PhD thesis offer
Power Electronics — Year 2022

High-frequency modeling of embedded power electronics converters for EMC analysis in automotive applications

Context

Electrical energy is managed by power electronics converters that ensure power transfer at different levels onboard vehicles, such as battery charging, traction inverter, or power supply for auxiliary systems (Fig. 1). While installed electrical power tends to increase, mass and volume impact should be kept minimal in embedded systems. In order to meet the ever-increasing needs for compactness, high power density is therefore a key design objective of power converters.

Recent technological advances in active power components have made it possible to increase both the energy efficiency of converters (notably allowing more compact cooling systems) and their internal operating frequency (allowing the use of smaller passive components). In automotive applications, these advantages directly translate into increased available space and autonomy. However, high frequency (HF) operation and associated fast switching transients of new SiC and GaN power devices are source of electromagnetic interferences (EMI), including undesired HF currents and radiated electromagnetic emissions propagating throughout the conversion system. Furthermore, the current trend toward more compactness brings various parts closer to each other, which worsens electromagnetic compatibility (EMC) issues that possibly impair the reliability of power converters. Thus, additional EMI attenuation techniques must be employed, which requires long development times and involves substantial extra cost as well as higher weight and volume than expected.

In this context, analyzing and improving the HF behavior of power converters to reduce the conducted and radiated emissions is a major challenge for the ever-growing electrification of vehicles. Predictive evaluation of EMI through computer simulation is therefore an essential goal at the design stage, using dedicated software tools as well as HF characterization and modeling methods. Notably, proper assessment of internal EMI sources and electromagnetic coupling paths inside a power converter is a key point to optimise their EMC design.

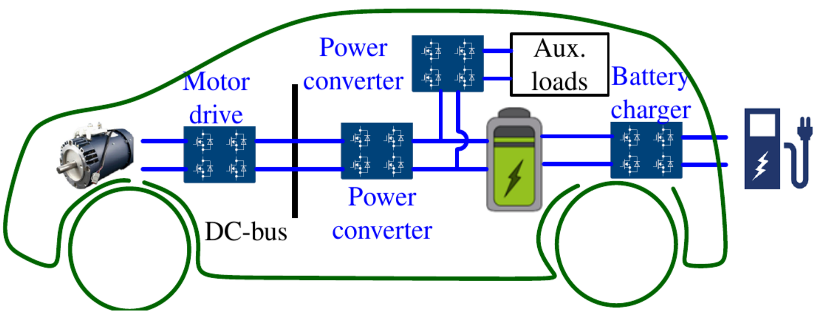

Figure 1: Power converters onboard an electric vehicle [1]

Industrial and academic environment

The PhD thesis takes place as a collaboration between INOVANCE Technology France, industrial partner of the project, and the Laboratory of Electrical Engineering and Power Electronics of Lille (L2EP).

INOVANCE Automotive of INOVANCE Technology group (https://www.inovance.eu) develops and manufactures Power Electronics & Electric Drives, focusing on Electric Vehicles since over 12 years. With a global cluster of partners, each year, more than 12 % of revenue invested to R&D, INOVANCE offers advanced development expertise and qualified mass products for On-Board Battery Chargers, Traction Inverters, DC/DC Converters, E-Motors and fully integrated eAxles (3in1).

The L2EP Power Electronics Team (https://l2ep.univ-lille.fr/en/) aims at designing compact static converters that operate at high frequency, in order to increase the power density of energy conversion systems while mitigating the EMI generated by fast switching of power components based on SiC and GaN semiconductor materials. Notably, compliance with electromagnetic compatibility (EMC) standards is an important design constraint. To this end, characterization and modeling techniques have been developed for recent GaN-based power devices, that constitute a major source of HF emissions, along with the assessment of the impact of printed-circuit-board connections [2–5]. The design by optimization of passive components has been developed for PCB-integrated smoothing inductors [6] and for EMI filters [7], including wideband models taking into account HF parasitic couplings [8]. By associating power cables [9] and taking into account EMI measurement equipment [10], the combination of these models makes it possible to predict the levels of HF emissions in a virtual prototyping approach and to estimate the impact of different conversion structures and their control law [11]. Finally, simulation methods have been proposed to reduce computation times [12, 13] and allow optimizations at the scale of a source/converter/load conversion chain.

Objectives

As a follow-up of EMC research activities, the objective of this thesis proposal is to extend the HF modeling and EMC design approaches to power converters dedicated to automotive applications. Because of potentially high electromagnetic field coupling between the nearby devices of such converter, EMC behaviour is much degraded. Notably, the internal EMI filter performance may be reduced in high frequencies, calling for additional internal shieldings that are difficult to design in early stage of virtual prototyping. Thus, this research work aims at improving HF models and simulation methods to assess the EMI behaviour inside power electronics converters in a wide frequency range (up to 200 MHz).

According to the scientific objectives, several steps will have to be considered. Based on typical power converter configuration, identification of EMI noise sources and propagation paths will be prerequisite to EMI analysis, along with modeling and simulation methods to assess conducted emissions in a wide frequency range. It will be necessary to characterise and model electromagnetic field and coupling between key devices and interconnections that impair the converter EMI behaviour. Experimental evaluation and comparison with simulation results will then be performed for both conducted and near-field radiated emissions. The obtained HF models will allow the determination and validation of EMI mitigation methods including proper shielding design to improve the converter HF behaviour. Application to industrial automotive converter will be carried out including electric powertrain and power supply system.

The work will naturally rely on the partners' expertise previously acquired on EMC modeling and design, and will allow the development of specific methods and tools to tackle the issues of high-frequency modeling for power converters. Special focus will be paid on internal electromagnetic field coupling, which is a key point to respond to the current challenges encountered in the design of embedded power converters. The work will take place at the L2EP laboratory and at INOVANCE Technology France facilities.

How to apply

Interested candidates should send their CV, motivation letter and latest transcripts by email to the L2EP academic supervisors:

Prof. Nadir IDIR & Dr. Arnaud VIDET : nadir.idir@univ-lille.fr, arnaud.videt@univ-lille.fr

Expected skills to succed in this project are solid scientific background and strong motivation to tackle the problematics of power converters design in a wide frequency range. To this end, prior academic knowledge or professional experience in the field of EMC is required, as well as proficient English for fluent communication between all partners.

References

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