



Dépasser les frontières :  
projet après projet  
Der Oberrhein wächst zusammen,  
mit jedem Projekt



Fonds européen de développement  
régional (FEDER)  
Europäischer Fonds für regionale  
Entwicklung (EFRE)



## Choice and design of DC/DC power converter for a Li-ion battery / supercapacitor hybrid energy storage system in electric vehicle applications

**Planned funding:** VEHICLE project co-financed by “INTERREG V Upper Rhine”.

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**Workplace:** L2EP-Centrale Lille

**Laboratory:** ICube (CNRS UMR 7357) & L2EP

**Team:** SMH-ICube & EP-L2ep

**Startup scheduled:** February, 2020

### VEHICLE project in a few words:

The VEHICLE project (AdVanced li-ion battEry/supercapacitor HybriD energy storage system with synchronous reluctance maCHine for electric vehicle applications) aims to develop adapted solutions to on-board energy storage systems through the hybridization of energy sources and the use of innovative machines for electric vehicles. The Upper Rhine region is home to leading-edge laboratories in the field of electric traction. VEHICLE is built to combine existing complementary expertise and create synergies to lead to the development of innovations, and establish a new research consortium in the Upper Rhine region. French, German, Luxembourgish and British researchers are involved with a network of 3 main academic partners (INSA Strasbourg, Hochschule Karlsruhe, and Hochschule Trier) and 6 associate partners (Centrale Lille - L2ep), Université Nantes, Sheffield Hallam University, CVC Südwest, IEE S.A, and CCIAE). The VEHICLE project is developed as part of the INTERREG V Upper Rhine program and the Offensive Science initiative. It is co-financed in the context of this initiative by the Grand Est Region in France, the Baden-Württemberg and Rhineland-Palatinate Länder in Germany.

### Worldwide energy context:

The transport sector is responsible for 27% of global CO<sub>2</sub> emissions. It is thus one of the main causes of global warming [1]. To reduce these emissions, many policies have been implemented to improve the energy efficiency of vehicles with an electrification partial (hybrid) or total (full electric). Today, the electric vehicle is now a credible option, and is already on the market despite the intrinsic constraints linked to the battery and the additional cost of equipment [2].

### Scientific objectives:

In the traction field, the energy storage system used in electric or hybrid vehicles remains the weak link: very expensive, limited in driving range, slow to recharge, etc. Today, the main axis of progress is undoubtedly based on the development of on-board energy storage systems providing solutions for improving the driving range, battery lifetime, volume, mass, total cost of ownership (TCO), or use of these storage systems [3]. One of the solutions proposed by vehicle industrial interests in the past few years is the hybridization of sources. In this context, the hybridization of batteries with supercapacitors offers good performance in terms of driving range, available power and service continuity [4]. This hybridization results in an electrical storage system with a high power density and a high energy density. There are several configurations to connect the energy storage sources to the use: serial, parallel and with one or two converters [2]. The crucial point for achieving good performance of

Hybrid Energy Storage System (HESS), in addition to energy management strategies, is the configuration choice and the design of lightweight and compact power converters with high efficiency [5].

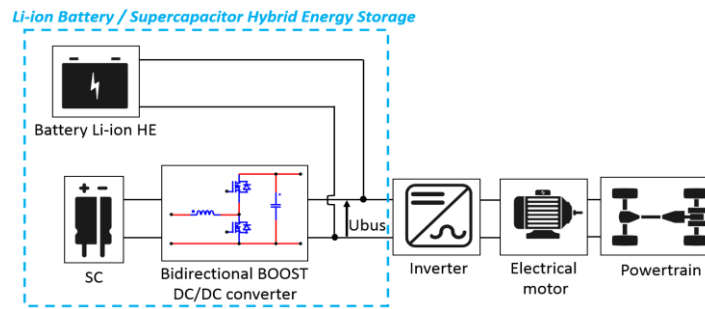


Figure. I : Li-ion battery / supercapacitor hybrid energy storage system

The aim of this internship is to carry out a choice and design of compact power converter for li-ion battery-supercapacitor HESS. The main focus will be on the different compact solutions and power electronics architectures in order to fulfil the needs for the electric powertrain. In parallel, the compact and high efficiency power converters can be improved by, for example, switching frequency optimization and soft-switching techniques to limit the size of the passive elements.

## Work Progress

This internship will mainly take place at the Power Electronics team of the L2EP in close collaboration with the ICube laboratory (INSA Strasbourg). He/she will first have to carry out bibliographic researches on different configurations to connect the hybrid energy storage sources. A formalization work on the choice of topologies for Li-ion battery / supercapacitor hybrid energy storage system will be developed. Then proposed methods and solutions will be compared to several test cases corresponding to electric vehicle applications. The choice and design of DC/DC power converter for a Li-ion battery / supercapacitor HESS in electric vehicle applications should be drawn up. A digital tool of HESS sizing previously developed will be coupled to proposed solutions, and a graphical interface will be adapted for effective use. Lastly, and according to the work progress, a laboratory prototype will be developed to validate and illustrate the approach and overall study of converter sizing.

## Candidate's skills:

**Specific knowledge:** Programming in, Matlab, and PSIM. Knowledge of power electronics and energy storage systems.

**Desired education:** Student about to graduate a Master or Engineer (Bac + 5) with a specialization in Electrical Engineering.

**Desired personal skills:** Strong motivation for innovation and the search for operational solutions in an industrial context. Motivation for the combination of simulation and experimentation.

## References:

- [1] J. J. West *et al.*, "Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health," *Nat. Clim. Chang.*, vol. 3, no. 10, pp. 885–889, 2013.
- [2] R. Sadoun, "Intérêt d'une Source d'Energie Electrique Hybride pour véhicule électrique urbain – dimensionnement et tests de cyclage," Thèse de Doctorat, ECOLE CENTRALE DE LILLE, 2013.
- [3] T. Mesbahi, N. Rizoug, P. Bartholomeus, R. Sadoun, F. Khenfri, and P. Lemoigne, "Optimal Energy Management For a Li-Ion Battery/Supercapacitor Hybrid Energy Storage System Based on Particle Swarm Optimization Incorporating Nelder-Mead Simplex Approach," *IEEE Trans. Intell. Veh.*, vol. 8858, no. c, pp. 1–1, 2017.
- [4] Z. Song *et al.*, "Multi-objective optimization of a semi-active battery/supercapacitor energy storage system for electric vehicles," *Appl. Energy*, vol. 135, pp. 212–224, Dec. 2014.
- [5] N. Allali, "Convertisseur haut rendement à dimensionnement réduit pour batterie hybridée puissance / énergie de véhicule électrique : Principe de source de courant contrôlée," Thèse de Doctorat, ECOLE CENTRALE DE LILLE, 2016.