Test method for opening and closing time of 500kV high voltage circuit breaker under double terminal grounding condition

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Abstract: The opening and closing time test of 500kV high voltage circuit breaker can evaluate the mechanical characteristics and three-phase synchronization performance of the circuit breaker. Due to the influence of the earth resistance circuit, the traditional test method of circuit breaker opening and closing time cannot be carried out when both ends are grounded. This paper first introduces the differential coil used to collect the signal, and then according to the requirements of field test, puts forward a test method for the opening and closing time of circuit breaker under the condition of double terminal grounding, and gives the basis for judging the opening and closing signal time. Finally, it compares and analyses the results of this method with the traditional high voltage circuit breaker opening and closing time test method, and obtains the conclusion of high voltage circuit breaker. The test method of grounding time division and closing time at both ends of the circuit breaker can fully meet the needs of field maintenance, which provides a new idea for the opening and closing time test of 500kV high voltage circuit breaker.

1. Introduction

As one of the most important power equipment in the power system, high voltage circuit breaker not only plays the role of controlling the live load current to meet the normal load current, but also plays the role of breaking and closing abnormal current within the specified time. Its reliability affects not only its own safe operation, but also the safe operation of other important power equipment in the system [1-3]. As the key equipment to ensure the safe and stable operation of power grid, the mechanical characteristic test is the primary means to measure its operation state. When the power grid fails, the high-voltage circuit breaker is required to act quickly to protect the safety of power equipment in the power grid. Therefore, the measurement of opening and closing time of high-voltage circuit breaker is of great significance. The opening and closing time of high-voltage circuit breaker is also an important routine maintenance item of high-voltage circuit breaker and an important basis for testing the performance of circuit breaker.

The current test method of opening and closing time of high-voltage circuit breaker needs to untie the grounding conductor at both ends of the circuit breaker, and then hang the test line at both ends of the circuit breaker for test. This method will have certain potential safety hazards. Therefore, many research institutions are exploring new methods to test the opening and closing time of high voltage circuit breaker under the condition of double terminal grounding. Hao Jiancheng of Liaoning Electric Power Research Institute and other scholars put forward the test method of grounding time division and closing time at both ends of the circuit breaker, and they found that this method can greatly improve the test efficiency and reduce the risk of test safety.
time at both ends of the circuit breaker, and verified it on the gas insulated switch (GIS) [4]; Reference [5] introduces a dynamic capacitance test method, which calculates the opening and closing time of high voltage open circuit breaker through the dynamic capacitance of air insulated open high voltage circuit breaker. The existing test methods have uncertainty in measuring the threshold, which will produce certain errors, and the test effect of open high voltage circuit breaker is not good due to the influence of electromagnetic field in substation. Therefore, it is still meaningful to study the test method of opening and closing time under the condition of double terminal grounding of high voltage circuit breaker.

This paper first studies the differential current coil used to collect the current signal, and then puts forward a method to calculate the opening and closing time of the circuit breaker by injecting the induced current into the fluid circuit of the circuit breaker and collecting the induced current signal on the other side of the high voltage circuit breaker when the electrical safety protection at both ends of the high voltage circuit breaker is grounded. The accuracy of this method is verified by field test in 500 kV substation.

2. Manufacture of signal acquisition device

The differential current coil is used to collect the current signal of 500kV high voltage circuit breaker. When the current in the conductor changes, the magnetic field around the conductor changes. According to the principle of electromagnetic induction, the output end of the coil generates the induced electromotive force[5].

Figure 1 Differential current coil

\[ e(t) = -n \frac{d\Phi}{dt} \]  \hspace{1cm} (1)

Where \( n \) is the number of coil turns, \( \Phi \) In order to obtain the magnetic flux through the coil section, the magnetic field intensity \( H \) and the magnetic flux density \( B \) are obtained from the full current law assuming that the magnetic field intensity is equal at all places on the coil section

\[ H = \frac{i(t)}{2\pi R} \]  \hspace{1cm} (2)

\[ B = \mu H = \frac{\mu i(t)}{2\pi R} \]  \hspace{1cm} (3)

Where \( \mu \) is the permeability, \( S \) is the cross-sectional area of the coil

\[ \Phi = \mu i(t)S/2\pi R \]  \hspace{1cm} (4)

\[ e(t) = -n\mu S/2\pi R \cdot di(t)/dt = -M \cdot di(t)/dt \]  \hspace{1cm} (5)

\( M \) is the mutual inductance between the current coil and the current carrying conductor under test.

It can be seen from equation (5) that the output voltage of the differential coil is directly proportional to the change rate of the measured current. The action time of the moving contact of the high voltage circuit breaker is only tens of microseconds, and the power signal we selected is above 10kHz, so the differential coil can have a better output, which can meet the requirements of the field test.
3. Test Method of Time Division Closing Time of Circuit Breaker with Both Ends Grounded

The test method of opening and closing time of high voltage circuit breaker is based on electromagnetic induction. High frequency current is injected into the ground wire at one end of high voltage circuit breaker, and the signal is received at the other end to judge the opening and closing state of high voltage circuit breaker. The wiring diagram of field test is shown in Figure 1. The circuit breaker, conductor, grounding wire and grounding grid in Figure 1 are defined as a fluid circuit. The closing and opening of the fluid circuit depend on the opening and closing operation of the circuit breaker. The high-frequency signal generator in Figure 1 injects high-frequency current signal into the flow circuit through the coupling coil. When the flow circuit is closed, a corresponding induced current will be generated in the differential coil[6-7]. However, when the flow is disconnected, there is no induced current in the differential coil. For the time of induced current generation and disappearance, the measurement can correspond to the closing and opening time of the circuit breaker. In the actual measurement, the differential coil is used to collect the current coil, and the induced current will be generated in the differential coil when the circuit breaker is closed; In the open state, there is no current[8]. The data acquisition card is used to transmit the collected induced current to the computer, and the oscilloscope is used to process the data to obtain the required measurement waveform. The time when the current waveform starts to establish is the time when the contact is conducting, and the time when the current waveform begins to disappear is the time when the contact is breaking. After determining the method of grounding time and closing time at both ends of the circuit breaker, it is necessary to test the opening and closing time of the circuit breaker through the cooperation of the data acquisition device and the operating mechanism.

![Figure 2 Wiring diagram of grounding time division and closing time test at both ends of circuit breaker](image)

When both ends of the high voltage circuit breaker are grounded, it is difficult to accurately measure and judge the opening and closing signal state of the circuit breaker. The specific methods are as follows: the opening and closing signal measurement method of the circuit breaker. The dynamic and static contacts of the high voltage circuit breaker, the grounding knife connected with the dynamic and static contacts and the grounding grid connected with the two grounding knives form a fluid passage. One end of the grounding knife connected with the fluid passage is clamped with a coupling device, and the other side of the grounding knife is wound with a differential coil. When the high-voltage circuit breaker is closed, the above fluid is closed, and the differential coil can collect the signal, which is used to judge that the circuit breaker is closed; When the high-voltage circuit breaker is opened, the above fluid is not closed, and the signal can not be collected on the differential coil, so it is judged that the circuit breaker is opened. Due to the different ground grid structure of each substation, the length and thickness of the ground knife lead wire will affect the fluid medium, which will lead to the signal quality of the signal collected by the signal acquisition caliper, thus leading to the difficulty of defining the criterion of high voltage circuit breaker closing and opening.
The technical solution for measuring the opening and closing signals of circuit breakers. In view of the above-mentioned problem about the threshold judgment of the closing and opening signal when the two terminals are grounded, the following two methods can be used to solve the problem after measuring in multiple substations.

Mode one increases the output power of high frequency power signal. The closed-loop control system is used in the measurement loop. In the test process, the high-frequency source signal and the signal received by the differential coil are monitored in real time by the instrument host, and the output power of the high-frequency power supply is adjusted according to the output signal strength of the differential coil, which is realized in a certain range, so that the output power of the differential coil will not be saturated due to the excessive output power, and the output power of the differential coil will not be too small, The differential coil can not receive the useful signal.

The second way is to adjust the judgment threshold of high voltage circuit breaker opening and closing signal. The setting of threshold is an important basis to judge the opening and closing state of high voltage circuit breaker. There is a strong electromagnetic interference in the substation. When we choose the threshold of differential coil output voltage signal, we need to consider the electromagnetic environment interference and the impedance of the grounding grid. The selection of threshold is not the bigger the better or the smaller the better. When the impedance of the local network is small, the test conditions are good, and the threshold can be larger. When the impedance of the local network is larger, the test conditions are poor, and the threshold can be reduced, so as to ensure the correct judgment of the opening and closing state of the high voltage circuit breaker.

In the actual use process, according to the actual situation of the substation, we need to measure the current signal value collected by the differential coil when the high-voltage circuit breaker is closed. According to the output voltage of the differential coil, we can determine the appropriate high-frequency power supply output power and threshold high-voltage circuit breaker opening and closing state.

4. Field Measurement and Test Method Verification
The on-site measurement of the on-off time of the high-voltage circuit breaker takes the 500 kV high-voltage circuit breaker as the test object. During the on-site test, the good contact of the grounding switches at both ends of the 500 kV high-voltage circuit breaker is ensured.
When the 500kV high-voltage circuit breaker is closed, the fluid flowing part composed of grounding grid, circuit breaker, cable and grounding switch is complete. At this time, the electrical signal sent by the high-frequency power supply is injected into the fluid flowing circuit by the coupling device, and the high-frequency signal is induced by the differential coil through the closed circuit, and the induced electromotive force is generated. The electromotive force is input to the signal acquisition box through the test line, and then transmitted to the oscilloscope through shaping and filtering. When the 500kV high-voltage circuit breaker is disconnected, the fluid circuit is disconnected. Although the high-frequency power supply is also generating the high-frequency signal, the differential coil can not collect the high-frequency signal, so the oscilloscope can not collect the high-frequency signal output from the signal box.

In order to verify the accuracy of the proposed test method, the traditional test method and the test method are used to test the opening and closing time of 500kV high voltage circuit breaker in the substation. The comparison of closing time is shown in Table 1, and the comparison of opening time is shown in Table 2.

![Figure 4: Oscillogram on oscilloscope when high voltage circuit breaker is closed](image)

As shown in Figure 4, the red line is the current signal collected by the differential coil in the fluid circuit composed of high voltage circuit breaker, wire, ground wire and grounding grid, and the blue line is the closing signal sent by the operating mechanism. By judging the time difference between the two lines, the opening and closing time can be obtained.

| LW15A-550/Y       | Traditional method / ms | Two terminal grounding / ms |
|-------------------|-------------------------|-----------------------------|
| Phase A           | 67.2                    | 67.3                        |
| Phase B           | 67.9                    | 67.4                        |
| Phase C           | 66.1                    | 66.2                        |

| LW15A-550/Y       | Traditional method / ms | Two terminal grounding / ms |
|-------------------|-------------------------|-----------------------------|
| Phase A           | 15.5                    | 15.5                        |
| Phase B           | 16.3                    | 16.2                        |
| Phase C           | 15.8                    | 15.9                        |
It can be concluded from table 1 and 2 that the data of the test method and the traditional measurement method are consistent with the traditional measurement method in the closing and opening time of the circuit breaker, and the accuracy of the test method for the earth time and closing time of both ends of the circuit breaker is verified.

5. Conclusion
Through the research on the test method of the circuit breaker when both ends are grounded, the following conclusions can be drawn.

1) Under the condition of electrical safety protection grounding at both ends of high-voltage circuit breaker, the detection method of opening and closing time of open 500kV high-voltage circuit breaker is proposed, which can meet the requirements of field test of circuit breaker.

2) The test method of grounding time division and closing time at both ends of 500kV high-voltage circuit breaker not only meets the requirements of data accuracy, but also has advantages.

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