# Using Modelling Software to Predict HEMP Filter Circuits that Meet PCI Requirements

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***Abstract*— This paper describes the design process of filters for use in high-altitude electromagnetic pulse (HEMP) protection of power line points of entry (POE) on a shielded facility. This process was applied to different EMP standards, each with their own levels of facility hardening, to develop the most compact and cost-effective filter for that application. New results from pulse current injection (PCI) tests on a filter with a short circuit load are presented.**

**Keywords—HEMP, filter, pulse current injection**

## I. Design process

Early EMP filter designs were generally adapted EMI filters fitted with input delay lines and high-energy transient suppressors at the front end to provide pulse protection in accordance with NATO specifications [1]. The introduction of MIL-STD-188-125 [2] established a more dedicated PCI test requirement for HEMP protection of $C^4I$ facilities conducting critical, time-urgent missions. The standard defines Acceptance testing of a HEMP power filter as a measure to demonstrate the performance of the protective device. It must reduce a well-defined early-time (E1) double exponential waveform pulse to less than a 10 A residual current and also be capable of tolerating the higher energy intermediate-time (E2) pulse, both without any degradation of the filter.

New filter circuits in the style of Figure 1 were designed from first principles to meet the PCI requirements rather than EMI attenuation. Core to this design process was the use of PSpice circuit modelling software, this simulated the pulse generator and filter components in order to achieve the necessary residual performance. The type of transient suppressor along with the inductive and capacitive filter component values were all varied in numerous permutations to find the best integrated solution. Circuits rated for a range of currents from 6 A up to 1200 A were built and then tested at an independent test laboratory. The peak let-through current was measured along with the rise time and root integral (energy content) of the residual pulse. The insertion loss of the filters and varistor parameters were measured before and after to check the circuits had not suffered degradation. Analysis of the measured results gave good correlation with computer simulation. This design approach produced superior residual currents compared to earlier modified EMI filters.

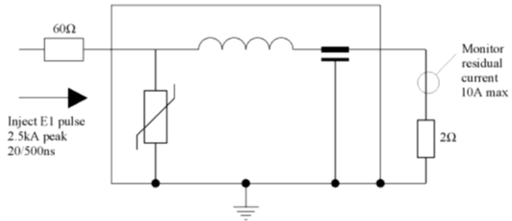


Fig. 1. Example of a simplified HEMP filter circuit.

## II. Lower requirements

Another international standard, IEC 61000-4-24 [3] describes test criteria for HEMP protection filters used in hardening important commercial sites, such as data centers and utility infrastructure. This is also particularly useful for applications were full protection is not warranted. The established design process was used to develop a range of power filters to meet the requirements of this standard. It uses the same E1 and E2 pulse defined in MIL-STD-188-125 meaning the same pulser could be used to evaluate the filter circuits. With a higher residual current limit of 50 A for Severity Level 2, the filter designs are much smaller, lighter and cheaper than standard HEMP filters.

## III. A short-circuit load

MIL-STD-188-125 also defines Verification testing in order to determine the operational performance of the facility hardening. The protected circuit is now powered with the filter in situ. The load impedance will be dependent on the equipment being protected and characteristics of the specific installation. The difference between the Verification load impedance and the Acceptance 2 Ω resistive load can have a large effect on the residual current. A potential problem is introduced where a filter could pass Acceptance test, yet fail Verification test upon installation. In an attempt to understand the filter performance under worst-case conditions the circuit was modelled with a short-circuit to ground on the load. The simulated result predicted that the residual current of an existing filter was now failing at 85 A. Failure was confirmed during independent laboratory tests. This filter had previously been tested and provided a residual current of 4 A with a 2 Ω load.

It was clear that the existing filter circuit was not suitable. Now the same PSpice design process was needed to develop a new circuit, in order to meet the residual current limit with a short-circuit on the load. An extra inductive component was inserted on the load side after the capacitive element and facing the short-circuit. A prototype filter was built and then tested by an independent laboratory and found to successfully meet the residual current limit.

## References

[1] NATO 2202.2.5/SHORC/C-83:1985

[2] MIL-STD-188-125-1 7 April 2005 “High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground Based C4I Facilities Performing Critical, Time-Urgent Missions, Part 1 Fixed Facilities”.

[3] IEC 61000-4-24:2015 “Testing and Measurement Techniques – Test Methods for Protected Devices for HEMP Conductive Disturbance”.