State of Charge (SOC) Governed Fast Charging Method for Lithium Based Batteries

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Abstract

Introduction:

Considering the world's current energy starved scenario and the requirement to persistently met the stringent emissions norms, electric vehicles (EVs) and hybrid-electric vehicles (HEVs) will soon become our most common modes of transportation. The numbers of EVs and HEVs sold worldwide are projected to increase by 3 times in the year 2020. Almost 100% of the EV and PHEVs and 50-60% of the HEVs will be powered by lithium batteries as amongst the available battery technologies, lithium batteries have better automotive advantages which include higher gravimetric energy density, higher cyclability, charge efficiency without memory effect, etc. However, its cost, safety issues and long charging durations are the major concerns. Though a large number of fast charging algorithms have been devised in the past decade, most of them induce an irreversible capacity loss due to the pumping of very high currents into the battery in short time durations which either impacts the battery performance in the long run or reduces its cycle-life.

A novel State of Charge (SOC) governed fast charging method for secondary lithium based batteries has been proposed which not only charges a battery many times faster than the normal CC-CV mode but also reduces the side-effects generally accompanied by various fast charging methods available in the literature. The proposed charging algorithm (Figure 1) takes into account the varying internal impedance of the battery at different SOC levels and minimizes voltage fluctuations. This charging method consists of four different charging regions indicated by C1, C2, C3 and C4. The first charging stage, C1 ($0 = SOC < 50$) is a multistage Constant Current region (m-CCi) where the battery is charged with gradually increasing current pulses and alternate rest periods taking into account its higher impedance at lower SOC levels. The second charging stage, C2 ($50 \le SOC < 85$) is a multistage Constant Current - Constant Voltage region (m-(CC-CV)) where high amplitudes charge pulses (8C-12C) are applied with alternate CV steps since lithium batteries have higher charge acceptance and demonstrates a flat discharge plateau in this region. The third stage, C3 ($85 \le SOC < 95$) is a multistage Constant Current region (m-CCr) with gradually decreasing current pulses and alternate rest periods which accommodates for lower charge acceptance at higher SOC levels. The final stage, C4 ($95 \le SOC = 100$) consists of a single Constant - Voltage (CV) step at Vmax (charge cut-off voltage) with gradually decreasing current which slowly brings the battery to equilibrium at the end of the charge.

Use of COMSOL Multiphysics®:

The proposed charging method has been demonstrated using a simulated lab test on a lithium-ion battery cell in our lab and modelled using the Battery & Fuel Cells Module along with the Events interface of COMSOL Multiphysics®.

Results:

The experimental vs. simulation results for the proposed charging algorithm is presented (Figure 2). The experimental and modelling results of other state-of-the art fast charging methods will be compared with the proposed charging method.

* Patent pending

Reference

Patents

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Paper

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Figures used in the abstract

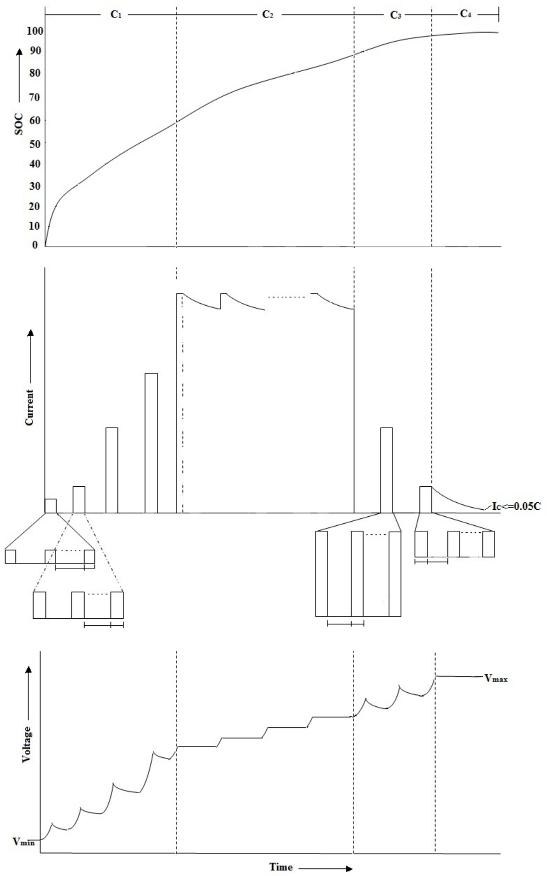

Figure 1: The proposed charging method

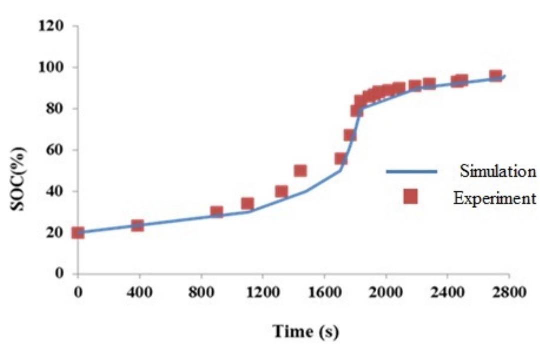

Figure 2: Experimental vs Simulation of the proposed charging method