Challenges and Solutions in the Commissioning of High-Voltage Power Transformer

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Abstract

This document serves as a pre-commissioning test report for a transformer with a rating of [KVA] and a voltage ratio of 11,000/433 V. It provides a comprehensive overview of the various tests conducted to ensure the transformer's readiness for operation. The tests included checks for oil leaks, air release, insulation resistance, temperature alarms, and trips, as well as ratio and magnetic balance tests. Additionally, the report outlines the process of clearing the transformer for charging. The transformer was successfully charged on a specified date and time and was initially kept on no-load before being fully integrated into the system. This paper highlights the adherence to standard testing procedures, ensuring the reliable and safe operation of the transformer.

Keywords: Pre-commissioning, transformer, kVA, 11,000/433V, oil leaks, insulation, temperature alarms, ratio test, magnetic balance, charging, no-load, air release, electrical grid, safety, performance.

I. INTRODUCTION

Transformers play a critical role in electrical power distribution networks by converting voltage levels to ensure efficient transmission and distribution of electricity. They are designed to either step up or step down the voltage to appropriate levels, facilitating the safe and efficient supply of power from generation sources to end-users. Before a transformer can be fully integrated into the power grid, it must undergo a series of rigorous tests to verify its functionality, safety, and reliability. This process is known as pre-commissioning, and it involves a range of inspections and evaluations to ensure the transformer operates correctly under various conditions.

This document provides a detailed pre-commissioning test report for a transformer with a specified kVA rating and a voltage ratio of 11,000V to 433V. The pre-commissioning phase is a critical step in the deployment of transformers, as it helps to identify and resolve potential issues before the transformer is energized and connected to the load. It includes essential tests such as checks for oil leaks, air release, insulation resistance, temperature alarms and trips, and the performance of ratio and magnetic balance tests. This paper aims to provide a comprehensive overview of these tests, their significance, and the results, ensuring that the transformer is fit for service. Pre-commissioning tests are essential for ensuring that transformers meet the required operational standards and can safely function within the electrical grid.

These tests serve several key purposes:

1. **Verification of Specifications**: During manufacturing, transformers are built to meet certain specifications. Pre-commissioning tests help verify that the transformer meets these specifications, including its voltage ratio, kVA rating, insulation properties, and other critical parameters. By confirming these specifications, the tests ensure that the transformer will perform as expected once it is connected to the grid.
2. **Ensuring Safety**: Safety is a paramount concern in electrical installations. Pre-commissioning tests help identify any defects or issues that could pose safety hazards, such as insulation failures, improper grounding, or oil leaks. Addressing these issues before the transformer is energized prevents potential accidents, equipment damage, or even fires.
3. **Preventing Operational Failures**: Transformers are long-term investments that should operate reliably for many years. Pre-commissioning tests help detect potential faults or weaknesses that could lead to

operational failures. By identifying these problems early, corrective actions can be taken to ensure the longevity and efficiency of the transformer.

4. **Enhancing Efficiency**: Transformers are critical components in the efficient transmission and distribution of electricity. Pre-commissioning tests, such as the ratio test and magnetic balance test, help ensure that the transformer operates at optimal efficiency. Efficient transformers reduce energy losses, which is essential for minimizing costs and maximizing the performance of the power grid.

II. TECHNICAL BACKGROUND

Transformers are essential components in electrical power distribution systems, designed to transfer electrical energy between circuits by varying voltage levels. They operate on the principle of electromagnetic induction, allowing for efficient transmission of electricity over long distances by stepping up or stepping down the voltage. In a typical power distribution network, transformers are used to increase voltage levels for transmission (reducing energy loss) and decrease voltage levels for safe distribution to homes, businesses, and industries. The functionality of a transformer revolves around its primary and secondary windings, which are wound around a magnetic core. When an alternating current (AC) flows through the primary winding, it generates a magnetic field, inducing a voltage in the secondary winding. The ratio of the windings determines the voltage transformation, making the voltage ratio a critical parameter. For example, a transformer with a ratio of 11,000V/433V is designed to step down the high-voltage supply to a safer, lower voltage suitable for distribution to consumers. Given the crucial role transformers play in power systems, ensuring their reliability and safety before integration is essential. This is where pre-commissioning tests come into play. These tests serve to confirm that the transformer is in proper working condition, adheres to design specifications, and is free from defects that could lead to operational failures or safety hazards. Comprehensive testing reduces the risk of faults, minimizes maintenance costs, and ensures the smooth operation of the power distribution network.

Insulation is one of the most critical components in a transformer, providing a barrier that prevents electrical currents from passing between different parts of the system, such as between windings or between the windings and the core. Proper insulation is necessary to prevent electrical shorts, which can lead to equipment damage, failures, and safety risks. Insulation resistance tests during pre-commissioning measure the quality of the insulation, ensuring it is within acceptable limits. Low insulation resistance may indicate moisture presence, contamination, or deterioration, all of which could compromise the safety and efficiency of the transformer.

Oil levels in transformers are equally important. Transformer oil serves as both an insulator and a coolant, helping to dissipate heat generated during operation. Proper oil levels are essential for maintaining optimal temperature control and preventing overheating, which could lead to insulation breakdown or other failures. During pre-commissioning, visual inspections and oil quality tests help detect leaks or signs of oil degradation. These checks ensure that the oil can effectively perform its dual role and that the transformer is adequately sealed against leaks.

The **voltage ratio** is another critical aspect of transformer operation. It dictates how the transformer converts high voltage to low voltage or vice versa. During pre-commissioning, ratio tests are conducted to verify that the transformer’s windings are correctly configured, and that the output matches the specified ratio. A discrepancy in the voltage ratio can indicate incorrect winding connections, damaged windings, or manufacturing defects, which must be addressed before the transformer can be safely energized.

Lastly, **magnetic balance** is tested to assess the integrity of the transformer’s core and windings. The core is the component that carries the magnetic flux, which is essential for the voltage transformation process. The magnetic balance test checks for uniform distribution of the magnetic field within the core, ensuring that there are no irregularities. An imbalance may indicate issues such as core displacement, winding faults, or short circuits, all of which could lead to inefficient performance or failures during operation.

In summary, transformers are vital for the efficient and safe transmission of electricity across vast distances and various voltage levels. However, their effective operation relies on proper insulation, oil levels, voltage ratio accuracy, and magnetic balance. Pre-commissioning tests ensure that each of these parameters meets industry standards, guaranteeing the transformer’s readiness for service. These tests help in identifying and addressing any potential issues before the transformer is connected to the grid, thus preventing disruptions in power supply, reducing maintenance costs, and prolonging the equipment’s lifespan.

III. STATEMENT OF THE PROBLEM

The reliability and safety of electrical power distribution systems heavily depend on the proper functioning of transformers. Prior to commissioning, it is essential to conduct comprehensive testing to ensure transformers are free from defects that could lead to inefficiencies, failures, or safety hazards. This document addresses the need for thorough pre-commissioning tests on a transformer with a rating of kVA and a voltage ratio of 11,000/433V.

Without these tests, issues such as oil leaks, insulation breakdowns, improper temperature regulation, or incorrect voltage transformation could compromise the transformer's performance, leading to potential disruptions in power supply and increased maintenance costs. The report details various tests, including checks for oil leaks, air release, insulation resistance, temperature alarms, ratio and magnetic balance, and confirms the transformer’s readiness for safe and efficient operation. This testing ensures that the transformer meets industry standards and is fit for integration into the power grid. By documenting these procedures and observations, the report aims to prevent unforeseen operational issues and extend the equipment's lifespan, enhancing overall system reliability.

IV. TEST METHODOLOGY

The pre-commissioning test of a transformer is a comprehensive procedure aimed at ensuring the equipment’s safety, reliability, and operational readiness before it is connected to the power grid. For a transformer with a rating of kVA and a voltage ratio of 11,000/433V, the following detailed tests were conducted as part of the pre-commissioning process:

1. *Visual Inspection:* Identify any visible signs of defects or damage. The transformer was inspected for external damages such as dents, cracks, or misaligned components. Special attention was paid to the bushings, terminals, and protective devices. Checks were performed to ensure that all fastenings were secure, and no parts were missing or improperly assembled. Detection of physical anomalies that might compromise safety or performance.

2. *Check for Oil Leaks and Oil Level Verification*: Confirm the integrity of the oil containment and verify the adequate oil level. The transformer oil level was checked using the oil gauge, and a visual inspection was conducted to detect any potential oil leaks around the gaskets, seals, and joints. The oil should be free from contaminants and at the correct level to ensure effective cooling and insulation. Ensures there are no leaks that could lead to insulation failure or overheating, confirming the system's proper sealing.

3. *Air Release:* Remove any trapped air from the transformer. Air release valves were opened to allow any trapped air within the oil to escape. This is crucial because trapped air can lead to partial discharge or reduced cooling efficiency. Elimination of air pockets, ensuring the efficiency of cooling and insulation.

4. *Insulation Resistance Testing:* Verify the insulation integrity between different components of the transformer. Insulation resistance tests were conducted using a megger between the primary winding to earth, secondary winding to earth, and between primary and secondary windings. The insulation resistance values were compared to acceptable industry standards. High insulation resistance indicates good insulation, while low resistance could signal the presence of moisture, contamination, or insulation degradation.

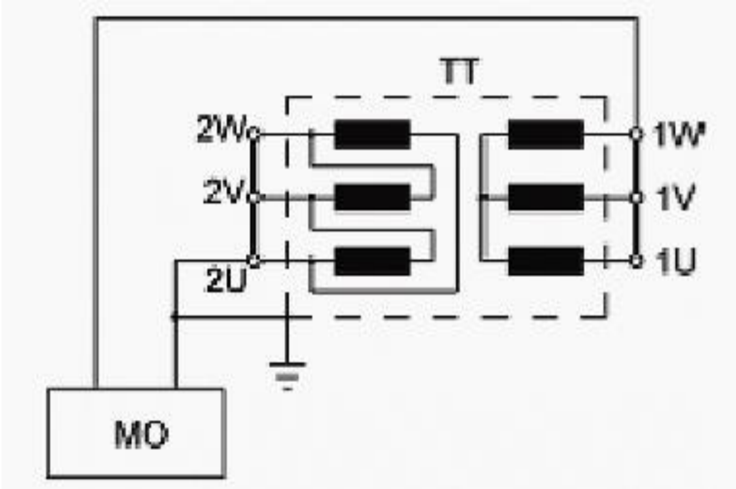

Figure 1. Circuit for measuring the insulation resistance

5. *Temperature Alarms and Trip Tests:* Ensure the correct functioning of temperature monitoring and protective devices. The transformer was equipped with temperature sensors and thermal protection devices. These systems were tested by simulating high-temperature conditions to check if alarms triggered at preset thresholds and if the transformer would shut down (trip) if the temperature continued to rise beyond safe limits. Verify that the temperature protection systems are operational, safeguarding the transformer against overheating.

6. *Ratio Test*: Confirm the accuracy of the voltage transformation ratio. A ratio meter was used to measure the voltage ratio of the transformer windings (primary to secondary). The measured ratio was compared to the rated voltage ratio of 11,000V/433V to confirm accuracy. This test also helps detect any issues with winding connections or turns ratios. Ensures that the transformer will provide the correct output voltage, crucial for proper operation.

Turns ratio = HV winding voltage / LV winding voltage
% Deviation = 100 * ((Measured TR) – (Designed TR)) / (Designed TR)
Where TR is turn ratio. The % deviation of the turn ratios should be ≤ 0.5 %**.**

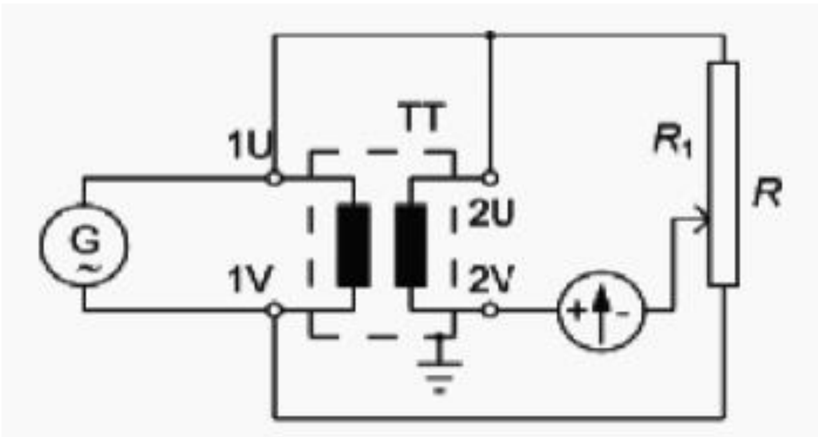

Figure 2. Circuit for the ratio measurement

7. *Magnetic Balance Test:* Assess the condition of the magnetic core and windings. Voltage was applied to one phase of the transformer, and the induced voltages on the other phases were measured. This test checks the magnetic circuit for any imbalance that might indicate winding short circuits or core issues. Confirmation of the magnetic symmetry of the core, which is essential for efficient and stable transformer operation. Any imbalance could indicate core damage or winding faults.

8. Functional Tests of Protective Devices: Verify the operation of protective relays and circuit breakers associated with the transformer. The relays were tested by simulating faults (such as overcurrent or earth faults) to check if they would respond appropriately by tripping the circuit breakers. The settings of these devices were checked and adjusted as per the system requirements. Ensures that the protective devices will function correctly during fault conditions, preventing damage to the transformer and other equipment.

9. Clearing the Transformer for Charging: Prepare the transformer to be energization by ensuring all parameters are within safe limits. After all the above tests, a final inspection was performed. The transformer was checked to ensure there were no loose connections, improper settings, or physical obstructions. The external connections were re-examined, and earthing was verified to be intact. Confirmed that the transformer was ready for safe energization without any risk of faults.

10. Charging and No-Load Operation: Gradually energize the transformer and observe its behavior under no-load conditions. The transformer was initially charged by connecting it to the power source. It was kept under no-load operation, and the system was monitored for any unusual noises, vibrations, or temperature changes. Voltage and current readings were taken, and the values were compared to expected levels. The transformer operated smoothly, with no irregularities detected during the no-load test, confirming that it was ready to be put on load.

11. Load Test (Optional): Ensure the transformer can handle the expected load once put into service. If required, a load test can be conducted by applying a controlled load to the transformer. The system's performance, temperature rise, and efficiency were monitored. Confirmation that the transformer could handle the expected load without overheating or voltage drops.

The pre-commissioning test methodology for the transformer with a kVA rating at a voltage ratio of 11,000/433V is a multi-step process that involves both physical inspections and electrical tests. Each step is designed to ensure the equipment's reliability, efficiency, and safety before it is put into service. These tests help identify and rectify any issues, minimizing the risk of faults and ensuring a smooth transition into active operation.

V. CONCLUSION-DISCUSSION

The pre-commissioning tests for the transformer with a kVA rating and voltage ratio of 11,000/433V ensured its operational safety and reliability. Comprehensive checks, including insulation testing, oil level verification, temperature monitoring, and ratio/magnetic balance assessments, confirmed the transformer's readiness. After successful no-load operation, the transformer was deemed fit for service, minimizing potential risks during actual load conditions.

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