Application of new intelligent double end grounding circuit breaker circuit resistance measurement technology

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Abstract: According to actual needs of the circuit breaker field measurement, by using induction coil as the basic principle of the proposed at both ends of the breaker is connected with the loop resistance test method. In this paper, we mainly study the circuit breakers at both ends of the ground state, circuit breaker loop resistance test design principle and theory model, solution method for the measurement of the small current signal criterion, research and development of the testing device, and through the two ends of the two devices on circuit breaker and GIS combination electric appliance grounding field test. Finally, to test this method and the traditional methods of test results were compared and analyzed, it is concluded that the two ends of the grounding circuit breaker loop resistance method can completely meet the needs of field maintenance and can improve the detection accuracy and instead of the traditional test methods.

1. INTRODUCTION

Circuit resistance of circuit breaker is usually small resistance of micro ohm level, so how to accurately measure its resistance value is a subject worth studying. At present, the most commonly used circuit resistance measurement method is DC voltage drop method, that is, into the circuit breaker more than 100A constant large current, measuring the voltage drop at both ends of the circuit breaker, according to Ohm's law to calculate the circuit breaker contact resistance value. However, in 220 kv, 550 kv, 1000 kv substation, working line will have a very high on the maintenance of over head lines, induction electromotive force, the induction electromotive force is enough to pose a threat to personnel safety, so in the high voltage circuit breaker in the maintenance, the static contact and moving contact are respectively through the knife to the earth, is mainly drain off the overhead lines have induction electromotive force induced charge [1-2]. Because the high voltage switch is connected to the earth through the ground knife at both ends of the maintenance, and because the earth conduction resistance is very small, about 200 milliohms, part of the current is bound to pass through the ground knife and the ground grid for shunt, thus affecting the accuracy of the test.

Therefore, it is necessary to develop an intelligent test device for circuit resistance of double-ended grounded circuit breakers, which can accurately and quickly measure circuit resistance parameters of circuit breakers in the case of double-ended grounded high-voltage circuit breakers. The device can reduce labor costs, improve testing accuracy, reduce safety risks to a certain extent, and promote the product in a large range of the country, to a large extent, increase economic benefits.
2. Circuit resistance test principle of circuit breaker

Circuit breaker circuit resistance is the effective resistance of the entire conducting circuit included in the switch body. The resistance of the conduction circuit of the circuit breaker is the sum of the contact resistance between the dynamic and static contacts and the resistance of the other connecting lines in the line. The resistance value of the contact resistance is far greater than the resistance value of the connecting line, that is, the resistance of the circuit is mainly determined by the contact resistance of the contacts. The resistance of circuit breaker's conductive circuit is tested by DC voltage drop method. The test wiring schematic diagram is shown in Fig.1.

![Figure 1. Schematic diagram of testing](image)

The current source outputs constant current through the standard resistor $R_0$ and the resistor under test $R_x$. The voltage signal $U_0$ on the sampling standard resistor $R_0$ is filtered and amplified and then sent to AD to be converted into digital quantity, and then the current value $I$ is calculated, as shown in Formula (1). Similarly, the voltage signal $U_x$ on the resistance $R_x$ to be measured is sampled, filtered and processed by multi-stage amplification, and then sent to AD for conversion into digital quantity. The resistance value $R_x$ is calculated by formula (2).

$$I = \frac{U_0}{R_0} \quad (1)$$

$$R_x = \frac{U_x}{I} \quad (2)$$

Under the influence of a very thin film resistance on the contact surface of the moving and static contacts, if the DC current applied is too small, the test resistance is greater than the actual resistance, and the results are inaccurate. Therefore, in order to improve the accuracy of the test resistance, according to the requirements of the relevant regulations, the applied DC current should be greater than 100A to break down the film resistance on the contact surface.

3. Test scheme for circuit resistance of two-end ground circuit breaker

3.1. Double end ground equivalent circuit of circuit breaker

When the circuit breaker is grounded at both ends, its equivalent circuit model is shown in Figure2[3].

![Figure 2. Two-end Earthed Equivalent Circuit Model of Circuit Breaker](image)
$R_1$ is the switch circuit resistance, $R_2$ is the left ground resistance, $R_3$ is the right ground resistance, and $R_4$ is the ground resistance between two junction points.

This design scheme is: the basic principle of loop resistance measuring instrument to provide a constant dc current $I$ (usually 100 a or 200 a), through the circuit breaker loop resistor $R_1$ form the current loop, without ground wire on both ends of the circuit breaker, at this time only need to measure the voltage between E and F (VEF), according to the ohm's law can be obtained by circuit breaker loop resistor $R_1 = \text{VEF}/I$. If both ends of the circuit breaker E and F are grounded, the equivalent circuit is shown in Figure 2.

$R_2$, $R_4$ and $R_3$ form shunt circuits. If common methods are used to measure, the true circuit resistance of their switches cannot be measured because $I_1 \neq I$. This scheme attempts to measure the shunt current $I_2$ by a clamp ammeter. So $I_1 = I - I_2$, $R_1 = \text{VEF}/I_1$. Thus, the circuit breaker resistance $R_1$ can be accurately measured.

### 3.2. Double end grounding test technology solution for circuit breakers

![Figure 3. Block Diagram of Implementation Scheme of Circuit Resistance Test of Double-End Grounded Circuit Breaker](image)

In view of the above mentioned problems about the circuit resistance testing of double-ended grounded circuit breakers, after measurement and investigation in multiple substations, the circuit breaker double-ended grounded circuit resistance testing is solved by the following methods[4].

Among them, $I$ is the instrument's constant current DC power supply (multiple current tap positions can be set according to needs); $R_1$ is the circuit resistance of the circuit breaker; $R_2$ and $R_3$ are ground wire resistors; $R_4$ is the ground resistance between two junction points; $R$ is the sampling resistor that detects the current of the constant current source; $C$ is a DC clamp ammeter used to measure the current value of $I_2$.

The instrument workflow is as follows:

- The key is used to select the current value of the output constant current power supply;
- Channel two measures the actual output current of the constant source;
- $I = \text{V mark}/R\text{ mark}$ ($R\text{ mark}$ is known internal shunt resistance);

According to the above design scheme, commissioned domestic well-known instrument manufacturer Jinyuan Scientific Instrument Co., Ltd. to produce a prototype JYL intelligent loop resistance tester (100C).
4. Field test of resistance test of circuit breaker double end ground loop

4.1. Instruments and equipment used
Circuit breaker double-ended grounding circuit resistance tester JYL consists of a host, XL100 test current clamp box, wire box. The host machine completes the functions of current and voltage signal acquisition, conditioning, algorithm processing, display, printing, storage, etc. XL100 test current clamp to complete the grounding terminal current signal acquisition; Wire box is used for loading test power cord, test wire, ground wire, etc[5].

4.2. Wiring mode of instrument

![Test Wiring Diagram (Current Shielding Method)](image)

Figure 4. Test Wiring Diagram (Current Shielding Method)

When the circuit breaker is grounded at single end or both ends are not grounded, the special test line shall be red to red, black to black in accordance with the color. The thick current line shall be connected to the corresponding I+ and I- terminals and tightened, while the thin voltage line shall be connected to the V+ and V- terminals and tightened, and the two ends of the tested product shall be held by two grips. If the current shielding method is used for measurement, the test clamp is clamped in the grounding lead wire and the other end is connected to the instrument current transformer socket.

4.3. Test data comparison and analysis of test data
A circuit resistance test was carried out on a 500kV double-ended grounded high-voltage circuit breaker in a substation in Liaoning Province, which contained double breakages (one end was connected to the knife switch and the other was connected to the current transformer). According to the specific position, it can be divided into 6 points A, B, C, D, E and F. There are 2 contact resistances, namely, 2 fracture static and static contact resistances, which are RAB and REF respectively. There are mainly two connection resistors, namely, two conductive rods on the side of the broken movable contact head and the triple box flange connection resistors, respectively RBC and RDE.

Method (1) The cutters on both sides of the circuit breaker are in the state of breaking off. The circuit resistance is measured by traditional test method without sensor.

Method (2) The cutters on both sides of the circuit breaker are in the closing state, and the circuit resistance is measured by the traditional test method without sensor.

Method (3) The cutters on both sides of the circuit breaker are in the closed state. The shunt current is collected by the clamp current sensor for circuit resistance measurement and measured by the current shielding method.
All the three detection methods choose 100A for testing. Only the grounding switch is operated, and the wiring position of the circuit resistance tester remains unchanged.

| Circuit resistance data difference of measurement method (1) and method (2) |
|---------------------------------------------------------------|
| Circuit breaker resistance | $R_{AB}$ | $R_{AC}$ | $R_{EF}$ | $R_{DF}$ | Total circuit resistance |
|----------------------------|---------|---------|---------|---------|-------------------------|
| Method for measuring double-ended grounding                   | 35.7    | 38.2    | 35.7    | 36.9    | 83.3                    |
| Traditional measurement method                                | 35.4    | 38.0    | 35.3    | 36.6    | 82.7                    |
| The difference                                                | 0.3     | 0.2     | 0.4     | 0.3     | 0.6                     |

From the table above shows, this circuit breaker testing data, for example, caused by ground loop circuit breaker double end tester constant-current source shunt effect, compared with the measured value and the actual value must be increased, the original value of the influence factors of about 0.81%, is more than the power industry DL/T 845.4 2004 "resistance measurement device through technical conditions part 4: loop resistance tester, permissible error $\leq 0.5\%$ requirement, so the test data can't reflect the breaker operation state.

Then list the test data of mode (1) and mode (3), as shown in Table 2:

| Circuit resistance data difference of measurement methods (1) and (3) |
|---------------------------------------------------------------------|
| Circuit breaker resistance | $R_{AB}$ | $R_{AC}$ | $R_{EF}$ | $R_{DF}$ | Total circuit resistance |
|----------------------------|---------|---------|---------|---------|-------------------------|
| Method for measuring double-ended grounding                          | 35.5    | 38.0    | 35.5    | 36.7    | 82.9                    |
| Traditional measurement method                                      | 35.4    | 38.0    | 35.3    | 36.6    | 82.7                    |
| The difference                                                      | 0.1     | 0.0     | 0.2     | 0.1     | 0.2                     |

As can be seen from the test comparison data in Table 2, since the high-precision clamp current transformer is used to shield the shunt in the cutting-gate ground circuit, the error of the test data in Method (3) is only 0.27% compared with the real data, so the current shielding method can effectively avoid the adverse impact of the shunt in the circuit on the test results.

5. Conclusions
In this paper, the key technology of resistance testing principle of two-end ground circuit of circuit breaker is studied. On this basis, a prototype is designed by using the equivalent model and testing principle, and a year-long field test is carried out. According to different test site, and in view of the problems arising from the test, analyzes the main factors affecting test proved that the high voltage circuit breaker in the electrical safety protection on both ends of the earth in a state of the current block test method, namely the current sensor induction method for the shunt current measurement accuracy and effectiveness of the high voltage switch, has further research value and application value, and considerable social and economic benefits.

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