Study of SOC dynamic estimation method of power lithium battery

Yanan Gou*, Xuezheng Han[a]

College of Mechanical and Electrical Engineering, Zaozhuang University, Zaozhuang, China

*Corresponding author e-mail: hyynan@163.com, [a]zzxyh5909@126.com

Abstract. The Partnership for a New Generation of Vehicles (PNGV) battery equivalent model is established on the basis of the existing charging state estimation method. Based on the kalman filtering algorithm, a state space expression based on the Davidson's battery model is established. Finally, Matlab/Simulink is used for simulating calculation. Simulation and experiment show that the selected PNGV model has high precision and can simulate the charging and discharging characteristics of the battery truly, so that the SOC estimation value is controlled within the range of high precision.

1. Introduction

Power battery refers to the battery that provides power for transportation vehicles [1, 2]. According to the different reaction principles of the battery, it can be divided into lead-acid power battery, nickel metal hydride power battery, lithium ion power battery and so on. Compared with other power batteries, li-ion battery has the advantages of high specific energy, high voltage of single battery, long cycle life, low self-discharge rate, no memory effect, strong adaptability to high and low temperature and no pollution [3]. Therefore, it is one of the most promising and widely used batteries in power battery.

Li-ion batteries are generally used with multiple joints connected into a lithium battery pack, so the corresponding battery management system must be designed to manage them, the state of charge (SOC) is one of the most important parameters of the battery management system [4, 5]. SOC is an important parameter to describe the residual power of li-ion battery and plays a vital role in the best performance of li-ion battery [6].

2. The Li-ion battery estimation

2.1. Common SOC estimation methods

According to the United States Advanced Battery Consortium, the SOC is defined as the percentage of the Battery's remaining capacity that is rated at a given discharge rate:

$$soc = \frac{Q_C}{Q_L} \tag{1}$$

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At present, the battery charging state estimation methods mainly include the ampere time integral method, open circuit voltage method, internal resistance analysis method, artificial neural network method and kalman filtering method [7]. In this paper, the PNGV equivalent circuit model of li-ion battery and the untracked kalman filter method based on this circuit model are proposed to estimate SOC, and then Matlab is used for verification and simulation.

2.2. The establishment of equivalent circuit model of li-ion battery
According to the United States Advanced Battery Consortium, the SOC is defined as the percentage of the Battery's remaining capacity that is rated at a given discharge rate:

2.2.1. The PNGV equivalent circuit: PNGV model is a battery equivalent circuit model proposed by PNGV battery experiment manual. Compared to the Davidson's battery model, the PNGV circuit model adds a capacitor on its basis, and the circuit model schematic diagram is shown in Fig. 1. In the model, is the open circuit voltage of the battery, it is a fixed function relation with the charged state at the same temperature; is the voltage at both ends of the battery; is the charge and discharge current of the battery; is the constant equivalent internal resistance of the battery; and are polarization internal resistance and equivalent capacitance respectively. Capacitance describes the accumulated open circuit voltage change during load current, and its value reflects the capacity of li-ion battery.

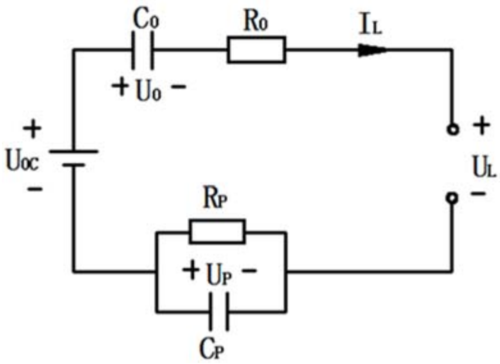

Figure 1. The PNGV equivalent circuit.

2.2.2. The PNGV equivalent circuit model state equation: According to the above schematic diagram, if the voltage of capacitor C_0 and C_P is U_O and U_P, the state equation of PNGV model is

$$\begin{bmatrix}\dot{U}_O\\ \dot{U}_P\end{bmatrix}=\begin{bmatrix}0 & 0\\ 0 & \frac{1}{-C_P R_P}\end{bmatrix}\begin{bmatrix}U_O\\ U_P\end{bmatrix}+\begin{bmatrix}\frac{1}{C_O}\\ \frac{1}{C_P}\end{bmatrix}[I_L] \tag{2}$$

$$[U_L]=[-1-1]\begin{bmatrix}U_0\\ U_P\end{bmatrix}+[-R_0][I_L]+[U_{0C}] \tag{3}$$

In the equation of state: $\dot{U}_P$ and $\dot{U}_O$ are respectively the derivative of time of U_P and U_O.

2.3. The untracked kalman filtering algorithm based on the PNGV battery model
Kalman filtering is an algorithm that using the state equation of a linear system to estimate the state of the system optimally through input and output observation data of the system.

For discrete systems, system state space model of Kalman is as follows:

$$X_{k+1}=A_k X_k+B_k U_k+W_k \tag{4}$$

$$Y_k = C_k X_k + V_k \tag{5}$$

Among them: U_k is the input vector of the system. Including current, SOC, internal resistance, Temperature, etc. Y_k is the output of the system and represents the working voltage of the battery. A_k, B_k, C_k are determined by the parameters obtained in the experiment, W_k is the process noise variable and V_k is the observation noise variable.

Definition:

$$\begin{cases} X_k = \begin{bmatrix} SOC_k & U_k^{R_P C_P} \end{bmatrix} \\ A_k = \begin{bmatrix} 1 & 0 \\ 0 & e^{-(\Delta t/\tau)} \end{bmatrix} \\ B_k = \begin{bmatrix} -(\frac{\eta \Delta t}{C}) \\ R_P(1 - e^{-(\Delta t/\tau}) \end{bmatrix} \\ C_k = \begin{bmatrix} \frac{dU_{OCk}(SOC,T)}{dSOC} & -1 \end{bmatrix} \end{cases} \tag{6}$$

According to the above contents, the SOC estimation flow chart is shown in Fig. 2.

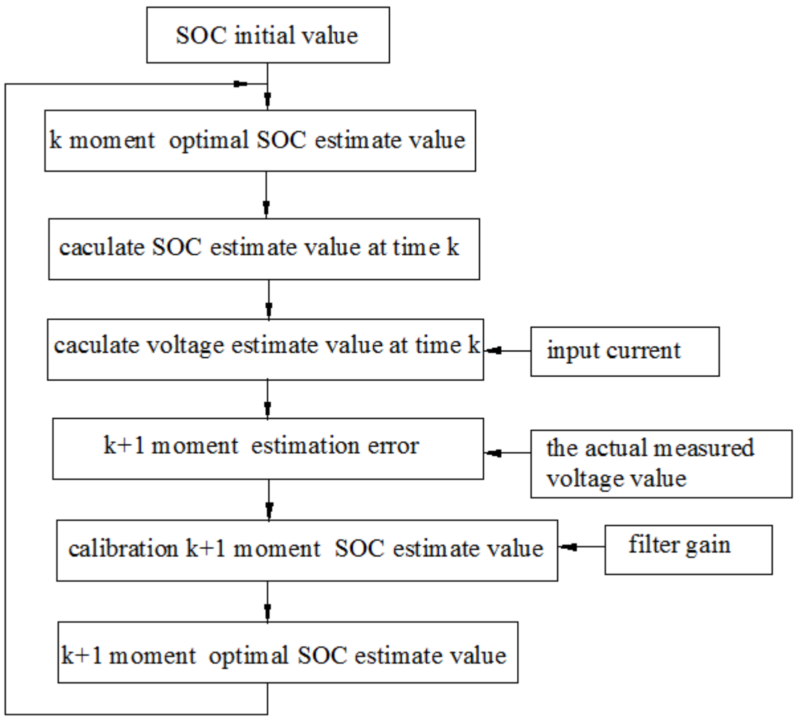

Figure 2. The SOC estimation flow chart.

3. The results analysis of battery SOC simulation

The experiment is in the Matlab environment, the specifications of li-ion battery are as follows: the output current is 100A, the battery capacity is 100Ah, and the simulation test of li-ion battery is carried out under constant current condition at room temperature of 25 degrees. The curves of experimental results and untracked kalman filtering in estimating SOC results during discharge are shown in Fig. 3. Table 1 shows the error of untracked kalman algorithm and true value.

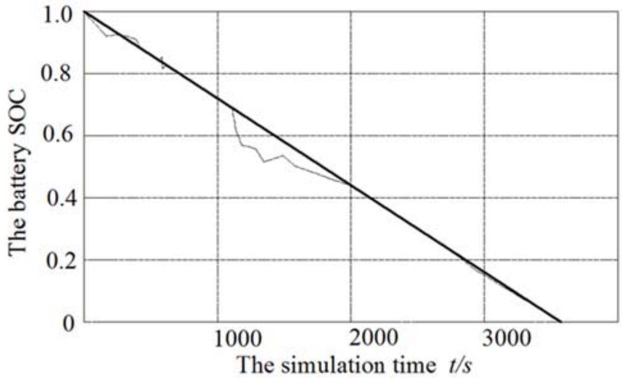

Figure 3. The battery SOC simulation results and experimental results.

Table 1. Estimated error table.

Estimation method	The simulation results	The experimental results
Discharge capacity	104.65Ah	101.11Ah
The error value	3.39%	0

From the analysis of capacity, it can be seen that the simulated discharge capacity is 96.61% of the actual discharge capacity.

It can be seen from Fig. 3 and Table 1 that under the condition of constant flow, the two methods have a good consistency in estimating the current SOC value. The interpolated SOC in the figure has a partial point mutation, which is caused by the model parameter error.

4. Conclusion

The prediction and estimation of SOC, as an important part of li-ion battery management system, is of practical significance to its research. In this paper, according to the PNGV dynamic battery equivalence model, considering the influence of temperature on the model parameter value and based on the untracked kalman filtering algorithm of the PNGV battery model, the SOC estimation block diagram is established by the state equation and the simulation analysis is carried out. Compared with simulation terminal voltage and measured terminal voltage, the error only accounts for 3.39%.The results show that the model parameters are accurate and effective, and the PNGV model has high precision.

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