A PORTABLE MIL-STD-188-125 E1 TEST SYSTEM

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Abstract

MIL-STD-188-125 establishes requirements and design objectives for high-altitude electromagnetic pulse (HEMP) hardening of both fixed and transportable systems [2,3]. A pulsed current injection (PCI) system is presented which produces a >1 kA peak current waveform suitable for compliance testing many of the systems outlined within the MIL-STD. A novel, planar Marx generator topology is utilized as the 60-Ohm Norton-equivalent source in a suitcase-style package capable of being carried by one person. Pulse characteristics, and coupling methods for wire-to-ground, shield-to-ground, and bulk cable common-mode testing are also discussed.

I. INTRODUCTION

Pulsed current injection (PCI) is a test method used to measure the performance of a point of entry (POE) against a high-altitude nuclear electromagnetic pulse (HEMP), by injecting current into communication, data, or power lines, either through a direct connection, or through the use of a coupler [1]. Using MIL-STD-2169 (classified) as a basis for the NEMP waveform characteristics, MIL-STD-188-125 provides an unclassified version of the NEMP waveforms and gives specifications for injecting these waveforms onto various conductors used in both fixed and mobile platforms [2, 3]. As new systems are built for U.S. DoD customers, these systems may need to meet the MIL-STD-188-125 requirement before being used in the field. PCI testing for these systems must be conducted immediately after the facility or mobile platform is constructed to ensure all of the protection devices are in fact stopping the injected HEMP waveform from penetrating beyond the bulkhead. This test, known as a "verification test" is performed with the conductors terminated into dummy loads on either side of the bulkhead. The terminal protection devices (TPD's) are isolated, and the test verifies that the TPD does in fact eliminate or attenuate the injected signal to an acceptable level at the interior of the bulkhead. An "acceptance test" on the other hand, occurs when the facility or mobile platform is completed and in full functioning condition [2]. Acceptance testing is a mostly qualitative test that occurs while all systems are up and running. The "pass" condition for this test is based upon the equipment within the facility or platform operating without upset after a pulse is applied.

Given the number of lines present, varied location, and physically complex nature of these tests, a mobile PCI tester was sought that allowed the test operator the ability to easily move the pulse generator and couplers from test-point to test-point. This paper describes a planar Marx generator-based PCI system that is capable of being transported by an individual, and meets all of the short pulse waveform requirements in MIL-STD-188-125-2 (mobile platforms), and some of the waveform requirements in MIL-STD-188-125-1 (fixed installations).

II. MIL-STD-188-125 REQUIREMENTS

For all POEs in mobile platforms, with the exception of the non-buried long line, the highest current defined in MIL-STD-188-125-2 for testing is 1 kA (as shown in Table 1) [3]. For fixed installations, MIL-STD-188-125-1 defines a peak current of 5 kA for all POE's except for non-buried antenna lines, which the standard gives a maximum injection current of 1 kA [2]. As a result, the pulser described in this document is well suited for the testing of mobile platforms.

Table 1. Source parameters and waveforms from MIL-STD-188-125-2

Class of Electrical POE/Type of Injection	**Peak S.C. Current (A)**	**Src. Imp. (ohms)**	**Rise-time (s)**	**FWHM (s)**
Intrasite power line POEs				
Short pulse common mode	*1000*	*≥60*	$\leq 2x10^{-8}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short pulse wire-to-ground	*500*	*≥60*	$\leq 2x10^{-8}$	$5x10^{-7}$ - $5.5x10^{-7}$
Intrasite control/signal /data line POEs				
Short pulse common mode	*1000*	*≥60*	$\leq 2x10^{-8}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short pulse wire-to-ground	*1000/√N or 100*	*≥60*	$\leq 2x10^{-8}$	$5x10^{-7}$ - $5.5x10^{-7}$

The type of injection listed in the left-most column of Table 1 is demonstrated in the diagrams of Fig. 1. For common-mode, all conductors in a circuit are excited simultaneously. For wire-to-ground testing, each conductor is excited one at a time with respect to ground [2].

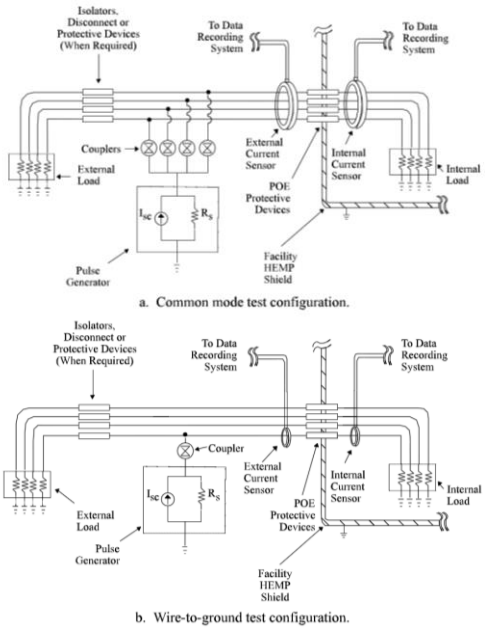

Figure 1. Pulsed current injection test configurations

It should also be noted in Fig.1 that internal and external loads are shown, as would be used in a verification test. Conversely, an acceptance test would instead have the conductors installed in their working state, with functioning equipment attached and running.

III. Pulsed Power

The source required by MIL-STD-188-125-1 and 2 is a Norton-equivalent source with an internal impedance of ≥60 ohms [2,3]. This internal resistance allows the double exponential current waveform described in Table 1 to be seen through the load, which is either a 2 ohm dummy load for common-mode/wire-to-ground verification testing, or a short circuit in the case of shield-to-ground testing.

A two-stage Marx generator was fabricated with the parameters shown in Table 2.

Table 2. Marx generator parameters

Parameter	Value	Units
Number of Marx generator stages	*2*	–
Maximum erected voltage	*46*	*kV*
Marx charge voltage	*23*	*kV*
Peak pulsed current direct drive at maximum charge voltage	*1.1*	*kA*
Capacitance per Marx stage	*20*	*nF*
Erected capacitance	*10*	*nF*
Maximum Marx energy per pulse	*10.5*	*J*
Pulse width (FWHM)	*500-550*	*ns*

The erected capacitance of 10 nF with a ~65 ohm internal resistance yielded the waveforms shown in Fig. 2 (into a short-circuit).

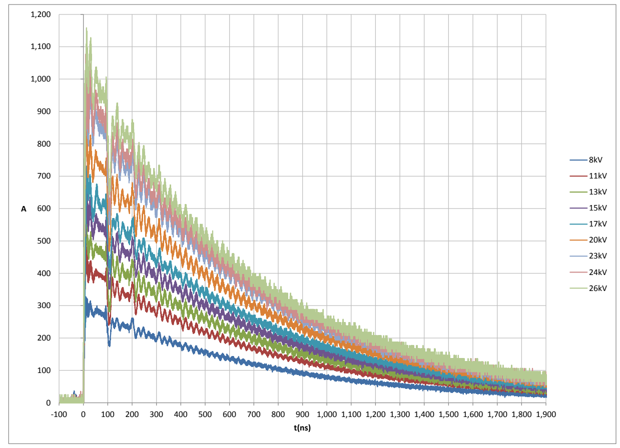

Figure 2. Marx generator output into a short circuit (charge voltage varied from 8kV to 30kV)

The Marx generator was contained in an aluminum enclosure filled with transformer oil for high-voltage insulation of the components. The trigger and stage spark gaps for the Marx were contained within a separate pressure vessel which used compressed dry breathing air for insulation. The combination of the planar Marx generator topology, compact high-voltage power supply, and a small SCUBA tank for dry air, allowed the entire system to be placed into a 25” x 20” x 9” plastic case as shown in Fig. 3.

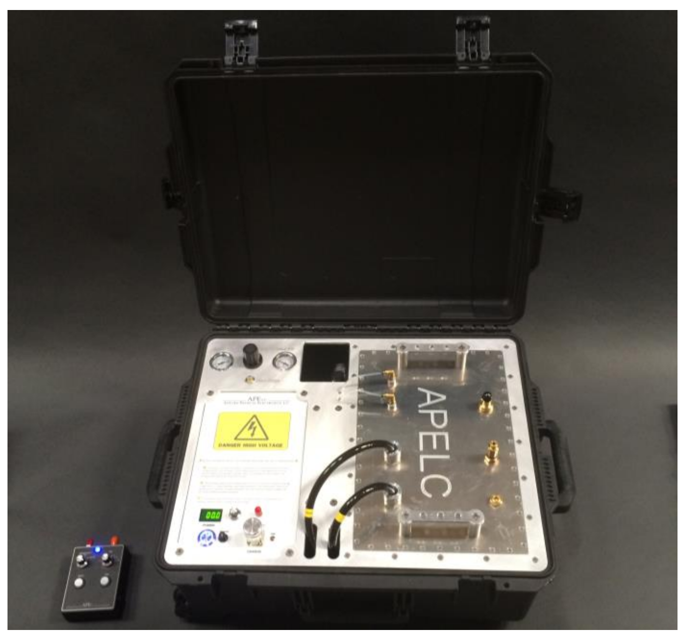

Figure 3. Two-stage Marx generator PCI system

IV. Coupling Methods

The PCI system described above terminated into a quick-disconnect fitting, allowing attachment of an RG-213 coaxial cable. Both ends of the cable were also terminated with quick-disconnect high-voltage connectors, allowing attachment of either a direct-connect fixture (Fig. 4), or an inductive coupler (Fig. 5). The inductive coupler was designed using the M5 NiZn ferrite from National Magnetics Group. This ferrite provided the combination of good high-frequency response, as well as the high saturation flux density needed to couple the 1kA pulse onto a cable without saturating the core material. The resultant waveform from using the inductive coupler placed on a calibration fixture is shown in Fig. 6. A Pearson model 110A current transformer was used to measure the pulse.

Figure 4. Direct-connect fixture (shown with Pearson current transformer)

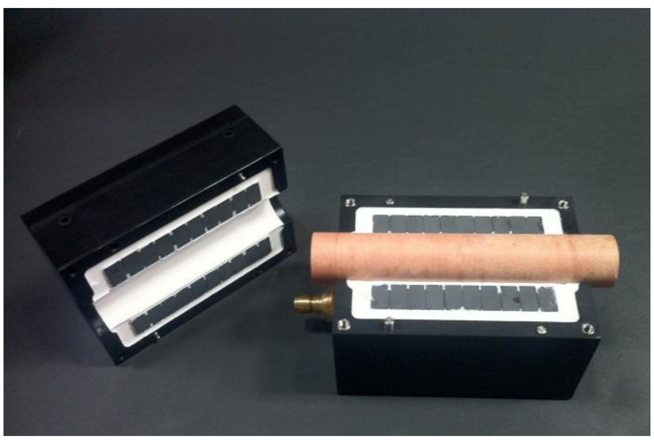

Figure 5. Inductive coupler

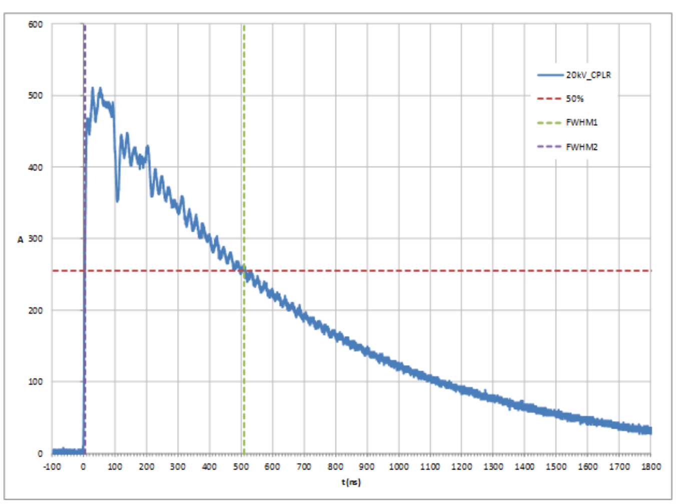

Figure 6. 500 Amp waveform using the inductive coupler

V. Conclusions

Utilizing a planar Marx-generator topology, a pulsed current injection system was fabricated which was capable of producing a >1kA short/E1 pulse as described in MIL-STD-188-125-1 and 2 in a package that was transportable by a single operator. An inductive coupler was also constructed that allowed the user the ability to inject the specified waveform onto a single cable or cable bundle without a direct connection being made to the conductor.

VI. References

[1] "American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3)," ANSI Std C63.14-2009, (2009).

[2] U.S. Department of Defense. "MIL-STD-188-125-1, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions. Part 1 Fixed Facilities ", (1998)

[3] U.S. Department of Defense. "MIL-STD-188-125-2, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions. Part 2 Transportable Systems", (1999)