Development of Novel Charging Protocols for Lithium ion Cells

Premanand Ramadass, Bala S. Haran, Ralph E. White and Branko N. Popov
Department of Chemical Engineering
University of South Carolina, Columbia, SC 29208

Introduction

Li-ion cells are ideally suited for powering most of the portable electronic devices due to their high energy density, high voltage range, and high capacity. However, the power requirements and the time needed to run the device vary widely based on the application used. While discharge characteristics vary charging profiles for all Li-ion cells remain the same.

The most common chargers available in the market follow a constant current charging protocol with very low applied current (C/5 to C/10). These chargers will obviously take more time for charging the cell based on its depth of discharge. Some rapid chargers are also available which follow a constant current-constant voltage (CC-CV) protocol with a higher value of charging current for the constant current part that will make the cell reach its cutoff potential sooner. This is followed by constant voltage protocol where the charger keeps the cell voltage at the specified cut off value. In general the total charging time is fixed.

Our capacity fade studies[1,2] on commercially available Li-ion cells show that, one of the reason for the capacity loss is overcharging the cell. The prime reason for capacity fade in Li-ion cells is the loss of the primary active material (Li^+). Since the open circuit potential of the cell directly depends on the amount of lithium available for intercalation, the cutoff potential for charging the cell will not be a constant value with cycling and hence the cells that are being charged by CC-CV protocol show more capacity fade with cycling.

Based on these observations it will be always better to control the current used to charge the cell for the entire charging time rather than controlling the voltage and monitoring the current decay. Our objective thus focuses on developing novel protocols for charging lithium ion cells that could lower the charging time, minimize effects due to overcharge and yield a comparable utilization with that of the conventional CC-CV protocol.

Experimental

Sony US18650S cells with a rated capacity of 1400 mAh were being used for studying the rate capability and utilization under various charging protocols. Arbin charger (BT-2000) was used for all charge discharge studies. It is important to develop charging protocols which will both minimize the charging time and reduce the capacity fade of these cells. Chang et al.[3], showed that charging the Li-ion cell with linearly descending current with time results in more than 2.5 fold reduction of charging time as compared to charging entirely using constant current. Based on this observation, we adopted a charging protocol called as the Linear Current Decay protocol (LCD) where the charging current decays linearly with time as per the expression, $I = I_o - k_1 t$, where 'I_o' is the initial charging current and 'k_1' is the linear current decay constant. Using this protocol several experiments were conducted with varying I_o and k_1. A modified linear current decay protocol (MLCD) is also used to charge the cell to compare the performance. The current expression used for MLCD is $I = I_o - k_1 t - k_2 \sqrt{t}$. Apart from LCD and MLCD protocols, two stage-charging protocols were also experimented with these Sony 18650 cells. The stages involve a combination of both the protocols. The prime objective here is to charge the cell sooner and to maintain the cell voltage at 4.2V (cut-off) for a considerable period of time during charging by controlling the current and to avoid overcharging the cell.

Results and Discussion

Table I gives a comparison of the charging performance of Sony 18650 cells when charged under different protocols. The results shown are based on the first five charge discharge cycles. The term utilization denotes the ratio between the observed capacities to the rated capacity of the cell. The charging performance with this new set of protocols would be compared with the CC-CV protocol as well as the CV protocol. Capacity fade studies are also in progress for some of these protocols. These will be presented along with the capacity fade results of CC-CV mode of charging the cells.

Acknowledgment

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References

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Table I: Charging Performance of the Sony US18650S Cells for the 2 New Protocols

Charging Protocol	**Charging Time(s)**	**Charging Capacity (Ah)**	**Utilization**
MLCD	3000	1.16	82.86%
Two Stage (MLCD & LCD)	3000	1.2	85.7%
CV	3000	1.045	74.6%