A Comparative Diagnosis Approach on Transformer's Insulating Oil

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Abstract. The immersed oil power transformer is so vital equipment in power system that maintenance-engineers take more cautious on transformer's insulating oil as the criterion of maintenance. The dissolved gas analysis (DGA) is known for an effective technique to detect transformer's incipient faults. In this paper, a practical method is presented that it took the data of Past Fault Record and ANSI/IEEE C57.104 Standard Rule to combine an approach by EXCEL software to diagnose transformer's insulating oil. The user only keys H_2, CH_4, C_2H_2, C_2H_4, and C_2H_6 those gases were decomposed via ASTM-D3612. The diagnosis result was showed in texts and the plotted figures through Pearson product moment correlation coefficient. This paper took some dates from Taiwan Power Company to verify that is validation and accuracy on the transformer's insulating diagnosis approach.

Introduction

Immersed oil power transformers in the power system not only play an important role as voltage conversion, but also strengthen the ability of supply and cut temperature down of transformer. If the quantity of dissolved gas analysis of insulating oil was not to meet maintenance criterion that it will pose transformer great threaten, in case of transformer fault which will be either a small area or a wide area of interruption electricity more than shut down exchange stock market. Thus the diagnosis of insulating oil is regarded as an important task. The insulating oil was been decomposed via chromatography instrument (ASTM-D3612), to yield nine kind of gas such as Ethane (C_2H_6), Hydrogen (H_2), Methane (CH_4), Carbon Dioxide (CO_2), Ethylene (C_2H_4), Acetylene (C_2H_2), Carbon Monoxide (CO), Nitrogen (N_2) , and Oxygen (O_2). [1]

Form among of the nine gases such as Hydrogen (H_2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4), Acetylene (C_2H_2), and Carbon Monoxide (CO) were named combustible gas (Total Combustible Gases, TCG), if any gas containing is over the standard criterion of ASNI/IEEE C57.104 which has to analyze what it happened. Based on a stable power supply and equipment safety of operation, which is a great problem for maintenance engineer to deal with accuracy diagnosis of insulating oil of transformer.

In this paper, we investigate the DGA methods. Then we combine the ANSI/IEEE C57.104 Standard Rule and the data of Past Fault Record which was compared with correlation coefficient to develop a transformer diagnosis tool by EXECL program which was taken Ethane (C_2H_6), Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4), and Acetylene (C_2H_2). The Diagnostic Flowchart is shown in Figure 1.

Transformer Fault Diagnosis Methods and Specification

The immersed oil transformer's insulating oil along with the transformer operating time and the measured of the cyclical time has makes vital relations with its life-span, however its increase value on ANSI/IEEE C57.104 standard ,as shown in formula(1): [2]

$$R = \frac{(S_T - S_O) \times V \times 10^{-6}}{T} \quad (1)$$

Where, R is increase of the TCG value (a milliliter/day), S_T is testing value, S_O is previous value, V was measured the transformer's volume as well as T is measured the duration of days. So the

quantity of the TCG , rely on the R's value which is classified "Normal", "Attention", "Abnormal", and "Overhaul" etc., four kind of symptom.

Be based on Dissolved Gas Analysis (DGA), the value of insulating oil has been diagnosed normality or abnormality in the body of transformer. In recent years, a lot of techniques have been developed to predict diagnosis the latent failure points of transformer by the gas content, such as the Key Gas method, Duval triangle method as well as Dornenberg method, Roger method, etc., [3]

The Pearson product moment correlation coefficient

The Pearson product-moment correlation has been used by researchers to compare testing's data sets with the data set of Past Fault Record to assess the coefficient of similarity. We can obtain a formula for r by substituting estimates of the covariance and variances based on a sample into the formula for r is [4]:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \quad (2)$$

The correlation coefficient is set at 0.7 for standard value by Pearson's correlation rule. The coefficient is getting more over 0.7 the testing data is getting more similar with Past Fault Record data whereas not similar.

The Data of Past Fault Record

The data of Past Fault record is taken form the maintenance of guidebook of electric device which was punished by Department of Power Supply, Taiwan Power Company. [5] The data was analyzed and sorted for five sets, each set consist of H_2, CH_4, C_2H_6, C_2H_4, and C_2H_2. Those gases were divided into five different data value and pattern, is shown Table 2. Form Among of five sets is used to compare diagnosis.

The ANSI/IEEE C57.104 Standard Specification were taken into the program. The anomalous properties values from decomposition of the insulating oil were shown in Table 1.

Table 1. ANSI / IEEE C57.104 Specification

Name	Content value	Property	Name	Content value	Property
H_2	> 1801	Danger	CH_4	> 1001	Danger
	> 701	Abnormal		> 401	Abnormal
	> 101	Aattentio n		> 121	Attention
	<100	Normal		<120	Normal
C_2H_6	> 151	Danger	C_2H_4	> 201	Danger
	> 101	Abnormal		> 101	Abnormal
	> 66	Attention		> 51	Attention
	< 65	Normal		< 50	Normal
C_2H_2	> 55	Danger	C_2H_2	>2	Attention
	>10	Abnormal		< 1	Abnormal

Table 2. The data of Past Fault Record

Gas	Figure for data of past-fault-record					
H2	H2	CH4	C2H6	C2H4	C2H2	Fault Model
	1.00	0.30	0.10	0.20	0.30	Arc & Partial Discharge
CH4	H2	CH4	C2H6	C2H4	C2H2	Fault Model
	0.50	1.00	0.30	0.45	0.02	Thermal & Low Partial Discharge
C2H6	H2	CH4	C2H6	C2H4	C2H2	Fault Model
	0.22	0.88	1.00	0.80	0.02	Thermal & Partial Discharge
C2H4	H2	CH4	C2H6	C2H4	C2H2	Fault Model
	0.30	0.60	0.20	1.00	0.02	Thermal
C2H2	H2	CH4	C2H6	C2H4	C2H2	Fault Model
	0.20	0.22	0.10	0.30	1.00	Partial Discharge

Comparative Diagnosis Approach on Transformer Fault Diagnosis in Practice

We took the Nan Ke E/S # 4Atr's insulating oil those gases data were dissolved from Research Institute of Taiwan Power Company on October 19th, 2012(before #4AT transformer repair) and on December 12th, 2012(after #4A transformer repair). Those were inspected gas data such as H_2, CH_4, C_2H_6, C_2H_4, and C_2H_2 are shown in Table 3. [6~7]

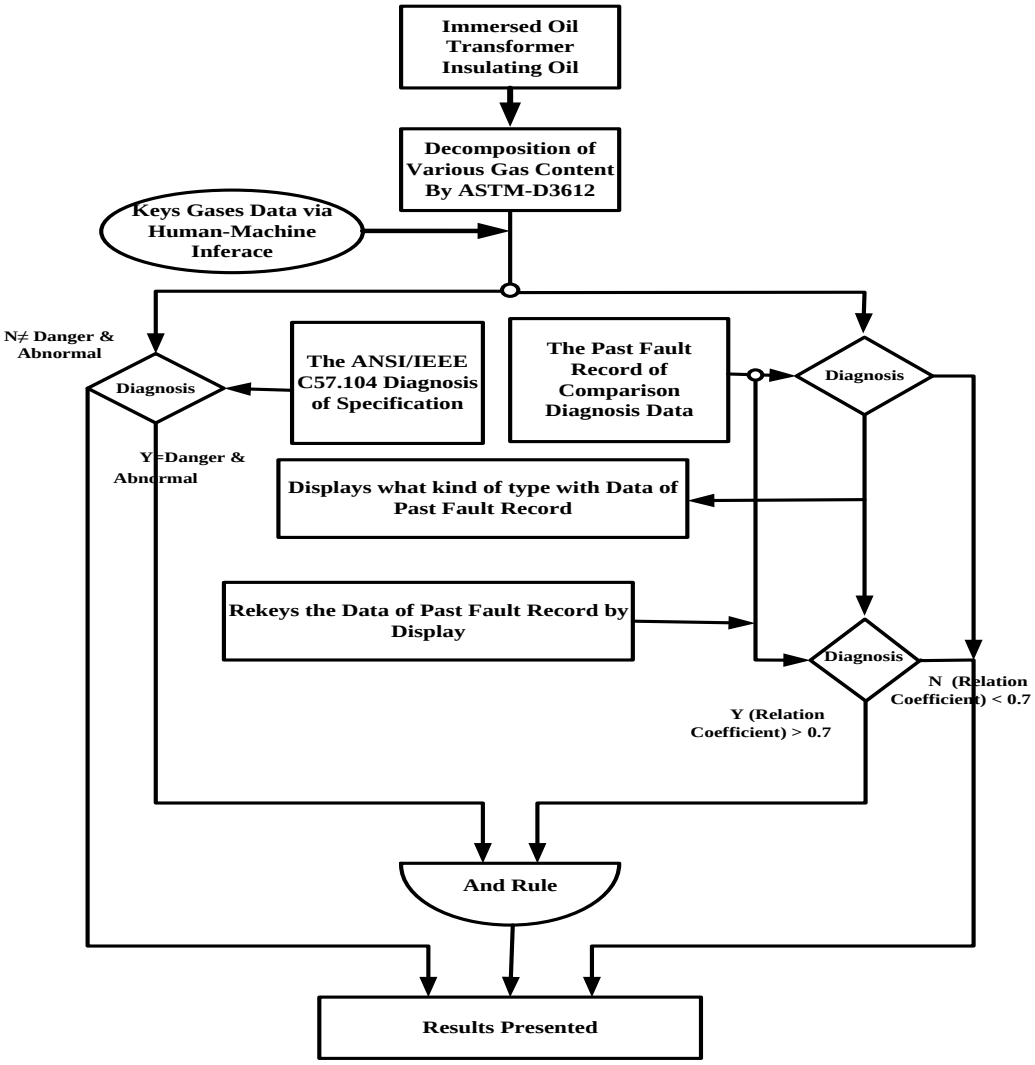


Figure 1. Diagnostic Flowchart

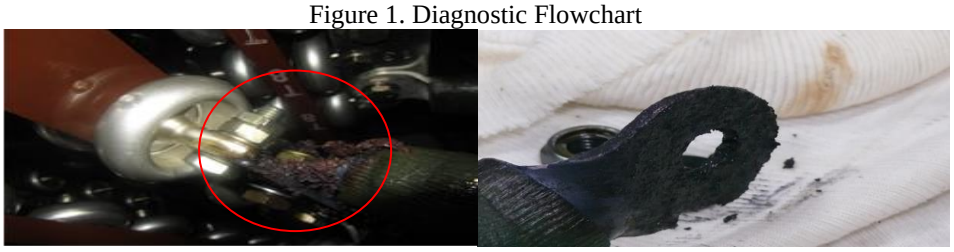


Figure 2. A Screw melting with copper

Diagnostic Practices and Verification

We only key the gases data of Nan Ke E/S #4ATr on October 19th, 2012. On form after a moment the reference data which was shown on form then rekey the reference data that it will yield a report's form which the result of the diagnosis was shown in in Table 4.

From the report form (before repair), we know the diagnosis of ANSI/IEEE C57.104 Standard Rule had H_2 (attention), C_2H_2 (attention), CH_4 (abnormal), C_2H_4 (danger), and C_2H_4 (danger), the correlation coefficient was 0.94 over the standard value 0.7. Because the ANSI/IEEE C57.104 Standard rule and the data of Past Fault Record with the Pearson's correlation conformed to the AND Rule, so we can diagnosed the #4ATr had an incipient fault in; we instantly shut the device down to check up. Eventually we found a screw melting with copper that was shown in Figure 2.

Table 3. Nan Ke E/S#4ATr gas data unit: ppm

	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2
2012.10.19 (before repair)	174	604	216	643	2.6
2012.12.12 (after repair)	3	12	10	10	0.2

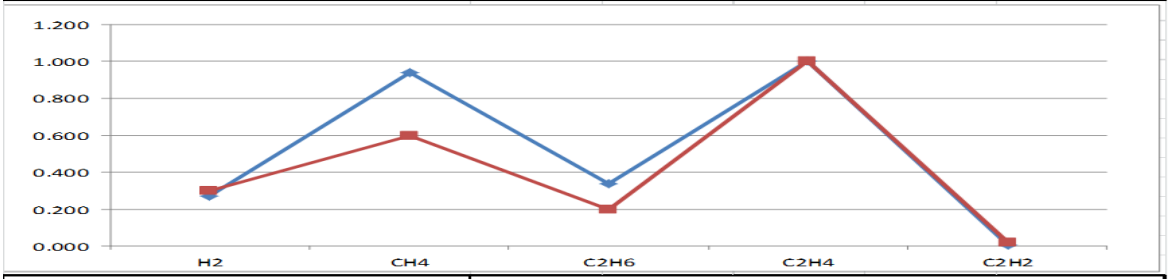
After two months (2012.12.12), the insulating oil was detected for normality, shown in Table 5. To confirm the tool we took some cases (in Table 6-7) from the Taiwan Power Company to verify.

Table 4. Transformer Fault Diagnosis Tool (before repair)

Tansformer Fault Diagnosis Tool					
Test place and date:	Nan-Ke E/S #4ATr 10.19,2012				
Gas Name	H2	CH4	C2H6	C2H4	C2H2
Key Test data	174	604	216	643	2.6
Maximism for test data	643				
Ratio for each / maximism gas	0.271	0.939	0.336	1.000	0.004

	FALSE	FALSE	FALSE	FALSE	FALSE
Data-set for past-fault-record	FALSE	FALSE	FALSE	FALSE	FALSE
which is distinguished	FALSE	FALSE	FALSE	FALSE	FALSE
H2,CH4,C2H6,C2H4,C2H2	0.300	0.600	0.200	1.000	0.020
as comparison-data of reference	FALSE	FALSE	FALSE	FALSE	FALSE
MAX	1				
Gas Name	H2	CH4	C2H6	C2H4	C2H2
Ratio for each / maximism gas	0.271	0.939	0.336	1.000	0.004
Rekey comparison-data of reference	0.300	0.600	0.200	1.000	0.020

1.Figure of comparison with testing and past-fault data



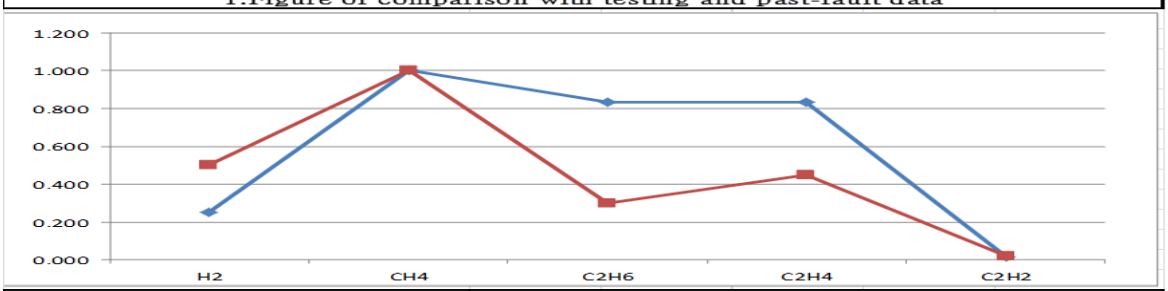
Ratio of Correlative Coeificient	0.94
2. Diagnosis for text of ANSI/IEEE Standard Rule	
H2	Attention
CH4	Abnormal
C2H6	Danger
C2H4	Danger
C2H2	Attention

Table 5. Transformer Fault Diagnosis Tool (after repair)

Tansformer Fault Diagnosis Tool					
Test place and date:	Nan-Ke E/S #4ATr 12.12,2012				
Gas Name	H2	CH4	C2H6	C2H4	C2H2
Key Test data	3	12	10	10	0.2
Maximism for test data	12				
Ratio for each / maximism gas	0.250	1.000	0.833	0.833	0.017

	FALSE	FALSE	FALSE	FALSE	FALSE
Data-set for past-fault-record	0.500	1.000	0.300	0.450	0.020
which is distinguished	FALSE	FALSE	FALSE	FALSE	FALSE
H2,CH4,C2H6,C2H4,C2H2	FALSE	FALSE	FALSE	FALSE	FALSE
as comparison-data of reference	FALSE	FALSE	FALSE	FALSE	FALSE
MAX	1				
Gas Name	H2	CH4	C2H6	C2H4	C2H2
Ratio for each / maximism gas	0.250	1.000	0.833	0.833	0.017
Rekey comparison-data of reference	0.500	1.000	0.300	0.450	0.020

1.Figure of comparison with testing and past-fault data



Ratio of Correlative Coeificient	0.68
2. Diagnosis for text of ANSI/IEEE Standard Rule	
H2	Normal
CH4	Normal
C2H6	Normal
C2H4	Normal
C2H2	Normal

Table 6. Some transformer gas data in practical unit: ppm

Date	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2
C1(2007.05.10)	44	41	88	7	10.1
C2(2010.09.05)	140	54	79	21	53.8
C3(2011.08.03)	181	74	84	58	51.4
C4(2011.12.26)	935	271	116	330	420
C5(2012.05.10)	239	346	78	787	24
C6(2012.07.08)	48	694	356	1077	0.4
C7(2013.09.23)	133	211	66	384	1.9

Table 7. Implementation of the results in practical

Name\Case	*ANSI/IEEE Text*							*Comparative Diagnosis Correlation Coefficient*						
	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
H_2	N	At	At	A	At	N	At	**0.5**	**0.83**	**0.91**	**0.91**	**0.98**	**0.94**	**0.99**
CH_4	N	N	N	At	At	A	At							
C_2H_6	At	At	At	A	At	D	At	Repair State						
C_2H_4	N	N	At	D	D	D	D	**N**	**Ac**	**Ac**	**Pd**	**Ac**	**Pd**	**Pd**
C_2H_2	Ab	D	D	D	A	N	N							

Symbols: N (Normal)、A (Abnormal)、At (Attention)、D (Danger)、Ac (Arc)、Pd (Partial Discharge)、C1 (Case1)、C2 (Case2)、C3 (Case3)、C4(Case4) 、C5 (Case5) 、C6 (Case6) 、C7 (Case7).

Summary

An electric engineer diagnoses the transformer's insulating oil which is so complicated that it's difficult because the amount of the element of gas and the ratio of gas are variables, so that affected the diagnosis of as a result. The Comparative Diagnosis approach can easy, accurate, and simple to verify what was happen up in transformer. It was validated well. This approach will be useful for engineers and technicians those who are in charge of transformer's maintenance.

Acknowledgment

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