Residual Life assessment with DGA, Furan content in transformer oil and Degree of polymerization of solid insulation

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Abstract- Power transformers are ' the heart of substation'. They are the vital links between generation and transmission. A failure can cause hug revenue loss to utilities. It can cause non availability of transformers for long hours. Several diagnostic tests are carried out and remedial actions are initiated through the operational lifetime of transformers for ensuring trouble free, non interrupted power supply to consumers. Oil filled transformers in service for more than 15 years, it is highly recommended to assess the remnant life. RLA can be done by assessing the deterioration of cellulose from furan concentration and degree of polymerization. This analysis helps utilities to take timely decisions regarding refurbishment or replacement of the transformer. This paper presents the real life case study of assessing the health of cellulosic paper insulation and transformer oil of six different transformers in the state of Punjab. All the transformers have been in service for more than 40 years.

Keywords – RLA, Degree of Polymerization, Furan content, Dissolved Gas Analysis.

I. INTRODUCTION

Power transformers are the most vital and costliest components of Electrical power systems. Optimal use of transformers ensure reliable and economic power supply. Due to deregulation of electrical utilities, They are under pressure of reducing the generation cost of electricity. Hence, left with the option of overloading of transformers. Overloading introduces transformers to thermal and electrical stresses and health deteriorates .Hence, condition monitoring is essential for checking the health of transformers. Condition monitoring tests include IR, Tan delta, Mag. balance, Turn ratio, Furan tests, Dissolved gas analysis. SFRA is also conducted these days.

Although the life of transformer is generally accepted to be 25 to 30 years. But still, there are many transformers in our electricity board which are in service for more than 40 years because of the elaborate condition monitoring . It is seen that large population is in service beyond 30 years, so RLA should be carried out for taking timely actions for replacement or refurbishment. This would help in preventing unpredicted outages, saving revenues also.

At first oil samples were collected from six different transformers. These samples were tested for different oil properties such as breakdown voltage, water content, tan delta, specific resistivity, Flash point, Pour point, Interfacial tension. Dissolved gas analysis was done and furan analysis was also carried out.

These all tests were conducted according to the different standards mentioned in table.

TABLE 1: STANDARDS FOR OIL PROPERTIES

S No.	Parameter	Standards	Inservice oil	New oil
1	Breakdown Voltage	IEC 60156-95	30(<72.5 KV) 40(>72.5 KV)	40(<72.5KV 50(>72.5KV
2	Water content	IEC 60814-1997	20(>170KV) 40(<170KV)	10(>170KV) 15(<170KV)
3	Total acidity	IEC 62021-2	0.3	0.03
4	Tan Delta at 90 deg. Celsius	IEC 60247:2004	0.2(>170KV) 0.1(<170KV)	0.015(>170 KV) 0.01(<170K V)
5	Specific resistivity at 90 deg. Celsius	IEC60247:2004	1 at 27Deg Celsius 0.1at 90 deg Celsius	6 at 90 deg. Celsius
6	Flash point	ISO 2719	125(min)	140(min)
7	Viscosity	ASTM D 7483		27 at 27deg Celsius
8	Density	ISO 12185	0.895 at 29.5 deg Celsius	0.895at 29.5 deg Celsius
9	Interfacial tension	ASTM D 971-91	15mN /m at 27deg. Celsius	35mN/ m at 27 deg.cel

All these parameters were measured and compared with the limits for in service oil. Similarly Furan analysis was done and from its concentration , degree of polymerization was calculated and thus remnant life of the transformers. Chendong's formula has been used for assessing the remnant life of transformers as it provides the most accurate results. From DGA , authorities can decide about replacement of oil.

II. TRANSFORMERS' SPECIFICATIONS

1. Transformer1

1	Voltage class	132/66 kv

2	Capacity	40/50 MVA
3	Cooling	ONAN/ONAF
4	Make	HEL
5	YOM	1974
6	Oil type	Naptha based
7	Age	42 years

Transformer oil was replaced in 2000 and 2008. But there were some irregularities in the DGA patterns of the oil since last few months.

2. Transformer2

1	Capacity	12.5 MVA
2	Voltage Class	132/66 KV
3	Make	Westing house
4	YOM	1975
5	Cooling	ONAN/ONAF
6	Oil type	Naptha
7	Age	41 Years

3. Transformer 3

1	Capacity	20MVA
2	Voltage Class	132/11 KV
3	Make	NGEF
4	YOM	1973
5	Cooling	ONAN
6	Oil Type	Naptha
7	Age	43 Years

4. Transformer 4

1	Capacity	12.5 MVA
2	Voltage Class	132/11 KV
3	Make	TELK
4	YOM	1974
5	Cooling	ONAN/ONAF
6	Oil type	Naptha
7	Age	42 Years

5. Transformer 5

1	Capacity	20 MVA
2	Voltage Class	132/11 KV
3	Make	TELK
4	YOM	1974
5	Cooling	ONAN/ONAF
6	Oil type	Naptha
7	Age	42

6. Transformer 6

1	Capacity	20 MVA
2	Voltage Class	132/66 KV
3	Make	NGEF
4	YOM	1973
5	Cooling	ONAN/ONAF
6	Oil type	Naptha
7	Age	43

Tests for oil properties, DGA ,Furan were conducted according to the standards mentioned in table 1.Furan tests decides the retirement of transformer ,also promising test as it needs only oil samples and transformer can stay online and ageing can be predicted.

TABLE8: OIL REPORTS

S NO.	PARAMETER	TR1	TR2	TR3	TR4	TR5	TR6
1	BREAKDOWN VOLTAGE	51.7	24.7	12.5	72.6	44.3	58.9
2	WATER CONTENT	26.4	37.6	73.2	13.9	23.1	18
3	TOTAL ACIDITY	0.02367	0.04327	0.04327	0.01540	0.01056	0.00921
4	TAN DELTA	0.059012	0.044558	0.09866	0.041666	0.037315	0.024045
5	SP. RESISTANCE	0.3	0.5	0.255	0.587	0.6	0.988
6	FLASH POINT	149	147	149	145	151	151
7	VISCOSITY	NT	NT	NT	NT	NT	NT
8	POUR POINT	NT	NT	NT	NT	NT	NT
9	INTERFACIAL TENSION	**11.70**	**08.77**	**10.37**	18.98	**12.19**	**12.48**

TABLE 9 : DGA TESTS REPORTS ARE AS FOLLOWS:

S NO.	DGA TEST	TR1	TR2	TR3	TR4	TR5	TR6	MAX.
1	H2	72	48	**3712**	NIL	**313**	82	100
2	CO2	1962	1340	2387	2367	**2924**	**3483**	2500
3	CO	265	75	39	185	275	335	350
4	C2H4	6	2	4	14	16	**98**	50
5	C2H6	18	28	18	27	28	36	65
6	CH4	7	3	10	10	13	9	120
7	C2H2	NIL	NIL	NIL	NIL	NIL	NIL	1

TABLE 10 : FURAN REPORTS FOR ALL TRANSFORMERS

S No.	Name	Tr 1	Tr2	Tr3	Tr4	Tr5	Tr6
1	5H2F	1.126	0.042	0.068	0.012	0.000	0.027
2	2FAL	0.045	0.0976	1.122	0.416	0.492	0.447
3	2ACF	0.114	0.065	0.092	0.057	0.000	0.000
4	5M2F	0.000 BDL	0.069	0.066	0.062	0.061	0.056
		1.285	1.153	1.348	0.547	0.553	0.530

III. DISCUSSIONS

A. Transformer 1,

Oil reports indicates low interfacial tension. Low interfacial tension is an indication of polar contaminants. It may also be an indication of poor compatibility of oil with materials used in transformer. All gases in DGA are within limits.
Corrective action is: Replacement or reclamation of oil.
From Furan analysis, Degree of polymerization was calculated as follows:
According to Chendong's formula **DP = (log(2 FAL) – 1.51) / -0.0035**
Concentration of 2FAL is 0.045 ppm.
DP for this transformer is 816 .
Now remaining age percentage is calculated as :
% Life = 100 * (DP – 200)/(1200-200)
61 percent % life is left.

This transformer is already of 42 years, hence remnant life seems contradictory. Reason for above is that oil replacements in 2000 and 2008.Due to which furans were washed away, hence concentration of 2FAL is remarkably less. As a result, remnant life is shown 61percent.

B. Transformer 2,

Oil reports of transformer showed :

- Low Breakdown Voltage indication of presence of contaminants like water or particles
- High Water Content accelerates the deterioration of paper
- Low interfacial tension confirms the presence of polar contaminants

Hence, Oil should be replaced or its reclamation.
Furan analysis of oil shows concentration of 2FAL is 0.976 ppm.
According to Chendong's formula **DP = (log(2 FAL) – 1.51) / -0.0035 = 434**
Values of 2FAL and DP indicates moderate deterioration of the transformer.
%life = 100 * (DP – 200)/(1200-200)
Hence, 23.4 percent is left.

C. Transformer 3

Dark reddish brown colour of oil confirms chemical contaminants and ageing. Low BDV and interfacial tension confirms high moisture level. High concentration of hydrogen indicates Partial discharging.CO2 shows cellulose decomposition. So needs immediate replacement.
From furan, 2FAL is 1.122ppm.It is a clear indication of overheating inside the transformer and cellulosic decomposition. Using Chendong's formula, DP value is 417,extensive deterioration.
Remnant life is **%life = 100 * (DP – 200)/(1200-200) = 21 %.**

D. Transformer 4

Dark reddish colour shows sediments. Apart from that, oil is healthy. Furan concentration is 0.416 ppm , DP is 540 means moderate deterioration. Remnant life is 34 percent. Due to previous oil replacements, 2FAL concentration is less. Hence transformer can work for next 10 years.

E. Transformer 5

Low interfacial tension, high water content , high concentration of hydrogen shows polar contaminants and low energy discharges. Low energy discharges are the symptoms of sparking or arcing between bad connections of discs or windings , breakdown of oil , discharges between clamping parts, bushings & tanks, high voltage & ground .Hence authorities were suggested to check for the above and replace the oil as it is heavily deteriorated.

DP is 519 and remnant life is 21 percent.

F. Transformer 6

It shows low interfacial tension and high concentration of CO2 and C2H2. Ethylene reflects thermal fault. Hence transformer should be checked for sparking or arcing between bad connections of discs or windings, breakdown of oil, discharges between clamping parts, bushings & tanks, high voltage & ground .

2FAL concentration is 0.447 ppm . DP is 531 and remnant life is 33%.

IV. CONCLUSIONS

On the basis of test reports and our experience, The authors feel that following points should be considered for condition monitoring.

1. The approach followed in carrying out measurement of furan content has helped in concluding that transformer oil needs replacement. Replacement can help the transformers to work for many more years.
2. Furan content in oil is non invasive test, does not involve taking outage of the transformer. It should be

monitored for all transformers. The frequency of monitoring depends upon concentration of furan content and rate of rise.

3. Total furan content in oil alone cannot be used for estimating the remnant life. DP test has to be considered for checking the health of transformer.

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