Research Progress of the Temperature Monitoring Technology of the Electric Joints in the Ring Main Unit

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Abstract. This article summarizes several existing temperature monitoring methods for cable joints inside the ring main unit, mainly introducing infrared temperature measurement, fluorescent optical fiber detection, passive wireless surface acoustic wave temperature measurement, and wireless temperature sensor measurement. Then, the above methods were compared, and the advantages and disadvantages of each method were clarified. Finally, the research on the temperature monitoring method of the cable joints in the ring main unit is summarized. And the follow-up development direction of the passive wireless surface acoustic wave temperature measurement method in the temperature measurement of the cable joints of the ring main unit is prospected. It provides some reference for the research on the temperature monitoring method of the cable joints inside the ring main unit in the future.

1. Introduction

With the development of the power system, the number of ring network cabinets is continuously increasing. As a very important power facility in the low-voltage distribution network, the ring network cabinet has a direct impact on the quality of power supply. However, the electrical joints inside 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 the fire accident will affect the operation of the ring main unit itself and the safety of the entire power supply line[1]. With the passage of time, the failure rate of the ring main unit of the distribution network is also increasing year by year. According to incomplete statistics, about 70% of the failures are caused by the heating of the connection part. Because the ring main unit is a fully enclosed device, its cabinet faults are not easy to detect in advance, the heating of each
connection part is not easy to measure, and the incoming and outgoing wires are cables. Once a fault occurs, it is difficult and time-consuming to find, which seriously affects the quality of power supply[2].

Therefore, grasping the temperature status of the cable joints of the ring main unit is particularly important for timely discovering hidden dangers and taking effective troubleshooting measures. Therefore, the development of the temperature monitoring method of the cable joints inside the ring main unit, the first time to understand the status of the ring main unit, avoid the occurrence of accidents, greatly reduce the downtime and maintenance workload, save maintenance costs, and have important economic and social significance.

This article summarizes the current research status of monitoring methods for the temperature status perception of cable joints inside the ring main unit. The advantages and disadvantages of different methods are compared to provide a reference for the development of the temperature monitoring technology of the cable joints in the ring main unit.

2. Method for monitoring the temperature of the cable joints of the ring main unit

With the development of sensing and communication technology, a variety of new sensors and monitoring methods have been produced, which provide a variety of solutions for the temperature monitoring of the cable joints of the ring network cabinet. This article mainly introduces the following four monitoring methods.

2.1. Infrared Thermometry

The most common infrared temperature measurement methods mainly include infrared thermal imager and infrared temperature sensor. In the power inspection, the infrared thermal imager is mainly used to detect the temperature of the power facilities. Using the temperature of the object to be measured, the infrared radiation emitted by the object is received by the detector of the infrared thermal imager, and then the infrared thermal image received by it is displayed on the fluorescent screen. Get the temperature distribution on the surface of the object through analytical judgment[3]. The basic principle of infrared thermal imaging camera temperature measurement is shown in figure 1 below.

![Figure 1. The basic principle of infrared thermal imaging camera temperature measurement.](image-url)

However, for the existing metal ring network cabinet, due to its fully sealed structure, infrared rays cannot directly pass through the metal shell to measure the measured point. It limits the application of the infrared thermal imager in the internal temperature measurement of the ring network cabinet. In response to this problem, literature [4] developed a closed infrared observation window for distribution network ring network cabinets, which selected chalcogenide glass with good infrared light transmittance as the basic material of the infrared observation window. After coating, its The infrared transmittance can be higher than 90%, which can meet the temperature measurement needs of infrared thermal imaging cameras. It has a multi-angle observation and measurement function, which can realize different angle observation and measurement by turning. By adding this infrared window to the ring main unit, the existing infrared thermal imager can be effectively used to measure the temperature of the internal cable joints, and defects can be found in advance, which will greatly reduce the incidence of accidents. This method improves the operation and maintenance level of the ring network
cabinet to a certain extent, but it is not real-time, there are hidden safety hazards, and the operation and maintenance workload is large.

2.2. Fluorescence fiber detection method

Literature [5] realized the online monitoring of the temperature of the T-type cable joint of the ring main unit based on the fluorescent optical fiber temperature measurement system. The system is mainly composed of two parts: photoelectric signal detection and processing and human-computer interaction management system. The photoelectric signal detection and processing part mainly completes the functions of fluorescence excitation, fluorescence detection, light signal detection and processing, and wireless data upload; the human-computer interaction management system part mainly completes the functions of data reception, display and storage. The overall system block diagram is shown as in figure 2.

![Figure 2. Schematic diagram of fluorescence optical fiber temperature measurement system architecture.](image)

It uses a fluorescence lifetime temperature sensor to collect the temperature of the joint. The principle is to measure the temperature by detecting the fluorescence afterglow generated by the fluorescent substance after being irradiated by the excitation light. The biggest advantage of this method is that after the fluorescent substance is determined, the fluorescence lifetime only depends on the temperature of the emitting fluorescent substance, and will not be affected by light source fluctuations and light coupling, which can effectively ensure the accuracy and stability of signal detection. By improving the cable insulation sheath and pouring the optical fiber sensor probe into the sheath, the temperature of the cable connector inside the sheath can be directly measured, and the optical fiber connector is reserved at the back for easy installation. The monitoring system can effectively sense the true temperature of the cable joints, and the measurement results are accurate. However, the internal space of the ring network cabinet is limited, and there are many measurement points. During installation, the arrangement of optical fibers is cumbersome, and there are safety hazards such as creeping. It is difficult to apply in practice.

2.3. SAW temperature measurement method

The principle of passive wireless surface acoustic wave temperature measurement is that when the surrounding environment (temperature) of the surface acoustic wave temperature sensor changes, the resonant frequency of the sensor also changes, and the echo signal of the sensor also changes accordingly. Changes can be obtained by analyzing the frequency, amplitude and other information of the echo signal to obtain the changes in the monitored parameters to achieve temperature measurement[6]. The structure of the temperature monitoring system for the cable joints of the ring main unit based on passive wireless surface acoustic waves is shown in the figure below. The system is mainly composed of passive wireless surface acoustic wave temperature sensor, reader and antenna, wireless DTU and monitoring terminal.
Figure 3. Schematic diagram of passive wireless surface acoustic wave temperature measurement system

Depending on the installation method, the sensor can be fixed at the measuring point of the cable connector by bolt connection, tie-up, gluing, etc., for temperature measurement. With the development of this measurement method, some manufacturers integrate the passive wireless surface acoustic wave temperature sensor on the plug of the T-type cable connector [7], and directly contact the sensor with the conductor of the cable connector to directly measure the cable conductor. The temperature is closer to the true temperature value than the measured outer surface temperature.

2.4. Wireless temperature sensor measurement method

The biggest difference between a wireless temperature sensor and a passive wireless temperature sensor is whether it is active or not, which in turn determines the difference in the wireless communication methods of the two sensors. The wireless temperature sensor needs to supply power to the temperature acquisition module through a battery, and then use the wireless communication module for wireless transmission. Literature [8] designed a temperature warning system based on ZigBee wireless communication for the electrical connectors of the high-voltage ring network cabinet. The network architecture of the temperature measurement system is shown in the figure below.

Figure 4. Wireless temperature sensor monitoring system based on ZigBee
The terminal sensing device integrates a temperature sensor and a ZigBee wireless communication module, which directly contacts the outer surface of the cable connector to measure the temperature at the connector. The installation method is similar to the passive wireless temperature sensor, which can be bolted, bound, glued, etc. In the literature [9], a temperature sensor based on ZigBee communication is built into the T-shaped cable head to achieve direct measurement of the temperature of the conductor inside the cable joint.

3. Comparison of temperature measurement methods for cable joints of ring main unit

The above four methods, including infrared temperature measurement method, fluorescent optical fiber detection method, passive wireless surface acoustic wave temperature measurement method, and wireless temperature sensor measurement method, are compared, as shown in Table 1.

| Method                           | Way of communication | Advantage                                           | Disadvantage                                                                 |
|---------------------------------|----------------------|-----------------------------------------------------|------------------------------------------------------------------------------|
| Infrared Thermometry            | Offline              | No need to install, easy to use, convenient for inspection | Non-real-time, unable to find hidden dangers in time; blocked by the cabinet, difficult to measure; easy to be interfered by external light, etc. |
| Fluorescence fiber detection method | Optical fiber | Passive, strong anti-electromagnetic interference ability, high real-time | High cost, easy to produce "creepage", and limited by installation space |
| SAW temperature measurement method | Wireless surface acoustic wave | Passive wireless, easy installation, high real-time | To a certain extent affected by the internal high-voltage electromagnetic environment |
| Wireless temperature sensor measurement method | ZigBee wireless transmission | Wireless communication, easy installation, high real-time | Active, need later maintenance, affected by internal high voltage electromagnetic environment |

The off-line measurement method mainly uses infrared thermal imager to measure the internal measurement points through the observation window. One is that it is interfered by external light, and the other is that the light transmittance of the glass reduces the accuracy of the measurement, and only the outside can be measured. The surface temperature cannot know the actual temperature of the conductor, and regular inspections are required. It is not real-time and it is difficult to find defects in time.

The optical fiber-based measurement method uses the sensitivity of fluorescent substances to temperature for temperature measurement. The optical fiber is passive and has strong anti-electromagnetic interference ability. The online monitoring system based on optical fiber can realize the real-time monitoring of the temperature of the cable joint of the ring network cabinet. The optical fiber sensor probe is embedded in the sheath, and the measurement is more accurate. However, the cost of optical fiber monitoring is high, and insulation issues need to be considered, which is prone to "creepage" and is limited by installation space.

Passive wireless surface acoustic wave temperature measurement method and wireless temperature sensor measurement method are both wireless measurement. There are many options for the installation method according to the different installation positions, and the installation is convenient. Especially built in the plug of the T-shaped sheath, it can sense the true temperature of the cable conductor. However, wireless temperature sensors need battery power supply, and battery life and electromagnetic compatibility are the main factors that make it difficult to be widely used. The passive
wireless surface acoustic wave temperature sensor is a passive sensor, maintenance-free installation, and more suitable for long-term monitoring in a sealed environment such as a ring network cabinet.

4. Summary and outlook
At present, the main methods for monitoring the temperature of cable joints in the ring network cabinet include infrared temperature measurement, fluorescent optical fiber detection, passive wireless surface acoustic wave temperature measurement, and wireless temperature sensor measurement. This article briefly introduces various methods and compares their advantages and disadvantages.

It can be seen from the above that whether it is optical fiber measurement or wireless sensor measurement, there are researches on embedding the sensor probe in the T-shaped cable connector sheath, which can realize the direct measurement of the conductor temperature, which is conducive to obtaining the true temperature of the conductor. In comparison, passive wireless surface acoustic wave sensors have more advantages, but the internal electromagnetic environment of the high-voltage ring network cabinet will affect the performance of the sensor to a certain extent, reduce external interference as much as possible, and improve the reliability of the sensor. This is a key direction of follow-up research.

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