Journal of Renewable Energy, Electrical, and Computer Engineering
Vol. 2, No. 2, September 2022, 47-54
e-ISSN: 2776-0049
DOI: https://doi.org/10.29103/jreece.v2i2.8567
Research Original Article

Analysis Oil Condition of Transformer PT-8801-A by Using the Method TDCG, Rogers Ratio, Key Gas, and Duval Triangle: A Case Study at PT. Perta Arun Gas

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Received: March 22, 2022 **Revision: June 10, 2022** **Accepted: August 17, 2022**

Abstract
The power transformer would have happened disturbanced that can cause a failure at a transformer. For this condition needed to maintenance power transformer, one of which is by analyzing transformer oil by using the TDCG method. This analysis is carried out to determine the diagnosis of faults in the transformer. This method are the condition of the analysis which is based on the amount of a gas dissolved on oil a transformer. This study used four methods for transformer failure analysis are TDCG method, Rogers-ratio, gas key, and duval triangle. The results obtained by the TDCG method of dissolved gas are 1332 ppm, the roger's ratio result a symptom of oil heat a transformer at 300oC, the key gas method results in overheating of oil, and the duval triangle method results in a low breakdown voltage analysis.
Keywords: Power transformer; transformer oil; analysis method

Introduction
The transformer is one of the components of the electric power system(Abu-Siada & Islam, 2012) that is very vital in the distribution of electrical energy (Nisworo et al., 2022), therefore its reliability in operation must be maintaine that the process of distributing electrical energy continues to run properly (Ismail et al., 2020). Over the Age of, oil transformer will experience a decrease in quality (Gouda et al., 2016). This happen because two factors are influence of stress (Voltage Stress) and heating (Thermal Stress) (Rahardjo et al., 2021). As a result, contaminants will form in the oil which can be in the form of solid, gas or liquid particles (Muttaqin et al., 2016).

To find out, the author will examine the analysis of the condition of transformer oil PT-8801-A at PT. Perta Arun Gas using the TDCG method (KRISNA & Bayusari, 2019), the methodRoger Ratio, methodKey Gas, and methodDuval are the form of concentration data of various type of fault gas which will later analysis and process to obtain information on indications of thermal and electrical failures in power transformer.

2. Problem Formulation

The formulation of the problems that arise are:

a) How to know at what temperature the transformer oil begin to not function as a coolant?
b) How to know gas failure (Fault Gtyapse) on the PT-8801-A transformer at PT. Perta Arun Gas?
c) How to find out the diagnosis of disturbances that occur in transformer oil?

3. Research Objectives

In accordance with the problems described above, the purpose of writing this thesis is to:

1. To find out at what temperature the transformer oil begins to not function as a coolant.
2. To find out the type ofFault Gas on the PT-8801-A transformer at PT. Perta Arun Gas
3. To diagnose disturbances that occur in transformer oil.

Literature Review
1. Transformer
Power transformer is an electrical power equipment that serves to distribute power or electrical power from high voltage to low voltage (Step Down) or vice versa, i.e. low voltage to high voltage (Step up). In the operation of the distribution of electric power, the transformer can be said to be the heart of the transmission and distribution (Nisworo et al., 2022). In this condition a transformer is expected to operate optimally continuously without stopping. Considering the hard work of such a transformer, the maintenance method must also be demanded as well as possible so that it is used properly and correctly to the maximum (Manjang et al., 2019).

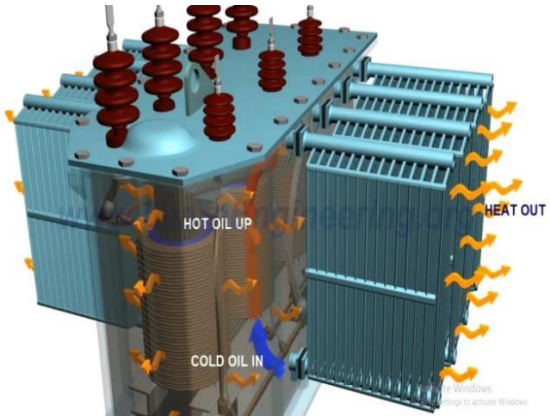


Figure 1 Oil in transformer

2. Transformer Oil

Transformer oil is mineral oil obtained by refining crude oil. In this used, this oil because to the influence of heat from losses in the transformer will result in hydrocarbons. As an insulating material, transformer oil must have a high breakdown voltage. This oil will fill the spaces between the coils in the core windings and other spaces in the transformer tank. The transformer does not have a rotating part, therefore the heat transfer process is carrie out by means of the core of the transformer iron being immersed or submerged in oil, which is calledwith Oil Immersed Type Transformer (Musil et al., 1995).

3. Formation of Dissolved Gas in Transformer Oil

Transformer insulation material consists of paper or cellulose insulation and oil. Both types of materials can be degrad because the influence of temperature pressure (Thermal stresses) and electrical pressure (Electrical Stresses). The effect of this pressure will cause the decomposition of gases dissolved in the oil with varying composition (Rozga et al., 2021). The following are dissolved gases that are commonly produced when transformer oil works:

a) Hydrocarbon and hydrogen gas: methane (CH4), ethane (C2H6), ethylene (C2H4), acetylene (C2H2) and hydrogen (H2)
b) Oxide gases: carbon monoxide (CO), and carbon dioxide (CO2)
c) Gases not from failure: nitrogen (N2) and Oxygen (O2)

4. Transformer Oil Disturbance Due to Dissolved Gas

There are four disturbances that can occur due to the formation of gases in the condition of the transformer operating, namely:

a) Arching(arc) the occurrence of an arc can produce hydrogen gas and acetylene gas in high quantities, besides methane and ethylene gas can also be formed but in small amounts. Carbon dioxide and carbon monoxide are also formed if these disturbances damage the paper insulation.
b) Overheating Of Oilor Overheating can also cause decomposition oil, and produces ethylene gas, methane with small amounts of hydrogen and ethane gas. If under the influence of electric pressure can produce acetylene gas.
c) Coronathe occurrence of corona in transformer oil could cause gas hydrogen, methane, ethane and ethylene gas.
d) Overheated Cellulose or heating paper insulation which can cause carbon dioxide gas and carbon monoxide in amount big

Materials & Methods

1. Flow Chat

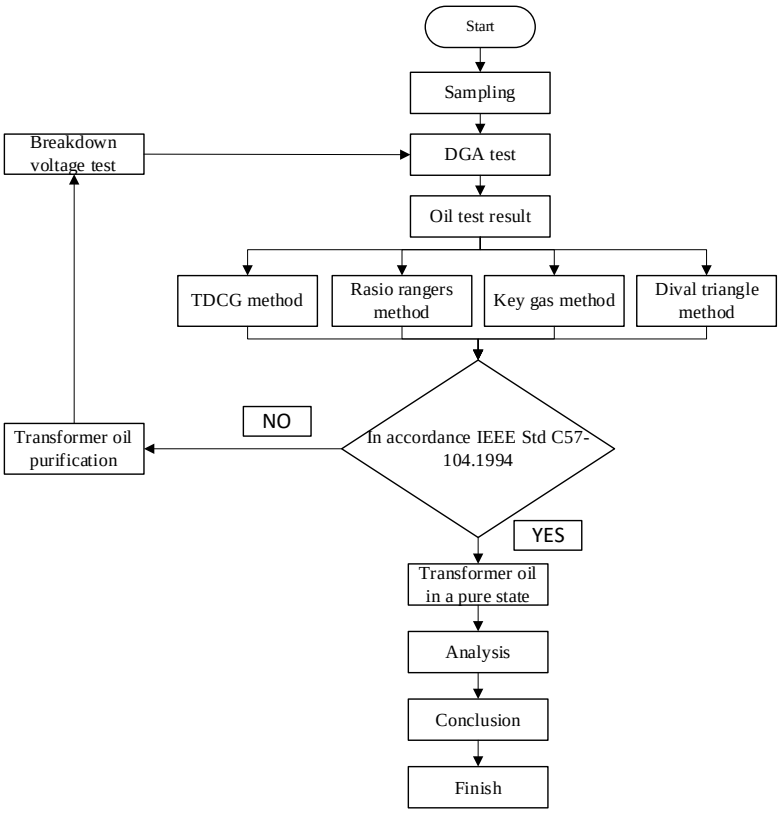


Figure 2 Chat Flow Diagram

2. DGA Analysis

Dissolved Gas Analysis (DGA)is one of the maintenance techniques that can be done to observe the condition of the transformer on the oil insulating material, to measure the gases that are emitted produced as a result of the degradation of insulating oil or other insulation such as paper, pressboard, and transformerboard. The composition of the concentration of gases that arise in the transformer oil can be related to the type of disturbance while the concentration of rising gases indicates the level of disturbance that occurs. One method that is widely used to determine the condition of transformer insulation is to analyze the dissolved gas in DGA oil (Dissolved Gas Analysis). By using gas chromatography, the type and concentration of gas in oil can be determined. Next from the type and concentration gas the represented transformer.

3. DGA Testing Steps

The steps taken to perform DGA testing:

1. Sampling of the existing insulating oil test on the transformer.
2. Extraction of gas using the DGA equipment itself.
3. Data interpretation, obtaining data results from the insulating oil sample test carried out.
4. Conclusions, after getting the results of the gas in oil data transformer so taken conclusion state oil transformer.

4. Analysis of Gas Extraction Result Data

One method that is widely used to determine the diagnosis of transformer isolation conditions is to analyze the dissolved gas in the oil (Dissolved Gas Analysis). The result of individual gas concentration is an analysis based on the individual amount detected in the transformer oil orParts Per Million(ppm) is the amount of combustible gas concentration dissolved in the tested oil sample.

Table 1 Limitation of dissolved gas conditions

		Dissolved gas condition			
No.	Gas type	Condition I	Condition II	Condition III	Condition IV
1.	H_2	100	100 – 700	701 – 1800	>1800
2.	CH_4	120	121 – 400	401 – 1000	>1000
3.	C_2H_2	35	36 – 50	51 – 80	>80
4.	C_2H_4	50	51 – 100	101 – 200	>120
5.	C_2H_6	65	66 – 100	101 – 150	>150
6	CO	350	351 – 570	571 - 1400	>1400
7.	CO_2	2500	2500 – 4000	4001 – 10000	>10000

Interpret data DGA based on IEEE Std C57-104-1991 standards such as:

a) Total dissolved combustible gas (TDCG) For diagnose disturbance transformer by methodTotal Dissolved Combustible Gas (TDCG) by adding the dissolved gases obtained in the transformer oil Parts Per Million(ppm) is the amount of gas concentration using the following equation:
Ppm = H2+CH4+C2H2+C2H4+C2H6+CO (1)

b) Roger's ratio method to diagnose disturbance transformer by methodRoger's . Ratiois a method of analyzing the dissolved gas content obtained in transformer oilParts Per Million(ppm) which is the amount of dissolved gas concentration by comparing the amount of gases obtained by the range code ratio equation as follows:

Table 2 Code rogers ratio

Range code rasio	$\frac{C_2H_2}{C_2H_4}$	$\frac{CH_4}{H_2}$	$\frac{C_2H_4}{C_2H_6}$
<0,1	0	1	0
0,1 – 1	1	0	0
1 – 3	1	2	1
>3	2	2	2

Case	Disturbance Type			
0	No fault	0	0	0
1	Low energy partial discharge	1	1	0
2	High energy partial discharge	1	1	0
3	Low energy discharger, sparking, arcing	1 – 2	0	1 – 2
4	High energy discharger, arcing	1	0	2
5	Thermal fault less than 150 ^{0}C	0	0	1
6	Thermal fault temp. 150 – 300 ^{0}C	0	2	0
7	Thermal fault temp. 300 – 700 ^{0}C	0	2	1
8	Thermal fault temp. over 700 ^{0}C	0	2	2

c) Key gas method another way to diagnose faults in transformer oil is by using the method Key Gasthe predominant gas type is formed.Key Gaswhich are used as indicators include hydrogen (H2), Carbon Monoxide (CO), Methane (CH4), ethane (C2H6), Ethylene (C2H4), and acetylene (C2 H2) comparison betweenParts Per Million(ppm) is the amount of dissolved gas concentration.

Table 3 Types of gas key failure

Key gas	Criteria	Disorder diagnosis
Asetilen (C_2H_2)	Concentrations of C_2H_2 and H_2 gases in large quantities, accompanied by the emergence of small amounts of ch4 and C_2H_2 gases, CO and CO_2 can also arise if decomposition occurs in cellulose	Arching
Hidrogen (H_2)	Concentrations of H_2 in large quantities, accompanied by the emergence of small amounts of C_2H_6 and C_2H_4 gases, CO and CO_2 can also arise if decomposition occurs in cellulose	Corona
Etilen (C_2H_4)	concentrations of C_2H_4 in very large amounts, large C_2H_6 and C H_4, H_2 in small amounts, and also a small concentration of CO	Overheating of oil
Carbon monoxide (CO)	Large concentrations of C0 and CO2. hydrocarbon gases may also arise.	Overheating of cellulose

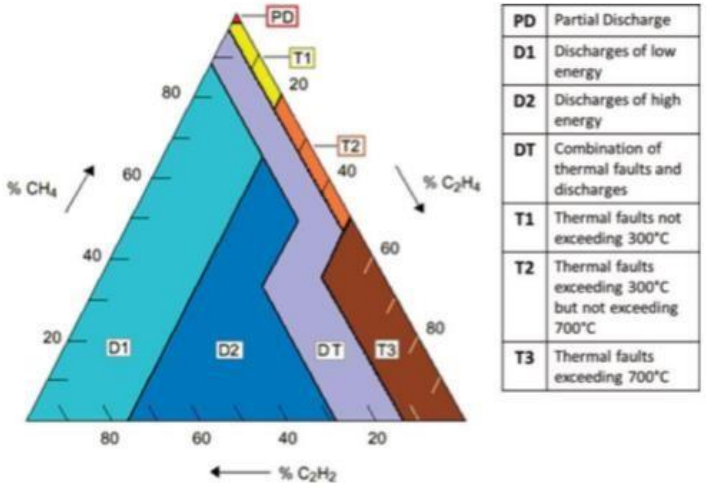
d) TriangleDuval diagnosing other faults in transformer oil is by triangleDuvalit detects the type of failure in the transformer oilParts Per Million(ppm) is the amount of gas concentration with the equation formula:

CH4 = _____X100%

C2H4 = _____X100%

C2H2= _____X100%

To know the coordinates of the duval triangle and the diagnosis of the disorder, it can be seen in the following figure:



PD	Partial Discharge
D1	Discharges of low energy
D2	Discharges of high energy
DT	Combination of thermal faults and discharges
T1	Thermal faults not exceeding 300°C
T2	Thermal faults exceeding 300°C but not exceeding 700°C
T3	Thermal faults exceeding 700°C

Figure 3 Coordinates of duval triangle

5. **Transformer Oil Purification**

Efforts can be made so that liquid insulation, especially transformer oil, has experienced heat symptoms caused by dissolved gases and particles in the transformer oil that have exceeded the limit and can be reused properly. Then it is done by purification, the transformer oil purification process is a combination of two processes, namely filtration and vacuum processes. This purification process can improve the low breakdown voltage (kV) due to the high water content and gas can also reduce the contamination content of the previous oil.

Figure 4 Transformer oil purification tool

6. Testing of Moisture Content and Translucent Stress

Testing of transformer oil is carried out either with the condition when symptoms occur or after being purified because the limit for insulation failure must be known which has exceeded the recommended limit by (SPLN 49-1:1982). So in this research will be carried out for transformer oil conditions that have been used and conditions after being purified (Purification) by using toolsLiquid Dielectric Test Set, model oil test 75, made by Foster Transformator Ltd. The desired input is 220 V AC, 50 Hz, 1 phase, with a current of 2.5 A, while the output is 0-75 kV AC. The standard used to test is the ASTM D877 standard.

Figure 5 Liquid dielectric test set

Results and Discussion

Based on the results of the gas content testing carried out in the PT-8801-A transformer oil condition laboratory, there was already damage to the liquid insulation. This can be seen with the production of Hydrogen (H2), Carbon Dioxide (CO2), Carbon Monoxide (CO), Methane (CH4), Ethane (C2H6), and Ethylene (C2H4).

Table 4 DGA transformer test data results

No.	Test parameters	PPM test results	Condition limitation IEEE std C-104-1991
1.	Hydrogen	77	100
2.	Methane	401	120
3.	Acetylene	20	35
4.	Ethylene	312	50
5.	Ethane	151	65
6	Carbon monoxide	371	350
7.	Carbon dioide	2732	2500
	TDCG	1332	720

1. Results of TDCG method analysis

The results or the concentration of combustible gases dissolved in the tested oil samples are known to be 1332 ppm. This has exceeded the conditions set by the IEEE standard, namely the C57-104-1991 standard.

Table 5 Results of TDCG method analysis

Condition	Concentration	Diagnosis
II	721 – 1920 PPM or the highest and individual concentration	1. Take precautions 2. conduct an investigation for each combustible gas that exceeds the normal limit

2. Method analysis results rogers ratio

For diagnose disturbance transformer according to the Rogers ratio method is a method of analyzing dissolved gas content by calculating the comparison method rogers Ratio:

1. _____=_____= 0.06 ppm by seeing range code ratio value < 0.1 then the value is 0
2. _____=_____= 5.2 ppm by seeingRange Code Ratio value > 3 then it is worth 2
3. _____=_____= 2.0 ppm by seeingRange Code Ratio value 1-2 then it is worth 1

Table 6 Results of the rogers . ratio method analysis

Sampel.	Ratio value			Diagnosis
PT-8801-A	Acetylne Ethylen	Methane Hidrogen	Ethylen Ethane	
	0	2	1	Thermal Fault Temp 300 - 700^0 C

3. Results of Key Gas Method Analysis

Another way to diagnose faults in transformer oil is to Key Gas Method based on the IEEE C57.104 standard. 1991 based on the type of gas that is typical or more dominantly formed at various temperatures.

Table 7 Analysis results of key gas method

Lock gas	Criteria	Disorder diagnosis
Ethylen	Very large concentrations of C_2H_4, large C_2H_6 and CH_4, small amounts of H2, and a small amount of CO	Overheating of oil

4. Results of Analysis of the Duval Triangle Method

For knowing temperature about the triangle method Duval based on the IEC standard 60599-2007-05 describes an analysis of the concentration of gas contained in the oil and the types of disturbances that occur in the oil insulation. So with calculations using the triangle formula Duval obtained the coordinates of the diagnosis that occurred:

- % CH_4 = _____X 100% = _____X 100% = 54,7%
- % C_2H_4 = _____X 100% = _____X 100% = 41%
- % C_2H_2 = _____X 100% = _____X 100% = 2,72%

So in the analysis using the triangle formula Duval the results obtained Methane % CH4= 54.7%, Ethylene % C2H4 = 41%, and Acetylene % C2H2= 2.72% the diagnostic coordinates that occur in this transformer oil are located at:

Table 8 Results of the duval triangle method analysis

D1	Discharger of low energy
T2	Thermal fault not exceeding 300 C but not exceeding 700 C
T3	Thermal faults exceeding 700 C

5. Test Results of Translucent Voltage and Water Content of Transformer Oil

The results of the transformer oil breakdown voltage test are 71 kV, the permissible limit for the amount of breakdown voltage must be > 30 kV/2.5 mm and the water content shows 1.5 mg/kg and the allowable limit for the water content is < 30 mg/kg.

6. Transformer Oil Purification Results

The results of purification with the purification machine used are the KLVC-4AXCT-IA model, so the oil data obtained on the PT-8801-A Transformer are:

Table 9 Report on the results of the oil transformer test data at PT. Perta Arun Gas

No.	Test parameters	PPM test results PT-8801-A	Condition limitation 1 IEEE std C 57-104-1991
1.	Hydrogen	40	100
2.	Methane	11	120
3.	Carbon monoxide	43	350
4.	Ethylene	5	50
5.	Ethane	95	65
6	Acetylene	0,5	35
7.	Carbon dioide	901	2500
	TDCG	195,5	720

With the results of the sample data above, the purification value of TDCG is reduced to a value of 194.5 ppm from the results before purification of 1332 ppm. Therefore, the results of the purification value after purification are much better than the limits set by the IEEE, namely the C57-104-1991 standard in Table 7

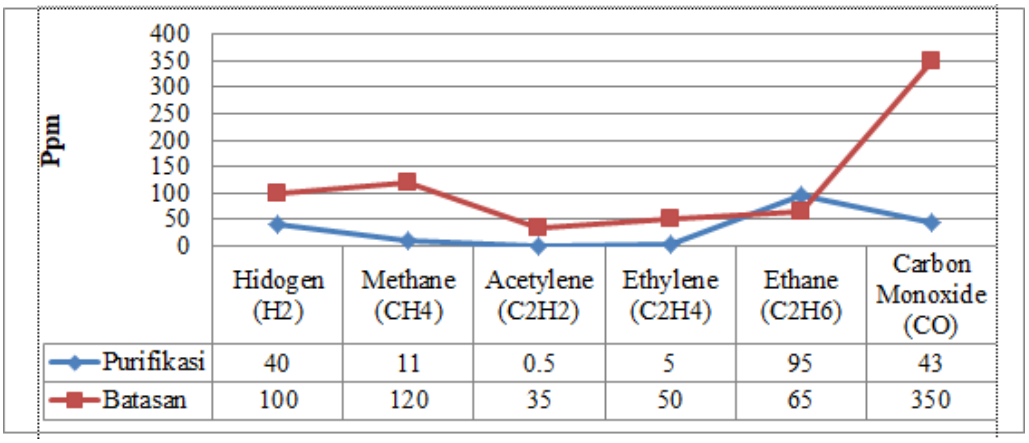


Figure 6 Graph of DGA Test PT-8801-A

Conclusions

Based on the results of the analysis regarding Dissole Gas Analysis (DGA) conclusions can be drawn, namely:

1. With the TDCG method, it can be seen that the concentration of combustible gas dissolved in the oil sample is 1332 ppm.
2. By methodRogers RatioIt can be seen that the symptoms of transformer oil overheating begin at a temperature of 300oC.
3. By methodKey Gasit is known that oil will cause disturbances Overheating Of Oil(excessive heat of the oil).
4. By Triangle methodDuval fault diagnosis low energy dissipation, medium range thermal fault 300-700oC, and the thermal error exceeds 700 C.
5. To overcomeFault Gasand high temperature purification of transformer oil (Transformer Oil Purification) namely before purification 1332 ppm and after purification to 194.5 ppm.
6. With the previous test the water content was 40 mg/kg and the breakdown voltage was 5 kV/2.5 mm after the

purification process the water content was 1.5 mg/kg while the breakdown voltage was 71 kV/2.5 mm.

Suggestions

1. For nor doing care repair condition transformer should conducted oil testing so that condition transformer can be addressed immediately so that more fatal demage can be avoided.
2. At least once a year to check the transformer oil so that it is known Fault Gas that happened.

Acknowledgments

The authors would like to thank Andik Bintoro and Asri for their help during sample preparation and authors also thanks to the Institute for Research Universitas Malikussaleh for their support on this research.

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