ScuDo

Scuola di Dottorato ~ Doctoral School

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XXXIV Cycle

Application in the loop approach to power semiconductor design and optimization

Alessio Gillone

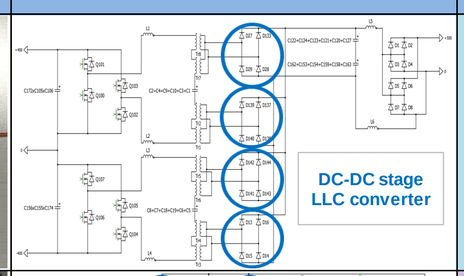
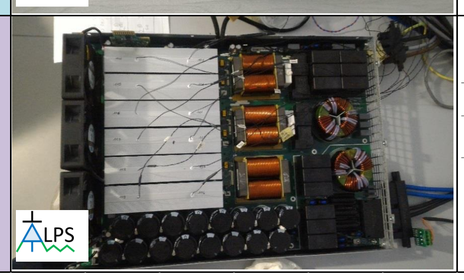
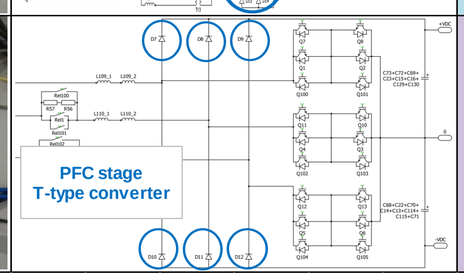
Supervisor: Prof. Sergio Ferrero, Prof. Fabrizio Pirri

Research context and motivation

- The research context is that of Power Electronic Converters, mainly oriented to industrial and automotive sectors.
- The electrification of the world is growing fast over the past few years, heavily changing the car market. HEV and BEV vehicles are now a reality and a lot of different and rapidly evolving power converters are required. In particular, applications such as On-Board-Chargers (OBCs), Fast Static Chargers and Motor Inverters are the typical power units to be focused on, when power semiconductors are taken into account.
- From the industrial production point of view, a certain power component earns a new design only if the trade-off between the performance requirements and cost is achieved. Moreover, the weight of these two features is different for each customer and it is strictly dependent on the specific application to target.
- In order to develop a new power diodes platform, reducing the mass production time to market, an “application oriented” fine-tuning of the electro-thermal parameters is necessary to reach the final goal in terms of efficiency, reliability and cost sustainability.
- The purpose of the research is to derive a useful strategy that use new or improved tools and methods to provide a quick feedback about semiconductors behavior to R&D Dept.
- This research is part of my **apprenticeship program** developed and pursued near to **Vishay Application Laboratory for Power Systems.**

Addressed research questions/problems

- Different circuital topologies require a very scrupulous analysis of **power diodes** working conditions, based on the considered application.

Application	EUT	Circuital topology case study	Diode platform
15kW 3-phase EV-Charger			30 A, 600V Ultrafast Diode
30kW 3-phase EV-Charger			60 A, 1200V Ultrafast Diode

- To evaluate the features of the engineering samples and to benchmark them with respect to the market competition, accurate experimental test benches must be setup.
- To avoid systematic errors and user-induced mistakes, rigid test procedures must be observed to pass the results validation phase.
- The measurement of the electrical and thermal characteristics such as the total converter efficiency has to be, as much as possible, stable and repeatable especially when gap of cents of percentage are fundamental to confirm a hypothesis or derive a clear conclusion.
- Only in this way is possible to highlight the correct “figures of merit” of components.

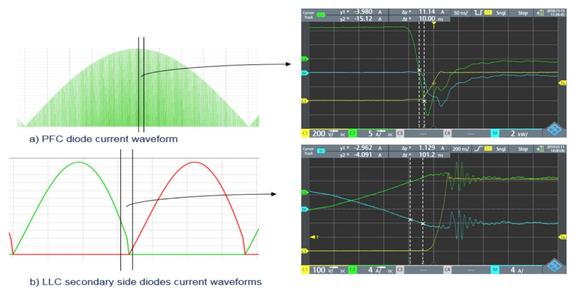
Submitted and published works

- M. Gregorio, F. Mandrile, R. Bojoi, A. Gillone and C. Damilano, "Fully MCU-Based DCM Control of On-Board Charger," 2019 International Symposium on Power Electronics (Ee), Novi Sad, 2019, In press.

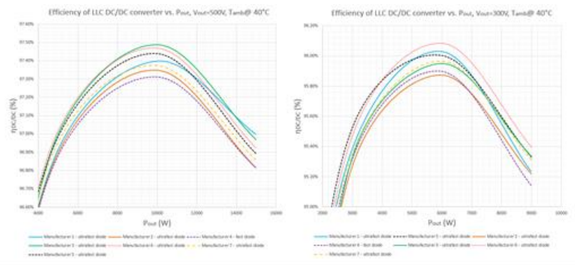
Novel contributions

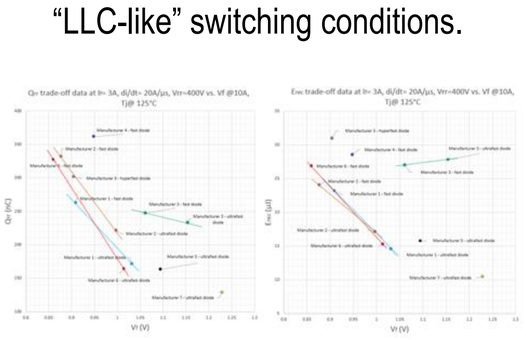
- Short-term and medium-term stability improvement of efficiency measurement system.
- Analysis of the interfacing thermal impedance of discrete packages considering various isolating media between case and heatsink to optimize semiconductor performances and to lay the basis for power losses prediction.
- HW and SW realization of an automatic switching tester to reproduce and explore with several DOF, the recovery of diodes experimented by a certain type of application.

Adopted methodologies



- Study of online waveforms: e.g. hard-switching applications vs. “LLC-like” switching conditions.
- Combination of static and dynamic characteristics obtained from testers to plot trade-off trajectories.





- Integration of trade-off trajectories with valid efficiency test results to successfully confirm the goodness of a new diode technological process.

Future work

- Implementation of a reliable method to directly measure the online junction temperature of semiconductors in the applications.
- Use of the switching automatic tester to generate and calibrate more accurate and complex behavioral model, especially around the operative application temperature.
- Fine-tuning of zero-point power stage model for each strategic topology in order to evaluate the power losses gap between different diodes of a benchmark.
- Comparison of predicted gap in power losses/efficiency with that of experimental tests to validate the complete analysis process.

List of attended classes

- 01QSXRU - The measurement of electrical impedance (05/03/2019, 2)
- 01LEVRV - Power system economics (10/05/2019, 3)
- 01LDVRU - Magnetismo nei materiali e misure magnetiche (12/06/2019, 4)
- 03LCLRO - Epistemologia della macchina (20/06/2019, 4)

POLITECNICO DI TORINO

PhD program in

Electrical, Electronics and Communications Engineering