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Report on the Ph.D. Thesis titled:

"**Modulation Algorithms of Power Electronic Converters for Shaping of Conducted Interference**",

submitted by Hermes José Lochi, at Uniwersytet Zielenógorski, Poland.

The Electromagnetic Compatibility (EMC) is an area that is attracting significant attention due to the steady increase in operating frequencies of electrical devices as well as steady increase of the number of interconnected devices within the infrastructure. The thesis is focused on the lower frequency (5kHz-150kHz) emissions generated by low power DC/DC converters used in applications such as smart grids where a large number of converters can contribute to the rapid overall increase of Electromagnetic Interference (EMI) that can negatively impact other devices. One of the ways of controlling EMC issues of power converters is to deploy switching control strategies of the converter switching frequency, namely either using deterministic switching modulation (DetM) or pseudo-random modulation (RanM). RanM approach results in the spreading of EMI spectrum over a wider range of frequencies. However, it has been shown that its measured levels depended on the characteristics of EMI-test bench system, i.e., the rate of switching time and the dwell time of EMI receiver, raising questions on the suitability of using RanM for EMI reduction. The main question the thesis aims to answer is to explore whether new dedicated converter control algorithms can be designed so that they can allow shaping of the EMI spectrum to meet required standards.

In order to answer this question the candidate has undertaken an interesting study in a topical area that is clearly a challenge to the community. A significant volume of work has been undertaken and a number of results presented.

The thesis is structured as follows:

- The introduction chapter briefly sets the scene on the effect RanM and DetM have on the EMI noise shape and sets the main research question and outline of the thesis.
- The Chapter 2 introduces the concepts of DetM and RanM and demonstrates the noise level generated by DetM and RanM of DC/DC converter. A number of results illustrating the RanM repetition rate and frequency change is shown in Figs.2.1-2.5. Figures 2.6 ad 2.7 are not clear and will be probed at the viva. The background theory of the rectangular pulse train, Fourier Transform and aggregation of pulse trains is given in Appendix.
- Chapter 3 introduces super-heterodyne frequency EMI test receiver that is used to perform selective measurements in the frequency domain. The background theory of the Discrete Fourier Transform (DFT) and Short-Time Fourier Transform (STFT) is presented. As STFT is used to selectively scan sections of the time signal the chapter also presents different windowing functions. The discussion about the link between the size of the time windows and its effect on the bandwidth of the signal and frequency resolution is given and explored in Figures 3.7 and 3.8. Figures 3.6 ad 3.9 are not clear and this will be probed at the viva.
- Chapter 4 presents the hardware for Pulse Width Modulation (PWM) that is using Intel Core i7 and FPGA R-series multifunction in combination with the LabVIEW to facilitate PWM process for DC/DC converters. The LabVIEW implementation of PWM is also given. The chapter demonstrates how controlling switching rate of change can be used to re-shape the frequency spectrum (Fg.4.21-Fig.4.25). Only duty cycle and resonant frequency are considered. The method handles the fixed-point processor and claims it as a novelty. The thesis does not overview other approaches in generating PWM and this will be probed at viva. The schematic of LabVIEW implementation are very difficult to follow.
- Chapter 5 presents conducted EMI measurements for PWM algorithms for a two-transistor step down DC/DC convertor operating at a low frequencies. The EMC test bed is also presented in this chapter. A number of results are presented for DetM and RanM with Quasi-Peak (QP) and average (AV) detectors for the worst-case scenario of duty cycle of 50%. RanM modulation with and without shaping is also analysed and shown that Frame Error rate can be decreased by 30% using RanM with shaping.

The thesis is written on a very high level with an assumption that the reader is an expert in the field. The structure of the thesis is difficult to follow – the theoretical material is scattered between the chapters and the appendices and acronyms and symbols are often not fully defined.

Below I list two areas of concern and will use the opportunity at the viva to identify whether these are simply issues of presentation as a written document rather than anything more significant.

- The review of existing work in the field needs to be re-thought and I think substantially expanded. A more comprehensive discussion is needed on the previous experimental and simulation approaches to characterise PWM and the shaping of the emission spectra so that the originality of the presented work can be ascertained. As an aspect of the PhD project is

original data collection, it is definitely important to address this weakness to reinforce the meeting of the award of a PhD criteria. This will be probed at the viva.

- Throughout the results section, chapters 4 and 5, I would like to clarify which results (if any) replicate existing published work and which are truly innovative. Also, it is not obvious how the results are validated and how they compare with the published literature. This will be probed at the viva.
- The main question that thesis aims to answer is: "Is it possible to develop new, dedicated converter control algorithms that allow shaping the spectrum of disturbances to meet standardisation or technical requirements?". Chapter 5 shows that shaping of the spectrum using a dedicated converter control algorithm that uses National Instruments PXI and FPGA with a fixed point processor *is possible*. However, it is not clear for which standards and requirements the tests are conducted and what was the ultimate aim of the EMI shaping.

The candidate has published a large number of conference papers and 3 journal publications on this topic. Notwithstanding the above comments I consider that the proposed work meets the formal requirements for the doctoral degree and I propose that the thesis is admitted to a public defence.

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