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Wireless Infrared Temperature Measuring System Design for Cable in Comprehensive Pipe Corridor

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Abstract: The comprehensive pipe corridor could realize the unified planning and construction of electricity, gas and communication, save urban land resources and beautify urban landscape. However, due to the narrow space and numerous pipelines in the pipe corridor, once the power cable fired, it would cause serious losses. This paper presented a wireless infrared temperature measuring system for power cable in the comprehensive pipe corridor based on infrared temperature measuring and radio frequency communication technology. This system used STM32 as the development platform, used AM2301 infrared temperature sensor to collect cable temperature, transmitted data of each temperature measuring node to the data management center through ESP8266 wireless module, and finally transferred the data of the management center to the server through RS485 bus, realizing the functions of multi-node temperature collection and wireless data transmission. It was verified by experiments that the measurement error of the temperature monitoring system was within 0.5°C, which could monitor the node temperature in real time, and provide guarantee for the safe operation and fire prevention of power cables in the comprehensive pipe corridor.

1Introduction

With the large-scale development of urban economy, land resources were increasingly scarce, so it was urgent to realize multi-functional urban construction in limited underground space. Comprehensive pipe corridor referred to the public tunnel of electric power, gas, communication and water supply under roads, factories or landscapes, so as to realize the functions of unified planning, unified construction, centralized construction and easy management. It could achieve the comprehensive development and utilization of urban underground space. The construction and operation of the comprehensive pipe corridor had greatly saved the urban land, which could effectively solve the problems of repeated road excavation, dense overhead wires and frequent pipeline accidents [1-3]. At present, China's Beijing, Shanghai, Qingdao and other cities had carried out the construction of underground comprehensive pipe corridor, and it was expected to build a number of internationally advanced underground comprehensive pipe corridor into operation in 2020, to improve the urban surface landscape.

Due to the large number of pipelines in the comprehensive pipe corridor, the causes of fire were complex, including electrical fire, open fire during maintenance, and combustible fire caused by gas. Among them, the most important was the power cable fire. In the comprehensive pipe corridor, due to external forces, high temperature and other reasons, the insulation of the cable insulation layer was aging, the insulation capacity was reduced, and leakage current would be generated. In serious cases, electric spark would be generated and lead to cable fire [4-5]. Since the comprehensive pipe corridor was located underground, the space was relatively narrow. Once a fire occurred in the power cable, the heat would accumulate in the space, and the fire would spread rapidly. The carbon monoxide and other toxic gases generated by the cable combustion could not be removed in time, which seriously affected the firefighters working [6]. Therefore, it was very important to design a reliable temperature measuring system and reduce the occurrence of the comprehensive pipe corridor fire at the source.

This paper studied and designed a wireless infrared temperature monitoring system for power cable equipment in the comprehensive pipe corridor. This system took the cable joint as the monitoring node, applied infrared temperature measurement technology and wireless communication technology, used STM32 low-power single-chip microcomputer as the main control chip, and used AM2301 to complete the cable infrared temperature measurement. Through low-cost serial wireless module ESP8266, a multi-node network was formed and wireless communication function was realized. The measured temperature data was collected and transferred in the data management center and transmitted to the server via the RS485 bus. The research content of this paper had important reference significance for the temperature monitoring and fire warning of power cable in the comprehensive pipe corridor.

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2System design overview

2.1Temperature measurement principle

Common methods of temperature measurement could be divided into contact type and non-contact type. The main methods of contact temperature measurement were semiconductor IC temperature sensor, thermocouple temperature sensor and fiber optic temperature sensor. Although the measurement accuracy of this method was high, the insulation performance was poor and the maintenance cost was large. The non-contact temperature measurement method was infrared temperature measurement, which could monitor the operating temperature of the target at a long distance. It had the advantages of wide measurement range, fast reaction speed and flexible use [7-9]. Considering the high insulation requirement of the comprehensive pipe corridor for the monitoring equipment, this paper adopted the infrared thermometer to measure the power cable temperature.

The theoretical basis of infrared temperature measurement technology was the thermal radiation law of black body. Any object as long as the temperature was higher than absolute zero would radiate energy, and energy intensity was proportional to the surface temperature of the object. The mathematical basis of infrared temperature measurement was shown in formula.1:

$$E = \varepsilon\delta\left(T^4 - T_0^4\right) \quad (1)$$

Where: ε —— object emissivity; T —— object surface temperature; T_0 ——ambient temperature.

2.2System structure

The cable wireless infrared temperature measuring system took STM32 as the development platform, AM2301 infrared temperature sensor as the temperature acquisition device, and ESP8266 wireless module as the information transmission device. The infrared temperature measuring system consisted of two parts: temperature acquisition node and data management center. The infrared temperature sensor first completed the collection of temperature data, and then used the universal IO interface of the single-chip microcomputer to complete the communication with the digital temperature sensor, and extracted the effective data through the protocol frame analysis. The temperature data was processed and encapsulated in the STM32 and transmitted to the communication interface of ESP8266, and the collected temperature data was transmitted to the data management center through wireless communication. After receiving the measurement data of each temperature measuring node, the data management center completed real-time interaction with the server through RS485 bus, and stored, displayed and analyzed the temperature data of each node. The system structure design was shown in figure.1.

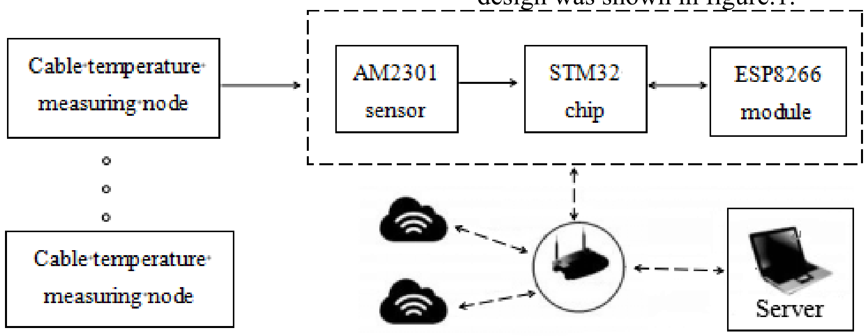


Figure 1. Structural drawing of infrared temperature monitoring system

3Hardware design

The suitable hardware choice was the premise and foundation of establishing the temperature monitoring system of the power cable, which had a direct influence on the stability of system control, the accuracy of feedback and the energy saving in use.

3.1Interface circuit design of infrared sensor

The infrared temperature sensor AM2301 could complete the field temperature acquisition and conversion, and sent digital temperature signal through SDA serial data interface. In order to improve the measurement reliability and stability, the pull-up resistance Rp of the sensor AM2301 was 4.7kΩ. In order to ensure the sufficient supply of the sensor voltage, prevent excessive line voltage distribution resulting in insufficient sensor operating voltage, and improve the service life of the sensor as far as possible, the supply voltage V_{cc} was 5.0V. There was strong electromagnetic interference in the comprehensive pipe corridor. In order to ensure the accuracy of monitoring signals, the sensor used an anti-interference circuit composed of R5 and C4, through verification, when R5 was 350Ω, C4 was 102pF, and C2 was 106pF, the measurement effect was better. The interface circuit of the infrared temperature sensor AM2301 was shown in figure.2.

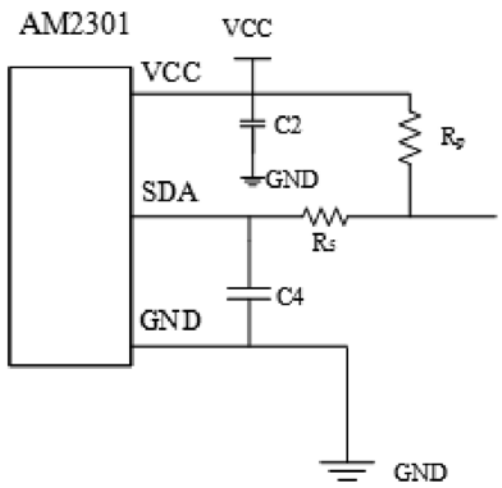


Figure 2. Interface circuit design of infrared temperature sensor

3.2Hardware design of temperature measuring node

Due to the volume limit of the infrared temperature sensor shell, STM32 was chosen as the main control chip of the design. STM32 was a 32-bit microprocessor designed for embedded applications with high performance, low cost and low power consumption. It had many high-performance peripherals and 12-bit ADC and DAC modules, especially suitable for high speed and large capacity distributed data acquisition systems. STM32 realized the interactive processing of data with the infrared temperature sensor through its own hardware IIC interface. Finally, the temperature data was uploaded to the server through SPI interface and ESP8266 wireless communication module. The ESP8266 wireless communication module operated at 2.4GHz and was capable of meeting conventional short-range wireless communication requirements. If the electromagnetic interference in the working environment was strong, a power filter circuit could be added to improve the node's anti-interference ability. The hardware structure of the temperature measuring node was shown in figure.3.

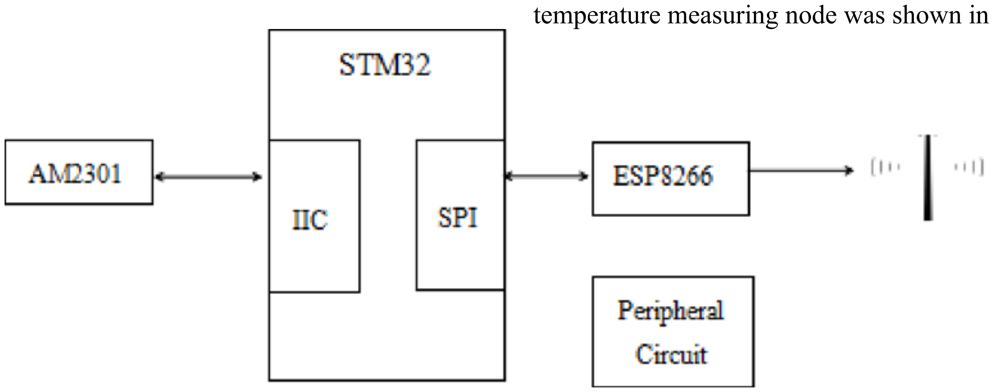


Figure 3. Hardware design of temperature measuring node

3.3Data management center hardware design

The data management center was responsible for receiving the temperature data of each temperature measuring node, realizing real-time interaction between the data management center and the temperature measuring node through the module ESP8266, and transmitting the data to the server through the RS485 industrial bus. The server stored and analyzed the monitored temperature data and responded to the changing trend of the cable node temperature data. The data management center contained radio frequency communication circuit and serial port communication circuit. The hardware structure design was shown in figure.4.

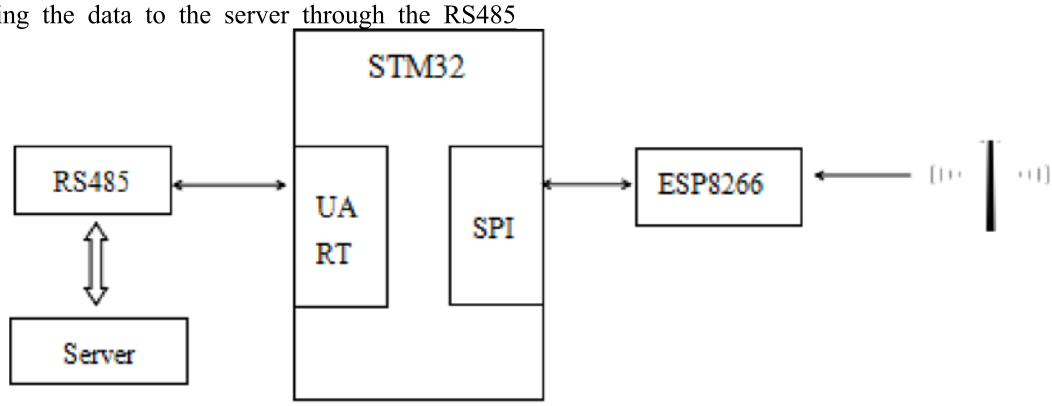


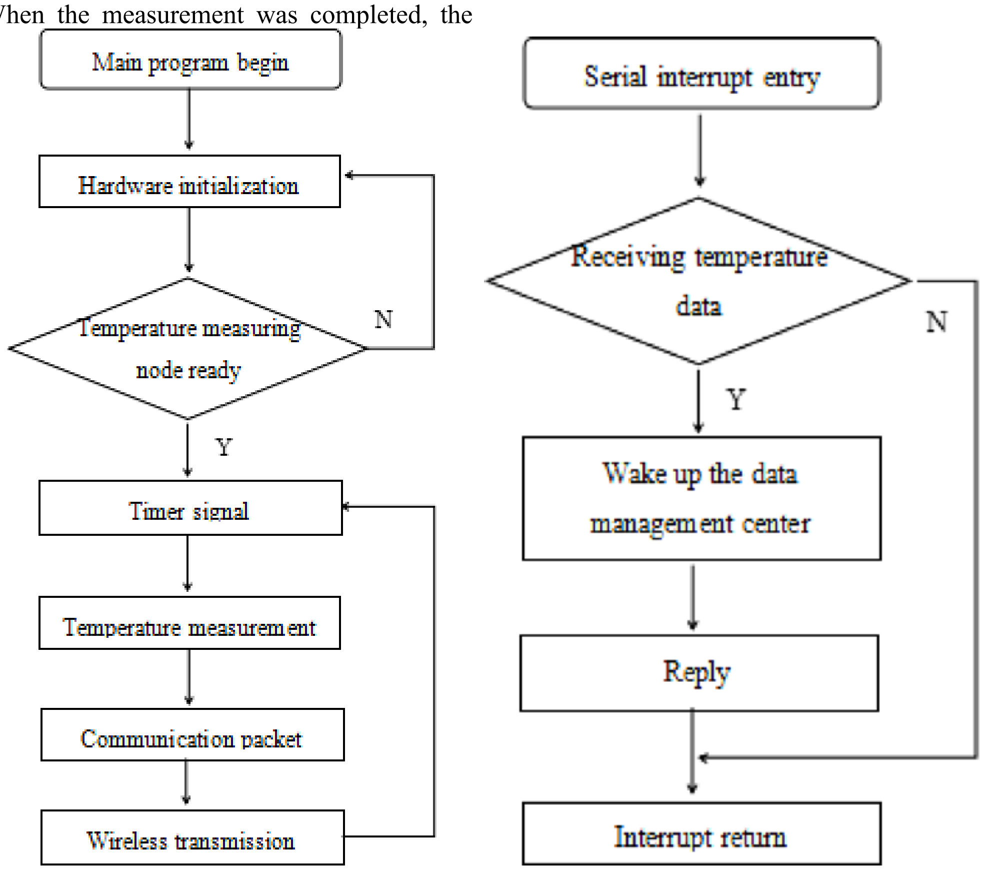
Figure 4. Hardware design of data management centre

4The software design

4.1Lower computer software design

The infrared temperature measuring node program was written in C language and consists of the node control main program, hardware equipment initialization program, radio frequency sending program, radio frequency receiving program, temperature data acquisition program and wireless data packaging program. Interrupt was used to complete reading of temperature data, sending and receiving of wireless communication packets. After each hardware initialized, the temperature measuring node was in the ready state, and then waited for the temperature data measurement command. When the measurement was completed, the temperature data was packaged and transmitted to the data management center by wireless transmission, and then continued to wait for the temperature measurement instruction. The wireless transceiver used the internal register ESP8266 to identify the transceiver completion status by means of interrupts.

The data management center program mainly included hardware initialization program, data interaction program with server and various temperature measuring nodes. After the data management center was powered on, it first completed the initialization of hardware resources, and then queried the server instructions. When the temperature acquisition command was received, the data management center parsed and sent the acquisition command to each node, and meanwhile encapsulated and transmitted the data information of each node to the server. The program design of temperature measuring node and data management center was shown in figure.5.



(a) Temperature measurementnode (b) Data management centre

Figure 5. Lower computer software design flow chart

4.2Upper computer software design

The upper computer software run on the server to complete the selection of communication equipment, communication parameter setting and communication mode selection. After receiving the packet sent by the wireless module ESP8266, the server used the highly reliable Tcp control protocol to obtain real-time data of the temperature measuring node, and developed the display interface in visual studio using C# language.

4.3Design verification

In order to verify the reliability of the wireless infrared temperature measuring system, the measuring node were tested in the experimental environment. The diameter of the object under test was 110mm, and the probe was 50cm away from the object. The test results showed that the temperature error was within 0.5°C, which met the temperature monitoring requirements of the cable in comprehensive pipe corridor. The test results were shown in table 1.

Table 1. Temperature test results (°C)

Measured value	44.5	50.3	55.2	59.8	65.1	70.2	74.8
Actual value	45	50	55	60	65	70	75
Error value	-0.5	0.3	0.3	-0.2	0.1	0.2	-0.2

5Conclusion

Aiming at the problem of temperature monitoring of power cable in the city comprehensive pipe corridor, this paper designed an on-line temperature monitoring system based on infrared temperature measurement and radio frequency communication, taking the sensor working environment and anti-interference problems into full consideration. It was verified by experiments that the measurement error of the system was within 0.5℃, and the temperature measurement data could be uploaded to the server in time, which was of great significance to the online temperature monitoring and fire prevention of power cables in the comprehensive pipe corridor.

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