Research on Thermal Insulation Measures of Power Equipment Condition Monitoring Device in Cold Regions

Yue Wang*, Peng Zhang, Jianquan Liang, Lin Li, Wei Sun and Jian Zhang

State Grid Heilongjiang Electric Power Co., Ltd. Electric Power Research Institute, Harbin, China

*Corresponding author: zhangp@hepri.hl.sgcc.com.cn

Abstract. Outdoor winter temperatures in other northern regions such as Heilongjiang Province are relatively low. As an important equipment of ensuring the safety of transmission lines, the stability of the condition monitoring devices is facing great challenges. In order to ensure that the condition monitoring device can operate reliably in winter, so as to avoid the influence of low temperature in winter on the reliability of the condition monitoring device, in this paper a device is designed that uses solar heat for heat preservation for power equipment condition monitoring device. The device uses an all-glass vacuum solar collector tube to convert solar energy into heat, and realizes instant feedback and control of temperature through a bimetallic temperature sensor. After testing, in winter, the internal temperature of the heat insulation box can be increased by about 30 ℃ compared with the outside, which can effectively improve the winter operating environment of the device.

Keywords: Thermal insulation measures, power equipment condition monitoring device, cold regions.

1. Introduction
The condition monitoring technology of power equipment is one of the important means of Ubiquitous Electric Internet of Things, and it is also an important front-end equipment adopted by the Internet of Things in the power industry in the future [1]. In view of the harsh environment in northern and western China, power grids with a large operation and maintenance span are more valuable. However, because of the long and cold winters in northern China, condition monitoring devices have problems such as reduced reliability, high failure rates, and high maintenance costs in low-temperature environments [2]. Once the condition monitoring device has fault misjudgment, etc., it is impossible to detect the fault of the power equipment timely and accurately, so that a large area of unplanned power outage may occur, which will affect the electricity consumption of industries, enterprises, and residents, causing irreversible huge losses [3]. According to the data of Jilin and Heilongjiang, the equipment failure rate in low temperature environment has increased by 33.1% [4], which makes it difficult for condition monitoring technology to exert good results. Therefore, applying thermal insulation facilities to the condition monitoring devices of power equipment in cold regions is of great significance to ensure the stable operation of the power grid [5].
2. Principle and design

2.1. Heat collection principle and design

In order to realize efficient and energy-saving heat supply means and avoid the electromagnetic interference to the condition, the all-glass vacuum solar heat collection tube is selected as the heat source after multiple comparison. [6-8]

After the conversion of solar energy to thermal energy in the all-glass vacuum solar heat collection tube, the hot air stays in the collection tube. Therefore, it is difficult to form a flow, and the hot air cannot flow out to provide a heat source for the heat insulation box [9-11]. For this reason, the current research designs a heat-raising plug-in to make the hot air in the heat collection tube to put out of the heat collection tube through the heat-raising plug-in board. The plug-in divides the internal space of the collector tube into two spaces connected at the bottom, so that the thermal control flows in the cavity as shown in Fig. 1. The cold air enters the channel and becomes hot air through having heat exchange with the heat collection tube. Since the heat collection tube is placed vertically, the hot air has a tendency to flow upwards, forming convection with the cold air entering the heat collection tube. Therefore, the heat-raising plug-in board circulates the air inside the heat collection tube. Cold air continuously enters, and after heat exchange in the collector tube, hot air is continuously output. As a result, the environment around the exit of the collector can be continuously heated, so that the heat output efficiency of the collection tube can be improved.

![Figure 1. Air flow sketch inside the solar heat collection tube.](image)

Since the plug-in shall have the heat insulation function, and the temperature inside the heat collecting tube can be as high as 200°C, it has higher requirements for its melting temperature. The current research has tested a variety of materials, and finally decided to choose inorganic ceramic fiber material, and attached the aluminum sheet to the inorganic ceramic fiber insert to maintain its hardness.

2.2. Temperature control design

In order to reduce the electronic interference of the heat insulation box to the monitoring device, this research avoided electronic temperature control method and turned to use physical method to carry out temperature control. After comparison, the research adopts a duplex metal temperature sensor, and uses the principle of thermal expansion and contraction of metal to convert temperature changes into kinetic energy. Considering the appropriate working temperature for the monitoring device, the designed temperature control component is shown as Fig. 2.
The present research fixes the outer ring of the duplex metal temperature sensor on the inner wall of the heat insulation box and attach the central shaft on the rotating shaft of the temperature control baffle, making it drive the rotation of the temperature control baffle. Its initial position is set at the suitable working environment temperature of the monitoring device in the heat insulation box. When the temperature of the working environment of the monitoring device is low, the temperature control baffle is in a horizontal state. The hot air derived from the heat collection tube passes through the air inlet A and the air inlet B sequentially through the heat flow conduction channel, and then enters the heat insulation box, so that the working environment temperature of the monitoring device rises. In summer or when the temperature inside the heat insulation box is too high, the temperature control baffle is rotated to a vertical state driven by the duplex metal temperature sensor. At this time, the air inlet B can be blocked, and the air outlet C and the air outlet D can be opened, so that the hot air discharged from the heat collection tube passes through the air inlet A and is directly discharged from the air outlet C. In addition, the air outlet D realizes the heat exchange between the inside of the heat insulation box and the outside, reducing the internal temperature of the heat insulation box. When the temperature is neither too high nor too low, since the rotation angle of the duplex metal temperature sensor is in a linear relationship with the temperature difference, the temperature control baffle will rotate, thereby adjusting the temperature in the heat insulation box accordingly. The overall cross-section view of the heat insulation box is shown in Fig. 3.

Figure 2. Schematic diagram of the temperature control component.

Figure 3. Cross-section design diagram of the temperature control component.
3. Insulation effect validation of the equipment

3.1. Heat collection test

In order to intuitively comprehend the light and heat conversion performance of the solar collection tube, several time points after and before sunset are selected to measure the external and internal temperature of the collection tube under different weather conditions in this research. For the internal temperature, a distance of 10cm from the tube orifice of the collection tube is selected for measurement. The measurement results are shown in Table 1.

| Weather     | Fine | Cloudy | Overcast | Rain |
|-------------|------|--------|----------|------|
|             | External temp | Internal temp | External temp | Internal temp | External temp | Internal temp | External temp | Internal temp |
| 9:00        | 21   | 108    | 19       | 77   | 15   | 52    | 13    | 51    |
| 11:00       | 23   | 117    | 20       | 84   | 17   | 55    | 16    | 53    |
| 14:00       | 24   | 121    | 22       | 88   | 18   | 57    | 17    | 54    |
| 17:00       | 22   | 106    | 20       | 79   | 17   | 54    | 14    | 52    |

It can be seen from Table 1 that the internal temperature of the collector tube is greatly affected by the weather. In other words, temperature is directly proportional to light intensity. However, its heating effect can meet the requirements of the monitoring device for the working environment temperature.

3.2. Heat preservation effect test of the heat insulation box

After the photo thermal heat insulation box of the condition monitoring device was manufactured, the external and internal temperature of the heat insulation box was measured in low-temperature weather. The measurement results are shown in Fig. 4. It can be seen from the measurement results in the table that the heat insulation box developed by the current research can effectively increase the temperature in the heat insulation box by 30°C in a low temperature environment, thereby achieving an appropriate working environment temperature for the equipment in low temperature conditions.

![Figure 4. Insulation effect test curve of the heat insulation box.](image-url)
4. Conclusions
This paper studies a luminous energy heat insulation box as a heat preservation measure for the condition monitoring device of power equipment operating in cold regions. The heat insulation box uses all-glass vacuum solar collection tube to provide heat source. It realizes the efficient utilization of heat energy through inorganic ceramic fiber attached with aluminum sheet plug-in, and uses the duplex metal temperature sensor to realize real-time feedback and control of temperature. The test proves that the heat insulation box can increase the internal temperature by 30°C compared to the external temperature, thus being able to meet the actual operation requirements of the condition monitoring device and effectively avoid the threat of temperature brought to the device operation stability.

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