Design of Substation Battery Remote Monitoring System Based on LoRa Technology

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Abstract. The function module of the current substation battery remote monitoring system is generally one-way, and the monitoring range is limited, leading to the extension of the monitoring response time. Therefore, the design of the substation battery remote monitoring system based on LoRa technology is proposed. According to the actual monitoring needs and standards, first build the main controller MCU, access the A/D conversion circuit, establish GPRS monitoring sensor device, and complete the color design of the system hardware; On this basis, the multi-target form is adopted to break the restriction of the monitoring range, and the multi-target remote monitoring function module is established. The associated monitoring range is limited. At the same time, the monitoring storage database is constructed to complete the design of the system software. The final test results show that the final monitoring response time is better controlled below 0.5s for the operation of six batteries, indicating that this method has better monitoring effect, stronger pertinence and practical application value.

Keywords: LoRa Technology · Substation Battery · Remote Monitoring System

1 Introduction

The substation battery is often used as the backup power supply in the power supply system. It is a DC power supply. When the main power supply system fails, the secondary system in the power system maintains its normal work through the power supply of the battery. Therefore, the stability of the substation battery in the actual operation process and its discharged capacity in the discharge process are of great significance to ensure the normal operation of power equipment [1]. At present, the management and remote monitoring of the battery in the substation are mainly one-way. While collecting the daily system operation data set information, it is also necessary to test the total capacity of the battery through the discharge test. In the process, the battery is replaced in a periodic manner to prevent the power supply system failure caused by insufficient battery capacity, and further expand the actual monitoring range. The greater the coverage of one-way monitoring, the longer the time will be spent, and the periodic replacement of battery will result in waste of battery resources and economic losses [2]. Moreover, the traditional substation battery remote monitoring system itself lacks pertinence. In the

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face of different power environments, the control effect of the monitoring area is also different. In order to ensure the change of the daily monitoring needs and standards of the substation, the monitoring program of the system is improved and optimized [3]. The so-called LoRa technology mainly refers to a low-power LAN wireless standard. Its name “LoRa” is Long Range Radio. The biggest feature is that under the same power consumption conditions, it spreads farther than other wireless methods, realizing the unification of low-power consumption and distance. Under the same power consumption, it extends 3–5 times the distance of traditional wireless radio communication [4]. Integrating this technology with the substation battery remote monitoring system can, to a certain extent, further expand the actual monitoring range, gradually build a flexible and changeable monitoring structure, and improve the quality and efficiency of monitoring [5].

In fact, in recent years, with the advance of smart grid, more and more substations have realized unattended operation, and the safe operation of substations is particularly important for the power system. After the evacuation of attendants, the demand for safety monitoring of batteries becomes very strong [6]. As a DC system that undertakes the tasks of secondary load power supply such as control, protection circuit and automatic device, its reliability will directly affect the normal operation of the substation [7]. At this time, the battery becomes the last line of defense of the DC system, which plays a particularly important role in the event of an accident in the substation. Using LoRa technology and intelligent information technology, the remote monitoring structure built can mark the abnormal position faster and more timely, collect the corresponding data and information, and transmit them to the preset position [8] through the channel. In addition, with the help and support of LoRa technology, the system can also monitor the internal resistance, temperature, voltage parameters, etc. of the substation battery in real time, help relevant personnel to analyze the performance of the battery, and grasp the operating status of the battery at any time [9]. In case of battery failure, the system will take alarm prompt measures to remind the maintenance management personnel to deal with the failure event in time to avoid accidents caused by battery failure, ensure the reliability and safety of the power supply system, reduce the possibility of battery failure caused by damage and aging of individual battery, and extend the service life of the battery. The application of LoRa technology has also enhanced the use of battery online monitoring system by maintenance personnel to a certain extent, avoided frequent on-site inspection, greatly reduced the workload, reduced injuries and accidents to relevant personnel, and laid a foundation for the subsequent development and innovation of the power industry and related technologies [10]. Therefore, the design and verification research of remote monitoring system for substation battery based on LoRa technology is proposed. Based on the actual remote monitoring requirements of the substation battery, a main controller MCU is constructed and connected to an A/D conversion circuit to reduce power consumption and cost. A GPRS monitoring sensing device is established and hardware design is completed. By utilizing LoRa technology, designing a multi-objective remote monitoring function module and an anomaly monitoring warning program, it is convenient to directly grasp the application status of substation batteries through the system. At the same time, a monitoring and storage database is constructed to facilitate the analysis of monitoring data, thus achieving the design of a substation battery remote monitoring system based on LoRa technology.

2 Design Hardware of Remote LoRa Monitoring System for Storage Battery

2.1 Main Controller MCU Design

The so-called MCU mainly refers to a kind of microcontroller unit (MCU), also known as single chip microcomputer or single chip microcomputer, which is to properly reduce the frequency and specification of the central process unit (CPU), and to properly reduce the memory, counter, USB, A/D conversion, UART, PLC, DMA and other peripheral interfaces, A hardware structure that forms overlay control.The selection of main controller MCU is also very important and critical for the design of monitoring system.It is possible to connect a single chip microcomputer into the hardware control structure, but it should be noted that the following aspects should be considered when selecting a single chip microcomputer: the reading and writing effect of the GPRS communication module SIM900, the control range of the LCD, and the correlation degree of the battery collection module. The single chip microcomputer that meets the above three items can be connected.Set a stable interface on the periphery of the MCU, select the SPI interface for GPRS communication, and the RS232 interface for communication with the S-BUS converter. Add a master control chip in the internal control structure to meet the requirements of system scalability as far as possible. On the basis of retaining the existing hardware structure, expand the new peripherals.The main controller selects the STC15F2K60S2 single-chip microcomputer, sets the number of on-chip integration to more than 100000 times, and associates the Flash program memory with the RS232 interface communicated by the S-BUS converter to form a stable control program.Set basic control indicators and parameters, as shown in Table 1.

Table 1. Main controller MCU index and parameter setting table

Main controller MCU indicators	Controllable parameter standards	Measured parameter standards
Working current/mA	35	45
Voltage/V	220	220
Number of RS232 serial interfaces/piece	12	18
Low level/dBm	80	100
High level/dBm	220	260

According to Table 1, complete the setting and research of MCU indicators and parameters of the main controller.Next, the GPRS wireless communication module is set based on the actual monitoring requirements and standards. This part can be controlled by combining the operation status analysis of the substation battery.To set the working voltage range, it is generally required to control between 2.4 V and 5.5 V.The watchdog and timer protection devices are set in the hardware structure to gradually improve the anti-interference capability of the system. A reliable reset circuit is set inside the control circuit, and the program structure is encrypted before transmission to form a stable control hardware control system.

Then, based on this, a single chip computer of STC15F2K60S2 model is connected to the current hardware structure, and the initial SIM300 wireless module, alarm module, keyboard input module, RS232 to TTL level circuit, and LCD1602 with backlight are connected.A small control circuit is designated in the control circuit, which is composed of an external crystal oscillation circuit and a reset circuit.The oscillation frequency of the external quartz crystal is 22M, and the reset circuit selects the resistance capacitance reset circuit. Next, based on the actual hardware control needs, set the external control circuit of the main controller MCU, and increase the converter interface to the non-standard nine pin RS232 serial interface. The electrical level standard of the RS232 serial interface is inconsistent with the TTL level of the MCU, which is easy to cause the current and voltage loops to press, To reduce the operation capacity of the battery, in order to achieve the communication balance between the main controller MCU and the converter, a RS232 TTL level access circuit is designed. The MAX232 chip is used to complete the setting and guidance of the serial interface circuit, and the TTL level 0V or 5V is converted to 3V to 15V or –3V to –15V through MAX232 to form a multi-directional controllable main controller MCU communication unit structure, as shown in Fig. 1.

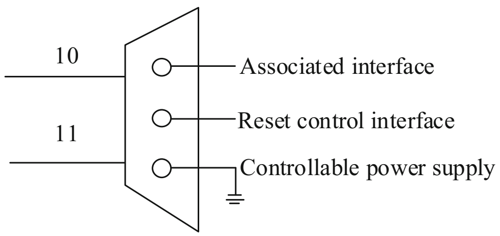

Fig. 1. Structure diagram of main controller MCU communication unit

According to Fig. 1, complete the design and research of the main controller MCU communication unit structure. Next, adjust the working voltage at this time to 4.5V–5.5V, and the working voltage at 5V is the optimal mode. When the working voltage is 5V, the working current is 2.0 mA. Set RS as data and command selection, R/W as read/write selection, and E as enable signal. When RS of battery is low level and R/W is high level, LCD of main controller MCU is in reading state; When RS is low level, R/W is low level, and enable signal E is high pulse. At this time, the main controller will write the instruction code into 1602 and convert it to the data reading state, strengthen the application effect of the main controller MCU, and complete the basic design.

2.2 A/D Conversion Circuit Design

After completing the design of the main controller MCU, the next step is to build the A/D conversion circuit.The remote monitoring of the storage battery generally requires the cooperation of the sensor, which adopts the form of SBUS bus redundant connection to ensure that after the sensor collects the working parameters of the storage battery, it obtains the SBUS data signal, realizes the communication with the main controller, sends the data to the main controller, and realizes the action of SBUS to RS232 circuit.The internal control circuit needs to use ICL3221, the main chip of ICL3221, and set RS232 interface.In this part, it should be noted that in order to ensure the application control effect of RS232 interface, one driver and two receivers can be connected to the CL3221 and ICL3221 main chips. The full duplex communication mode is used to set the basic A/D conversion circuit form and calculate the transmission rate of the circuit, as shown in Formula 1 below:

$$H = \sum \eta i + \kappa^2 \Re c \tag{1}$$

In Formula 1: η indicates the communication control range, i indicates the control times, κ indicates the serial port protocol distance, $\Re$ represents the lowest voltage, c indicates the sensing coverage. According to the above measurement, the calculation of the circuit transmission rate is completed.Adjust the transmission rate standard of the battery remote monitoring system to control it between 120 ~ 250kbps, and the working voltage of the modified times is 3 V~5.5 V, so as to ensure that the working circuit of ICL3221 is in normal and stable operation state under the condition of low power consumption.At this time, set the serial port of RS232 communication protocol between ICL3221 and MCU, set the converter in the A/D conversion circuit, process the collected data signal, and send the serial port protocol through the S-BUS bus. Under normal conditions, SBUS signal enters from the SBUS TXD of the circuit, and is sent to ICL3221 from the T1-IN terminal after being amplified by the connected triode OP07AJ and processed by the circuit, ICL3221 receives the data conforming to the RS232 communication protocol standard. At this time, the A/D conversion circuit can control the transmitted data at the same time, collect analog signals, read the data using the main controller, and achieve specific control and monitoring functions through an A/D conversion circuit.

Then, based on this, an analog resistor is connected in series to the output circuit of the current sensor to convert the current signal into a voltage signal.AD7705 is selected as the main chip of AD conversion, which has low power consumption, low cost, accuracy and resolution to meet the system requirements. At this time, the control value of A/D conversion circuit is set according to the actual remote monitoring requirements and standard changes, as shown in Table 2.

Set and analyze the control value of A/D conversion circuit according to Table 2. At this point, the corresponding TCP/IP protocol stack can be established through the internal integration of SIM300, and the control instructions of TCP/IPAT circuit can be expanded by integrating the actual requirements and standard changes, and the AT instruction set can be used to conduct differentiated control processing on the conversion circuit, so as to better realize the transmission and application of GPRS data, further

Table 2. A/D conversion circuit control value setting table

Conversion circuit indicators	Fixed standards	Controllable standard
Main chip type	SIM300	Integration SIM300
Conversion rate	1.3	1.5
Control frequency/time	12	16
Minimum voltage/V	5.5	6.5
Circuit expansion times/time	8	12
Number of pins/piece	32	64
Working voltage/V	4	4.5

improve the design of hardware structure, and reduce the occurrence of error control, control delay and other problems.

2.3 Design of GPRS Monitoring Sensor Device

After completing the design of A/D conversion circuit, the next step is to build and access the GPRS monitoring sensor device.Generally, before the design of GPRS monitoring sensor device, it is necessary to define the range and distance of sensor coverage, and ensure the reliability and stability of the circuit when making PCB board.Several sensing layers are designed and the sensing device is designed in four stages, as shown in Table 3.

Table 3. Setting table of multi-stage sensing device

Sensing stage	Number of TC15F2K60S2 chip pins/piece	Peripheral expansion control ratio
Phase 1	12	1.13
Phase 2	12	1.25
Phase 3	16	1.27
Phase 4	18	1.31

Set the multi-stage sensing device according to Table 3. Then, based on this, the PCB circuit board was designed. However, in the actual design process, attention should be paid to the crystal oscillator operation state of the MCU. At the same time, a sensor monitoring device should be set close to the STC15F2K60S2 chip pin for this purpose to minimize its interference to the surrounding devices. Try to use SMD components, ground wires, and power wires to walk together. The ground wire, power wire, and signal wire should not form a loop. The circuit part that needs external expansion module should be placed on the periphery of the circuit board to facilitate wiring with the expansion module, so that the application coverage of GPRS monitoring sensor device in the system main controller PCB hardware structure can be improved. Next, according to the actual needs and standards, set the decoding of the sensor return data frame, as shown in Table 4.

Table 4. Decoding setting table of returned data frame of sensor device

Directional parameters	Data A + Data B	Exponential, mantissa	Price
Voltage	0 x 55, 0 x 00	0.1010,101	13.12
Voltage	0 x 42, 0 x 01	0.1011,102	14.61
Temperature	0 x 66, 0 x 02	0.1012,103	15.02
Impedance	0 x 81, 0 x 03	0.1013,104	15.37

According to Table 4, complete the setting of decoding the returned data frame of the sensing device.At this time, analyze the operation of the battery. Under the same conditions, the greater the discharge current of the battery, the greater the current is due to the existence of its own internal resistance, the more power it consumes, and the less power it can supply for the external circuit. Therefore, we can take GPRS monitoring sensing correction measures to a certain extent for the residual capacity of the battery when discharging with different discharge currents. The residual capacity of the battery will be affected by temperature, so first correct the temperature and calculate the corresponding corrected capacity, as shown in Formula 2 below:

$$K_{corr} = \frac{t_{act}^2}{l(t_{init} + t_{std})} \tag{2}$$

In Formula 2: l indicates the number of sensing times, t_{init} and t_{std} represent the current correction deviation and the actual correction deviation respectively, t_{act} indicates the sensing orientation value. According to the above measurement, the calculation of the correction capacity is completed. According to the obtained values, the control and monitoring indicators of GPRS monitoring sensors are adjusted to form a stable remote monitoring structure, and the design of the system hardware is completed.

3 Design of Remote LoRa Monitoring System Software for Storage Battery

3.1 Multi Target Remote Monitoring Function Module Design

After completing the design of the system hardware, the next step is to integrate the LoRa technology to design the software in the battery remote monitoring system. Firstly, the function module of multi-target remote monitoring is designed. Generally, in order to increase the controllability of the system and improve the monitoring efficiency and quality, the system is divided into monitoring modules such as system management, basic data management, battery condition monitoring, battery operation monitoring, battery charge and discharge monitoring and analysis, battery internal resistance analysis, battery performance analysis, status alarm, and comprehensive report. Through the organic combination of these functional modules, the online monitoring and analysis of the battery can be realized after the effectiveness verification and scientific analysis of the real-time monitoring data. The specific structure is shown in Fig. 2.

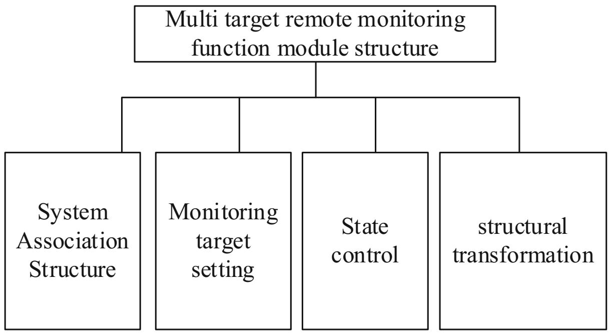

Fig. 2. Structure diagram of multi-target remote monitoring function module

According to Fig. 2, complete the design and analysis of the structure of the multi-target remote monitoring function module. Next, integrate the LoRa technology to analyze and verify the key application function modules. First, the basic system management is designed and analyzed. This part mainly manages system users, permissions and other information. The setting content mainly includes the sub modules of menu management, role management, company management and user management.

The system administrator can assign corresponding roles to each user by adding users on a daily basis to control the user's permissions. At the same time, the system administrator can set the initial control indicators and parameters according to the coverage of different function monitoring modules, as shown in Table 5.

According to Table 5, set and study the index parameters of the multi-target remote monitoring function module.Next, the basic data management module is designed. This part usually needs to be divided into multiple layers, mainly providing some basic data for system operation. Generally, the number of daily reaction battery operation and some frequently used data will be uniformly maintained. In this system, the basic data management function mainly includes two sub modules, namely, parameter setting module and battery pack maintenance module. Basic data management mainly includes sub function structure and directional function structure. All of them play a targeted role in the daily operation and maintenance of the battery.

Then, based on this, the main monitoring function module of battery operation is designed. The battery has strict requirements for operation, and serious consequences will be caused if there are environmental problems, so it is very important to monitor its operating parameters. The traditional battery operation monitoring is mainly completed manually, and the status of the battery is measured regularly. With the development of technology, using equipment to monitor the battery system in real time and online will gradually replace manual testing as the main means of battery testing. However, most of the automatic monitoring is only limited to the monitoring of battery voltage,

Table 5. Index Parameters of Multi target Remote Monitoring Function Module

Remote monitoring function module	Define	Controllable value
USER	Daily control and setting of users	User management and permission control
Permission settings	Setting of system control permissions	Application of system functions
Roles	User + administrator	Administrator + User Settings
menu management	Basic functional control	Fixed application function settings
Units Manager	Monitoring Content Management	Internal control structure setting
Sub module design	Related module design	Sub module control

current, temperature and other operating parameters, which is difficult to achieve real-time monitoring of battery performance. Remote monitoring connects the monitoring equipment with the battery, collects and reports the battery voltage, charge and discharge current, temperature or individual voltage and other operating parameters in real time, and conducts charge and discharge management, effectively making up for the weakness of manual inspection. Multi objective remote monitoring module can further expand the actual monitoring range, and form more controllable monitoring standards. The control of monitoring error shall be strengthened to the greatest extent to strengthen the application level of each functional module.

3.2 Abnormal Monitoring and Warning Program Design

After the design of the multi-target remote monitoring function module is completed, the next step is to build an exception warning program combined with LoRa technology.In the daily operation process, the system will combine the actual situation, provide abnormal conditions for the system operation, and give real-time alarm. When a battery is found to have abnormal conditions, the system will automatically give an audible alarm. The thresholds of these alarms can also be modified by the user. Next, on this basis, in combination with the abnormal state, we use professional software to carry out abnormal statistical processing, and summarize and integrate the corresponding data and information. The system can make classification based on the abnormal monitoring conditions and generate corresponding statistical reports and test reports in combination with LoRa technology. It can generate corresponding battery operation reports by month, month and day. Through these reports, the performance and operation of on-site batteries can be analyzed, providing relevant data support for further decision-making.

The data analysis and statistical process of the statistical report are not fixed, but make targeted adjustments with the change of the actual situation, with strong pertinence and stability. Not only that, combined with LoRa technology, the system will also collect relevant information about the battery in the front-end substation, and then judge the collected data. If there is an exception, there will be an exception information table. If it is normal, there will be an exception information table in the history information table. The system will automatically generate the corresponding operation data table according to the time set by the user in combination with LoRa technology.

3.3 Monitoring Storage Database Design

After completing the design of the exception warning program, the next step is to build the monitoring storage database. Monitoring database design is a series of processes that store records previously stored manually in a database, analyze and extract relevant records, and then design according to database requirements in combination with LoRa technology. When designing the database, you should first design the table according to the storage requirements, then design the fields and their storage types, as well as the primary key, foreign key, non empty constraints and other relationships. Combined with LoRa technology, LoRa multi-dimensional recognition sensing program is constructed to correlate with the database. The design process is also quite complex. Generally, people with database design experience design the database according to the functional design of the project. In the process of design, the following issues also need to be considered, specifically as follows: First, consider the scalability of database tables, comply with the three paradigm principles of data design, try to ensure that a table only stores data of one entity, and reduce data coupling. The second is to consider the integrity of the database. When designing, try to consider the usefulness of the data in each field to reduce the redundancy of data. The third is the change of database performance. Consider whether to establish indexes separate meters, etc., so as to improve the running speed. For database design, it is very important to ensure data integrity and reduce data redundancy by combining LoRa technology. It is very important to design a reasonable database table structure. Generally, the database design needs to be reviewed after completion. The system database designed this time combines LoRa technology, uses the MYSQL database association form, and the database table tool designed is Power Designer as shown in Table 6.

Table 6. Database Table Tool Information Table

Database Field Description	Types of	Notes
ID	One-way	Address
ORG-NAME	Attributive name	Name
ORG-TEL	Bidirectional	Phone
ORG-ADDRESS	Int	Work address
NOTE	Other	Memo

According to Table 6, complete the setting and analysis of database table tool information. Next, combine LoRa technology to build a one-way control program in the monitoring database to form a more controllable monitoring structure. On this basis, the personnel information table needs to be used as the system user information storage, and personnel information is the primary prerequisite for system operation. The personnel information controlled in this part generally shows the personnel information of the substation. The users of the system are roughly divided into system administrators and operation and maintenance personnel. The system administrator is mainly responsible for managing all functions in the system. It can operate all functions in the system and view all monitoring information; Maintenance personnel can see the functions of battery performance analysis, status monitoring, statistical report, status alarm, etc.

The personnel information table set in the monitoring repository mainly maintains information such as the name, real name, password, contact number, contact address, affiliated unit, registration date, and other relevant information used when logging in. When designing the database, we also designed the field length and data type of the personnel information table, which is mainly used to maintain the values that are often used in the system and will change frequently, so that users can flexibly set the parameter values according to the use conditions, thus reflecting the flexibility activity. Reduce the need to modify the code or database when a value changes. Users can directly master the application of the substation battery through the system, which is more convenient. In addition, the monitoring database stores information data, which is also convenient for subsequent monitoring and analysis.

4 System Test

This time is mainly about the analysis and design of the actual effect of the remote monitoring system for the storage battery in the substation based on LoRa technology. Considering the authenticity and reliability of the final test results, the analysis is carried out by means of comparison. Substation G is selected as the main target object for the test, and professional equipment and devices are used to collect relevant system design data and information. According to the actual design requirements and standards, the final system test results are analyzed. Next, the basic test environment is built based on LoRa technology.

4.1 Test Preparation

In combination with LoRa technology, this time is mainly to build the test environment for the battery remote monitoring system of G substation. First, you need to set the background data management server (DMS). The service device is mainly the core of the battery online monitoring system, which is responsible for monitoring the operation of the whole system. Its functions include: system initialization, setting BDCU working status, reading monitored data, graphic display, database processing, data analysis and other modules. First, initialize the system clock, set internal environment variables and issue initialization instructions to BDCU in combination with the designed battery monitoring requirements and standards. On this basis, it is also necessary to set BDCU working status: start or stop BDCU operation. And build association with the program

Table 7. Battery Operation Monitoring Reading Table

Describe	Offset start address	Offset End Address
Number of batteries/piece	12	16
Battery monitoring voltage average value/V	12	16
Average value of battery monitoring resistance/Ω	3.2	4.1
Internal resistance of battery/Ω	5.5	6.2
Monitoring time/s	1.01	0.82
Directional monitoring difference	2.72	3.62
Actual monitoring difference	1.92	2.71

reading monitoring data to read the battery operation data monitored by BDCU, as shown in Table 7.

Complete the setting of the battery operation monitoring reading program according to Table 7.Next, set the graphic display structure to display the status of each battery cell in a graphic manner. Audible and visual alarms will be given to battery cells that have detected excessive data, and the monitored values include internal resistance, voltage, etc. Then, the acquired data and information will be transferred to the database for equivalent processing. Store historical data, provide original data for data analysis, analyze the trend of historical curve of internal resistance of specific battery cells according to the historical database, arrange battery cells in the order required by specific requirements, and output backward batteries in the report. The data server (DMS) is connected to the internal network of the substation to provide database support to authorized network users, so that these users can get the battery data monitored by the system in real time for subsequent use. So far, the basic test environment has been set. Next, specific test research is carried out in combination with LoRa technology.

4.2 Test Process and Result Analysis

After completing the establishment of the basic test environment, next, combined with LoRa technology, the remote monitoring system of G substation battery is measured and analyzed. First, six batteries are selected as the main target objects for testing in the substation, and a corresponding number of monitoring nodes are set around the batteries. The nodes are connected and overlapped with each other to form a cyclic monitoring structure. The acquired data is processed and transferred to the display unit program for subsequent use.

Through in-depth data analysis of the voltage, current, internal resistance, temperature, etc. of the substation, the system makes reasonable adjustment and correction to ensure that the battery is in the most stable state, comprehensively judges the condition of the battery and reasonably and effectively predicts its performance. The measurement is carried out in three stages. Three distances of 14 km, 20 km and 24 km are set to test the remote monitoring system, and the monitoring response time is calculated, as shown in Formula 3 below:

$$T = d^2 - \left(\vartheta + \sum dw\right) - \varphi \quad (3)$$

In Formula 3: d indicates the directional monitoring range, ϑ indicates the overlapping monitoring range, w indicates the monitoring times, φ indicates directional deviation. According to the above determination, complete the analysis of the test results, as shown in Table 8.

Table 8. Comparison and Analysis of Test Results

Measuring the battery	14 km monitoring response time/s	20 km monitoring response time/s	24 km monitoring response time/s
Storage battery1	0.21	0.37	0.41
Storage battery2	0.25	0.31	0.47
Storage battery3	0.23	0.36	0.42
Storage battery4	0.26	0.37	0.42
Storage battery5	0.29	0.32	0.47
Storage battery6	0.26	0.37	0.41

According to Table 8, the analysis of the test results is completed: for the operation of six batteries, the final monitoring response time is better controlled below 0.5s, indicating that the monitoring effect of this method is better, more targeted, and has practical application value.

5 Conclusion

The above is the design and verification research of the remote monitoring system of the substation battery based on LoRa technology. In the hardware part of the substation battery remote monitoring system, the communication unit structure of the main controller MCU is designed, and an A/D conversion circuit is constructed based on actual monitoring needs to reduce system errors and delays. Select a GPRS monitoring sensing device to form a stable remote monitoring structure. In the system software section, a multi-objective remote monitoring function module, abnormal monitoring warning program, and monitoring storage database were designed to improve the monitoring effect and achieve the monitoring function of the system. Through experiments, it has been verified that the monitoring effect of this system is better and more targeted.

Compared with the initial battery monitoring mode, this integrated LoRa technology has designed a more flexible, variable and stable detection structure. At the same time, combined with the actual monitoring needs, further expand the scope of monitoring, strengthen the monitoring efficiency, and provide reference and theoretical reference for the innovation and upgrading of subsequent related systems. The future substation battery remote monitoring system can further research intelligent monitoring and more intelligently monitor battery status to improve battery efficiency and lifespan.

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