Original Research Article

Design of remote monitoring system for lithium battery operating status

ABSTRACT

The safety of lithium batteries has always been an important problem that restricts the rapid development of lithium batteries. In view of the problems such as the untimely and difficult monitoring of the thermal runaway behavior of the lithium battery energy storage system, a remote monitoring system for the operating state of lithium batteries based on ZigBee and NB-IOT technology is designed. The real-time collection of the operating parameters of lithium batteries is realized through various sensors, the whole system is constructed by the Internet of things technology, and the uploading of operating parameters is realized through the network. It is verified that the system can operate stably, collect the operating parameters of lithium battery and upload relevant data in real time, facilitate the remote monitoring of staff, and provide a strong guarantee for the safety of lithium battery energy storage system.

Keywords: ZigBee; internet of things; fault warning; lithium battery.

1. INTRODUCTION

With the gradual reduction of energy and the rapid deterioration of the environment, countries in the world will accelerate the transformation to clean and low-carbon energy in the future. In order to achieve this goal, the development of new energy such as photovoltaic, wind power and hydrogen energy has become the key. However, new energy has randomness and uncertainty. Only by configuring relevant energy storage power stations can the storage and use of new energy be promoted. Lithium battery has become one of the major electrochemical energy storage technologies due to its good characteristics [1]. With the increasing proportion of lithium battery energy storage system in the whole energy storage system, the safety problem of lithium battery energy storage system has become increasingly prominent. The lithium battery energy storage system is usually composed of a lot of lithium battery cells in series and parallel. When the battery pack is put into use, there will be a certain gap between the individual batteries due to the different manufacturing processes, and the difference between the battery packs will be greater. When some batteries are in safety conditions, the performance of the single battery pack or the whole energy storage system will be affected, and the aging of the battery pack will be aggravated, and even safety problems will occur. Domestic and foreign lithium battery researchers generally believe that the abuse of lithium battery such as overheating, overcurrent, overcharge, overdischarge, extrusion, and acupuncture is the root cause of thermal runaway of lithium battery [2]. Before the thermal runaway of the battery occurs, the operating state of the battery will change, and some parameters will be abnormal, such as voltage, current, gas concentration, stress, temperature, etc. Therefore, real-time monitoring of these parameters and early warning of some abnormal parameters will provide great help for preventing the thermal runaway behavior of lithium batteries.

In view of the demand for monitoring the operating state of lithium batteries, researchers have carried out various studies and given a variety of solutions. Reference[3] conducted overcharge experiments on lithium iron phosphate battery modules and found that H2, CO and CO2 can well reflect the process of overcharge and out of control of lithium batteries. Reference [4] et al. Aimed at the problems such as the difficulty of temperature monitoring in the traditional energy storage power station and the heavy workload of manual inspection, they used the fiber Bragg grating sensor to monitor the temperature of the lithium battery module of the energy storage power station in real time, and used the temperature information to warn the energy storage power station, which greatly reduced the accident rate of the energy storage power station. Reference [5] and Reference [6] designed the monitoring system of energy storage power station based on

CAN bus to solve the problem of difficult information transmission of lithium battery energy storage power station, and realized the information transmission between multiple lithium batteries and actuators.

However, the above monitoring system and monitoring methods are all aimed at the lithium battery module, which can not well solve the monitoring demand of single lithium battery. In fact, all kinds of lithium battery accidents are caused by the thermal runaway of the single battery. The monitoring of the temperature, gas and other parameters of the battery module can not accurately reflect the operating state of the single lithium battery, and the failure can not be found in time only by monitoring the parameters of the lithium battery module. At the same time, at the present stage, the monitoring of some parameters of the lithium battery energy storage power station still requires the staff to regularly visit the energy storage power station and collect the parameter information of the energy storage power station. In order to realize the safe operation of the lithium battery system, a remote monitoring system for the operation state of the lithium battery is designed in this paper. The system collects the operating parameters of the single lithium battery through the microcontroller, such as voltage, current, internal temperature and strain. At the same time, these parameters are transmitted through ZigBee and NB-IOT in real time, making the energy storage power station a huge node of the Internet of things, The background staff can obtain the operation data of the energy storage power station in real time through the system to provide guarantee for the safety of the energy storage power station.

2. OVERALL SYSTEM DESIGN

The architecture of this monitoring system is the traditional Internet of things standard architecture, which is composed of the perception layer of information collection, the transmission layer of data transmission and the application layer of data visualization. The architecture is shown in Figure 1. The system can realize the collection, processing, transmission and data visualization of the operating parameters of the lithium battery energy storage power station.

(1) Perceptual layer

The sensing layer is composed of the information acquisition module inside the energy storage station. Stm32f103zet6 is adopted as the system controller, which can realize the real-time collection of lithium battery temperature, voltage, current, strain and other parameter information, and realize the data transmission between the sensing layer and the transmission layer.

(2) Transport layer
The transport layer is a bridge connecting the perception layer and the application layer, and can realize data transmission between the perception layer and the application layer. First, the transmission layer needs to access the sensing layer device to upload the collected data to the application layer; Secondly, the transport layer should send the commands and information of the application layer to the perception layer to ensure the reliable transmission of data and instructions.

(3) Application layer
The application layer is the bridge between the user and the monitoring system, and is composed of local host, cloud host and mobile phone applet. The application layer is responsible for realizing the visualization and storage of operation data, as well as the alarm of abnormal state and the distribution of control data.

The monitoring system uses DS2438 chip to collect the voltage of lithium battery, acs712 Hall sensor for current collection, MAX6675 chip for temperature collection, and Wheatstone bridge to measure the deformation of lithium battery. The collected data of the single battery will be transmitted to the ZigBee aggregation node through ZigBee, and the data of the ZigBee aggregation node will be uploaded to the cloud platform through NB-IOT [7], so as to realize the remote monitoring of the operating parameters of the lithium battery. At the same time, the thresholds of various parameters can be set on the cloud platform. When the parameter value exceeds the set threshold, an alarm will be given automatically. The alarm information will be displayed on the cloud platform and sent to the user through wechat. Rechargeable batteries can be used for power supply of the lower machine. When the lower machine uploads the collected data to the cloud platform, it enters the sleep state. After the next wake-up, the data will be transmitted again, so as to achieve the purpose of low power consumption and long-time work.

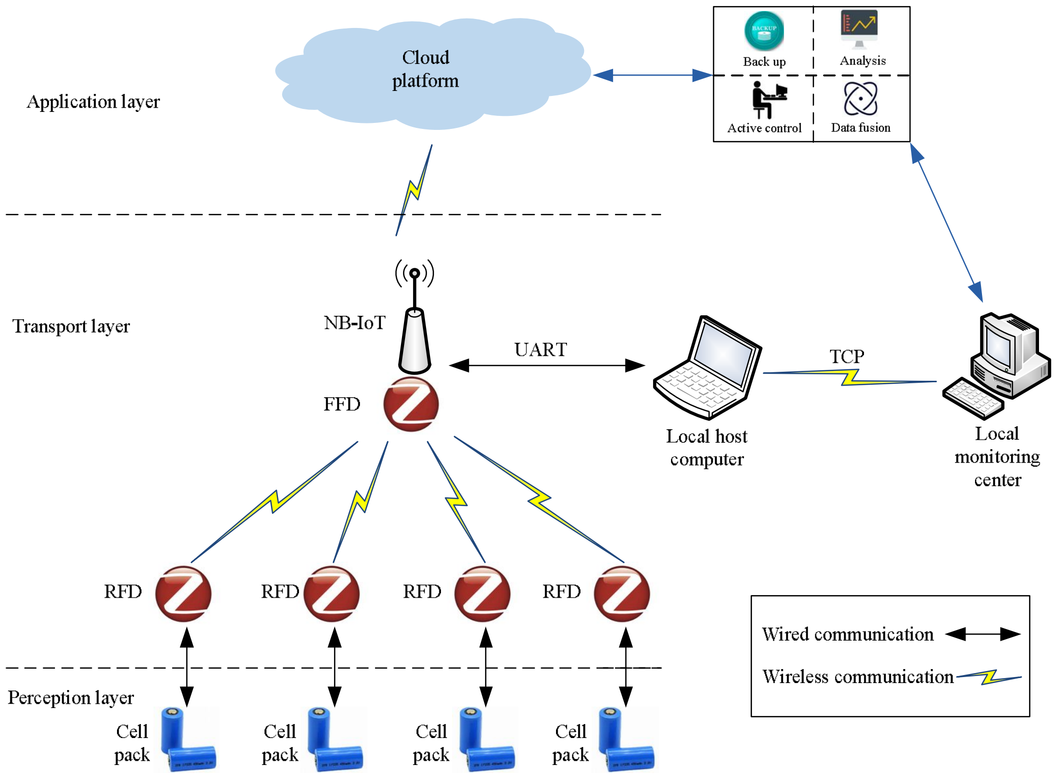

Fig. 1. Monitoring system architecture

3. MONITORING SYSTEM DESIGN

3.1 SYSTEM HARDWARE DESIGN

The hardware part of the system is mainly composed of various acquisition circuits, ZigBee nodes, NB-IOT modules and main control chip circuits. The MCU connects various parameter collection sensors through I/O interface to collect the parameter information of the lithium battery operation process, then uploads the lithium battery operation parameters to the main control module through ZigBee module, and the main control module uploads the collected lithium battery information to the cloud platform.

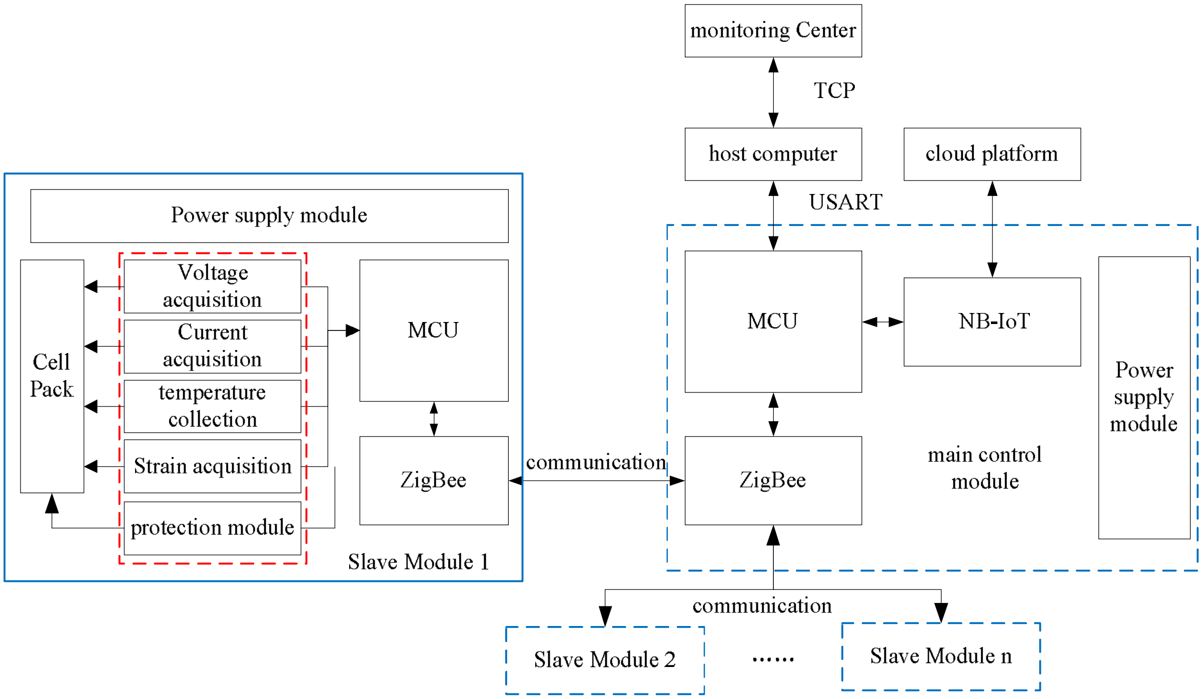

Fig. 2. Hardware structure diagram

3.1.1.Slave Module MCU

The slave module MCU is responsible for collecting the operating information of the battery pack and calculating the SOC of the battery. The collected information determines whether the battery is in overcharge, over-discharge, overheating, or other problems. When an abnormal situation occurs, disconnect the external circuit of the battery pack to ensure its safety of the battery pack. When no abnormal situation occurs, the collected information is uploaded to the main control module through the ZigBee module, and at the same time, it receives the instructions issued by the main control module and performs related operations.

3.1.2. Voltage Acquisition Module

At present, the materials of lithium batteries are mostly ternary lithium or lithium iron phosphate. The discharge cut-off voltage of a single battery is about 3.2-3.7v, and the charge cut-off voltage is about 3.6-4.2v. After research, it is decided to use DS2438 chip to monitor the lithium battery. The DS2438 monitoring chip is produced by Dallas company of the United States. It can communicate with the microcontroller through a single bus, and has a power-off protection register inside to ensure the accuracy of data [9]. The voltage collection range of the DS2438 chip is 0-10V, which can directly connect the lithium battery with the chip pin. When the chip receives the collection command, the internal A/D converter will convert the voltage to realize the collection of the battery voltage.

3.1.3 Current Acquisition Module

The current collection of this design uses the current sensor acs712 launched by Allegro company. Acs712 is designed based on the Hall effect principle. The hall sensor built in the chip can convert the input current into voltage value, maintain a good linear relationship within the input and output range, and the sensitivity is about 100 mV / A, which can meet the requirements for current collection [10].

3.1.4 Temperature measurement module

Thermocouple and MAX6675 are used for temperature collection. Thermocouple is a common temperature measuring device in the temperature collector, which can convert the temperature change into µ The V-level voltage signal [11] can be converted into the temperature value of the measured object through the relevant circuit. MAX6675 has the functions of cold end compensation, thermocouple disconnection detection, linearity correction, etc. the temperature acquisition resolution is 0.25 ℃, and the working voltage is 3.3-5 v. MAX6675 has built-in 12 bit AD acquisition circuit, which can convert the voltage signal collected by the thermocouple into a digital quantity that can be directly read by the main control chip. The maximum temperature that can be read can reach 1024 ° C, meeting the demand of lithium battery temperature measurement.

3.1.5 Strain Measurement Module

This design uses ad580 and ad624 to design the strain collection circuit. The front end of the strain collection circuit is ad580, which converts the voltage with an input range of 4.5-30v into an output voltage of 2.5V to ensure the stability of the voltage of the strain collection circuit. The Wheatstone bridge consists of two resistors with a resistance of 120 Ω, two strain gauges and a potentiometer. Selecting 120 Ω strain gauge can reduce the heat generated by the strain gauge [12]. Since the resistance between the strain gauge and the resistance is not the standard 120 Ω, a certain bias voltage will be generated when the strain gauge is not deformed. Adding a potentiometer to the bridge can adjust the bias voltage of the Wheatstone bridge. When the strain gauge is subjected to 600 με The output voltage of Wheatstone bridge is about 2 MV. The variable gain amplifier chip ad624 is selected for the voltage amplification part. A resistance of 100 Ω is connected between pins 1 and 8 to amplify the voltage 1000 times.

3.1.6 ZigBee Communication Module

The communication module is mainly composed of ZigBee module and NB-IOT module. ZigBee is also divided into cell collection node and information collection node. The cell collection node mainly sends the collected parameter information of the cell to the ZigBee collection node. The parameter information of the collection node can be uploaded to the local host computer or the cloud through NB-IOT.

The NB-IOT communication module is the tas-nb-161 module of Tashi Internet of things group. It is mainly composed of antenna circuit, SIM card seat circuit, reset circuit and power supply circuit. It communicates with the main control chip through 485, and uses its built-in communication chip to upload the received parameter information to the cloud server.

3.2 Software Design

The system software mainly realizes the functions of lithium battery data acquisition, data processing, data transmission and data reception。

When the monitoring system is started, MCU initializes each module and chip. The initialization steps include: chip initialization, parameter zeroing, serial port initialization, 485 communication mode configuration, ZigBee module, NB-IOT module, interrupt and timer initialization. After the initialization of each module, first open the ZigBee module to realize the networking of the ZigBee module, and then open the NB-IOT module to enable the NB-IOT to establish a connection with the cloud platform. Then, the system periodically collects the temperature, voltage, current, strain and other parameter information of the single lithium battery, and transmits the collected data to the collection node through the ZigBee module. Then, the NB-IOT module and the serial port upload the data to the cloud platform and the local host computer. The local host computer and the cloud platform process the data to complete the visualization of the parameters. When the lithium battery parameters are abnormal, the host computer and the cloud platform send an early warning message and notify the staff.

3.2.1 Design of Voltage Acquisition Software

DS2438 is a single bus element. The communication between the main control chip and DS2438 requires three steps: initialization, Rom identification and data exchange. The initialization consists of the reset pulse sent by the main control chip and the response pulse sent by DS2438. The reset pulse informs DS2438 to initialize, and the response pulse informs the master chip DS2438 that initialization has been completed [13]. When the main control chip receives the response pulse of DS2438, it will send a ROM command to control DS2438 to access a specific function. When DS2438 collects voltage, it needs to send relevant conversion command to collect.

3.2.2 Design of Temperature Acquisition Software

The voltage value of the thermocouple needs to be converted by MAX6675 for the temperature collection of lithium battery. The accuracy is 0.25 ℃, and the temperature will fluctuate during the measurement. In order to improve the temperature measurement accuracy, the average filtering method is adopted for the collection: 10 temperature data are collected each time, one maximum value and one minimum value are removed, and the average value of the middle eight values is processed.

First initialize the MAX6675 so that the initial value is 0. When pin 6 and pin 5 of the MAX6675 are at low level, enter the reading state, read the conversion value once, and then judge the conversion value. If the conversion value is not "1", move the data left by one bit. If the conversion value is "1", phase or the conversion value with 0x01, and then move the data value left by one bit. After reading 16 bits, proceed to the next step [14]. Since the valid data bits of MAX6675 are 12 bits, it is necessary to shift the data value by three bits to the right. After the collection of 10 data values is completed, the bubble method is used to sort the 10 data in the array, and then the maximum value and the minimum value are removed. The average value of the middle eight data values is processed as the final value of the lithium battery temperature.

3.2.3 ZigBee Communication Software Design

As the intermediate link of system communication, ZigBee mainly completes data transmission and reception. Therefore, the stability of ZigBee and the efficiency of real-time data transmission are more important. In this design, ZigBee is initialized first. Initialization includes baud rate configuration, I / O pin configuration, pin clock configuration, system clock configuration, etc. Finally, ZigBee is configured as broadcast mode to form ZigBee communication network, and data transmission can be carried out after the equipment enters the network [15].

3.2.4 Design of NB-IOT Communication Software

NB-IOT mainly realizes the communication between the main control chip and the cloud database. In this design, the NB-IOT communicates with the master chip through RS485. The NB-IOT module uploads the collected data to the cloud platform using the mqtt protocol. The initialization and parameter configuration of the device are controlled by the at command [16].

3.2.5 LabVIEW Host Computer Design

According to the design requirements of the system, LabVIEW upper computer needs to complete data communication, data display, data storage and other functions. By setting the internal visa plug-in, LabVIEW can communicate with the main control chip through the serial port [17]. When the data is transmitted from the main control chip to the upper computer, the data needs to be displayed on the upper computer. In order to visually observe the change trend of relevant parameters and compare the differences of relevant parameters of multiple lithium batteries, the display control in LabVIEW is required. Waveform diagram and waveform icon in LabVIEW can display real-time waveform. In order to display real-time time time at the same time, this design uses waveform diagram as graphic display control. In order to analyze the state of the lithium battery in the future, it is necessary to store the collected data. There are many data storage methods in LabVIEW, among which the access database is commonly used. The lithium battery data can be stored and modified by adding, deleting, modifying, searching and other related operations. The front panel of LabVIEW is used to set relevant parameters and display data. The layout should be as intuitive, clear and concise as possible. The figure shows the display interface of the lithium battery monitoring system. The display interface is used to display the temperature, voltage, current, strain and SOC of the lithium battery. The number of waveform diagram display curves can be modified according to the number of monitored lithium batteries, which can not only visually observe the change trend of parameters, but also compare the differences of multiple lithium battery parameters.

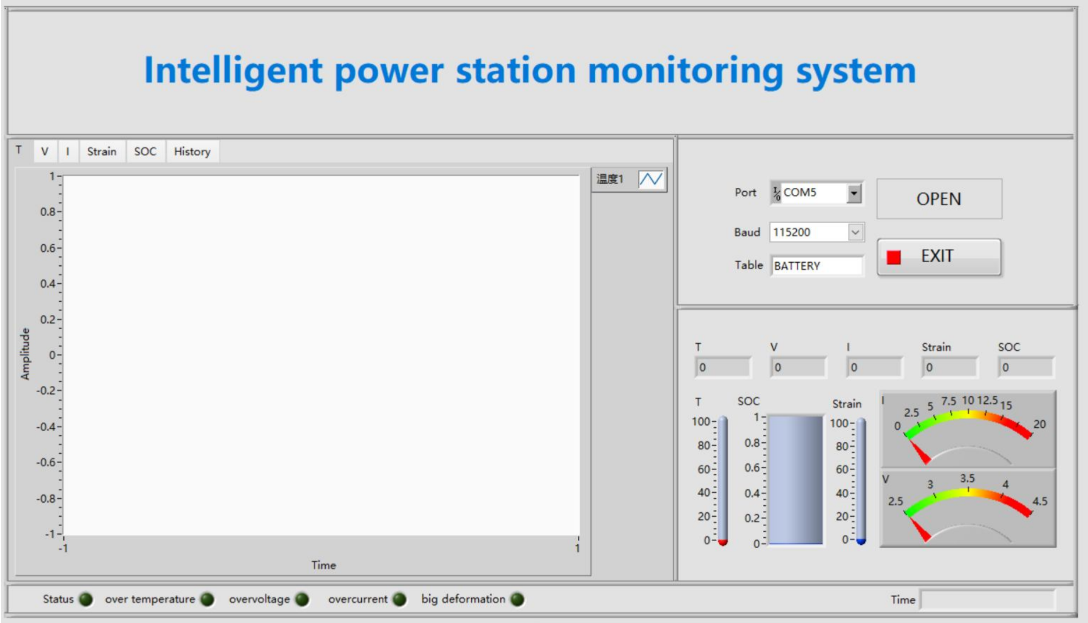

Fig 3 PC monitoring platform

4. SYSTEM TEST

In order to verify the accuracy of the collected parameters and the stability of the data transmission of the monitoring system, and make the system more safe and reliable, a 5000mAh lithium battery was selected for the test. The lithium battery monitoring system is shown in Figure 4. After the system is powered on, the lithium battery operation parameter information can be collected.

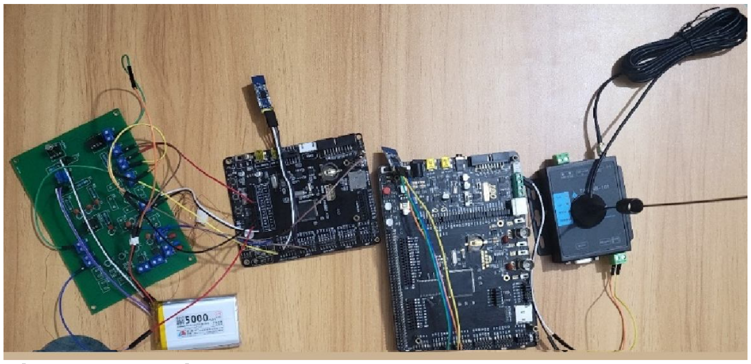
Fig 4 Test equipment

4.1 Data Transmission Stability Test

The data transmission process of the monitoring system consists of the parameter acquisition of the sensing layer, the data transmission of the transmission layer and the data reception of the application layer. The sensing layer collects and uploads data every 2 seconds, including lithium battery temperature, voltage, current, strain, SOC, DC internal resistance and other information. In order to ensure the stability of data transmission, check bits will be added to the data artificially during the transmission process. The application layer will receive the data only after the check is successful. This experiment will use the above equipment to monitor the lithium battery, and analyze the stability of the monitoring system in the transmission process by testing the data transmission and acceptance during the operation. According to the sampling and data transmission frequency of the monitoring system, the equipment shall send 1800 pieces of data per hour. By checking the amount of data in the database, the data received by the monitoring system per hour is shown in Figure 5. According to the test results, the success rate of data reception of this system can reach 99.09%, and the transmission process is stable, which can meet the actual use requirements.

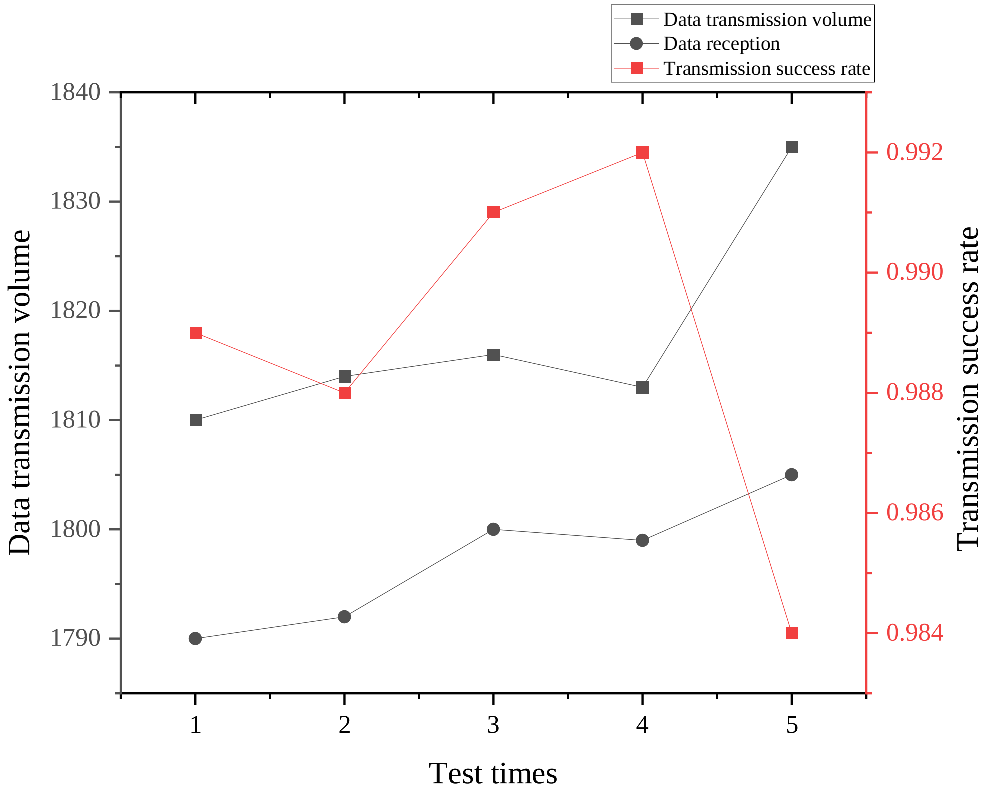

Fig 5 Test equipment

4.3 FUNCTION TEST OF LOCAL UPPER COMPUTER

The application layer of the monitoring system includes the cloud platform and the self-developed local upper computer. The author tested the monitoring system in the laboratory. The test equipment is shown in Figure 6. The test contents are as follows:

Lithium battery operation status monitoring: The purpose of this test is to verify whether the data collection, data transmission and data visualization of the monitoring system work normally. The temperature, voltage, current, strain and SOC of the single lithium battery can be displayed in real time on the local upper computer interface. At the same time, the monitoring system can set the threshold value of lithium battery parameters. When some parameters reach the threshold value, an alarm will be given. The staff can also view the historical data of lithium battery work.

Alarm function test: The purpose of this test is to verify whether the monitoring system can give an early warning when the lithium battery is abnormal. During the test, the temperature of the thermocouple will be controlled manually. When the temperature exceeds the threshold value, the system will give an alarm to complete the test. From the experimental results, it can be seen that the system can give an alarm when the temperature exceeds the limit for 10 times.

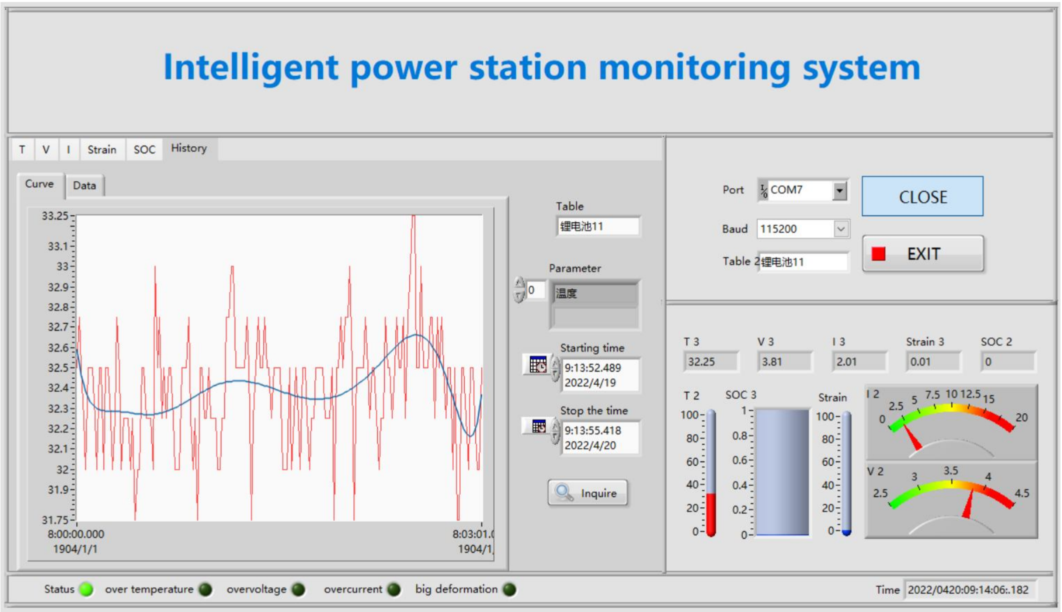

Fig 6 Current measurement accuracy test

4.4 CLOUD PLATFORM TEST

The Internet of things technology is developing rapidly, and various cloud platforms are also emerging. Comparing the functions, costs and use thresholds of different cloud platforms, the Tashi Internet of things cloud platform will be adopted in this design. Tashi cloud platform can realize data visualization, historical data query, data download, cloud and mobile alarm. The test results are shown below.

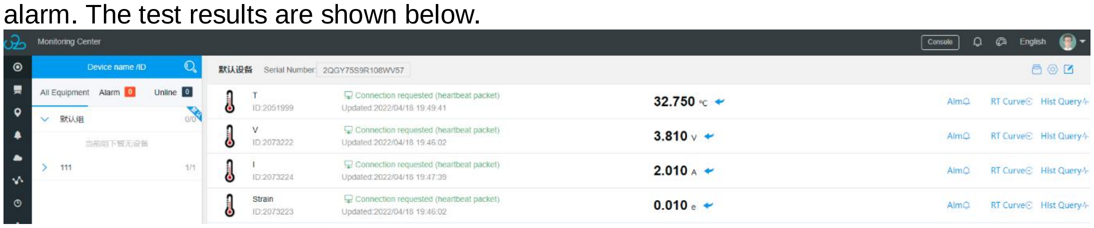

Fig 7 Overcharge protection test

5 CONCLUSION

Stm32f103zet6 embedded chip is used as the main control chip in the remote monitoring system of lithium battery running state designed this time, and ZigBee and NB-IOT modules are installed. The main control chip adopts AD acquisition and single bus communication protocol to collect temperature, voltage, current and strain. The collected relevant data is sent to the ZigBee aggregation node through ZigBee, and then uploaded to the cloud platform through the mobile base station through NB-IOT, or uploaded to the local host computer through the serial port. Staff can observe the operation status of lithium battery in real time through online cloud platform, wechat applet and local upper computer. This system improves the shortcomings of the traditional monitoring system of lithium battery energy storage power station, such as less monitoring data, short transmission distance, high power consumption and low coverage, and provides good help for the development of the remote monitoring system of lithium battery.

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