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Impacts on load distribution and ageing in Lithium-ion home storage systems

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Abstract

In parallel cell circuits within Lithium-ion home storage systems, the components of the circuit have an enormous influence on the load distribution and as consequence on the battery lifetime. Quality spreads within a batch of cells exist also as deviation in the connection quality. This paper presents the impacts of the system components on the load distribution and the ageing in parallel-connected circuits for exemplary module designs of commercial available home storage systems. Experimental and simulated studies show high deviations between the performances and lifetimes of several systems due to the circuit design.

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Keywords: Lithium ion; battery module; analysis; modeling; topology; cycle ageing

1. Introduction

Energy storage plays an important role in the energy supply, as soon as the installed capacity of renewable energy, like photovoltaic (PV) with intermittent power, exceeds certain levels. Modern lithium ion (Li-ion) battery systems are able to deal with the challenges posed by the use in stationary storage applications.

A Li-ion battery system is an ensemble of modules, which are in turn made up of a defined number of individual cells being serial and/or parallel (XsYp) connected to each other. Battery modules, composed of low-priced cylindrical cells with average capacities of 2-3 Ah are very common in commercial home storage systems. Herein it

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is very comfortable for the integration in private households to stay below 48 V, which leads to a connection of several cells in parallel to aggregate the required power. In parallel circuits asymmetric load distribution can occur, which was already shown in former publications from Kamalisiahrodui et al. [1] and Bruen and Marco [2]. Reasons for asymmetric load distributions are for example unequal cell characteristics like the electrical internal cell resistance R_{cell} and the nominal capacity C_n, which was already reported by Gogoana et al. [3]. They have shown that R_{cell} can spread up to 24.7 % and C_n up to 3.6 % within a batch of 72 cells. Fleckstein et al. reported [4], that unequal temperatures within a battery module due to active cooling cause also individual ageing behavior. At least a circuit of battery cells consists, beside cells, out of the electrical resistance of the connection $R_{transfer}$ (weld, bolts…etc) and the electrical interconnection resistance R_{inter} in form of a current collector. Depending on their resistance values and the circuit design, they can affect asymmetric load distribution within parallel-connected cells and as consequence the ageing behavior of the system.
In this paper, we would like to add a new aspect on the investigation of parallel-connected cells and introduce via experiment and an electrical-thermal model, how the load distribution is determined on deviations of the chosen circuit components and the circuit design within commercial PV home storage systems. The impacts on the ageing and the performance during the operation within high fluctuated PV supply will be discussed.

2. Battery modelling

2.1. Electrical-thermal modeling

For an accurate modeling of a Li-ion battery system, it is mandatory to consider the electrical and thermal behavior of the cell and the system. Therefore we would like to present an equivalent circuit model (ECM) coupled to a thermal model.
Electrical battery models should be able to describe the electrical cell behavior and that of the battery system. In the specific case of parallel-connected cells it means the interaction between cells in terms of different State of Charges (SOC) due to a divergent load distribution, which influence the cell characteristic like the open circuit voltage (UOCV) and R_{cell}. Fig. 1 presents the ECM with respect to the elements of the circuitry for two exemplary studied topologies (T1 and T2) for n parallel-connected cells.

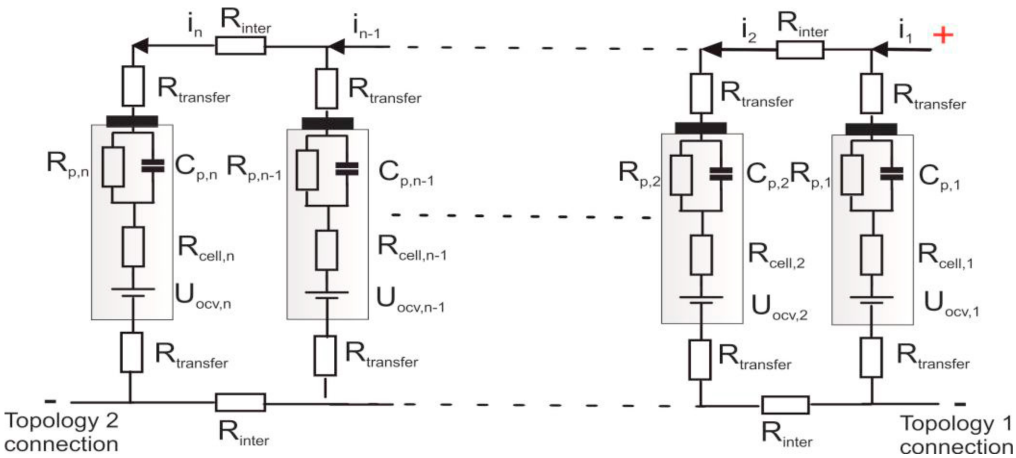

Fig. 1. ECM for n parallel-connected cells in form of two different topologies.

The circuit components R_{inter} and $R_{transfer}$ are represented in form of an ohmic resistance. Those resistances depend only on the used materials, the geometry of the current collector and also on the chosen connection technique. A summary of available ECM for single cell modeling is given by He et al. [5]. For our single cell model, we chose the Thevenin Model, which exist of UOCV, R_{cell} and one RC-circuit (with R_p and C_p), which represents over-voltages U_{RC} in form of diffusion, charge transfer and double layer effects.
R_{cell} presents ohmic resistance effects caused by the electrodes, separator and the electrolyte. It depends on the cell