Destruction Scenario of Power Supply Due to Conducted Pulse from HEMP

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Abstract— This article presents the effects of a high current conducted pulse, induced by a high-altitude nuclear electromagnetic pulse (NEMP/HEMP) coupling on a global electric power distribution network, on the electrical behavior of a flyback switch-mode power supply. Current and voltage measurements have been performed around each destroyed component during the injection to build a power supply destruction scenario.

Keywords-HEMP; NEMP; Switch-Mode Power Supply (SMPS); component destruction; susceptibility

I. INTRODUCTION

Several studies show that the conducted parasitic current, of hundreds of amperes and voltage of several kilovolts, induced by the coupling of a HEMP on a global electric distribution network, involves the destruction of equipment's power supplies plugged to the grid [1]. Whereas the power supply is impacted first, only few studies deal with the effects of EMP on switch-mode power supplies (SMPS) [2]. Due to the system complexity, only ascertainment of the electronic equipment destruction is done and only few studies propose an analysis of the destruction effects at component level. However, the precise understanding of the mechanisms leading to the SMPS destruction are still insufficient to allow correct prediction and modelling. In this context, a failure scenario of a SMPS has been determined with the understanding of each component failure.

II. EXPERIMENTAL SETUP

A current injection platform gives the possibility to reproduce electrical bi-exponential stresses of several hundreds of amperes (some tens of nanoseconds rise time and hundreds of nanoseconds duration) representative of disturbances induced by the coupling of an HEMP, as defined in the IEC 61000-2-9 standard, on distribution network long cables. After preliminary analyses, a 57 W flyback SMPS, representative of a majority of commonly used power supplies, has been specially designed in order to facilitate the destructions understanding, and manufactured of 100 samples. Its simplified electrical schematic is given in Fig. 1. High current pulse injections have been carried out firstly only in differential mode on the designed power supply. In fact, the interference signal at the SMPS input cannot be considered as a pure common mode signal but also contains a differential mode part due to the contribution of several elements, such as unbalance of SMPS input impedances on phase and neutral.

This study has been carried out with the support of Direction Générale de l'Armement belonging to the French Ministry of the Armed Forces.

III. FAILURE SCENARIO

In order to understand the mechanisms leading to each component failure, current and voltage measurements have been specially performed during the destruction, in "harsh" and noisy environment, with appropriate probes.

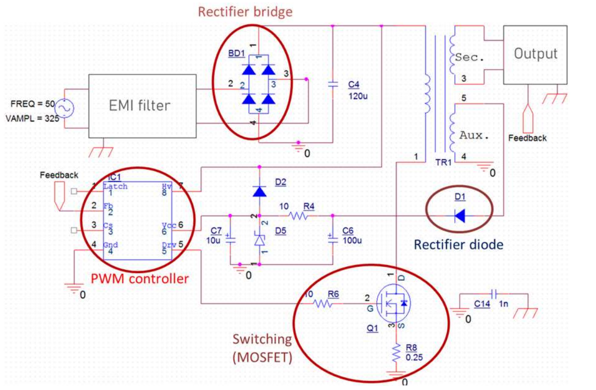

Figure 1. Simplified electronic schematic of the SMPS.

SMPS analyses after their failure have shown that the same components were destroyed due to too high currents of several hundreds of amperes. These components are (circled in Fig. 1): rectifier bridge, MOSFET and its associated resistors, diode of the PWM controller supply and PWM controller. After hundred SMPS destructions, a scenario giving the chronology of the destruction events has been built. The chronology has been determined through current and voltage measurements carried out at different specific nodes during the destruction of the SMPS and by analyzing the datasheet maximum ratings and the destroyed components (using X-rays and optical microscope).

IV. CONCLUSIONS

In this paper, effects of current pulse injection of several hundreds of amperes on a representative flyback SMPS have been studied. It has been observed that four main components were often destroyed and the failure mechanism of each of these components has been explained. Measurements have permitted to build a scenario explaining the SMPS failure through the chronology of destruction events. This scenario is a first step in order to model the susceptibility of power supplies during an electrical pulse injection.

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