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Dissolved Gas Analysis of 115 kV Steel Industry Transformer using new IEEE Standard

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***Abstract*—This paper discusses the application of the IEEE C57.104-2019 standard to analyze faults in transformer of steel industry. The IEEE C57.104-2019 standard provides clearer details than the IEEE C57.104-2008 standard. It uses statistical data obtained from oil samples from various DGA experts who have collected transformer oil sample data for decades. This standard also provides analytical examples to allow the user clearly understand the process in this standard.**

Keywords—dissolved gas analysis, transformer, IEEE C57.104-2019, Duval triangle, Duval Pentagon

I. INTRODUCTION

Transformers are the heart of the distribution system that distributes electricity to city areas, rural areas, homes and industrial facilities. All relying on transformers to reduce voltage levels down to a level where they can be used. It is therefore very useful if we are able to know the state of the transformer as a normal, abnormal, or critical state. It allows consumers to maintain using this transformer, planned outage or even takes the transformer in a critical state to inspect at manufacture and temporarily use another transformer. Maintenance planning of such transformers has fewer losses than it would force the transformers to operate until they failed.

Dissolved Gas Analysis is a method for analyzing transformer oil that has been in use since the 1960s. From the very beginning to the present, the data used for analysis by many DGA experts have been collected. Modern technology provides a good understanding of the details of gas formation processes that influence the assessment of the severity of transformer faults. The main purpose of DGAs is to distinguish whether the transformer in use is in normal or abnormal status.

II. PROCEDURE ACCORDING TO IEEE STANDARD

A. Procedures for interpretation of DGA results

Fig.1 is a flow chart that provides a suggested process to review the DGA results.

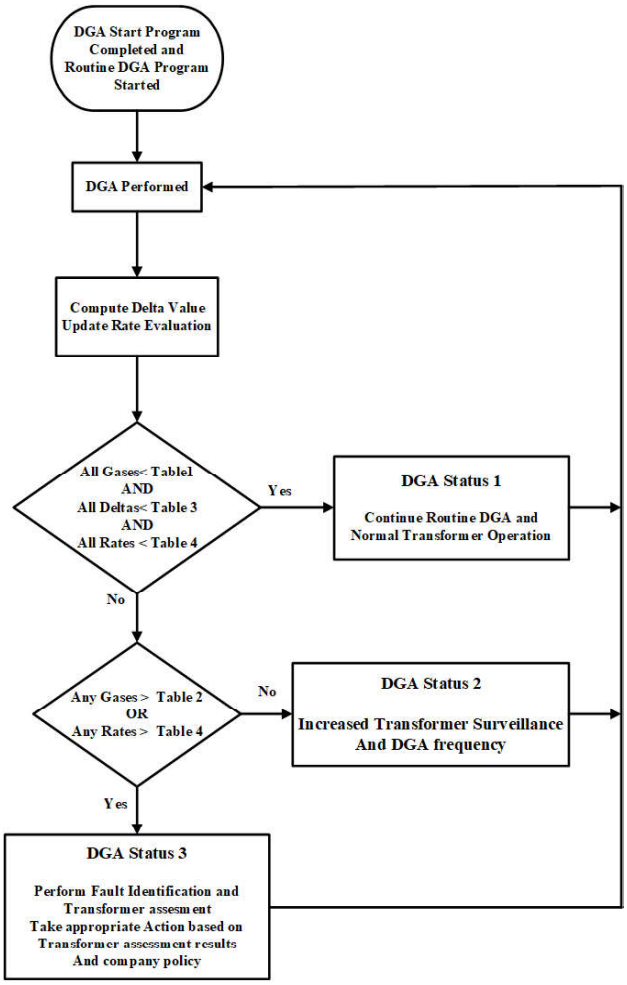

Fig. 1. DGA interpretation flow chart

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IEEE standard has classified transformers into status as follows.

B. DGA Status

a) DGA Status 1: Transformers in this state have a lower gas value than Table 1 and the difference between the current and previous DGA results (Delta) is lower than Table 3 and the multi-points rate is lower than that of Table 4.

It is considered to be a normal transformer according to the statistics of DGA results. DGA testing shall be performed at the intervals specified in this standard.

TABLE I. 90TH PERCENTILE GAS CONCENTRATION IN µL/L(PPM)

	O_2/N_2 Ratio ≤ 0.2				O_2/N_2 Ratio > 0.2			
	Transformer Age in Years				Transformer Age in Years			
	-	1-9	10-30	>30	-	1-9	10-30	>30
H_2	80	75	75	100	40	40	40	40
CH_4	90	45	90	110	20	20	20	20
C_2H_6	90	30	90	150	15	15	15	15
C_2H_4	50	20	50	90	50	25	60	60
C_2H_2	1	1	1	1	2	2	2	2
CO	900	900	900	900	500	500	500	500
CO_2	9k	5k	10k	10k	5k	3.5k	5.5k	5.5k

TABLE II. 95TH PERCENTILE GAS CONCENTRATION IN µL/L(PPM)

	O_2/N_2 Ratio ≤ 0.2				O_2/N_2 Ratio > 0.2			
	Transformer Age in Years				Transformer Age in Years			
	-	1-9	10-30	>30	-	1-9	10-30	>30
H_2	200	200	200	200	90	90	90	90
CH_4	150	100	150	200	50	60	60	30
C_2H_6	175	70	175	250	40	30	40	40
C_2H_4	100	40	95	175	100	80	125	125
C_2H_2	2	2	2	4	7	7	7	7
CO	1.1k	1.1k	1.1k	1.1k	600	600	600	600
CO_2	9k	5k	10k	10k	5k	3.5k	5.5k	5.5k

b) DGA Status 2 : Transformers in this state have a gas value higher than Table 2 or have a multi-points rate of gas higher than Table 4. It is considered suspicious and requires further confirmatory testing. By considering the cause of gas formation, If the fault diagnosis results show that the problem is Partial Discharge, Low-Temperature fault (T1),or Stray Gassing (S). This is not urgent but still affects the life of the insulation. The sampling frequency of transformer oil should be increased.

c) DGA Status 3 : Transformer with Status 3 is considered as probably suspicious. Online dissolved gas monitoring may be considered if close monitoring is necessary. Probable causes of gas generation using DGA interpretation procedures should be investigated. The transformer should be placed under increasing surveillance and additional transformer testings are recommended.

TABLE III. 95TH PERCENTILE VALUE FOR ABSOLUTE LEVEL CHANGE BETWEEN SUCCESSIVE LABORATORY DGA SAMPLES IN µL/L(PPM)

	Maximum µL/L(ppm) variation between consecutive Laboratory DGA samples	
	O_2/N_2 Ratio ≤ 0.2	O_2/N_2 Ratio > 0.2
H_2	40	25
CH_4	30	10
C_2H_6	25	7
C_2H_4	20	20
C_2H_2	Any Increase	Any Increase
CO	250	175
CO_2	2500	1750

TABLE IV. 95TH PERCENTILE VALUES FROM MULTI-POINTS RATE ANALYSIS WITH ALL GAS LEVELS BELOW TABLE I VALUES IN µL/L/YEAR

	Maximum µL/L/year(ppm/year) rate in function of the period Between first and last point of the DGA series (3 to 6 samples)			
	O_2/N_2 Ratio ≤ 0.2		O_2/N_2 Ratio > 0.2	
	Period between first and last point of the series			
	4-9 Mo	10-24 Mo	4-9 Mo	10-24 Mo
H_2	50	20	25	10
CH_4	15	10	4	3
C_2H_6	15	9	3	2
C_2H_4	10	7	7	5
C_2H_2	Any increasing rate		Any increasing rate	
CO	200	100	100	80
CO_2	1750	1000	1000	800

III. DGA DATA FROM 115 KV TRANSFORMER

The DGA data from the transformer are interpreted using Standard IEEE C57.104-2019. The DGA data used in this paper are sampling 5 times, 4 March, 2 June, 28 October, 27 November, and 18 December 2020. Transformer ratings are as follows; 60/72 MVA, 115/22 kV, 3-phase, Oil Natural Air Forced(ONAF). It was manufactured by EKARAT-DAIHEN in 1993. The DGA test results of this transformer are shown in Table V.

TABLE V. DGA DATA OF THE TRANSFORMER

Component Gas	Dissolved Gas Concentration(ppm)				
	4/3/20	*2/6/20*	*28/10/20*	*27/11/20*	*18/12/20*
H_2	16	2	15	15	15
CH_4	112	35	126	119	123
C_2H_6	232	142	253	247	239
C_2H_4	5	3	5	8	5
C_2H_2	0	0	0	0	0
CO	116	27	133	123	134
CO_2	825	704	873	912	825
N_2	33,552	46,071	32,794	25,854	30,543
O_2	3,232	1,7480	3,332	1,040	2,100

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The transformers O2 / N2 ratios shown in Table VI. The DGA delta between successive samples shown in Table VI.

TABLE VI. O_2/N_2 RATIOS OF TRANSFORMER

	Dissolved Gas Concentration(ppm)				
	4/3/20	*2/6/20*	*28/10/20*	*27/11/20*	*18/12/20*
O_2/N_2	0.09	0.38	0.10	0.04	0.07

TABLE VII. DGA DELTA(PPM) BETWEEN SUCSESSIVE SAMPLE

Sample Date	Level change between successive DGA samples(ppm)						
	ΔH_2	ΔCH_4	ΔC_2H_6	ΔC_2H_4	ΔC_2H_2	ΔCO	ΔCO_2
2/6/20	-14	-77	-90	-2	0	-89	-121
28/10/20	13	91	111	2	0	106	169
27/11/20	0	-7	-6	3	0	-10	39
18/12/20	0	4	-8	-3	0	11	-27

The gas concentration of the transformer in Table V was compared with the gas concentration in Table II. It was found that the gas concentration of CH_4 and C_2H_6 above the O_2/N_2 > 0.2 in the transformer age in the year category of 10 to 30 years in Table II. When comparing the delta values in Table VII with those in Table III in the same category shown that the CH_4 and C_2H_6 gases exceeded the norm. It means this transformer is in DGA Status 3. Mitigative actions or other responses should be considered (i.e., online monitoring).

IV. FAULT TYPE IDENTIFICATION

This is a procedure for determining the fault type using the Duval Triangle and the Duval Pentagon.

A. Identification using Duval Triangle 1&4

Duval Triangle ratios for Duval Triangle 1 and Duval Triangle 4 are calculated in Table VIII and Table IX respectively. These relative % values are the coordinates of the DGA point in Duval Triangle 1 and 4. The triangle 4 method allows for distinguishing between faults S, O, PD, R, which are of relatively minor concern in a transformer, and potentially more dangerous faults C, which involve possible carbonization of paper.

TABLE VIII. DUVAL TRIANGLE RATIOS FOR DUVAL TRIANGLE 1

Data Point	Sample Date	$\%CH_4$	$\%C_2H_4$	$\%C_2H_2$
1	4/3/20	95.7	4.3	0.0
2	2/6/20	92.1	7.9	0.0
3	28/10/20	96.2	3.8	0.0
4	27/11/20	93.7	6.3	0.0
5	18/12/20	96.1	3.9	0.0

TABLE IX. DUVAL TRIANGLE RATIOS FOR DUVAL TRIANGLE 4

Data Point	Sample Date	$\%H_2$	$\%CH_4$	$\%C_2H_6$
1	4/3/20	4.4	31.1	64.4
2	2/6/20	1.1	19.6	79.3
3	28/10/20	3.8	32.0	64.2
4	27/11/20	3.9	31.2	64.8
5	18/12/20	4.0	32.6	63.4

The Duval Triangle 1 diagnostic method is reported in the T1 region and Duval Triangle 4 method is reported in the O region. It identifies overheat in paper or oil without carbonization of paper and loss of its insulating properties.

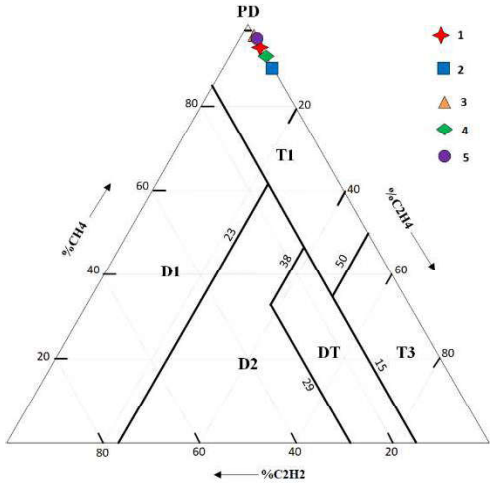

Fig. 2. Duval Triangle 1

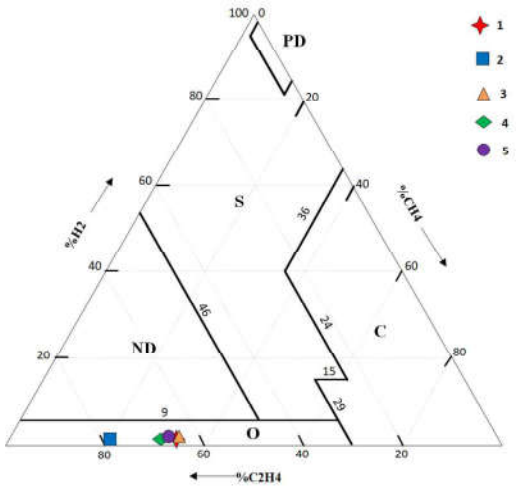

Fig. 3. Duval Triangle 4

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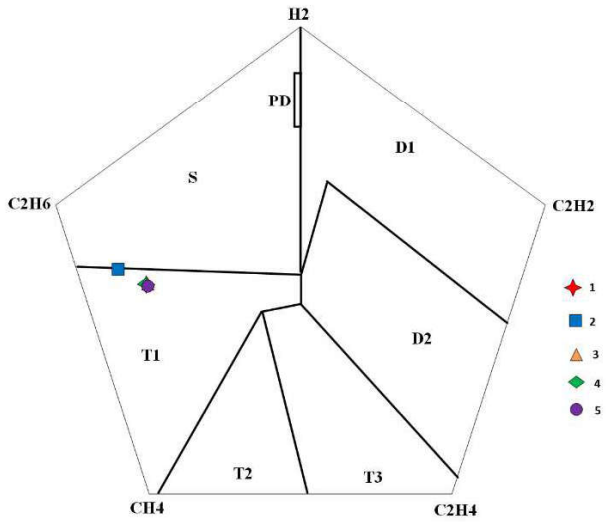

Fig. 4. Duval Pentagon 1

The Duval Pentagon 1 diagnostic method is reported in the T1 region and Duval Pentagon 2 method is reported in the O region. It identifies overheat in paper or oil without carbonization of paper and loss of its insulating properties. If thermal faults (T1, T2, and T3) have been identified with Duval Pentagon 1, more information can be obtained on these faults with Duval Pentagon 2, as in the case of Duval Triangle 4 and 5.

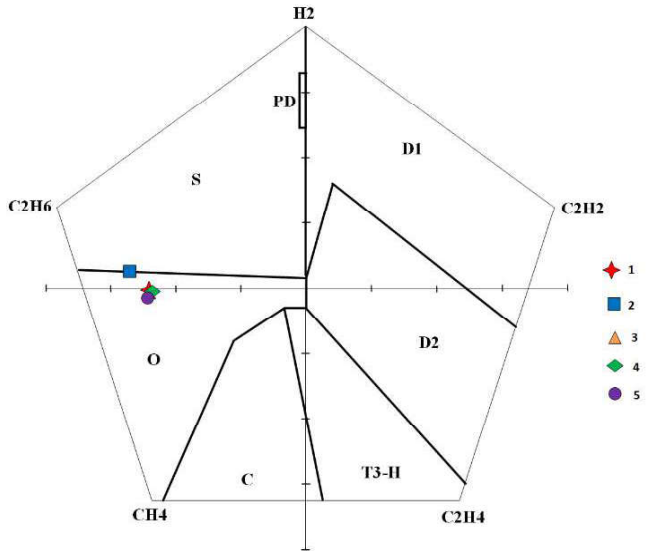

Fig. 5. Duval Pentagon 2

The Pentagon 2 method allows for detection of the 3 basic types of electrical faults(PD, D1, and D2) as in Duval Pentagon 1, and to further distinguish between the 4 additional sub-types of thermal faults of D2(S, O, C, and T3 in mineral oil only). In Duval Pentagon 2, faults T3 in mineral oil only are indicated as T3-H.

V. CONCLUSION

The IEEE C57.104-2019 standard is used to indicate the DGA status of the transformer, which affects the surveillance in use and decides if additional maintenance should be performed.

The addition of a section for the fault type identification using Duval Triangle 1,4 and 5 or Duval Pentagon 1 and 2 has also improved the accuracy of the fault classification.

DGA samples from steel industry transformers were used for this analysis. In conclusion, the transformer is in DGA Status 3. The sampling frequency of transformer oil should be increased. From the fault type identification, the result indicates that there are heat points in the oil or paper that do not affect the dielectric strength. It does not burn the insulating paper.

In the future, the DGA of Arc Furnace transformers will be studied using this standard to analyze DGA results. It used to monitor the deterioration of the transformer insulation and assemble it for further maintenance.

REFERENCES

[1] "IEEE Guide for the interpretation of Gases Generated in Oil-Immersed Transformers," IEEE Std.C57.104- 2019, 2019.

[2] "IEEE Guide for the interpretation of Gases Generated in Oil-Immersed Transformers," IEEE Std.C57.104- 2008, 2008.

[3] Jeff Golarz,"Understanding Dissolved Gas Analysis (DGA) Techniques and Interpretations," 2016 IEEE/PES Transmission and Distribution Conference and Exposition (T&D), pp.1-5, 2016.

[4] Triparna Nandy, Amit Gupta, Nikhileshwar P. Adhikari, "Study of Dissolved Gas Analysis for Pre Determination of Faults in Transformers," 2016 International Conference on Computation of Power, Energy Information and Commuincation (ICCPEIC), pp.634-642, 2016.

[5] T.Bhavani Shanker,H.N.Nagamani,Deepthi Antony,and Gururaj S Punekar,"Case Studies on Transformer Fault Diagnosis using Dissolved Gas Analysis," 2017 IEEE PES Asia-Pacific Power and Energy Engineering Conference(APPEEC), pp.1-3, 2017

[6] S. N. Hettiwatte, H. A. Fonseka,"Analysis and interpretation of dissolved gases in transformer oil: A case study," 2012 IEEE International Conference on Condition Monitoring and Diagnosis, pp.35-38, 2012.

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