Performance of Commercial Li-ion Batteries Cycled with a Rapid Charging Protocol

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

Introduction:

Li ion cells are of paramount interest these days because of it's high electrochemical potential. However the system is very sensitive to voltage and a strict protection voltage has to be ensured for proper charging. This is because of the fact that there exist a number of side reactions at potentials close to where lithium intercalates in the carbon electrode.

The most common method of charging adopted by the commercial chargers follow a very low (C/5) rate constant current charging until the voltage reaches the cut-off point (usually 4.2 V). The voltage is then held constant until the current tails off to a predetermined low value to ensure complete transfer of the active material from the positive to the negative electrode. However this charging mode takes an excessive time though it's a safe mode of charging. Increase in the charging current rate in the same protocol will charge the battery at a faster rate but the system is kept at the cut-off potential for most part of the charging which accelerates the capacity fade. The possibility of charging the cell completely at constant voltage is also not attractive for the same reason. Studies in capacity fade have shown that the system shows a poor performance when charged beyond the cut-off potential[1]. Previous studies[2, 3] on capacity fade of commercial Li-ion cells also shows that, one of the reasons for the capacity loss is overcharging the cell. Thus our objective is to develop new rapid charging protocols for Li-ion cells that will minimize the overcharging effects and to study and compare its cycling performance with that of conventional CC-CV charging mode.

Experimental and Discussions:

Chang et al.[4], state 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. We extended this protocol in developing a charging method, which follows a decaying current function with time. The protocol has been optimized to charge the battery at a faster rate. Instead of following a linear current decay the current was decreased according to an empirical equation. The equation was obtained by fitting the current vs. time curve obtained during charging the cell at a constant potential of 4.2 V.

Sony US18650S cells with a rated capacity of 1400 mAh were used for these studies. The following studies were carried out to compare the new charging protocol with that of the conventional CC-CV and the CV mode of charging.

a) New Protocol: Cells were cycled in this mode using the decay protocol for a period of 5400 minutes in which complete charging is done. (98% SOC) Discharge was done at 1A until the voltage reaches 2.5V.

b) CC-CV cycling: Cells were cycled in this mode using 0.9A (average current of the new protocol) until it reaches 4.2V and then held at 4.2 volts until a predetermined time, equivalent to the same state of charge attained at the end of 5400 seconds in the new protocol during the first cycle. Discharge was done at 1A until the voltage reaches 2.5V.

c) CV cycling: Cells were cycled in this mode using 4.2V until the SOC reaches 98% (first cycle) and discharge was done at 1A until the voltage reaches 2.5V.

Cycling studies are now in progress to compare the new protocol with the conventional charging protocols. Arbin charger (BT-2000) was used for all charge discharge studies and Solartron SI 1255 HF Frequency Response Analyzer (FRA) and Potentiostat /Galvanostat Model 273A were used for the ac-impedance studies. For studies until 150 cycles the capacity fade for the rapid charging protocol was found to be lower compared with the conventional mode of charging. A detailed performance study for this newly developed protocol will be presented.

Acknowledgment:-

Financial support provided by National Reconnaissance Office for Hybrid Advanced Power Sources # NRO-00-C-1034 is acknowledged gratefully.

References

1. Takei, K Kumai, Y. Kobayashi, H. Miyashiro, N. Tereda, T. Iwahori, T. Tanaka, *J. Power Sources*, **2001**, 97-98, (697-701)
2. Ramadass Premanand, A. Durairajan, Bala Haran, Ralph White and Branko Popov, *J. Electrochem. Soc.*, **2001**, 149, (A54).
3. D. Zhang, B. S. Haran, A. Durairajan, R. E. White and B. N. Popov, *J. Power Sources*, **2000**, 91, (122).
4. S.K. Chang, A.A. Andriiko, A.P. Monko and S.H. Lee, *Journal of Power Sources*, **1999**, 79, (205-211).

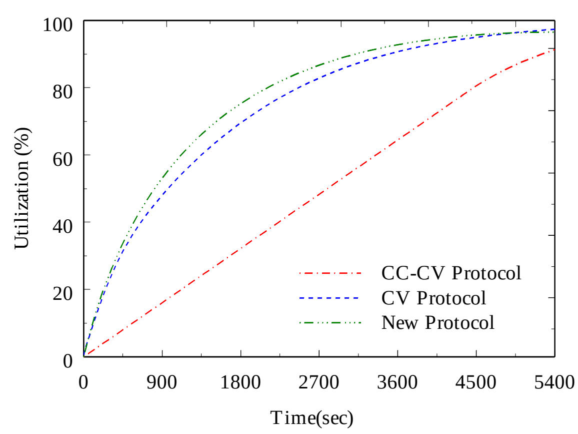

Fig1: Comparison of charging utilization for various modes of charging.