Stochastic Approach to Modelling Emissions of Multiple Power Electronic Converters

Erjon Ballukja, Iqra Aitbar, Karol Niewiadomski, David W.P. Thomas
GGIEMR
University of Nottingham
NG7 2RD, Nottingham, UK
erjon.ballukja@nottingham.ac.uk

Mark Sumner
PEMC
University of Nottingham
NG7 2RD, Nottingham, UK
mark.sumner@nottingham.ac.uk

Robert Smolenski
IAEE
University of Zielona Góra
Zielona Góra, 65-516, Poland
r.smolenski@iee.uz.zgora.pl

***Abstract*—The aim of this paper is to describe the effects of time delays (Δt) between the switching of several converters on the statistical quantification of the common mode current caused by a multiple converters set-up. To this end, the time delays are considered to be random variables following uniform distribution and Polynomial Chaos (PC) method is used. The preliminary results show that by simply changing the times at which the converters start switching, we achieve a statistical variability of harmonics of common mode current.**

***Index Terms*—Electromagnetic Compatibility, Polynomial Chaos, Power Electronic Converters**

I. Introduction

In modern smart grids, power electronic (PE) converters are responsible for most of the electromagnetic interference (EMI), especially in the conducted emissions (CE) frequency range. Therefore, they cause electromagnetic compatibility (EMC) issues. In many smart grid applications, multiple converters are used simultaneously and, currently, there are no standards which allow testing devices in such conditions. In [1] the authors provided a statistical view of the Conducted Emissions, based on Pearson's random walk approach. Our paper explores the influence of such time delays on the statistical quantification of the common mode current caused by several converters operating simultaneously. To achieve the goal, contrary to [1] where a purely mathematical model, followed by computationally demanding Monte Carlo (MC) simulations, was used, we employ a circuit simulation in combination with Polynomial Chaos technique [2].

CE are mostly caused by the presence of the so-called parasitic elements. Identifying the sources of CE is a demanding and complicated task, especially when dealing with a grid which involves several interference sources. A possible approach to this problem is that of modelling the parasitic elements by means of equivalent capacitances, inductances and resistances. Then, the values of these elements can be treated as random variables. This approach allows assessing their influence on CE, as shown in [2]. Now, assuming a setup of $N = 1...4$ PE devices, identical between each other and where the only variable is the time Δt at which each device starts operating, the main research question is: *what is the distribution of the common mode current in a multi-converter setup, where the converters start operating randomly*?

This project research is funded by the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 812391 and 955646.

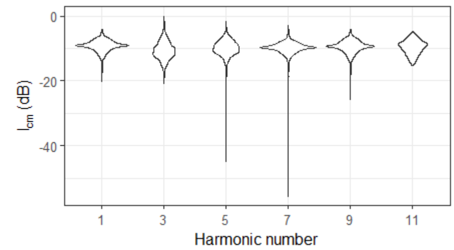

Fig. 1. Distribution of Common Mode Current for 4 Converters.

II. Methodology

The methodology is the following: 1) the variables Δt_i for $i = 1, \ldots, 4$ are drawn from a uniform distribution $\mathcal{U}(0, 1/F_s)$ following a Latin Hypercube sampling scheme, 2) for each sample a time domain simulation with sampling frequency 276 MHz is performed, 3) out of a single simulation run, I_{CM} is measured and converted to frequency domain through Fast Fourier Transform (FFT) with a frequency step of 1 kHz, 4) we save only the first 6 odd harmonics of the switching frequency and compute the magnitude in dB, 5) at each harmonic, a PC model is constructed.

III. Conclusion

Fig. 1 shows the preliminary results of the distribution of the common mode current at the first 6 odd harmonics, taken in the setup consisting of 4 converters. The values are drawn from the PC models. As one can see, the distributions are mostly uni-modal with large left tails in harmonics 5 and 7. This shows that in case of CE in such grids, statistical assessment is needed to better understand the behaviour of the grid.

References

[1] J. Bojarski, R. Smoleński, A. Kempski, and P. Lezynski, "Pearson's random walk approach to evaluating interference generated by a group of converters," *Appl. Math. Comput.*, vol. 219, pp. 6437–6444, February 2013.

[2] K. Niewiadomski, A. Pena-Quintal, D. W. Thomas, and S. Sumsurooah, "Sensitivity Analysis of Parasitics in Power Electronic Circuit through Sobol' Indices," in *2021 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC)*, 2021, pp. 1–4.