Impact of Internal Resistance on the Consistency of Lithium ion Energy Storage Batteries

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Abstract. This paper mainly studies the impact of internal resistance on the consistency of Lithium-ion batteries. The results shown that the inconsistent internal resistance of the cells forming the series-connected battery pack will reduce the performance of battery pack, and the higher initial internal resistance difference, the worse the consistency of cells of the series-connected battery pack.

Introduction

The internal resistance of battery is the resistance encountered by the current flowing through the battery inside when the battery is operating, generally the internal resistance includes AC resistance and DC resistance. When the batteries are connected in series to form a pack, the energy loss \( W = IR^2 \) (\( W \) is the energy loss; \( I \) is the current flowing the battery; \( R \) is the internal resistance), at this time, the battery current \( I \) flowing each monomer battery is consistent, if the internal resistance \( R \) is inconsistent, then \( W \) is inconsistent, the energy loss \( W \) of the batteries of high internal resistance \( R \) is high accordingly, and produces more heat, making temperature rises quickly, and the battery may have the danger of deformation and explosion. The internal resistance will also affect the charge voltage distributed in each battery, make some batteries reach the highest charging voltage limit in advance. When the batteries are connecter in parallel to form a pack, the internal resistance and current are in inverse proportion in the discharging process, the batteries operate at different discharge rate and affect the service life of the battery pack [1-6]. Therefore, this section mainly studies the impact of internal resistance on the consistency of battery pack.

The Consistency Tests

Test Sample

The model and the parameters of cell in this paper as follows:

1) The model: domestic battery, rated voltage 3.7 V, rated capacity 11 Ah, internal resistance < 6 m\( \Omega \), weight < 320 g
2) Dimensions: 133 mm\( \times \)66 mm\( \times \)18 mm.
3) The composing of the battery: the cathode material is LiMn\textsubscript{2}O\textsubscript{4}, the anode material is graphite, the electrolyte is LiPF\textsubscript{6}, EC and DMC, and battery separator is celgard 2325.

Test Instrument

Thermostat box, model SPHH-101; Integrated battery tester, MACCOR battery performance test systems; Data acquisition system, model MV2000. The test is shown in Figure 1.
Test Method

The method of consistency tests in this paper as follows: 4 cells of better capacity (10Ah ± 20 mAh), initial open-circuit potential (3.7V ± 10 mV) and internal resistance (6 mΩ ± 0.5mΩ) consistency are selected, respectively, to form 2 cell blocks and resistance (6 mΩ) connected in series, respectively, charged and discharged and monitored the real-time voltage, to study the impact of internal resistance on the consistency of battery pack. The test is shown in Figure 1.

Results and Discussion

The charge and discharge tests results of Lithium-ion batteries are shown in Table 1, Figure 2, Figure 3 and Figure4.

Table 1. The results of the consistency tests.

<table>
<thead>
<tr>
<th>Test conditions</th>
<th>Sample No.</th>
<th>The initial internal resistance / mΩ</th>
<th>The maximum charge voltage /V</th>
<th>The minimum discharge voltage /V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/3C</td>
<td>R-1-V</td>
<td>11.79</td>
<td>8.402</td>
<td>5.392</td>
</tr>
<tr>
<td></td>
<td>R-2-VIII</td>
<td>11.96</td>
<td>8.400</td>
<td>5.381</td>
</tr>
<tr>
<td>1.5C</td>
<td>R-1-I</td>
<td>11.94</td>
<td>8.385</td>
<td>5.376</td>
</tr>
<tr>
<td></td>
<td>R-2-IV</td>
<td>12.18</td>
<td>8.385</td>
<td>5.342</td>
</tr>
<tr>
<td>2C</td>
<td>R-1-IX</td>
<td>12.25</td>
<td>8.389</td>
<td>5.346</td>
</tr>
<tr>
<td></td>
<td>R-2-XII</td>
<td>11.89</td>
<td>8.389</td>
<td>5.346</td>
</tr>
</tbody>
</table>
Figure 2. The voltages curve of two battery groups at 1/3C charge and discharge condition.

Figure 3. The voltages curve of two battery groups at 1.5C charge and discharge condition.
The data is shown in Table 2.

Table 2. The tests data.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>initial internal resistance / mΩ</th>
<th>initial internal resistance difference / mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1-V</td>
<td>11.79</td>
<td>0.17</td>
</tr>
<tr>
<td>R-2-VIII</td>
<td>11.96</td>
<td></td>
</tr>
<tr>
<td>R-1-I</td>
<td>11.94</td>
<td>0.24</td>
</tr>
<tr>
<td>R-2-IV</td>
<td>12.18</td>
<td></td>
</tr>
<tr>
<td>R-1-IX</td>
<td>12.25</td>
<td>0.36</td>
</tr>
<tr>
<td>R-2-XII</td>
<td>11.89</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 thru Figure 4 and Table 2 show that the inconsistent internal resistance of the cells forming the series-connected battery pack will reduce the performance of battery pack, and in the charging process, the charging voltage distributed to each battery of the series-connected battery pack is different due to different internal resistance, making the battery charging voltage inconsistent that the voltage of batteries of higher internal resistance may reach the highest charging voltage limit in advance with the charging process in progress, thus to prevent overcharge of the batteries of higher internal resistance, and ensure the charging safety and the batteries not stopping charging before most batteries have not fully charged yet. In the discharging process, the current in the series-connected batteries is the same that the batteries of higher internal resistance have higher voltage drop and higher energy loss, and produce more heat. The heat is higher, the battery temperature rises and internal resistance becomes further higher, thus the batteries enter a vicious cycle again. If the heat has not dissipated in time, part of the batteries may cause thermal runaway, thus resulting in existence of safety risk of whole battery pack. For the parallel-connected battery pack, the charging current distributed to each battery is different, the batteries of higher charging current, their voltage rises faster due to different internal resistance. So in order to guarantee the safety, it has to stop charging before most batteries have not been fully charged yet, ensuring the actual total energy of the system is much lower than the design value of the system.

Summary

Based on the foregoing test results, analysis and discussions, the conclusion can be obtained as follows: the inconsistent internal resistance of the cells forming the series-connected battery pack will reduce the performance of battery pack, and the higher initial internal resistance difference, the worse the consistency of cells of the series-connected battery pack.
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