International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:6, No:8, 2012

An Elin Load Tap Changer Diagnosis by DGA

Hoda Molavi, Alireza Zahiri, Katayoon Anvarizadeh

Abstract**—**Dissolved gas analysis has been accepted as a sensitive, informative and reliable technique for incipient faults detection in power transformers and is widely used. In the last few years this method, which has been recommended by IEEE Power & Energy society, has been applied for fault detection in load tap changers. Regarding the critical role of load tap changers in electrical network and essential of catastrophic failures prevention, it is necessary to choose "condition based preventative maintenance strategy" which leads to reduction in costs, the number of unnecessary visits as well as the probability of interruptions and also increment in equipment reliability. In current work, considering the condition based preventative maintenance strategy, condition assessment of an Elin tap changer was carried out using dissolved gas analysis.

Keywords**—**Condition Assessment, Dissolved Gas Analysis, Load Tap Changer

I. Introduction

LOAD tap changers (LTCs) for power transformers are essential components of the electrical networks. It has been estimated that a third of all transformer failures can be traced to faulty LTCs [1], [2].

Since LTCs are the only movable part of power transformers, they suffer from various aging mechanisms [3]. Common LTC failures are being caused by mechanical malfunction, increased contact resistance, localized thermal stress, material failure, breakdown of the insulating oil (coking), contact wear, improper design or high loads [1].Utilities seek new methods and technologies to extend the service intervals and monitor equipment condition to avert catastrophic failures, reduce maintenance costs and increase the reliability of power delivery and distribution [1].Corrective maintenance, Period based preventative maintenance and Condition based preventative maintenance are three classical maintenance strategies [4]. The concept of corrective maintenance is generally considered unacceptable for LTCs, considering their important role on running the distribution system. Regarding the variation in duty between different tap changers in a same utility and the recognition of the high reliability of in service tap changers, the traditionally using "period based preventative maintenance" is going to be replaced by "condition based maintenance" which offers several advantages to the utility as following [5]:

- Reduction in the required number of maintenance visits
- Reduction in maintenance costs
- Reduction in the possible interruptions to supply
- Reduction in the number of catastrophic failures
- Increment in the reliability of power delivery and distribution

H. Molavi is with chemistry and process group, Niroo Research Institute, Tehran, Iran (e-mail:hmolavi@nri.ac.ir)
A. Zahiri is with chemistry and process group, Niroo Research Institute, Tehran, Iran (e-mail:azahiri@nri.ac.ir).
K. Anvarizadeh was with chemistry and process group, Niroo Research Institute, Tehran, Iran.

There are several methods which are used as condition monitoring and diagnostic methods for LTCs, some of which are mentioned bellow. These techniques could detect the incipient signs of deterioration which enables utilities to choose "condition based maintenance" as their maintenance strategy.

- Dissolved gas analysis (DGA) of oil [6]-[8]
- Dissolved metals in oil analysis [8]-[10]
- Suspended particles in oil analysis [8]-[10]
- Acoustic and vibration fingerprints [7], [8], [11]
- Motor power fingerprints [11]
- Position measurement of the driving axis [11]
- Static and dynamic resistance measurements [7], [11] [13]
- Temperature difference measurement [7], [11]
- Infrared thermography [6]
- Chemical implants [14], [15]

In current study, condition monitoring of an Elin load tap changer was done using dissolved gas analysis for a three-month interval by sampling in two stages. The obtained results from two stages were compared and interpreted.

II. Performance Procedure

A. The Selected LTC

An Elin load tap changer of a 125 MVA power transformer in a 230/63 substation was selected as the experimental pilot. It is worth noting that 230/63 kV transformers are considered as the most frequent used power transformers in Iran.The pilot LTC had a sampling valve in the bottom of the equipment which facilitated sampling procedure. Furthermore it was possible to have overhaul over the equipment in the near future which enables the authors to have eye inspection over the selected LTC to compare their predictions with the results from inspection. After choosing the LTC, a form containing characteristic information of the selected LTC and its transformer was filled. The information included the company's name, the substation name and address, transformer's name, voltage level range etc. It also comprised LTC's information such as tap changer's type, its manufacture, oil volume, breathing type, sampling valve position etc. Some of the characteristics of the selected LTC have been presented in Table I.

TABLE I
The Characteristics of the Selected LTC

LTC's type	MLG3.720
Operating time	26 years
Last Overhaul date	2003

Regarding the information in Table I and the recommended maintenance interval by manufacturer, the overhaul operation should be performed over the equipment at least 2-5 years ago.It is worth noting that according to manufacturer advice, overhaul operation should be performed every 5-7 years or the number of operation of 70,000, depending on which is reached first.

B. Experimental Work and Sampling

Before each sampling a form containing some essential information such sampling date, number of operation since the last overhaul, oil and environment temperature etc. was filled. In Table II, the mentioned data has been presented for each sampling stage.

TABLE II
THE INFORMATION FOR EACH SAMPLING STAGE

	1st stage sampling	2nd stage sampling
Sampling date	March 2012	June 2012
Number of operation since last overhaul	203030	203528
Tap position	20	22
Oil temperature	28ºC	29ºC
Environment temperature	18ºC	21ºC

It should be noted that oil sampling was performed according to ASTM D 3613 standard. The samples were tagged, packed and forwarded to the laboratory considering the mentioned standard [16].

III. ANALYSIS PROCEDURE

Dissolved gas analysis was carried out considering ASTM D 3612 standard in a reliable laboratory [17].

IV. RESULTS INTERPRETATION

DGA data interpretation was performed by comparison of each sampling stage data to the LTC monthly watch criteria presented by Youngblood et al. [18]. If none of the concentrations exceeds the threshold values, the LTC performance is determined as normal operation.

In case of exceeding one of the gas concentrations from its threshold value, the possibility of fault presence was investigated by gas concentration ratio method presented in reference [19]. If the ratios are in the "Needs attention" range, the equipment is in normal operating condition. In the case laying data in the "Possible damage" or "Detected damage" range fault exists in the equipment. In this condition using the Duval triangle 2, the fault type would be identified [20].

In addition of mentioned interpretation, a comparision between DGA results from two sampling stages was performed.

V. RESULTS AND DISCUSSION

In Figs. 1 and 2 dissolved key gases concentrations and other dissolved gases concentrations including total dissolved combustible gases concentration (TDCG) in oil for each sampling stage are presented, respectively. Moreover, the results from two sampling stages were compared in these figures. For both sampling stages, the concentrations of hydrogen, ethylene and acetylene (key gases) are beyond the LTC monthly watch criteria; therefore the gas ratio method was applied.

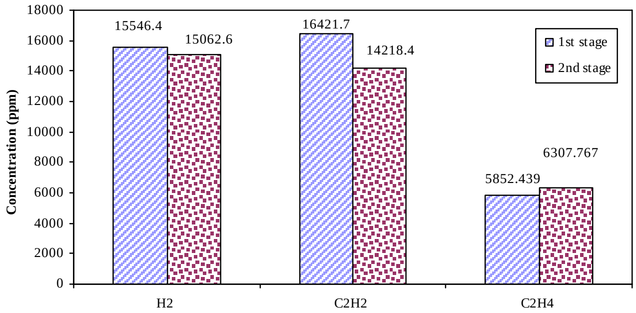

Fig. 1 Dissolved key gases concentrations for the selected LTC for the 1st and 2nd stages of sampling

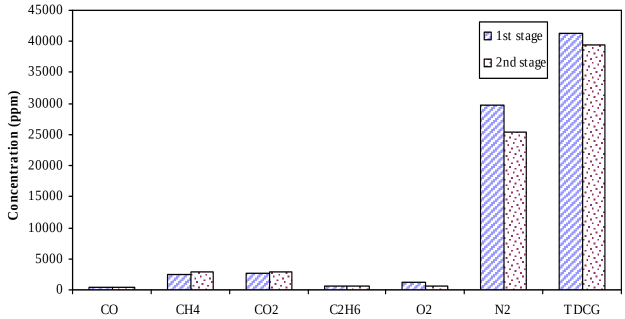

Fig. 2 Other dissolved gases concentrations for the selected LTC for the 1st and 2nd stages of sampling

In order to use mentioned method, the following ratios were calculated.

$$FR = \frac{C_2H_2 + H_2}{CH_4 + C_2H_6 + C_2H_4 + C_2H_2 + CO + H_2} \quad (1)$$

$$R_1 = \frac{CH_4 + C_2H_6 + C_2H_4}{CH_4 + C_2H_6 + C_2H_4 + C_2H_2} \quad (2)$$

$$R_2 = \frac{CH_4 + C_2H_6 + C_2H_4}{C_2H_2} \quad (3)$$

$$R_3 = \frac{C_2H_4}{C_2H_2} \quad (4)$$

For obtained data from both sampling stages, all ratios were laid in "Needs attention" range.

To ensure the fault absence in the equipment, the Duval triangle 2 was applied for each sampling stage, as shown in Figs. 3 and 4. The Triangle coordinates corresponding to DGA results can be calculated as follows:

$$\%CH_4 = \frac{CH_4}{CH_4 + C_2H_4 + C_2H_2} \times 100 \quad (5)$$

$$\%C_2H_4 = \frac{C_2H_4}{CH_4 + C_2H_4 + C_2H_2} \times 100 \quad (6)$$

$$\%C_2H_2 = \frac{C_2H_2}{CH_4 + C_2H_4 + C_2H_2} \times 100 \quad (7)$$

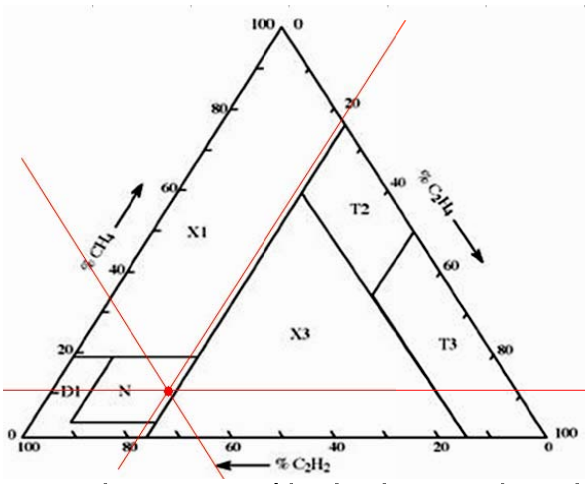

Fig. 3 Condition assessment of the selected LTC using the Duval triangle 2 for the 1st stage sampling

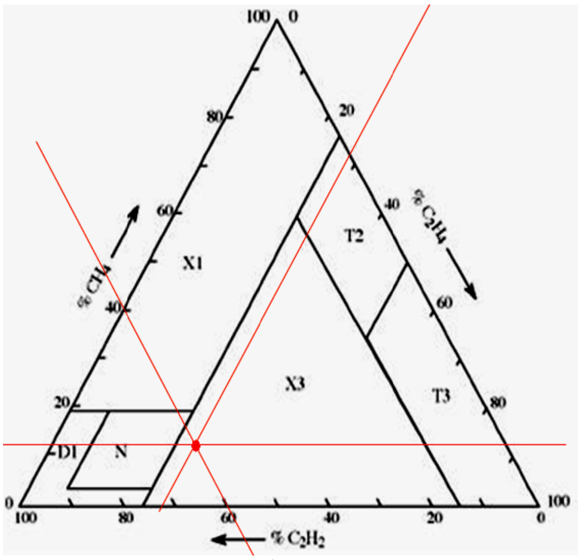

Fig. 4 Condition assessment of the selected LTC using the Duval triangle 2 for the 2nd stage sampling

Regarding Fig. 3 for the 1st sampling stage, the crossing point is located in N section which corresponds to normal operation and fault absence. For the 2nd sampling stage (Fig. 4), the crossing point is placed in X3 section which corresponds to in progress coking and heavy coking or increased resistance of the contacts or severe arcing.

Considering the obtained results from DGA data interpretation, in the first sampling stage the equipment was in good condition. However regarding the recommended overhaul criteria by manufacturer, the overhaul operation should have performed at least 2-5 years ago. For the 2nd sampling stage, there exist signs of defects in the equipment. It is recommended to test or inspect the LTC for signs of faults. In case of impossibility of inspection in near future, in order to prevention of catastrophic failures it is advised to perform the DGA test in three-month intervals.

VI. Summary

Since the "condition based preventative maintenance strategy" is accepted as the most convenient maintenance strategy, condition monitoring over an Elin load tap changer was performed using Dissolved Gas Analysis (DGA) for a three-month interval by sampling in two stages.The oil sampling was done according to ASTM D 3613 standard, and samples were analyzed considering ASTM D 3612. DGA data interpretation was carried out using Threshold value method, Gas concentration ratio method as well as the Duval triangle 2 method. Data interpretation for the 1st sampling stage showed no fault existence. However, the results of 2nd sampling stage revealed the existence of in progress coking and heavy coking or increased resistance of the contacts or severe arcing. In conclusion, the equipment needs to be test or inspect for signs of faults. In case of impossibility for this recommendation it is advised to repeat the DGA test in three-month intervals which helps to be aware of the equipment condition and also to avert catastrophic failures.

Acknowledgment

The authors gratefully acknowledge the colleagues in NRI: Mr. Zhaam, Mr. Ahmadi, Mr. Ghadimi and also Dr. Porkar from IGMC. We also would like to acknowledge NRI and also Mr. Marjanmehr and Mr. Fathi for supporting this research.

References

[1] Hans-Ulf Sc ellhase, Robert G. Pollock, Av ral S. Rao and Erik C. Korolenko, B rry Ward, Load Tap Changers: I vestigations of ontacts, Contact Wea and Contact oking, Proceedings of the Fort -Eighth IEEE Holm C nference on Electrical contacts, 002, 259-272.

[2] EPRI Repor #1001946: " evelopment f Load Tap Changer Monitoring echnique: Mec anism of Coki g", Technical rogress, December 20 1.

[3] Jur Erbrink, dward Gulski, Johan Smit, R ry Leich, Exp rimental model for diagnosing on-load tap changer co tact aging with dynamic resistance me surements, 20t International onference on E ectricity Distribution, 009, 1-4.

[4] P. Lyonnet, entenance plan ing- methods an mathematics, hapman and Hall, 199 .

[5] M. A. Redfer and W R C Ha dley, Duty base maintenance fo on-load transformer t p changers, Po er Engineering ociety Summer eeting, 2001. IEEE, vol.3, 1824-1829.

[6] Melinda kay ontgomery, Pa viz Rastgonfard, Instrumentation and data acquisition te hniques for de elopment of p edictive mainte ance of load tap chan ers, Proceeding of the Thirtieth Southeastern Sy posium on Digital Ob ect Identifier, 1998, 220-224.

[7] Jur J. Erbrink Edward Gulski Johan J. Smit, aul P. Seitz, B n Quak, Rory Leich, nd Ryszard Mal wski, Diagnosi of Onload Tap Changer Contact De radation by Dynamic Re istance Meas rements, Transactions n Power Delive y, IEEE, 2010, ol. 25, 2121-21 1.

[8] New Equipm nt and Perform nce Design Re iew – LTC Ma agement Course Mater als (EPRI, 2006, 1012350).

[9] Levand, L., " etals Analysis n Transformers, Load Tap-Changers and Oil Circuit Br akers", Chemist's perspective, S ring 2007.

[10] Levand, L., Griffin, P., "Condition Assessment of Oil Circuit Breakers and Load T p-Changers by the Use of aboratory Testing and Diagnostics", Chemist's perspective, Summer 2 04.

[11] Jur J. Erbrink, Edward Gulski, Paul P. Seitz, Rory Leich, Advanced on-site diagnosis of transformer o -load tap chang r, Conference ecord of the Electrical nsulation, IEEE 2008, 252-256.

[12] J.J. Erbrink, E. Gulski, J.J. Smit, L.A. Chmura, R. Leich, P.P. Seitz, B. Quak, Condit on Assessment f On Load Tap hangers using ynamic Resistance M asurements.

[13] IEEE Guide for Dissolved Gas Analysis in Transformer Load Tap Changers, IE E Std C57.139, 010.

[14] Nick Dominelli, Ed Hall, Ian Wyle, Dave Casson, Powertech Labs, Inc., Bruce Nichol , Nichols Applied Technology, LLC, Luke van der Zel,

EPRI, Chemical wear implants and online monitoring for electrical contact wear.
[15] Rowland James, Nick Dominelli, Ed Hall, Bruce Nichols, Technology and methods for monitoring the extent of wear of LTC and OCB contacts.
[16] ASTM series, Vol. 10.03, Electrical Insulation Liquids and Gasaes, Electrical Protective Equipment, D3613-98 Standard Practices for Sampling Electrical Insulating Liquids.
[17] ASTM series, Vol. 10.03, Electrical Insulating Liquids and Gases; Electrical Protective Equipment, D 3612-02 Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography.
[18] Youngblood, R. Baker, C., Jakob, F., Perjanik, N., “Application of Dissolved Gas Analysis to Load Tap Changers”. Available at: www.weidmannacti.com/u/library/dga_to_ltcs.1.pdf
[19] H.U. Schellhase, I. Wilye, M. Lau and B. Ward, Load tap-changer diagnostics: a critical review of the past ten years. EPRI (1999).
[20] Duval, M., "The Duval Triangle for Load Tap Changers, Non-Mineral Oils and Low Temperature Faults in Transformers", IEEE Electrical Insulation Magazine, November/December 2008, Vol. 24, no. 6, pp. 22-29.

NRI (Niroo Research Institute) of Iran started its activities in 1997. It has played a leading role in developing new technologies for Electric Power Industry ever since. NRI is the major research organization affiliated to the Ministry of Energy of Iran. NRI is performing the dual task of meeting the present and future demands of electric power industry, while making a better use of available resources, preserving the environmental and maintenance costs as low as possible. NRI has invested considerably in providing adequate conditions to achieve its objectives. The main building and laboratories of this institute are located in the north-west of Tehran. Research activities are carried out in 6 various research centers, consisting of 18 technical research departments, using the facilities of 9 advanced laboratories.

Hoda Molavi is an assistant professor in Chemical Engineering at NRI. She received her PhD degree in Chemical Engineering in 2010 from University of Tehran. Furthermore, she received her MSc (2006) and BSc (2004) degrees from University of Tehran and University of Mazandaran, respectively. She is a member of Iranian Nanotechnology Society (INS). She has been awarded as top graduating student of nanotechnology in 2011.Her current research area is condition monitoring of electrical equipments using oil analyses, application of nanotechnology in increment of equipment's efficiency.

Alireza Zahiri is a researcher in Chemical Engineering at NRI since 2002. He received his MSc (2004) and BSc (2002) degrees in Chemical Engineering from University of Mazandaran and Amirkabir University, respectively.He is a member of Iranian Corrosion Association (ICA) and Iranian Association of Chemical Engineering (ICHE). His current research interests are condition monitoring of equipment by oil analyses, life assessment, bi-metallic catalysts, PCBs' destruction, paint and coating, failure analysis.

Katayoon Anvarizadeh was a researcher in Chemistry in NRI (1996-2011). She received her MSc and BSc degrees in Chemistry from Azad University and Al-zahra University, respectively. Her research area was condition monitoring of equipments using oil analysis.