Testing of Transformer for its Reliability

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***Abstract-*. Transformers are the most important equipment electrical network. Failure of a Transformer leads to loss of revenue besides affecting reliability of power supply to consumers. In order to ensure that Transformers provide long and trouble-free service, several diagnostic tests are carried out and remedial actions initiated throughout their operational lifetime. Many methods are there which access the Residual life of transformer like Tan & and capacitance measurements for windings, Degree of Polymerisation, Insulation Measurement Test, Dissolved gas Analysis, Partial Discharge measurement, Magnetising current measurement etc. These methods can help the utilities in making optimum use of the Transformers and also taking timely decisions regarding refurbishment / replacement of Transformers.**

I. INTRODUCTION

A. *Why RLA?*

1. System Availability to be maintained around 98% which is difficult to sustain with ageing asset(20 to 25 years)
2. Asset condition necessary for short/ medium/long term maintainance planning and investment under O & M
3. Manpower directly deployed for maintainance activity depleting due to increase in number of substation thus condition based maintainance to be adopted in place of routine/preventive maintenance
4. It is necessary to identify mid life defects in equipments for corrective action. prevention of major failure by proper condition checks, timely rectification action and consequent saving in O & M cost
5. RLA incorporate specialized testing not covered under routine test maintainenance viz SFRA,RVM,PD,DOMINO etc

B. *Methodology of RLA Study*

a) Literature Survey
b)Collection of information
c)Identifying problematic assets
d)Grouping problematic equipments
e)Assessing requirement of advanced testing
f) Testing of Representative samples

RLA of TRANSFORMER

- Tan Delta and capapcitance measurement for Windings
- Tan delta and Capacitance measurement for bushing
- Partial discharge measurement
- Insulation Resisitance Measurement (Polarization Index)
- Magnetizing Current measurement
- Ratio Test
- Dissolved Gas Analysis
- Oil Parameter test

C. *Degree Of Polmerisation(DP)*

The number of Glucose rings is measure of quality of Cellulose.I is called DP. Non-aged paper will have DP of around 1400-1000. When DP reaches 200 , It indicate the end of the life.

The remaining life can be predicted with the formula:

Life % age Rem= 100*(DP-200)/(1200-200)

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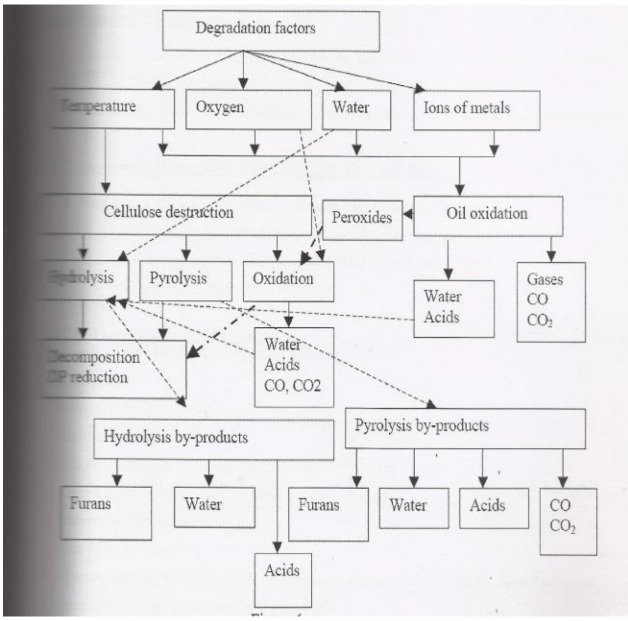
De-Polymerisation:

De-polymeristion is the splitting of glucose chains
a) Thermal De-Polymerisation: Due to heat produce Glucose, Water,CO,and CO2 (Glucose releases into the oil , immediately convet=rted into furans)
b) Oxidative De-polymerisation: Due to presence of oxygen produce acid and ketones
c) Hydrolytic De-polymerisation : Due to presence of water: Thus water is the cause and result of Depolymerisation



Main Cause of faster Ageing:
Presence of Water and Oxgen: With air-cell type conservators, oxygen availabilty is reduced. The water is then main cause of faster ageing.

Effects of water on Ageing:
'a) If moisture increases from 0.5% to 1%, the rate of ageing of cellulose doubles for given temperature
b)Increasing miosture content in the paper to 3% gives ageing acceleration by factor 20

II. POWER TRANSFORMER DIAGNOSTICS USING ONLINE TESTING METHODS

a) Each sysytem shall be suitable for two transformer presently
b) Monitoring syatem shall be such that in future it shall be possible to connect two more transformer

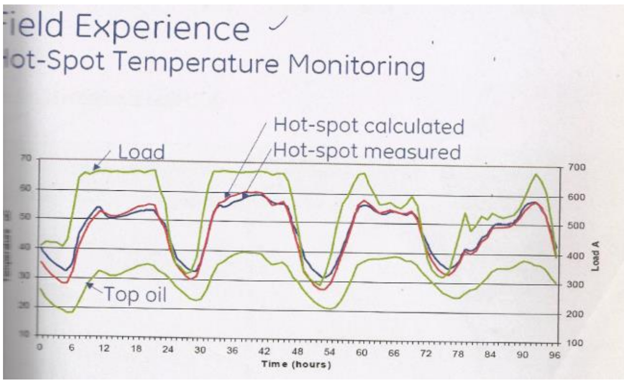
A. TOLCM-Online DGA
a) The detection of fault gases atleast H2, CO, C2H2 and CH4
b) Moisture in Oil
c) Moisture in Winding
d) Gas Quantity in Buchholz relay- sensor may be installed in upper part of relay

B. TOLCM- Transformer Tap Changer
a) Tap position
b) Power cosumption by Tap changer
c) Total number of operations
d) Duration of tap change operation- alarm in case duration is more than preset
e) Oil temperature difference between tap changer and main tank

C. Factors Responsible for accelectraed ageing of a Transformer
a) Heat
b) Oxygen
c) Moisture
d) System fault

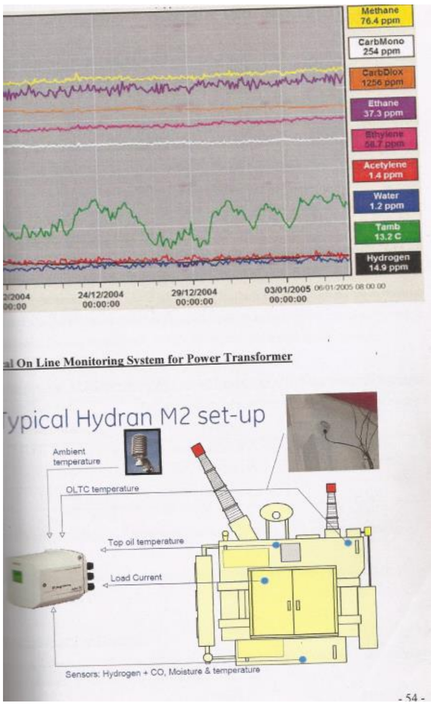
On line Moisure Messurement / assessment & Comparison with DLA

	Trf -I	Trf-II	Trf-III	Trf-IV
Year of Commissiong	2003	1972	1977	1976
Bottom oil temperature	48 C	54C	60 C	37 C
Oil PPM	7	30	52	62
R S Bottom Oil	4%	15.20%	20.80%	56.80%
ResidualPaper Moisture	1.41%	2.39%	3.34%	5.08%
Classification	Normal	Medium Wet	Wet	Very Wet and Critical
Die;ectric Loss Angle of Winding	.0037	.0068	.0067	.013



Online Monitoring of Fault Gsases

PARAMETER	VALUE
GAS MEASURED	MEASUREMENT RANGE(PPM)
HYDROGEN	5-5000
METHANE	1-50000
EHTHANE	2-50000
ETHYLENE	1-50000
ACETYLENE	1-50000
CARBON MONOXIDE	1-50000
CARBON DIOXIDE	10-50000
Oxygen	100-50000



III. DIFFERENT TESTING AND THEIR ANALYSIS

Testing of a transformer:

A. *Insulation resistance measurement*

IR measurement is the simplest and most widely used test to check the soundness of transformer insulation. This test reveals the condition of insulation ,presence of any foreign contaminants in oil and also defect inside the transformer

B. *Maintainance/ Testing procedure*

IR measurement shall be taken between the winding collectively and the earthed tank and between each winding and the tank , the rest of the winding being eathed .Before taking measurement the neutral should be disconnected from the earth.

Combination of IR measurements for different type of Transformers and Reactors

Auto Transformer	Auto Transformer for 3 winding	Shunt Reactor
HV+ IV to LV	HV + IV to LV	HV to E
HV+ IV to E	HV +LV to IV	
LV to E	HV +IV+LV to E	

Where HV- High Voltage, IV- Intermediate Voltage, LV- Low Voltage/ Tertiary voltage , E- earth . Oil temperature and IR values at intervals of 15 seconds, 1 minute and 10 minutes are recorded.

C. *Evaluation of Test results*

Insulation resistance varies inversely with temperature and is generally corrected to a standard temperature using nomographs/ curve . Suppose IR value of 300 Mohm at 70 C to be converted at 40 C the curve will give a factor K for difference in temperature (70 C- 40 C)=30 C. K for 30 C temperature is 4.2 so IR vallue at 40 c will be 4.2*300=1260 Mohm

Difference in temperature(C)	Correction factor(k)
10	1.65
20	2.6
30	4.2
40	6.6
50	10.5

Min Insulation Values for one minute resistance measurement of Transformers is obtained by R= CE/ KVA
R= Insulation resistance in Mohm
C= 1.5 for oil filled transformer at 20 C , assuming that transformer insulating oil is dry, acid free
E= Volatge rating in V
KVA= Rated capacity of winding under test

D. *Capacitance and Tan delta Measurement*

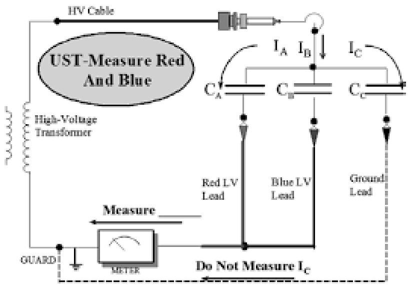
- Insulation relates to medium ability to prevent fow of current i.e poor conductivity
- Dieectric implies that medium or material has specific measurable properties such as Dielecric Strength, Dielectric Constant, Dielectric Loss and Power Factor
- Tan delat and capacitance Measurement Of Bushing

IV. MODES OF MEASUREMENT

There are three modes of measurement
1) Ungrounded Specimen test(UST)
2) Grounded Specimen Test(GST)

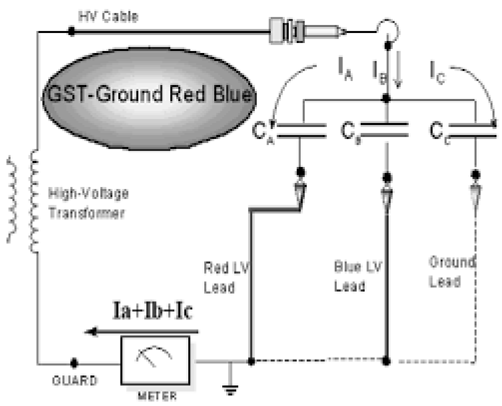
A. *Ungrounded Specimen test(UST)*

The Ungrounded Specimen Test (UST) is referred to as the test of an insulation sample that is not grounded. This test configuration automatically provides a ‘guard’ connection that can be used effectively to measure only one component out of a multi component insulation system. The UST is of great advantage as its ‘guard’ connection is also ‘ground’.



B. Grounded Specimen Test(GST)

The Grounded Specimen Test (GST) is referred to as the measurement of an insulation sample that has one of its terminals grounded. To conduct a GST test, the measuring circuit of the instrument used must be ungrounded to make the measurement possible. As most pieces of electric power system equipment is grounded, the grounded specimen test must be used if the equipment is to be tested in the installed condition. GST is therefore the most important and most frequently used test. Most up-to-date test equipment also offer a grounded specimen test with guard-GSTg. This connection allows one to measure one component of a multi-component, grounded, insulation system.



V. CAPACITANCE AND TAN Δ MEASUREMENT FOR BUSHING

Capacitance and Tan δ Measurement for Bushing provides an indication of the quality and soundness of insulation in the bushing. Portable capacitance and Tan bridge such as Schering bridge or transformer arm bridge, power supply and standard capacitor is used for measurement of Capacitance and Tan δ

A. Testing Procedure

a) Ensure that test specimen is isolated from other equipments
b) Position the test set at least 6 feet (180 cm) away from test specimen to be tested.
c) To prevent damage to the test set always the capacitance multiplier dial to the SHORT position , the capacitance measuring dials to the “O” position.
d) Keep the UST-GST switch to UST position
e) Keep interference suppressor switches in off position
f) Connect the ground terminal of test set to low impedance earth ground
g) Connect control unit to the high voltage unit using two 5 feet long shielded cables
h) Connect the low voltage cable with red sheath to be “ Cx” red terminal of the test set .Make sure the connector locks to the receptable.
i) Connect the external interlock cable to the interlock terminal of the test set
j) Connect the high voltage cable with black sheath to the high voltage terminal of high voltage unit.
k) For 3-ph auto-transformer, short together all 400KV, 220 KV and Neutral bushing

B. Measurement of C1 Capacitance and Tan delta

a) Connect the crocodile clip of the HV cable to the top terminal of the shorted HV/IV bushing. Unscrew the test tap cover , insert a pin in the hole of the central test tap stud by pressing the surrounding contact plug in case of 245 KV OIP bushing and remove he earth strip from the flange by unscrewing the crew.
b) Connect the LV cable to the test tap of the bushing under the test to the capacitance and tan kit through a screened cable and earth the flange body. Repeat the test for all body by changing only LV lead connection of the kit to the test tap of bushing which is to be tested.

VI. PARTIAL DISCHARGE MEASUREMENT

A. What is Partial Discharge?

Electric discharges that do not completely bridge the electrodes are called partial discharge
a) magnitude of such discharge is usually small
b) They cause progressive deterioration and lead to ultimate failure
c) Essential to detect their presence through a non destructive tool

B. Classification Of PD

a) Internal Discharge
b) Surface Discharge
c) Corona Discharge

C. Purpose of PD measurement

a) To certify that no harful pd source exsist
b)To detect and localize areas within the transformer which are exposed to higher dielectric stresses
c) Specified in internatinal standards(IEC,IEEE)
d) Carried out in conjuction with dielectric test in high voltage laboratories using ac- voltage in power frequency range

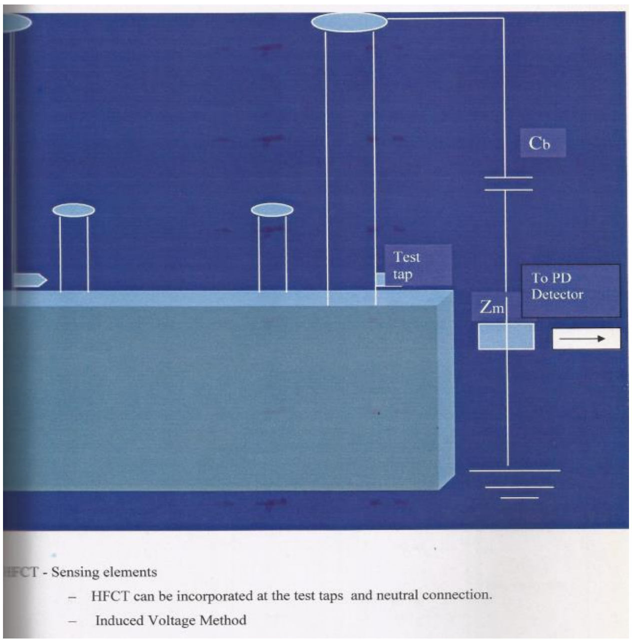
D. PD sources in Transformer

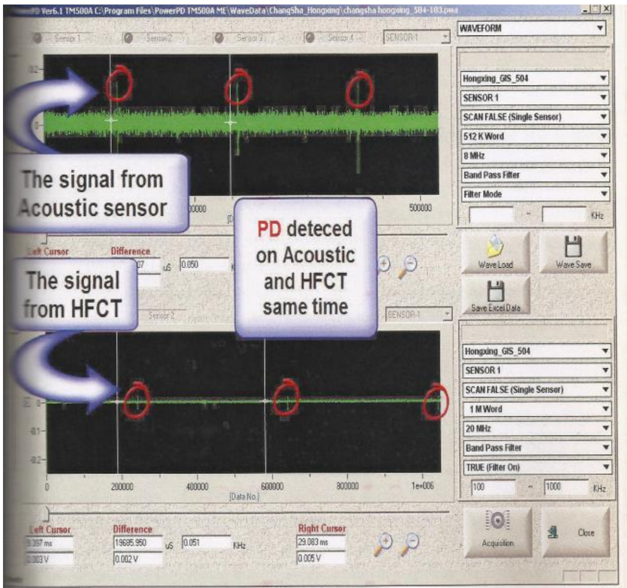
a) Delamination
B) Voids
c) Bubbles
d) Free metallic particles
e) Fixed metallic particles
f) Moisture
g) Bad connection of electrostatic shields
Surface tracking

E. Methodlogy Used

a) Signals from four AE sensors and HFCT are measured simultaneously
b) data is saved in computer

c) Software analyze the frequency of measured signal , brust time, spectrum and localisation of source
Data viewed in trent, table iew, 2d graph, 3d graphic and amplitude





(Fig : Monitor Displaying the PD location)

a) Prsctical eperience confirmed that the modern PD measuring devices can provide a high sensitivity to PDs in feild conditions, quite comparable to one achieved in laboratory test at transformer factories
b) Such technique may be effectively used as on-line dianostic inatrument for monitioring o power transformer, shunt reactor, CT, CVT
c)However instruments should distinguish between dangerous discharges and the probled that donot effect quipment function to critical extent

VII. MAGNETIZING CURRENT TEST

Magnetising current test is performed to locate defect in magnetic core structure, shifting of windings, failure in turn to turn insulation or problem in tap changers. These conditions change the effective reluctance of magnetic circuit thus effecting the current required to establish flux in the core.

A. *Testing Procedure*

a) The test comprises a simple measurement of single phase current in one side of the transformer usually the low voltage side
b) 3 phase transformers are tested by applying 3 phase ac supply HV terminals Keep the tap position in the lowest position
c) Measured the voltage applied on each phase and current in each phase of HV terminal
d) After completion of the above steps keep the tap position in normal position and repeat the above steps
e) After completion of the above steps keep the tap position in Highest position and repeat the above steps
f) keep the tap position in Highest position and Keep LV and HV terminal open
g) Measure the phase to phase voltage between the IV terminal and current on each IV terminal
h) Record the test result

VIII. DISSOLVED GAS ANALYSIS

DGA is probably the most powerful tool or detecting fault in electrical equipment in service. Thermal and electrical distributions in the operating transformer are two most important causes of dissolved gases in oil. The gases produced from thermal decomposition of oil and solid insulation are because of losses in conductors due to loading. Also decomposition occurs in oil and solid insulation is due to occurrence of arc. In case of electrical disturbances the gases are formed principally by ionic bombardment. The gases are generated mainly because of cellulose and oil insulation deterioration. In the normal operation of the transformer, gases such as Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4), Acetylene (C_2H_2), and Ethane (C_2H_6) and so on are released

Methods of DGA

a) Doernenburg Ratio Method
b) Rogersratio Method
c) Duval Triangle Method

VIII. CONCLUSION

In this paper the analysis of life assessment of transformer is done so that due to failure of transformer there should not be any type of fault occur in electrical systems. Various methods are explain in the paper like Tan & and capacitance measurements for windings, Degree of Polymerisation, Effect of moisture, Dissolved gas Analysis, Partial Discharge measurement, Magnetising current measurement are described

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