

Study on State of Charge Estimation of Batteries for Electric Vehicle

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Abstract. The battery state of charge (SOC) is characterized as an important parameter of the battery residual capacity state. It can only be indirectly estimated through the collected voltage, current and temperature data. Accurately estimate SOC of power battery is an important and challenging task. It is an important premise to design the battery management system. Researchers do a lot of research work in order to improve the accuracy of SOC estimation for electric vehicle batteries. The SOC estimation research made great headway and many classic estimation methods appeared. This paper discusses 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. This paper analyzes the influence of charge and discharge rate, temperature, self-discharge and aging on SOC. It has important meaning for the further development of power battery SOC estimation.

Keywords: Electric vehicle; State of charge; Kalman filter.

1 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 number of remaining battery power is an important parameter in the process of using. Accurately and reliably get the battery SOC is the most basic and the top priority to the battery management system. 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, etc. 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.

2 Definition analysis

A precise definition of SOC is the premise for SOC estimation of electric car batteries. 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 rated capacity under the same conditions when the battery in a certain discharge ratio. The mathematics type is expressed as:

$$SOC = Q_C / C_t \quad (1)$$

Motor Company has the different definition of SOC as follows:

$$SOC = \frac{\text{Surplus usable energy}}{\text{Total usable energy}} = \frac{W_{hE} + \int_0^t P(t) dt}{P_{atres}} \quad (2)$$

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.

3 Method discussion

3.1 Ah counting method

Ah counting method uses the integral of load current to estimate SOC. If the current is measured accurately and has enough data of start state estimation, then it is a simple and stable method which can be used for all electric car batteries shown in the article[1]. First of all, Ah counting method requires the fixed start state of SOC for estimation. In fact, the hybrid power system may start work or end work at any time. Therefore, in the initial stage, SOC measurement errors appear larger. Secondly, Ah counting method is suitable only for stable load occasions. But when hybrid power system works, the working condition is complex and each work device for homework need different power. The change frequency is fast which causes the battery often working in the severe electrochemical reaction process and makes the accumulative measurement error of SOC larger.

3.2 Open-circuit voltage method

Open-circuit voltage method uses the corresponding relationship of battery open-circuit voltage and SOC to estimate SOC by measuring the battery open-circuit voltage. Open-circuit voltage method is a high precision and simple method, but it has a higher demand of rest time. The battery should be stalling for long time so that it can obtain the stable value of open-circuit voltage. It is only applicable to the electric car in the stop state, not for the dynamic battery SOC estimate. However, hybrid power system is frequent to start, charge and discharge, and the working conditions is complex and changeable. Due to the volatile working current, it is difficult for open-circuit voltage to be stable in a short time. And the needed time for stability influenced by many factors such as the stop state of SOC, discharge current, change frequency, is difficult to determine. The battery open-circuit voltage in numerical is close to the battery electromotive force as is described in the article[2].

3.3 Kalman filtering method

The core 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 [3][4][5][6] 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:

$$x^{k+1} = A_k x_k + B_k u_k + w_k = f(x_k, u_k) + w_k \quad (3)$$

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.

4 Impact factors

4.1 Charge and discharge rate

Utilize constant current for batteries discharging at different rate, the greater the current, the less power released. When charge batteries at different rate, the filled effective power is also different. We define that C_{dl} is the remaining battery power under the standard current I , C_{dl} is the totally released power under the standard current I (often $C/3$). Where C_{dl} is the actual net battery power at current I .

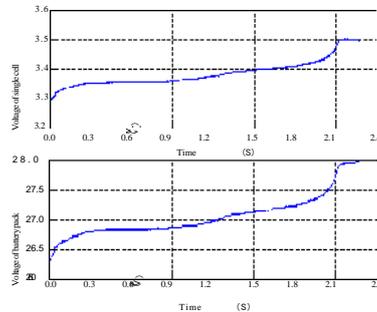


Fig. 1. The lithium battery voltage is 24V and the capacity is 100Ah. The charging electric voltage curve under 35A is shown in the figure.

5 Conclusions

In the point of research methods, there are many choices for SOC estimate. From the practical application, Ah counting method is the most commonly used method. Neural network and Kalman filtering method are more promising approaches in the recent development. But they still need to continuously research and practice. The battery charge and discharge rate, temperature, self-discharge, aging and other factors have significant effects on SOC estimate. How to accurately estimate battery SOC of electric vehicle in the changing current work conditions is still a difficulty. It also need us work hard to solve it.

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References

1. C B Zhu, COLEMAN M and HURLEY W G, 'State of charge determination in a lead-acid battery: combined EMF estimation and Ah-balance approach', 35th Annual IEEE Power Electronics Specialists Conference: Power Electronics Society, Aachen, Germany, 2004, pp.1908-1914
2. James H A, Alfred T and Barry W J, 'A battery state of charge indicator for electric wheelchairs', IEEE Transactions on Industrial Electronics,1992
3. Gregory L P, 'Kalman-filter SOC estimation for LIB cells', Proceedings of the 19th International Electric Vehicle Symposium. 2002
4. PLETT G L. Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs, Part 1. Background [J].Power Sources, 2004, 134(2): 252-261
5. PLETT G L. Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs, Part 2. Modeling and identification[J]. Power Sources, 2004, 134(2): 262-276

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6. PLETT G L. Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs Part 3. State and parameter estimation [J]. Power Sources, 2004, 134(2): 277-292