Feasibility Study for Assessment the Effects of Charging Profile on the Performance of Commercial Lithium-ion Batteries

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Abstract

In this paper, Lithium-ion iron phosphate (LFP) and Lithium-ion nickel manganese cobalt oxide(NMC) cells are used to investigate the influence of the charging profile on the battery efficiency, charge time, charge/discharge capacity, life cycle, internal impedance and temperature rise. Furthermore, this research provides an extended analysis to select the proper charging method, which can be used for designing the battery charging control strategy. In this paper, different charge methods are tested and analyzed by using PEC battery tester and Bio-logic Impedance Spectroscopy device.

Introduction

This paper is part of a research project, which aims to investigate the opportunities for using the second life batteries after their replacement from plug-in electric vehicles (PHEVs), hybrid electric vehicles (HEVs) and battery electric vehicles (EVs) in smart grid applications. In these applications, the charging profile and the quality of the charging system play a key role in the lifetime and the reliability of the battery. It means that the performance of the batteries mainly depends on the strategies of the charging system, which are utilized to reduce the charging time for fast charging, and to improve the battery performances. For Li-ion batteries, the overcharge happens when the restored electrons exceed the rated capacity. When these batteries are frequently operated in the overcharge state, they will be possibly damaged. A simple battery charge strategy of a constant-current and a constant-voltage (CC-CV) is widely used to avoid this problem. The CC-CV method not only avoids the overcharge state, but also achieves a full battery capacity. One can observe that it is unsuitable for a rapid charge, because the charging process needs a constant voltage that may increase the charge time. As is clear from literature, the impact of the charging methods on the characteristics of battery (such as the internal resistance, parameters of battery, capacity fade, efficiency, life cycle and temperature) has not addressed.

Consequently, this paper presents a comparative evaluation of different charge methods such as Constant Current (CC), Constant Current -Constant Voltage (CC-CV), Constant Current-Constant Voltage with Negative Pulse (CC-CVNP), and Multistage Constant Current-Constant Voltage (MCC-CV).

Results and Discussion

Batteries with different rated capacities and chemistries are charged using different charging methods. In addition, a constant current discharge profile is used for all cases at 5It. For example, Table 1 shows five cases. After 100 cycles, one can observe that the CC method time of takes less charge time and less capacity fade. However, the CC method cannot prevent the overcharge. Furthermore, it cannot provide a full battery capacity. Therefore, the CC-CV method can used to overcome the drawbacks of the CC method. By using negative pulse during charge process, one can observe that this method can reduce the capacity fade compared to CC-CV without using a negative pulse (see table 2). Furthermore, the CC-CV with negative pulse takes the same charging time as CC-CV without including a negative pulse (see table 3).

Table.1 Five cases for the charging process.

Cases	Case 1	Case 2	Case 3	Case 4	Case 5
Name	CC	CC-CV	CC-CVNP	CC-CVNP	CC-CVNP
I_{dis} (Amp.)	35	35	35	35	35
I_{charge} (Amp.)	7	7	7	7	7
I_{np} (Amp.)	-------	------	3.5	7	3.5
N	-----	-------	40	40	20
T_{ndis} (Sec.)	-------	--------	3	1	5
T_{ch} (Sec.)	--------	-------	88	89	180
T_{idle} (Sec.)	---------	----------	2	2	2

Where: I_{dis} is discharge current, while I_{charge} is charging current. I_{np} is a current of negative pulse, and N is number of negative pulse. T_{ndis} is the pulse width of negative pulse, while T_{ch} is the pulse width of charge. T_{idle} is the idle time.

Table.2 Capacity Fading after 100 cycles.

Cases	Case 1	Case 2	Case 3	Case 4	Case 5
The remaining capacity(%)	99.85	98.88	99.02	98.91	99.90

Table.3 the charging time.

Cases	Case 1	Case 2	Case 3	Case 4	Case 5
Charging time (Sec.)	3550	4375	4600	4409	4525

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