Comparison and Circuit Modeling of Coupling Techniques of Pulsed Current Injection Tests

Yi Zhou, Yan-zhao Xie
State Key Laboratory of Power Equipment and Electric Insulation
National Center for International Research on Transient Electromagnetics and Applications
School of Electrical Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, China
zhouyi107@stu.xjtu.edu.cn; yzxie@mail.xjtu.edu.cn

Abstract— In standards related to PCI tests, the pulse generator is well characterized while coupling method is not unspecified. To study the response in circuit under test and effect of DUT, four different coupling techniques are modeled and compared in this paper.

Keywords: coupling technique; coupler; PCI; HEMP

I. INTRODUCTION

Pulsed current injection test was firstly applied in MIL-STD-188-125 Appendix B, which is a test method for measuring performance of a device under test (DUT) against pulsed current caused by HEMP.

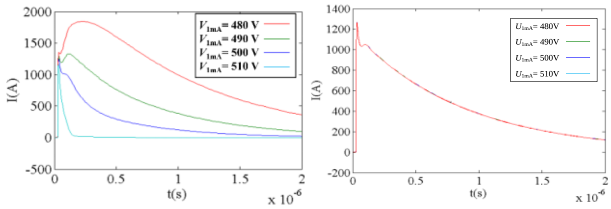
The pulse generator used in PCI tests (short pulse) is characterized with a short-circuit current with a double exponential waveform with peak current up to 5 kA, rise time no longer than 20 ns, and pulse width from 500 ns to 550 ns, while source impedance is at least 60 Ω.

The coupling method is not specified in MIL-STD-188-125 except that introduction of a coupler must not interfere with normal circuit operation. Further research on waveform of the circuit under test, response and effect are still needed to be developed. In this paper, four types of coupling techniques of PCI test are modeled and analyzed.

II. DIRECT COUPLING TECHNIQUE

The direct coupling technique connects the output of pulse generators directly to the DUT. Typically, a resistive coupler includes 60 Ω resistors and non-linear components such as varistors and GDT, which is often used to isolate the circuit under test and pulse generator. The rated voltage of varistors and the DC breakdown voltage of GDT shall be higher than the operating voltage of circuit under test.

The parameters of metal oxide varistors (MOV) are usually tested under DC, AC, 8/20 μs pulse and etc. According to experiment results, the switching voltage V_0 of MOV under pulse with rise time 20 ns is observably higher than V_{1mA}, and linearly related to V_{1mA}. However, V_0 is usually not tested or offered by manufacturers.



(a) (b)

Figure 1. Injected Current via MOV with Different V_{1mA} (a) With No Current Equalization Structure. (b) With the Structure

Difference in V_0 or V_{1mA} due to the manufacturing process will lead to distortion and disequilibrium of the injected current when several ports are injected at once, as shown in Figure 1. A current equalization structure is shown in Figure 2. Using such a structure, a resistive coupling network is designed, which can inject pulse currents into a device with 1 to 4 ports.

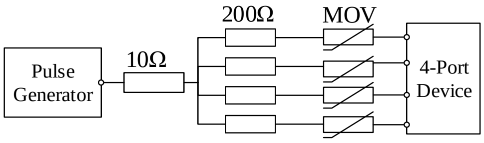


Figure 2. 4-port Coupler with Current Equalization Structure

Figure 3. Resistive Coupling Network

III. INDIRECT COUPLING TECHNIQUE

Inductive coupling technique based on magnetic cores can be applied without interrupting the cable bundle to test. Unlike a current injection clamp for BCI test, an inductive coupler is much larger and heavier since the magnetic core is more likely to be saturated. Due to the big size and frequency characteristics of the magnetic core, inductive couplers usually perform under 30 MHz. The introduction of inductance also leads to a slower rise time.

Capacitive coupling technique is often used in wire-to-ground tests. Some capacitive couplers can be combined with decoupling components to isolate the DUT and external loads. However, capacitive decoupler behaves like a low pass filter which is not compatible with signal integrity.

Crosstalk coupling technique is often applied as a long transmission line placed in parallel to a nearby cable. This technique is introduced in [3]. One advantage of this coupling technique is its ability to modify the coupling factor. Low coupling efficiency at low frequency and need of ports for long cables limits the use of the coupler.

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", July 1998

[2] J. Chen *et al*., "Behavior Comparison of Metal Oxide Arrester Blocks When Excited by VFTO and Lightning," in *IEEE Transactions on Electromagnetic Compatibility*, vol. 57, no. 6, pp. 1608-1615, Dec. 2015.

[3] IEC/TR 61000-1-3 (2002-06) Electromagnetic compatibility (EMC) – Part 1-3: General - The effects of high-altitude EMP (HEMP) on civil equipment and systems.