# The De-nosing Method Based on Wavelet Analyse Apply to BMS

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***Abstract*—The electric vehicle is a kind of motor vehicle which uses storage battery as the energy source. The different grounds compared with conventional vehicle are that for new energy vehicle, we need to show the remain driving distance, the SOC value of power battery and the power consumption per 100 km. the accuracy of above three statistics effects on the judging ability of driver for the endurance of the vehicle. However the estimation results of these three statistics is influenced by the veracity of the discharge current of storage battery. Consider the above problem, this paper propose an idea that before estimation using the discharge current, we must de-noise by the method based on wavelet analyze, which can improve the veracity of the discharge current and further improve the accuracy of the above three statistics estimation results.**

***Index Terms*—wavelet analyze; de-nosing; SOC; electric vehicle**

## I. INTRODUCTION

Energy and environmental issues are the two major themes of the development of the automotive industry in the 21st century. For this theme, new energy vehicles have become a new product of the contemporary era, and battery technology is one of the core technologies of electric vehicles in new energy vehicles. Batteries are complex electrochemical systems. There are a lot of studies on battery management technologies at home and abroad, and many achievements have been made [1, 2]. In China, it is considered that the battery management system (BMS) mainly has the following functions: battery status parameter acquisition (including temperature, voltage, current, etc.); accurate estimation of battery state of charge (SOC); early diagnosis of unhealthy batteries; comprehensive monitoring of the safe operation of the battery pack; preventing overcharging and overdischarging of the battery. The battery real-time parameters (current value, etc.) fed back by the battery management system are the preconditions for estimating the important statistics of the entire vehicle, such as SOC estimation, driving range, and 100 km energy consumption. The accuracy of current signal acquisition directly affects the accuracy of the above statistics estimation. However, the environment where the vehicle is located is complex and the road conditions are complex and varied, making it difficult for the collected current signal to be affected by the ambient noise and become inaccurate. If high-precision sensors are used to reduce the noise in the acquisition parameters, it will inevitably cause a significant increase in the cost of electric vehicles. In order to ensure the high quality of battery state parameters while reducing the cost of electric vehicles, this paper proposes to use wavelet analysis denoising method to deal with the battery parameter data collected - power battery current signal. Reduce the proportion of noise in the collected data as much as possible to ensure the accuracy of vehicle statistics such as follow-up SOC estimation, driving range, and 100 km energy consumption, as well as comprehensive monitoring of the safe operation of the battery pack and early diagnosis of unhealthy batteries.

First of all, this paper uses the SOC value estimation of power battery and the driving range of vehicle as an example to introduce the commonly used estimation methods to illustrate the importance of power battery for the above two kinds of statistical estimation. Subsequently, the process of noise reduction by wavelet analysis and its application in power battery current signal processing of new energy vehicles are introduced. Finally, the effectiveness and practicability of the proposed method are discussed through simulation.

## II. SOC ESTIMATION

Accurate estimation of the state of charge of the battery is an important basis for charge and discharge control and power optimization management of the electric vehicle battery, which directly affects the service life of the battery and the power performance of the vehicle, and can predict the course of the electric vehicle's continued driving. However, the battery SOC cannot be directly measured. It can only be estimated by parameters such as battery terminal voltage, charge and discharge current, and internal resistance.

### *A SOC Definition*

SOC refers to the ratio of the remaining power to the total battery capacity [3]. Usually, the state of charge when the battery is charged at a certain temperature until it can no longer absorb energy is defined as $soc = 100\%$, and the state of charge that can no longer discharge the battery is defined as $soc = 0\%$ . which is:

$$soc = \frac{Q_c}{Q_i} = 1 - \frac{Q}{Q_i} \quad (1)$$

Where $Q_c$ is the remaining charge ( $A \cdot h$ ); $Q$ is the amount of battery discharge ( $A \cdot h$ ); $Q_i$ is the battery with a constant current $i$ discharge, it has the capacity ( $A \cdot h$ );

Because the SOC is affected by the charging rate, temperature, self-discharge, and aging, adjustments are made in actual use. Different electric vehicles use the definition of SOC to form inconsistencies. The most commonly used definition is:

$$soc = soc_0 - \int_0^t \frac{\eta_1 i}{Q} dt \quad (2)$$

In the formula, $soc_0$ is the initial state of charge and discharge; $Q$ The rated capacity of the battery ( $A \cdot h$ ); $i$ is the instantaneous current of the battery ( $A$ ); $\eta_1$ Coulomb efficiency coefficient, is the average Coulomb efficiency of the whole process of charging and discharging of the battery.

*B Electricity Accumulation Method (Ampere Time Integration Method)*

The characteristics of the battery itself and the operating environment of the electric vehicle determine many factors that affect the SOC value and have a dynamic relationship. Therefore, the SOC value cannot be directly obtained, and the SOC value can only be predicted based on the external characteristic model of the battery. Until now, it is generally believed that several external parameters such as current, voltage, internal resistance, and temperature of the battery can reflect the SOC of the battery under certain conditions and within a certain range. Therefore, many methods have been proposed to estimate the SOC value, but they are insufficient. The ideal did not effectively solve the actual problem. Some methods are too complex to implement or the cost is too high (such as neural network method, Kalman filter method, and density method, etc.). Some errors are too large to be practical (such as open circuit voltage method, etc.), so only the easy-to-implement AH method (AH) is described here.

The hourly integration method estimates the SOC of the battery through the battery's charge and discharge power, and compensates the SOC according to the temperature and discharge rate of the battery [4]. The basic principle is:

$$soc = \frac{Q_0 + \int_0^t i_c \eta dt - \int_0^t i_d dt - S}{Q} \quad (3)$$

Where $Q$ is the rated capacity of the battery ( $A \cdot h$ ); $Q_0$ is the initial charge of the battery ( $A \cdot h$ ); $\eta$ is the charging efficiency; $S$ is the self-discharged charge ( $A \cdot h$ ); $i_c$ is the charge current ( $A$ ); $i_d$ is the discharge current ( $A$ ).

This method is simple and easy to use, the algorithm is stable, so the current application is more extensive, in the early use of the battery to control the corresponding conditions of use can be used as reference standards for other methods. However, there are also certain problems, one of which is that because the current measurement is inaccurate and the correction factor is affected by many factors, it is difficult to obtain the exact value of the SOC, and the error will increase as the time accumulates. Based on this, it can be seen that it is necessary to denoise the detected battery discharge current value.

## III ENERGY CALCULATION IN DRIVING RANGE

The energy conversion of electric vehicles in the continuous driving range mainly refers to the conversion of the energy output from the energy source into the energy consumed when the electric vehicle is running. There are many methods for calculating the energy in the driving range of electric vehicles at home and abroad. Give the principle of equal energy for theoretical analysis.

The car power balance equation is:

$$P_M = \frac{1}{\eta}\left(\frac{Gf cos\alpha Va}{3600} + \frac{C_D A V_a^3}{76140} + \frac{G sin\alpha V_a}{3600} + \frac{\delta G V_a}{3600g}.\frac{dV}{dt}\right) \quad (4)$$

$$p_M = \frac{1}{\eta}(p_f + p_W + p_i + p_j) \quad (5)$$

Where $p_f$ is the power consumed by the rolling resistance; $p_W$ is the power consumed by the air resistance; $p_i$ is the power consumed by the gradient resistance; $p_j$ is the power consumed by the acceleration resistance [5].

Single battery discharge current:

$$I = \frac{P}{U_B n_b \eta_{total}} \quad (6)$$

Where $\eta_{total}$ is the total efficiency of the mechanical system and the electrical system; $U_B$ is the battery terminal voltage; $n_b$ is the number of battery cells in parallel.

Considering the Peukert equation, when the battery discharge current I is greater than the rated discharge current $I_e$, the total energy has to be reduced. Single battery's sustainable discharge time:

$$t = \frac{C_e}{I}\left(\frac{I_e}{I}\right)^{n-1} \quad (7)$$

When $\frac{I_e}{I} \le 3$ , $n = 1.313$ ; When $\frac{I_e}{I} > 3$ , $n = 1.414$ .

*A Constant Speed Method Mileage Calculation [6]*

When the electric vehicle is running at constant speed, the slope resistance and the power consumed by the acceleration resistance are negligible, and the calculated mileage is calculated as $S = V_a t$.

*B Working condition method driving mileage calculation*

When the electric vehicle is measuring the continuous driving range under the working condition test, it generally includes several operating conditions such as start, acceleration, uniform speed, deceleration, and rest. According to the National Bus 6, firstly, the energy consumption is calculated separately for the operating conditions, then the total energy consumption is calculated, and it is required to consider the regenerative braking during the uniform deceleration process, that is, the regenerative braking charges the battery for a short time. In addition, after the braking, the vehicle still has a section of the neutral sliding distance. Therefore, it is generally possible to continue the course $7\% \sim 20\%$. Therefore, when calculating, the driving range of the working condition should consider the energy provided by the regenerative braking.

The distance for each start, run, and stop of the vehicle is defined as a travel interval. The accumulated energy for each interval is equal to the total energy that the battery can release. The total distance traveled by the car is the calculated driving range.

## IV DENOISING METHOD BASED ON WAVELET ANALYSIS

An important application of wavelet analysis is signal denoising. There are mainly two kinds of denoising ideas: based on wavelet transform modulus maxima denoising [6] and wavelet threshold shrinkage denoising [8]. Comparing the two signal denoising principles, the signal reconstruction algorithm based on the alternating projection method in the modular maximum denoising has a large amount of calculation and a complicated program, so the speed is slow. The advantage of the wavelet threshold shrinkage method is that the noise is almost completely suppressed. Moreover, the peak point reflecting the original signal can be well preserved [7]. Therefore, this paper introduces wavelet threshold shrinkage denoising.

*A Wavelet basis*

Due to the different natures of orthogonality, tight support, disappearance moment, regularity and symmetry, the choice of wavelet basis function will have a certain influence on the denoising effect. In this paper, based on the balance of vanishing moment orders and the length of support set, we decided to use sym6 wavelet as the wavelet basis. SymN wavelet is the approximate symmetric wavelet function proposed by Daubechies. It is an improvement to the db function, and its wavelet base is shown in Figure 1.

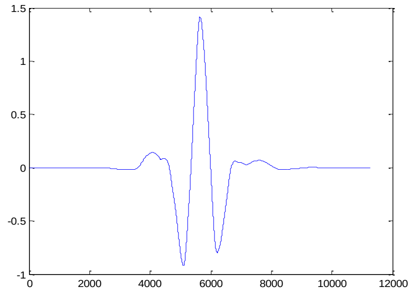


Fig.1 Curve of sym6 wavelet basis

*B Wavelet threshold shrinkage method for denoising*

The implementation of the wavelet threshold shrinking method is basically divided into three steps:

(1) Wavelet decomposition of the signal: Select a wavelet and determine the number of wavelet decomposition layers, then perform N-layer wavelet decomposition on the signal;

(2) Wavelet decomposition threshold quantization of high-frequency coefficients: A threshold is selected for the high-frequency coefficients of each layer from the first layer to the N-th layer to perform threshold quantization processing. Generally, there are two choices, hard threshold and soft threshold.

(3) Reconstruction of one-dimensional wavelet: Wavelet reconstruction of one-dimensional signal is performed according to the low-frequency coefficients of the Nth layer of the wavelet decomposition and the high-frequency signals from the first layer to the N-th layer after the quantization processing.

A one-dimensional signal containing noise can be expressed as:

$$s(n) = f(n) + e(n), \quad n = 0,1,\Lambda\ N-1 \tag{8}$$

Among them, $f(x)$ is a useful signal, usually a low-frequency stationary signal, and $e(k)$ is a noise signal, which appears as a random high-frequency signal.

For the one-dimensional signal in equation (8), the wavelet transform is:

$$w_{j,k} = 2^{j/2} \sum_{n=0}^{N-1} f(n) \psi^*(2^j n - k) dt \tag{9}$$

Where $w_{j,k}$ is the wavelet coefficient and $\psi(\cdot)$ is the wavelet basis. From the linear properties of the wavelet transform, we know that the wavelet coefficient $w_{j,k}$ obtained by the decomposition consists of two parts, one part is the wavelet coefficient $u_{j,k}$ corresponding to the signal $f(x)$, and the other is wavelet coefficients corresponding to the noise $e(k)$, remember $v_{j,k}$. For the signal $f(x)$, due to its non-uniform spatial distribution, the wavelet coefficients $u_{j,k}$ at each scale corresponding to it are only at a few specific positions $(j,k)$ and have larger amplitudes, while the amplitude of the random white noise $v_{j,k}$ varies. The increase in decomposition layer rapidly decays.

In the wavelet threshold denoising method, the threshold function reflects different processing strategies and different estimation methods for wavelet coefficient moduli above and below the threshold. Let $w_{j,k}$ be the original wavelet coefficient, $\tilde{w}_{j,k}$ be the estimated wavelet coefficient, and $T$ be the threshold. The soft threshold function expression is as follows:

$$\tilde{w}_{j,k} = \begin{cases} w_{j,k} + T, & w_{j,k} \le -T \\ w_{j,k} - T, & w_{j,k} \ge T \\ 0, & \left| w_{j,k} \right| < T \end{cases} \tag{10}$$

## V SIMULATION AND APPLICATION

### *A Simulation*

In order to verify the above-mentioned wavelet threshold denoising effect, we first select a typical test signal bump signal for verification test. The Bump signal and the effect after denoising are shown in Fig. 2.

In Fig. 2, Fig. 2-(a) is a bump signal used to verify the algorithm; Fig. 2-(b) is a noise-added bump signal; Fig. 2-(c) is obtained by de-noising using wavelet threshold shrinkage method. It can be seen from the figure that the use of wavelet threshold shrinkage method can remove noises on the basis of preserving useful signals.

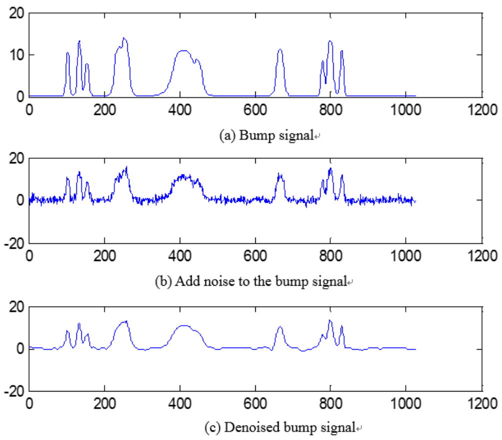


Figure 2 bump signal and results after denoising

### *B Application Verification*

Based on the above verification of the de-noising effect of the wavelet threshold shrinkage method, it is applied to the de-noise processing of the discharge current signal of an electric automobile battery. The accuracy of the current signal directly affects the SOC estimation result of the battery. The battery current signal and the current signal denoised by the wavelet threshold shrinkage method are shown in Figure 3. Figure 3-(a) shows the actual battery current signal. The signal is taken from the actual current value of the pure electric vehicle in the actual working condition. Figure 3-(b) shows the denoised current signal. Figure 4 shows the removed noise signal.

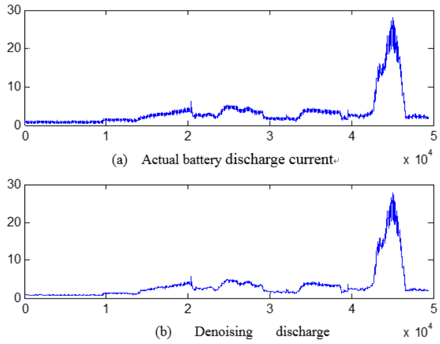


Fig. 3 Battery discharge current and denoising results

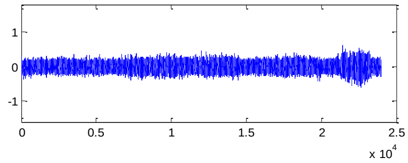

Figure 4 Removed noise signal

It can be seen from Fig. 3 that the signal in Fig. 3-(b) removes the noise on the basis of retaining the characteristics of the original signal. It can be clearly seen from the figure that the burrs representing the noise in the noise-removed signal are much reduced. As can be seen from FIG. 4 , the amplitude of the removed noise is approximately 0.2.

## VI CONCLUSION

New energy vehicles have become an important direction for the development of the modern automobile industry because of their advantages in energy and the environment. For new energy vehicles, the driving mileage, the energy consumption per hundred kilometers, and the remaining electricity (SOC) are all important statistics. However, the above statistics still have inaccuracies in terms of estimation. One of the reasons is that the real-time current signal acquisition of the power battery is caused by environmental interference. To solve this problem, in order to improve the quality of the collected current signal, the idea of using wavelet threshold shrinkage to remove noise was proposed. Before the above three statistics were estimated, the battery discharge current measurement value was first denoised to make the battery discharge current measurement. The value is more accurate to ensure the accuracy of the statistic estimation and give the driver more accurate information. The simulation experiment proves the effectiveness and practicability of the algorithm.

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