LABORATOIRE D'ELECTROTECHNIQUE ET D'ELECTRONIQUE DE PUISSANCE DE LILLE

# Master project, 2017-2018

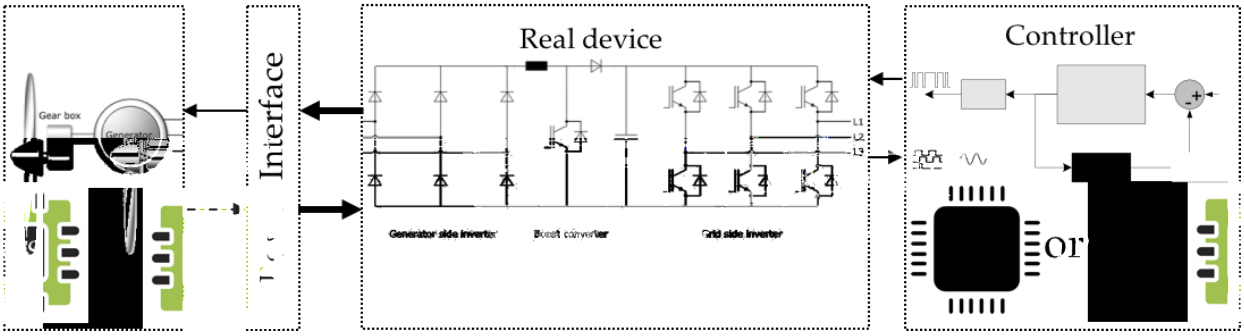
## *Design of coupled planar inductor for a high bandwidth power amplifier dedicated to PHIL applications*

**supervisors:** Xavier Margueron, L2EP – Centrale Lille, xavier.margueron@centralelille.fr, Frédéric Colas, L2EP - ENSAM, Frederic.colas@ensam.eu,

Francis Delpech and Olivier Sentier, Puissance+

### Context

Power Hardware-in-the-Loop (PHIL) simulation involves interfacing a Real-Time Simulator with a power device such as inverters, motors or transformers and through a power interface as illustrated in the figure below.




In this kind of application, the quality and the bandwidth of the power interface is of paramount importance as stability problems can occur if this interface is too slow for example. Puissance+ is company which designed such interface. Their products are based on linear technology. They have the advantage to generate high quality signals and to have high bandwidths which can reach 25kHz at a rating of 100kVA. However, this technology is intrinsically non-regenerative so that this power interface cannot reinject the absorbed energy in the power supply.
Puissance+ in collaboration with L2EP is designing a new power interface based on switching technology to overcome this drawback. The main objective is to design a power amplifier which can reach the same bandwidth but probably with less quality in signal generation and which is able to inject absorbed energy to the power supply. L2EP has proposed several topologies: they are all based on an association of several switching cells through coupled inductors.
For building process reasons, Puissance+ wants to study the possibility to design these coupled inductors with a planar technology.

### Objectives

The objectives of the proposed internship are to study the relevance of using coupled planar inductors (CPI) for the proposed applications. After the bibliographic study, a CPI will be designed based on specifications. Finite element analysis (FEA) will be performed to validate the design. These simulations will also enable to understand phenomena and evaluate losses inside the CPI. Then, a prototype will be realized and characterized to validate the proposed design.

### Work steps

1. Bibliographic study on coupled inductors. Application to planar devices: Concept, technology & design
2. Design of a CPI based on specifications
3. Validation through FEA[i]
4. Conception of a prototype[ii]
5. Characterization and tests

### Salary

900€ to 1000€/month

### Localization

50% at Puissance+ in Montauban
50% at ENSAM in Lille

### Keywords

Power amplifier, coupled planar inductor, design, modeling

**Skills**

- General knowledge in electrical engineering and switching converter
- Basic knowledge on magnetic materials
- Software: Matlab, Ansys

**References**


[1] D. O. Boillat and J. W. Kolar, "Modeling and experimental analysis of a Coupling Inductor employed in a high performance AC power source," *2012 International Conference on Renewable Energy Research and Applications (ICRERA)*, Nagasaki, 2012, pp. 1-18.

[2] F. Forest, E. LabourÉ, T. A. Meynard and V. Smet, "Design and Comparison of Inductors and Intercell Transformers for Filtering of PWM Inverter Output," in *IEEE Transactions on Power Electronics*, vol. 24, no. 3, pp. 812-821, March 2009.

[3] E. Laboure, A. Cuniere, T. A. Meynard, F. Forest and E. Sarraute, "A Theoretical Approach to InterCell Transformers, Application to Interleaved Converters," in *IEEE Transactions on Power Electronics*, vol. 23, no. 1, pp. 464-474, Jan. 2008.

[4] F. Forest, T. A. Meynard, E. Labouré, B. Gelis, J. J. Huselstein and J. C. Brandelero, "An Isolated Multicell Intercell Transformer Converter for Applications With a High Step-Up Ratio," in *IEEE Transactions on Power Electronics*, vol. 28, no. 3, pp. 1107-1119, March 2013.

[5] B. Cougo, *Design and Optimization of InterCell Transformers for Parallel MultiCell Converters*, Thèse de l'Université de Toulouse, 29 octobre 2010.


[i] FEA will be performed using Ansys Software

[ii] The prototype will be realized with technological resources involved in the various locations of the L2EP (ENSAM Lille, Centrale Lille and Univ. Lille)