Analysis of Transformer Conditions using Triangle Duval Method

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Abstract. Electrical or thermal failure that occurred in the transformer oil can produce a dangerous gas called gas fault. By indicating the content of dissolved gases in the transformer oil, can be obtained information about what happened to the oil so it can be estimated indication of the type and cause of the failure in the transformer. The method used to identify and analyze the dissolved gases in oil is called Dissolved Gas Analysis (DGA). In this study conducted by the DGA Duval Triangle method for transformer oil used in geothermal power plant UPJP Kamojang PT. Indonesia Power. The results using Duval Triangle method produces thermal failure and partial discharge.

1. Preliminary

In the electric power transformer system is one of the vital parts, which serves to distribute electrical energy to the low voltage and high voltage to, the delivery takes place within the same frequency. This function is known as the term step-up and step-down,As electrical devices, transformers must never be separated from failures, especially the failure of thermal and electrical failure or what we call electrical breakdown. The failure of the type that usually occur in the transformer, namely: Arcing, Sparking, heat disorders and Partial Discharge [1].

Therefore, the reliability of the transformer also need to be maintained, and the necessary preventive measures to determine the condition of the transformer. One method often used is the method of DGA (Dissolved Gas Analysis). Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4), acetylene (C_2H_2) and Air (H_2O) [2].

2. DGA Testing

2.1 Sampling Process Oil

The sampling process oil in the transformer is divided into stages, due to prepare the equipment for oil sampling and sampling procedures of the oil in the transformer. For the first part is a tool that is used for sampling are: Syringe, oil flushing units, buckets, gloves, wipes and vials.[3] In the next stage of the sampling process transformer oil and gas extraction process to determine the gas content in the transformer.

2.2 Gas Extraction Process

a. Gas Chromatograph is a technique for separating substances - certain of a joint compound, usually substances - are separated by evaporation rates (volatility).[4]

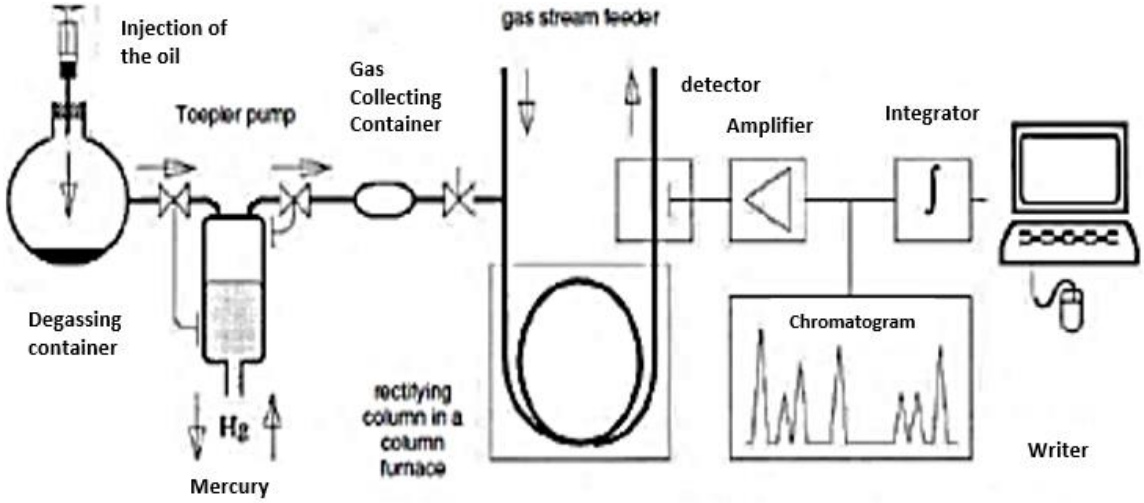

Figure 1. Method Chromatograph

b. Photoacoustic Spectroscopy (PAS), (hydrogen, methane, oxygen, and others) basically have the ability to absorption of electromagnetic radiation that is unique and distinctive. This capability is usually applied to the infra-red spektokopis method to produce an effect of photo acoustic. Absorption of electromagnetic radiation by gases will increase the gas.[5]

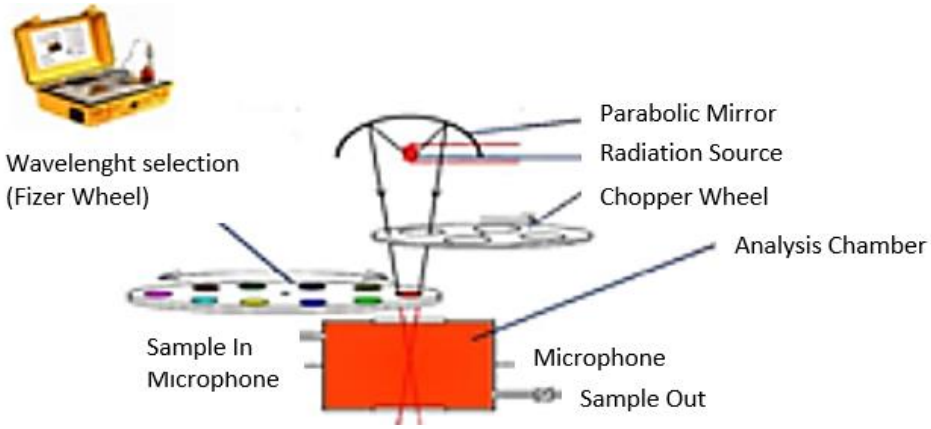

Figure 2. Photoacoustic Spectroscopy Method

Results obtained from the extraction of gas will be used as input to the gas content analysis or DGA. DGA analysis of the calculation results can be obtained an indication of the failure of the transformer is likely to emerge.[6]

2.3 Analysis of Data From Extraction

After the gas is separated from the oil sample through the extraction process, it can be data in the form of gas contained in the sample, then the data is analyzed using Dissolved Gas Analysis. The method used is:

2.3.1 Limit IEEE / Total Dissolved Combustible Gases. TDCG is one type of Dissolved Gas Analysis method to classify the type of combustible gas, the higher the gas content obtained it must do further tests. [7]

Table 1. Standar TDCG

level	Concentration (Ppm)	Description TDCG
1	<= 720	Indications that the normal transformer operation
2	721 - 1920	Indications high starting a gas composition, there arises the possibility of failure, prevention of the symptoms do not continue.
3	1921 - 4630	Indications decomposition of a high level of insulation. The failure may have occurred. Make prevention of disorder does not continue.
4	> 4630	Indications of deterioration are very high and the decomposition / damage to the insulator is already widespread. Imminent damage to the transformer. Soon

2.3.2 Key Gas. Key gas is defined as gas - gas that is formed in the transformer oil coolers are quantifiable and can determine the type of failure occurs yan, based on the type of gas that is typical or dominant formed at various temperatures. [7]

Table 2. Standar Key Gas

Fault	Key Gas	Criteria	Gas Percent Amount
Arcing	Acetylene (C_2H_2)	Large amount of and (and minor quantities of (, (CO), and may Also exist if cellulose is Involved(H_2)(C_2H_2)(C_2H_4)(CO_2)	(H_2) : 60% (C_2H_2): 30%
Corona (Low Energy PD)	Hydrogen (H_2)	Large amount of some, with small quantities of (and (. CO and may be comparable if cellulose is Involved.(H_2)(CH_4)C_2H_6)C_2H_4)(CO_2)	(H_2) : 85% (CH_4) : 13%
Overheating of Oil	Ethylene (C_2H_4)	Large amount of (less amount of (, some quantities of andC_2H_4)C_2H_6)(CH_4)(H_2)	(C_2H_4): 63% (C_2H_6): 20%
Overheating of Cellulose	Carbon Monoxide (CO)	Large amount of CO and Hydrocarbon gases may exist(CO_2)	CO: 92%

2.3.3 Roger Ratio. Roger Ratio method is one of the DGA methods by comparing the value / amount of gas that is different by dividing the gas with other gases. [8], Comparison of the gas used by themselves have some reference standards starting from IEC Standards, CEGB Standards and ASTM Standards. Type of gas used as a comparison, namely: Hydrogen (H_2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4)and acetylene (C_2H_2) . [9]

2.3.4 Triangle Duval. This method uses a triangular plot for analyzing interference, Methane (CH_4), Ethylene (C_2H_4) and acetylene (C_2H_2). When using the Triangle Duval necessary to determine the existence of a problem or not, how to determine the existence of a problem or not the gas is contained in the transformer oil is to ensure at least one of hydrocarbons or hydrogen should be at the level of L1. [10]

In addition, Duval triangle method was created to help method - other analytical methods. This method is a closed system (closed system) is different from the method of Key Gas and Gas Ratio which is (open system), so that this method can reduce the percentage of cases outside the analytical criteria.[11]

Table 3. Limit L1

Gas	Limit L1 ppm
H_2	100
CH_4	75
C_2H_2	3
C_2H_4	75
C_2H_6	75
CO	700
CO_2	7000

Now that we know that we obtain the data entered in L1 criteria, then the data previously obtained we calculated by using a calculation formula Duval Triangle, namely:

$$\%CH_4 = \frac{CH_4}{CH_4+C_2H_4+C_2H_2} \text{ x } 100\%$$

$$\%C_2H_2 = \frac{C_2H_2}{CH_4+C_2H_4+C_2H_2} \text{ x } 100\%$$

$$\%C_2H_4 = \frac{C_2H_4}{CH_4+C_2H_4+C_2H_2} \text{ x } 100\%$$

Function formula above is to determine the value of (X, Y, Z) which represent the value of the proportion of CH_4, C_2H_4 and C_2H_2, from 0% to 100%, the first assumption in all three grades, namely: (CH4 + C2H4 + C2H2) = S in ppm, then calculation of the third value in percent of the gas is X = CH_4% CH4 = 100 (A / S), Y = C_2H_4% C2H4 = 100 (B / S), Z = C_2H_2% C2H2 = 100 (C / S). So the value in (CH4 + C2H4 + C2H2) must equal 100%.C_2H_4[12]

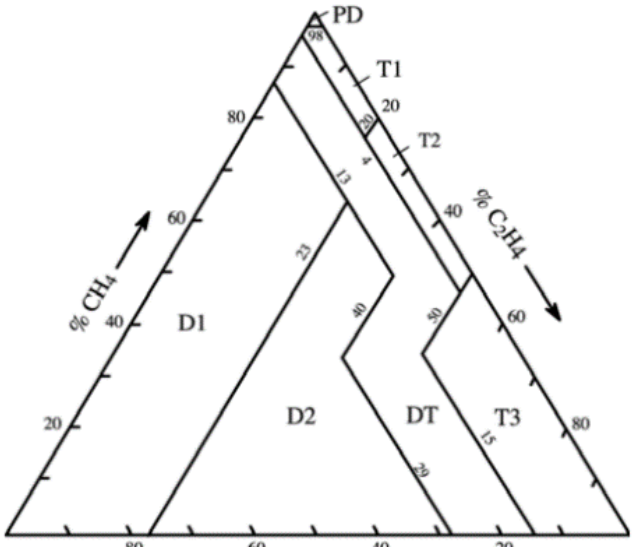

Figure 3. Triangle Duval

Table 4. Types of Disorders of the Duval Triangle

Symbol	Fault	examples
PD	Partial discharge	Discharge of the cold plasma (corona) type in gas bubbles or voids, with the possible formation of X-wax in paper
D1	Discharges of low energy	Partial discharges of the sparking type, inducing pinholes, punctures in carbonized paper. Low energy arcing carbonized inducing perforation or surface tracking of paper, or the formation of carbon particles in oil.
D2	Discharges of high energy	Discharges in paper oil, with the power of follow-through, the resulting in extensive damage to paper or large formation of carbon particles in the oil, metal fusion, tripping of the equipment and gas alarms.
T1	Thermal Fault T <300°C	Evidenced by turning brownish paper (> 200°C) or carbonized (> 300°C).
T2	Thermal Fault 300 <T<700°C	Carbonized of paper,the formation of carbon particles in oil.
T3	Thermal fault T> 700°C	Extensive formation of carbon particles in oil, metal coloration (800°C) or metal fusion (1000°C)

3. Result and Discussion

This study uses data derived from geothermal power plant UPJP Kamojang PT. Indonesia Power. The data in the form of content of the extracted gas in transformer oil, gas content in transformer oil is used as a sample calculation is the gas content in transformer oil T31 during the period 2012 - 2017. The sample is what will be used as the calculation in Duval Triangle methods of analysis**.**

Prior to the Duval triangle analysis on the data obtained, first do data matching with the limit L1, because not all types of data acquired is at the limit L1. Adjustment function here is the first step in the analysis process, it is undeniable that the limit L1 is one of the conditions required in the analysis of Duval Triangle as the minimum limit indication of failure on the transformer.

Table 5. Data Transformer T31

date`	H_2 ppm	C_2H_4 ppm	CO ppm	CO_2 ppm	C_2H_4 ppm	C_2H_6 ppm	C_2H_2 ppm
11/27/12	32	5	243	2405	1	8	0
11/12/2012	32	1	243	2300	6	10	0
03/07/2013	45	6	511	5944	1	10	0
12/16/2013	34	5	379	6188	7	8	0
03/20/2014	5	2	4	64	1	1	0
07/24/2014	48	6	336	3406	1	6	0
25/09/2014	54	7	462	4460	1	5	0
11/06/2014	90	13	525	5588	1	7	21.6
07/11/2014	33	11	348	4257	1	69	0
11/12/2014	42	7	500	5384	1	8	0
01/22/2015	44	10	551	6744	2	7	0
07/04/2015	49	9	548	7476	5	8	0
16/10/2015	55	14	641	10395	5	6	0
12/04/2015	48	11	633	11025	5	13	0
01/19/2016	52	9	633	11819	5	12	0
03/08/2016	51	10	601	11 865	3	16	0
26/07/2016	39	11	641	13835	13	5	0
19/12/2016	22	1	36	209	3	3	0.5
29/05/2017	38	4	132	419	2	3	0.5

Table 6. Data transformer T31 is at L1 Limit

date`	H_2 ppm	CH_4 ppm	CO ppm	CO_2 ppm	C_2H_4 ppm	C_2H_6 ppm	C_2H_2 ppm
11/06/2014	90	13	525	5588	1	7	21.6
07/04/2015	49	9	548	7476	5	8	0
16/10/2015	55	14	641	10395	5	6	0
12/04/2015	48	11	633	11025	5	13	0
01/19/2016	52	9	633	11819	5	12	0
03/08/2016	51	10	601	11 865	3	16	0
26/07/2016	39	11	641	13835	13	5	0

Table 6 shows the data transformer T31 is at the limit L1, can be seen on the vulnerable 04-07 - 2015 to 26 - 07-2016 gas CO_2 content in transformer oil contains very high, CO_2 exceeding the limit on Limit L1 of 7000 ppm, because it should be noted rise on CO_2 can also affect the temperature rise in cellulose. On April 11 - 06-2014, gas content increased in C_2H_2 the transcend limit L1. The increase in C_2H_2 the type of failure can cause Arcing.

3.1 Triangle Duval

Duval triangle method using three gas in the process are: CH_4, C_2H_2, and C_2H_4. The third gas present value (X, Y and Z) on. X for the value% CH4, C2H4% Y for value, and Z value% C2H2. If it is assumed further that the value - the value of determination serves as a meeting point in determining the type of interference on Duval Triangle.

Data on April 11 - 06-2014 indicates that the value of H_2 = 90 ppm CH_4 = 13 ppm, CO = 525 ppm CO_2 = 5588 ppm C_2H_4 = 1 ppm C_2H_6 = 7 ppm, and C_2H_2 =21.6 ppm , said to be worth using because the Duval triangle method has a C_2H_2 value that exceeds the limit L1, the final result of these data are:

$$\%CH_4 = \frac{13}{13+1+21.6} \text{ x } 100\% = 35\ 519\%$$

$$\%C_2H_2 = \frac{21.6}{13+1+21.6} \text{ x } 100\% = 59.02\%$$

$$\%C_2H_4 = \frac{1}{13+1+21.6} \text{ x } 100\% = 5{,}464\%$$

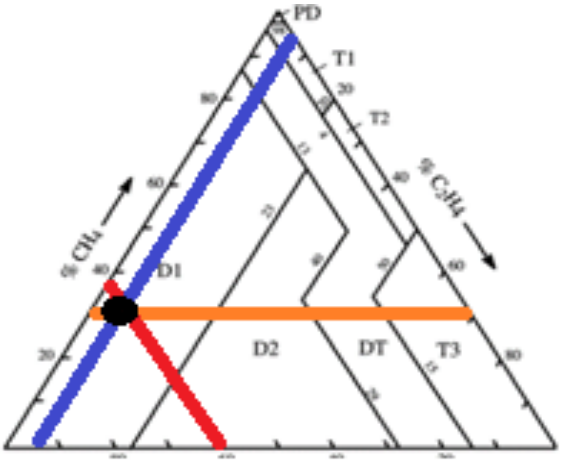

Figure 4. Failure on the type transformer

Table 7. Analysis on Transformer T31using Triangle Duval Method

date`	H_2 ppm	CH_4 ppm	CO ppm	CO_2 ppm	C_2H_4 ppm	C_2H_6 ppm	C_2H_2 ppm	Fault
11/06/2014	90	13	525	5588	1	7	21.6	D1
07/04/2015	49	9	548	7476	5	8	0	T2
16/10/2015	55	14	641	10395	5	6	0	T3
12/04/2015	48	11	633	11025	5	13	0	T2
01/19/2016	52	9	633	11819	5	12	0	T2
03/08/2016	51	10	601	11 865	3	16	0	T2
26/07/2016	39	11	641	13835	13	5	0	T3

The results of the analysis can be seen in Table 7, that the transformer T31 has the possibility of symptoms - symptoms of failure are diverse ranging from Partial Discharge, Thermal Fault 300 < T < 700°C, and Thermal fault T > 700°C. This is because in some cases have increased activity in the C_2H_2 and CO_2, where the gas is a gas trigger of failure - the failure.

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