The Influence of Temperature on the Secondary Use of Lithium Iron Phosphate Power Battery

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Abstract. At different temperatures, we test the charge and discharge performance of lithium iron phosphate power batteries after retirement, and study the effect of temperature on the performance of decommissioned batteries, including the test of capacity and energy, and the battery voltage test. Experimental results show that low temperature will lead to a decrease in charge and discharge capacity and energy, and affect the performance of decommissioned batteries.

1. Introduction
In 2020, the output of power batteries in China will be 83.4GWh. Among them, the output of lithium iron phosphate batteries is 34.6GWh, accounting for 41.4% of the total output [1]. With the increasing number of retired batteries, the total retired power battery exceeds 250000t [2]. The external characteristics of lithium-ion batteries are sensitive to the environment conditions, especially affected by the ambient temperature, and the mileage of the battery can be reduced greatly under low temperature conditions. In order to study whether the retired lithium-ion battery can meet the requirements of echelon utilization, in addition to testing its own performance, it should also consider the influence of external conditions that may be received during the secondary use process, such as temperature and humidity. At present, the research on the utilization of echelons mainly focuses on the recovery method, the cycle performance and safety of the retired batteries. Wang Suijun and others [3] took 84% of the residual capacity of lithium iron phosphate battery as samples, and conducted thermal safety experiments at room temperature and -10°C after charging and discharging cycle, and studied its low temperature safety.

In this paper, the retired lithium iron phosphate battery is taken as the research object. According to GB/T 31467.2-2015 [4], the charge and discharge experiments were carried out at -10°C, 0°C, 25°C and 50°C, and the voltage characteristics and capacity changes of the battery were studied under different temperatures. This paper provides a reference for the utilization of the retired power cell and the improvement of the evaluation system.
2. Experiment and Procedure

2.1. Selection of Battery Samples
There are great differences in residual capacity, voltage and endurance of power batteries after decommissioning. The capacity of the worst cell determines the capacity of the entire battery pack[5-6]. In order to ensure the accuracy of the experiment, the battery cells needed in the experiment should have the same terminal voltage and internal resistance, and meet the similar discharge capacity at room temperature and the same size. In this experiment, the retired GRP6633065 lithium iron phosphate power battery was selected, with the rated capacity of 1100mAh. The specific parameters are shown in Table 1.

| Appearance | Size | Voltage | Resistance | Residual discharge capacity |
|------------|------|---------|------------|----------------------------|
| Good appearance, no damage | Length 67.0 ± 0.5mm, Width 33.0 ± 0.5mm, Thickness 6.3 ± 0.2mm | 3.65V±0.1V | 7.0±1.5mΩ | Room temperature 1063±1mAh |

2.2. Experimental methods
In addition to the influence of temperature on the performance of the power battery, humidity and pressure also have a great influence on the performance of the power battery. Therefore, in order to ensure the accuracy of the experiment, the humidity of the experimental environment is 70%, and the atmospheric pressure is 96kPa [7]. In order to reduce the influence of other factors on experimental results, the battery samples were divided into two groups with four cells in each group. The charge and discharge tests were carried out at -10℃, 0℃, normal temperature and 50℃ respectively.

As shown in Fig 1, the battery was charged to full charge with constant voltage and let it stand for 1 hour. Then, the battery was discharged at a constant current of 0.05C to a voltage of 2.0V and let it stand for 1 hour. Next, the battery voltage was charged to 3.6V with a constant current of 0.05C and let it stand for 1 hour.

Figure 1. The process of charge and discharge
3. Experimental Results and Discussion

3.1. Capacity and energy test

According to the above test method, the two sets of batteries were charged and discharged at different temperatures. Considering that high current charge and discharge may lead to lithium evolution of lithium batteries, which affects the test results and the safety of the experiment, this experiment uses 0.05C Charge with small current. As shown in Fig 2 and Fig 3, Fig (a) and Fig (b) reveal the relationship between battery capacity, energy and time of the first battery. Fig (c) and Fig (d) reveal the relationship between battery capacity, energy and time of the second battery. Figure 3 indicate the capacity and energy changes of the two sets of batteries at different temperatures during the charging phase.

Combining the data analysis of Fig 2 and Fig 3, it can be seen that within a certain temperature range, as the temperature decreases, battery capacity and energy decrease with decreasing temperature. In a low temperature environment, battery capacity is significantly attenuated. At -10°C, it is just about 90% of the normal temperature capacity. The charging capacity at 50°C is slightly higher than normal temperature.

The reason for the low-temperature capacity degradation is that the electrolyte used in lithium-ion batteries, as an organic liquid, becomes viscous at low temperatures, resulting in a decrease in lithium ion transmission capacity, and a severe deviation from the electron migration speed, causing a polarization reaction of the battery, resulting in a decrease in the battery capacity, and the battery can be the released energy is reduced and the performance is degraded. When charging in a low-temperature environment, the lithium ions migrated from the positive electrode cannot be inserted into the negative electrode material in time, and a lithium evolution reaction occurs, resulting in lithium dendrites, resulting in a decrease in battery capacity and, more seriously, piercing the separator and causing a short circuit.

At 50°C, battery capacity has increased compared to normal temperature. The main reason is that the increase in temperature increases the activity of ions in the electrolyte and improves the speed of chemical reaction inside the battery. Nevertheless, the reaction between lithium ions and the electrolyte is irreversible. It will contribute to the capacity of the lithium-ion battery to decline and further deteriorate the battery performance.
3.2. Discharge voltage

According to Fig 4 and Fig 5, we can see that the discharge time is 76700s when the current is discharged at 0.05C under normal temperature. Respectively at -10℃ and 0℃, the discharge time is 76330s and 76180s. In an environment of 50° C, the discharge time is 77840s. It can be seen that as the test temperature of the battery decreases, the charge and discharge time of the battery becomes shorter. Because the ionic conductivity in the electrolyte decreases with the decrease of temperature and the loss of lithium ions is serious, resulting in a decrease in battery life. It can be seen from the figure that although the time for the battery to reach the charge-discharge cut-off voltage at 50℃ is longer than that at room temperature, this is due to the increased activity of chemical substances inside the battery due to high temperature, but it will still affect the battery life. Not suitable for long-term exposure to high temperature environment.
Figure 4. Voltage and time

Figure 5. Voltage and capacity

4. Conclusion
In this paper, it’s shown that temperature plays an important role in the performance of the battery. Charging and discharging in a low temperature environment will reduce the performance of the battery, and the energy released will be significantly lower than that at normal temperature. We should using the battery in a low temperature environment. Furthermore, when using retired power batteries in cascades, more attention should be paid to the battery working environment and the control of the internal temperature of the battery, and the battery should be kept in a normal temperature as much as possible.


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