Design and realization of high voltage disconnector condition monitoring system

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Abstract. The operation status of the high voltage disconnector directly affects the safe and stable operation of the power system. This article uses the wireless frequency hopping communication technology of the communication module to achieve the temperature acquisition of the switch contacts and high voltage bus, to introduce the current value of the loop in ECS, and judge the operation status of the disconnector by considering the ambient temperature, calculating the temperature rise; And through the acquisition of the current of drive motor in the process of switch closing and opening, and fault diagnosis of the disconnector by analyzing the change rule of the drive motor current, the condition monitoring of the high voltage disconnector is realized.

1. Introduction
High-voltage disconnector is the largest and most widely used high-voltage electrical equipment in power station, substation, and whole power system. But because of its main function of isolation, the manufacturer and user haven’t paid enough attention to it even if its, structure is relatively simple and easy to make [1]. For a long time, the reliability of the high-voltage disconnector was significantly lower than that of other substation equipment. Therefore, high voltage disconnector has become the weakest link of electrical equipment in the running process, and its frequent failure has also become one of the important issues affecting the safe operation of the power grid [2].

For the traditional open disconnector, the two main categories of impact on its safe and reliable operation are: On the one hand, because of long-time operation, oxidation and dust laying, the current carrying part of high-voltage disconnector will constantly gain heat, what is worse is that too much heat may cause insulation aging, breakdown, or a short circuit, which may bring a major accident, and serious economic losses[7]; on the other hand, improper installation and adjusting of high voltage disconnector or mechanical clamping caused by corrosion problems may lead to the disconnector closing not in place, the operating torque increased and the decline in mechanical transmission parts strength, and further cause the overheating of conducting circuit, and a transmission mechanism of insulator rupture damage and deformation and other serious accidents [5].
2. System Structure
The high-voltage switch contact temperature and prediction system based on the wireless frequency-hopping communication technology is composed of two parts: the hardware temperature measuring device and the temperature analysis software [8].

2.1. The Hardware of the System
The temperature unit is arranged according to the number of contact points of the high voltage disconnector, at the same time measuring bus temperature. The online temperature monitoring system is composed of several wireless temperature measuring units [3, 4], wireless relay communication module, wireless gateway and monitoring center network system. The operating mechanism of disconnector selects the current acquisition module to measure the drive motor current [5], and uses the IO switch node to return to the disconnector state, using the network communication mode.

High voltage disconnector status monitoring system is shown in figure 1.

• Wireless temperature measurement module: Temperature sensing transmitter is composed of wireless transmitter module, temperature sensor and temperature layer. Contact of temperature sensor is according to the position and shape of the object to be measured, to achieve the temperature acquisition and signal emission.

• Ordinary temperature measurement equipment is used in the product of single channel communication, once the channel is occupied, the temperature data will be sent failed. Frequency hopping technology is used between wireless frequency module and wireless relay communication module. It will automatically switch to another channel communication when the channel is interfered. There are 64 available channel resources, and it will be effective to ensure the stability of data transmission, reliability and anti-jamming.

![Figure 1. Illustration of status monitoring system](image)

• Wireless transfer communication module: The wireless communication module identifies the data sent by the wireless temperature module, and the data transfer is sent to the wireless communication network computer to provide the data channel between the node and the host computer for the monitoring center computer.

• Current acquisition module: The current acquisition module is used to collect the three-phase current of the high-voltage disconnector, and the data is transmitted to the host computer through the optical fiber communication.

• Monitoring center network system: The network system is composed of a data server, a collection computer and a switch with a wireless communication device. It provides the hardware platform for the software and provides the ECS data channel.
2.2. The Structure of System Software

Wireless frequency hopping communication technology of high voltage switch contact temperature measurement and forecast system based on detection and monitoring system design, it is an important link of comprehensive detection and control of power system, and can run independently in the power plant and substation site.

Monitoring center software using Windows Server operating system, MS-SQL2008 database software, application software using B/S structure, and it selects Asp.net development tools. The software system manages all equipment running, the temperature signal of each temperature sensor to monitor regional identification reception, calculation, processing, alarm temperature detection, monitoring, display, overheating and fault judgment, and achieve temperature acquisition, data judgment, data preservation, system communication and other functions. The software system is shown in figure 2.

![Diagram of software system](image)

**Figure 2.** Diagram of software system

3. Realization of State Monitoring Function

State monitoring function includes the disconnector contacts the normal operation of the temperature detection and disconnector operation process.

3.1. Temperature Monitoring and Alarm

The temperature acquisition module sends the data of the contact temperature, the bus temperature and the ambient temperature to the database according to the certain time interval, at the same time, according to the current value of each branch extracted from the ESC system, the temperature rise can be calculated:

$$\tau_{st} = \frac{I^2 R}{\alpha F}$$

In it:

- \(\tau_{st}\): Stable temperature (°C)
\[ \alpha : \text{Coefficient of total heat conductor (W/m}^2\text{.}\degree\text{C)} \]

I: The current flowing through the conductor (A)

F: Heat conductor area (m²)

R: Conductor resistance, the change of resistance with temperature is not necessarily consider.

After calculating the temperature rise, the management system calls the corresponding data in the database, the measured temperature of the switch contact or the high voltage bus is compared with the maximum allowable temperature and the temperature rise (according to the specification for electric materials: copper: 110 °C; aluminum: 100 °C; silver: 120 °C). When the value exceeds the allowable value, the system sends an alarm to alert the operator automatically, and the state of high voltage disconnector is diagnosed, in view of the problems, the corresponding suggestions are put forward, so as to provide reference for the operators and solve the corresponding problems as soon as possible, so as to avoid unnecessary economic losses. In addition, WEB service system also provides monitoring point temperature browsing, change curve, statistics, printing and other functions.

3.2. Monitoring of Mechanical Performance during Operations

There are many forms of disconnector operation faults. The severity and location of the faults are also different. However, it all show that the operating torque is increased, the transmission card is not smooth, and the motor current waveform changes compared with the normal situation. And the normal switching process of the high voltage disconnector generally requires 7 - 8s time. Switch status signal should be returned within 8s, or there may be a fault [2, 6].

Typical current waveforms are shown in Figure 3.

![Figure 3. Motor current envelope waveform in different operating condition of the disconnector](image-url)
We use the analysis of the current signal of the driving motor and the comparison of the closing time, and the mechanical faults of the high voltage disconnector can be effectively detected. The corresponding relationship between the mechanical properties and the motor current can be summarized as shown in table 1.

Table 1. The Corresponding Relation between the Main Mechanical Defects and the Current Characteristics of the Drive Motor

| Mechanical state         | Type of defect            | Variation of motor current characteristic                      | Current peak period |
|--------------------------|---------------------------|-----------------------------------------------------------------|--------------------|
| Closing or Opening       | is not in place           | The peak value of the current waveform is too large             | 5-7s               |
| Unsmooth operation       |                           | The peak value of the current is too large                      |                    |
|                           |                           | The peak time is changed,                                       |                    |
|                           |                           | The running time is longer                                      |                    |
|                           |                           | The circuit failure                                             |                    |
|                           | Power failure             | No current signal                                               | Indefinite         |
|                           |                           | Mechanical fault                                                |                    |
|                           | Refuse separation         | Abnormal current waveform                                       |                    |
|                           | Refuse separation         | The peak of the starting current is serious                     | 0-2s               |
|                           | Refuse to close           | The current value is too small                                  |                    |
|                           | Fastener fall off         | And the waveform is stable                                      |                    |
|                           | Balance spring failure    | The current peak is large                                       | 5-6s               |

In the daily operation and maintenance management of substation, the drive motor current acquisition hardware system can be installed in the electric operating mechanism, and real time detection of the motor current signal in the operation of the disconnector is realized by the remote software system, and clamping fault diagnosis of disconnector can also be achieved. Compared with the normal working condition, the motor current signal in the closing operation can be used to judge the existence of the mechanical failure and the severity of the disconnector. Combined with the operation of the disconnector and the rotation mechanism, the location of the mechanical failure can be preliminarily judged, and the operation and maintenance measures can be taken in order to prevent the expansion of the accident to cause more damage.

4. The Features of System

The results are accurate and the transmission effect is stable. The system solves the problem of on-line temperature measurement of high voltage electrical equipment by traditional contact method; the wireless sensor is used to accurately monitor the temperature of the electrical equipment switch contact and the high voltage bus. Compared with the display wax sheet and infrared temperature measurement, the wireless sensor also has the advantages of quick response speed, small volume, easy installation, etc. The use of advanced wireless frequency hopping technology can successfully avoid the high voltage equipment in the electromagnetic field and channel interference, to ensure data integrity.

Remote monitoring and fire alarm. The system successfully achieved 24 hours online monitoring and remote monitoring, automatic early warning when the temperature exceeds the maximum allowable value, the location, name and temperature value of the measured object shown on the monitoring center computer screen, at the same time the voice alarm started, The system also provides advice and treatment method of characteristic curve of measured point temperature data to ensure the safe operation of power transmission and transformation equipment.
Convenient and flexible operation. The system is easy to learn and to enhance the ability of the transformer substation to cooperate with each other, and improve the comprehensive intelligence of substation and the flexibility of operating mode.

5. Conclusion
The state monitoring system of high voltage disconnector based on wireless frequency hopping communication technology can be used for 24 hours real-time monitoring of switch contacts and high voltage bus temperature. It uses the temperature sensor to ensure accuracy of data acquisition, to ensure the stability of data transmission by wireless frequency hopping technology. The measured location, name, number, and temperature curve will be shown on the computer of the control room. The temperature rise can be calculated according to the current value extracted from ECS to effectively ensure the accuracy of early warning system; by comparing the current signal of the driving motor and the disconnector under the normal condition, mechanical fault can be effectively detected. If there is any fault, the system can quickly issue a warning, and put forward the corresponding measures to solve the fault, avoid serious accidents, and provide a basis for the operation and maintenance to staff.

The system has been put into operation in a 220kV substation, the disconnector state detection, greatly facilitate the elimination of hidden dangers of staff, so as to prevent accidents especially fire, ensure the safety of power transmission equipment, ensure the safe and stable operation of power system.

6. References
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