Research on New Leakage Detection Technology for Converter Valve Cooling System

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Abstract. In order to solve the problem that the traditional leakage detection device of converter valve cannot accurately locate the leakage point, a leakage detection and location device of converter valve with two functions of leakage detection and leakage location is designed based on the leakage detection principle of sensor cable and through software programming. On this basis, an experimental platform is built, and the test results show that the short distance positioning error is within (±15 cm), which confirms the effectiveness of the device and the accuracy of positioning.

1. Introduction

As the core equipment of HVDC transmission system, converter valves generate a lot of heat during operation, so special water cooling system and converter valves are needed for heat exchange [1]. Valve cooling system is one of the most important auxiliary equipment in HVDC transmission system, and its safety and stability are directly related to the operation of the whole HVDC system [2]. Due to the long-term pressure operation of valve cooling system, joint loosening and pipeline aging are easy to occur. There is a risk of valve body leakage [3]. When valve cooling system leakage occurs, it will affect the normal operation of the converter valve, and even cause direct current blockade or burning the valve body. At present, the leakage detection method used in the system mainly reflects the leakage situation through the leakage device [4-5]. According to the current operation data, the slight leakage fault accounts for the majority. Because of the high temperature of the converter valve, the slight leakage can be easily evaporated and dried, making the leakage point difficult to find [6]. Therefore, it is necessary to develop a leak detection device which can detect and locate quickly.

2. Leakage Detection Technology

With the construction of pipelines, leak detection technology has also been continuously developed, from the simplest manual sectional inspection to the more complex computer software and hardware combination method [7]. According to the different detection objects, it can be divided into direct detection method and indirect detection method. Direct leak detection method has the characteristics of high sensitivity, rapid detection and can be used for micro leak detection, but most of them have the
shortcomings of high cost and discontinuous detection. It is only suitable for short distance pipelines and sensitive areas with high sensitivity requirements. Indirect leak detection method is widely used in pipeline leak detection at present. The method mostly adopts the method of combining hardware and software, which has the characteristics of fast, accurate and strong automation. It is difficult for a single leak detection device to meet the needs of practical work, so in the application, the characteristics of various leak detection methods are generally considered, and several detection methods are used together to form a comprehensive leak detection system with reliability and economy.

At present, leak detection methods based on second-generation wavelet transform and multi-level hypothesis test [8], leak detection method based on pattern recognition [9], leak detection method based on fuzzy neural network [10], and leak detection method based on constant current source [11-12]. But these methods all have big defects: some can only detect the leakage state without locating, others can locate, but the positioning accuracy is not high [13-14]. Therefore, this paper develops a leakage detection and location device for the cooling system of the converter valve. By installing a distributed leakage sensing system in the valve hall, the distributed leakage monitoring and high-precision leakage location can be realized, and the hidden danger of leakage can be eliminated in time. It has important application value to ensure the long-term stable operation of the converter valve.

3. Working Principle of Leakage Detection Device

Leakage detection and positioning system is composed of an inductive cable for detecting liquid leakage and a controller with positioning display and alarm. When the leakage occurs, the induction cable sends the signal to the controller. After being processed by the microprocessor, the precise location of the leakage is displayed and the alarm is given at the same time. Induction wires are composed of four different types of wires, two of which are made of conductive polymers. The resistance per unit length is precisely processed and fixed. The structure sketch of induction wires and cables is shown in Figure 1. When there is no leakage, the current value between two conductors is normal. When the inductor is immersed in the leakage, the two conductive polymers are shortened and the measured current value changes. According to Ohm's law, the controller can get the location of the fault leakage point and send out the leakage alarm [15].

![Figure 1. Structural schematic diagram of induction cables](attachment:induction_cable.png)

According to the principle of leak detection of sensor cable, a locating circuit is designed [16]. As shown in Figure 2, I is the source current, V is the high impedance voltage, and X is the length from the detection end to the leak. The resistance per unit length of the sensing cable is defined as K. According to Ohm's law $R_X = V/X/I$, it can be obtained:
Because the current through the high impedance voltmeter can be neglected, so $V_X = V_R - V_B$, the formula for locating the leakage point is as follows:

$$X = \frac{V_X}{IK}$$ \hspace{1cm} (1)

$$X = \frac{(V_R - V_B)}{IK}$$ \hspace{1cm} (2)

Figure 2. Schematic diagram of positioning circuit

4. Design of Leakage Detection and Location Device

The leakage detection and location device of the cooling system of the converter valve is composed of the leakage detection host, the monitoring system, the lead-out line, the induction line, the jump line, the termination end, the fixing clamp, the alarm positioning control device, the branching device and the label. The leakage induction line is fixed on the pipeline inside the converter valve tower through the fixing clamp, and the non-leakage detection component is connected with the induction line through the jump line. The front end of the leakage induction line connects the branch through jumper, and the end connects the termination end; the branch connects the alarm positioning control device through the lead-out line; the alarm positioning device connects the acousto-optic alarm device and the monitoring system separately, at the same time uploads the data to the leak detection host server, and notifies the maintenance personnel through various alarm modes. The device schematic diagram is shown in Figure 3.

Figure 3. Principle diagram of leakage detection device for cooling system of converter valve
4.1. Device Function
The device has three main functions: self-inspection, leak detection and leak location. Self-inspection is mainly to check whether there are problems in the device itself after the device starts to work, to avoid the error brought by the device's own fault to the experiment, and to ensure the normal operation of the device. Leakage detection mainly uses the material characteristics of the sensing cable which is sensitive to liquid to detect the leakage around the sensing cable. Leakage location is to locate the leakage point accurately according to Ohm's law after determining the leakage around the sensor cable, and then to determine the specific location of the leakage in the computer room by calculating the relationship between resistance and length.

4.2. Device Workflow
According to the design idea of the leak detection and location device, the working flow of the device is drawn, as shown in Figure 4.

![Figure 4. Workflow of Leakage Detection and Location Device](image)

5. Experiments and Results Analysis
Eleven leak points (1m; 2m; 4m; 8m; 16m; 25m; 34m; 42m; 46m; 48m; 49m) were set up from the detection end to the termination end to simulate the small leak. The experimental results show that the location of each leak point shows the distance as shown in Table 1 when the leak occurs.

| Leakage point | Setting up the position of leaking water | Display the location of the leak |
|---------------|----------------------------------------|---------------------------------|
| 1             | 1.00m                                  | 1.04m                           |
| 2             | 2.00m                                  | 2.11m                           |
| 3             | 4.00m                                  | 4.10m                           |
| 4             | 8.00m                                  | 8.14m                           |
| 5             | 16.00m                                 | 16.08m                          |
| 6             | 25.00m                                 | 25.12m                          |
| 7             | 34.00m                                 | 34.06m                          |
| 8             | 42.00m                                 | 42.09m                          |
| 9             | 46.00m                                 | 45.94m                          |
| 10            | 48.00m                                 | 47.88m                          |
| 11            | 49.00m                                 | 48.85m                          |
From Table 1, it can be seen that the maximum error of positioning display is 15 cm, which can meet the practical engineering application requirements, thus fully proving the effectiveness and accuracy of positioning device.

6. Conclusion
The leakage detection and location device for the cooling system of the converter valve designed by using the sensor cable for leakage detection and accurate positioning method can quickly detect the leakage status of the system and locate the leakage position. The leak signal is transmitted to the host server by wireless transmission. At the same time, the maintenance personnel are notified by real-time alarm, telephone voice, short message, e-mail and other alarm methods to ensure that the alarm can be dealt with in time. The test results show that the short distance positioning accuracy can reach ($\pm 15$ cm), which proves the validity of the device and the positioning accuracy.

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