The Compensation Method for Temperature Rise Test of 750kV Magnetic Controllable Reactor

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Abstract. The article introduces the principle of Magnetic Controllable Reactor(MCR) in power system applications, the temperature rise test is the important type test in the factory, but it will lead to errors of the temperature rise test results in the factory because the test conditions in the factory is different from the actual operation circuit. In this paper, a compensation method for temperature rise test is introduced, which can make up for the shortcomings of temperature rise test in factory, and the results of simulation by PSCAD and measurement show that the method presented in this paper is effective.

1 Introduction

Magnetic Controllable Reactor(The paper referred to as "MCR") is the power equipment, which is suitable for super / ultra-high voltage power system suppression over-voltage and reactive power compensation. MCR can also solve frequency overvoltage under the long-term no-load operation mode and transmission network losses under overload issues. The MCR is not only as reliable as the transformers maintenance, but also has low grid losses, low cost, small harmonics. MCR can be directly linked to the high voltage line and bus [1].

Temperature rise test of transformer/reactor is one of the important test items in type test to identify product quality. The purpose of temperature rise test is to determine whether the temperature rise of each component of transformer/reactor meets the requirements of relevant standards, so as to provide a reliable basis for long-term safe operation of transformer or reactor [2-3].

Due to the limitation of test equipment, the capacity of the magnetic controllable reactor is far more than the power supply capacity. In addition, there is no FACTS(Flexible AC Transmission Systems) in the factory test system, and the reactive power balance of the system can not be adjusted in real time. If the selected capacity of the fixed capacitor is inappropriate, the phenomenon of over-voltage for the power windings will occur during the test process. This paper introduces a compensation method for temperature rise test, which makes up for the shortcomings in the process of factory temperature rise test.

2 The Principle of MCR

The magnetic controllable reactor automatically adjusts the trigger angle α according to the voltage variation of the power grid (the deviation of the voltage of the power grid from the standard value), and changes the core saturation of the reactor by changing the DC current of the DC control winding, thus changing the equivalent impedance of the reactor, so as to achieve the purpose of regulating the reactor capacity. The principle diagram of the magnetic controllable reactor is shown in Figure 1.

Fig 1 Principle diagram of single-phase magnetically saturated controllable reactor

The three-phase magnetically controlled reactor is composed of the power windings, the compensation windings and the control windings. Its wiring diagram is shown in figure 2.

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Fig 2 Wiring diagram of three-phase magnetically controlled controllable reactor

(1)MCR power winding, Wye connection, single-phase has two windings in parallel with the grid, the other end to the earth, rated voltage is 800kV.

(2)MCR compensation winding, delta connection, supply energy to the rectifier, rated voltage is 40.5kV.

(3)MCR control winding, which has two windings. The two windings has dotted terminal, rated voltage is 41.85kv.

(4)The excitation transformer, as viewed from the compensation winding, is a step-down transformer winding end, the capacity is 1MVA, a voltage is 40.5kv, secondary voltage 0.2kv, Y / Δ connection

MCR is based on the three-winding transformer structure design, which is using the direct current to control core saturation, therefore the inductive impedance will change. As follows, after the power winding is energized, the compensation winding used for suppression of current third harmonic will induce a corresponding voltage and supply the rectifier device power. When the current flows out from the three-phase bridge rectifier, a DC current flow into the control winding, by changing the saturation of the core thereby changing the controllable reactor side of the net impedance.

3 Introduction of Temperature Rise Test And Test Problem

Testing of MCR is performed in two stages. First stage
- testing of MCR at the factory of origin, Second stage
- testing of MCR at the substation after mounting and connection to the grid.

Temperature rise test is a kind of type test at the factory of origin. The traditional temperature rise test examines the average temperature rise of winding and the temperature rise of oil top layer. If the two measured values of temperature rise do not exceed the allowable temperature rise limit specified in the standard, the transformer is considered to have passed the type test of temperature rise test.

3.1 Introduction of the test circuit

Figure 3 750kV single phase MCR temperature-rise test wiring diagram

Figure 3 is a 750kV single phase MCR temperature rise test wiring diagrams, in which:

(1) Plant generators with a capacity of 60MVA, because then single-phase controlled reactor temperature rise test conducted, so the generator needs to change the single-phase method.

(2) Capacitor towers, uncharged switching mode, in accordance with the demand of reactive power capacity of linear compensation, but not supply real-time compensation.

(3) Step-up transformer capacity of 63MVA, the ratio is:

$$(1700/\sqrt{3})\text{kV}/132\text{kV}.$$

(4) Single-phase MCR.

(5) DC control and protection system, which controls the DC output and protect the control circuit.

(6) Excitation transformer, the ratio is: 6kV/0.535kV.

(7) Excitation generator, the capacity is 6MVA.

3.2The Impact of MCR's Characteristics On the Temperature-Rise Test

Through the introduction 3.1 shown the test circuit can be equivalent to a single large load of small power supply systems. Because there is no FACTS devices, the real time reactive power balance could not be adjusted, can only rely on a fixed capacitor tower linear compensation, but when MCR temperature-rise test carry out, the impedance of MCR will change nonlinear, when MCR high voltage winding current from no load to rated current state changes, the reactive power which capacitor tower supply would not accurately follow the nonlinear changes impedance of MCR, if we rise generator export voltage to MCR rated voltage may cause capacitive reactive power to the generator, the resulting over-voltage may damage insulation of MCR.

Fig 4 shows the over-voltage curve on the grid side caused by the variable impedance between the capacity tower capacitor and magnetic controllable reactor.

Figure 4 the over-voltage curve on the grid side

Also, because when the control winding together with the rated excitation current, it will lead to single-phase controllable reactor two core columns saturation inconsistent, because there is no control of the three-phase windings connected in parallel with the high voltage winding will result in both sides of the control winding inducing overvoltage.

So if we want to complete temperature-rise test, we need to solve the following problems:

(1)Make sure the high voltage winding current from the load current to the rated state, capacitor impedance changes do not cause capacitive reactive send down cause overvoltage.

(2)Under MCR temperature-rise test conditions, the effect of the control winding voltage and harmonic voltage to the rectifier

4The Compensation Method for Temperature Rise Test of single-phase MCR

Based on the IEC standards, there is no MCR temperature-rise standard definition. But from the IEC60076-2 standard oil type transformer temperature-rise test for significance: to ensure the transformer / reactor operates at a nominal state oil average winding temperature and the temperature does not exceed the IEC standard requirements, means the power equipment pass the test.

It should be introduced that MCR temperature -rise test on single-phase power-up sequence: power winding load, applied control winding to excitation current ,when the rated excitation current reached, the power winding applied to voltage, when the rated current reach ,stop the high voltage winding voltage and start the temperature-rise test timing.

However, as described in Article 3.2, with the power winding voltage of the application process, the impedance is changing, and this has led to a fixed-capacity capacitor could not follow MCR impedance change process.

The MCR nonlinear impedance limit the temperature-rise test. If we can guarantee MCR impedance range is limited, the inductive reactive power should be always higher than the capacitive reactive power, can make the temperature-rise test carried out smoothly. Therefore, the mothed is feasible to increase in the compensation side suitable impedance, this method can not only protect the MCR’ s core saturation impedance will not change dramatically, but also can ensure the compensation winding be assessment by the temperature-rise test.

Figure 5 the equivalent circuit diagram of magnetic controllable Reactor

Fig 4 is the equivalent circuit diagram of the magnetic controllable reactor. The compensating impedance of 75 mH is connected to both ends of the compensating winding, and the excitation current is adjusted in the range of 1400 A to 2000A. Each simulation excitation current is increased by 100 A. After the excitation current is stable, the voltage of the grid side is started and the simulation test is carried out.

Figure6 the simulation model of magnetic controllable reactor based on PSCAD

Figure 7 simulation curves of excitation current at 1400A

Table 1 the effect of excitation current on grid measurement impedance

Excitation current (A)	Voltage of control winding to earth (V)	Variation range of impedance measured by grid side (Ω)	Impedance Change Value of grid side
1400	90	1296-1336	40
1500	95	1296-1330	34
1600	100	1296-1324	28
1700	110	1296-1317	21
1800	110	1296-1310	14
1900	110	1296-1303	7
2000	110	1296-1299	3

Based on this approach, the author uses the PSCAD simulation, simulation results are as follows:

Figure 8 Control winding voltage and voltage to earth

Figure 9 Control winding voltage harmonic analysis

Figure 8 and Figure 9 is the data, which the author use the software of PSCAD to simulate. The high voltage reaches the rated current work status, the status satisfied to the temperature-rise test. The control winding voltage amplitude and harmonics of voltage wouldn't be hazards to the rectifier, meet the test requirements.

According to the above compensation method, the temperature rise test of 750 kV magnetic controllable reactor was carried out in the factory, and the temperature rise test was carried out successfully. The test curves are as follows:

Figure 10 Measured control winding voltage and voltage to earth

Figure 11 Control winding voltage harmonic analysis

5. Conclusion

The results of simulation prove the compensation method is effective for solving the risks of temperature-rise test, and ensuring the smooth progress of the test. The simulations also verified by experiments magnetic

controllable reactor characteristic impedance variations and harmonic levels.

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