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Calibration method of SOC characteristics of spacecraft battery pack simulator

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Abstract

A significant parameter of the spacecraft battery pack simulator is the state of charge (SOC) parameter, which is one of the parameters that users are most concerned about during the use of the spacecraft battery pack simulator. Other parameters of the spacecraft battery pack simulator, such as terminal voltage, current, pressure, temperature, etc., are always given together with the value of the state of charge (SOC) in which they are located. The battery SOC parameter is a process quantity, and only one SOC estimation value can be obtained. In the battery simulation, the simulator gives the time-varying SOC value during the charging and discharging process according to the initial SOC state, charging and discharging conditions. Therefore, the time-varying SOC value given by the battery pack simulator must be accurately calibrated to ensure the accuracy of the battery pack simulator SOC change.

1 Introduction

In order to ensure the output performance of the spacecraft battery pack simulator, it needs to be calibrated, its voltage, current, internal resistance and other parameter values are traced to a higher standard, and the SOC (state of charge) parameter must be measured and calibrated. In order to ensure that the charge-discharge process characteristics of the spacecraft battery pack simulator are consistent with the actual battery charge-discharge process characteristics, it is necessary to carry out its calibration technology research, develop a spacecraft battery pack simulator charge process characteristic calibration device, and develop a spacecraft battery pack simulator SOC characteristic calibration device, so as to provide accurate calibration services for the spacecraft battery pack simulator, improve the quality and reliability of the spacecraft power supply system to ensure technical content and process.

2 Calibration system composition

The calibration system includes a simulator SOC curve generation module, a standard SOC curve generation module, and a calibration module. The simulator SOC curve generation module extracts the SOC curve from the actual data and uses the integration method to form the SOC output by the spacecraft battery pack simulator. Characteristic curve.Standard SOC curve generation module builds an equivalent circuit model of the spacecraft battery pack based on the second-order RC equivalent circuit model modeling method, and continuously updates the model parameters and SOC values; the curve calibration module is in the above two modules Based on the generated test SOC curve and standard SOC curve, the measured SOC curve data is compared with the standard SOC curve data, and data calibration and curve compensation are performed. Preferably, the module further includes functions such as waveform display and quantitative evaluation.

2.1 Simulator SOC curve generation module

In the case of obtaining better current information, this project considers using the ampere-hour integration method to form the SOC characteristic curve output by the spacecraft battery pack simulator. [1, 2]

The ampere-hour integration method is the basic method for measuring SOC, and it is currently the only method that can accurately calculate the SOC of a battery pack. The AH integration method is to accumulate the current flowing into and out of the battery pack per unit time, thereby obtaining the amount of charge that can be discharged during each round of discharge of the battery pack,determining the change in the SOC value of the battery. The calculation formula is:

$$SOC_{t_1} = SOC_{t_0} - \frac{1}{C_A}\int_{t_0}^{t_1} \eta \times i(t)dt \qquad (1)$$

SOC_{t_1} is the state of charge at time t_1,SOC_{t_0} is the state of charge at time t_0, C_A is the initial capacity of the battery, η is the charge and discharge coefficient, i is the charge and discharge current, and t is the charge and discharge time .

For the spacecraft battery pack simulator, during each charge and discharge simulation process, the initial capacity C_A, the initial capacity SOC_{t_0} of the spacecraft battery pack simulator, and the charge and discharge coefficient η and the charge and discharge current i are input conditions. Then, the precise integration algorithm can be designed by formula (1) to obtain the real-time SOC of the spacecraft battery pack simulator. [3]

2.2 Standard SOC curve generation module

The charge and discharge process of the spacecraft battery pack is complicated, and the parameters interact with each other and have a nonlinear relationship. An effective equivalent circuit model must be established to simulate the above-mentioned complex characteristics of the spacecraft battery pack. [4,5]

This paper presents a model method, which is based on a second-order RC equivalent circuit model and is suitable for modeling a variety of batteries. The traditional battery model is an ideal voltage source connected in series with a resistor, which is only suitable for linear simulation. Compared with the traditional model, the second-order RC equivalent circuit model has higher accuracy and wider versatility. The model has good applicability to the working state of the battery. The state space equation of the model can be obtained through circuit analysis, which is convenient for analysis and application, and its accuracy is high.

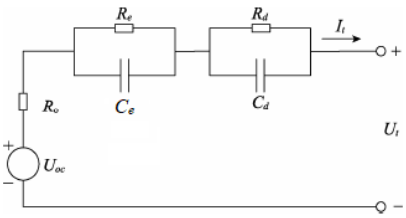

Figure 1. The second-order RC equivalent circuit model of the spacecraft battery pack

2.3 Curve calibration module

The SOC waveform comparison is based on the previously obtained standard curve and test and test data of the SOC characteristic calibration of the spacecraft battery pack simulator. These data are statistically analyzed to obtain another test SOC characteristic curve, and the two curves are compared. Specifically, it performs feature extraction, recognition analysis, and accuracy analysis on waveforms, and uses a curve convolution method to measure the similarity of the waveforms.

Convolution is a mathematical operator that generates a third function from two functions f and g, and represents the area of the overlapping part of the functions f and g after flipping and translation. If a function participating in the convolution is regarded as an indicator function of the interval, the convolution can also be regarded as a generalization of "moving average". By using the convolution theorem, the convolution operation in the time domain or the space domain can be equivalent to the frequency domain multiplication operation, so that fast algorithms such as FFT can be used to implement effective calculations and save the operation cost.

The measured points are discrete data points, and two discrete sequences should be convolved to determine the similarity of the two curves. Here we take the matrix of discrete convolution algorithm.

The convolution and $f(n)$ of two discrete sequences $x(n)$ and $y(n)$ are defined as

$$f(n) = x(n) * y(n) = \sum_{m=-\infty}^{\infty} x(m)y(n-m) \quad (2)$$

The convolution sum of two sequences $x(n) = x(n) * u(n)$ and $y(n) = y(n) * u(n)$ starting from $n = 0$ is

$$\begin{aligned} f(n) &= \sum_{m=-\infty}^{\infty} x(m)u(m)y(n-m)u(n-m) \\ &= \left[\sum_{m=0}^{n} x(m)y(n-m)\right]u(n) \end{aligned} \quad (3)$$

The factor $u(n)$ on the right side of the above formula indicates that the result of the convolution sum is also a sequence starting from $n = 0$.

The convolution sum of a windowing sequence $x(n) = x(n) * w_{N_1}(n)$ of length $N1$ starting from $n = n_1$ and a windowing sequence $y(n) = y(n) * w_{N_2}(n)$ of length $N2$ starting from $n = n_2$,

$$w_{N_1}(n) = \begin{cases} 1 & n_1 \leq n \leq n_1 + N_1 - 1 \\ 0 & otherwise \end{cases} \quad (4)$$

$$w_{N_2}(n) = \begin{cases} 1 & n_2 \leq n \leq n_2 + N_2 - 1 \\ 0 & otherwise \end{cases} \quad (5)$$

$$f(n) = \sum_{m=-\infty}^{\infty} x(m)w_{N_1}(m)y(n-m)w_{N_2}(n-m) \quad (6)$$

The obtained convolution sum is also a windowing sequence, starting from $n = n_1 + n_2$ and having a length of $N_1 + N_2 - 1$.

It can be known from the above convolution operation that two finite-length sequences are still finite-length sequences after convolution. The length is the sum of the lengths of the two sequences minus 1. The starting position of the result is the sum of the starting positions of the two sequences, and the cut-off position is the sum of the ending positions of the two sequences. Based on this, the position vector of the convolution result can be obtained.

3 Experimental verification

In order to verify the effectiveness of the algorithm, a simple simulation was performed using MATLAB software.

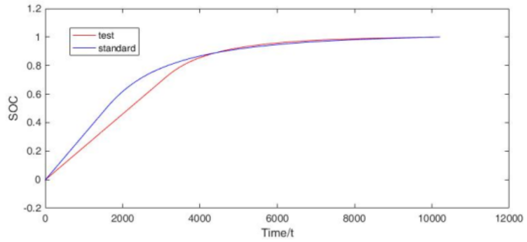

Figure 2. The comparison of the curves of the lithium battery charging process.(The similarity between the two curves at this time is calculated by the above algorithm to be 81.56%).

4 References

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