Research on Monitoring System of Cable Joints of Ring Network Cabinet Based on Wireless Temperature Sensor

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Abstract. In this paper, a state monitoring system for the cable joints of the ring main unit is constructed based on the passive wireless temperature sensor. Considering the sensor packaging structure and housing material, a temperature sensor that can meet the monitoring requirements of the T-shaped insulating sheath of the cable joint is designed. Based on the thermal circuit method, the real temperature value of the internal cable joint is calculated by using the outer surface temperature of the T-shaped insulating sheath to provide more accurate data for monitoring and early warning. The background monitoring software of the monitoring system is designed to realize the temperature of the T-shaped cable joint in the ring network cabinet. Online monitoring and abnormal early warning facilitate the operation and maintenance personnel to take timely measures, which can effectively improve the operation and maintenance efficiency of the ring cabinet of the distribution network and ensure the reliability of power supply.

1. Introduction
With the continuous increase of my country's power grid capacity and the continuous increase of voltage levels, it is becoming more and more important to ensure the reliability of power supply. The ring main unit is one of the important roles in the power distribution system, and its safe operation directly affects the power supply reliability of the power system[1]. The internal electrical joints of the ring main unit are prone to heat due to various reasons. If the temperature of the electrical joints is too high, serious oxidation will occur, and the service life of the cable will be shortened; it will cause the electrical joints to explode, insulation breakdown, burning and other hazards, causing large-scale power outages and fire accidents. It will affect the operation of the ring main unit itself and the safety of the entire power supply system[2]. Therefore, real-time temperature monitoring of the fully enclosed ring main unit, pre-alarm and elimination of hidden dangers are effective measures to avoid major power accidents, and are of great significance to ensure the safety and reliability of power supply.

The common faults of the ring main unit are mainly internal cable joints and poor contact of the connector conductors causing abnormal overheating, which in turn accelerates insulation aging and leads to breakdown[3]. For a closed ring main unit, it is very difficult to realize non-power failure
detection under normal operating conditions. The offline infrared temperature measurement currently used is greatly affected by the metal shell of the ring main unit, and accurate detection cannot be carried out without opening the ring main unit[4]. In addition, regular inspection is a non-real-time detection method, with a long detection period, hidden dangers cannot be discovered in time, and the actual application effect is not good. Therefore, it is necessary to develop and design a technical means for online real-time monitoring of the electrical contact temperature in the urban ring network cabinet to realize online real-time monitoring of temperature. When a fault occurs, it can promptly report to the police and indicate the location of the fault point, improve the operation and maintenance efficiency of the ring network cabinet failure, and ensure the safe, stable and reliable operation of the urban ring network cabinet.

Due to the high voltage and strong magnetic field environment inside the ring main unit, the traditional temperature measurement methods such as thermal resistance temperature measurement, thermocouple temperature measurement, and infrared temperature measurement cannot meet the actual monitoring requirements. In recent years, with the development of passive wireless surface acoustic wave sensing technology, the problem of difficulty in monitoring the internal temperature of the ring network cabinet can be effectively solved. The surface acoustic wave sensor has wireless transmission, no battery, strong anti-interference ability, high safety and stability[5], and basically no maintenance after the sensor is installed successfully. Therefore, it is very suitable for temperature monitoring of the electrical contacts in the ring network cabinet.

In this paper, based on passive wireless surface acoustic wave temperature sensing technology, a temperature state monitoring system for the cable joints of the ring main unit is established. Considering the structure and materials, the sensor package shell is designed to make it suitable for the T-shaped insulating sheath of the cable joint. Obtain the actual internal temperature of the cable joint through the conversion of the external surface temperature to the actual temperature, design software that meets the monitoring requirements of the cable joint of the ring main unit. And realize the online temperature monitoring and early warning of the T-type cable joints of the ring main unit, and provide an effective basis for the operation, maintenance and repair of the ring main unit.

2. The overall design of the state monitoring system of the ring main unit
This monitoring system consists of a passive wireless temperature sensor, a data collector, an on-site display terminal, a wireless DTU and a remote monitoring platform installed on the T-shaped sheath of the cable connector. The overall structure of the monitoring system is shown in Figure 1.

Figure 1. Schematic diagram of the overall architecture of the monitoring system.
The temperature measurement sensor is a surface acoustic wave temperature sensor, which can be conveniently installed on the outer surface of the T-shaped insulating sheath through a shell design to collect the external temperature data of the sheath. The data collector collects the temperature data obtained by the temperature sensor through the collector antenna, and connects to the local display terminal through RS485, so that the operation and maintenance personnel can check the status of the ring network cabinet on the spot. It can also connect to the wireless DTU via RS485 to remotely transmit data to the monitoring center.

The monitoring center software processes the temperature data measured by the sensor, obtains the actual temperature at the cable joint, and implements the display of the temperature data, alarms in time for abnormalities, and realizes the monitoring and active warning of the cable joint status of the ring network cabinet.

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3. Temperature sensor design

The temperature sensor used in this article is a passive wireless surface acoustic wave temperature sensor. The package of the sensor is mainly designed. Considering the appearance structure and materials, the sensor is designed to meet the monitoring requirements of the T-shaped cable joint of the ring network cabinet.

3.1. The working principle of temperature sensor

A surface acoustic wave is an elastic wave that propagates along the surface of an elastic body. Its propagation speed is slower than that of a longitudinal acoustic wave and a transverse acoustic wave propagating in a solid. Its attenuation is small and it can travel a long distance[6]. The structure of the surface acoustic wave temperature sensor is shown in Figure 2.

![Figure 2. Schematic diagram of temperature sensor structure.](image)

Surface acoustic wave temperature sensors are divided into delay type and resonance type[7]. The temperature measurement principle of resonant temperature sensors is shown in Figure 3. When the surrounding environment (temperature) of the surface acoustic wave temperature sensor changes, the resonant frequency of the sensor also occurs. At the same time, the echo signal of the sensor also changes accordingly. By analyzing the frequency and amplitude of the echo signal, the change of the monitored parameter can be obtained to realize the temperature measurement. The corresponding relationship between frequency and temperature is:

$$\frac{df}{f} \approx \frac{1}{v} \frac{\Delta v}{\Delta T} \cdot dT = TCF \cdot dT$$  \hspace{1cm} (1)

Among them, $TCF$ is the frequency-temperature coefficient of the temperature sensor.

![Figure 3. Schematic diagram of temperature measurement principle of surface acoustic wave temperature sensor](image)
3.2. Sensor package design

(1) Sensor structure design

Most of the cable insulation sheaths are T-shaped, and their appearance is round. In order to facilitate the installation of the temperature sensor, the sensor packaging structure is designed into an arc shape, as shown in Figure 4. The sensor is fixed on the sheath by tying the wrist, and the inner arc side is in close contact with the T-shaped insulating sheath during installation. The temperature sensor chip is close to the inner arc side of the package shell, which can more accurately measure the temperature data on the outer surface of the T-shaped insulating sheath.

![Temperature Sensor](image)

Figure 4. Temperature sensor schematic

(2) Selection of sensor housing material

In order not to affect the electrical performance of the cable joint, the sensor shell and the strapping wrist are made of insulating materials, and they are in close contact with the T-shaped sheath during installation, which not only realizes temperature monitoring, also ensures the safety of the cable.

4. System software design

4.1. Monitoring software design

The background monitoring software displays the uploaded cable joint temperature data collected by each temperature sensor, and monitors the changes in temperature data in real time. Realize the real-time numerical display of temperature, historical data query, user authority management, communication parameter setting and other human-computer interaction functions. As shown in Figure 5 below, the specific functions are as follows:

(1) The temperature data needs to be displayed by real-time data value/curve. The temperature data needs to indicate the temperature measurement point, which is convenient for the staff to visually monitor.

(2) When a temperature alarm message is generated, the monitoring master station can immediately respond on the interface and prompt the staff.

(3) With a complete storage function of temperature data, users can flexibly query historical storage data and view them in the form of curves or data tables.

(4) Other functions, such as parameter setting.
4.2. Temperature monitoring alarm program design
The temperature data collected by the sensor is the temperature data of the outer surface of the T-shaped sheath. In this paper, the thermal path method is used to calculate the actual internal temperature by using the surface temperature. The outer surface temperature $T_n$ of the T-sheath measured by the sensor is converted to obtain the actual temperature inside the cable joint as $T_n'$. Compare $T_n'$ with the set threshold $T_{set value}$. When $T_n' < T_{set value}$, the cable joint is normal. When $T_n' > T_{set value}$, it is judged that the temperature of the cable joint is abnormal, and an alarm is issued immediately to realize the real-time monitoring and warning of the temperature of the T-shaped cable joint. The program logic is shown in Figure 6.

5. Conclusion
In this paper, based on the surface acoustic wave sensing technology, the passive wireless temperature sensor is designed for the faults caused by the poor contact of the cable joints and the quality problems in the ring mains cabinet of the power distribution system. Considering the sensor packaging structure and housing material, etc., the sensor can meet the temperature monitoring requirements of the T-shaped sheath of the cable joint of the ring main unit, and the installation is convenient. The thermal path method is adopted to calculate the internal temperature through the outer surface temperature of the temperature sensor, thereby improving the accuracy of the monitoring results. The thermal circuit method is used to calculate the internal temperature through the temperature of the outer surface of the temperature sensor, thereby improving the accuracy of the monitoring results, and the monitoring software is designed. Realize the remote online monitoring and early warning of the cable joint status, greatly improve the intelligent level and operation and maintenance efficiency of the ring main unit, which is of great significance to guarantee the safe and reliable operation of the ring main unit of the distribution.
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