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Zigbee Based Temperature Monitoring System for Electric Cable Junction

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Abstract. According to the problem that the electric cable junction is prone to produce heat and consequently cause failure, the temperature monitoring system based on the infrared temperature measure technology and wireless communication technology is proposed in this paper. The indirect monitoring technique of high-voltage cable and distant data transmission are realized by this temperature monitoring system. The special infrared temperature measure probes are employed to detect the electric cable junction and the temperature values at different locations collected by the Zigbee wireless transmission network are transmitted to the special monitor background. The whole system is comprised of four parts: infrared temperature probe, communication control module, communication repeater and remote monitoring system. The pre-warning of temperature anomaly of the cable junction can be made by the system, which can avoid the enlarging the incidence of the faults, locate the faults, save the repair time and improve the power system reliability.

Keywords: Electric cable junction; infrared temperature measure; Zigbee; temperature monitoring

1. Introduction

With the increasing demand for the electric cable of the power plants and substations, the short circuit faults and fire accidents produced by the cable junction heating become more and more, which brings about enormous economic loss to the power system and the consumers. In the circumstance of the power load continuously increasing and power quality deterioration, the temperature of cable junction in the switchgear is easy to rise. When the temperature of cable junction excesses the critical temperature tolerated by the cable, the cable junction is likely to produce short-circuit arc. The current operating time of line instantaneous trip current protection is not as short as the time of cutting off the power before the arc's enlargement, which often leads to the arc's enlargement and transferring and thus the whole bus bar's flashover. In this case, the backup protection of the main transformer is applied to remove the whole bus bar and consequently enlarge the power failure range. The operating temperature of the cable junction is the important parameter to reflect its operation state. The operation temperature is a physical quantity changing relatively slowly. If the effectively measure is applied before the operating temperature arriving at the critical point, there will be enough time to transfer or reduce the cable load and then make cooling or maintenance[1],[2].

The high failure rate of cable junction has been given great attention by the maintenance personnel. The artificial timing inspection tour is applied to solve this problem and the hand-held infrared temperature testing equipment is employed to examine the cable junction temperature. The disadvantages of this method lie in its failure of real-time detection and dead angle detection, which is not easily reached by the personnel and in that it is easy to result in the personnel casualty if some sudden events occur while artificially measuring the temperature. Accordingly, the Zigbee based temperature monitoring system for electric cable junction is proposed in this paper. In this system the non-contact infrared thermometer sensor is employed to examine the

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cable junction temperature real-timely, and temperature can be transmitted to the monitoring center by the special Zigbee temperature measurement network. The designed system can detect the cable junction with temperature anomalies timely and effectively, avoid the enlargement of the power failure area, accelerate the repair schedule and reduce the outage time.

2. Infrared Thermometric Techniques

The surface of the object with temperature above the absolute temperature (-273℃) continually radiates out infrared ray, the wavelength of which is about 0.78 μm to 100 μm. The principle of infrared thermometry is using the pyroelectric effect to translate the infrared ray to electrical signal. The pyroelectric material mainly includes crystal, ceramic, plastics and so on.

The infrared thermometer system consists of optical system, photodetector, signal amplifier, signal processing and so on. The optical system assembles the infrared radiation energy of the object inside its view field. The infrared energy focuses on the photodetector and is translated into corresponding electrical signal, which will be translated into temperature of the target [3].

To the energized high-voltage or low-voltage electric equipment, the infrared temperature measurement can real-timely realize the non-contact and nondestructive measure from long distance. Consequently, there is no need changing the primary and secondary connection while applying the infrared temperature measurement to monitor the cable junction temperature, which is convenient for the upgrade and improvement of the present system.

3. Zigbee wireless Communication Technology

Zigbee is a limited range, low-complexity, low power consumption, very low-cost, two-way wireless communication technology. It is a communication technology about networking, security and internet applications based on IEEE 802.15.4 wireless standards.

Zigbee supports the three network topologies: star, peer-to-peer and hybrid network, and each network has its own advantages. The star network takes a strong functional master device as the network center to coordinate the whole network operation and the other master devices or slave device are distributed in its coverage area. The control and the synchronization of the star network is simple and it is applicable to the situation with few devices. The peer-to-peer network can be divided into point-to-point and cluster tree, and it is connected by the main devices. The peer-to-peer network can supply higher reliability. The hybrid network is combination of the star network and the peer-to-peer network, the subnets of which are connected in the form of star network while the master devices of which are connected in the form of peer-to-peer network. The hybrid network is applicable to the complicated network and it has more practicability in practice [4].

Zigbee network concludes the Full Function Device (FFD) and Reduced Function Device (RFD). The FFD supports the entire function and characteristic defined by the standard, while the RFD supports the reduced function and requires the least memory capacity. FFD can communicate with FFD or RFD, while the can communicate with the FFD only. The communication between the RFDs has to be transmitted by the FFD. The FFD can not only send and receive the data but also possess the router's function. The connection of the devices is given in Figure.1.

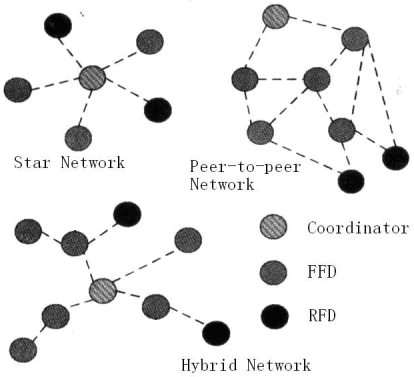

Figure.1 Structure diagram of Zigbee network connection

4. The Overall Scheme of Temperature Measurement System

There are many points in the switchgear whose temperature needs to be measured, such as the upper contact and lower contact of three-phase switch and the cable junction. These points are near to each other, so a set of communication control module, which connects the temperature probes by the bus communication, is considered to implement the temperature measurement of the points in the switchgear. The structure of the temperature measurement system is given in Figure.2.

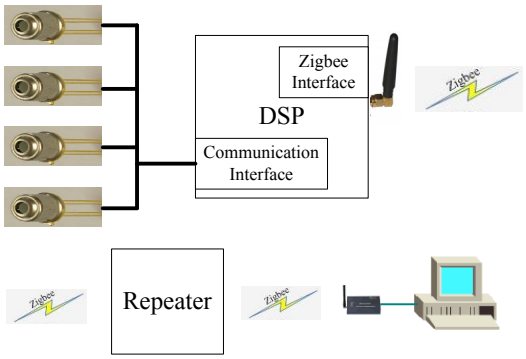

Figure.2 The structure of temperature measurement system

The temperature probes are MLX90614 from MELEXIS Inc., which are non-contact infrared temperature induction chips. It integrates the infrared thermopile sensors and a custom signal modulation chip in the TO-39 encapsulation. The advanced low-noise amplifier, a 17-bit ADC and the powerful DSP components are integrated in the signal modulation chip, which can realize the high precision temperature measure.

The work temperature of the MLX90614 is -40℃~85℃, while the range of temperature to be measured is -70℃ ~380℃. The large range test precision can achieve to 0.5℃, which can absolutely meet the requirement of the temperature measurement of the power system switchgear [5].

The TI CC2520 is employed in the Zigbee communication controller. The CC2520 is second generation ZigBee® transceiver for the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications by offering state-of-the-art selectivity/co-existence, excellent link budget, operation up to 125°C and low voltage operation [6]. In addition, the CC2520 provides extensive hardware support for frame handling, data buffering, burst transmissions, data encryption, data authentication, clear channel assessment, link quality indication and frame timing information. These features reduce the load on the host controller.

The MSP430 single-chip made from TI Inc. is employed in the communication control module, the main function of which is to acquire the temperatures transmitted by the probes by the IIC bus and to send the temperature value out by the Zigbee protocol. This module distributes the exclusive 16-bit address for each probe, the address information being sending out while the temperature values are sending out.

The remote control system receives the temperature values transmitted from the communication control modules by the Zigbee protocol and then transmits the values to the control computer by the USB communication method. The actual system wiring diagram can be plotted by controlling the data analysis software on the computer and the temperature data at different points can be refreshed real-timely based on the different address numbers.

5. Functional Characteristics

The whole temperature measuring system is comprised of four parts: infrared temperature probe, communication control module, communication repeater and remote monitoring system [7].

5.1 Infrared temperature probe

MLX90614 can directly transform the temperature signal to digital signal and put out by IIC protocol. IIC protocol adopts bus structure, and it can directly connect the probes in series. The controllers can allocate different addresses for every probe. In the switchgear the three-phase cable junctions need real-time monitoring. The IIC bus interface provides great convenience for this need.

5.2 Communication control module

Communication control module is the key part of the whole system .It acquires the temperature values from different probes and identifies the correctness by appropriate arithmetic.

The communication control module communicates with the remote control monitoring system by Zigbee protocol and acquires the wide area synchronous time information. The module labels the acquisition time and acquisition address, send them to the communication repeater or remote monitoring system through wireless transmission [8].

The communication control module falls into the RFD of the Zigbee communication structure. It can only communicate with the communication repeater or remote monitoring system. There is no data exchange between the communication control modules.

5.3 Communication repeater

The distance between the communication control module and the remote monitoring system is different in different application. The transmission distance of the Zigbee can reach to 1000m in open environment, but the transmission distance in the substations is limited. The communication repeater is designed to solve this problem. It transmits the data from the monitoring system to all of the control modules in its communication area and uploads the temperature information of the all control modules in its area to the monitoring system [9].

5.4 Remote monitoring system

The remote monitoring system concludes the communication receive module and the monitoring software. The communication receive module is situated in the most terminal of the Zigbee protocol and receives all of the wireless data. The data is delivered to the monitoring software by the USB interface [10] [11].

The remote control software's main features are as follows:

- Communication function: the software can connect to every infrared temperature probe in the system by Zigbee wireless communication network and set or read the values saved in every probe.
- Real-time monitoring function: the software can real-timely collect the temperature values and working state of every probe.
- Query and trend prediction function: the software saves the temperature values of every probe and enables the users to carry through kinds of queries, such as time query, range query and mutation query. And according to the operator's choice, the software can automatically draw the temperature curve of the electric cable junction and consequently predict the temperature change trend.

The monitoring software is the interactive window for the user and system, and is the system brain to manage and command the system operation. The software written by VC and SQL server realizes many functions: network time setting, temperature real-time monitoring, temperature limit alarming, data recording and querying, user management and so on. This software has friendly interface and easy operation.

6. Conclusion

Based on the infrared temperature sensing technology and the Zigbee wireless communication technology, the real-time temperature detection system for cable junction in the power system switchgear is designed, the structure and principle of which is expounded. This system can give an alarm when the cable junction temperature is too high and consequently avoid the fire accident due to the cable junction's high temperature. The operation temperature of the cable is recorded to supply the detailed reference for the cable's reliable operation and sequentially ensure the power system safe operation [12].

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