Design of an Intelligent Fiber Bragg Grating Temperature Measurement System for Electrical Equipment

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Abstract. For the power system, the main reason for many fire accidents is that the temperature of electrical equipment is too high, and now the widely used fire detector can only detect the fire that has occurred. If the temperature change of electrical equipment can be tracked in real time and the alarm information can be sent in time when the operating temperature is too high, the fire of power system can be scientifically and effectively prevented. The use of fiber Bragg grating sensor can provide a basis for the realization of the theoretical conception. For the traditional temperature measurement system, fiber Bragg grating temperature measurement system has the advantages of convenient maintenance, fault detection, less affected by light source power fluctuation, information sharing and long service time. It can effectively measure the temperature of isolated contact of high-voltage switchgear, the temperature of wet steam inside steam turbine and the surface temperature of power cable, etc. This paper researches a design of fiber Bragg grating temperature measurement system.

Keywords: Power System, Electric Vehicle, Fiber Bragg Grating, Temperature Measurement System

1. Introduction

According to the classification of overheating phenomenon of electrical equipment in power system [1], there are two kinds of internal thermal fault and external thermal fault. For the external thermal fault, it is mainly due to the high temperature of some poor cramping exposed joints of electrical equipment under the action of high current, which is easy to bring greater safety risks for electrical equipment [2]. For the internal thermal fault, it is mainly due to the overheating of electrical equipment caused by some cables, which are sealed to the inner materials, make high temperature of electrical equipment after long-time operation. After detecting the internal of the electrical equipment, the materials around the fault location can be detected. Compared with traditional sensors, fiber Bragg grating sensor has higher anti electromagnetic interference ability, higher sensitivity and lower loss. It belongs to the category of passive independent devices, and also began to be applied in real life, which has more advantages than traditional sensors.
2. Current Situation of Temperature Detection in Power System
Nowadays, most of the electrical equipment is concentrated in the power transmission and transformation area of the power system [3]. Nowadays, many substations have begun to use unattended working mode, using the centralized control center to monitor the working state of the substation. Generally speaking, a centralized control center has about ten substations, and the electrical equipment in the substation is in high load operation most of the time, it often leads to high temperature of the equipment, and finally leads to thermal failure. In the internal and external thermal faults of electrical equipment, part of the thermal faults can be found by the staff in the embryonic stage, which can be dealt with timely and effectively. Some thermal faults cannot be cut off when they occur. However, more thermal faults can not be detected by using the existing temperature measurement technology, so that the staff can not track the temperature changes of the equipment in time, and some equipment have thermal faults before they are found by the staff. The reason and location of thermal fault of electrical equipment mainly include the following aspects: thermal fault of inner aluminum bar joint in enclosed switch cabinet, thermal fault of isolating knife switch contact part, thermal fault of connector on capacitor bank, thermal fault of HV bushing joint and thermal fault of current transformer connector.

3. Characteristics of Fiber Bragg Grating Temperature Measurement System
For the fiber Bragg grating electric power temperature measurement system [4], its characteristics mainly include the following aspects: firstly, multiple fiber Bragg grating sensors can be connected in series to a single fiber, thus forming an overall array to achieve the purpose of distributed temperature measurement. Secondly, the layout of fiber Bragg grating electric temperature measurement system is simple with short use process and less fault points in the operation process, and there are greater advantages in the future equipment maintenance and fault detection work. Third, the central wavelength of the reflected light can be used to present the measured equipment, for it is hardly affected by the power fluctuation of the light source. Fourthly, in the process of using FBG system, the absolute value is measured, it is unnecessary to calibrate it. Fifthly, compared with other traditional sensors, the service life is significantly increased. Sixth, the use of fiber Bragg grating temperature measurement system can be found in the bud of thermal fault in time, which can effectively achieve the purpose of early prevention.

4. Design of Power Cable Temperature Measurement System Based on Fiber Bragg Grating
4.1. Overview of Design Framework
In the fiber Bragg grating power temperature measurement system, the fiber will be fused with the sensor, and then connected to the fiber Bragg grating signal processor. The RS232 interface is used to connect to the background calculator. The temperature changes are monitored and can be displayed and saved in the calculation, so that the effect of monitoring the temperature of the cable joint can be realized. Once the temperature of the cable joint is too high, the fiber Bragg grating power temperature measurement system sends alarm information to the staff in a timely manner [5].

For the refractive index of fiber Bragg grating, the thermal light effect temperature and elastic-optic effect can affect the refractive index of fiber Bragg grating, which is greatly affected by temperature and humidity and lead to the shift of reflected light wavelength, so as to change the axial strain of fiber grating, and finally change the grating distance. After processing the data, the changes of humidity and temperature can be obtained [6]. In order to accurately and timely detect the temperature change of high-voltage cable in the cable, the detection part should be divided into different alarm zones. In one zone, fiber Bragg gratings with the same wavelength should be placed in all monitoring points, so that the corresponding wavelength of the area is the same as the reflection wavelength of each detection point. Once the temperature changes, the detected wavelength will shift, and the system will alarm by exceeding the set value. At the same time, the fiber Bragg grating temperature measurement system can monitor the temperature of the cable tunnel, the temperature of the cable trench and the
temperature of the cable interlayer, which can effectively monitor the power cable. Meanwhile, the fiber sensor for temperature measurement can be pasted on the surface of the cable, and the fiber Bragg grating temperature measurement system can be used to monitor the change of the surface temperature of the cable and combine with the current flow in the cable, so as to construct a complete data curve and calculate the temperature coefficient in the cable. In addition, the relationship between cable surface temperature and current can be calculated according to the temperature of core wire and the difference of cable surface temperature, in order to ensure the normal use of power equipment.

4.2. Software Structure Design
The system software includes three layers [7]: client layer, service layer and data layer. For data layer, it can save cable geographic data information and temperature data information, while service layer has web server, middle layer and GIS Server. Service layer receives and responds to data reading request sent by client. GIS Server mainly interacts with data information and extracts the data needed by users according to the data layer. The middle layer can transform the data stored in GIS Server into bitmap in SVG format, and the client layer can feed back the information provided by customers. For the FBG temperature control system, it has two parts: client software and server software [8]. The server operating system applies Microsoft Windows Server2003, and SQL Server 2008 for the database. The client software is developed by WebGIS. The whole software mainly includes the following modules: firstly, it is a real-time module, which can display the temperature change of electrical equipment under normal working conditions. Secondly, the alarm module, the staff can set the desired threshold in the system, once the cable temperature is too high or too low, it will send an alarm to the staff. The third, map module, the system can build information map display according to the direction of the cable, the staff can zoom in and out and move it, and can also enter into different small monitoring zones. Finally, the historical curve module, through the analysis and research of the data stored in the system, presents the corresponding change curve to the staff.

4.3. Data Layer Design
Geographic information data is composed of map information and layer data information. Therefore, the geographic data information should be sorted into corresponding data tables according to the corresponding specifications, and stored in the database server, so as to display the geographic data information for customers. The system uses the mode of numerical storage to store the corresponding geographic data information in the database. Numerical storage is a coordinate value used to identify geographic feature information and stored by the numerical type in the storage process of data information.

For the cable temperature data, it plays a very important role in the system [9]. As long as the cable temperature data information in the database is maintained regularly, the corresponding implementation data can be displayed in the client in real time.

4.4. Service Layer Design
The service layer includes GIS Server, middle layer and web server [10]. The main function of the service layer is to correspond the commands of the client, and to convert the GML format information data into SVG documents. For GML format, it can be regarded as a kind of geographic markup language. Taking XML as the basis in the process of usage, the spatial data model is used to standardize the geospatial data, which makes the sharing of geospatial data more convenient.

5. Practical Application of Fiber Bragg Grating Temperature Measurement System

5.1. Measuring the Surface Temperature of Power Cable
For the tunnel, the temperature has a great impact on the cable, so the relevant temperature of the tunnel should be confirmed in advance, so as to carry out effective monitoring methods and ensure the normal use of the cable. The fiber Bragg grating temperature sensing system can be used for
distributed continuous temperature measurement of the cable, and can cooperate with the air conditioning system and ventilation device to ensure that the cable is in the range of normal operating temperature under different ambient temperatures. In addition, fiber Bragg grating temperature measurement system can also be used for overheating early warning, which can early warn some faults that cannot be monitored by traditional sensors. After combining with the fire alarm system, it can effectively meet the starting conditions of the fire protection system.

5.2. Measurement of Wet Steam inside Turbine
For the whole power system, thermal power unit is in a very important position, wet steam affects the safe and economic use of steam turbine. In large and medium-sized automobile engines, the wet steam with high content will have a great impact on the working efficiency of steam turbine. Therefore, real-time measurement of wet steam content has very important practical significance.

5.3. Monitoring the Temperature of Isolated Contact of High Voltage Switchgear
For power workers, it is difficult to monitor the temperature of isolated contacts in high-voltage switchgear. The contact environment has strong electromagnetic field and high-voltage particularity. The use of fiber Bragg grating temperature measurement system can not only measure the temperature change, but also transmit data information in real time. It has the advantages of small transmission loss, light sensor weight and small system volume, as well as good insulation performance and anti-interference ability.

5.4. Other Applications
The fiber Bragg grating temperature measurement system can also monitor the temperature distribution of large and medium-sized generators and transformers, and diagnose and protect overheating faults. In addition, it can also measure the temperature of enclosed electrical equipment, geothermal power station, oil pipeline and heating system of thermal power plant. As a new technology, fiber Bragg grating temperature measurement system can monitor the temperature change of high voltage cable in real time.

6. Conclusion
In recent years, with the rapid development of China's social economy and the continuous improvement of science and technology, fiber Bragg grating sensing technology has also been rapid development. As a new technology, it has been widely concerned by people from all walks of life. At present, it has been applied in the field of petroleum, intelligent materials and structures, as well as aerospace field, etc. However, in China, the research on fiber Bragg grating temperature measurement system started late and developed slowly, existing many problems. With the progress of science and technology and the development of society, fiber Bragg grating temperature measurement system will be more widely used in China.

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