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DESIGN AND IMPLEMENTATION OF REMOTE MONITORING TERMINAL FOR TRANSMISSION LINE SAG

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Abstract

In the past, the transmission line condition monitoring often needs to be realised by manual method. This traditional method has great limitations and can not carry out real-time monitoring of the transmission line. In this paper, based on Narrowband Internet of Things (NB-IoT) wireless communication technology, a modern remote monitoring terminal for transmission line sag is designed to solve the real-time monitoring of transmission line status and reduce a series of transmission line accidents caused by sag. The specific design will start from the hardware and software, and the FreeRTOS operating system is used in the design process to ensure the real-time information processing. At the same time, a number of sub-tasks are established, such as sensor data acquisition, data filtering processing, *etc.* Through the system design, the sag status online monitoring and remote transmission functions are completed. To test the feasibility of the terminal design, the OneNet cloud platform was used for implementation research, and the results showed that the platform could view historical data and corresponding curve changes, which confirmed the feasibility of the terminal design, and could be applied in the remote monitoring of the arc of the transmission line to ensure the efficient operation of the transmission line.

Key Words

Transmission line: Sag, remote monitoring

1. Introduction

With the development of power facilities, although it improves the stability and economy of the system, it also brings greater security risks, which will directly affect the development of the entire modern industry. High-voltage power transmission is an important part of energy transmission, and the transmission lines are generally hung outdoors, whose reliable and safe operation directly affects the benefits of the entire power system. Once the transmission line fails, it is bound to bring huge losses to the entire power system [1]–[3]. In addition, due to the increasing demand for electricity in modern industry, to improve the transmission capacity, many transmission lines increase the maximum operating temperature of the conductor from 70°C to 80°C to meet the increased power load demand. In such a high temperature working environment, more attention should be paid to wire sag to avoid major electrical accidents [4]. For example, Qin *et al.* studied the tight line early warning system of high voltage lines on the basis of stress change rate, and tested the early warning function of the system, including sag and stress early warning and the early warning effect after increasing the stress change rate. The final test results show that the system can accurately warn. It provides the necessary data support and safety support for the erection construction and safety [5]. For another example, the ice thickness estimation method of transmission lines on the basis of world sequence iteration, and specifically conducted empirical research on scenarios with different wire lengths through simulation experiments. The results confirmed the feasibility of this estimation method proposed by this scholar, which can accurately estimate the ice thickness of transmission lines. It has made a positive contribution to the safety of transmission lines [6]. For this reason, all-weather sag monitoring of transmission lines is born along the trend, and has become a key link in predicting potential faults. In addition to the southern region, the transmission lines in many regions will be covered with ice, and some of them will be broken, the pole and tower toppling and flashover problems are the problems that the power sector is always concerned about. In this regard, have carried out a detailed study on the monitoring of ice covering of overhead transmission lines, and proposed a phase-sensitive optical time domain reflection-based technology to carry out real-time monitoring of ice covering of transmission lines with the help of this technology, and grasp the specific conditions of transmission lines in a dynamic way, making due efforts for the operation and maintenance of transmission lines [7]. In the same year, the built-in algorithm of transmission line sag observation device with the help of multivariate heterogeneous data fusion technology, including pitch conversion, height difference conversion, device distance starting length calculation,

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sag calculation, sag comparison of each sub-wire, sub-wire calculation, *etc.* The results found that the measured values all met the requirements of the specification, which confirmed the reliability of the algorithm design. It can further promote the development of research in the field of transmission line sag [8]. The ice covering of transmission lines will lead to the increase of wire weight, which will lead to the increase of sag. The ice covering can be monitored in real time by measuring the sag of transmission lines. The sag angle and the angle of hanging point will be different with different ice thickness. In turn, the degree of icing and failure of transmission lines can be predicted by measuring the angle or sag of suspension points. Therefore, to promote the development of remote monitoring of transmission line sag, the hardware and software of transmission line sag remote monitoring terminal are designed and studied in this paper, and the final implementation is carried out with the help of OneNet cloud platform. The results confirm the feasibility of terminal system design and can monitor transmission line sag situation in real time.

2. Basic Concept of Transmission Line Sag

The vertical distance between any point on the transmission line and the connection of the two support suspension points is called the sag. There are many types of sag, such as central point sag, lowest sag, maximum sag, *etc.*, [9], [10]. When the height difference between the two suspension points of the transmission line reaches the minimum value, the central sag of the transmission line is closer to its own maximum sag, then it can be approximated that the maximum sag is located in the centre of the transmission line. Because the lowest point of the transmission line may be outside the transmission distance, so the calculation of the lowest point sag is of little significance, so the calculation of the sag refers to the calculation of the maximum sag. Sag is influenced by many factors, such as conductor stress, ambient temperature, wind speed and direction, transportation capacity, and ice cover. Conductor stress is one of the most prominent influencing factors. With the increase of conductor stress, sag decreases. The change of ambient temperature will cause the thermal expansion and contraction of the transmission line, and then affect the sag of the transmission line. That is, the higher the temperature, the greater the elongation of the wire, the higher the sagging degree. An increase in transmission capacity leads to an increase in transmission line temperature, which in turn leads to an increase in conductor sag.

3. Hardware Design of Arc Remote Monitoring Terminal

The remote monitoring terminal design of transmission line sag is carried out according to the actual working conditions of the transmission line. On the basis of the Internet of Things (IoT), the wireless transmission monitoring platform is built, the data collected by the inclination sensor is calculated by the processor, and the sag parameters are obtained. Combined with the collection of global position system (GPS) position information, the data is transmitted to the remote control centre through wireless transmission. In terms of hardware design, its specific architecture is shown in Fig. 1.

It can be seen that the hardware of the arc remote monitoring terminal is mainly composed of inclination sensing, signal processing amplification and filtering circuit, analog to digital (A/D) converter, GPS module, narrowband IoT (NB-IoT) wireless communication module, microcontroller unit (MCU) minimum system, temperature acquisition module, and power module. Among them, the inclination sensor is mainly responsible for measuring the inclination angle of the lower suspension point of the transmission between files, and then obtaining the corresponding data signal through signal adjustment, amplification filtering, and A/D conversion. Then, the data signal is transmitted to the processor for processing, and after internal program calculation, the sag parameters between files are obtained. The temperature acquisition module is responsible for collecting the temperature of the operating environment, and the purpose of collecting is to obtain accurate inclination data for the subsequent temperature compensation of inclination data. The GPS module is responsible for collecting the position information of the monitoring terminal, and transmits the collected position information to the processor. After processing, it will be transmitted to the wireless communication module together with the sag data, and then transmitted to the remote platform. The remote platform can visualise the transmission line sag according to the position information of multiple monitoring points, and realise the real-time remote monitoring of the transmission line sag.

4. Arc Remote Monitoring Terminal Software Design

To make efficient and reasonable use of microprocessor resources, simplify program design and reduce development time, and ensure the reliability and real-time performance of the whole system, FreeRTOS real-time operating system is selected. The system has many functions, such as task management, time management, message queuing, semaphore, software timer, memory management, and coroutine, *etc.* It can meet the needs of engineering applications to the greatest extent. The specific working principle of the software system is shown in Fig. 2.

It can be seen that after the system is started, the system and peripherals are initialised first, and then the OS is initialised. Finally, the task scheduler schedules each sub-task. Among them, the task scheduler is the core of FreeRTOS, in this function to achieve the current time to perform a given task, of course, it can also quickly jump from one task to another task, forming a multi-task simultaneous scene, the same task scheduler also has a variety of working modes, such as preemptive mode, if necessary, choose different working modes to meet the actual needs. Ensure the real-time and reliability of the system. After the FreeRTOS real-time operating system

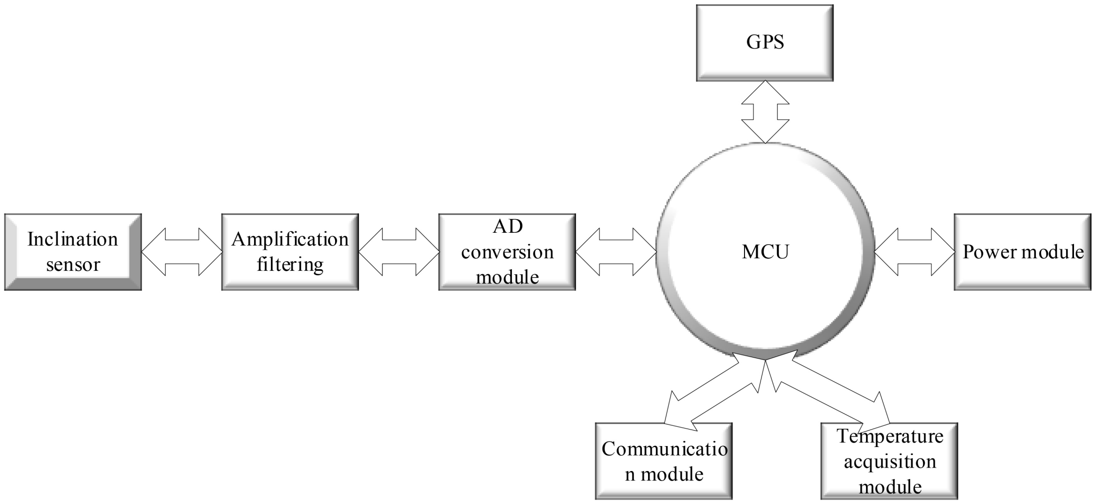

Figure 1. Overall hardware design of arc remote monitoring terminal.

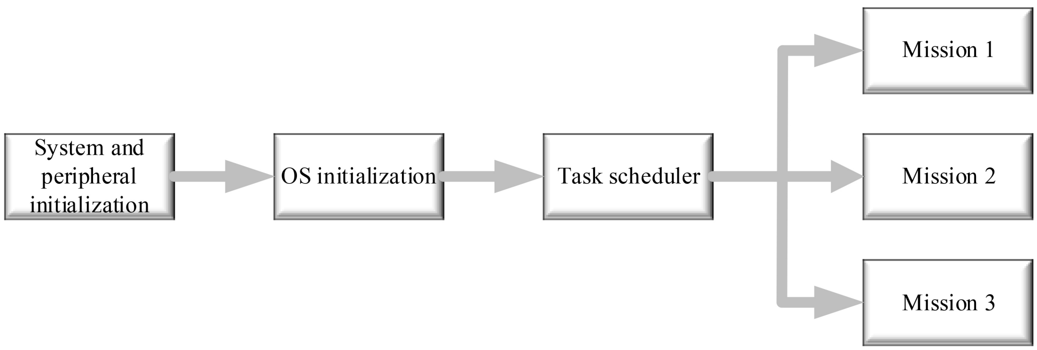

Figure 2. FreeRTOS real-time operating system working principle.

is transplanted into MCU, the final monitoring terminal software system is obtained, and the specific working principle is shown in Fig. 3.

It can be seen that after the system is started, the initial inclination sensor is first used, and the transmission line inclination data is collected, filtered, and calculated with the help of this module. The next module is the initialisation GPS module, which realises information collection and analysis. The next step is to initialise NB-IoT, which is responsible for transferring the collected data to the cloud platform for subsequent processing.

4.1 Inclination Sensor Data Acquisition and Processing Task Design

The inclination data acquisition task in terminal program mainly consists of SCA100 and ADS1114 converter. Among them, the inclination sensor SCA100 is mainly responsible for converting the inclination information into analog signals, and the analog converter converts the analog signals into digital signals to facilitate the MCU processing. The information transmission between the ADS1114 module and MCU mainly relies on 12C communication mode, and the inclination information is transmitted to the MCU processor for processing through corresponding data and clock pins. The specific work flow of the ADS1114 module is shown in Fig. 4.

It can be seen that the inclination information acquisition task waits for the blocking time or semaphore to arrive. If the conditions are met, then 12C start signal can be sent to the analog to digital converter, indicating that the inclination information has been read. After accepting the reading work, 12C end signal is sent to end the reading operation, and the data is stored and processed by digital filtering.

4.2 Digital Filter Design

To avoid the random interference of the data, the method of limiting the amplitude and eliminating the jitter filter is used. Limiting is to determine the maximum possible value and the minimum possible value in the system according to the actual situation, and then calculate the maximum deviation of the allowed value of two adjacent measurements, and then judge the measurement error by comparison. When there is a large deviation, the measurement is regarded as invalid. The effective value and counter of a system are first designed to eliminate vibration. When data is collected by the system, it is compared with the effective value first. If the data is greater than the effective value, then the counter is added by 1. In

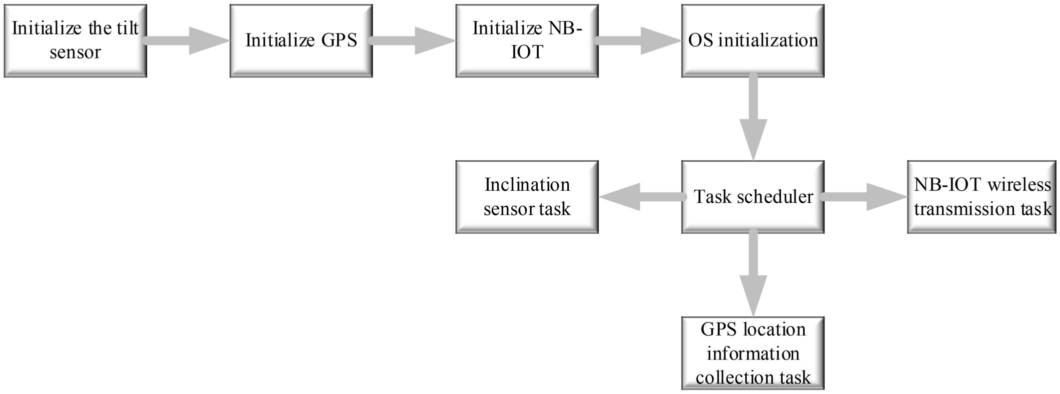

Figure 3. Overall design of remote monitoring terminal software.

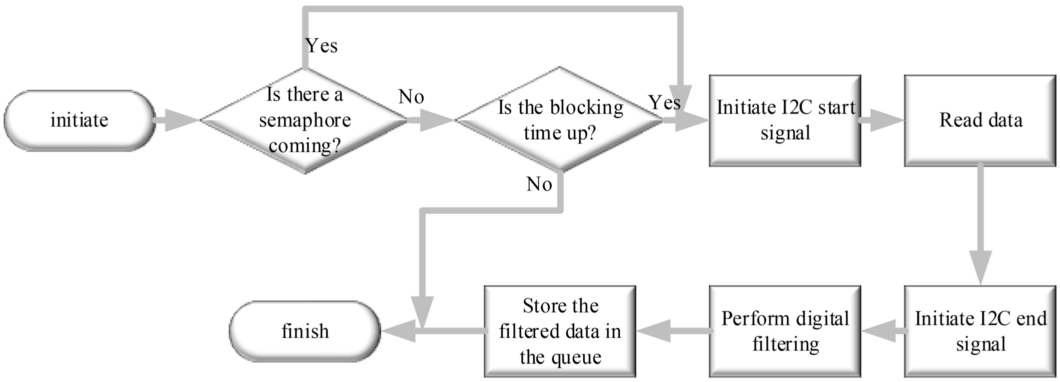

Figure 4. Data acquisition and processing task design of inclination sensor.

this way, the error caused by accidental factors is reduced, and the data with slow data change has a better filtering effect. The specific data filtering process is shown in Fig. 5.

4.3 BC28 Communication Program Design

In this software design, the wireless communication mode used is NB-IoT communication mode, and the specific design process is shown in Fig. 6.

BC28 can use AT + NBAND to query the current frequency band information, if the return value is 5 or 8, then the value is correct, if not, then it needs to use AT + NBAND = 5 or 8 command configuration, and finally restart with AT + NRB command. With the help of AT + NCONFIC to query module configuration information, the main functions include automatic network search and scrambling control, both of which are set to open, if not open, the following settings are performed:

AT + NCONFIG = AUTOCONNECT, TRUE

AT + NCONFIG = CR_0354_0338_SCRAMBLING, TRUE (Enable scrambling control)

AT + NRB() Restart module

NB-IoT modules will have a separate international mobile equipment identity (IMEI) number, which can generally be obtained by the AT + CGSN = 1 instruction. The BC28 module signal strength is 0–31, if 99 is returned, then the module may not enter the initialisation state, or the birth signal is abnormal. If the signal is below 10, then the signal will be poor. After the initialisation of the BC28 module, wait for the completion of the data collection task. Because the information to be transmitted in the design is out of the sag information, as well as the GPS location information, in the program design process, it is necessary to determine whether these two kinds of data have completed the update, and only after it is confirmed that the data can be transmitted to the cloud platform through the wireless communication module.

4.4 Software Design of GPS Module

The GPS module first needs to perform initialisation operations, such as setting the baud rate, information format, and measurement frequency of the GPS module. After the settings are correct, the module can run normally. Because the FreeRTOS system is used in this design, the corresponding information collection task needs to be created in the system to read the position information collected inside the GPS module. The task mainly completes the collection of position information. First, the execution condition of the task is that the blocking time arrives or the semaphore from the inclination information collection task is received. When the condition is met, the relevant function is used to determine whether the GPS module is ready. However, the data collected at this time

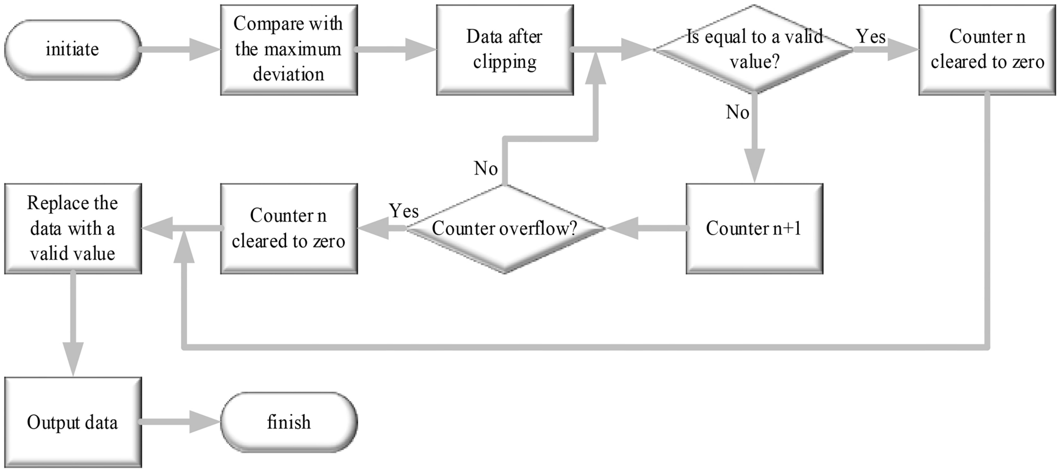

Figure 5. Digital filter design flow.

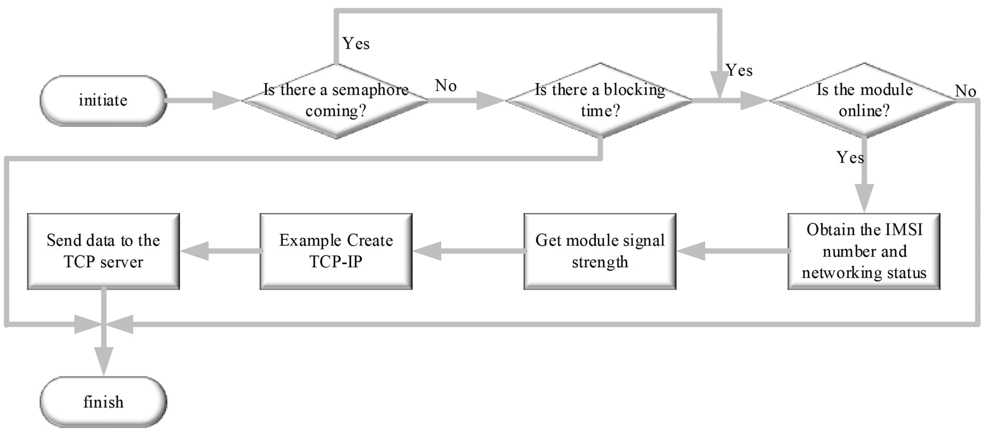

Figure 6. BC28 communication program design flow.

is not latitude and longitude information, and needs to be analysed according to the data format of the information, converted into specific location information, and stored to facilitate subsequent information interaction. The specific design flowchart is shown in Fig. 7.

5. Concrete Realisation of Remote Monitoring Terminal of Arc of Transmission Line

5.1 Sag Monitoring Model Simulation Test

According to the relationship between suspension point and maximum sag, wire LGJ240/30 is selected as the research object, and simulation test is carried out. Because the angle of the suspension point can reflect the change of the maximum sag in real time, when the interval is 120 m and the height difference of the suspension points at both ends is 5 m, the relationship between the two is shown in Fig. 8.

If the spacing is 75 m and the suspension point height difference is 3 m, the relationship between the two is shown in Fig. 9.

It can be seen that the relationship between the angle of the suspension point and the maximum sag is an approximate one time function. This is because in the actual measurement link, the angle of the suspension point is 0–15 degrees, and the output of this angle interval can approximate the linear relationship.

5.2 Temperature Compensation Analysis of Tilt Module

Because the monitoring terminal is built outdoors, it is necessary to compensate the temperature of the inclination module. Firstly, it is necessary to calculate the relationship between temperature and offset voltage compensation with the help of (1).

$$\begin{aligned} \text{Offcorr} &= -0.0000006 * T^3 + .0001 * T^2 - 0.0039 \\ &\quad * T - 0.0522 \\ \text{OFFSETcomp} &= \text{ofset} - \text{offcorr} \end{aligned} \tag{1}$$

In the formula, Offcorr represents the offset error caused by temperature, T represents the actual temperature, ofset represents the voltage value without compensation, and OFFSETcomp represents the actual voltage value after compensation and correction. Because the design terminal operation area is located in Northeast China, the outdoor temperature in summer can reach

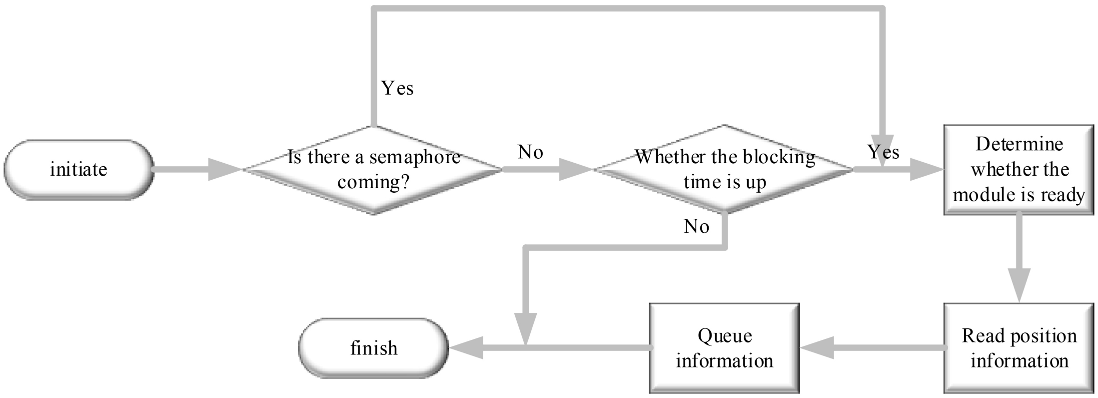

Figure 7. Software design flow of GPS module.

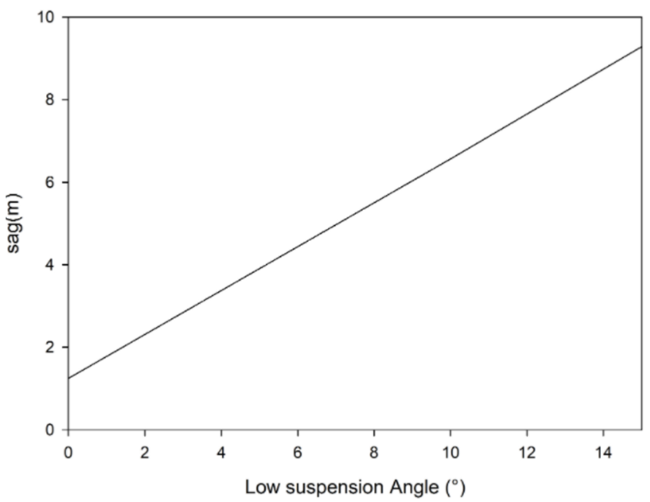

Figure 8. The relationship between suspension point and maximum sag when the spacing is 120 m and the height difference of suspension point is 3 m.

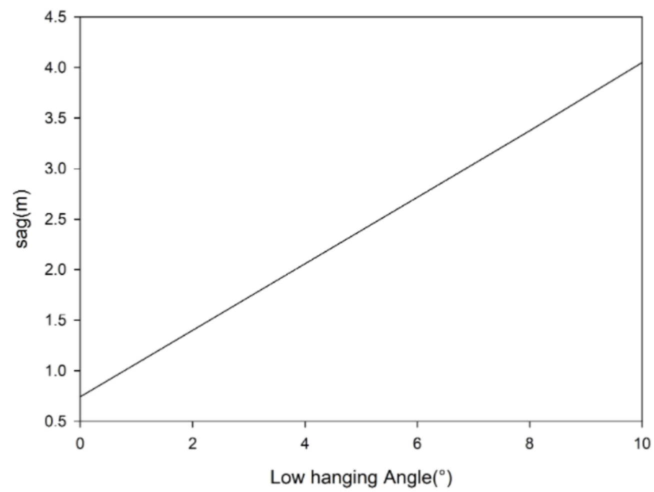

Figure 9. The relationship between suspension point and maximum sag when the spacing is 75 m and the height difference of suspension point is 3 m.

40°C, and the outdoor temperature in winter can reach -40°C. Therefore, combined with the actual environmental conditions, the compensation calculation between -40°C and 50°C is carried out with 10°C as a gradient, and the results are shown in Fig. 10.

It can be seen that with the gradual decrease of outdoor temperature, the offset error between the actual compensated voltage and the uncompensated offset voltage will gradually increase, and when it reaches -40°C, the offset error reaches 0.302. At the same time, the temperature compensation of sensitivity is also calculated here, and the relationship between the two is shown in (2).

$$\begin{aligned} \text{scorr} &= -0.0011 * T^2 + 0.0022 * T + 0.040 \\ \text{SENScomp} &= SENS * (1 + scorr/100) \end{aligned} \tag{2}$$

In the formula, scorr represents the sensitivity change caused by temperature, T represents the temperature, SENS represents the uncorrected sensitivity, and SENScomp represents the corrected sensitivity. The temperature conditions for compensation calculation are consistent with the above conditions, and the results obtained are shown in Fig. 11.

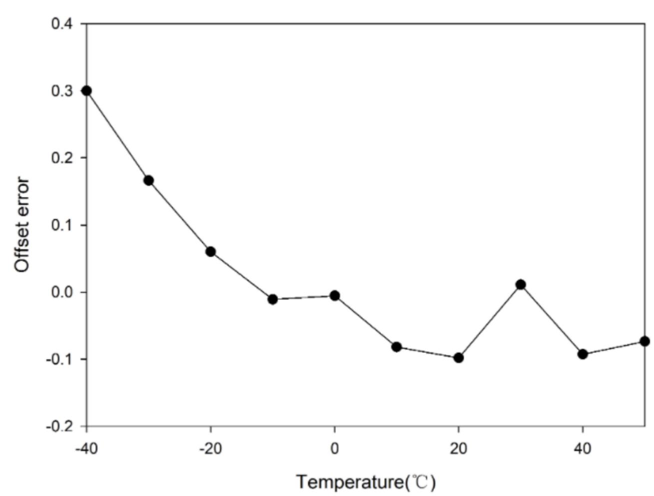

Figure 10. Temperature compensation between -40°C and 50°C.

It can be seen that after the output of the inclination sensor is compensated, the accuracy of the inclination measurement data is increased, the error is reduced, and the accuracy of the sag measurement is increased.

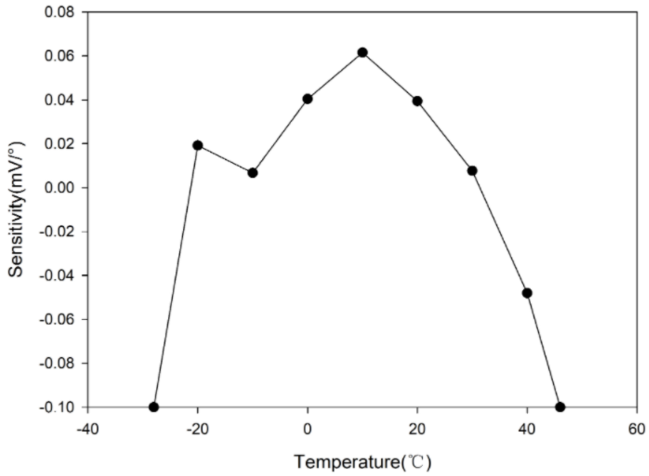

Figure 11. Relation between sensitivity compensation and temperature.

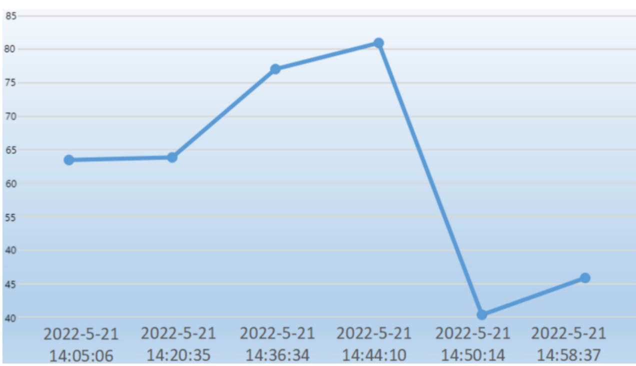

Figure 12. Cloud platform implementation results.

5.3 Simulation Test Based on Cloud Platform

The cloud platform used in this paper is OneNet cloud platform, and the specific simulation test steps are as follows: first, establish transmission control protocol (TCP) data transparent transmission server, second, create the corresponding sag monitoring equipment, third, create a data flow that matches the hardware end, and fourth, the network debugging assistant will transfer the required data to the platform. After uploading data, you can see the uploaded data displayed in the data stream. With the help of this platform, data is stored, and the final simulation test results are shown in Fig. 12.

It can be seen that the historical data and the corresponding curve can be viewed by the platform, and the remote monitoring of the data is realised, which provides a guarantee for the safe operation of the transmission line.

6. Summary

In summary, this paper first understands the basic concept of transmission line sag, which lays a theoretical foundation for the subsequent system design and implementation. Secondly, the hardware and software of the remote monitoring terminal of the transmission line arc are designed, and the overall design structure is given in the hardware design link. In the software design, the data acquisition and processing task, digital filtering, BC28 communication program, and other aspects of the inclination sensor are designed, and a reasonable design scheme is given. Finally, the feasibility of remote monitoring terminal design of transmission line sag is tested by OneNet cloud platform. The results show that historical data and corresponding curve changes can be clearly viewed, and remote monitoring of transmission line sag can be realised, providing a strong data guarantee for transmission line operation. Through this study, the difficulty of reviewing the remote monitoring data of transmission line sag has been solved, and the historical data can be checked in time, and the characteristics and rules of transmission line sag can be mastered through the analysis and comparison of time-domain data, which has a positive role and contribution in transmission line operation and maintenance.

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