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Case Study Of the Failed 15.75/220kV, 250MVA Generator Transformer: An Overview

Laxman Rao Alur,
Asst Engineer(Elect)

Abstract: *Transformer has vital role in the emerging electric Power Systems and is the one of the main equipments in the Power System. So monitoring and maintaining their healthiness is very essential, by monitoring Transformers periodically and taking required action results in increase of life of Transformers and also we can avoid secondary damages, electrical/mechanical hazards to human beings working near Transformers. If any problem is found while periodical testing /monitoring we can go for a planned shutdown which can save huge Generation Loss due to failure of Transformers in case of Generating Station. In general failure of Transformer can cause non availability of Generation/Transmission/ distribution for some time. So it's very necessary to monitor and take suitable action. Whenever any abnormalities are found in Transformers else it leads to failure of equipment further affecting the Power System Stability. Failure of one of the Generator Transformer has been discussed here.*

Key words: *Transformer, condition monitoring, healthiness, routine testing, Dissolved Gas Analysis*

I. Introduction

A transformer is a static machine used for transforming power from one circuit to another without changing frequency. Power transformers have an important role in power flow in large power systems. Their better performance gives high efficiency and enhanced power transfer capability. However, various power transformer failures in the recent past have acquired much attention towards failure analysis. Transformers are reliable and offer trouble free service if they are monitored time to time by maintenance and operating engineers. There are many different maintenance actions, to be performed on a power transformer some of them are monthly basis, some other are quarterly, some are half-yearly basis, and some of them are yearly basis. by doing these routine maintenance we can avoid failures to maximum extent which may be caused by internal faults, but some time external faults can cause severe damage to the transformer. In this paper we can see one of the methods of testing the given power transformer i.e. Dissolved Gas Analysis, wherein the transformer oil is tested for its gas composition and thus the transformer condition can be known.

II. Dissolved Gas Analysis (Dga)

DGA is the study of dissolved gases in transformer oil. Insulating materials within transformers and electrical equipment break down to liberate gases within the unit. The distribution of these gases can be related to the type of electrical fault, and the rate of gas generation can indicate the severity of the fault. The identity of the gases being generated by a particular unit can be very useful information in any preventative maintenance program. Online monitoring of electrical equipment is an integral part of the smart grid. When gassing occurs in transformers there are several gases that are created. Enough useful information can be derived from nine gases so the additional gases are usually not examined. The nine gases examined are:

- Atmospheric gases: hydrogen, nitrogen and oxygen
- oxides of carbon : carbon monoxide and carbon dioxide
- hydrocarbons: acetylene, ethylene ,methane and ethane

Thermal faults are detected by the presence of by-products of solid insulation decomposition. The solid insulation is commonly constructed of cellulose material. The solid insulation breaks down naturally but the rate increases as the temperature of the insulation increases. When an electrical fault occurs it releases energy which breaks the chemical bonds of the insulating fluid. Once the bonds are broken these elements quickly reform the fault gases. The energies and rates at which the gases are formed are different for each of the gases which allows the gas data to be examined to determine the kind of faulting activity taking place within the electrical equipment.

- Insulation overheating deteriorates the cellulose insulation. In this case DGA results show high carbon monoxide and high carbon dioxide. In extreme cases methane and ethylene are at higher levels.
- Oil overheating results in breakdown of liquid by heat and formation of methane, ethane and ethylene.

- Corona is a partial discharge and detected in a DGA by elevated hydrogen.
- Arcing is the most severe condition in a transformer and indicated by even low levels of acetylene.

Interpretation of the results obtained for a particular transformer requires knowledge of the age of the unit, the loading cycle, and the date of major maintenance such as filtering of the oil. The IEC standard 60599 and the ANSI IEEE standard C57.104 give guidelines for the assessment of equipment condition based on the amount of gas present, and the ratios of the volumes of pairs of gases. After samples have been taken and analyzed, the first step in evaluating DGA results is to consider the concentration levels (in ppm) of each key gas. Values for each of the key gases are recorded over time so that the rate-of-change of the various gas concentrations can be evaluated. Any sharp increase in key gas concentration is indicative of a potential problem within the transformer.

Dissolved gas analysis as a diagnostic technique has several limitations. It cannot precisely localize a fault. If the transformer has been refilled with fresh oil, results are not indicative of faults. These gases are to be isolated from the sample and analyzed quantitatively using gas chromatography process. This technique enables proper diagnosis of the transformer condition in service and can also suggest preventive measures. The quantities of gases generated from the transformer oil and their types help in identifying the various fault conditions. Now, the relative quantities of all these gases give the oil decomposition energy during a particular fault. Each fault has its own characteristic amount of energy. Elevated concentrations of gases may signal corona, discharge, over heating arcing Table.1indicates the

Table.1

Gas	Normal Limits (ppm)	Action Limits (ppm)
Hydrogen (H2)	150	1000
Methane (CH4)	25	80
Ethylene (C2H4)	20	150
Acetylene (C2H2)	15	70
Ethane (C2H6)	10	35
Carbon dioxide(CO2)	10000	15000
Carbon monoxide(CO)	500	1000

Table.2

Gas detected	**Primary Interpretation**	**Secondary Interpretation**
Hydrogen (H2)	corona effect	arcing ,overheated oil
Methane (CH4)		Arcing, serious overheated oil
Ethylene (C2H4)	Thermal fault, local or over heated oil	Corona, arcing
Acetylene (C2H2)	Electric fault like arcing and sparking	Severely over heated oil
Ethane (C2H6)		Thermal fault like corona & over heated oil
Carbon dioxide (CO2)	Cellulose decomposition	
Carbon monoxide (CO)	Overheated cellulose decomposition	
Oxygen (O_2) & Nitrogen (N_2)	Indicator of system leaks over pressurization or changes in temperature	

healthiness of Transformer and Table.2 indicates the interpretation from the DGA

III. Past Dga Reports Analysis

Following are the results of DGA of past 2years

a) Dissolved gas Analysis results of the Generator Transformer for the year - 2013

Table.3			
Gases (DGA 2013)	Ppm	Normal Limits (ppm)	Action Limits (ppm)
Hydrogen (H2)	ND	150	1000
Methane (CH4)	1193	25	80
Ethylene (C2H4)	2643	20	150
Acetylene (C2H2)	ND	15	70
Ethane (C2H6)	399	10	35
Carbon dioxide(CO2)	3794	10000	15000
Carbon monoxide(CO)	ND	500	1000

As per table gas ppms are above normal values as mentioned in table.1 it was recommended to carry out internal inspection, for this lifting of bell tank was mandatory. But for lifting of bell tank transformer has to be shifted to repair bay for which includes oil draining, dismantling of connected radiator pipe lines, HV bushings, LAs, LV links etc resulting in a very long shut down. So planned for inspection only through the inspection windows provided at sides of Transformer but no hot spot/arcing was observed. Clearance for charging the Transformer was given.

b) Dissolved gas Analysis results of the Generator Transformer for the year – 2014

Table.4			
Gases (DGA 2014)	ppm	Normal Limits (ppm)	Action Limits (ppm)
Hydrogen (H2)	22	150	1000
Methane (CH4)	144	25	80
Ethylene (C2H4)	215	20	150
Acetylene(C2H2)	ND	15	70
Ethane (C2H6)	38	10	35
Carbon dioxide(CO2)	718	10000	15000
Carbon monoxide (CO)	255	500	1000

After DGA there was an increasing trend in gases. Again it was recommended for internal inspection so internal inspection was carried out by lifting the main tank and found arcing at some contacts of B-phase OCTC and these contacts were replaced and transformer was taken into service.

But After running satisfactorily for few months Unit was tripped on Class-A protection i.e. operation of Transformer Buchholtz relay.

Again internal inspection carried out its observed that **inter turns shorting in Y-phase**

IV. Tests

To know any other damages/ problems following tests are carried out

1.Insulation resistance Test

IR	**T1(15s)**	**T2(60s)**	**PI**
HV TO E	15.4 GΩ	23.6 GΩ	1.52
LV TO E	10 GΩ	15 GΩ	1.49
HV TO LV	13 GΩ	19.3 GΩ	1.47

2.Turns Ratio Test

TAP POSITION	**R**	**Y**	**B**
1	512.3	9.416	10.53
2	514.3	9.289	10.41
3	516.9	9.169	10.28
4	528	9.045	10.15
5	527.6	8.923	10.02
6	532.6	8.805	9.896
7	534.2	8.687	9.770
8	551.2	8.461	9.516
9	556.3	8.456	9.518
10	564.5	8.337	9.392
11	579.7	8.210	9.266
12	510.3	8.115	9.135
13	510.3	8.001	9.011
14	514.1	7.889	8.888
15	507.4	7.776	8.765
16	522	7.667	8.641
17	531.5	7.559	8.519

3.HV milli amps test
Applied 1Ø230V, 50Hz

Phase	**Tap1**	**line**	**Tap1**
RN	9.26mA	RY	9.42mA
YN	133mA	YB	133mA
BN	9.36mA	BR	9.22mA

4.OC Test:
LV side applied : 415V

Phase	**Current**
R	542mA
Y	1.8A
B	537mA

5. Magnetizing Balance Test
HV side applied: 415V

HV SIDE			**LV SIDE**		
RY	**YB**	**BR**	**ry**	**yb**	**br**
427	48	54.3	45.5	0.38	45
214	9.56	429	23.03	0.017	23
420	430	850	45.4	0.38	45.7

6. Winding Resistance Test
(Vector Group Ynd1)

	1 Amps applied		mΩ	25 Amps applied		μΩ
Tap	RN	YN	BN	Ry	yb	br
1	128.35	126.81	129.32			
2	125.13	124.51	126.43			
3	122.26	122.58	123.69			
4	120.38	120.02	121.78			
5	118.28	118.14	119.97			
6	115.45	115.43	117.73			
7	112.67	112.59	114.41			
8	109.81	109.81	111.73			
9a	106.81	106.87	108.89			
9b				1002.1	1415.3	1136.9
9c	106.95	106.83	108.72			
10	109.97	109.69	111.72			
11	112.63	112.21	114.45			
12	115.63	115.46	117.58			
13	118.31	118.12	119.91			
14	120.43	120.21	121.82			
15	122.54	122.46	123.93			
16	125.51	124.98	126.66			
17	128.35	126.91	129.55			

V. Conclusion:

The above test results shows abnormal condition of transformer showing inter turn shorting in Y-ph 400kV winding. As Transformers are very important in power system network for power evacuation its our duty to monitor them periodically. Any failure leads to unplanned shutdown causing problems in power system stability. As Power Transformers are very costly, a bad maintenance OR any manufacturing faults leads to

failure and in case of such failures with Generator transformers leads to loss of generation resulting in both Generation Losses and equipment loss. Some times these failures may cause secondary damages also e.g. damages to nearby equipments and humans. Therefore After samples have been taken and analyzed, the first step in evaluating DGA results is to consider the concentration levels (in ppm) of each key gas , if we found any gases present at higher levels we should take immediate actions to resolve the problems.

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