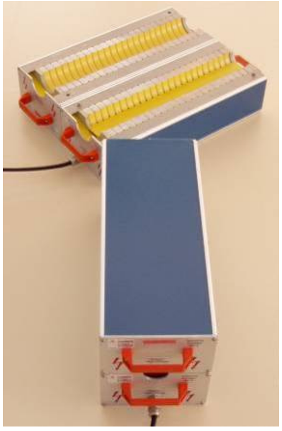

Figure 6 : Picture of the inductive coupler

Specifications

Type	**IC3B**
Frequency range	180 kHz - 60 MHz (+0 / -10dB)
Maximum peak voltage	100 kV (500 ns pulse)
Maximum peak current	≥ 5 kA
Max. diameter of the tested cable	63 mm
Connector	rings terminals
Weight	~55 kg
Dimensions (W x H x L)	21 x 25 x 77 cm

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3.2 Capacitive couplers and isolation devices

The capacitive couplers shown below can be used for the wire-to-ground coupling of the short pulse on any type of cables. They allow the injection of the pulsed current when the cables are in services. The different versions are adapted to the signal or to the mains supply connexions.

The capacitive coupling can be combined with the isolating network DS3 or DL3. See the *chapter 4 Isolating devices* for more information on the isolation network.


Figure 7 : Picture of a capacitive couplers CCS3 and CCL2500

Specifications

Reference	**CCS3**	**CCL2500**	**DS3**	**DL3**
Type of signal	signal	mains supply	signal	mains supply
Type	coupler	coupler	decoupling box	decoupling box
Nominal voltage (DC - 400 Hz)	230 V	230 V	230 V	230 V
Nominal current (DC - 400 Hz)	60 A	-	10 A	60 A
Number of lines	4	1	4	2
Max pulse voltage (500 ns)	> 80 kV	> 80 kV	> 80 kV	> 80 kV
Max DC voltage	> 35 kV_{dc}	-	-	-
Maximum peak current	> 5 kA	> 5 kA	> 5 kA	> 5 kA
Signal cut-off frequency	-	-	3 kHz (- 3 dB)	3 kHz (- 3 dB)
Connector	connecting bars	Multicontact	connecting bars	connecting bars
Weight	14 kg	2.6 kg	17 kg	14.5 kg
Dimensions (L x H x W)	70 x 24.5 x 42 cm	27 x 14 x 16 cm	56 x 24.5 x 50 cm	56 x 24.5 x 50 cm

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4. Isolating devices

The purpose of these decoupling devices is to isolate the "external load" (= the mains, the auxiliary equipment, etc.) from the pulses injected by the generators.

Unfortunately using isolating devices is not always possible due to the fact that these devices can also block the signal if their frequency is in the same range than the pulse. So we generally recommend to inject the pulses only on lines and connections which are not connected to active auxiliary equipment.

A) Short pulse decoupling

Due to the high voltage of the short pulse generator, the decoupling requires capacitors and inductances of large dimensions. In addition, the rather high value of the decoupling components will exhibit a low pass filter behaviour not compatible with most of the ordinary data signals. Other coupling / isolating methods must be used in these cases.

We propose some isolating devices included in the capacitive coupling cabinet (DS3 or DL3). See specifications in chapter 4.2 Capacitive couplers and isolation devices.

B) Intermediate pulse decoupling

Because the frequency content of the pulse is the range of some Hz to some kHz, it is not possible to use isolating devices. The signals and even the mains 50 / 60 Hz will be blocked by the decoupling devices. Finally the size, weight and price of these devices will be prohibitive.

C) Charge line pulser decoupling

Because the pulse is injected directly on the coaxial connection, isolating devices are neither possible nor needed.

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5. Termination loads

A set of 0.2 / 0.5 / 2.2 / 50 ohm termination loads are usually proposed as option. These loads can be connected to the end of the tested lines, inside or/and outside the protected area to terminate the line and absorb the injected current pulse.

Figure 8 : Picture of termination resistor box TLB4

They are not applicable to the AC / DC supply.

The termination loads consist of a box containing 4 resistors of different values. The specifications are the following:

Type	***TLB4***
Standard	MIL-STD-188-125-1/-2
Resistance values	0.2 / 0.5 / 2.2 / 50 ohm
Energy	16.5 kJ
Peak voltage (short pulse)	30 kV
Power	70 W
Connector	proprietary
Weight	12 kg
Dimensions (cm)	52 x 35 x 25

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6. System monitoring

The recommended test monitoring comprises current and voltage sensors, an oscilloscope and a PC with its software for automatic control, data acquisition and automatic report generation.

Current sensors

Required are at least two current sensors: one measuring the injected current and one for the residual current.

Residual voltage sensor

In order to have a good measurement sensitivity, two residual voltage sensors are recommended:

one 1000x voltage probe and one 100x voltage probe.

Optical link transmission

For reliable measurement, the transmission between the sensors and the control room has to be immune to the generated field. A fibre optic link is recommended for each sensor. The proposed optical transmission comprises 4 links:

- 2 x Acquisition Module (50 Ohm) for current sensors
- 1 x Acquisition Module (1 MOhm) for voltage sensors

Digital Oscilloscope

We recommend a digital oscilloscope with following characteristics:

- 4 channels digital oscilloscope
- 2 GHz bandwidth
- 5 Gs/s (10 Gs/s max)

It has to be noticed that the oscilloscope has to be integrated in the control and measurement software.

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7. Control and data acquisition system

7.1 Data acquisition software

Montena proposes a customized data and acquisition software to ease the test procedure and to reduce the risk of human errors. This software is developed by montena with Labview, specifically for this test setup.

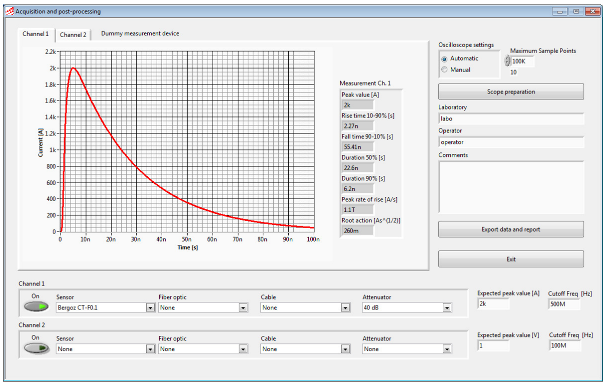
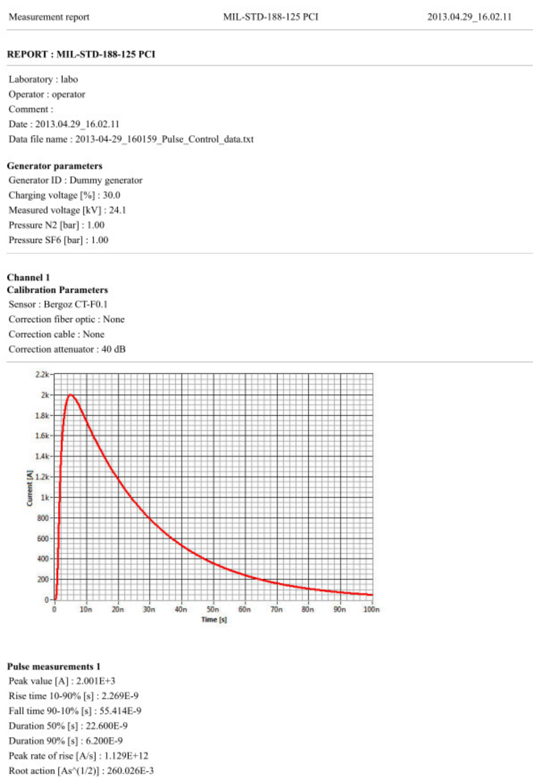


Figure 9 : Example of Montena's LabView based application



Measurement report MIL-STD-188-125 PCI 2013.04.29_16.02.11

REPORT : MIL-STD-188-125 PCI

Laboratory : labo
Operator : operator
Comment :
Date : 2013.04.29_16.02.11
Data file name : 2013-04-29_160159_Pulse_Control_data.txt

Generator parameters
Generator ID : Dummy generator
Charging voltage [%] : 30.0
Measured voltage [kV] : 24.1
Pressure N2 [bar] : 1.00
Pressure SF6 [bar] : 1.00

Channel 1
Calibration Parameters
Sensor : Bergoz CT-F0.1
Correction fiber optic : None
Correction cable : None
Correction attenuator : 40 dB

Pulse measurements 1
Peak value [A] : 2.001E+3
Rise time 10-90% [s] : 2.269E-9
Fall time 90-10% [s] : 55.414E-9
Duration 50% [s] : 22.600E-9
Duration 90% [s] : 6.200E-9
Peak rate of rise [A/s] : 1.129E+12
Root action [As^(1/2)] : 260.026E-3

Figure 10 : Example of a automatically generated test report

The proposed software is built with the existing basic blocks developed by montena to control the generators and the measurement equipments, to collect measured data, and to process the data for display and automatic report generation.

The software contains calibration panels to set the correction factors of sensors and transmission links.

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The software can be designed according to the specific customer's needs of the PCI test system operation and will be presented to the end customer for approval before its final implementation.

Montena delivers the software as well as the source code. The end customer has then the possibility to extend / modify this software according future needs. Of course montena can also be mandated for these eventually future adaptations.

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8. Electric POE protective devices

A set of NEMP filters can be optionally proposed to perform FAT, SAT and other types of calibration or reference tests. The recommend list of filter samples comprises:

AC power line filters

One NEMP AC power line filter for 4 lines (3L + 1N) 400/230V, 50/60Hz for up to 40Amp.

DC power line filters

Two NEMP DC power line filters for a DC powering up to 30V DC / 10A.

Data line filters

Two NEMP fast data protectors - (up to 155 MBit/s)

(For a single Ethernet 10/100 MBit/s application two (2) protectors are necessary - one protector for one wire pair).

Digital telephony line filters

Two NEMP low to medium data rate protectors - (up to 2MBit/s).

VHF test filters

Two NEMP VHF antennas lines filter - (DC – 1000 MHz).

9. Services & Support

9.1 Manuals and documentation

The provided documentation comprises:

- A system level installation and user manuals
- Installation and user manuals of each delivered equipment
- An installation and user manual for the data and acquisition software
- Source code of the data and acquisition software

9.2 Onsite installation and training

Montena provides worldwide onsite installation performed by montena's engineers with help of skilled and unskilled workmen provided by the customer.

A comprehensive training session is offered and will be given directly after installation. This training will be provided by an engineer from montena and includes the test system installation, operation and maintenance.

The content of the training sessions will be defined according to the end customer desires.

9.3 System acceptance

The test system acceptance procedure is performed with a verification of the generated test pulses and comprises:

- A measurement of the generated current and voltage pulses
- A measurement of residual current and voltage pulses behind the provided NEMP filters
- A comparison with the typical specifications of the filters.

The acceptance comprises two phases:

- A FAT (factory acceptance test) at Montena in Switzerland to demonstrate the system performance (one week for 2 people from the end customer)
- A SAT (site acceptance test) performed at the end customer location, after the system installation. An acceptance report is delivered and signed by both the end customer and montena. The warranty period starts at the signature of this acceptance document.

9.4 Maintenance

No periodical maintenance other than calibration of the measurement equipment is required.

On customer request montena can offer this calibration service with support of montena's authorized local representative.

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10. Montena

Montena has been incorporated in 1903 as capacitor manufacturing company.

In 1978, the montena EMC division was created to address the arising EMC related problems. Since then montena has earned a worldwide reputation for its leading-edge skills in the fields of high voltage, high frequency and electromagnetic fields.

Montena can count on highly specialized know-how in the field of the electromagnetic compatibility. These skills are put to good use in the development and construction of various kinds of equipment, especially EMC test equipment and fast electrical pulse generator.

Montena designs, builds and markets equipment and accessories for EMC tests. The range of products includes antennas, TEM cells, striplines, field sensors, all kind of pulse generators, test benches, etc.

Montena's high voltage pulse generators are mainly used for EMC tests, high speed imaging and pulsed light decontamination. Montena also builds pulse generators according the custom specific needs.

10.1 MIL STD Systems references

Montena has sold and installed more than 20 NEMP simulators according to MIL STD 461, RS105 worldwide in the last 5 years.

The list below shows some references of test systems according to MIL STD 461, MIL STD 188-125 and other military standards.

Marx pulse generator 320 kV, rise time 5 ns / duration 80 ns with control unit

for NEMP test according to MIL STD 461 / RS105

NEMP test system according to MIL STD 461E - RS105 loading voltage 80 kV

rise time 2.3 ns / duration 23 ns

with 1.8 m high radiation line

NEMP test system according to MIL STD 461E - RS105

Marx pulse generator 120 kV, rise time 2.3 ns / duration 23 ns

with 2.7 m high radiation line

NEMP test system according to MIL STD 461E - RS105

Marx pulse generator 230 kV, rise time 2.3 ns / duration 23 ns

with 3.6 m high radiation line

NEMP test radiation for tests according to MIL STD 461E - RS105

Marx pulse generator 800 kV, rise time 2.3 ns / duration 23 ns

with 9 m high radiation line

NEMP test system according to MIL STD 461E - RS105

Loading voltage 75 kV

rise time 2.3 ns / duration 23 ns

connected to a GTEM, 1m septum height

HV pulse generator 12kV, rise time 5 ns / duration 200 ns

High voltage pulse generator 80kV, rise time 5 ns / duration 500 ns

for Pulse Current Injection (PCI) test according to MIL STD 188/125, appendix B (short pulse)

Marx pulse generator 350 kV, rise time 5 ns / duration 500 ns with control unit

for Pulse Current Injection according to MIL STD 188/125, short pulse

Pulse generator 3 kV, rise time 0.6 µs / duration 3.4 ms

for Pulse Current Injection according to MIL STD 188/125, intermediate pulse

Variable pulse length generator 25 kV, rise time < 5 ns

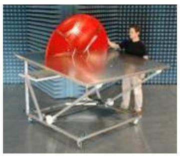
for Pulse Current Injection test according to MIL STD 188/125

Square pulse generator

for immunity test according to MIL STD 461 / CS115

Damped Sinusoidal pulse generator

for immunity test according to MIL STD 461 / CS116



HIRA antenna

Half impulse radiating antenna for the generation UWB E-field pulses (Ultra Wide Band pulses with sub nanosecond pulse duration)

ESD 300kV and P-static test system for helicopter and airborne systems

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