

# High-Voltage Test Technology and Fault Handling of Power Transformers

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## Abstract

**High-voltage tests are critical in the handover and maintenance of substations, which can detect the insulation strength of transformers, identify potential faults, and ensure the normal operation and safety of transformers. High-voltage test technology for power transformers refers to testing power transformers under certain high voltage to verify whether their insulation performance meets requirements, discover hidden troubles, and take corresponding treatment measures. This technology can effectively guarantee the quality and reliability of power transformers and improve their operation efficiency and safety. This paper analyzes and discusses high-voltage test technology and fault handling of power transformers.**

## Keywords

**Power Transformer; High-Voltage Test; Insulation Performance; Fault Handling; Operation Efficiency.**

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## 1. Introduction

As important core equipment in modern power systems, power transformers serve as the "heart" of power transmission and distribution, undertaking the crucial task of voltage conversion, energy transmission and power distribution between different voltage levels. They are widely used in various links of power systems, from large-scale power plants and substations to industrial and mining enterprises, urban and rural power supply networks, and even household power consumption, directly determining the stability, efficiency and safety of the entire power supply system. With the continuous development and upgrading of power systems in recent years, driven by the rapid advancement of smart grid construction, renewable energy integration (such as wind power and photovoltaic power), and the increasing demand for high-quality power supply in social production and people's lives, the performance requirements for power transformers have been gradually raised to a higher level. Specifically, these requirements include higher operation efficiency to reduce energy loss during long-distance power transmission, lower energy consumption to conform to the global low-carbon development trend, better operational reliability to avoid sudden failures that may cause large-scale power outages, and stronger adaptability to cope with complex and changeable operating environments [1].

However, in the long-term process of production, transportation, installation and operation of power transformers, they are often affected by various internal and external factors, which may lead to insulation degradation, component damage or even serious faults. Internally, factors such as gradual aging of insulation materials (including oil-paper insulation, rubber insulation, etc.) under long-term electrical stress and thermal stress, manufacturing defects in core and winding during production, and

uneven distribution of internal electric fields will damage the insulation performance of transformers. Externally, environmental pollution (such as industrial waste gas, dust, chemical pollutants, and salt spray in coastal areas) will corrode the external insulation structure and shell of transformers; extreme weather conditions (such as high temperature, severe cold, thunderstorm, and lightning) will impact the stable operation of transformers; in addition, human errors in operation, improper maintenance, and lack of regular inspection during the operation process may also induce potential faults. Once insulation degradation or faults occur in power transformers, it will not only affect the normal operation of the transformers themselves, leading to equipment damage and economic losses, but also may cause cascading failures in the power system, resulting in large-scale power outages, which will bring serious impacts on industrial production, social order and people's daily lives.

To detect and solve these potential problems in a timely and effective manner, prevent the occurrence of major faults, and ensure the safe, stable and efficient long-term operation of power transformers, high-voltage test technology has been widely applied in the inspection, maintenance and fault diagnosis of power transformers. This technology uses professional test equipment and scientific test methods to simulate various working conditions of transformers under high-voltage environment, detect key performance indicators such as insulation resistance, dielectric loss, partial discharge, and breakdown voltage of transformers, and accurately identify potential insulation defects and early fault signs. Through high-voltage tests, relevant personnel can grasp the actual operating status of power transformers in real time, formulate targeted maintenance and maintenance plans, eliminate hidden dangers in the bud, extend the service life of transformers, and provide a strong technical guarantee for the safe and stable operation of the entire power system.

## **2. High-Voltage Test Methods for Power Transformers**

### **2.1 Winding Grounding Method**

The winding grounding method is one of the most widely used methods in high-voltage tests. In this method, the high-voltage winding is grounded and high voltage is applied to the low-voltage winding to detect whether the insulation performance of the transformer meets the required standards. This method can evaluate the insulation strength of the transformer through high-voltage tests on the low-voltage winding, so as to ensure the safety and reliability of the transformer [3].

Grounding fixes the potential of the high-voltage winding at the ground potential, preventing dangers to personnel and equipment. In addition, this method only needs to apply high voltage on the low-voltage side, avoiding excessive pressure on high-voltage equipment and reducing the cost of test equipment and maintenance. However, the winding grounding method is only applicable when the insulation strength of the high-voltage winding and the low-voltage winding is the same. Otherwise, other methods such as resonance method or series method should be adopted.

### **2.2 Inter-Winding Grounding Method**

The inter-winding grounding method is used to detect the insulation performance of transformer windings. In this method, the high-voltage winding and the low-voltage winding are grounded separately to judge the insulation strength between the two windings. Since the high-voltage and low-voltage windings usually have different insulation strengths, this method can accurately detect insulation problems in the winding with lower insulation strength.

During the test, if the results show that the low-voltage winding has insulation defects, repair or replacement is required to ensure the normal operation of the transformer.

### **2.3 Induced Withstand Voltage Test**

Induced withstand voltage technology for power transformers uses the induction method to carry out high-voltage tests and measure the insulation withstand capacity. This technology is generally used in transformer production and maintenance, which can effectively detect insulation performance and ensure safe operation [4].

The low-voltage side of the transformer is connected to the power supply, and the high-voltage side is tested by induced withstand voltage. High-frequency induction is used to transmit high-voltage signals to the windings through inductive coupling. A high-voltage generator and a high-voltage probe can be used to measure electrical parameters and evaluate the insulation capacity. For unqualified transformers, the insulation structure can be repaired or replaced.

#### **2.4 Series Resonance (Power-Frequency AC) Withstand Voltage Test**

The high-voltage test of power transformers is to verify whether the insulation system can withstand the electric field strength under rated voltage and whether there are defects in the insulation system. The series resonance withstand voltage test is a common high-voltage test method, which can carry out high voltage tests without damaging the tested equipment.

The steps include preparing test equipment, correct wiring, setting test parameters, slowly increasing voltage, maintaining for a period and then reducing to zero, and recording voltage, current, time and test results. Strict safety operation procedures must be followed during the test.

#### **2.5 Power-Frequency DC Withstand Voltage Test**

The power-frequency DC withstand voltage test is a commonly used method to test whether the transformer insulation system can bear the electric field strength under rated voltage and detect insulation defects.

The test voltage is 2.5 times the rated voltage plus 1 kV, and the test duration is 15 minutes. After the test, the test equipment and site should be cleaned up in time, and protective measures should be taken to avoid damage to personnel and equipment.

### **3. Test Items of High-Voltage Test Technology**

#### **3.1 Dielectric Loss Measurement Test**

Dielectric loss measurement is an important part of high-voltage tests. Dielectric loss refers to the sum of thermal loss caused by molecular oscillation and energy loss caused by charge movement under AC electric field. Measuring dielectric loss is an important index to evaluate the performance of insulation materials.

The steps include preparing test devices, preprocessing the transformer to stabilize temperature and eliminate residual charges, carrying out high-voltage tests, measuring dielectric loss values by a bridge method, and analyzing insulation performance. If the dielectric loss exceeds the standard, the transformer should be overhauled or the insulation materials should be replaced.

#### **3.2 Inspection and Test of On-Load Tap-Changer**

The on-load tap-changer is an important component that adjusts the output voltage in real time during operation to ensure stable and reliable voltage. The inspection and test items include:

- 1) Checking whether the wiring is correct and firm;
- 2) Inspecting whether the contacts and contactors are in good condition;
- 3) Checking the mechanical parts such as gear transmission and limit devices;
- 4) Testing the voltage regulation function;
- 5) Carrying out load switch tests with actual load.

### **4. Common Faults and Treatment Methods**

#### **4.1 Winding Short Circuit**

Winding short circuit usually results from insulation damage caused by long-term operation and aging. In high-voltage tests, short circuit will cause a sharp increase in current and a large amount of heat, which may damage the transformer or cause fire. Once found, the test should be stopped immediately, and the damaged winding should be repaired or replaced. Regular insulation tests and maintenance can reduce such faults.

## 4.2 Insulation Breakdown

Insulation breakdown means that the insulation layer is broken down and fails due to insufficient insulation strength or excessive test voltage, which will cause short circuit or arcing and irreversible damage. In case of insulation breakdown, the test should be stopped immediately, and the damaged insulation materials should be replaced. A comprehensive inspection should be carried out to ensure the safety and reliability of the equipment [1].

## 4.3 Equipment Failure

The reliability and stability of test equipment are crucial. Equipment failure may be caused by quality problems, improper use, overload, overheating, vibration or environmental factors. Once equipment failure is found, professional personnel must carry out maintenance or replacement. Preventive measures include selecting high-quality equipment, standard operation and regular maintenance.

## 4.4 Test Errors

Test results may be affected by errors due to limitations of equipment and test conditions. To avoid errors, test equipment with high precision and reliability should be selected and calibrated regularly. Test conditions such as voltage, time, temperature and humidity should be controlled in accordance with standards. Test personnel should be professionally trained and operate in strict accordance with procedures [2].

## 4.5 Automatic Tripping

Automatic tripping during high-voltage tests may be caused by many reasons. If it is caused by improper operation, external inspection can be omitted. If it is caused by non-human factors, a comprehensive inspection must be carried out to prevent fires and other accidents. When a fire accident occurs, the automatic protection mechanism will start the circuit breaker. If there is no automatic tripping mechanism, manual operation is required.

## 5. Conclusion

In summary, high-voltage test technology is an important method to detect whether the insulation performance of power transformers meets requirements. By applying high voltage to transformer windings and insulation structures, potential faults can be found. The test voltage is usually 2.5 or 3 times the rated voltage, and the test time is generally 1 minute or more. High-voltage tests are static tests without load connection.

Before the test, the transformer should be pre-tested and pre-treated to ensure safety, accuracy and reliability. During the test, the stability and accuracy of test equipment should be maintained to avoid test errors.

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