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Study on State of Charge Estimation of Batteries

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Abstract—

The battery state of charge (SOC) is known as an important inner parameter of the battery residual capacity. It can only be indirectly estimated using the measured voltage, current and environment temperature data. Estimating SOC correctly for a battery is an important and difficult task. This estimation is important role of battery management system. A lot of research is going on to improve the accuracy of SOC estimation for electric vehicle batteries.This workpresents the definition of battery SOC and introduces the existing shortcomings of various SOC estimation methods in the application. Study on the principle and application of the SOC estimation algorithm against many existing technical difficulties of SOC estimation algorithm for power batteries is very necessary. Different methods about how to estimate SOC accurately has important meaning for the further development of power battery SOC estimation.

Keywords—
Electric vehicle; State of charge; Kalman filter

I. INTRODUCTION

As the energy crisis is gradually approaching, the electric vehicle (EV) development of energy saving and environmental protection will be the future development direction. The batteries get more and more widely used in the electric car or hybrid power system. The battery SOC which describes the amount of remaining battery power is an important parameter in the process of using EVs. Estimating accurate and reliable SOC is the most basic and the top priority to the battery management system (BMS). It is the basis to command the battery status and decide to reasonably use battery next. For example, disconnect the battery to make sure it will not discharge inordinately, change it when the battery is failure and provide the battery surplus work time for users. But, due to the complicated battery structure and the influence factors such as discharge current, battery internal temperature, self -discharge, aging, which increased the difficulty of SOC calculation.

Therefore, it has great significance to study the principle and application of power battery SOC estimation methods. In the hybrid power system, the battery is in the typical work condition of changing current. The traditional SOC estimation strategy based on constant current far can't meet the need. In the drive of that background, battery SOC estimation research made great headway, many classic estimation methods appeared. The main consideration is more scientific and safe to choose and use the battery, not battery design and production. Against many existing technical difficulties of the power battery SOC estimation algorithm, this paper discusses and studies the power battery SOC estimation. It has the important meaning for the further development of power battery SOC estimation.

II. SOC DEFINITION

SOC is mainly referred to the percentage of present restored charge of lithium battery, and it is one of the most important parameters of battery management systems[1]. The battery SOC can be defined from power or energy. From the point of view of power, SOC can be defined as the ratio of remaining power and the

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rated capacity under the same conditions when the battery in a certain discharge ratio. The mathematics type is expressed as:

$$SOC = \frac{Q_c}{Q_N} \quad (1)$$

Where Qc is standard remaining capacity Q_N is
nominal capacity.

EV Company's has the different definition of SOC as follows:

$$SOC = \frac{Surplus\ \ usable\ \ energy}{Total\ \ usable\ \ energy} = 1 - \frac{W_h}{W_{he}} \quad (2)$$

The above conclusion of SOC definition regarded the monomer battery as the research object. The electric vehicle uses battery pack, so it is still a project to define the SOC of battery pack because of the battery modules which are not enough symmetrically. In the actual application, a simple method is regarding the battery pack as a cell battery monomer. To ensure the safety of the battery, it often utilizes the monomer battery of worst performance to define the battery pack SOC.

III. SOC Estimation Methods

A. *Ah counting method*

The ampere hour (Ah) counting method mainly makes use of the Peukert equation to change actual current into standard current, and takes integration of time to estimate SOC. We define the initial state as SOC0, so the present value SOC can be calculated:

$$SOC = SOC_0 - \frac{1}{Q_n}\int_0^t \eta_i idt \quad (3)$$

Here, ηi is the current efficiency coefficient computed and deduced by the Peukert equation.

The ampere hour counting method is one of the simplest and most universal methods for SOC estimation. Nevertheless, SOC estimation error, as time goes on, becomes increasingly greater because deviation caused by inaccurate current sensor measurement would be gradually accumulated.

B. *Open-circuit voltage method*

Open-circuit voltage method uses the corresponding relationship of battery open-circuit voltageand SOCto estimate SOC by measuring the battery open-circuit voltage. Voltage based SOC estimation uses the open circuit voltage (OCV) of the battery cell as the basis for calculating SOC or the remaining battery capacity. There is a corresponding curve between the open circuit voltage and SOC for each battery. However, this method requires battery to rest for a long time in order to obtain stable voltage. Furthermore, OCV curve is sensitive to different discharge rates and temperature. Therefore this method is effective for measuring SOC only at the initial stage and end stage [2].

C. *Kalman filtering methodFinally*

The basic idea of Kalman filter theory is to make the minimum variance in the sense of the optimal estimation of the power system state. The literature of [2],[3],[5] describes the Kalman filter structure. For the application of SOC estimate, the battery is regarded as a power system, and SOC is an internal state of the system. The general mathematics form of battery model State equation can be obtained as:

$$x_{k+1} = A_k x_k + B_k u_k + w_k = f(x_k, u_k) + w_k \quad (4)$$

The Kalman filtering method is on researching. This method can make the estimate of SOC constant convergence to the real value when the initial SOC value is incorrect. It is very suitable to solve problems of battery self-discharge.

IV. CONCLUSION

In the point of research methods, there are many choices for SOC estimate. From the practical application, Ah counting methodis the most commonly used method.Neural network and Kalman filtering method aremore promising approachesin the recent development. Butthey still need to continuously research and practice. The battery charge and discharge rate, temperature, self-discharge, aging and other factors have significant effects onSOC estimate. How to accuratelyestimate battery SOC of electric vehiclein the changing current work conditionsis stilla difficulty. It also need us work hard to solve it.

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