Long-time Induced Overvoltage Withstand Test of 800kV Step-up Transformer of Laxiwa Hydropower Station

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Abstract: The variable frequency method is used to carry out the long-time induced overvoltage withstand test of Laxiwa 800kV Step-up transformer. The test conditions, selection of main test equipment and measures against interference are studied in the paper, which provides reference for other transformer tests with 800kV or higher voltage class.

Key words: Power transformer, long-time induced over-voltage withstand test, variable frequency method, Laxiwa hydropower station

The Laxiwa hydropower station is the station with largest installed capacity along Yellow River basin, even in the north of China now. The low voltage side voltage of its 800kV step-up transformer (260MVA single-phase double-winding transformer) is 18kV; its turn ratio is the largest among the 750kV-stage transformer; besides, low-voltage winding to ground capacitance is greater 1.3 times than that of 750kV step-down transformer. Estimation of main parameters of long-time induced overvoltage withstand test for 800kV step-up transformer; selection of test equipment and anti-interference measures are studied in the paper based on characteristics of 800kV step-up transformer. Besides, problems occurring during the test are analyzed and summarized.

1. Selection of Test Equipment and Parameter Calculation

1.1 Test equipment

The 800kV step-up transformer test of Laxiwa hydropower station adopts variable resonant test system without PD, which is mainly composed of variable frequency power supply, exciting middle transformer and compensation reactor. The test system is characterized by small volume, flexible wiring mode and low requirement for power supply capacity. Now, the whole set of equipment is mostly used to conduct long-time induced overvoltage withstand test. Main parameters of test system is shown in Tab.1.

Tab.1 Main parameters

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Rated capacity/MVA</th>
<th>Rated input voltage/kV</th>
<th>Rated output voltage/kV</th>
<th>Rated output frequency/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable cabinet without PD</td>
<td>400</td>
<td>0.38±10%</td>
<td>0-0.35</td>
<td>20-300</td>
</tr>
<tr>
<td>ET without PD</td>
<td>400</td>
<td>0.340-0.42</td>
<td>35x2/6x2</td>
<td>80-300</td>
</tr>
<tr>
<td>Compensation reactor</td>
<td>1H</td>
<td>400</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>4.2H</td>
<td>1320</td>
<td>66</td>
<td>66</td>
<td>45-300</td>
</tr>
<tr>
<td>7.4H</td>
<td>660</td>
<td>66</td>
<td>66</td>
<td>100-300</td>
</tr>
</tbody>
</table>
Exciting transformer low voltage 380V in parallel and high voltage 35kV in parallel; adopt inductance to compensate; two 4.2H compensation reactors, two 7.4H compensation reactors and one 1H compensation reactor are in parallel and then they are in parallel with exciting transformer high voltage side. The wiring of long-time induced overvoltage withstand test is shown in Fig.1.

![Fig.1 Wiring of long-time induced overvoltage withstand test](image)

1.2 Parameter Calculation

The 800kV step-up transformer of Laxiwa hydropower station is forced-oil water cooling double-winding transformer; the model is DSP-260000/800; rated voltage is (800/\(\sqrt{3}\))/18kV; no-load loss is 108.1kW. Prior to the test, suitable test frequency must be estimated. The capacity of testing transformer is large and high capacitive current will pass through test circuit during the test; however, reactive component of power supply capacity mainly depends on capacitive current of test object. Hence, it is necessary to adopt reactor parallel resonant compensation to make up for reactive capacity and minimize the needed power supply capacity.

The transformer HV - LV to ground capacitance is 16.3nF. Based on the experience, the lumped parameter of entrance capacitance is 16.3/7=2.32nF.

The transformer ratio represented by the letter k = (800/\(\sqrt{3}\))/18=25.66; high-voltage side capacitance is converted to low voltage side capacitance \(2.32k^2 = 2.32 \times 25.66^2 = 1527.6\)nF. Then based on parameters of selected reactor, we can calculate the resonant frequency of variable frequency power supply f = \((1/2\pi) \sqrt{LC} = (1/2\pi) \sqrt{1527.6.57 \times 10^{-9}} = 169.6\)Hz.

The current of compensation reactor can be calculated according to the formula: \(I=U/(2\pi\times f\times L)\)

4.2H reactor current \(I_L=6.0A\)

7.4H reactor current \(I_L=3.4A\)

1H reactor current \(I_L=25.4A\)

The no-load loss of power transformer can be calculated according to the formula \(P_0=\infty f^{1.6}\times B_m^2\).

\(B_m\infty U/f,\) low voltage side of testing transformer is \(1.5U_m/\sqrt{3}\) (\(U_m\) is the highest working voltage of equipment). The voltage is 27kV. Hence, when the test frequency is 169.6Hz, \(P_{169.6} / P_{50}=(169.6/50)^{1.6} \times (B_{169.6}/B_{50})^2,\) namely, \(P_{169.6}=(169.6/50)^{1.6} \times (\frac{27\times 50}{18\times 169.6})^2 \times 118=162.9kW.\) In the formula, \(P_{50}, P_{169.6}\) is the no-load loss when the rated voltage is 18kV; rated frequency is 50Hz and test voltage is 27kV and...
test frequency is 169.6Hz.

According to no-load loss at test frequency (169.6Hz), the active power current of low voltage side is \( I = \frac{P_{169.6}}{U_{\text{max}}} = \frac{162.9}{27} = 6.03 \text{A} \).

At that time, output side current of variable frequency cabinet is 6.03×83.33=502.5A. However, the relationship between output current and input current is \( I_0=1.414I_p \) that is, 502.5/1.414=355.4A. Therefore, proper power supply and cable can be selected according to the estimation.

2. Problems and Solutions

(1) When conducting the test for one of power transformer, raise the voltage to \( 1.5U_m/\sqrt{3} \) and then last 3min; there is a sudden increase in the quantity of partial discharge. The oil is spurted into the air from the pile head of 1H reactor terminal. The test data conforms to the standards after changing the reactor: The current of 1H reactor has been close to rated current 30A during the test and the reactor contact has loosened, causing a spurt of oil. Consequently, it is suggested that the infrared thermometer and clip-on ammeter be used to monitor the temperature and current of test equipment and key points, especially the reactor.

(2) When conducting the test for second transformer, it is found that it is impossible to raise the voltage to \( 1.7U_m/\sqrt{3} \); variable frequency cabinet output has been close to saturation if the voltage is \( 1.5U_m/\sqrt{3} \); the problem is solved by virtue of connecting one cable to power supply cable phases in parallel. Therefore, the selection of power supply cable should be based on estimated current and great margin remains. The cable should not be long; otherwise, the input side voltage of power supply point is not consistent with that of variable frequency cabinet.

(3) When conducting the phase-C main transformer, the quantity of partial discharge at \( 1.5U_m/\sqrt{3} \) is 280pC; then last for 10mins and the quantity of partial discharge increases slowly; when the time reaches 25min, the quantity of partial discharge grows to 550pC; impulse signals with different amplitudes appear in the first and third quadrants; the numbers is growing slowly and the amplitude increases. Based on waveform analysis, it is determined that this situation is not indicative of internal discharge of power transformer. Meanwhile, it is found that there is an obvious rise in 1H reactor temperature. It is believed that the temperature of oil-immersed reactor rises as a result of high test current after phase B main transformer test; when the temperature is not cold, the phase C main transformer test is continuing so that the temperature of reactor obviously rises during the test, causing an increase in the quantity of partial discharge. The next day another test is conducted for the phase C main transformer and the test data meets the requirements.

3. Anti-interference Measures
(1) Dismantle scaffolds around testing transformer; ground all metallic components reliably which cannot be dismantled to ensure no floating potential.

(2) Variable frequency cabinet, step-up transformer, test instrument and compensation reactor should be grounded to one exclusive grounding point under the bottom of main transformer. In other words, the test system is one point grounding without grounding loop.

(3) Separate test power supply from construction site power supply; prior to the test, dust bushing and force the air out of bushing hoist seat; ensure no communication tools such as two-way radio around the site.

(4) All connection wires in the test shall adopt those with sufficient section areas. The aluminum foil busbar is applied in this test.

(5) There is the interference on the construction site before power on due to environment complexity; if welding machine, cutting machine and crane are closed, the interference lessens; however, it still cannot meet the requirements of test; through negotiation, all agrees that the test should be conducted at night.

4. Conclusions

The method of using variable frequency power supply as test power supply rather than other methods can meet the requirements of 750kV induced overvoltage withstand test. The step-up transformer of Laxiwa hydropower station has large capacity; the transformer ratio is great and the test environment is poor; so it is important to select test equipment and take anti-interference measures. For example, proper inductance should be selected for parallel reactor.