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On-site Tests on HV Power Transformers

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ABSTRACT

This paper presents a general view and description of the test setup, test equipment as well as tests performed on site, including HV withstand tests. A description of high voltage tests, including partial discharge monitoring and measurement, is also included. A short discussion on non-performed lightning and switching impulse tests is also presented.

Since 1992, on-site HV tests have been performed in more than 110 power transformers in South America ranging from 30MVA to 440MVA, 115kV to 765kV (AC) and 600kV (DC), helping large electric power utilities and industrial plants increase their business performance.

The results show that on-site tests, including high voltage tests, on high voltage power transformers is fully possible and reliable. It can be selected as a proven method for diagnosis and final acceptance of new and repaired or even refurbished power transformers.

KEYWORDS: Transformer, Power Transformer, Tests, Electrical Tests, On-site Tests, HV Tests.

1. INTRODUCTION

On-site tests on high voltage power transformers is of increasing interest as part of transformer commissioning, as a diagnostic tool for condition assessment and as an acceptance test just after transformer repair or refurbishment.

A power transformer is one of the most important and expensive pieces of equipment in electric power systems. Economic operation of electrical energy generation, transmission and distribution is closely related to power transformers' reliability and availability.

In the actual context of power system operation, on-site tests on power transformers is adding value to electrical systems operation, enabling electrical utilities and users efficient diagnosis or reliable acceptance of a transformer, supporting business optimization and adding quality to transformers submitted to on-site repair or refurbishment.

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2. ON-SITE TEST APPLICATION

As regards complex electrical equipment such as high voltage power transformers, internal insulation is subject to defects due to several reasons associated to bad material, design, manufacturing processes or resulting from shipment.

On-site electrical tests are for the test voltage to simulate on the transformer under testing the equivalent stresses which may be established during service condition.

Basically, electrical tests on power transformers are grouped in type and routine tests. The goal of a routine test is to check correct manufacture of HV insulation while the goal of a type test is to confirm correct design of HV insulation.

In addition, the application of on-site tests may be able to be separated in:

- commissioning tests: as part of the on-site equipment commissioning procedure in order to demonstrate that shipment and erection have not caused any new defects to HV insulation;
- on-site repair or refurbishment: as part of the repair or refurbishment procedure in order to demonstrate that repair or refurbishment have been successfully completed and HV insulation is free of dangerous defect; and
- diagnosis: as part of a diagnostic procedure in order to provide reference values to further tests or to confirm results obtained from other types of test.

Up to date, on-site high voltage withstand tests including partial discharge monitoring and measurements are the most significant tests in order to quantify HV insulation quality. The use of a separate HV source is more informative than measurement at normal operation voltage, as it allows investigation of the HV insulation performance with voltage.

Alternating voltages are most important for on-site tests [3]. Other voltage shapes for simulation of overvoltages have been used; however, they are strongly dependent on availability of on-site testing systems.

The application of HV on-site tests has been a good practice in South America. Since 1992, on-site HV tests have been performed in more than 110 power transformers ranging from 30MVA to 550MVA, 115kV to 765kV (AC) and 600kV (DC). Large electric power utilities and industrial plants are the main customers to this technology.

3. LV ON-SITE TESTS

Low voltage routine tests on power transformers have been carried out on site for many years as part of commissioning, repair, refurbishment and diagnostic processes.

The following LV tests are normally performed:

- insulation resistance (core and structure-core);
- polarity, phase angle displacement and phase sequence;
- voltage ratio;
- winding ohmic resistance;
- windings and core insulation resistance measurements (Megger test);
- windings insulation power factor and capacitances;
- condensing bushings capacitances and power factors;
- no-load losses and excitation current at 90%, 100% and 110% of rated voltage (AC separate source);
- load losses with reduced current (separate AC source); and

- short-circuit impedances.

In some cases, special on-site tests are also performed, namely:
- frequency response (FRA);
- infrared-scan; and
- acoustic emission and partial discharge location; and
- insulation characterization through RVM or dielectric spectrography.

4. HV ON-SITE TESTS

In recent years, several successful high voltage on-site tests have been reported as acceptance test of large EHV power transformers repaired on site [1].

As a natural extension, the same on-site testing technology has also been applied in many cases as an efficient diagnostic tool for large transformers where a fault has been detected by another means. More recently, the same technology has also been used as an acceptance test for new transformers after problematic factory-station shipment.

The following HV tests have been performed on site:
- AC applied voltage;
- longtime induced voltage (1 hour) with electrical and acoustic monitoring and measurement of Partial Discharges and voltage level up to 150% of rated voltage feed by a separate controllable source; and
- no-load energization with rated voltage during 24 hours with electrical and acoustic monitoring and measurement of Partial Discharges and voltage level up to 115% of rated voltage feed by a separate controllable source.

Electric tests are also normally monitored by means of oil sampling and corresponding analysis of dissolved gases.

Figure 1 shows de number of HV on-site tests performed in South America, mainly in Brazil, since 1992.

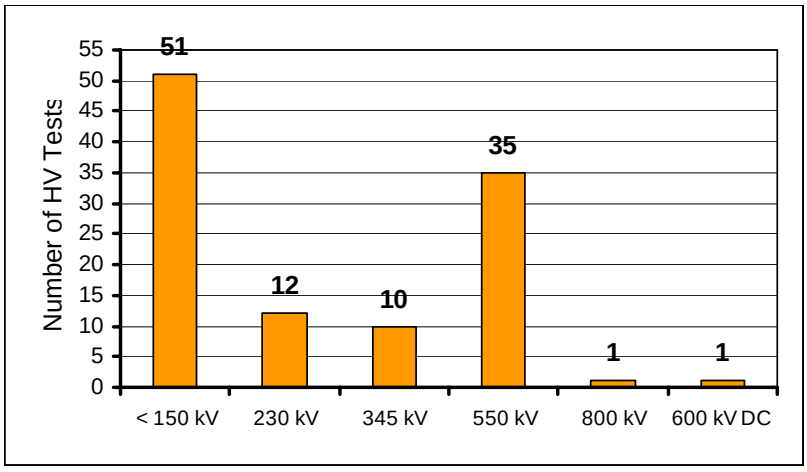

Figure 1 – HV On-site Tests (South America and Brazil – since 1992)

From the above, one may note that more than 110 units have undergone HV tests on site for several purposes. In the EHV range of 550kV and above more than 37 units have been already tested.

The numbers above reflect the confidence power utilities and industrial plants have in the application of on-site tests on their transformers whenever necessary. These numbers can also be used to complete the survey performed by CIGRE in 1994-1995, where the importance of on-site tests has been reduced [2].

5. HV ON-SITE TEST SETUP

To perform HV on-site tests, a complete set of mobile testing equipment is made available at field, including:

- variable frequency 60-240Hz motor-generator group. There are three motor-generator groups available: 300kVA, 850kVA and 2MVA. The proper group is selected according to transformer power and voltage;
- step-up and regulating transformers;
- reactive power compensating capacitors and reactors;
- no-load and load measuring system; and
- partial discharges measuring and monitoring system as per IEC60076-3 and IEC60270.

Figure 2 shows a general single-line diagram of the test setup connection normally used for HV power transformer on-site testing.

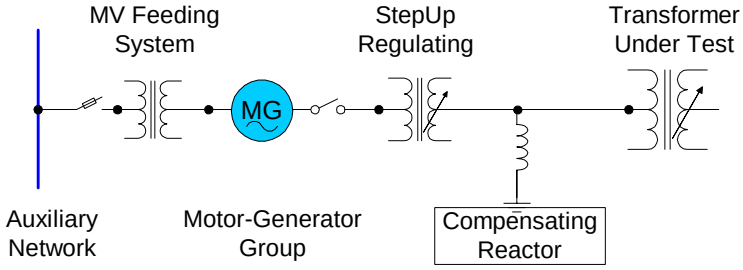

Figure 2 – Test Setup
Single-Line Diagram

Figure 3 shows a large 400MVA, 500/345/13.8kV and transformer under dielectric testing in a substation yard, with detail of the motor-generator mobile group used to perform high voltage electric AC tests.

Figure 3 – Transformer (400MVA, 500kV) under HV On-site Testing
and Motor-Generator Group (2MVA)

6. HV ON-SITE TESTS APPLIED FOR DIAGNOSIS

In many cases, HV on-site tests have been used for diagnostic purposes on large power transformers.

The process of this application typically starts based on previous events such as:

- detected event of in oil dissolved gas generation increase given up partial discharge as a possible diagnosis using dissolved gas analysis methods; or
- detected mechanical event such as overacceleration during a shipment operation.

In several cases, HV induced voltage with partial discharge electrical and acoustic monitoring has been successfully used to detect and locate partial discharge in large power transformers.

As an example, figure 4 shows a 4-year old 300MVA, 550/138/13.8kV on-load regulating transformer under on-site testing at a substation yard.

Figure 4 – Transformer (300MVA, 550kV) under HV On-site Testing and PD Location

During the test, partial discharge activities were measured (up to 7500pC at 130%Un) and located in the HV winding exit areas. Figure 5 shows the results of PD location through the application of 3 acoustic sensors.

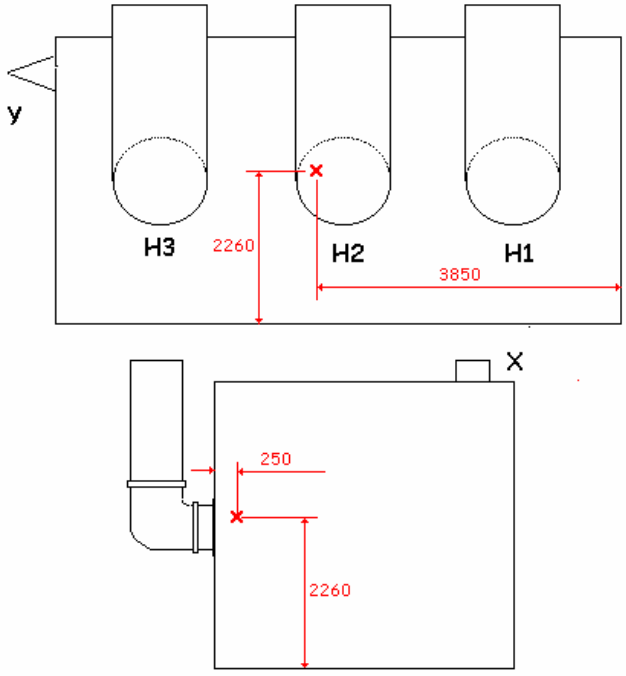

Figure 5 – PD Location Acoustic Sensors and Triangulation Method

The transformer has been visually inspected internally and partial discharges evidences have been located in the area indicated by the previous test induced test. After that, the transformer has been shipped back to factory and disassembled for complete repair.

Figure 6 – PD Location: Acoustic and Visual

7. HV ON-SITE IMPULSE TESTS

Due to high costs and limited availability of testing equipment, lightning and switching impulse tests are not performed.

Nowadays, however, these limitations must not be considered as restrictions to the execution of a transformer on-site complete repair when performed with the use of technology and processes qualified to this application. The non-performance of these impulse tests must be based on manufacturer's proven ability to design windings, internal insulation and main insulation systems in a reliable way according to specified transient voltage specific required conditions and also on its experience with this kind of repair work.

Thus, the corresponding winding performance can be adequately certified by means of a qualified combination of design review, application of adequate method and manufacturing processes as well as tests performed in factory.

Results of on-site repairs performed since 1992 and the reliable operating performance of transformers after repair certify the established repair processes, even when impulse standardized tests cannot be performed.

8. CONCLUSIONS

The results show that on-site tests, including high voltage tests, on high voltage power transformers is fully possible and reliable. The results and experience accumulated over more than 12 years have shown that, in completion to GIS equipment and HV-cable systems, large HV power transformers can be also tested on site.

HV tests can be selected as a proven method for commissioning, diagnosis and final acceptance of new and repaired or even refurbished power transformers.

Through right high-quality application of on-site testing technology, it has been possible to optimize the whole on-site process associated to erection, diagnosis and repair of large HV power transformers. Cost and time have been reduced dramatically without reduction of expected reliability.

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