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

Master project, 2024-2025

— High Power Density Design of a HF Transformer for an EV Embedded Charger —

Supervisors: Dr Xavier MARGUERON xavier.margueron@centralelille.fr, L2EP – Centrale Lille Institut
Dr Arnaud VIDET arnaud.videt@univ-lille.fr, L2EP – Univ. Lille

Context

Power density is of main importance in EV chargers, particularly when the converter is embedded. The Power Electronics (PE) Team is working on a new generation of embedded charger based on a novated low-loss matrix topology (patent filed). Inside the isolated converter, the High Frequency (HF) transformer is a key device that will deeply impact the efficiency and volume of the charger.

Objective

The aim of this master thesis is to design a HF transformer for the matrix charger and to compare this solution to conventional ones (typically including an active rectifier alongside a Dual Active Bridge – DAB) in terms of losses and power density trade-off.
This master thesis is linked to the PE team project dealing with new type of high-density EV charger (Figure 1) and a L2EP patent deposited this year. Conventional (DAB-like) design is no-longer valid in this new converter topology and requires new compromises due to the matrix converter operation mode.

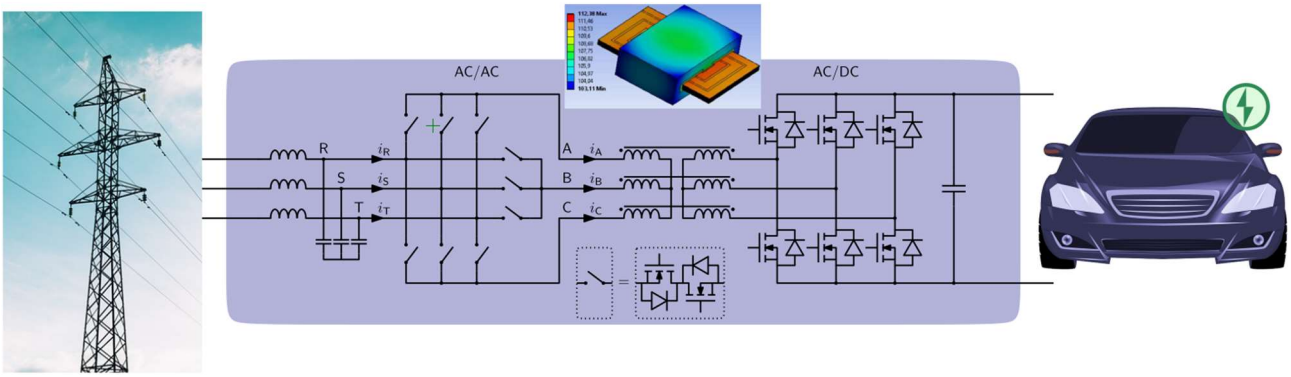

Figure 1 : matrix-based AC/DC charger topology including HF transformer

Work steps

- Bibliographical review on HF transformer sizing and modeling, and charger topology (*bibliographical part*)
- Design of a 2-winding HF transformer for a conventional PFC + DAB topology (*scientific project*)
- Study of matrix topology with circuit simulation to obtain voltage and current waveforms and determine electric constraints of the transformer (*internship*)
- Design of a HF transformer for this topology + Finite Element Analysis (FEA) simulation to estimate its main parameters (losses, leakage inductance…) (*internship*)
- Comparison of topologies in terms of HF transformer performances (volume, losses) and converter overall power density and efficiency (*internship*)

The work will take place in ESPRIT building

Keywords

EV charger, High-frequency transformer, Design, Power density, Efficiency, Optimisation

Skills

- General knowledge in electrical engineering and switching converters
- Basic knowledge on magnetics

- Software: Matlab, SIMetrix, FEMM, Ansys

References

[1] N. Patel, L. A. C. Lopes, A. Rathore and V. Khadkikar, *"A Soft-Switched Single-Stage Single-Phase PFC Converter for Bidirectional Plug-In EV Charger,"* in IEEE Transactions on Industry Applications, vol. 59, no. 4, pp. 5123-5135, July-Aug. 2023

[2] C.W. T. McLyman, "*Transformer and Inductor Design Handbook"*, 4th ed. Boca Raton, FL, USA: CRC Press, 2011.

[3] W. G. Hurley and W. H. Wolfle, *"Transformers and inductors for power electronics: Theory, design and applications"*. John Wiley & Sons Ltd., 2013.

[4] A. van den Bossche, V. C. Valchev, "*Inductors and transformers for power electronics"*, Boca Raton: Taylor and Francis, 2005

[5] R. Bakri, G. Corgne and X. Margueron, *"Thermal Modeling of Planar Magnetics: Fundamentals, Review and Key Points,"* in IEEE Access, vol. 11, pp. 41654-41679, 2023

[6] J. S. Ngoua Teu Magambo et al., *"Planar Magnetic Components in More Electric Aircraft: Review of Technology and Key Parameters for DC–DC Power Electronic Converter,"* in IEEE Transactions on Transportation Electrification, vol. 3, no. 4, pp. 831-842, Dec. 2017

[7] W. Tan, X. Margueron, L. Taylor and N. Idir, *"Leakage Inductance Analytical Calculation for Planar Components With Leakage Layers,"* in IEEE Transactions on Power Electronics, vol. 31, no. 6, pp. 4462-4473, June 2016

[8] D. Das, N. Weise, K. Basu, R. Baranwal and N. Mohan, *"A Bidirectional Soft-Switched DAB-Based Single-Stage Three-Phase AC–DC Converter for V2G Application,"* in IEEE Transactions on Transportation Electrification, vol. 5, no. 1, pp. 186-199, March 2019

[9] L. Schrittwieser, M. Leibl and J. W. Kolar, *"99% Efficient Isolated Three-Phase Matrix-Type DAB Buck–Boost PFC Rectifier,"* in IEEE Transactions on Power Electronics, vol. 35, no. 1, pp. 138-157, Jan. 2020