HEMP POWERLINE FILTER DESIGNS MEET PULSE CURRENT INJECTION REQUIREMENTS OF MIL-STD 188-125

The intense electromagnetic pulse (EMP) from a single nuclear missile – detonated miles above the Earth – could disable civil and commercial infrastructures as well as defence computer and communications networks.

A large solar flare or geomagnetic storm, which may occur at any time, could also produce a similarly devastating outcome. The specific resultant pulse from any such event is known as a High-altitude ElectroMagnetic Pulse or HEMP.

Such a HEMP event could disable or destroy a significant portion of the national grid, along with local substations, unprotected items of electrical equipment and electrical controls for public utilities, services and process industries over a wide area. Much equipment containing unprotected microchips would be rendered inoperative within milliseconds. Such a pulse may equally destroy the electronics within military command and control centres as a precursor to a mass assault or surgical strike.

MPE's High-altitude ElectroMagnetic Pulse (HEMP) filters have been designed, independently tested and fully meet the pulse current injection (pci) requirements of MIL-STD 188-125. They incorporate metal oxide varistors as a front-end transient suppressor giving an ultra high-speed response to arrest the incoming pulse. Then, with secondary and tertiary suppressors separated by inductors at later stages, these units give highly effective protection to the cable entry points of AC mains power, telephone and data control lines against induced pulse currents.

Tests have shown that purpose-designed HEMP filters to protect cable entry points are far more effective than adapted catalogue EMI filters in terms of residual pulse performance, size and weight. Since 2004 MPE has been designing and manufacturing such custom HEMP filters, compliant to MIL-STD, that counter the effects of the pulse types defined as early-time E1 (50 kV/m within 10 ns) and intermediate-time E2 (100 V/m between 1 microsecond and 1 second). Most importantly, the MPE filters have been designed for pulse performance not insertion loss, and the transient suppressors, input inductors and filter are treated as an integrated solution. MPE tests the pulse currents and voltages at each stage within the circuit to confirm the operating function of each component, prior to arranging testing of the whole under full load conditions, ensuring that the highest levels of product reliability are consistently achieved.

The procedure for checking compliance of a HEMP filter with the specification for the E1 pulse is to inject the pulse into the front end of the filter and monitor the residual current flowing through a 2 ohm resistive load connected between the output terminal and earth. For higher current filters the resistive load is replaced by one of value given by V/I where V and I are the voltage and current ratings of the filter. For the E1 pulse, the generator source resistance is specified as 60 ohms, so the peak applied voltage supplied by the generator needs to be 150kV. The maximum acceptable residual current through the 2 ohm load is 10A peak, and there are also limitations on residual pulse risetime and energy.

Fig.1: HEMP filter design from MPE (right) is far smaller and lighter than its market alternative (shown left, with 30cm ruler in between)

For the E2 test, pulses are injected in a similar manner, but there is no requirement to monitor the residual pulse: the filter must just survive the pulse without damage.

Given insufficient demand to justify dedicated designs, normal practice has been to select a standard catalogue EMI filter and adapt it, using an inductive input filter and fitting high-energy transient suppressors at the front end to provide pulse protection. When tested, pulse attenuation performance may not meet the MIL-STD requirement, so remedial measures in the form of additional filter and suppression components may be needed. Although with this approach there is little initial design cost, major hidden costs may appear in terms of remedial action.

Because most catalogue EMI filters are designed for continuous wave insertion loss performance rather than pulse handling, MPE decided to design a range of filters from first principles to suit the pulse requirement of MIL-STD 188-125, i.e. to attenuate the magnitude of a 2500A 20/500ns E1 pulse to less than 10A, and to tolerate the E2 pulse. The transient suppressor and filter capacitive and inductive components were treated as an integrated solution. Circuits were built and tested, and pulse currents and voltages monitored at each stage in the circuit, to analyse the effect and contribution of each component and also the interaction between components.

Transient suppression devices were evaluated including spark gaps, metal oxide varistors (MOVs) and silicon avalanche diodes. The varistor was finally chosen for

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