The 2013 World Congress on
Advances in Nano, Biomechanics, Robotics, and Energy Research (ANBRE13)
Seoul, Korea, August 25-28, 2013

Parameter Identification for State of Discharge Estimation of Li-ion Batteries

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ABSTRACT

This paper presents the method of parameter identification in the state of discharge of lithium-ion batteries. In this study the equivalent circuit diagram of one time constant model is used. This modeling method describes the process how to identify important parameters of the equivalent circuit by measurement data. The comparison between the measurements and the estimates as the result of genetic algorithms searching for parameters shows model parameter accuracy.

1. INTRODUCTION

The method to define full charge of battery state can be defined by the state of charge method (SOC) by current measurement called ampere-counting method. This method can define the battery state based on the charge and discharge state which is transferred current in and out of the battery. The SOC estimation method is possible to have an error in case of full charge system. Also the SOC is the functional method of the open circuit voltage which typically faces the estimation problem for battery's dynamic identification model. The dynamics model is better to use mathematical process. In term of the open circuit voltage, SOC can be calculated by analyzing only the battery current and voltage at the output of battery terminal. With this analysis method the battery equivalent circuit is used. The equivalent circuit parameters would be identified by employing measurements.

This paper presents the parameter identification by using genetic algorithms for state of discharge estimation of Li-ion batteries. The one time constant model (OTC) of battery equivalent circuit is used to study. The model-based simulation data and the measurement data are compared. The simulation data are provided by the simulation block diagram and the measured data are implemented to assess the accuracy of the foundation model based on SOC estimation method [1].

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2. ONE TIME CONSTANT EQUIVALENT CIRCUIT MODEL

The OTC equivalent circuit model consists of an ideal voltage source (V_{oc}), a parallel RC network (R_1 and C) (describe the battery transient response during charge and discharge) in series with a resistor in order to describe the internal resistance (R_0) in the approximation dynamic behavior of Li-ion battery [2]. In Fig. 1, the equivalent circuit model with describing the battery transient response during charging and discharging in battery system is depicted. V_C is the voltage across the parallel RC network of C1. I_L represents the load current. The electrical behavior of the OTC model can be described in continuous time by equation (1)-(4).

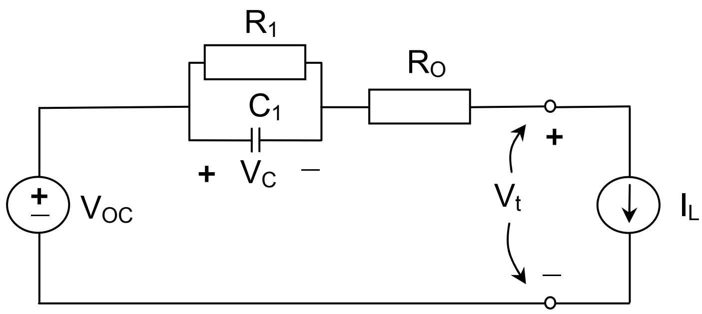

Fig. 1 Battery equivalent circuit diagram of one time constant model (OTC).

$$V_t = V_{OC} - R_O I_L - V_C \tag{1}$$

$$I_L = \frac{V_C}{R_1} + C\frac{dV_C}{dt} \tag{2}$$

$$\frac{dV_t}{dt} = \frac{1}{R_1 C}(V_{OC} - R_O I_L - V_t) + \frac{I_L}{C} \tag{3}$$

$$\frac{dV_t}{dt} = -\frac{1}{R_1 C}V_t + \frac{1}{R_1 C}V_{OC} + (\frac{1}{R_1 C^2} - \frac{R_O}{R_1 C}) + I_L \tag{4}$$

Although a set of the above formulas can have an analytical solution, a numerical solution in discrete-time domain is preferred. By employing Euler's forward difference, the time-stepping solution at time step *k+1* with respect to the battery terminal voltage can be derived as described in equation (5)-(6)

$$\frac{V_{t,k+1} - V_{t,k}}{\Delta t} = -\frac{1}{R_1 C}V_t + \frac{1}{R_1 C}V_{OC} + (\frac{1}{R_1 C^2} - \frac{R_O}{R_1 C}) + I_L \tag{5}$$

$$V_{t,k+1} = V_{t,k} + \Delta t \left\{ -\frac{1}{R_1 C} V_t + \frac{1}{R_1 C} V_{OC} + \left(\frac{1}{R_1 C^2} - \frac{R_O}{R_1 C} \right) + I_L \right\} \quad (6)$$

3. ESTIMATION OF MODEL PARAMETERS

The estimation procedure for OTC modeling is demonstrated without environment condition of temperature and aging effects. The experimental parameter identification of the battery is fixed at room temperature of 25 °C. Fig. 2 shows the simulation block diagram of Li-ion battery with the parameter set up as in Table 1.

The charging and discharging process from the simulation block diagram in Fig. 2 can be measured the output voltage as shown the characteristic waveform for battery in Fig. 3. The time between t_a to t_b is the sub-interval of discharge with a constant current ($I_{discharge} > 0$). The steep decrease of the output voltage can be seen due to the internal resistance (R_0), and then the output voltage continues to decrease exponentially controlled by the OCV regarding the decreased state of charge. And for the sub-interval at t_b to t_c , the battery is charged with a constant current. The steep increase of the battery output voltage due to internal resistance and it continues to increase exponentially control by OCV regarding the increasing state of charge.

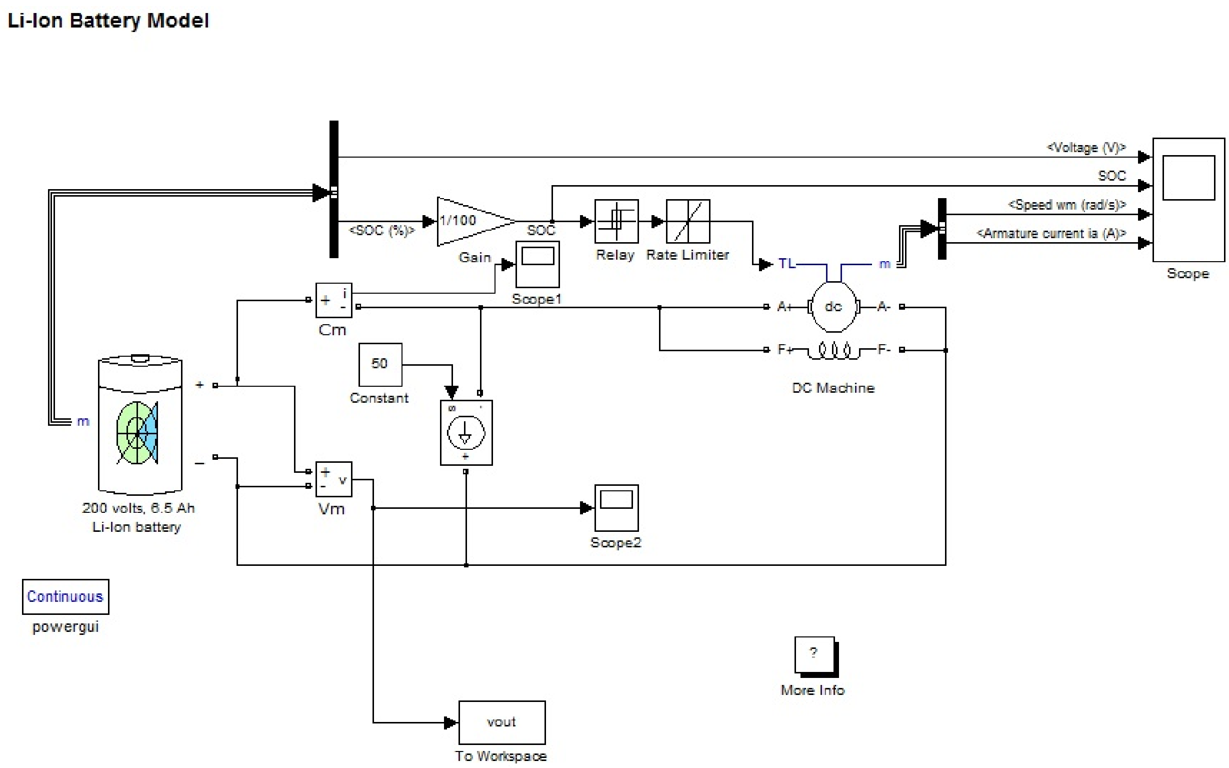

Fig. 2 Simulation block diagram.

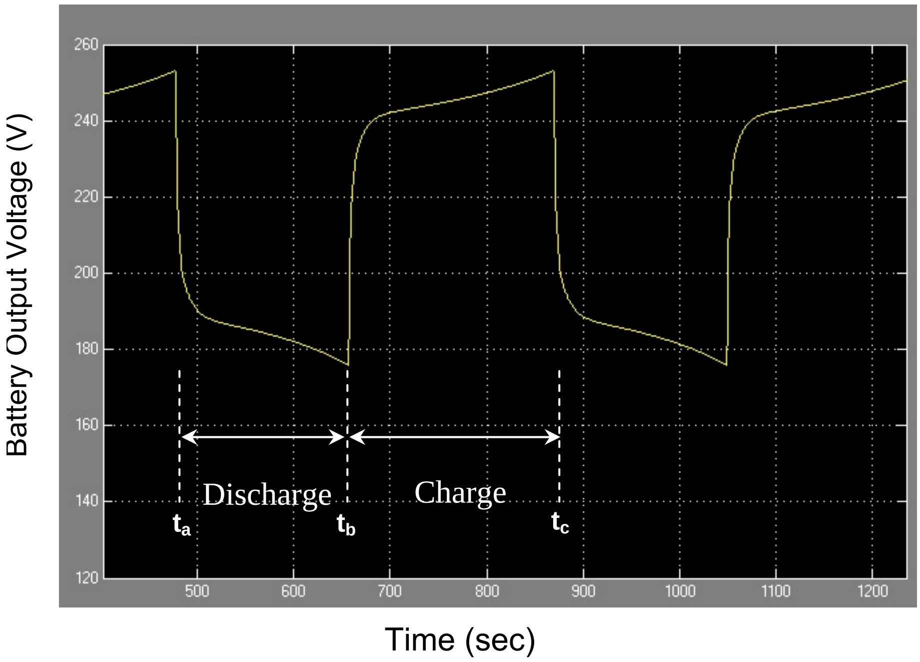

Fig. 3 Characteristic waveform of the battery output voltage during charging and discharging process of lithium-ion cells.

4. ESTIMATION OF OTC MODEL PARAMETER

The model of battery parameters are estimated by measuring output voltage during discharged sub-intervals of time between t_a to t_b. These output voltage has the dynamic characteristics of the battery in sub-interval of time during between t_a to t_b which can be measured or calculated [3}-{4] regarding to the one time constant model by setting I_L to zero in equation (4). This paper would like to present the battery parameters modeling by using the output voltage measurement and estimate battery parameter by applying nonlinear data fitting to search for the value which lead to the best fit between measurement giving and the nonlinear function solution. In this case genetic algorithm is used for searching three parameters consist of R_o, R_1 and C in equation (4) with the necessary constant value as show in Table 1.

Table 1 Li-ion battery data

Typical Rated Capacity (Ah)		6.5
Norminal Voltage (V)		200
Initial State of Charge (%)		100
Charge condition	Maximum Capacity (A)	53
	Fully Charged Voltage (V)	232
Discharge condition	Nominal Discharge Current (A)	2.861

5. EXPERIMENTAL RESULT

The assessment and modeling lithium polymer battery cells from Turnigy Power Systems are used. The battery test bench is set up for the model identification of model parameters. This assessment is applied the current signal with rectangular shape. During the operation time, battery output voltage is measured as show in Fig. 4. The result of output voltage data for state of discharge is used to identify battery parameter by genetic algorithms. The genetic algorithms is the method for searching the parameter R_o, R_1 and C (Eq. (4)) in which the sum square error between the measurement and the simulation is minimized as shown in Table 2.

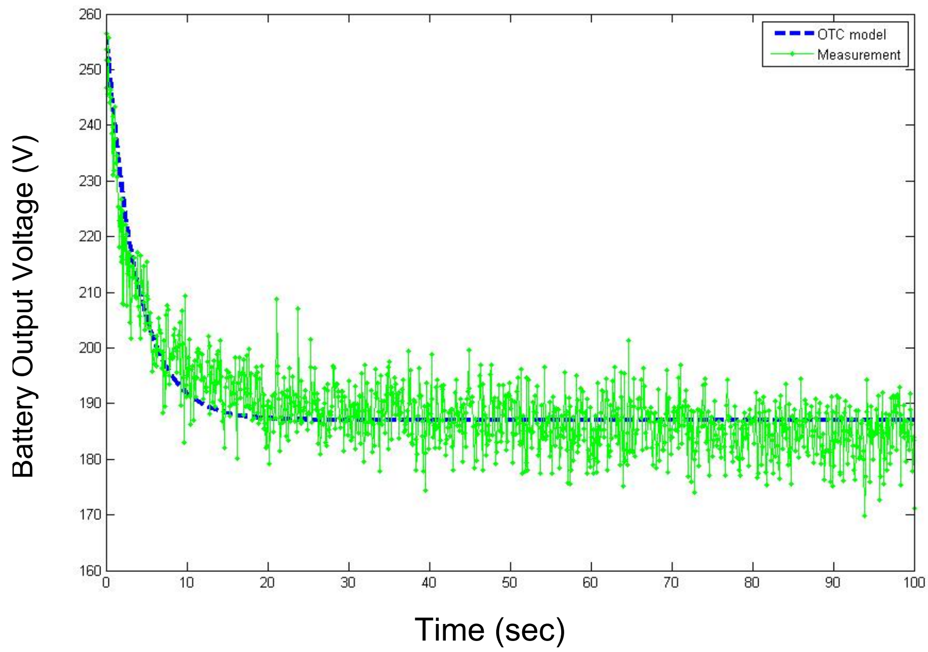

Fig. 4 Output voltage measurement and curve fitting results during discharging process

Table 2. Optimal parameters obtained by using genetic algorithms

Ohmic Resistance (R_O) (mΩ)		2.6361
RC-Network Element	Resistance (R_1) (mΩ)	1.3164
	Capacitance (C) (10^5F)	2.8913

Fig. 4 illustrates the parameter identification for state of discharge estimation of Li-ion battery can be fixed by using genetic algorithm to search the proper parameter value. The solid line represents the measurement data and the dash line represents the simulation data acquired by using one time constant model of the optimal parameters as shown in Table 2.

6. CONCLUSIONS

This paper present the equivalent circuit diagram for the dynamic of the battery. The OTC model describes the dynamic characteristics of the battery estimation. The RC-network and ohmic resistance parameters are important in dynamics of the lithium-ion battery which are expected for the accurate solution method of parameter identification. The parameters of the equivalent circuit diagrams of lithium-ion cells from characteristic measurements are demonstrated. The identifying parameters from measurement data by using genetic algorithms can be implemented to search for model parameters of Li-ion batteries during discharge state.

REFERENCES

[1] Giacomo, M. (2010) “Battery Management system for Li-Ion Batteries in Hybrid Electric Vehicles”, M. Sc. Thesis, Dept. of Information Engineering, University of Padova, Padua, Italy.

[2] Hongwen, H., Rui, X., and Jinxin, F. (2011) “Evaluation of Lithium-Ion Battery Equivalent Circuit Models for State of Charge Estimation by an Experimental Approach”, Journal of Energies, 4: 582-598.

[3] John,S. (2013) “Modeling the Lithium Ion Battery” Journal of Chem. Educ., 90(4): 453-455.

[4] Hans-Georg, S. (2010) “Comparison of Several Methods for Determining the Internal Resistance of Lithium-Ion Cells”, Journal of Sensors, 10: 5604-5625.