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An attempt to investigate transformer failure by Dissolved Gas Analysis

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Abstract: Reliable and continued performance of power transformer is the key to profitable generation, transmission & distribution. Power transformer failures lead to power supply interruptions in developing nations like India. DGA technique plays an important role in nullifying these unforeseen interruptions. One of the best methods of detecting certain problems which can lead to failure of the transformer is dissolved gas analysis (DGA). failure rate of transformers is very high in India - 25% per annum which is not favorable compared to international failure rate of 1-2%. To prevent failures, effective analysis and diagnosis needs to be investigated. Transformer failures presented in this paper are catastrophic and of high interest. Case studies are presented here for the transformers which have higher fault gas concentrations.

An attempt has been made in this paper to assess in-service transformers, new transformers after factory tests and internal condition of service on load tap changers by dissolved gas analysis.

Keywords: *Power Transformer, Dissolved gas analysis, On load tap changer.*

1.0 INTRODUCTION

Power transformers performance implies power system efficiency. Various power transformer failures lead to minor / severe power supply interruptions raising need of predictive, preventive and corrective maintenance.

Power transformer substation is expensive and they are the most valuable asset in a substation. Unexpected failures of these transformers cause major disturbances to operating systems resulting in unscheduled outages.

Tap changer is a very important component of a power transformer. About 30% of reported failures of substation power transformers are related to the ageing effects on On load tap changer (OLTC's). Due to this high failure rate, it is very important to monitor condition of power transformers OLTC closely. DGA in OLTC compartment has become more common as a reliable tool to detect and identify problems and severity in OLTC's.

Factory test is the phase in which the behavior of new transformer is assessed. The transformer is filled with oil and undergoes thermal and / or electrical testing viz partial discharge, heat run, insulation test, chopped lightning and impulse test. DGA before & after these factory tests is very important to assess the internal condition of new transformer at factory.

2.0 DISSOLVED GAS ANALYSIS

Power transformer is a critical and capital intensive asset within a power system.

Power transformer can fail due to any combination of mechanical, electrical or thermal stresses. Such failures are sometimes catastrophic and includes

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irreversible internal damage. Regular monitoring by DGA can provide useful information about the condition of transformer and prior information of the failures at very initial stages of fault.

The DGA technique is very sensitive as it detects gas dissolved in oil in parts per million (ppm) by the use of gas extraction system and a gas chromatograph. It is possible to check whether a transformer under service is being subjected to normal ageing or abnormal ageing resulting in thermal and electrical faults inside the transformer.

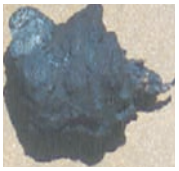
Maintenance of Transformers by DGA:

1. Routine Maintenance or Preventive maintenance – Integral part of annual maintenance program, DGA to know transformer internal condition and plan maintenance schedule.
2. Predictive Maintenance – Concerned with units which have shown definite warning signal (Alarm). DGA after a warning signal to know the cause.
3. Corrective Maintenance – DGA after the failure of a transformer to assess the reason for failure, rectify the problem and monitor the transformer by periodic DGA to assure the correctiveness.

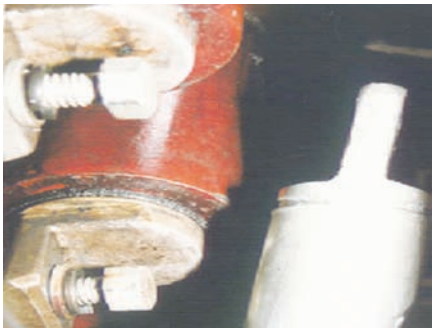
Few case studies indicating these objectives are discussed here.

ROUTINE MAINTENANCE – CASE 1	
75 MVA Generator Transformer	
Gas quantities in ppm	
Methane	3844
Ethane	1566
Ethylene	***4150***
Acetylene	257
Hydrogen	2500
Carbondioxide	5000
DGA indicates strong overheating in the transformer – Hot spot in core shorting links, bad contacts / joints and tank circulating currents. Immediate internal inspection recommended.	
Findings: Found accumulation of carbon deposits on 5 of 6 tap switches on OLTC points.	

ROUTINE MAINTENANCE – CASE 2		
250 MVA, 15/230 KV Transformer		
Gas quantities in ppm	1st DGA	2nd DGA after 3 months
Methane	547	631
Ethane	199	386
Ethylene	***530***	***924***
Acetylene	ND	ND
Hydrogen	18	81
Carbondioxide	2905	3449
ND-None detected		
DGA indicates circulating currents and or overheated joints. Immediate internal inspection recommended to locate the fault.		
Findings: Terminal lug connecting for tap 14 Bφ inside the main tank got melted & cut. Replaced - R & Yφ HV bushing, all LV bushing, OLTC tap 14, Bφ defective lug.		

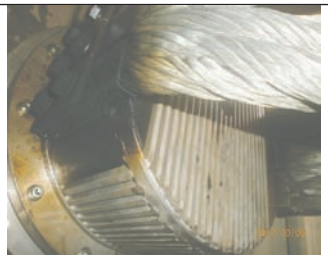


Tap changer 14th R Phase tap melt, broken, cut into 2 pieces



14th Tap Rφ Rectified tap

ROUTINE MAINTENANCE – CASE 3			
315 MVA, 15.75/400 KV Generator Transformer			
Gas quantities in ppm	1st DGA	Immediately filtered - DGA after 3 months of filtration	DGA after 4 months of filtration
Methane	1488	440	1075
Ethane	641	151	379
Ethylene	***2551***	***738***	***2215***
Acetylene	1	ND	ND
Hydrogen	49	58	21
Carbon dioxide	918	395	548
ND-None detected			
Continuous increase of ethylene after filtration of oil confirms the presence of fault. DGA indicates thermal fault of high temp.>700 degree C, Overheating of copper due to eddy currents bad connections / joints. Immediate internal inspection of Transformer is recommended to locate the fault.			
Findings: Two flexibles from windings to LV bushing (R phase) was found heated. Bushing terminal surface had pitted due to loose connection in fixing bolts. Flexibles and surface of LV bushing were smooth grinded and reconnected.			



Heated Bushing

Heated Bushing

Pitted Bushing

Burnt leads

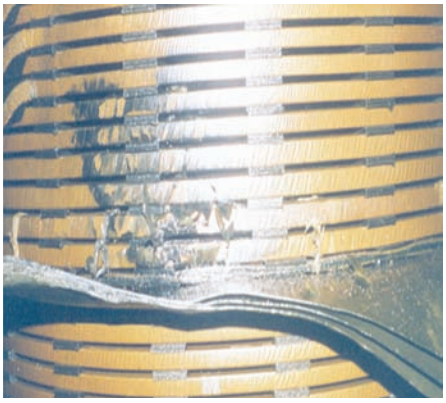
Rectified Bushing

PREDICTIVE MAINTENANCE – CASE 1		
12.5 MVA, 66/11 KV Transformer		
Bucholtz actuation reported & oil was filtered 3 months back		
Gas quantities in ppm	Top	Bottom
Methane	7863	8146
Ethane	2436	2547
Ethylene	***23782***	***24847***
Acetylene	1185	1226
Hydrogen	163	172
Carbon dioxide	1376	1496
DGA indicates thermal fault of high temp.>700 degree C, Overheating of copper due to eddy currents bad connections / joints. Immediate internal inspection of Transformer is recommended to locate the fault.		
Findings: Fault confirmed. 4 nos. of bushing rods, LV cups & flexible connections were burnt, all of them replaced.		

PREDICTIVE MAINTENANCE – CASE 2		
55 MVA, 110/11 KV Transformer		
Reported Bucholtz actuation & oil was filtered 2 months back		
Gas quantities in ppm	Just after filtration	After bucholtz actuation
Methane	4	247
Ethane	2	44
Ethylene	2	***783***
Acetylene	ND	***5008***
Hydrogen	ND	116
Carbon dioxide	320	2063
ND-None detected		
DGA indicates thermal fault coupled with arcing. Immediate internal inspection of transformer recommended.		

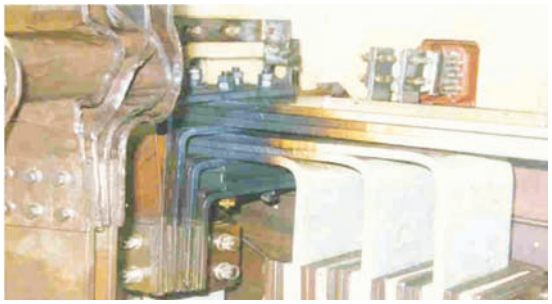
Findings: It was found that B phase HV winding middle coil was burnt out. Core & Coil assemble was rebuilt.

ARC – INSIDE TANK DUE TO INTER TURN FAULT



INTER TURN FAULT ON HV WINDING MIDDLE LIMB

PREDICTIVE MAINTENANCE – CASE 3		
65 KVA RECTIFORMER		
Bucholtz actuation & oil was filtered 6 months back		
Gas quantities in ppm	Oil	Bucholtz gas ppm
Methane	15	244
Ethane	24	166
Ethylene	***57***	***1107***
Acetylene	***16***	***589***
Hydrogen	***109***	***1578***
Carbondioxide	982	3208
DGA indicates discharge of low energy -general conductor overheating. As bucholtz contains high concentrations of hydrocarbon gases and since ethylene is high, it is a overheating fault. Internal inspection of transformer is recommended.		
Findings: The utility has confirmed the presence of a overheated / damaged joint inside the transformer.		



Faulty Joint

CORRECTIVE MAINTENANCE – CASE 1		
12.5 MVA, 66/11 KV Transformer		
Repaired & Re-commissioned after filtration		
Gas quantities in ppm	MIDDLE	BOTTOM
Methane	1225	933
Ethane	709	601
Ethylene	***6795***	***5698***
Acetylene	329	268
Hydrogen	20	ND
Carbondioxide	639	716
ND-None detected		
Presence of high concentration of hydrocarbon gases indicates that the fault continues to exist. To draw a conclusive remark, It is suggested to conduct a reference DGA after filtration and monitor by DGA monthly for 2-3 times.		

CORRECTIVE MAINTENANCE – CASE 2		
15 MVA, 15/6.6 KV Transformer		
Failed Transformer		
Gas quantities in ppm	After failure	1 year before failure
Methane	1085	32
Ethane	150	41
Ethylene	2754	16
Acetylene	***3842***	ND
Hydrogen	1053	ND
Carbondioxide	590	2811
DGA indicates that the failure was due to severe arcing in the Transformer.		

TRANSFORMER FACTORY TESTS:

In factory, the new transformer is filled with oil and subjected to thermal & electrical stress by conducting short circuit test, heat run test, temperature rise test, chopped lightning impulse

test etc.,. DGA is a quality control procedure before and after these factory tests on power transformers to indicate that the design is fool proof. As only small quantities of gases are generated during factory tests, utmost care is necessary in sampling of oil samples, analysis and interpretation of results. Even a rise is 5-10 ppm of gases after the factory tests is a matter of concern.

NEW TRANSFORMER IN FACTORY–CASE 1		
Fault observed during temperature rise test. DGA conducted Before and After fault rectification.		
Gas quantities in ppm	Before fault rectification	After fault rectification
Methane	184	ND
Ethane	32	ND
Ethylene	***243***	ND
Acetylene	10	ND
Hydrogen	101	ND
Carbondioxide	298	168
ND-None detected		
DGA indicated overheating of copper due to eddy currents, bad contacts/Joints.		
Findings: Imbalance flux problem has resulted in overheating.		

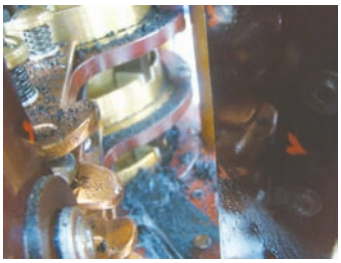
NEW TRANSFORMER IN FACTORY – CASE 2		
DGA before and after Heat run test.		
Gas quantities in ppm	Before Heat run test	After Heat run test
Methane	1	6
Ethane	ND	2
Ethylene	ND	***15***
Acetylene	ND	***7***
Hydrogen	ND	ND
Carbondioxide	212	272
ND-None detected		
DGA indicates low temperature overheating.		

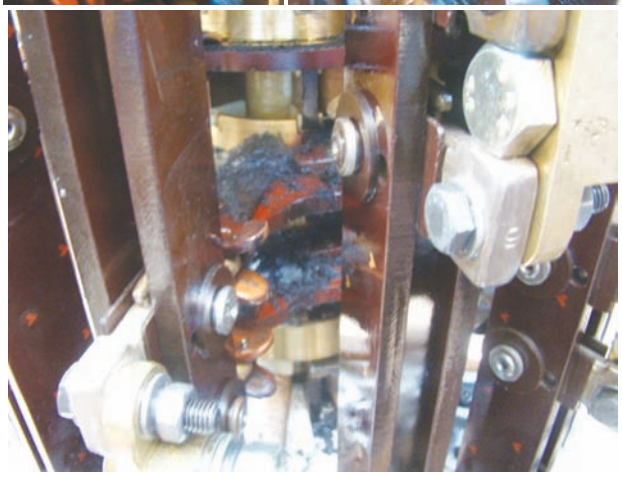
ON LOAD TAP CHANGER:

Regular testing and maintenance of on load tap changers (OLTC) is an important part of transformer asset management. OLTCs are the most vulnerable components of a power transformer and their failure occurs due to contacts failure.

DGA helps to detect OLTC failure due to burning or overheating of contact points. It has been estimated that more than 30% of transformer failures are due to faulty LTC's. Ethylene the key gas for overheating and Acetylene the key gas for arcing is routinely found in LTC compartments and will vary with the numbers of operations.

ON LOAD TAP CHANGER – CASE 1	
33 MVA Transformer	
Gas	Concentration in ppm
Methane	14895
Ethane	16349
Ethylene	***19412***
Acetylene	72
Hydrogen	2189
Carbondioxide	4562
Analysis: DGA indicates thermal fault of 150-300 Deg. C – Increasing hot spot temperature varying from small hot spot in core shorting links, bad contacts / joints and tank circulating currents. Immediate internal inspection of Transformer is recommended to locate the fault.	
Findings: Abnormality in Y & B phase OLTC was observed and is rectified. Completely melted contacts were observed on inspection.	

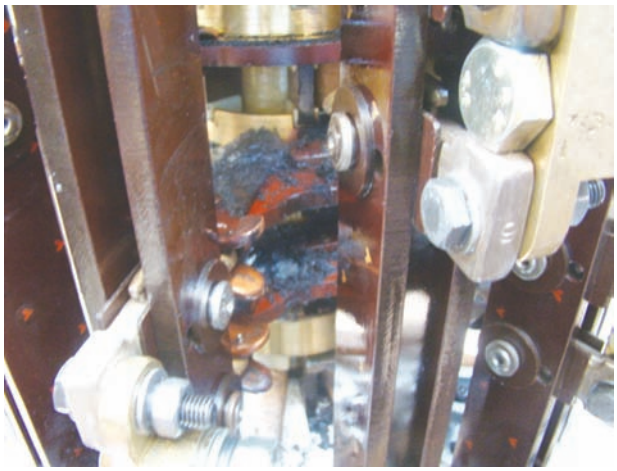




ON LOAD TAP CHANGER – CASE 2	
10 MVA, 6.6 KV Rectifier Transformer	
Gas	Concentration in ppm
Methane	4254
Ethane	1584
Ethylene	***7390***
Acetylene	86
Hydrogen	1782
Carbondioxide	2723

Analysis: DGA indicates thermal fault of high temperature greater 700 Degree C. Immediate internal inspection of Transformer is recommended to locate the fault.

Findings: Arcing in the tap changer was confirmed. Heat up between moving contacts and fixed contacts in position 2 & 7 was noticed.



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Fault Location at Tap Changer (Heat Up between Moving Contacts & Fixed Contacts in position:2&7

CONCLUSIONS:

Dissolved gas analysis is a proven diagnostic technique for predicting the internal condition of Transformers.

In DGA, faults can be predicted at incipient stage itself. DGA can provide advanced warning of developing faults, Convenient scheduling of repairs, Status check of New & repaired units and Monitoring of units under problem.

DGA is typically a critical first step in any power transformer failure analysis. The cause of transformer failures indicated by DGA can help to improve the equipment reliability by proper maintenance scheduling leading to enhanced life of power transformers.

ACKNOWLEDGEMENT:

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