Measuring Method of the Internal Temperature of UHV DC Voltage Measuring Device

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Abstract. For many years, it has been difficult to measure the internal temperatures of gas insulated equipments in high voltage apparatuses. This paper presents a method of measuring the internal temperature of UHV DC Voltage measuring device, which uses the temperature sensor of fluorescent decay time optical fiber transmission as the instrument. The method could accurately measure the internal temperature when the device is running. The paper mostly expounds the selecting temperature sensor and arrangement mode of sensor and detailed test method. The test method could determine the internal temperature of UHV DC voltage measuring device, as the same time could also provide references for measuring the internal temperatures of gas insulated equipments in high voltage apparatuses.

1. Introduction

UHV DC voltage measuring device is the key equipment in the UHV DC transmission system, which is mainly used for measuring the DC voltage of the bus bar and providing the voltage signal to the measuring instruments and secondary protection devices [1-3]. The main parameters of the UHV DC measuring device used in the project are nominal voltage of ±800kV, operating current of 2mA and rated power of 1600W. A prototype of ±800kV UHV DC voltage measuring device designed by a company is shown in figure 1. The prototype is mainly based on the principle of RC divider in parallel. SF6 gas is used for insulation, the second output is digital, and the product height is about 10m. The DC voltage measuring accuracy meets the requirement of 0.2 %.

Transmission lines of UHV DC projects in China are long and span several provinces and cities. The internal temperature of the device during operation may vary greatly by region and seasonality [4-5]. The DC voltage measuring device designed based on the principle of resistance-capacitance partial pressure has a great relationship with the applied voltage and temperature. The influence of temperature changes on the measuring accuracy during the operation of the device cannot be ignored. Therefore, the relevant standard explicitly states that the measuring voltage divider resistance of the DC voltage measuring device should have sufficient thermal stability so as to ensure that the measuring accuracy of the device meets the design requirements within the specified temperature range [6]. The working current of ±800kV UHV DC voltage measuring device during normal operation is 2mA and the heating power is 1600W. The important part in the design and manufacture is to select the appropriate insulation medium and adopt reasonable internal structure so that the device can meet the requirements of insulation and effective cooling. And the device operates at different ambient temperatures, both to meet the requirements of measuring accuracy and long-term reliable operation [7-8]. To meet the above requirements, it is necessary to know the full temperature range of
the device during operation. A method of measuring the internal temperature of UHV DC voltage measuring device is provided in the article, which can accurately obtain the internal temperature rise during operation of the device. If the internal temperature rise during operation of the device is measured, the full range of temperatures corresponding to the device operating in different regions and in different seasons can be calculated. In the manufacture of products by more appropriate selection of appropriate measuring devices to ensure that the measuring accuracy of the device meets the requirements within the full temperature, meanwhile reasonable control of manufacturing costs.

2. A method of measuring the internal temperature of UHV DC voltage measuring device

2.1. The temperature sensor of fluorescent decay time optical fiber transmission

Inflatable sealed insulating structures are used in UHV DC voltage measuring devices and a built-in temperature sensor is used to measure the internal temperature of the device. The prerequisite for the implementation of this method is that the built-in temperature sensor should not affect the insulation of the device or affect the voltage division ratio of the device. Conventional platinum resistance and wireless temperature sensors cannot meet this requirement. The method in this paper is to select the temperature sensor of fluorescent decay time optical fiber transmission (hereinafter referred to as fluorescence temperature sensor) [9], which has the characteristics of good insulation, high voltage resistance, corrosion resistance and high temperature resistance, and can be used under the harsh conditions of strong electromagnetic. Fluorescent temperature sensor used to measure the temperature of the fluorescence probe is a fluorescent material temperature sensing material, and the material will emit fluorescence while excited by the excitation light. The length of the fluorescence lifetime is related to the temperature (the fluorescence decay time is called the fluorescence lifetime). The temperature measurement can be achieved by the fluorescence lifetime characteristics [10-13]. The biggest advantage of using the fluorescence lifetime to achieve temperature measurement is that the temperature of the target to be measured depends only on the time-constant characteristics of the fluorescent material regardless of other variables in the system, such as changes in the intensity of the
laser light source, transmission loss, optical coupling efficiency, etc. This method has certain advantages over other temperature measurement methods [14].

Fluorescent temperature sensor temperature measurement principle is shown in figure 2. The microcontroller drives the optical signal processing system and emits a bunch of excitation light, which is transmitted to the fluorescence probe through the optical fiber. When the excitation light stops transmitting, the probe will emit fluorescence at this time, and the fluorescence will be returned to the optical signal processing system through the optical fiber. The processed system obtains and processes the data to calculate the temperature value.

**Figure 2.** Temperature measurement principle of the optical fiber temperature sensor.

2.2. Implementation scheme

For descriptive convenience, a ±800kV UHV DC voltage measuring device is equivalent to a device consisting of a high voltage insulator and an internal first and second measuring voltage element. Insulation gas is filled between the high-voltage insulator and the internal measuring voltage element. Voltage measurement components are connected by the upper, middle and lower voltage flange connected in series. Fluorescent probes of the built-in fluorescent temperature sensors which are used to measure the temperature rise inside the device are attached to the three connecting voltage equalized flange surfaces. The top and bottom of the high-voltage insulator are fitted with the upper and lower flanges, and the upper flange is fitted with three (or more) optical connectors that are connected to their respective optical connectors by optical fibers. The optical fiber connector and the external optical signal processing unit are connected through their optical fibers, and the schematic diagram is shown in figure 3.

The height of ±800kV UHV DC voltage measuring device is about 10m. The following issues are focused on solving in the implementation scheme.
2.2.1. *The laying of temperature fluorescence probes and optical fibers inside the device.* The rated operating voltage of the UHV DC voltage measuring device is ±800 kV. The internal and external insulation of the device shall not be affected by the installation of the fluorescent temperature sensors. Prior to the implementation of the program, the selection of the optical fiber pressure-proof and the placement of the fluorescent probe must be done carefully to ensure that the buried probe and the optical fiber have no influence on the measurement and insulation characteristics of the device and can detect the temperature in different locations.

2.2.2. *Tightness during the test.* The internal components of the ±800kV UHV DC voltage measuring device operate in an SF6 gas-tight, hermetically sealed environment at a pressure of 0.35MPa. Therefore, one of the key issues that should be considered is how the temperature information of the internal temperature of the device detected by the fluorescent temperature sensor is transmitted to the outside through the gas inside the sealed device without affecting the gas-tightness of the device. The optical fiber connector selected during the test is shown in Figure 4, and the sealing flange of the device with a plurality of optical fiber connectors designed according to the experiment is shown in

![Diagram of optical fiber and seals](image)
The device must be tested for air tightness before the test, requiring the optical connector and the sealing flange to meet the airtight requirements of the device during the internal temperature test.

2.2.3. Installation and debugging. After the fluorescent probe and the optical fiber are installed inside the device, a sealing flange is arranged on the upper flange of the device and the internal optical fiber is connected with the internal optical interface of the optical fiber connector. The upper flange is sealed and assembled to ensure the device is airtight. The external optical interface of the optical fiber connector is coupled with the optical signal processing unit through the communication optical fiber. Site commissioning is carried out in the high voltage insulation hall of XI'AN High Voltage Apparatus Research Institute (XIHARI). The installation site is shown figure 6.
3. Verification test
In order to verify this method, a test was conducted to measure the internal temperature of the device. The verification test was carried out in the high voltage insulation hall of XIHARI. The test system of ±1200kV DC voltage was used to apply the test voltage in the lab. Straight bus bars were used as high-voltage connections during the test to avoid corona generation during the test. In order to ensure the validity of the temperature measurement data, a fluorescence temperature sensor with a calibration certificate was used in the test. The rated voltage of +800kV was applied during the test. The application time was from the moment when the device prototype was applied until the device prototype reached thermal equilibrium. The criterion for the device prototype to reach thermal equilibrium conditions is that the temperature change within the device during the voltage application does not exceed ±0.5℃ per hour.

After about 12 hours of +800 kV voltage test, the device reached the specified thermal equilibrium, and the embedding temperature data was obtained in table 1. Table 1 shows the internal temperature distribution of the unit and shows that the maximum internal temperature rise of the unit is about 29K.

| Buried point No.1 of upper metal flange | Buried point No.2 of upper metal flange | Buried point No.3 of middle metal flange | Buried point No.4 of middle metal flange | Buried point No.5 of lower metal flange | Buried point No.6 of lower metal flange | Ambient temperature |
|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|---------------------|
| 42.4                                   | 42.3                                   | 36.9                                   | 36.6                                   | 33.2                                   | 33.1                                   | 13.5                |

4. Conclusion
Through the above verification test, the internal temperature distribution of the device under rated voltage operation and the maximum temperature rise inside the device are obtained. From the experimental data, it can be deduced that the device operates in the operating temperature range of hot and cold regions in China, and provides the basis for selecting the measuring device suitable for the operating temperature range [15-19]. The proposed method of temperature measurement provides an intuitive view of the internal temperature of the unit during operation and also provides a means of measuring the internal temperature of gas-insulated products in high voltage applications.

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