Fast Charging Strategy Optimization Based on Electrochemical Model and Dynamic Programming for a Lithium-ion Battery Cell

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Abstract

Fast charging of lithium-ion batteries is critical to commercial application of electrical vehicles (EV). Recharging lithium-ion batteries using standard charging methods usually takes more than one hour which is considerably longer than refueling an internal-combustion-engine (ICE) car. Fast charging can decrease the charging time with higher charging current which, however, adversely affect the cycle life, performance and safety of the battery. The charging energy efficiency can be reduced because of the increased heat generation during fast charging. Therefore, controlling the temperature rise and improving the charging energy efficiency are desired for well-designed fast charging strategies.

The objective of this work is to optimize the charging current profile for a 26650 cylindrical lithium iron phosphate (LFP) battery based on an electrochemical thermal coupled cell model in conjunction with dynamic programming. Figure 1 (a)-(c) shows the schematic of computational domain and the coupling between the models. The cell models are developed using the battery module of COMSOL Multiphysics 5.3. The dynamic programming is implemented using Matlab. Figure 1 (d) represents a multi-stage constant current (MSCC) fast charging strategy for charging the cell from 0 % to 80 % of its rated capacity within 30 minutes. To optimize the MSCC charging strategy, we set the goal of the optimization as the maximum charging energy efficiency or/and the minimal the temperature rise and charging voltage. The constraints of the optimization include temperature and cell voltage, which are applied to prevent thermal runway and reduce the capacity fade. The optimized charging current profile from various initial temperatures, ambient temperatures, and heat transfer coefficients will be compared. The effect of constraints on optimization results will be also discussed.

The optimization results show that the optimized fast charging protocol can improve the charging energy efficiency and reduce the temperature rise as compared with the traditional charging protocol. In addition, the charging protocol is optimized at different cycle numbers to further reduce the capacity fade for the whole battery cycle life.