Master Thesis project, 2023-2024

Use of an innovative electric vehicle power architecture for the reduction of its DC-DC converter

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Context

With the risk of a shortage of the resources needed to manufacture batteries, electric vehicles (EVs) with a smaller size and shorter range should be considered. However, the energy-power densities pairing of the batteries currently used in EVs leads to a sharp degradation in the power output of small EVs. To avoid this problem, a Hybrid Energy Storage System (HESS) can be an interesting solution. In this type of system, a DC-DC converter is needed to interface the batteries. However, this device represents a "dead weight" in the system (Figure 1) and should be as light as possible. The interfacing DC-DC power converter is then a key element to an efficient HESS.

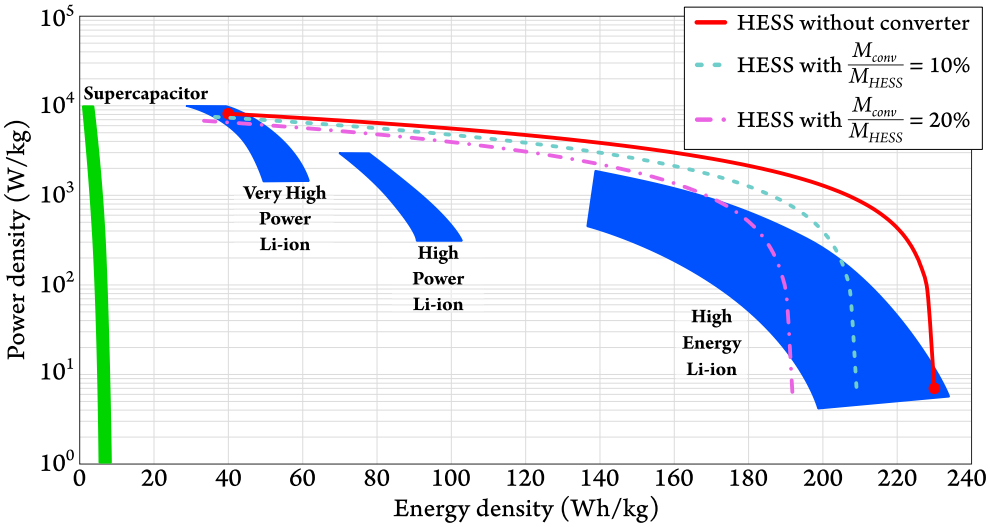

Figure 1: Influence of the converter mass in a HESS.

Objective

The goal of this master thesis is to propose new energy management strategies that will be applied to an innovative coupling architecture (Figure 2). This architecture enables a reduction of the DC-DC converter in terms of weight, mass and losses. The management strategy applied to it is used for the sizing of this converter. Due to the difference in voltage levels between the batteries, the converter used needs to be an isolated topology. This way, the sizing of its magnetic components is also considered.

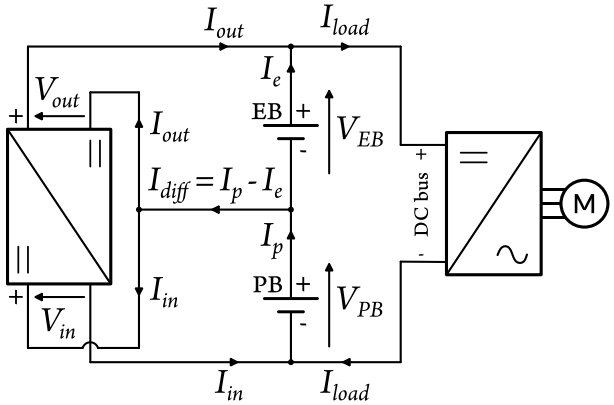

Figure 2: Series architecture

This master thesis proposition is seen as a continuation of the PhD thesis recently defended entitled “Power-energy batteries hybridization with reduced sizing coupling converter: Application to urban electric vehicles” (hal.science/tel-04192122v1). In it, the series architecture was studied, along with another innovative architecture called cascade based on a controlled current source. It was proven that the interfacing DC-DC converter can be reduced depending on the coupling architecture used to power an electric vehicle (Figure 3).

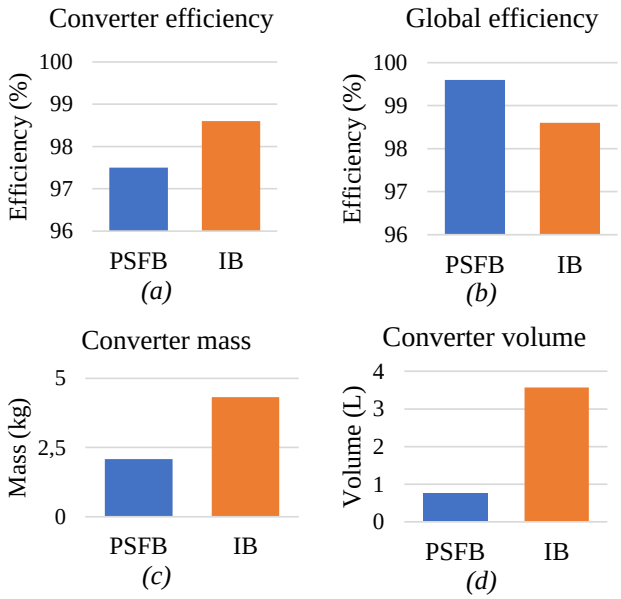

Figure 3: Comparison between a converter adapted to the series architecture (Phase-Shift Full-Bridge - PSFB) and another designed for a conventionally used architecture (Interleaved Boost - IB).

Work steps

This work is suitable with master thesis: bibliographical project, scientific project and master thesis. The work will be divided in some steps:

1. Bibliographical review on Hybrid Energy Storage Systems, energy management strategies and coupling architectures applied to electric vehicles.
2. Study of simulations from the PhD thesis.
3. Proposition of strategies for the sizing of the DC-DC converter.
4. Numerical validation.
5. Experimental validation on the test bench developed during the PhD.

Keywords

Electric vehicles, Hybrid energy storage system, Power electronics, DC-DC converter

Localization

The work will take place at the L2EP laboratory in ESPRIT building (Campus for Science – Villeneuve d’Ascq).

Skills

General knowledge on power electronics (specifically DC-DC converters), MATLAB programming, Simulink simulations.

References

[1] C. F. Freitas, “Hybridation de batteries puissance-énergie avec convertisseur de couplage à dimensionnement réduit : Application aux véhicules électriques urbains”. PhD Thesis, Centrale Lille Institut, 2023.
[2] C. F. Freitas et al., “Low-volume and high-efficiency converter solution for inter-facing a Hybrid Energy Storage System (HESS)”, 2021 IEEE Vehicle Power and Propulsion Conference (VPPC), pp. 1-6, 2021.
[3] C. F. Freitas et al., “Ragone plot-based method for sizing an Electric Vehicle's Battery-Battery Hybrid Energy Storage System (HESS)”, 2021 IEEE Vehicle Power and Propulsion Conference (VPPC), pp. 1-6, 2021.
[4] N. Allali, “Convertisseur haut rendement à dimensionnement réduit pour batterie hybridée puissance/énergie de véhicule électrique : Principe de source de courant contrôlée”. PhD Thesis, École Centrale de Lille, 2016.
[5] D. Lemian and F. Bode, “Battery-Supercapacitor Energy Storage Systems for Electrical Vehicles: A Review”, Energies, *15, 5683, 2022.*