Proactive SoC Balancing of Li-ion Batteries for Automotive Application

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Abstract : The demand for battery electric vehicles (BEV) is steadily increasing, and it can be assumed that electric mobility will dominate the market for individual transportation in the future. Regarding BEVs, the focus of state-of-the-art research and development is on vehicle batteries since their properties primarily determine vehicles' characteristic parameters, such as price, driving range, charging time, and lifetime. State-of-the-art battery packs consist of invariable configurations of battery cells, connected in series and parallel. A promising alternative is battery systems based on multilevel inverters, which can alter the configuration of the battery cells during operation via semiconductor switches. The main benefit of such topologies is that a three-phase AC voltage can be directly generated from the battery pack, and no separate power inverters are required. Therefore, modular battery systems based on different multilevel inverter topologies and reconfigurable battery systems are currently under investigation. Another advantage of the multilevel concept is that the possibility to reconfigure the battery pack allows battery cells with different states of charge (SoC) to be connected in parallel, and thus low-loss balancing can take place between such cells. In contrast, in conventional battery systems, parallel connected (hard-wired) battery cells are discharged via bleeder resistors to keep the individual SoCs of the parallel battery strands balanced, ultimately reducing the vehicle range. Different multilevel inverter topologies and reconfigurable batteries have been described in the available literature that makes the before-mentioned advantages possible. However, what has not yet been described is how an intelligent operating algorithm needs to look like to keep the SoCs of the individual battery strands of a modular battery system with integrated power electronics balanced. Therefore, this paper suggests an SoC balancing approach for Battery Modular Multilevel Management (BM3) converter systems, which can be similarly used for reconfigurable battery systems or other multilevel inverter topologies with parallel connectivity. The here suggested approach attempts to simultaneously utilize all converter modules (bypassing individual modules should be avoided) because the parallel connection of adjacent modules reduces the phase-strand's battery impedance. Furthermore, the presented approach tries to reduce the number of switching events when changing the switching state combination. Thereby, the ohmic battery losses and switching losses are kept as low as possible. Since no power is dissipated in any designated bleeder resistors and no designated active balancing circuitry is required, the suggested approach can be categorized as a proactive balancing approach. To verify the algorithm's validity, simulations are used.

Keywords : battery management system, BEV, battery modular multilevel management (BM3), SoC balancing
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