

Lithium battery model establishment

Qinghe Liu^{1, a}, Xueqi Shou^{1, b} and Shouzhi Liu^{1, c}

¹School of automobile, Harbin Institute of Technology, Weihai 264209, China;

^aqingheliu@sina.com, ^bhitsxq@163.com, ^cLsz1572@163.com

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Abstract. In this paper lithium polymer battery was regarded as the object and one battery model based on second order RC network battery model was established and the model parameters were identified. The parameters' identification are verified.

Introduction

Electrical vehicles have high requirements on lightweight design, reliability and safety, but the battery and battery management technology restrict cars' development. Through the research of lithium polymer battery, one kind of battery management system was designed to real-time monitor status of the battery pack, grasp the remaining capacity of the battery pack, implementing effective equilibrium management and timely handling of hazardous conditions. Therefore, the batteries can be safe, reliable and efficient operation.

Model establishment and parameters identification

Lithium polymer battery's characteristic test can be divided into capacity and charge&discharge test, discharge rate test, open circuit voltage (OCV) and equivalent inner resistance test, etc. [1] The 3.7V/16Ah high capacity Lithium polymer battery is used in the paper. Electromotive Force (EMF) has important significance in battery model establishment, parameters identification and SOC estimation. [2] In the paper, The OCV replaced EMF to complete the test and analysis as EMF can't be measured directly. The 3.7V/16Ah high capacity Lithium polymer battery is used and the main characteristic parameters of the battery is are listed as shown in table 1-1 and the object is shown in figure 1

Name	Values
Cell rated capacity	16Ah
Nominal voltage	3.7V
Charge cut-off voltage	4.2V
Discharge cut-off voltage	3.0V
Max charge current	3.0C (15°C~45°C)
Max discharge current	15.0C (15°C~65°C)
Initial inner resistance	2.5mΩ

Table1 3.7V/16Ah cell main characteristic parameters

μC-XCF08 cell test system is used as the cell tester. The minimum sampling interval of the system is 0.1s, the sampling precision is ±0.1%. Battery's working condition can be defined. Cell voltage, current, temperature and charge&discharge capacity can be real time monitored and recorded. The tester is shown in figure2.



Fig.1 3.7V/16Ah cell



Fig. 2 cell test system

The OCV-SOC fitted curve has a high fitting degree in the SOC range from 0% to 100% when it comes to 7 order fitting. The fitted relation curve is shown in figure 3 and the function is described as equation 1, where the $V_{ocv}(SOC)$ is battery's open circuit voltage.

$$V_{ocv}(SOC) = 86.33 \cdot SOC^7 - 327.1 \cdot SOC^6 + 502.6 \cdot SOC^5 - 403.2 \cdot SOC^4 + 182 \cdot SOC^3 - 46.13 \cdot SOC^2 + 6.536 \cdot SOC + 3.173 \quad (1)$$

Rebounded voltage is the value caused by equivalent impedance which make electrode potential deviated from equilibrium potential in battery's charge and discharge process. The equivalent impedance mainly contains two parts, ohm inner resistance and polarize inner resistance. [3] The paper use exponential fitting method which introduced by reference[4] to fitting the battery voltage to current response curve. The test result is shown in figure 4.

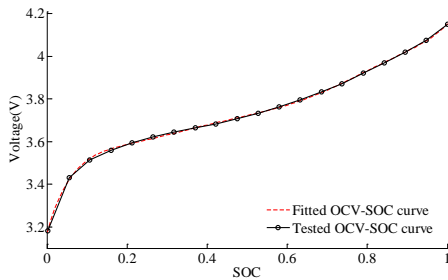


Fig.3 Polynomial fitted OCV-SOC curve

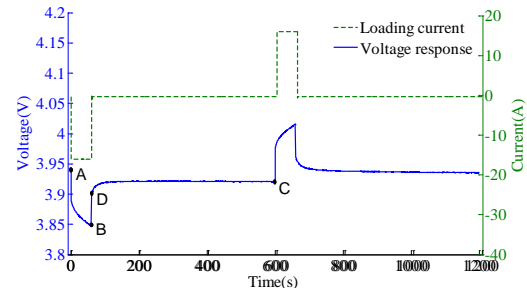


Fig. 4 1C pulse current charge&discharge test curve

An equivalent circuit model based on Thevenin model was proposed. The model took full account of battery's OCV characteristics and rebounded voltage. The model is shown in figure 5.

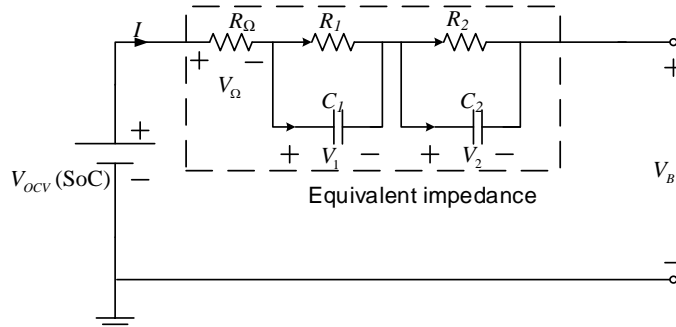


Fig.5 Lithium polymer battery's equivalent model

Where $V_{OCV}(SOC)$ is the open circuit voltage which has the fixed mapping relation with battery's SOC in a certain temperature. R_0 is the ohm inner resistance, R_1 、 R_2 is the polarize internal resistance, C_1 、 C_2 is the polarization capacity.

According to the equivalent circuit, the mathematic relation between each part are shown blow.

$$\begin{cases} V_{OCV} = f(SOC) \\ SOC = SOC_0 - \frac{1}{Q_N} \int \eta I dt \\ C_1 \cdot \frac{dV_1}{dt} + \frac{V_1}{R_1} = I \\ C_2 \cdot \frac{dV_2}{dt} + \frac{V_2}{R_2} = I \\ \frac{V_\Omega}{R_\Omega} = I \end{cases} \quad (2)$$

Where SOC_0 is initial SOC, Q_N is battery's rated capacity, η is coulombic efficiency which can got through charge&discharge experiment. Discretized the equation 2 and the parameters were calculated by MATLAB as is shown in table 2.

Table 2 battery model parameters

R_Ω (m Ω)	R_1 (m Ω)	R_2 (m Ω)	C_1 (F)	C_2 (F)	Q_N (C)
3.25	0.78875	0.561375	27418	8677	63695

According to the relationship between each parameter, implemented the battery equivalent circuit model in MATLAB/Simulation. The model simulation structure as shown in figure 6.

The C_1 、 C_2 、 R_0 、 R_1 、 R_2 in figure 4 are equivalent impedance parameters in battery equivalent circuit model., Q_N is calibrated battery rated capacity, SOC_0 is initial SOC, can be Set arbitrarily from 0 to 1. Working voltage would outputted when excitation current inputted.

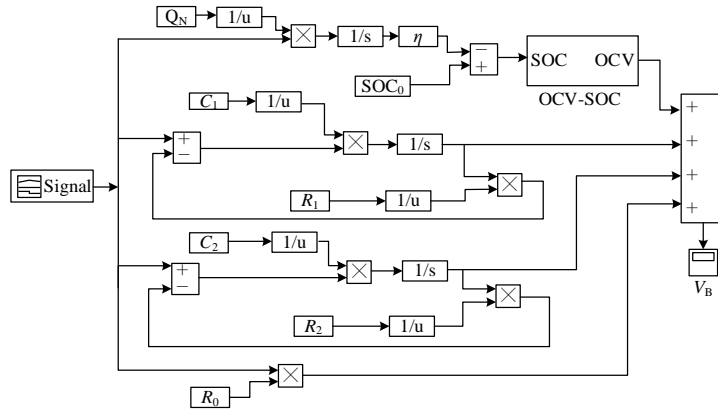


Fig. 6 battery model simulation structure

Inputted the pulse current, which equals to tested current, to the simulation model, the simulation curve as shown in figure 7 compared to the experiment result.

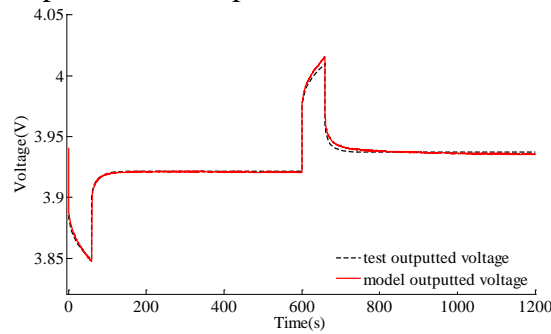


Fig. 7 pulse current simulation and test result

As shown in the figure, the largest fitting error between terminal voltage test and pulse current input based voltage response is 11 mV. The fitting rated is high which means the model and identified parameters are accurate.

Imported user-defined working condition to further verify the accurate of the model. The imported current as shown in figure 8. The charge&discharge current switched frequently in this

working condition so that it can verified the model and parameters' identification accuracy well. Tested battery charge&discharge in user-defined working condition based on battery test system, the simulation and verification results are expressed in figure 9.

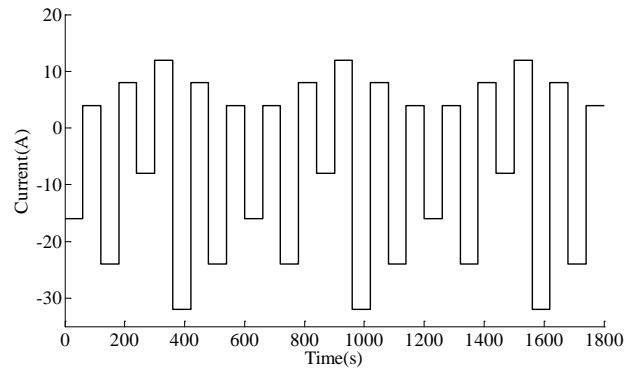


Fig. 8 battery charge&discharge current in user-defined working condition

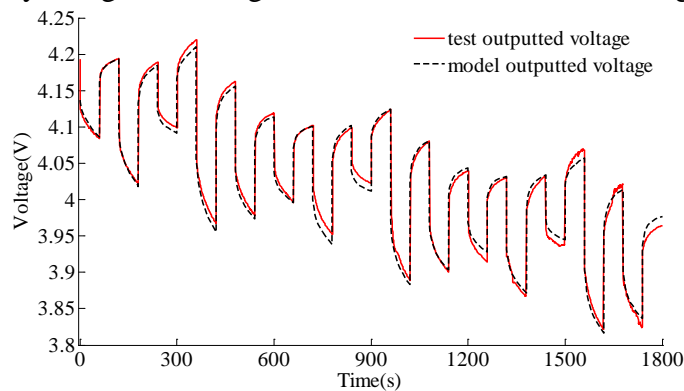


Fig. 9 user-defined working condition simulation and test result

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