Research on Battery Characteristics and Management System of New Energy Vehicle Based on BMS System Design and Test

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Abstract. The use of green energy is becoming increasingly important in today's society. As a result, electric vehicles are presently the most eco-friendly means of public and personal mobility. In order to improve the safety, energy storage capacity and service life of batteries, research on designing and testing battery characteristics and management system for new energy vehicles based on BMS system is proposed. This paper mainly studies the BMS test system platform design and SOC estimation method. A modular integrated BMS automatic test platform for electric vehicles is designed. Based on PXI hardware architecture and LabVIEW software development environment, the platform meets the test items recommended by BMS automotive industry. The results show that the actual SOC value is compared with the estimated value of BMS. The BMS under test is discharged for 100s at 440A constant current and then charged for 100s at 440A constant current. The SOC estimation accuracy of the BMS under test is detected by the test platform, and the SOC estimation errors are all within 2%, which meets the standard requirements. Therefore, Test items that meet the recommendation standard of BMS automotive industry are suitable for the factory inspection and type inspection items of BMS products for electric vehicles, and the modular platform design is conducive to the subsequent expansion and upgrading of BMS test functions.

Keywords: Battery management system; Test platform; New energy sources; Electric car; Modularize
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1 INTRODUCTION

With the outbreak of energy crisis and serious environmental pollution such as smog, in order to protect the ecological environment, more and more attention has been paid to low-carbon design. Low-carbon design mainly relies on energy efficient utilization, developing green materials and reducing carbon dioxide emissions, and achieves energy saving and emission reduction through innovation and design. As energy storage, batteries play an important role in the power system. The battery with excellent performance can support the smooth operation of the system. If the battery is charged or discharged within the safe working range, the service life of the battery will be longer [1]. Energy shortages and environmental issues may be considerably reduced with the development and deployment of electric vehicles (EVs). Electric vehicle performance and battery lifespan, on the other hand, are dependent on an adequate battery arrangement in order to meet the various battery performance standards [2, 3]. Improper charging and discharging process can reduce the performance of the battery and shorten the service life of the battery [4].

Continuous heat and gas generation follow safety blunders, triggering battery rupture and the ignition of combustible materials. The external environment is the most common source of internal battery disturbances (which regulates temperature, voltage, and electrochemical reactions). As a result, the working environment of the battery has a significant influence on its safety. Moreover, all of these precautions, current LIBs are far safer than previous generations, while researchers are trying to improve battery safety much more. With the development of society, people pay more and more attention to the ecological environment during the development of human civilization. Driven by high-tech achievements, new energy vehicles came into being [5]. The continuous supervision of battery packs is crucial to electric vehicle safety, reliability, and efficiency. This study delves deeply into numerous aspects of battery management systems (BMS) [6, 7].

Electric vehicles have become an important direction of automobile transformation under the background of energy crisis. The research on electric vehicles has gone through more than ten years of development. Relevant departments pay more and more attention to electric vehicles, and invest a lot of manpower, material resources and financial resources, hoping to realize independent research and development of electric vehicles as soon as possible. Battery management system is the core technology of electric vehicle, and it is also the bottleneck restricting the further improvement of electric vehicle technology level at present. So how to carry out future research based on existing achievements and promote the progress of core technologies have become a key topic in related fields [8, 9]. Given the importance of BMS and its functionality in the safe operation of ESSs, the objective of this study is to offer a technical evaluation of BMS for applications in transportation, electrification, and future electric automobiles with a heavy focus on uniformity This report also contains a full evaluation. During the functioning of the BMS, the components, architectures, and safety risks Furthermore, it investigates technical standards connected to the BMS in order to assist in the development of new standards. Therefore, this paper designs a modular and integrated BMS test platform based on PXI hardware architecture and LabVIEW software development environment, which meets the test items recommended by BMS automotive industry and is suitable for the factory inspection and type inspection items of BMS products for electric vehicles. And the modular platform design is conducive to the subsequent expansion and upgrade of BMS test function. The overall design block diagram is shown in Figure 1.

The previous section is the introduction to the paper. The section 2 is the literature survey of the work been done in the field. The section 3 is the research methodology. The section 4 covers results analysis. The section 5 concludes the manuscript along with the future scope.

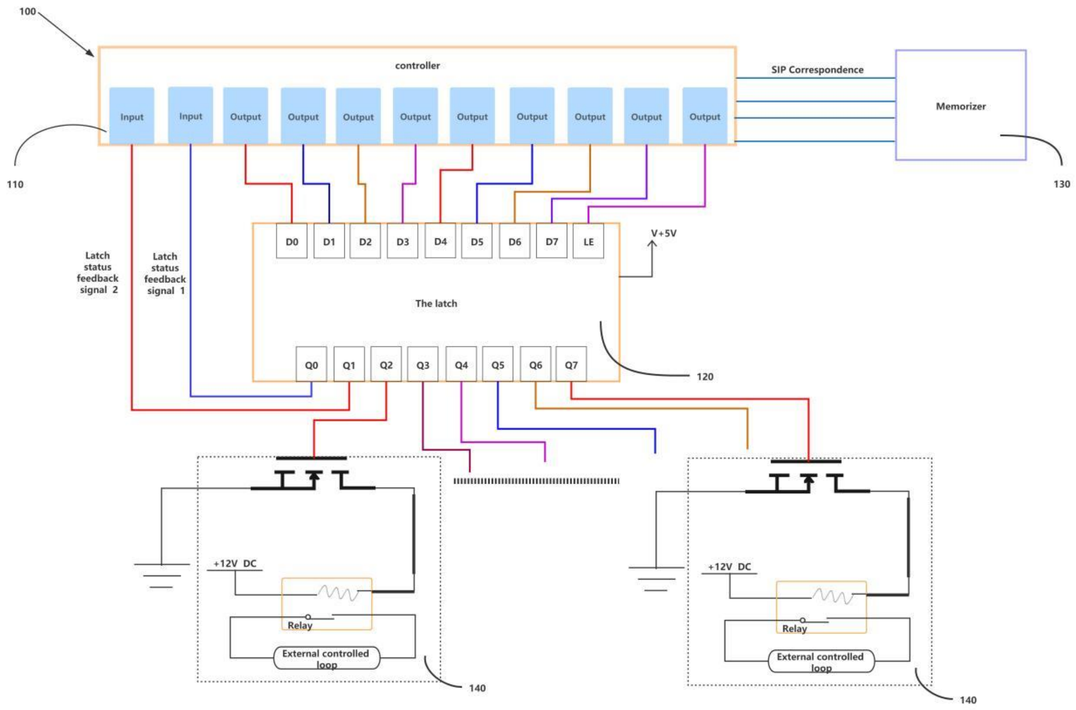

Figure 1: Overall design block diagram of BMS test system.

2 LITERATURE REVIEW

The application determines the amount of complexity of a BMS. In compared to other applications, the BMS in EVs must perform a number of complex tasks. As a result, the lack of an adequate technological framework for the BMS continues to hinder EV progress. The BMS must be able to handle the difficulties of power batteries, such as their enormous capacity, high power, wide temperature range, and difficult working conditions [10, 11]. A solid battery model is vital in battery behavior analysis, battery state monitoring, real-time controller design, temperature management, and fault diagnostics. Furthermore, crucial internal battery states such as state of charge (SOC), state of health (SOH), and internal temperature cannot be directly detected, despite the fact that these states are critical in managing battery performance and must be monitored using proper estimation approaches [12].

The development of new energy vehicles involves many key technologies, and the power battery as its main driving energy source is the core component that restricts its development [13]. Understanding the battery status based on several characteristics such as state of charge (SOC), temperatures, current rate, charging, and discharge condition is crucial for enhancing EV efficiency and safety [14, 15]. Key technologies such as battery life, charge and discharge efficiency and thermal management of power battery have become the focus of everyone's research. The power battery management system is a control system based on optimal management and protection of power batteries. The power battery management system with good performance not only ensures the reliability of the power battery, but also increases the safety of the power battery [16].

The battery management system developed by Singh, K.V. and others is used for the monitoring, management and balance control of power nickel-hydrogen batteries. The single-chip microcomputer is used to collect the terminal voltage, temperature, charge-discharge current and total voltage of the battery pack. On-line state judgment and fault diagnosis of each single battery are carried out to determine the charging and discharging mode of the battery pack, which greatly prolongs the service life of the battery. The decision-making is automatically completed by a power four-quadrant inverter. The system runs successfully [17]. ZM Tong put forward that the main function of the battery management system is to detect the voltage of the battery, the current in the process of charging and providing electric energy for the automobile and the temperature of the battery equipment, and then effectively estimate the amount of electricity in the battery, and finally achieve the balance of charging and discharging [18].

The most crucial elements governing the performance of lithium-ion batteries in electric vehicles are the operating temperature and voltage. The cell's operational voltage, current, and temperature must all remain inside the "Safe Operation Area" (SOA) shown by the green box at all times. If the cell is utilized outside of the secure zone, it might be irrevocably damaged [19, 20]. Liu, T believes that the battery management system estimates the remaining capacity (SOC) of the battery by detecting the battery voltage, charge and discharge current and battery pack temperature, controls the battery charge and discharge balance, manages the battery pack thermally and communicates with the vehicle monitoring system and charger through CAN, thus realizing coordinated control and optimized charging, ensuring battery safety and prolonging battery life. Among the many functions of BMS, SOC estimation, balance control and thermal management are the core [21].

Mishra, S.P. puts forward that SOC is the basis for judging a series of battery failures such as overcharge and over discharge, and its determination is the focus of BMS. At the same time, it is very difficult to accurately estimate SOC because SOC is highly nonlinear during battery use [22]. Gao, Q. believes that the traditional SOC estimation methods include open-circuit voltage method, internal resistance method and ampere-hour method, and the new estimation methods in recent years include fuzzy logic algorithm model, adaptive neural fuzzy inference model, linear model method and Kalman filter estimation model [23]. Through balanced control, Park, S., et al. investigates the parameter consistency of battery cells, which can be divided into active equilibrium and passive equilibrium. Passive equilibrium belongs to energy dissipation type, and there is energy loss in the control process. It is a simple and practical equilibrium method [24].

Kolosnitsyn, D.V. puts forward that BMS on the market at present has active equilibrium control and passive equilibrium control. The main task of BMS thermal management is to make the battery work in an appropriate temperature range and reduce the temperature difference among various battery modules [25]. Singh, K.V. thinks that in terms of software, the R&D of many BMS enterprises is at the world leading level, and the SOC estimation accuracy in the laboratory stage can reach 2% [26]. ZM Tong. et al. put forward that BADICHEQ system was designed and completed in 1991 led by Mentzer Electronic GmbH and Wemer Retzlaff, and the first loading experiment was carried out in December 1991. After continuous improvement, the system can measure the voltage, current and temperature of 20 battery cells at the same time and control the charging current of the main charger and battery state information and abnormal alarm information measured by the system can be displayed on the instrument panel [27]. Liu, T. tests that the development of new energy vehicles involves many key technologies, and the power battery as its main driving energy source is the core component that restricts its development. Key technologies such as charge and discharge efficiency and thermal management of power battery have become the focus of research [28].

This article sets out the requirements for an automotive BMS, the many topologies that may be employed, and a typical master/slave BMS installation for hybrid and battery vehicle applications, with a focus on the challenging design features.

3 RESEARCH METHODS

3.1 BMS Test System Platform Architecture and Functions

3.1.1 BMS test system platform architecture

BMS test system architecture mainly consists of hardware platform and software platform, as shown in Figure 2. The hardware platform provides various hardware resources and communication interfaces for BMS test system. The hardware platform is mainly composed of industrial control host, system test cabinet and communication interfaces. The software platform is designed based on LabVIEW development environment, which can realize the functions of BMS test system, such as human-computer interaction interface design, test process editing, test data analysis and result discrimination, and test report output [29]. Generally speaking, when the battery of new energy vehicle is charged, the charging curve under ideal state is shown in Figure 3.

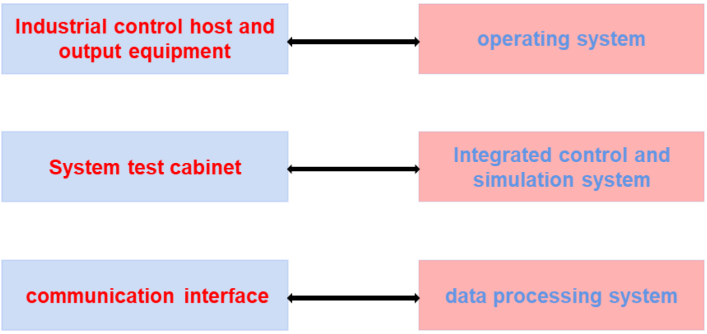

Figure 2: BMS test platform architecture.

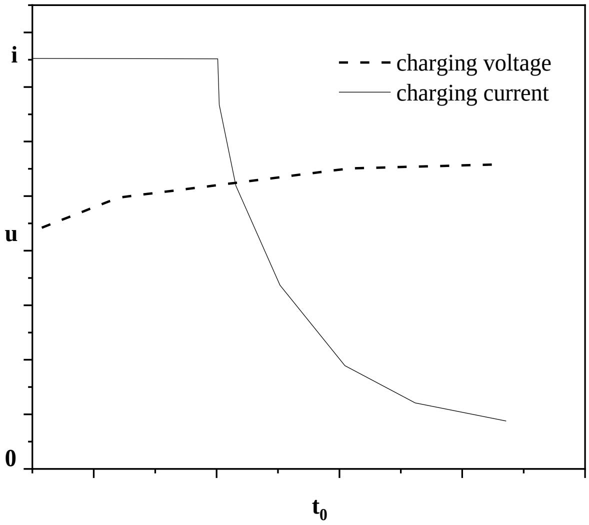

Figure 3: Battery charging curve of new energy vehicle.

3.1.2 Design of test system software platform

The figure 4 is the test architecture of the BMS. It will judge the reliability and veracity of the battery for the longer use in electric vehicles. Through this only, the efficiency of the battery has been judged under various operations. As shown in Figure 4, the software architecture of the test platform mainly includes three categories: test process management, data processing and analysis, and system protection management. Test process management mainly includes BMS test item selection, test process editing and test data saving. Data processing analysis mainly includes test data analysis, test result discrimination, test report output, etc. System protection management is mainly divided into protection management design such as system self-check, hierarchical authority management and system security protection [30, 31]. The working condition simulation function (especially the complex working condition or real vehicle working condition simulation function) is the shortcoming of the current BMS test system platform. Therefore, the software platform of this test system adds Fuds (Federation of charging and discharging modules) and DST (dynamics tress test) charging and discharging modules on the basis of the four typical charging and discharging modules of QC/T897-2011, and opens the function of operating mode editing for users, so that the parameters of BMS such as SOC estimation accuracy, SOC error correction speed and SOP estimation accuracy can be detected more accurately [32].

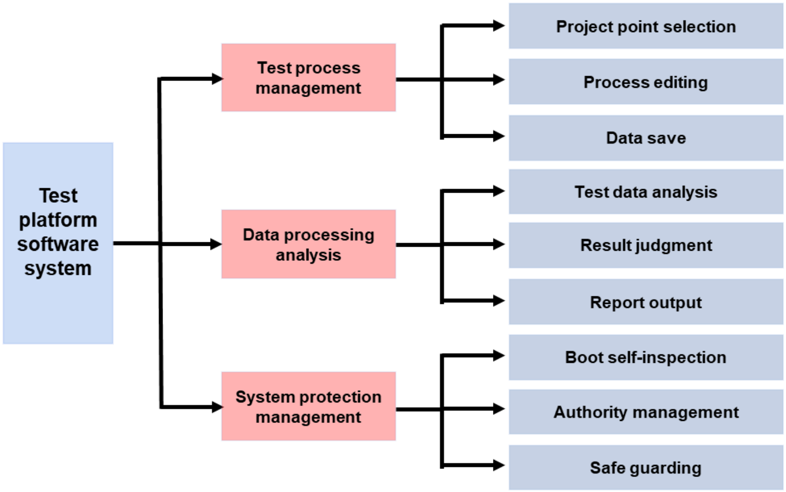

Figure 4: Battery charging curve of new energy vehicle BMS test platform software architecture.

3.2 BMS Test System Function

Due to the deficiency and imperfection of BMS standard, BMS test platform can realize the factory inspection and type inspection of BMS products according to the recommended standard document of automobile industry "Technical Conditions of Battery Management System for Electric Vehicles". Under the linkage control with the environmental box, BMS products can be operated at high and low temperatures and other climate and environmental tests [33]. According to the functional characteristics of BMS, the functions of this test platform include the following points:

- **State parameter and estimation accuracy test:** total voltage measurement accuracy, total current measurement accuracy, single cell (battery pack) voltage measurement accuracy, temperature measurement accuracy, insulation resistance measurement accuracy, SOC cumulative estimation error accuracy, SOC error correction speed test, SOP estimation accuracy test, etc.
- **Fault diagnosis test:** high/low battery temperature, high/low battery cell (battery cell) voltage, high battery cell (battery cell) consistency, high charge/discharge current (power),

weak insulation, high/low SOC, SOC jump, low/high total voltage, external/internal communication interface failure, large battery system temperature difference, high voltage interlock failure, and total voltage/battery voltage exceeding.

- **Electrical adaptability test:** DC power supply voltage test, overvoltage test, superimposed AC voltage test, power supply voltage ramp-up test, power supply voltage transient change test, reverse voltage test, short circuit protection test, etc. Other functional tests: Battery balance management test (active/passive balance state test, balance current test, etc.), insulation resistance test, high voltage resistance test, communication function test, charging simulation test, etc. [34, 35].

3.3 Definition and Estimation Method of Battery Characteristics of New Energy Vehicles

As a description parameter of battery capacity status, SOC reflects the remaining capacity of the battery and can be charged and discharged in advance by grasping the SOC information of the battery. Its value is defined as the ratio of the remaining capacity of the battery to the nominal capacity of the battery, and the common percentage is shown in Formula (3.1):

$$SOC = Q_c / C_e \tag{3.1}$$

In this formula: Q_c is the remaining energy of the battery, C_e is the nominal capacity of the battery. Generally, the state of the battery charging to the highest voltage at a certain temperature is defined as 100% in charge state, and the state of the battery discharging to the termination voltage is defined as 0% in charge state.

3.3.1 Several common SOC estimation methods

The ampere-hour integral (Ah) method is the simplest, most reliable and most commonly used method at present. It refers to the way of integrating and accumulating the accumulated electricity input or output, that is, the product value of time and current flowing into or out of the battery pack, to calculate the charged and discharged electricity of the battery, and then to add and subtract the initial electricity and the integrated value. Calculate the remaining charge of the battery, and then compare it with the total charge of the battery to obtain the SOC value [36]. It regards the battery as a closed system, does not study the relationship between the relatively complex electrochemical reaction of the battery and its internal parameters, but only pays attention to the external characteristics of the system. The calculation formula of this method is shown in formulas (3.2), (3.3) and (3.4):

$$SOC = SOC_0 \pm \frac{C_{i(t)}}{C_0} \tag{3.2}$$

$$SOC_0 = \frac{C_0}{C_e} \tag{3.3}$$

$$C_{i(t)} = \eta \int_0^t i\,d\tau \tag{3.4}$$

SOC_0 is the initial value of SOC. C_0 is the capacity of the battery discharged at a calibrated constant current. C_e is the rated capacity of the battery. η is the charge and discharge efficiency.

3.3.2 Open circuit voltage method

This method is often used to estimate the initial value SOC_0 of the battery, the electromotive force of the battery is approximately equal to the open circuit voltage of the battery. It is pointed out that when the performance of Keng ion battery is completely stable, there is a monotonic increasing relationship between the open circuit voltage (OCV) and SOC, and this linear relationship is little affected by the environmental temperature and battery aging factors. We can measure the OCV of the battery and use their proportional relationship, and estimate the SOC directly. The relationship between OCV and SOC can be expressed as shown in formula (3.5):

$$SOC = \frac{OCV - U_0}{U_T - U_0} \tag{3.5}$$

U_0 is the discharge termination voltage. U_T is the highest charging voltage.

4 RESULT DISCUSSIONS

4.1 Measurement Accuracy Test of State Parameters

Comparison of test results of single voltage acquisition, total voltage and total current acquisition accuracy of BMS to be tested is shown in Figure 5 and Figure 6. The results show that the maximum error of BMS acquisition voltage is 3mV, which meets the requirements of national standard. Figure 5 and Figure 6 show the acquisition accuracy test of BMS total voltage and total current respectively, and the maximum error of BMS total voltage is 1V and the maximum error of total current is 0.6A, which meets the national standard requirements.

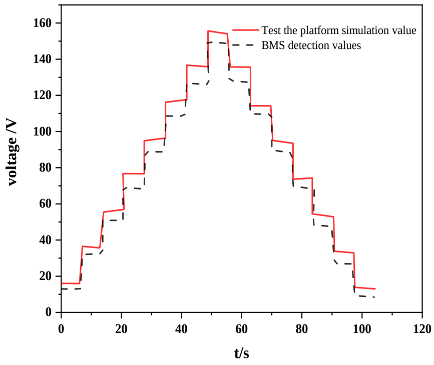

Figure 5: BMS total voltage acquisition accuracy test.

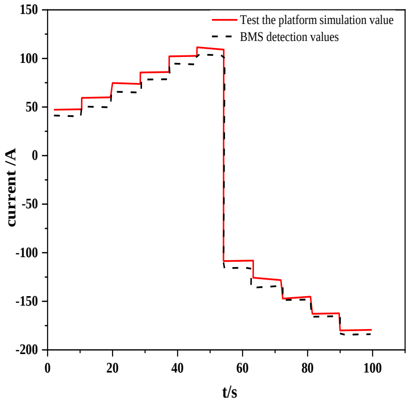

Figure 6: BMS total current acquisition accuracy test.

4.2 SOC Estimation Accuracy Test

The SOC estimation of BMS is a key index to measure the quality of BMS products. The national standard requires that the cumulative SOC estimation error of pure electric vehicles and plug-in hybrid electric vehicles should not be more than 5%, and that of plug-in hybrid electric vehicles should not be more than 15%. Even, in 2017, the Ministry of Science and Technology released 14 key projects, including new energy vehicles, which are national key research and development plans, and suggested that the estimation error of SOC of power battery system should not be more than 3%. Therefore, the formula of this test platform based on SOC truth value is shown in formula (4.6):

$$SOC = \frac{Q_0 - Q_1}{Q_0} \times 100\% \tag{4.6}$$

Q_0 is the initial available capacity of the battery system. Q_1 is battery system discharge recorded for BMS test platform.

Compare the SOC real value with BMS estimated value to determine whether the SOC estimated error is within the standard requirements. Under the working condition shown in figure 7, the BMS under test is discharged for 100s at 440A constant current, and then charged for 100s at 440A constant current, and the SOC estimation accuracy of the BMS under test is detected by the test platform. The comparison results are shown in figure 8, and the SOC estimation errors are all within 2%, which meets the standard requirements.

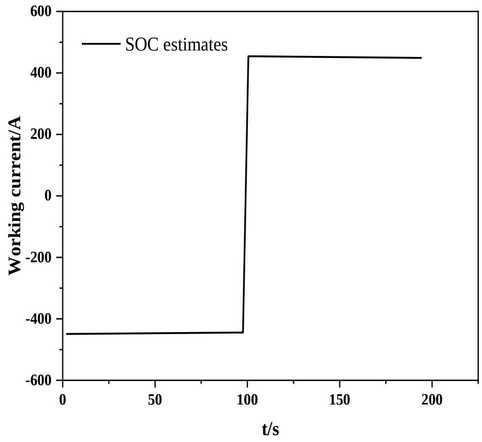

Figure 7: Typical working conditions of 7SOC estimation.

4.3 Fault Monitoring and Diagnosis

BMS products with high stability, high reliability and high precision can effectively improve the battery utilization rate of new energy vehicle fleet, prevent the battery from being overcharged or over discharged, prolong the service life of the battery, monitor the running state of the battery pack and each battery cell in real time, and effectively prevent unexpected accidents of the battery pack, and give early warning in case of emergency. Therefore, this test platform has the function of diagnosing various faults of BMS. The diagnostic items include high/low total voltage, high charging current, high discharging current, high/low SOC, high/low module voltage, high/low module temperature, high module temperature difference, insulation fault, communication fault, relay fault, fan fault, fuse fault, etc. The test platform can accurately simulate BMS fault signal and compare it with BMS through communication, so as to accurately judge the accuracy of BMS fault diagnosis function. Batteries are essential components of the power system because they store energy. The system's smooth operation can be aided with a high-performance battery. If the battery is charged or discharged within the safe operating range, its service life will be prolonged. Improper charging and discharging practices can damage battery performance and reduce service life. The primary benefits of the proposed architecture are superior battery pack balancing during operation and intrinsic cell fault resistance. In fact, if the system detects a completely damaged cell in the pack, it can permanently skip it.

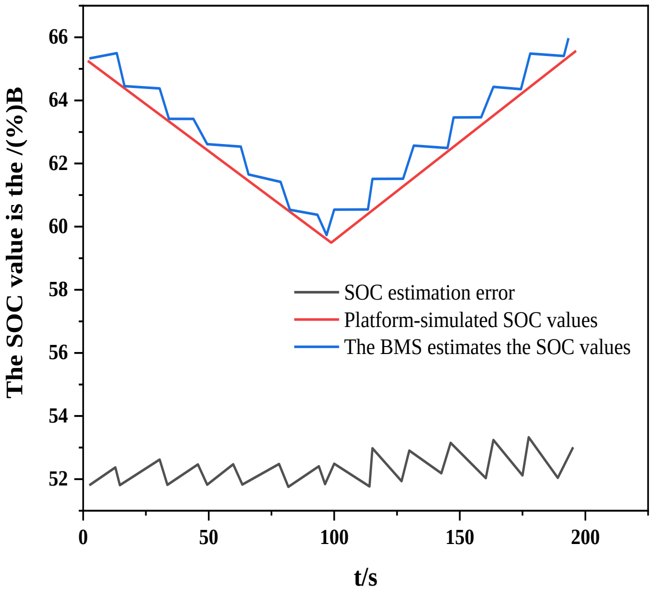

Figure 8: SOC precision test results comparison.

5 CONCLUSION

The battery management system of new energy vehicles is the core technology of electric vehicles, and improving the technical level of the battery management system is the key to improve the independent research and development capability of electric vehicles. This paper tests a large number of different types of BMS ranging from 20 to 120 strings, and the test results show that, the platform can meet the factory inspection and type inspection items of different BMS existing in the market, and has sufficient system stability, and can perform one-click automatic test function after the test items are selected. Through the detection of BMS test platform, products with low monitoring accuracy, imperfect safety function and low performance reliability can be identified which can ensure the characteristics of high safety and high reliability of BMS for electric vehicles. I hope this article can provide reference for related research, promote the progress of research and development of battery management system for electric vehicles, and promote the progress of new energy vehicle industry. Many battery models misrepresent actual battery discharge behaviour. When the batteries are nearly empty and the load is removed from the battery, the voltage rises; when the load is restored and the current resumes, the voltage decreases to the nominal value. Future battery types should be able to mimic this type of discharge behavior. Furthermore, battery performance of the model should be increased further.

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