A novel capacity management system for leveling cells in a lithium-ion battery pack

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The number of lithium-ion batteries for stationary storage and electric vehicles has expanded rapidly worldwide in the last years. The high voltage required for most applications is realized by serial connection of a large number of single battery cells. These cells have inherently different characteristics like internal resistance, capacity or self-discharge rate which results in different state of charge levels for all cells during operation. Therefore, cell balancing is a requirement for the operation of reliable and long-living storage systems.

This study presents an investigation and proof-of-concept of a novel capacity management system for leveling single cells in a lithium-ion battery system. It is based on providing individual charge or discharge currents to each cell in addition to the main current of the serially-connected configuration. This allows to set and keep each cell at the same state of charge irrespectively of different capacities. We refer to this concept as Q-leveling. It is illustrated in Figure 1.

The advantages of Q-leveling include: (a) The weakest cell in a series connection no longer determines the useful capacity of the entire battery. More usable energy is therefore available over the entire life cycle of a battery. (b) As a result, cells with different initial capacities (e.g., scatter from production) can be used in the system. (c) The aging mechanisms of a battery caused by a series connection are compensated or almost completely avoided. (d) As a result, the expected lifetime of a battery system with Q-leveling is almost comparable to the life expectancy of a single cell.

We show the demonstration of this concept using a 48 V lithium-ion battery consisting of 15 serially-connected LFP/graphite cells with a capacity scatter between 38 Ah and 76 Ah. The system was subjected to stationary and dynamic load tests, while voltage and current of individual cells were independently monitored. The novel capacity management system was able to keep the state of charge of all cells on the same level within +/- 3 % under both stationary and dynamic conditions. In addition, the system was able to integrate and operate a cell that was unknown beforehand in terms of capacity and initial state of charge.

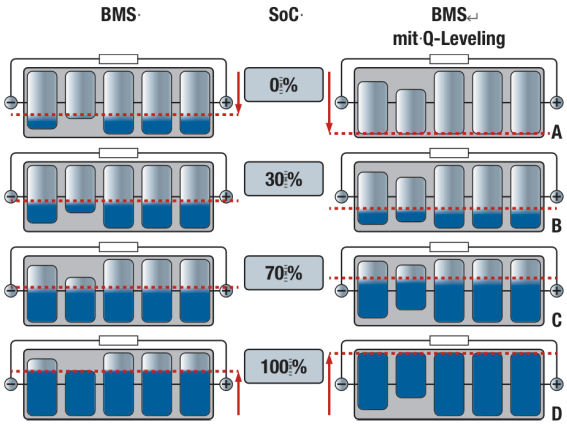

Figure 1: Comparison of state of charge levels of batteries with classical battery management system (BMS, left) and a BMS with Q-leveling (right).