Variability of PCI Results in HEMP/IEMI Power Filters

Sergio N. Longoria
Technical Product Line Manager, Filters
ETS-Lindgren Inc., Cedar Park, Texas, USA
Sergio.longoria@ets-lindgren.com

Abstract**—**This paper discusses the variability of results when doing Pulsed Current Injection (PCI) testing of HEMP/IEMI power filters. Proliferation of pulse testing equipment manufacturers and testing laboratories have made it necessary to investigate whether all field testing is being done in the same way. There is some evidence that suggests that field tests can vary and these may be the result of test setup, equipment used, or other causes. This paper presents data on some of the actual field conditions that were investigated as possible causes for variability of results. While the testing presented here was done in the laboratory, the intent was to simulate actual conditions in the field. These field conditions include variables such as different lengths of cable, varying pulse amplitudes and pulse widths that could cause PCI residual results to vary between tests and testing laboratories. We investigate if testing standards provide the necessary guidance to insure repeatability of results. What follows is an overview of the findings observed when high amperage filters were PCI tested to E1 and there was some variability in the test results.

I. PCI TESTING STANDARDS

A. *IEC 61000-4-24*

Since most pulsers are difficult to control, especially when it comes to the critical values of peak amplitude and width. These must be given within certain practical parameters. The critical parameters to test with are given in this standard as follows: rise time, peak amplitude, etc. Table 1 presents this as indicated in IEC 61000-4-24. It will be noted that most of the parameters do indicate a tolerance.

Type	Rise time	FWHM[1)]	Source impedance[2)]	Peak short-circuit current	Specifications
CEP_1	< 10 ns	100 ns ±30 %	400 Ω ±15 Ω	4 000 A ±10 %	IEC 61000-2-10, 99 % severity for elevated conductor, for cable length longer than 200 m
CEP_2	< 10 ns	100 ns ±30 %	400 Ω ±15 Ω	500 A ±10 %	IEC 61000-2-10, 50 % severity for elevated conductor, for cable length longer than 200 m
CEP_3	< 25 ns	500 ns ±30 %	50 Ω ±5 Ω	400 A ±10 %	IEC 61000-2-10, for buried conductor in the ground conductivity of 10^{-4}, for cable length longer than 10 m
CEP_4	< 25 ns	500 ns +10 %	> 60 Ω	2 500 A ±10 %	According to [1], Wire-to- ground
CEP_5	< 25 ns	500 ns +10 %	> 60 Ω	5 000 A ±10 %	According to [1], Common-mode, under installed conditions only.

Table 1. Parameter and tolerance for E1 test waveform.

In Appendix A of this standard, it was investigated how these parameters were affected by the variation of the size and the length of test cables. But the standard does not speak of residual variations given by changes in cable test lengths. It was noted that changes in the length of resistor load wire does not have a significant impact on residuals.

B. *MIL-STD-188-125*

E1 testing according to this standard does not indicate a tolerance for the peak amplitude of the pulse as can be seen in table 2. Higher rise times seem to produce higher residuals and neither standard addresses a minimum rise time, only a maximum. Results with varying rise times will be presented.

Class of Electrical POE	Type of Injection	Peak Short-Circuit Current $\hat{I}$ (A)	Source Impedance[1] Z_s (Ω)	Risetime τ_R (s)	FWHM (s)	Acceptance Test Load Impedance (Ω)
Commercial Power Lines (Intersite)						
Short Pulse	Common mode[2]	5,000	≥ 60	$\leq 2\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	Not applicable[2]
Short Pulse	Wire-to-ground[3]	2,500	≥ 60	$\leq 2\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[4] 2 or V_{rated}/I_{rated}

Table 2.

II. PCI FIELD TESTING

A. *Cable Length and Testing Waveform*

In the IEC standard it is recommend that the test cable be as short and thick as possible. The MIL standard makes no such recommendation. It is up to the testers actually doing the field testing how to interpret what they must do. In the testing that was performed, the practical length of the cable was much longer than the one used on the IEC study. In fact this is simply too short for what the typical conditions are in the field. So we set out to investigate what the residuals would be and how the test waveform would be affected by three different lengths of cable. In the field as in the lab, a series of calibration shots are done. Figure 1 shows how these are typically done. This same cable then is used to perform the tests.

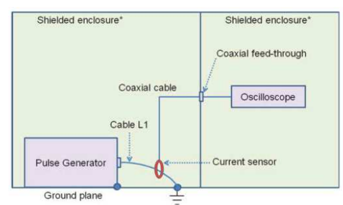

Figure 1. Typical test set up for calibration

B. *Other Factors Affecting Results*

It was also investigated how much the MOV threshold voltage affects the residuals. MOV's are commercially available and while their threshold voltage falls within certain limits, these vary according to the manufacturer and are not adjustable. The main concern here is that MOV's with higher threshold voltages do produce higher residuals. A variation of the resistive loads use for acceptance testing can also give different residual results. And thus the recommendation is that these should also have a tolerance.

III. REFERENCES

1. 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, 7 April 2005.

2. IEC 61000-4-24 Ed 2.0 (2015): Electromagnetic Compatibility (EMC) – Part 4 - 24: Testing and measurement techniques – Test methods for protective devices for HEMP conducted disturbance.