Numerical Simulation of Power-grid Overloads and Short-circuit Protections

Chaouki Kasmi* and Damien Coiffard
Wireless Security Lab
French Network and Information Security Agency
Paris, France
*chaouki.kasmi@ssi.gouv.fr

Muriel Darces and Marc Hélier
Sorbonne Universités
UPMC Univ. Paris 06, UR2, L2E,
F-75005, Paris, France

***Abstract*—Spurious electromagnetic emanations can propagate along the power-grid cable network of critical infrastructures, which poses unacceptable risks for their *security* and *safety*. According to international standards, protective devices have to be inserted in low-voltage distribution networks in order to prevent physical damages due to either overload or short-circuit. We propose here to characterize these devices by measuring their scattering parameters in order to estimate their effects on the conducted propagation of electromagnetic interference along the power network.**

Keywords-component: Protective devices; Power-grid; Electromagnetic interferences;

I. Context

Many studies [1-3] have been devoted to the analysis of the conducted propagation of intentional and unintentional electromagnetic interferences (EMI) along the power-grid. It has been shown that the low-voltage distribution network acts as a guiding structure for these interferences. The use of models [3] has shown that we are able to analyse the conducted propagation of EMI along low-voltage cable networks. Models of such a network have been improved by the integration of appliances impedance [3] in electromagnetic simulation software.

In order to go further in the improvement of power-grid models, we propose to measure the scattering parameters of protective devices, obtained from different manufacturers and of several current-rates, at radio frequencies. Moreover the measurements have been performed with the power-supply turned on and shut off (respectively *off-line* and *on-line* states of devices) in order to know if appliances connected to the power network can be damaged by high-power electromagnetic attacks in both configurations. The measurement results have been inserted in the CRIPTE Code [4] simulation software developed by ONERA.

II. Overload's and Short-circuit's protections

International standards [5] define the protective devices (fuse-based breakers and magnetic-based breakers) that have to be added to the power network structure in order to protect a facility from physical damages that may be due to short-circuits or overloads. Both types of devices have been connected to a Vector Network Analyzer, thanks to simple adapters based on 50 Ω connectors. The scattering parameters of the device under test have been obtained by removing the effects of the test fixture. This has been achieved by using a *software-based de-embedding* procedure [6] and the deterministic modelling of the adapters.

III. Integration in the CRIPTE Code

The CRIPTE code [4] allows analyzing the conducted propagation of electromagnetic interferences in *topological networks* by solving the *BLT* equation. The modelling of complex cable networks is based on the combination of uniform sub-networks by means of *tubes* (representing the cable bundles), connected by *junctions,* as well as end points characterized by *loads*.

The *tubes* can be characterized either by the per-unit-length parameters obtained thanks to a 2D-field solver or by the measured per-unit-length parameters of cable bundles. Concerning the *junctions,* they can be characterized by impedance or scattering parameters. The last approach has been derived to insert the scattering parameters of devices in their *on-line* and *off-line* states as 4-port junctions.

Low-voltage power network models [3] have been improved by using the measured scattering parameters of the tested protective devices. It will be shown how the electromagnetic interferences are affected by those protective devices. Several outcomes will be also presented.

References

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