POWER TRANSFORMER OIL TESTING, TRIPPING AND AVAILABILITY CALCULATIONS

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ABSTRACT

The periodic maintenance schedules/preventive maintenance schedules being carried out on power transformers (PTR) by an electric power utility are discussed in this paper. The various diagnostic tests to be conducted on the power transformer as per periodicity including transformer oil sample tests are also discussed in this paper. The state of the art diagnostic tests such as FURAN Analysis and oil sample reports are presented, discussed and a typical oil sample test report and a FURAN analysis test report is also included in this paper. The data on failures of Power Transformers of an electric power utility for a period of 3-5 years is compiled and failure analysis is carried out. The details of interruptions occurred on the Power Transformers in some substations for a period of one year (2010-2011) is collected and a cause-wise analysis of the Power Transformers is carried out and presented in this paper.

Key words: *Transformer testing, Furan analysis, Oil testing, Availability, Failures, Down time*

INTRODUCTION

From the cause-wise analysis and % tripping calculations,it is noticed that the interruptions due to 'Attending Thermoscan Points'[1], 'General Maintenance' and 'Tan Delta & MRT Testing' [2]are prominent and are of longer duration than the one's due to other causes.

This implies that the interruption outage of PTRs due to 'Planned Interruptions' is more. Planned outages are essential to perform various maintenance checks on the PTRs at regular intervals. However,by analyzing the % tripping[3], it is required to reduce the duration of outage due to these planned outages. The major change required in a substation to give prospective results to this is to make the existing substations automated. It is required to make the 220KV and 132KV substations automated to drastically reduce the interruptions duration due to the maintenance procedures adopted

This paper presents cause-wise failure analysis of the Power Transformers with oil testing, tripping and availability calculations.

TRANSFORMER TRIPPING AND DOWN TIME

% Tripping Calculations

REASON FOR TRIPPING: INCOMING SUPPLY FAILED

Date	Tripped on	Charged at	Duration (Hrs.)	Cause of Interruption
23-10-10	18:54	22:38	03:45	LV charged due to incoming supply failed
23-10-10	18:17	21:56	3:02	Due to incoming supply failed
23-10-10	22:56	23:58	01:02	Due to red hot noticed at 220KV H/T ,Due to incoming supply failed
18-12-11	06:15	06:52	00:37	Incoming supply failed
15-10-11	10:08	10:13	00:05	132KV Ghanapur incoming supply failed
15-10-11	10:08	10:13	00:05	132KV Ghanapur incoming failed

TOTAL DURATION FOR TRIPPING DUE TO INCOMMING SUPPLY FAILURE =8.6hrs
TOTAL NON AVAILABILITY DURATION OF ALL THE PTR'S =139.52hrs

%tripping = (total duration of tripping for particular reason)/(total non-availability duration of all the PTR'S) x100

% Tripping =8.6/139.52 = 6.16%

IMLIBAN TRIPPING DATA:-

80MVA PTR-III Interruptions

Date	Tripped on	Charged at	Duration (Hrs.)	Cause of Interruption
7-9-11	08:50	11:30	02:40	HT LC to ADE/m/IBN damaged jumper and clamps
5-11-11	11:02	14:30	03:28	R-Phase CT clamp of 132KV Chandrayangutta replacement, maintenance work and MRT relay testing
11-11-11	08:40	11:30	02:50	For maintenance work
24-11-11	06:15	06:20	00:05	HT for changeover of load onto Chandrayangutta
24-11-11	07:40	07:42	00:02	HT changeover onto Chandrayangutta Substation
4-12--11	07:55	13:20	05:25	HT for replacement of 3-Phase 132KV feeder, CT of 132KV Chandrayangutta feeder
18-12-11	06:15	06:52	00:37	Incoming supply failed
31-12-11	13:50	15:05	01:15	PTR tripped and Y-Phase PT blasted

CALCULATION OF AVAILABILITY FACTOR

160MVA PTR-I (AVAILABILITY FACTOR)

The availability factor of a Power Transformer is the amount of time that it is available for transmission of power over a certain period, divided by the amount of the time in the period.

Where Availability=8760Hrs, Non availability=Period during which it is tripped

Availability Factor of PTR= (Availability-Non Availability)/Availability

Non-availability=27.81hrs

Availability=8760hrs

Availability Factor of PTR= (8760-27.81)/8760 = 99.68%

A. Suggestions to improve Availability Period

The following automation techniques can be used to make automations related to PTRs:

- Embedded system based transformer oil testing machine
- Transformer over-heat protection with intimation to EB (Electricity Board)
- Wireless transformer status monitoring system using microcontroller

Among other reasons that amount to a larger tripping duration is due to 'Incoming Supply Failure'. This can be tackled by employing 'Redundant Incoming Supply System'. Whenever supply from the incoming substation fails, the contactor at the panel must automatically switch over to supply of other substation. This largely nullifies interruptions due to incoming supply failure.

For tackling the interruptions due to Thermoscan Points and Red Hot, a sufficient number of High Precision Thermovision cameras have to be employed at the yards.

Interruptions due to 'Top-up Oil in Conservator' or 'Oil Leakage' can be dealt craftily by employing 'Thermoseal Compounds'. This method arrests Oil Leakage from the tank and the interruptions can be largely reduced.

TRANSFORMER OIL TESTING

Oil sample tests are conducted

1. To check the healthiness of Transformer.
2. To see if the oil in the transformer has the optimum properties and parameters.
3. To see if the Transformer Oil has to be reclaimed or replaced.

The various oil sample tests are

1. BREAKDOWN VOLTAGE (BDV)
2. WATER CONTENT TEST
3. ACIDITY TEST
4. RESISTIVITY &TAN DELTA TEST
5. DISSOLVED GAS ANALYSIS (DGA)
6. FURAN ANALYSIS
7. INTERFACIAL TENSION (IFT)

FURAN ANALYSIS

Under Furan analysis we test the quantity of cellulose present in insulation paper. If any paper is left undisturbed for few years and then if we touch it then it will tear. The reason is cellulose content present in the paper gets reduced. As the age of the transformer increases the cellulose present in insulation paper gets transfers to oil as a result of which insulation breaks occur. Here cellulose is nothing but furan particles. Furan analysis is same as dissolved gas analysis but in DGA we separate gases whereas in FURAN Analysis we separate liquids.

Furan is a high performance liquid chromatography (HPLC) system.

Internal faults can be known by DGA and furan analysis without opening transformer. Furans will be tested yearly once for transformer greater than 10 years.

STAGES OF OXIDATION

Fig 1. Oxidation states of oil

The Corporate Office of APTRANSCO has circulated uniform format for testing of PTRs coming from the field and formulated preventive maintenance measures of PTRs which have to be followed as per periodic schedule for compliance. It is learnt that the field engineers are complying with the uniform formats set by CTI (Corporate Training Institute),AP.

The Uniform Format was prepared in the corporate office by both the transmission as well as in house inspecting authority i.e., quality assurance wing.

RESULTS ANALYSIS

Oil Sample Reports

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TEST REPORT

Report No: R&D LAB/CTI/ 2012-317

Ref: ADE/LINES/PDT/F.NO. 1 /D.NO.39 /DT.01.02.2012

EQUIPMENT DETAILS		SAMPLE DETAILS	
Station	ANANDAPURAM 132kV	Date of Sampling	1-Feb-2012
Make & Capacity	ANDREW YULE & 10/16 MVA	Date of Receipt at R&D Lab	2-Feb-2012
Sl.No & Year of mfg.	13.62 & 2001	Oil Temperature (°C)	50
Voltage Rating (kV)	132/33	Winding Temperature (°C)	57
Date of Commissioning.	12-Jun-2002	Average Load (MW)	12.00
Date of last Filtration	---------	Sampling Point	BOTTOM
Date of Oil Change	---------	Sample Container	
Equipment	TRANSFORMER		

TEST RESULTS

OIL PARAMETERS Reference Standard: IS-1866-2000				Dissolved Gas Analysis Test Method: IS:9434-1992/IEC-60567 Reference Standard IEC 60599		
OIL PARAMETERS (unit of measurement)	Voltage Range	Violation Limit	Measured Value	PARAMETERS	Unit of measurement	Measured Value
Appearance	BROWN			Hydrogen(H2)	ppm	----
Acidity (mg KOH/g)	All Voltages	0.3 MAX	0.2467	Methane(CH4)	ppm	----
B.D.V. (kV)	170Kv & Above	50 MIN	----NA----	Ethylene(C2H4)	ppm	----
	72.5Kv - 170 kV	40 MIN	56.7	Ethane(C2H6)	ppm	----
	< 72.5kV	30 MIN	----NA----	Acetylene(C2H2)	ppm	----
Density @ 29.5°C (g/cm3)	All Voltages	0.89 MAX	----	Carbon Monoxide(CO)	ppm	----
Kn.Viscosity @ 27°C (Cst)	All Voltages	27 MAX	----	Carbon dioxide(CO2)	ppm	----
Flash Point (°C)	All Voltages	140 MIN	----	Furan Analysis (Test method:IEC:61198)		
Resistivity @ (90°C) E12 ohm-cm	All Voltages	0.1E12 MIN	0.0836	Furaldehyde Content(ppm)	DP Value	Significance
Tan Delta @ (90°C)	170Kv & Above	0.2 MAX	----NA----	<0.1	700-1200	Healthy
	Below 170kV	1.0 MAX	0.266	0.1-1	450-700	Moderate Deterioration
Water Content (ppm)	170Kv & Above	20 MAX	----NA----	1-10	250-450	Extensive Deterioration
	Below 170kV	40 MAX	27.3	>10	<250	End of Life
Inter Facial Tension @ 27°C (Dynes/cm)	All Voltages	15 MIN	13.6	2-Furfuraldehyde mg/kg		----

REMARKS:
ACIDITY IS AT THRESHOLD LIMIT, RESISTIVITY AND IFT ARE BEYOND LIMIT. AS PER IS-1866-2000 IT IS RECOMMENDED FOR REPLACEMENT/RECLAIMING OF OIL.

The above report is an oil sample test report conducted on one of the PTRs from Andapuram Substation. The acidity level of oil is at threshold level which indicates that the oil has severe

acid levels. This in turn has affected the color of oil turning it brown. Hence it is recommended that the oil to be replaced.

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TEST REPORT

Report No: R&D LAB/CTI/ 2012-420

Ref: ADE/M/SPNG/Hyd/F.Oil sample /D.NO.520/11 ,Dt.16.02.2012

EQUIPMENT DETAILS		SAMPLE DETAILS	
Station	SHAPURNAGAR 220kV	Date of Sampling	16-Feb-2012
Make & Capacity	BBL & 50 MW	Date of Receipt at R&D Lab	16-Feb-2012
Sl.No & Year of mfg.	4957-2 & 2007	Oil Temperature (°C)	48
Voltage Rating (kV)	132/33	Winding Temperature (°C)	52
Date of Commissioning.	19-Feb-2007	Average Load (MW)	38.00
Date of last Filtration	19-Feb-2007	Sampling Point	BOTTOM
Date of Oil Change	19-Feb-2007	Sample Container	
Equipment	TRANSFORMER		

TEST RESULTS

OIL PARAMETERS Reference Standard: IS-1866-2000				Dissolved Gas Analysis Test Method: IS:9434-1992/IEC-60567 Reference Standard IEC 60599		
OIL PARAMETERS (unit of measurement)	Voltage Range	Violation Limit	Measured Value	PARAMETERS	Unit of measurement	Measured Value
Appearance	C&T			Hydrogen(H2)	ppm	5.76
Acidity (mg KOH/g)	All Voltages	0.3 MAX	------	Methane(CH4)	ppm	15.99
B.D.V. (kV)	170Kv & Above	50 MIN	----NA----	Ethylene(C2H4)	ppm	92.12
	72.5Kv - 170 kV	40 MIN	70.3	Ethane(C2H6)	ppm	10.78
	< 72.5kV	30 MIN	----NA----	Acetylene(C2H2)	ppm	ND
Density @ 29.5°C (g/cm3)	All Voltages	0.89 MAX	------	Carbon Monoxide(CO)	ppm	135.18
Kn.Viscosity @ 27°C (Cst)	All Voltages	27 MAX	------	Carbon dioxide(CO2)	ppm	912.74
Flash Point (°C)	All Voltages	140 MIN	------	Furan Analysis (Test method:IEC:61198)		
Resistivity @ (90°C) E12 ohm-cm	All Voltages	0.1E12 MIN	101	Furaldehyde Content(ppm)	DP Value	Significance
Tan Delta @ (90°C)	170Kv & Above	0.2 MAX	----NA----	<0.1	700-1200	Healthy
	Below 170kV	1.0 MAX	0.000529	0.1-1	450-700	Moderate Deterioration
Water Content (ppm)	170Kv & Above	20 MAX	----NA----	1-10	250-450	Extensive Deterioration
	Below 170kV	40 MAX	2.7	>10	<250	End of Life
Inter Facial Tension @ 27°C (Dynes/cm)	All Voltages	15 MIN	------	2-Furfuraldehyde mg/kg		------

REMARKS:
AS PER IEC 60599 THERMAL FAULT OF GREATER THAN 700degC SUSPECTED IN THE TRANSFORMER

The BDV value of oil has exceeded the prescribed limits in the above sample which indicates that a possible thermal fault has occurred on the PTR.

CONCLUSION

The fault free operation of power transformers is a factor of major economic importance and safety in power supply utilities and industrial consumers of electricity. In the current economic climate, Industries/Supply utilities tighten their control on capital spending and make cutbacks in maintenance, an increased awareness is placed on the reliability of the existing electric power supply. Down time is at a premium. Often, the loading is increased on present units, as this will defer purchasing additional plant capacity. Thus the stress on the transformer increases. The net total effect of the thermal, electrical and mechanical stress brought on by increased service needs to be monitored to ensure reliability. APTRANSCO houses an In-house quality assurance wing for ensuring the quality of the maintenance schedules and quality control aspects.Regular sampling and testing of insulation oil taken from transformers is a valuable technique in a preventative maintenance program. If a proactive approach is adopted based on the condition of the transformer oil, the life of the transformer can be extended which in turn proves resourceful for saving a huge amount of capital in delivering power to the entire state.It is evident from the cause-wise analysis table and % Tripping calculations that the interruption outage of PTRs due to 'Planned Interruptions' is more.

Planned outages are essential to perform various maintenance checks on the PTRs at regular intervals. However, analyzing the % tripping, it is required to reduce the duration of outage due to these planned outages. The major change required is to make the existing substations automated. We can use the following automation techniques to make automations related to PTRs:

- Embedded system based transformer oil testing
- Transformer over-heat protection with intimation to Electricity Board
- Wireless transformer status monitoring system using microcontrollers

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