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

Master thesis, 2026-2027

Title : Development of a Low level Electro-Thermal Control Strategy for a Modular Battery with Loss Minimization

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Context

The increasing electrification of transportation and industrial systems requires battery packs with improved efficiency, reliability, lifetime, and thermal performance. Furthermore, the development of repairable and eco-designed power converters, supported by Life Cycle Assessment (LCA), is becoming increasingly important to reduce environmental impacts, facilitate maintenance and extend system lifetime. Integrating repairability and life-cycle considerations into the converter design can help identify more sustainable architectures while limiting resource consumption and the environmental impact associated with component replacement and end-of-life.

For this, Modular battery architectures offer significant advantages in terms of scalability, flexibility, redundancy, and fault tolerance. However, the operation of a modular battery involves complex interactions between its electrical and thermal behaviors.

The electrical operating conditions of each module directly influence heat generation through resistive and power-electronic losses, while the temperature of the modules affects their electrical characteristics, efficiency, available power, and ageing mechanisms. Consequently, considering the electrical and thermal dynamics independently may lead to suboptimal operating conditions and increased losses.

Advanced control strategies can exploit the modularity of the battery to distribute power among the different modules according to their electrical states, temperatures, and operating constraints. A local or close-to-module control approach could therefore enable a more efficient management of the battery while limiting thermal stress and minimizing energy losses.

Objective

The objective of this Master thesis is to develop a **local electro-thermal control strategy for a modular battery**, with the objective of minimizing the overall operating losses while satisfying electrical and thermal constraints.

The master thesis will include:

- A state of arts
- Development of an electrical and thermal model of the modular battery suitable for control design.
- Use the losses model developed for power-electronic switching and conversion losses.
- Development of a local control strategy allowing the power/current distribution between battery modules to be dynamically adjusted.
- Formulation of a loss-minimization problem subject to constraints such as module temperature, current, voltage, SOC and requested battery power.
- Investigation of suitable control and optimization approaches, such as constrained optimization.

- Evaluation of the proposed strategy through simulation and comparison with conventional battery management/control strategies.
- Analysis of the trade-off between efficiency, thermal uniformity, computational complexity and battery operating constraints.

The final objective is to demonstrate that an electro-thermal-aware local control strategy can reduce the losses of a modular battery while maintaining safe and balanced operating conditions.

Key word

Modular battery; Battery management system; Local control; Electro-thermal modeling; Thermal management; Loss minimization; Power distribution; Model Predictive Control; Optimization; Battery efficiency.

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