The LiFePO$_4$ battery sorting method based on temperature analysis

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Abstract. Using temperature as the main state basis for sorting the LiFePO$_4$ battery can solve the problem of insufficient response to the internal working state of the cell. By tracking and monitoring the status of each cell inside the module, which can reflect the consistency of the complex system after large-capacity grouping. Here, the dynamic temperature change of the LiFePO$_4$ battery is detected, the temperature rise and the temperature rise rate are compared. The corresponding temperature rise rate of the old cell were significantly higher than the new cell. The temperature difference can be used to judge the consistency of the single cells in the battery module.

1 Introduction

When electric energy or heat energy of the battery pack input and output, the same degree of the parameters, like voltage, state of charge, temperature, capacity, its decay rate, self-discharge rate and its changes over time etc., between single cells were called the consistency of the battery [1-4]. After combined into a battery pack, because of the differences in battery manufacturing raw materials, production parts, production processes, and use environment, there will inevitably be differences in the performance of the monomers [5]. As the number of single cells increase, the differences between the monomers obvious significantly. At present, more than a dozen single batteries were generally selected for series battery in electric bicycles, but hundreds or even thousands of battery cells were applied in electric vehicle, so the inconsistency caused by the differences between the individual cells will be more obvious [6]. The cycle life of the same batch of single cells can reach thousands of times, but after the battery pack was connected in series and parallel, its life span was only a few hundred times, which was the typical inconsistency. The inconsistency of the single cells in the battery pack not only affected the correct judgment of the state of charge and health of the battery pack, but also caused the capacity degradation and life expectancy of the battery pack, and may even cause safety problems [7].

In view of the inconsistency of the LiFePO$_4$ battery, two methods are proposed by researchers, the first was to monitor and manage the state of the cells in the battery pack through the battery management system (BMS) [8], where the equalization system was commonly used in battery management, like adjust the battery's power and voltage and other state parameters, so that the cells in the same battery pack can be maintained in a consistent state of output. The second was to sort the cells into groups through the measurement and comparison of similar parameters, such as voltage, internal resistance, and capacity before the batteries are grouped to improve the consistency of the cells in the battery pack [9].

The disadvantages of the methods in the application process are as follows. Firstly, the state of the cell can only be adjusted based on the certain criterion such as voltage and apparent SOC, and such external parameters, cannot completely reflect the internal working state of the battery (such as SOH, etc.). Secondly, the cells were tested in the static state, the dynamic working conditions during the actual operation of the cells cannot be reflected. Thirdly, the use environment of the battery in practical applications such as energy storage systems or electric vehicles were relatively complicated, and the existing static sorting methods cannot cope with the battery consistency requirements of complex systems after large-capacity grouping of batteries [10].

During the working process, the aging of the cell and the change of internal resistance will be reflected by the heat generation in the working state [11]. Due to the internal aging of the old cell (such as the amount of active lithium, electrolyte impurities, SEI film thickness, etc.) was larger than the new cell, when the new cell and the old cell of the same model was charged and discharged in parallel, resulting in the large energy loss of the old cell [12]. The lost energy will be reflected in the form of heat, and the corresponding temperature rise rate of the old cell were significantly higher than the new cell. Using temperature as the main state basis for sorting the LiFePO$_4$ battery can solve the problem of insufficient response to the internal working state of the cell. By tracking and monitoring the status of each cell inside the module, which can reflect the consistency of the complex system after large-capacity grouping. By the

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charging and discharging test of the LiFePO₄ battery, to
detect the dynamic temperature change of the cell, 
compare the temperature rise and the temperature rise 
rate, to reflect the internal performance of the cell during 
dynamic working process. The LiFePO₄ battery 
showed good performance at 20~30°C, considering the 
LiFePO₄ battery may operate under extreme conditions, 
the effects of temperature (-5°C, 25°C, 35°C) were 
investigated. The method can be used to identify battery 
inconsistencies and screen unqualified batteries.

2 Materials and Methods

The LiFePO₄ battery produced by CALB (Luoyang) Co., 
Ltd., has a single cell voltage of 3.2 V and a nominal 
capacity of 72 Ah, was used in the experiment. Electric 
charging and discharging tests of the LiFePO4 battery 
are conducted by the BTS-5V 600 A battery testing 
ingrument (Shenzhen Xinwei Electronics Co., LTD). 
Each cell was discharged to 2.5V at a constant current of 
1C. After standing for 10~12 hours to ensure the stable 
state of the battery voltage, followed by putting the 
battery under different temperature conditions at -5°C, 
25°C, 35°C for 5~8 hours, which was achieved through 
Tomino high and low temperature test chamber (Jiangsu 
Tomino Environmental Testing Equipment Co. LTD), to 
create different charging and discharging test 
environments of cells. The K-type thermocouple was 
directly arranged at the centre of the outer surface of 
each cell, and the temperature data collection and storage 
were realized through YOKOGAWA MV2000 series 
paperless recorder. The cell was charged with 1C 
constant current until the cell was fully charged, 
discharged each cell to 2.5V at a constant current of 1C, 
and record the temperature change during the charging 
and discharging process.

3 Results & Discussion

To understand the internal performance of the cell during 
the dynamic working process, charging and discharging 
tests were performed and analysed at -5°C, 25°C, 35°C. 
Detecting and recording the dynamic temperature 
changes of the batteries, and comparing the temperature 
rise and the temperature rise rate. 

Figure 1-3 showed that the temperature change trend 
of the cell during charging and discharging at -5°C, 25°C, 
35°C. The used cell was used in the energy storage 
power station for one year, and the new one was 
purchased from the same manufacturer. Due to the 
internal aging of the old cell (such as the amount of 
active lithium, electrolyte impurities, SEI film thickness, 
etc.) was larger than the new cell, the aging of the cell 
and the change of internal resistance will be reflected by 
the heat generation in the working state. When the 
ambient temperature kept at -5°C, 25°C or 35°C, the 
temperature rise of the old cell with a higher degree of 
aging was obviously higher than the new cell during 
charging and discharging. The corresponding data 
changes were shown in Table 1-3. At -5°C, the 
maximum temperature difference, the average 
temperature rise rate of the used cell were 18.74 and 
2.602×10⁻³, respectively. The maximum temperature 
difference, the average temperature rises rate of the new 
cell were 13.90 and 1.930×10⁻³, respectively. At 25°C, 
the maximum temperature difference, the average 
temperature rises rate of the used cell were 8.22 and 
1.412×10⁻³, respectively. The maximum temperature 
difference, the average temperature rises rate of the new 
cell were 5.73 and 7.96×10⁻⁴, respectively. At 35°C, the 
maximum temperature difference, the average 
temperature rises rate of the used cell were 12.73 and 
1.176×10⁻³, respectively. The maximum temperature 
difference, the average temperature rises rate of the new 
cell were 10.16 and 1.411×10⁻³, respectively. The results 
showed that the temperature difference can be 
used to judge the consistency of the single cells in the 
battery module.

3.1 The temperature change of the LiFePO4 
during charge and discharge process at -5°C

![Figure 1. Temperature change trend during charging and 
discharging process at -5°C.](image_url)

Table 1. Analysis of the cell's temperature changes.

<table>
<thead>
<tr>
<th>Name</th>
<th>Maximum temperature (°C)</th>
<th>Maximum temperature difference(°C)</th>
<th>Average temperature rise rate(°C/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The used cell</td>
<td>13.74</td>
<td>18.74</td>
<td>2.602×10⁻³</td>
</tr>
<tr>
<td>The new cell</td>
<td>8.895</td>
<td>13.90</td>
<td>1.930×10⁻³</td>
</tr>
<tr>
<td>The used cell</td>
<td>13.74</td>
<td>18.74</td>
<td>2.602×10⁻³</td>
</tr>
</tbody>
</table>

3.2 The temperature change of the LiFePO₄ 
during charge and discharge process at 25°C

![image](image_url)
batteries were grouped in series or parallel, the batteries numbered 4 and 6 can be discard and more suitable batteries can be continued to screen in the same way.

3.3 The temperature change of the LiFePO₄ during charge and discharge process at 35°C

3.4 Consistency identification of 10 single cells

Ten pieces of cells from the same manufacturer were tested, and the temperature change data in charging and discharging process of the cells were recorded. The temperature change during charging and discharging was shown in Figure 5. The temperature rises of two of them was significantly higher that of the other eight. The eight pieces of cells had a similar temperature rise. When

4 Conclusion

Through the detection and analysis of temperature changes, the problem of insufficient response to the internal working state of the cell can be solved. The dynamic temperature change of the cell can be detected by the charging and discharging test. Comparing the temperature rise and the temperature rise rate, to reflect the internal performance of the cell during the dynamic working process. Considering the cell may operate under extreme conditions, the effects of temperature (-5°C, 25°C, 35°C) were investigated. The temperature rise of the old cell with a higher degree of aging was obviously higher than the new cell during charging and discharging. The method can be used to identify battery inconsistencies and screen unqualified batteries.
the module, which can reflect the consistency of the complex system after large-capacity grouping. It can improve the energy efficiency of the energy storage module and guarantee the safety of the energy storage module.

Acknowledgments

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References