Overview of Power Lithium Battery Modeling and SOC Estimation

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Abstract. Power lithium battery is the hotspot of current research. This paper introduces the mechanism model and equivalent circuit model from the external characteristics and internal characteristics of lithium battery, and analyzes the applicable scenarios and principles of these two models. According to the existing model, the principle of the SOC, the advantages and disadvantages and the existing problems of the ampere-time integral method, the open-circuit voltage method, the neural network algorithm and the Kalman filter algorithm are introduced.

1. Introduction
Power lithium battery is a common tool for storing electrical energy, and the storage and release of electrical energy is achieved by a reversible chemical reaction between the electrodes [1-2].

For power lithium batteries, the voltage, current, internal resistance, and time of use can be measured by external means, but only through these external parameters can not meet the actual needs of the project. In practical applications, it is often necessary to know the other battery. The current powerful computer simulation technology provides a viable technical means for battery research. Power lithium battery modeling and state estimation are important boosts for battery research. By establishing different models, the state parameters of the battery are predicted and estimated within the tolerance range to complete different engineering simulation requirements. The model is completely computer-generated and can be repeatedly tested on a computer without the need to build complex hardware devices. Compared with traditional experimental methods, modeling and simulation is more convenient and cost-effective.

2. Battery common model

2.1 Mechanism Model
The mechanism model refers to the model established by the electrochemical principle inside the battery. The model is analyzed from the microscopic point of view, which can accurately reflect the diffusion of ions inside the battery under different conditions, the chemical reaction of the electrode and the proton membrane, and the electron. Through the model, parameters such as SOC of the battery charge and discharge, heat generation, and cycle life of the battery can be predicted. This model is generally represented by a more complex multi-order partial differential equation. Although this model is more accurate, the parameters in the model are mostly difficult to implement in practical engineering applications.
2.2 equivalent circuit model
The equivalent circuit model pays more attention to the external characteristics of the battery, and uses various methods to fit the response relationship between the current and terminal voltage of the battery. The state and battery life is able to predicted by the parameters of voltage, current and internal resistance that can be measured. Usually this model consists of voltage source, resistor, capacitor, inductor and other circuit components. The battery's hysteresis characteristics, polarization characteristics, etc. are simulated by different component combinations to obtain the external response of the battery as much as possible. A common second-order equivalent circuit model is shown in Figure 1. The output equation and the state equation are as shown in equation (1). This model is widely used in practical engineering research.

\[ \begin{align*}
V_0 &= \frac{R_1}{1+R_1C_1} I \\
V_2 &= \frac{R_2}{1+R_2C_2} I \\
V_L &= V_{OC} - IR_0 - V_1 - V_2
\end{align*} \]

3. SOC estimation
The SOC referred to as state of charge. According to the SOC, the battery life can be inferred in real time, and the overcharge and over discharge of the battery can be prevented by setting the SOC warning value. There are many ways to estimate SOC [3-13].

3.1 Ampere-time integration method
The An-time integration method first measures the initial capacity, and then continues to get the capacity of the battery through integration. The relationship between current and SOC can be given by equation (2).

\[
SOC = SOC_0 + \frac{1}{C_n} \int t \eta Idt
\]

This is an open-loop algorithm. It can't perform error correction. It requires high current measurement. Once an error occurs, its error value will accumulate continuously, resulting in more and more errors.

3.2 OCV method
After the battery has been left to stand for a while, its internal electrochemical reaction reaches a stable equilibrium state. Its terminal voltage has a significant function relationship with the SOC of the battery. Especially used in the state of the two ends of the battery. The method of voltage estimation of the battery SOC can achieve better results. Shanghai University Microelectronics Research and Development Center, Deng Wei carried out the calculation of battery soc, and gives the OCV-SOC.
The open circuit voltage method is simple and easy to implement, and the measurement accuracy is high after the battery is left for a long enough time. However, the significant shortcomings of the open circuit voltage are manifested in two aspects: First, the battery must be allowed to stand for a long time, and the terminal voltage can reach a stable state. However, the battery is generally used frequently, and the operating current changes greatly, so the terminal voltage cannot be shortened in a short time. Stable, so the SOC cannot be accurately estimated in real time. Second, due to the existence of a voltage platform, such as lithium iron phosphate battery, during the SOC 30%-80% period, the curve of the terminal voltage and SOC is approximately straight, and the voltage variation range is very small. The current hardware technology cannot guarantee the SOC to voltage measurement. The accuracy requirement, the estimated SOC error during this period is very large. There are few application scenarios in real life.

3.3 Kalman Filtering Algorithm

The Kalman filter algorithm is an algorithm proposed by Kalman in 1960 [15-16]. The Kalman filter uses noise-containing measurements to estimate the current state of a dynamic system with unpredictable perturbations [17]. Kalman filtering provides an effective solution to some states in the system that cannot be directly measured. The Kalman filter algorithm is a recursive algorithm.

Each state estimate is calculated from the state estimate at the last moment and the current measured value. It does not store all the observed data, which effectively improves the computational efficiency [18]. The Kalman filter is very robust and its structure is shown in Figure 3.

![Kalman filter algorithm structure diagram](image)

The figure shows:

- Equation of state: \( X(k+1) = A(k)X(k) + B(k)u(k) + w(k) \) (3)
- Equation of measurement: \( y(k) = C(k)X(k) + D(k)u(k) + v(k) \) (4)

According to the schematic diagram of power Lithium battery model, write formulas (5) and (6).
After continuous iteration, the SOC value can be obtained.

3.4 Neural Network Algorithm

In view of the strong nonlinear characteristics of lithium-ion batteries and the difficulty of modeling, relevant scholars have proposed a strategy to establish a lithium-ion battery system model using neural networks. BP neural network is used in many aspects and in many fields. It has simple model, strong combination and fast calculation speed. It plays an important role in intelligent control, nonlinear fitting and data processing [19-21]. BP neural network has strong nonlinear fitting ability and can solve nonlinear problems well. The structure is shown in Figure 4.

Through the analysis of the algorithm of the neural network, the parameter prediction using this method does not need to consider the state and characteristics of the system. It only needs to collect the sample data of the relevant input and output, and can be accurately established through the internal adaptive training mode of the network. Neural networks algorithm can accurately estimate the SOC parameters for the functional model between the parameters.

The neural network mode has good anti-interference effect, accurate prediction and comprehensive automatic adjustment mechanism. It ensures that the selection of sample data is reasonable and sufficient, and an accurate function model can be obtained to achieve high-precision SOC estimation. The algorithm can adapt to different kinds of dynamics.

![Neural network algorithm structure diagram](image)

Figure 4. Neural network algorithm structure diagram

4. Conclusions

A single SOC estimation algorithm has certain drawbacks. For example, the integration time method is easy to cause cumulative error. Compared with the Kalman filter algorithm, it is a relatively complete estimation algorithm. Since the Kalman filter algorithm has no precise requirements for the initial value of the SOC, it can obtain relatively accurate estimation values, which has become the research focus of the SOC estimation algorithm for lithium batteries. The various extensions and variants of the Kalman filter algorithm also make the algorithm more and more complete.

The research on the future SOC estimation method will be perfected from four aspects: First, through a large number of experiments, a rich database will be established, so that the soc estimation can be based on evidence and can be checked; secondly, relying on hardware technology to improve...
current. The measurement accuracy of voltage, etc., guarantees the accuracy of the basic data used to estimate the SOC. Third, the accurate battery model is introduced to more realistically characterize the dynamic characteristics of the battery during use. Finally, various algorithms are integrated. In short, different correction methods are introduced in different stages of SOC to minimize the error in different states and improve the estimation accuracy.

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