ISSN 2229-5518

Modern Diagnostic Tests for Condition Monitoring of Power Transformers of Koteshwar HEP

Ashutosh Gairola, Sanjay Rawat
THDC India Ltd.

Abstract

Power transformers are the most vital component of the power transmission and distribution infrastructure. Transformer failures cost enormous amounts of money, in the form of unexpected outages and unscheduled maintenance. All electrical utilities therefore aim to avoid these failures/outages and try to save money by usage of condition based maintenance techniques in addition to the time based practices. One of the most crucial factors determining the lifetime of a transformer is condition of insulation. Routine tests are conducted on transformers to determine the condition of power transformers. Modern insulation diagnostic tests are able to provide us the information regarding present condition of the transformer. Therefore combination of the routine measurements tests with modern diagnostic techniques helps to get a better picture of the condition of insulation. The present paper discusses the modern insulation diagnostic techniques being conducted at THDCIL Koteshwar HEP (4X100 MW) for Condition Assessment of Generator Transformers.

I . INTRODUCTION

Power transformers are one of the most important and costly apparatus in a power system. The reliable and efficient fault free operation of transformer has a decisive role in the availability of electricity supply. In transformer, oil and paper insulation get degraded under a combination of thermal, electrical, chemical, mechanical, and environmental stresses during its operation. The reliability and availability of the power supply can only be assured by proper maintenance of power transformers. Routine tests such as measurement of breakdown voltage, moisture content, flash point, acidity of the oil or performing DGA etc are conducted on transformers to determine the condition of power transformers. Further other electrical tests conducted are measurement of Tan delta/ capacitance/ dissipation factor (DF) or winding resistance etc. Maintenance practices of transformers are changing drastically, shifting from a time based maintenance towards a predictive approach, in which corrective actions are carried out as a function of the present conditions. Predictive maintenance involves conduction of modern monitoring and diagnostic tests capable of assessing the present conditions of transformers and evaluation of their potential residual life. Transformer failure statistics indicate that most failures have occurred before reaching their expected designed life. Therefore utilities shall have such maintenance practices which include modern monitoring and diagnostic for condition assessment. Accordingly various modern insulation diagnostic tests are being conducted at THDCIL Koteshwar HEP (4X100 MW) for Condition Assessment of Generator Transformers has been discussed next.

TRANSFORMER SPECIFICATIONS	
Transformer Rating	123 MVA
Connections	High Voltage: Star Low Voltage: Delta
Manufacturer	M/s BHEL Bhopal
Phases	3
Rated Voltage of HV Winding	420 kV
Rated Voltage of LV Winding	13.8 kV
Rated Current of HV Winding	169.1 A
Rated Voltage of LV Winding	5145.9
Impedance HV-LV (Normal tap)	14.5% +IS Tol.

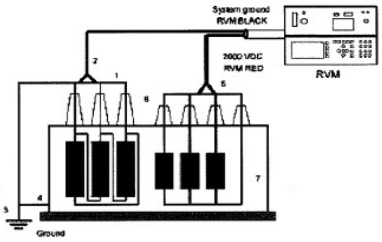
Fig.1 Generator Transformer of Koteshwar HEP

II. RECOVERY VOLTAGE MEASUREMENT (RVM)

Recovery Voltage Measurement (RVM) is an important diagnostic test for power transformer. Polarisation occurs in an insulating material, on application of D.C. field is well known in Physics. Transformer insulation is composite in structure consisting of paper/ pressboard and mineral oil. These structures exhibit space charge polarisation effects, which are strongly influenced by the moisture content and ageing by products. Space charge polarisation in multiple dielectric media on application of DC voltage is a known mechanism. This polarisation in paper oil insulation system is a process by which the mobile charge carriers diffuse across the more conducting portion up to the interface with the less conducting components. Impurities such as moisture, ageing by products etc tend to collect at the interface between components of composites and increase the electrical conductance at the interface. The increased conductivity leads to an increase in dielectric losses. The time constant associated with polarisation effects is inversely proportional to dielectric losses of insulation system. As dielectric losses of paper and oil increases, polarisation time constant tends to shift towards lower values indicating ageing of paper oil insulation.

If composite paper oil insulation is subjected to a sequence of charging and discharging processes and measuring corresponding recovery voltages, then a plot of recovery voltages against charging times would exhibit a dominant peak. The polarization processes that have time constant equal to one of the charging times in the sequence undergo maximum excitation and the corresponding recovery voltage would have a maximum value. The dominant time constant is therefore, a function of moisture content in the paper. The increase in the moisture content in the transformer insulation can also occur due to oil leakage or small repair with temporal and partial discharge of oil or due to defects in the breathing system/ filter etc. as the moisture accelerates the degradation processes in the cellulosic paper, there is a strong need for monitoring its level in the paper.

International Journal of Scientific & Engineering Research, Volume 7, Issue 12, December-2016
ISSN 2229-5518



1. short circuit high voltage side
2. connect high voltage side to test system ground (**black** clip)
3. grounding of the high voltage side
4. ground transformer tank
5. short circuit low voltage side and connect to the test voltage (red clip).
6. assure clean bushings and proper contacts to the test cables
7. oil and paper temperature must be stable. Tests with insulation temperature below 8°C are not recommended

Fig.2 RVM Test Schematic Diagram

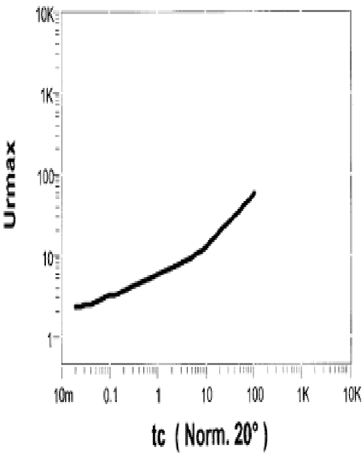


Fig. 3 Sample RVM Test Report

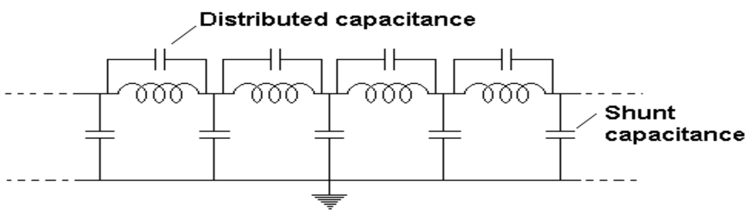
III. <u>SWEEP FREQUENCY RESPONSE ANALYSIS TEST (SFRA)</u>

Sweep Frequency Response Analysis (SFRA) is a reliable tool for assessment of mechanical condition the windings. Transformers are subjected to mechanical stresses during transportation, short circuit faults near the transformer, transient over voltages such as switching, lightening etc. Mechanical Stresses cause Winding displacement or deformation, winding collapse in extreme cases, such mechanical defects eventually lead to dielectric faults in the winding. Especially winding insulation of old transformers can become vulnerable to short circuit forces because of the reduced mechanical strength and the shrinkage of the aged paper which may result in a loss of winding clamping pressure. In most cases, a displacement of a winding after an external short circuit does not immediately lead to a transformer failure, but there is a high risk that a mechanical damage in the turn or coil insulation due to abrasion or crushing of the aged, brittle may eventually cause an insulation breakdown during at the next overvoltage stress. Therefore, this method for detection of winding movement and failures is of high importance, because opening a transformer and visual inspection is time consuming and expensive.

<u>Method Basics</u>

A transformer consists of multiple capacitances, inductances and resistors, a very complex circuit that generates a unique fingerprint or signature when test signals are injected at discrete frequencies and responses are plotted as a curve. Capacitance is affected by the distance between conductors. Movements in the winding will consequently affect capacitances and change the shape of the curve. The SFRA method is based on comparisons between measured curves where variations are detected. One SFRA test consists of multiple sweeps and reveals if the transformer's mechanical or electrical integrity has been jeopardized.

SFRA is capable of detecting Core movement, Winding deformation and displacement, Faulty core grounds, Partial winding collapse, Broken or loosened clamping structures, Shorted turns and open windings. The Principle in Frequency Response Analysis is analysis of Transformer as a complicated network of distributed inductance, capacitance & resistance (LCR network) as shown in figure C:



ISSN 2229-5518

Fig. 4: Distributed LCR Network of Transformer

Test Setup

In a transformer each winding turn is linked to the other inductively or capacitively. Each winding exhibits a characteristic frequency response which acts as the finger print. Any winding movement results in substantial changes in the values of L & C at the local level. Any winding movement causes changes in the characteristic frequency response.

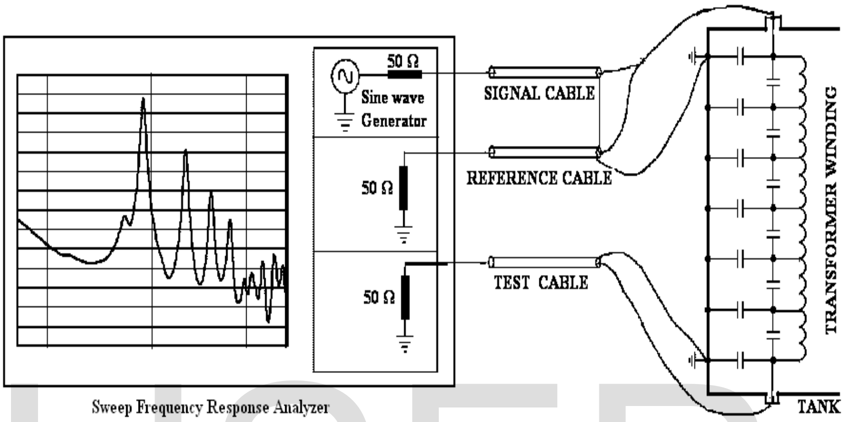


Fig. 5 Test Schematic Diagram

Test method consists of application of a sinusoidal signal to one end of the winding (V_i). Output voltage (V_0) is measured at the other end of the winding and other windings are left open.

Interpretation of the results

- Condition assessment is based on comparison of the present signature with the earlier patterns obtained on the same winding under healthy condition.
- Comparison of responses of different phases of the same winding at the same tap position.
- Comparison of responses of different transformers of the same design

Analysis

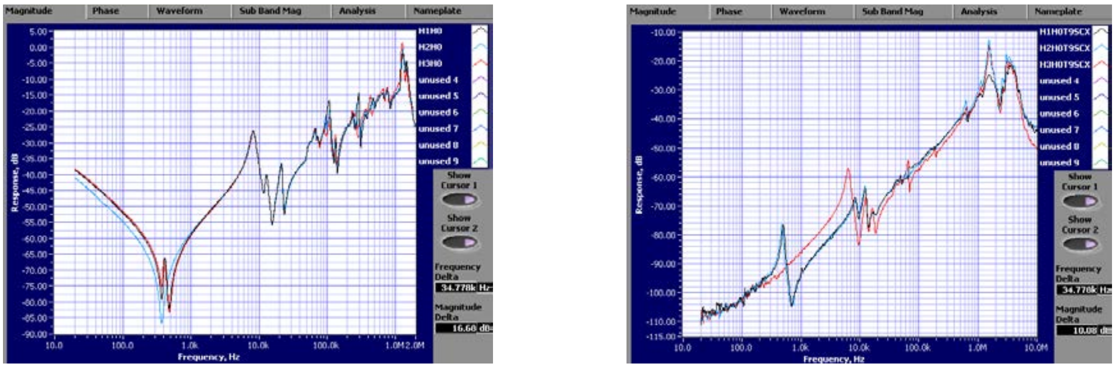
Low frequency response:

- Winding behaves as a simple LR circuit formed by series inductance and resistance of the winding (At low frequencies capacitance acts as almost open circuit)
- At low frequencies winding inductances are determined by the magnetic circuit of the transformer core.

High frequency response:

- Winding behaves as LCR circuit.
- Winding exhibits many resonant points.
- Frequency responses are more sensitive to winding movement

SFRA provides characteristic pattern of Transfer gain versus frequency.



Sound pattern Faulty pattern

Fig. 6 Typical Patterns of SFRA

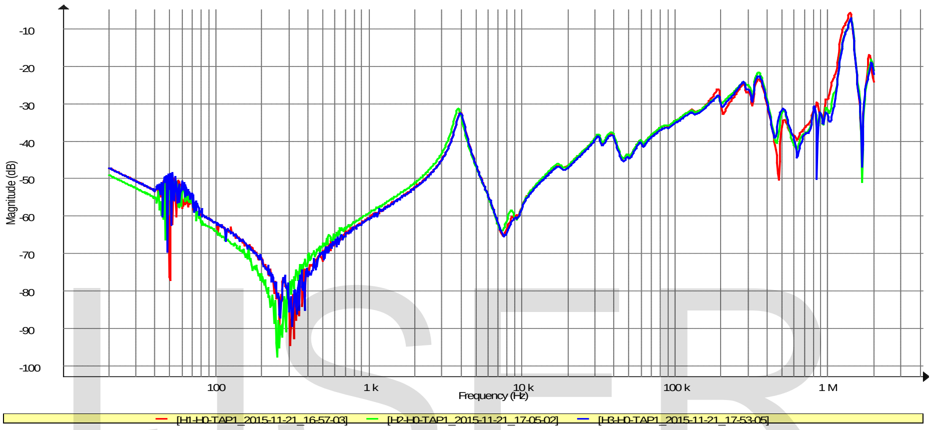


Fig. 7 Sample Magnitude response of SFRA test

IV. ONLINE PARTIAL DISCHARGE (PD) MEASUREMENT

Partial discharge (PD) measurement is online condition monitoring test for generator transformer. One of the serious defects in electrical equipment is PD, occurrence of PD degrades the electrical insulation leading to the failure of the electrical equipment. Early detection of PD occurring in high voltage equipment will help to avoid such failures. Therefore measurement of PD is one of the important diagnostic techniques for assessing the condition of power equipment. The conventional electrical method for measurement of PD is well established and widely accepted. However, electrical PD method has certain limitation which has resulted in development of alternate techniques. Acoustic Emission (AE) detection scheme is one of popular technique due to development of high frequency sensors, instrumentation and necessary software. .

Acoustic method for PD measurement is based on detection, acquisition and analysis of acoustic emission signals generated during PD activity. Acoustic emissions are transients elastic waves generated by the rapid release of energy from localised sources within material. In transformers acoustic emissions occur due to small scale breakdown (PD) and other events such as arching, tracking and heating. When this happen, acoustic emissions are produced which can propagate through oil and other insulating media. High frequency piezoelectric sensors mounted strategically on the wall of the transformer can detect these acoustic emissions and measure time of arrival of the signal and signal feature.

AE sensors are mounted at suitable positions on the outer surface of the transformer tank to pick up the acoustic signals originating from the defects within the transformer. The arrangement of sensors on wall have been shown in fig below

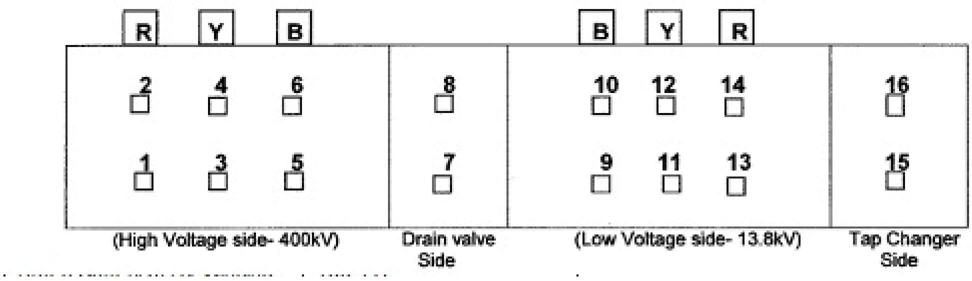


Fig. 8 Location of AE sensors in transformer

Once presence of PD is detected, geometrical location of PD source is essential for initiating effective corrective action. The ability to locate AE source is one of the important feature of multi channel AE detection system. This aspect of AE technique is the main reason for gaining importance over conventional electrical technique.

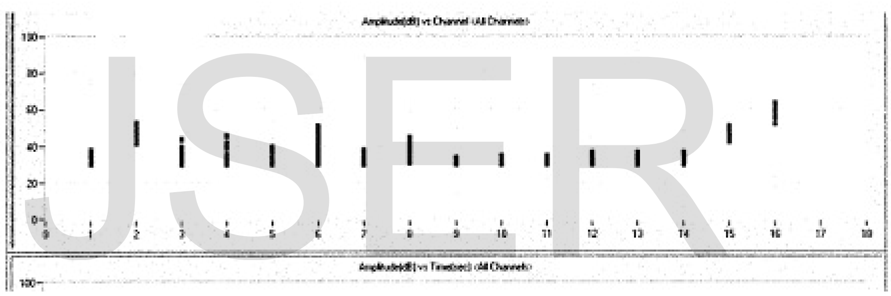


Fig. 9 Sample test report of PD test

V. ONLINE INFRARED THERMAL IMAGING

Infrared thermo vision camera/ scanners are utilized for detection of loacl hot spots in the transformer and their connections. Incipent faults caused by poor connections, corrosion, bockage in radiators, abnormal surface heating etc gets easily detected by these temperature scanners. During operation of any transformer, the localised hot spot can be easily detected without any breakdown/ outage. Then equipment can be put for maintenance for attending the same.

VI. CONCLUSION

Condition monitoring is a powerful & reliable diagnostic tool to protect large & expensive power transformers. The ultimate goal of condition monitoring is to access the present condition of transformer and anticipate/analyse the problem in transformer (if any) so that the appropriate measures can be taken before occurrence of outages. In addition to the routine tests conducted in transformer, it is better to conduct other modern diagnostic tests, since each test gives some limited information regarding the condition of transformer. Further it is desirable to perform online tests for behaviour & performance assessment during load conditions.

VII. REFERENCES

ISSN 2229-5518

[1] Stephanie Uhrig, Martin Anglhuber, Rene Hummel, Michael Kruegar, “Advanced Methods for Insulation Diagnostics on Power Transformers”.

[2] Piyush Verma, Yog Raj Sood, Jashandeep Singh, “Review Of Important Diagnostics Parameters For Power Transformer” Proceedings of the 16th International Symposium on High Voltage Engineering.

[3] Amit Kumar Mehta, RN Sharma, Sushil Kumar, Anil Kumar “Modern Diagnostic Facilities for Power Transformers in TIFAC-CORE” Int. J. on Recent Trends in Engineering & Technology, Vol. 05, No. 02, Mar 2011.

[4] M. de Nigris, R. Passaglia, R. Berti L. Bergonzi, R. Maggi, “Application Of Modern techniques For The Condition Assessment Of Power Transformers” CIGRE Session 2004.

[5] CPRI “Report on Diagnostic Tests on Generator Transformer at THDC India Limited Koteshwar Uttarakhand”.