Multi-objective optimization of power electronic converters

Electronic Power Conversion is a key element for the development of sustainable modern lifestyle, and represents both an interesting field of research and a challenging market. The optimization of the power conversion application is a process running since several years, and the efforts required to achieve significant benefits are constantly growing, while gradually evolving toward complete redesign of the systems. This means that for small system performance variations, very different requirements for the single components may be necessary, involving completely different technologies and manufacturing capabilities. Different technologies require time and investments for the industry to be implemented efficiently on a large production scale required by electronics, so understanding the various possibilities for the market and being able to predict the next steps of evaluation of the applications is key to have the right technology ready to kick in when the marker requires it.

Given that from a Power Converter designer point of view Components selection is a discrete task that depends on the available components in the market, existing Multi-Objective Optimization frameworks have undermined the impact of the Materials and Components selection on the overall performance of the converter.

Hence the present thesis in collaboration with Vishay Semiconductor Italiana is a contribution to the improvement of the Multi-Objective Optimization framework for power electronics converters in the Material and Component level of the framework that enables to get a further improvement of the overall figures of merits of the power converter and understand the impact of design choices at the Materials and Components level of the framework.

Starting from the Semiconductors Physics this thesis explain how the individual device characteristics are modified, the performance trade of the Silicon, Silicon Carbide and Gallium Nitride Semiconductor, the challenges of each technology and their impact on the overall performance of the converters.

On the other hand, for Inductors and Transformer, this thesis evaluates the different analytical formulas that has been proposed in time for the magnetic components design and proposed an effective and practical algorithm for the magnetic component design that consider the new available powder cores and the advantages of using litz wire for high frequency inductor/transformers.

Using the concepts presented in this thesis a DC/DC converter for Next Generation Electric Vehicle Charger is presented being able to maximize its performance while explaining the correlation between the performance of the converter and the different semiconductor technologies and magnetic component design options; in terms of winding and core materials. The designed converter is a 22kW LLC converter that work in buck region in order to be able to comply with the wide output voltage range requirement (Vout=700V-200V).