# Modelling of a Thevenin Battery Model for Accurate Parameter Estimation

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ABSTRACT

Rechargeable batteries play an important role in the industry because of the potential for future technologies to be used as energy sources for storage elements in green technology applications such as electric vehicles and photovoltaic systems. This renewable energy source can be stored in a battery cell or in a battery pack, and this will help reduce dependence on fossil fuels. Lithium-ion batteries are widely used in electronic devices such as laptops, smartphones, and digital cameras. Accurate battery information, such as State-of-Charge (SOC), current, and voltage are essential to circuit designers so as to manage the energy consumption of the battery power supply system. In addition, the safe operation of the battery is necessary to avoid battery damage from overcharging or overcharging. Therefore, it is important to deal with the problem accurately.

## 1. Introduction

In order to reflect the working principle of lithium-ion batteries (LIBs) and the relationship between them, it is very important to establish the LIBs model, which is divided into an electrochemical model (CM), a machine learning model, and an electrical model (ECM). The electrochemical model is a mechanism-based model that can be used to describe the electrochemical behavior of lithium-ion batteries. However, the electrochemical model considers many parameters related to the internal materials of lithium-ion batteries, which are difficult to obtain. In addition, the correlation calculation with the electrochemical model is very extensive, so it is difficult to apply the model in practice. Although previous work has investigated the reduction and simplification of electrochemical models, this may reduce the accuracy of the models, even if the calculations are still fairly extensive. By contrast, the machine learning model of LIBs can be considered a black box model because it does not take into account the electrochemical and physical properties of LIBs; the model directly establishes the relationship between system inputs and outputs. However, the machine learning model relies on a large amount of data for training, and the results are still applicable only to data similar to the original training data. ECM is a common battery model that uses basic electrical components such as capacitance and resistance to describe the external characteristics of the battery. ECM is simple, the result is satisfactory, and it is suitable for EV applications. Common ECMs include the $R_{int}$ model, the Thevenin model, n-order resistance capacity (n-RC) model, PNGV model, and GNL model[1]. In this paper, the model of the Thevenin battery is studied.

## 2. OCV Identification Based on Discharge Segments

### 2.1 Experimental Data Acquisition

The experiment involves placing the battery pack in a low-temperature environment, recording with the data recorder, and charging and discharging with the charger. The outline of the experiment is shown in Table 1.

Table 1 - Model parameter extraction experimental profile

| Step | State | Condition | Notice |
|---|---|---|---|
| 1 | Soaking | Chamber internal temperature -10℃ | More than three hours. |
| 2 | Discharging | To Minimum Terminal Voltage (45V) | Constant current charge |
| 3 | Rest | - | 2 hours |
| 4 | Charging | To Maximum terminal voltage (75.6 volts) | Constant current-voltage charge |
| 5 | Rest | - | 2 hours |
| 6 | Discharging | 5% discharge based on discharge time | Constant current discharge |
| 7 | Rest | - | 2 hour |
| | Repeat | Step 6~7 | Repeat 19 times |
| 8 | Discharging | Full discharge from 5% to 0% | Constant current discharge |
| 9 | Rest | - | 2 hours |

### 2.2 Modeling and Parameter Identification

The first-order circuit model is used in the Thevenin battery model. Based on the simplest *Rint* model, a set of RC resistive capacitors is added to simulate the polarization reaction of the battery, which is a typical equivalent model of the battery circuit. The structure of the Thevenin circuit model is shown in Fig. 1(a). In this model, the ideal voltage source $U_{ocv}$ is used to represent the open circuit voltage (OCV) of the battery, and the OCV of the lithium battery directly corresponds to the SOC. $R_0$ is the ohmic resistance of a battery, which represents the characteristic of a battery mutation. $R_0$ is used to simulate the gradual polarization of lithium-ion battery voltage by using an *RC* link consisting of $C_1$ and $R_1$.

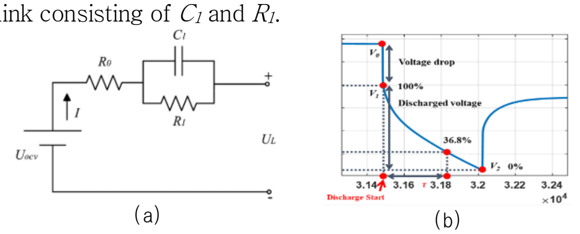


Fig.1 (a) Equivalent circuit model of a LIB; (b) Discharge voltage curve

The parameters of each model may be extracted from the curve of Fig. 1(b) through Eq. (1)-(4) where $\tau$ is the time constant[2] and I is the discharge current, which is specified as positive and negative. The performance of the system is calculated based on the circuit structure and analysis calculation. In enterprise content management, the mathematical expression of the model can be deduced by extracting the model parameters using SOC, and creating a lookup table[3]. The terminal voltage is estimated by using the prepared lookup table, while the extracted primary RC model parameters are used to model, and the estimated terminal voltage is compared for precision.

$$U_{ocv} = V_0 \quad (1)$$

$$R_0 = \frac{(V_0 - V_1)}{I} \quad (2)$$

$$R_1 = V_1 - \frac{V_2}{I} \quad (3)$$

$$C_1 = \frac{\tau}{R_1} \quad (4)$$

The parameters of the first-order RC equivalent circuit model are calculated (Fig. 2 shows the parameters), and then the simulation model is established to simulate the real-time charging and discharging process.

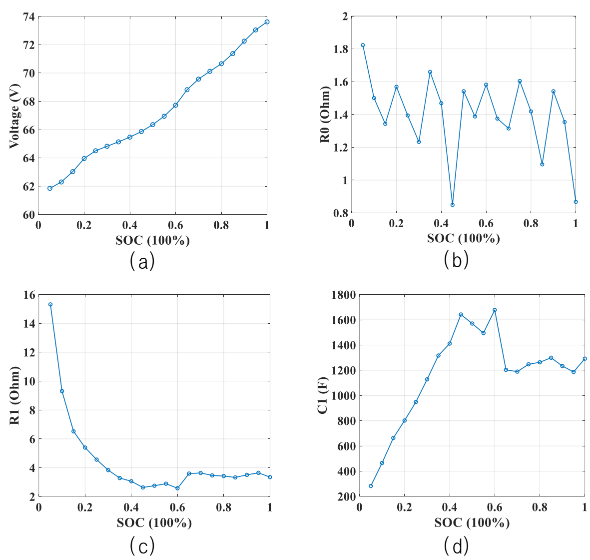

Fig. 2: Extracted parameters (a) OCV; (b) $R_0$; (c) $R_1$; (d) $C_1$

## 3. Experimental Verification

The estimated terminal voltage is compared with the measured voltage. The error between simulation and experimental data is analyzed. From Fig. 3, it can be seen that the error between simulation data and experiment data is small. The average error is within 1V and the maximum error is within 3V. The results show that the model is accurate enough.

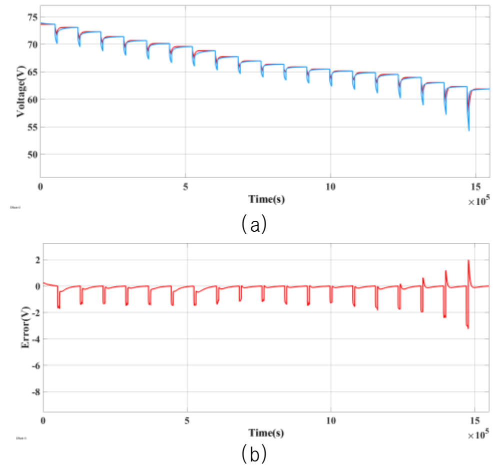

Fig.3 (a) Model voltage; (b) Model error

## 4. Conclusion

The first-order RC equivalent circuit is selected as lithium electric charge for lithium ferric phosphate battery. The battery parameters are extracted by the discharge experiment, and then the battery charging and discharging model is established using a Thevenin battery model. Combined with the experimental data of charging and discharging the battery, and the comparison results of the model, the first-order RC circuit model can realize more accurate charging and discharging process simulation with a certain reference value.

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## 참 고 문 헌

[1] L. Kangqun et al., "State-of-charge estimation combination algorithm for lithium-ion batteries with Frobenius-norm-based QR decomposition modified adaptive cubature KF and H-infinity", Proceedings of the Elsevier, Volume 263, Part C, 2023, October.

[2] A. Rahmoun, "PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review): Modelling of Li-ion batteries using equivalent circuit diagrams ", ISSN 0033-2097, R. 88 NR 7b/2012, 2012, July.

[3] L.W. Yao et al., " Modeling of Lithium-Ion Battery Using MATLAB/Simulink", Proceedings of the IEEE, Vol. 13, pp. 1729-1734, 2013, April.