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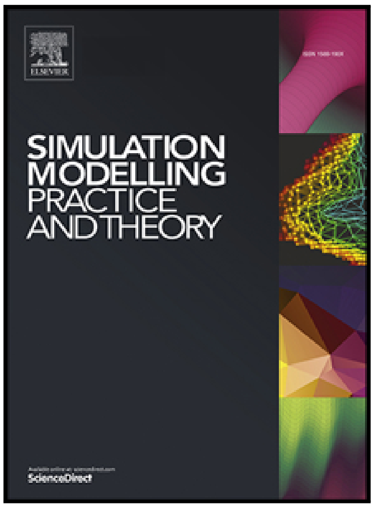


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# Design methodology for a dc-dc power conversion system with EIS capability for battery packs

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**Abstract**

This paper presents a design methodology for a dc-dc power conversion system (PCS) for battery packs. The methodology provides with an optimal design of the PCS and the associated inductive-capacitive filter interfacing the battery pack with the PCS. The PCS adds superior capability over conventional designs, which is performing current and voltage perturbations at the battery terminals for the so-called Electrochemical Impedance Spectroscopy (EIS). This technique is an option for battery state-of-charge (SoC) and state-of-health (SoH) assessment. The design is optimal in the sense that it minimizes volume and system power losses. Such multi-objective optimization is addressed adopting the theory of weighted sum and Pareto front. The methodology is tested through a case study, addressing a lithium-ion battery pack. The offered analyses permit to identify the impact in system performance of diverse design variables such as dc-link voltage for the PCS and its switching frequency.

*Keywords:* Batteries, H-bridge, LC filter, Electrochemical Impedance Spectroscopy (EIS)

## 1. Introduction

The technological advance in battery-based energy storage systems is one of the key challenges for the modernization of many cornerstone fields of the society, such as the electrical networks and the electro-mobility, for instance.

The current catalog of commercially available electrochemistries is vast. Each type offers different performance in many aspects such as cost, cyclability, energy and power density, efficiency, charge and discharge current rates, and so on; hence each type is best intended for providing different applications [6]. In general terms, but specially for high performance battery types such as lithium-ion ones, continuous monitoring and protection is needed, and this is provided by the so called battery management systems (BMS devices hereinafter). A BMS is an electronic board interfacing the battery itself (or the considered pack of batteries connected between them in series and/or parallel) with the power conversion system (PCS), which is a power electronics based module permitting an effective energy exchange between the batteries and the electrical system the energy storage solution is connected to. The PCS is usually composed by various power conversion steps. For grid connected solutions, a usual topology is that based on a front-end inverter interfacing with the AC grid. This inverter is then connected in series with a dc-dc converter that interfaces with the battery pack with a passive filter in between. Such dc-dc converter is the one in charge of actually managing the energy storage system. In turn, there are different types of BMSs and these can be classified in terms of their complexity including from centralized to distributed architectures. The BMS is the system in charge of carrying out several functions related to the battery data acquisition, state-of-charge (SoC) and state-of-health (SoH) monitoring and control, so as to ensure proper and safety operation during the battery lifetime [14, 20]. So the BMS is equipped with digital and analog inputs and outputs to read and evaluate external signals such as voltages and temperatures, and also to govern the power electronics of the battery to perform charge and discharge processes.

In regards of SoC, the BMS implements different algorithms for calculation. Basic ones are based on Coulomb counting [1], while sophisticated ones implements optimization routines including predictive and adaptive state estimation to fit battery parameters online [49]. While these technologies are widely employed in field, other powerful techniques, such as the so-called equivalent impedance spectroscopy (EIS) are still explored in laboratory environments. EIS is based on calculating the electrochemical impedance of the battery at different electrical frequencies [47, 44, 9, 4]. From this information, the SoC, SoH and temperature can be estimated [3, 37, 36]. EIS technique can be applied through two modes: the galvanostatic and potentiostatic modes. In the former, the transfer function for the equivalent impedance of the cell is deduced from the evaluation of the alternative voltage across the cell while applying a small alternative current through it. On the other way round, in the latter mode, is the voltage across the cell and not the current through it, what is imposed for the experiment. The frequency of such perturbation can be comprised in a very wide range including from $10^{-2}$ Hz to $10^{5}$ Hz. Such wide range is due to the need of representing a wide variety of

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