Optimizing Charge-Discharge of a Lithium-ion battery based on its cycle life study

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Lithium-ion batteries are being extensively used as a cleaner source of energy in EVs and HEVs as well as in portable electronic devices. A proper charging mechanism is necessary to ensure safe and efficient operation of the battery. Constant current (CC), constant current-constant voltage (CC-CV) and multistage constant current-constant voltage (MSCC-CV) charging algorithms are the commonly used mechanisms. The magnitude of charging current to be applied, duration of application and end-of-charge voltage, however, are based on heuristics/estimates which do not account for the impact these factors have on charging time, lifetime of the battery and safety of operations [1].

Equivalent electric circuit models for the battery have been used recently to optimize the charging process of a battery. Optimal charging current of a lithium-ion battery was determined considering multiple objective functions namely time of charge, temperature rise and energy loss [2]. The resultant multi-objective optimization problem was converted into a single objective problem using the weighted sum approach. Perez et al. [1] used similar approach, however, the objectives considered were different, namely, reduction in state of health of the battery (SOH) and time of charge.

In the present work, we have used a first principles based charge-discharge model to perform a cycle life study [3]. During the charging process, formation of SEI layer on anode particles irreversibly consumes the active lithium ions, accounting for the cycle life aging. The above model considering simultaneous transport of ions in both solid and electrolyte phase is then being optimized for a fixed number of charge-discharge cycles considering different charging mechanisms. The optimization yields the profile of charge-discharge current with time which minimizes the four objectives, i.e., time of charge, energy loss, temperature rise and aging of the battery. Instead of performing a single-objective optimization, we chose multi-objective optimization to simultaneously minimize all the four factors stated above, which gives a set of Pareto optimal charge-discharge current profiles.

Pareto optimal profiles obtained this way can be used as set points in a Battery Management System providing adaptive charging-discharging strategies based on the cycle requirements and battery specifications. For e.g., while a mechanism involving higher charging currents is useful for charging during daytime operation of an EV to reduce the charging time; low charging currents during the non-operational hours reduces the energy loss, temperature rise and the aging. The profile thus obtained ensures an efficient and robust usage of the battery.

References:

[1] H. Perez, X. Hu, S. Dey and S. Moura, IEEE Transactions on Vehicular Technology, pp. 1-1, 2017.

[2] K. Liu, K. Li, Z. Yang, C. Zhang and J. Deng, Electrochimica Acta, vol. 225, pp. 330-344, 2017.

[3] G. Ning, R. E. White, B. N. Popov, Electrochimica Acta 51 (2006) 2012–2022.