On-site AC Dielectric Test of UHV Reactors

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Abstract: The AC dielectric test is the most direct and effective method to examine the insulation performance of electric equipment. The paper presents an AC dielectric test, which is conducted at 1000kV Nanyang station for UHV reactors via the method of series resonance. The test frequency can be limited within the range of 45-65Hz by proper combination of compensation capacitors and reactors. The test needs less equipment and lower power capacity, which is suitable for on-site AC dielectric test.

Key words: UHV, reactor, AC dielectric test

Introduction

Both GB 50150-2006 Electric Equipment Installation Engineering - Standard for Hand-Over Test of Electric Equipment and DL/T 596-1996 Preventive Test Code for Electric Power Equipment stipulate the method and voltage value of AC dielectric test for reactor. There are 7 UHV reactors installed at the 1000kV Nanyang switch-gear station. In order to examine the insulation performance of these reactors, an AC dielectric test was conducted.

1. UHV Reactor Brief

The main parameters of AC transmission line include series resistance, series reactance, parallel capacitance and conductance. When the AC transmission line transmits the power, the current on the serial reactor lags behind the voltage and series reactor absorbs reactive power; the voltage on the parallel capacitance lags behind the current and the parallel capacitance sends out reactive power. When the reactive power that AC transmission line sends out is equal to absorbed one, the line transmission power is its natural power and voltage amplitudes along the line are the same; when the transmission power of line is less than natural power, the reactive power the line sends out is greater than absorbed reactive power and the voltage amplitude of line tail is higher than head; when the transmission power is more than natural power, the reactive power the line sends out is less than absorbed reactive power and the voltage amplitude of tail is lower than head.

One distinguishing feature of UHV transmission line is that the reactive power produced by line capacitance is great. Take 100km UHV line as an example. Its reactive power can be up to 400-500Mvar at 1000kV rated voltage and 1100kV maximum running voltage, 5 times than 500kV line. Therefore, if the AC UHV transmission line transmits small

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power, the reactive power generated by parallel capacitance is greater than that consumed by series reactor; the voltage rises, posing a threat to the safety of equipment and system. In order to keep the reactive power of UHV transmission line balanced, especially voltage rising and power frequency overvoltage, it is necessary to install the fixed UHV parallel reactor at the sending terminal and receiving terminal or either terminal to perform reactive compensation. The UHV parallel reactor can absorb the reactive power and reduce the residual reactive power and limit the power frequency overcurrent under light load condition.

Compared with common HV parallel reactor, the insulation of UHV reactor has the following characteristics: ① The running voltage is high. To reduce the dimensions of equipment and cut production cost, the UHV system lowers the level of overcurrent and insulation level of test equipment through using the arrester with large capacity and high performance. The ratio of operating voltage to test level increases in comparison with UHV. ② The significance of equipment improves. The capacity of UHV line transmission reaches 3000MW and the insulation fault of UHV reactor will directly cause the whole line not to transmit the load. ③ The dimensions of equipment are great. Some factors, such as increasing size of UHV reactor, stray capacitance and partial heating pose a threat to stable operation of insulation. In view of these characteristics, there is a need to carry out the insulation test upon the installation of UHV reactor.

2. AC Dielectric Test

The AC dielectric test is the most effective and strictest method of testing the capability of test object insulation to withstand all kinds of overvoltage. It is of great significance to ensure safe operation of equipment.

The AC dielectric test's voltage, waveform, frequency and voltage distribution conform to actual operating conditions. The insulation defect can be effectively found.

The wiring of on-site AC dielectric test is determined by the requirement of test object (voltage and capacity) and available test equipment. The test object with large capacity should match with large test equipment and power supply. However, it is difficult to do that on site. In such case, the method of series, parallel resonance or series & parallel resonance is used to fix the problem of not enough capacity based on actual situation.

2.1 Series resonance method (voltage resonance)

When the rated voltage of test transformer cannot meet the needed test voltage but the current does, the method of series resonance can be utilized to fix the problem. The wiring of series resonance is shown in Fig.1.

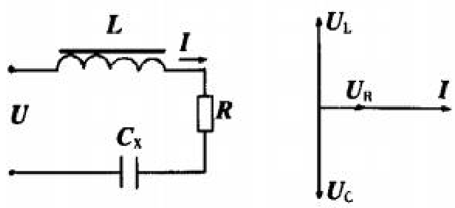

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Fig.1 Wiring of series resonance

The voltage of test object Cx is determined by the current in the test circuit and its value can be many times higher than output voltage. Hence the target voltage can be obtained via this method.

There are two advantages: ① if the breakdown by test object occurs, the resonance terminates and high voltage disappears; ② After the breakdown, the current reduces and as a result, the breakdown points of test object do not expand.

2.2 Parallel resonance method (current resonance)

When the rated voltage of test transformer can meet the needed test voltage but the current does not, the parallel resonance can be utilized to compensate for the current. The wiring of parallel resonance is shown in Fig.2.

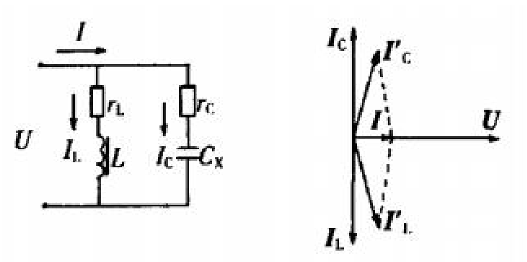

Fig.2 Wiring of parallel resonance

The inductive reactance is represented by X_L while X_C for capacitive reactance. When $X_L = X_C$, the circuit generates the resonance. At this time, the two branch current is high, but the total current I≈0 and the voltage on the X_C is equal to the voltage of power source. In fact, there is the loss of resistance and iron core so the circuit current is not likely to be equal to zero.

2.3 Series & Parallel resonance method

When the rated voltage and current of test transformer do not meet the requirements, the series and parallel resonance method can be used. Its wiring is shown in Fig.3.

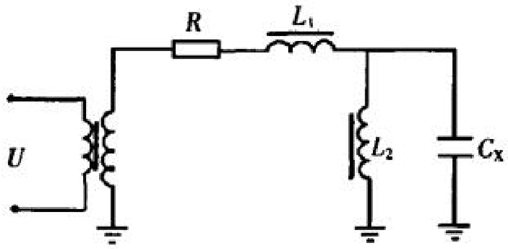

Fig.3 Wiring of series and parallel resonance

During the AC dielectric test, the measurement of test voltage includes: ① at the LV side of test transformer ② use voltage transformer ③ use the HV static voltmeter ④ use the capacitive voltage divider. At present, the method used at site is to use the capacitive voltage divider to measure. The structure of this kind of voltage divider is simple; it is easy to carry and the accuracy is high.

The breakdown voltage of insulation decreases as the time increases. Therefore, the AC withstand voltage time is 1min. There are two reasons for that. On the one hand, it facilitates observing the test object and exposing the insulation with weakness; on the other hand, the time is not too long so that the breakdown of insulation is avoided.

3. On-site AC Dielectric Test of UHV Reactor

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The Henan Electric Test Research Institute carried out the AC dielectric test for 7 reactors at 1000kV Nanyang UHV station. The method of series resonance is adopted in the test and test frequency is adjusted to 50Hz or so.

3.1 Calculation of test frequency and selection of test equipment

The wiring of AC dielectric test for UHV reactor is shown in Fig.4. By adopting the principle of series resonance, it uses exciting transformer to excite the circuit of series resonance; adjusting the output frequency of variable frequency power cabinet makes the inductance and capacitance in the circuit series resonance; the resonant voltage is the applied voltage on the test object. The resonant frequency of circuit depends on the inductance of test reactor and the capacitance of test object. The AC dielectric test requires 45-65Hz power frequency.

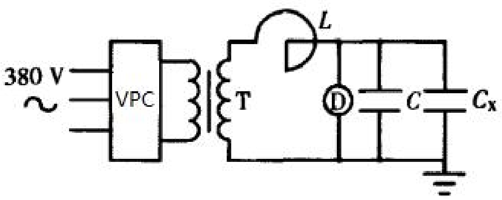

Fig.4 Wiring of AC dielectric test for UHV reactor

Cx - Test object equivalent grounding capacitance

L - Test reactor

C - Compensation capacitor

D - Capacitive voltage divider

T - Exciting transformer

VPC - Variable frequency power cabinet

The calculation of test frequency is as follows:

Cx -- 6100pF

C -- 2500pF

L -- 200H

When one section of test reactor is directly in series with reactor equivalent grounding capacitance, the resonant frequency of circuit is:

$$f=\frac{1}{2\pi\sqrt{LC}}=\frac{1}{2\pi\sqrt{L\times(C_x+C)}}=\frac{1}{2\times3.14\sqrt{200\times(6100+2500)}\times10^{-12}}=121.4Hz$$

The result is not within 45-65Hz. In order to make the resonance frequency fall within the range, available test equipment is combined and resonance frequency of circuit is calculated respectively. Finally, it is found that two sections of 200H test reactors in series and four sections of 4000pF compensation capacitors and reactor equivalent grounding capacitance in parallel can make the resonance frequency fall within the range. The circuit inductance L = 200×2 = 400H. The capacitance is the sum of UHV reactor equivalent grounding capacitance, compensation capacitor and capacitive voltage divider, namely, C=6100+4000×3+2500=24600pF.

$$f=\frac{1}{2\pi\sqrt{LC}}=\frac{1}{2\times3.14\sqrt{400\times24600\times10^{-12}}}=50.7Hz$$

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3.2 Test procedure and results

Only other routine tests are conducted and test results are qualified can the AC dielectric test be carried out. The stewing time of UHV reactor should be more than 96h during the test. Before the test, two secondary windings of bushing current transformer are short-circuit grounded. Procedures are as follows:

(1) Before test, use the megger to measure the winding insulation of UHV reactor to confirm whether the winding insulation is normal;

(2) Wiring according to the diagram; after short circuit to head and tail terminal of reactor winding, apply the AC voltage to the ground directly to conduct the test;

(3) Boost the voltage from zero and do not impulse switch-on. There is no limit to the speed within 40% of test voltage and afterwards boost the voltage in a constant speed and the speed is 3% of test voltage per second;

(4) The test voltage is 80% of applied withstand voltage value (184kV) and the test time is 1min;

(5) After the test is over, reduces the voltage to zero; change the wiring after disconnecting the power supply;

(6) Use the megger to measure the winding insulation of UHV reactor. If the insulation resistance after the dielectric test falls by 30%, it means that the reactor fails to pass the AC dielectric test.

During the process of test, if the humidity, temperature and surface dirt cause the reactor surface to flash discharge or air discharge, it does not mean that the reactor is not qualified. After the reactor is cleaned and dried, then the test is conducted.

The AC dielectric test is conducted for 7 UHV reactors on site. Test frequency is 50.4Hz while the input current of variable frequency cabinet is 70A. All reactors pass the AC dielectric test one time and the performance of UHV reactor insulation is good.

4. Conclusions

(1) The seven UHV reactors pass the AC dielectric test one time, which indicates that the first batch of UHV reactors developed by China has good insulation performance.

(2) The method of series resonance is used to conduct the AC dielectric test for UHV reactor. It needs not so many equipment and the requirement for power capacity is low, which is applicable to be used on site.

(3) The reasonable combination of compensation capacitor and reactor can make the test frequency fall within the range of 45-65Hz power frequency, which meets the requirement of test.

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