A NEW APPROACH FOR DGA INTERPRETATION OF IN-SERVICE POWER TRANSFORMER

Over a decades, Dissolved Gases Analysis (DGA) has been used as a common techniques to detect the incipient faults in oil-filled power transformers. It has been proven that generation of certain gases in power transformer is an indication that a failure is pending. Nowadays, DGA has become standard practice as part of transformer maintenance for many electric power utility companies.

Despite the sensitive and accurate of DGA measuring the gases, the proper use and interpretation of gas dissolved in oil is still not fully understood by many people. Moreover, the introduction of new interpretation techniques and standards has make the DGA interpretation is more complicated and may require experts to interpret it.

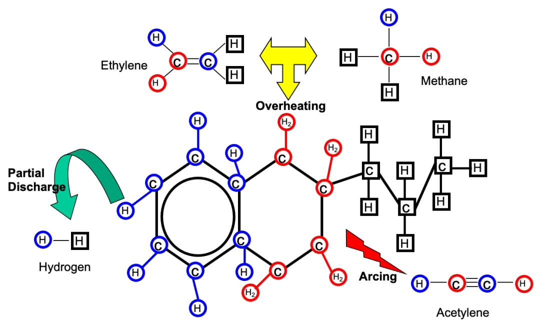
INTRODUCTION

Transformer is one of the most important and highest investment assets in electrical substation. The failure of in-service power transformer can cause supply interruption and revenue losses to power utilities and plant operator. With transformer fleet around the globe are in ageing state condition and operating beyond its design life, the transformer condition assessment and failure analysis is a highly important.

During in-service and under different operating stresses; thermal, electrical, mechanical and environmental, the insulation system will be deteriorated and gaseous by-product are formed. The concentration and the relation of the individual gases allow a prediction of whether a fault has occurred and what type it is likely to be and thus enabling prompt remedial action to be taken before the catastrophic failure occurs. These gases can be detected in transformer insulating oil using sensitive and reliable Dissolved Gas Analysis (DGA) techniques.

GAS GENERATION IN OIL

The causes of gas generation in insulating oil lie in the breaking of carbon-hydrogen and carbon-carbon bonds in the mineral oil molecules. Active hydrogen atoms and hydrocarbon fragments are formed. These free radicals can combine with each other to form gases such as molecular hydrogen, methane, ethane, or can recombine to form new condensable molecules. Further decomposition and rearrangement processes lead to the formation of products such as ethylene and acetylene. These processes are dependent on the presence of individual hydrocarbons, on the distribution of energy and temperature in the neighbourhood of the fault, and on time during which the oil is thermally or electrically stressed.



Thermal fracture of hydrocarbon chain molecules

FAULT GASES IDENTIFICATION

The potential faults in power transformer such as overheating, partial discharge and arcing produce a range of gases. Analysis on the concentration of theses gases can be used to identify the type and estimate the severity of the fault. Based on physical inspection of hundreds of faulty transformers and DGA results, the correlation of faults and its associated gases are established.

Faults	H2	CO	CO2	CH4	C2H2	C2H4	C2H6	O2
Cellulose ageing		x						
Oil decomposition	x			x	x	x	x	
Leaks in oin expansion system, gasket			x					x
Thermal fault-cellulose	x	x	x	x				x
Thermal fault in oil -150oC-300oC	x			x			x	
Thermal fault in oil -300oC-700oC	x			x		x	x	
Thermal fault in oil -700oC	x			x	x	x		
Partial discharge	x			x				
Arcing	x			x	x	x		

The correlation of gas generation and its associated faults

DGA INTERPRETATION

Attempts to correlate the type of faults with the gases produced in transformer oil began as early as 1928 by Buchholz. He realised that the gases produced by thermal faults in power transformers could be used as a protective device. This resulted in the development of the Buchholz relay. Since then, a several DGA interpretation methods have been introduced to analyse the gases dissolved in oil. Most of the DGA diagnostic tools in use today can be found in the IEEE C57.104 or IEC 60599 guides. In recent years, both standards have been revised to address some issues found during analysis of transformer condition and after investigating transformer failure.

Some of the DGA diagnostic tools are simpler; compare gas concentration with guideline to determine the different warning levels or using single ratio of gases. Others are more complex, taking multiple gas ratios and fitting them to a precise range of values. This articles presented the latest diagnostic tools available in IEEE and IEC guides.

DGA Norms Value

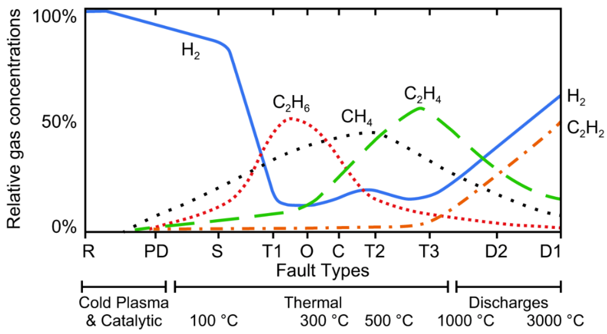
IEEE C57.104 has proposed a norm value to classify the DGA results. The classification process and recommendations are based on gas levels and level variation norms obtained from a statistical analysis of a large population of DGA results (90th and 95th percentiles). Transformers with DGA Status 1 are considered as probably normal. Transformers with DGA Status 2 are considered as possibly suspicious and warrant additional investigation. If the fault diagnosis reveals an issue of partial discharges, low temperature fault, or stray gassing, this would be treated as a less urgent issue, but still may affect future life of the insulation system. Transformers with DGA Status 3 are considered as probably suspicious. The transformer should be placed under increased surveillance and additional transformer testing is recommended. Consultation with the transformer manufacturer or a transformer expert is also recommended.

		O_2/N_2 Ratio ≤ 0.2				O_2/N_2 Ratio > 0.2			
		Transformer Age in Years				Transformer Age in Years			
		Unknown	1 – 9	10 – 30	>30	Unknown	1 – 9	10 – 30	>30
Gas	Hydrogen (H_2)	80	75		100	40	40		
	Methane (CH_4)	90	45	90	110	20	20		
	Ethane (C_2H_6)	90	30	90	150	15	15		
	Ethylene (C_2H_4)	50	20	50	90	50	25	60	
	Acetylene (C_2H_2)	1	1			2	2		
	Carbon monoxide (CO)	900	900			500	500		
	Carbon dioxide (CO_2)	9000	5000	10000		5000	3500	5500	

90th percentile gas concentrations as a function of O2/N2 ratio and age in µL/L (ppm)

Key Gases Method

Key Gases Method uses individual gas level and relative proportions of the key gases in the transformer to indicate different types of faults. It is based on the quantity of fault gases that are released from the insulating oil as the chemical structure breaks at varying temperatures in the transformer and at different energy level.



Relative percentage of dissolved gas concentrations in mineral oil as a function of temperature and fault type

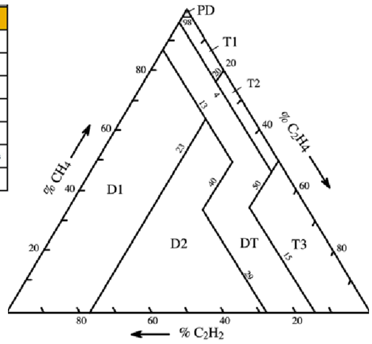
CO2/CO

The degradation of solid insulation produces Carbon Monoxide (CO) and Carbon Dioxide (CO2). The analysis of CO2/CO ratio was used as a key indicator to detect a fault that involved solid insulation material. If the ratio is below 3, it is strong indication of fault in paper, either hot spot or electrical arcing with temperature above 200oC. If the ratio above 10 then it indicates overheating fault at temperature less than 150oC. However, It should be noted that the use of CO2/CO ratios may also suffers from the presence of accidental's CO2 from air and also variations in O2 concentration present in the transformer incipient fault area (high O2 favours formation of CO2). In addition, if the oil is sufficiently heated in the presence of excess O2, this will also generate some CO and CO2.

Duval Triangle

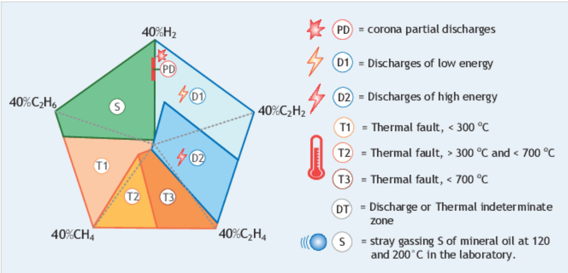
The Duval Triangle method was developed from IEC TC10 databases and an existing IEC 60599 Ratio method. It is a triangular plot which each side representing a 0% to 100% relative value of methane (CH4), ethylene (C2H4) and acetylene (C2H2). Plotting of the result then places the data somewhere within the triangular. The area within the triangle is then divided into seven separate regions corresponding to different fault classifications.

ZONE	FAULT INDICATION
T1	Thermal fault, ≤300 °C
T2	Thermal fault, >300 °C, ≤700 °C
T3	Thermal fault, >700 °C
D1	Discharges of low-energy
D2	Discharges of high-energy
DT	Combination of thermal faults and discharges
PD	Partial discharge



Duval Triangle Plot

Duval Pentagon



Fault zone boundaries in Duval Pentagon

In recent DGA interpretation technique, a new Duval Pentagon method has been introduced. Duval Pentagon uses 5 hydrocarbon gases in a single graphical representation to help detect multiple faults. The relative percentage of every gas is calculated and plotted on the axis between the pentagon center and the pentagon summit. Once the corresponding gas axis on 5 gases was plotted, the center or centroid of the irregular polygon drawn from these five points was then calculated mathematically. The fault zone is divided into six basic electrical and thermal faults used by IEC, IEEE and Duval Triangle, with additional diagnosis on possible of stray gassing phenomena.

DIAGNOSTIC METHODS SUMMARY

The most important aspect of DGA diagnostic methods is being able to correctly diagnosis recent or potential faults within a monitored transformer. Dissolved gases in oil data by themselves do not always provide sufficient information to evaluate the integrity of the transformer. The history of the transformers in terms of maintenance, previous faults and etc, is an important part of the information required to make an evaluation. As all these variables affect gas generation in different ways, the development of a rigorous method of analysis is extremely difficult and the prognosis of insulation performance is almost impossible.

DGA diagnosis techniques presented thus far use fault gas concentrations or ratios based on the practical experience of various experts. Now, with the availability of extensive DGA data, an alternative approach to DGA data interpretation have been developed using Artificial Intelligence (AI) techniques, Fuzzy logic, and Neural Networks techniques.

Next Issue

Application of Online Monitoring System for Power Transformer Health Assessment

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MasterClass Training: 'Life Management of Power Transformer'

TNB Labs will organised MasterClass Training on "Life Management of Power Transformer" on 20-23 September 2022 at Bangi Resort Hotel. This 4 days training will include classroom theory, case studies, hands-on session and lab tour of TNB Labs facilities@TNB Research Centre. The participants will also receive one copy of technical book entitle "Condition Assessment and Life Management of Power Transformer".

For more detail information, please contact:
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Course Brochure

Scan and download Masterclass Training brochure

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