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A Research on Influence of Cut-off Point for Fast-charging LFP Battery

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Abstract: Since Lithium iron phosphate (LFP) battery can provide high-rate charge and discharge, they have significant advantages in high power applications. But high-rate charge and discharge brings difficulties to the estimation of SOC [1] of LFP battery and the security of using can't be ensured. Starting from its own characteristics and influence of actual working condition, this paper analyzes the effect brought by using battery electromotive force (EMF) as cut-off point and terminal voltage as cut-off point respectively on capacity of LFP battery, and studies the relationship between battery capacity[2] and environmental temperature, charge-discharge rate, the internal resistance of the battery when EMF is used as cut-off point. It provides a theoretical basis for the LFP application of high power.

Keywords: LFP battery, SOC, cut-off point, influence factor, battery capacity

I. INTRODUCTION

Though there are a lot of algorithms about estimating the SOC of battery, such as Neural network method [3], fuzzy control method [4], Calman filter calculation method [5], grey theory algorithm [6], etc. However, it is mainly aimed at the influence of the factors such as environment temperature, charge or discharge rate and cycle life on the SOC of the battery. With the improvement of the performance of LFP battery, the application of fast charging technology [7] is more and more widely. Constant voltage charging stage in the charging process is no longer required but high rate constant current charging is needed. Due to the internal resistance of the battery, the cut-off point of discharge and charge has become an important factor. If not controlled well, it will not only lead to lower utilization of battery energy but also lead to shorter cycle life, even lead to safety issues.

II. CUT-OFF POINT OF LFP BATTERY

The battery EMF characterizes the ability of chemical energy transmute into electrical energy, It is the sole criterion for LFP battery to stop working. The battery terminal voltage characterizes the capacity of the battery doing work. The relationship between battery terminal voltage and EMF is as follows:

Charge $U=V-I_1r$ (1)

Discharge $U=V+I_2r$ (2)

U= battery EMF, V= battery terminal voltage, I_1= charging current, I_2= discharge current, r= battery internal resistance.

Due to the limitation of the existing technologies, the EMF of the battery in the working can't be directly tested. According to the formula (1) and (2), the battery EMF can be measured by the compensating method. But the internal resistance of the battery is affected by actual condition and battery life [8], so it is difficult accurately estimating the battery internal resistance value, so it difficult to accurately calculate the battery EMF. With increase of the battery working current and resistance, the difference of battery EMF and terminal voltage has become wider, and this will produce deviation of battery SOC estimation. The reason why the existing battery management strategy (BMS) [9] used the terminal voltage as cut-off point does not exist this kind of problem, because there is a constant voltage charging process. The battery voltage is constant and the current gradually become smaller in this period. There is a narrowing gap between the battery EMF and terminal voltage at the end of the battery charging. Due to the current application of fast charging battery does not have a constant voltage charging process, there is a large deviation of the battery's EMF and terminal voltage. If the battery charging cut-off voltage is the initial value, the battery is lower utilization of energy. If compensation voltage is set too high, the battery will be excessive charged and increase danger. In order to more reasonable control the battery, the change of battery internal resistance of battery need to be monitored constantly in battery

BMS.

III. TEST METHODS

The nominal capacity of LFP battery used in this paper is 1.1Ah, and the nominal voltage is 3.2V. In order to know the effect of different cut-off point on the SOC of the battery, the battery needs to meet the condition that the terminal voltage and EMF are as the cut-off point simultaneously, and monitor the internal resistance of the battery at the same time. In order to meet the needs of the experiment, the experiment test battery voltage and internal resistance by the AC resistance tester measurement.

The cycle mechanism of charge and discharge is as follows: (1) at room temperature (25℃), discharge with a constant current 1C to 2.4V, the purpose is to eliminate the prior impact on the operation of the battery; (2) at the same temperature and rate, rapid charge to 3.6V; (3) repeat steps (1), (2) 5 times; (4)at the same temperature (25℃), repeat the steps(1), (2), (3), but the charge and discharge rate were changed to 0.5C, 2C, 3C, 4C, 5C; (5) at the same rate 1C, repeat the steps(1), (2), and (3), but the environmental temperature was changed to -10℃, 0℃, 10℃, 20℃, 30℃, 40℃, 50℃.

IV. THE EFFECT OF CUT-OFF POINT OF LFP BATTERY ON CAPACITY

4.1 Define parameter

First, calculate the charge and discharge capacity (C1) witch terminal voltage is from 2.4V to 3.6V; secondly, according to the formula (1) (2) to calculate the charge and discharge capacity (C2) witch battery EMF is from 2.4V to 3.6V; thirdly, analysis data and create table.

Define η as the capacity difference percentage, which characterizes the capacity difference between the two cut-off methods.

$$\eta = \frac{|C_1 - C_2|}{C} * 100\% \qquad (3)$$

C1= battery capacity which terminal voltage is as the cut-off point, C2= battery capacity which EMF is as the cut-off point, C= the nominal capacity of the battery.

4.2 Analysis data

According to the formula (3), draw the picture ofηwith the environmental temperature and the charge-discharge rate changing.

Figure (1) gives the relationship between η and LFP battery charge and discharge rate. From the figure can be seen that with increase of current of the cell charging, the η increases and its change is exponential distribution. But with discharge current increase the change of η is very small, almost unchanged in the discharge process. So the battery capacity influence by charging cut-off point is relatively large. When the charging current is 5C, the capacity difference is about 12% with different cut-off point. Therefore, when the battery is high rate charged, it can no longer use battery terminal voltage replace EMF as cut-off point for battery.

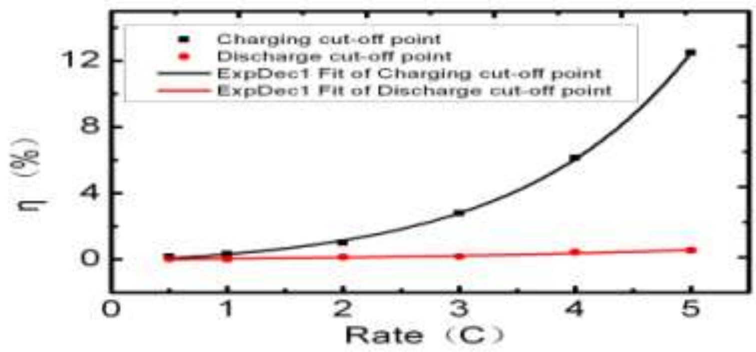

Figure 1

Figure 2: gives the relationship between η and environmental temperature the LFP battery working. From the figure can be seen from the figure that when the temperature changes, charging cut-off point of battery has a major impact on capacity. when the environment temperature is -10℃, the capacity difference is about 14% with different charge cut-off point. But different discharge cut-off point has little impact on battery discharge capacity [10]. Therefore, when the battery is in the low environmental temperature, the same as charging with high rate, the battery charging cut-off point can't be replaced the battery EMF by the battery terminal voltage.

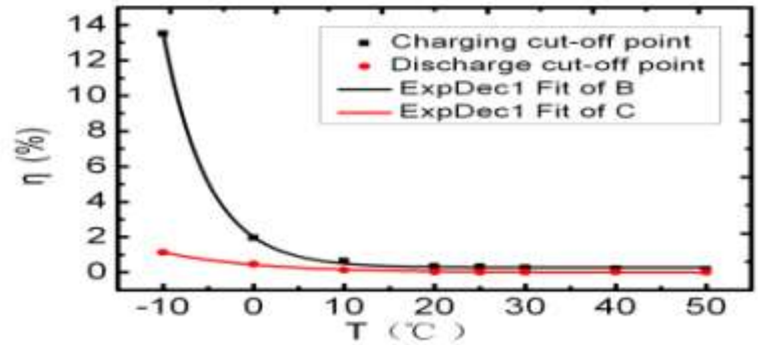

Figure 2

When charging, the battery terminal voltage's value is bigger than the EMF's. On the basis of same cut-off point voltage value, if Select terminal voltage as a cut-off point, then the charging capacity of battery is less than the capacity of EMF as cut-off point, And With the charge rate increases, the lower the temperature, the greater the gap between the capacity. Thus, the battery fast charging at low temperatures, the EMF must be selected as the charging cut-off point, rather than the terminal voltage, otherwise the impact on the battery capacity is very large.

V. CONCLUSION

With the higher charging current and the lower working environmental temperature, the more impact created by different cut-off point on the SOC of the battery, especially the cut-off point of the charging process. So, in the application of fast charging technology, we can't replace the EMF with the terminal voltage of the battery, otherwise, we can't accurately estimate the SOC of battery. So this has put forward higher requirements for the battery control, because the working environment temperature, battery charge rate and cycle life affect the internal resistance of battery. Therefore, we not only need Real-time measurement of the terminal voltage of the battery, but also need real-time measurement of battery internal resistance in order to accurately calculate battery EMF. Only in this way can we improve the utilization of the battery and ensure the safety of the battery.

REFERENCE

[1]. Jun Xu,Binghe Liu,Xinyi Wang,Dayong Hu. Computational Model of 18650 Lithium-ion Battery with Coupled Strain Rate and SOC Dependencies[J]. Applied Energy,2016.

[2]. Xin Jin,Jun-qiu Li,Puen Wu,Xiaopeng Zhang. Researches on Modeling Methods of Battery Capacity Decline Based on Cell Voltage Inconsistency and Probability Statistics[J]. Energy Procedia,2016,88:.

[3]. Mansour Sheikhan,Reza Pardis,Davood Gharavian. State of charge neural computational models for high energy density batteries in electric vehicles[J]. Neural Computing and Applications,2013,226.

[4]. WANG TW, YANG M J, SHYU K K, et al. Design fuzzy SOC estimation for sealed lead-acid batteries of electric vehicles in reflexTM [C], 2007 IEEE International Symposium on Industrial Electronics Proceedings, Piscataway, NJ. 2007: 95-99.

[5]. BHANGU B, BENTLEY P, STONE D, et al. Nonlinear observers for predicting state of charge and state of health of lead acid batteries for hybrid electric vehicles ［J］. IEEE Transactions on Vehicular Technology, 2005,54(3): 783-795.

[6]. Jianming Hu，Yuanrui Chen．Application of grey theory to predict the residual capacity of battery in hybrid electric vehicle［J］．Communication power technology，2009，26(5): 54-58．

[7]. Shichao Zhang , Wenkui Lin, Wei Yu. A Portable Fast Charging Power Supply Design for Lithium Batt ery Pack with Cell-Capacity-Balancing Method [J]. International Journal of Research in Engineering a nd Science. 2016,06:2320-9364.

[8]. Todorović Andreja,Grgur Branimir,Rajović Jelena. Influence of current and temperature on discharge characteristics of electrochemical nickel−cadmium system[J]. Hemijska Industrija,2010,644.

[9]. Xinjie Gao,Donglin Su,Li Zhai,Xinyu Zhang. Diagnosis Method of Radiated Emission from Battery Management System for Electric Vehicle[J]. Energy Procedia,2016,88.

[10]. Ying Wang, Wenkui Lin, Wei Yu. Researching on Discharge Efficiency of Battery Pack with Redundan t Cells[J]. International Journal of Research in Engineering and Science, 2016,07: 2320-9364.