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Dissolved Gas Analysis (DGA) Testing Analysis on 150kv Power Transformers

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ABSTRACT
This research used a laboratory experimental method with a quantitative approach. The aim was to measure and analyze the dissolved gas content in power transformer oil and to explain the measurement results based on the IEEE C57.104-2008 standard and PT PLN's Decree No. 0520 K/DIR/2014. The research objects were Power Transformers 1 and 2 of the 150 kV Titi Kuning Substation on Jalan Suka Tirta No. 54b, Medan, North Sumatra. The analysis used two methods to determine the condition of this transformer: TDCG and Key Gases. The first method is to measure the contents of Hydrogen (H2), Acetylene (CH2), Ethylene(CH4), Ethane (CH6), Methane, Carbon monoxide (CO), and Carbon dioxide (CO2). The second method involves summing the values of Gas Chromatography Method (TDCG) for Dissolved Gas Analysis (DGA) analysis, and the third method is a key gas method for determining the type of damage or abnormalities in a transformer.

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INTRODUCTION

PT PLN (Persero) is a company that provides electricity for the public interest in Indonesia. In line with one of PLN's missions, which is to operate the electricity business and other related fields, oriented towards customer satisfaction, it is crucial for PLN (Persero) to improve the reliability of electricity distribution. PT PLN (Persero) has several implementing units, each with its own roles and responsibilities. Some well-known implementing units are the transmission implementing unit, responsible for the distribution of high and extra-high voltage electricity, and the customer service implementing unit, responsible for the distribution of medium and low voltage electricity.

To improve the reliability of electricity distribution, PT PLN (Persero) needs to conduct maintenance activities. Maintenance is a business activity that aims to achieve organizational goals, implement strategies, and implement organizational work plans. Maintenance in PLN's transmission units includes preventive and corrective maintenance activities. Preventive maintenance is a routine, scheduled maintenance strategy to ensure equipment or assets continue to function according to their intended purpose. The primary

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goal of preventive maintenance is to maximize the lifespan of equipment or assets and prevent malfunctions that could lead to power outages. Corrective maintenance is performed to repair damaged equipment or assets, with the aim of restoring them.

Power transformers are the most crucial component in transmitting electrical power. Power transformers function to change voltage, either by increasing or decreasing it. The condition of power transformers is crucial, as they are relatively expensive and spare transformers are scarce. Therefore, regular monitoring of the condition of existing power transformers is essential. Power transformers contain insulating oil. This insulating oil protects the transformer from electrical failures within the transformer itself. To determine whether there are any abnormalities in the transformer, the impact of the abnormality can be determined by conducting a Dissolved Gas Analysis (DGA) test. This test allows companies to take immediate action on the transformer.

Related Research

The two main causes of gas formation in operating transformers are thermal and electrical disturbances. Conductor losses due to loading produce gas from the thermal decomposition of oil and associated solid insulation. Gas is also produced from the decomposition of oil and insulation exposed to arc temperatures. Generally, decomposition gas is formed primarily by processes in which the surface of a material contains high-energy charged ions. Mineral insulating oil is composed of many molecules with the chemical groups CH3, CH2, and CH3 held together by carbon molecular bonds. The gases detected in Dissolved Gas Analysis (DGA) tests are Hydrogen (H2), Acetylene (CH2), Ethylene (CH4), Ethane (CH6), Methane (CH4), Carbon monoxide (CO), and Carbon dioxide (CO2).

DGA Test Data Interpretation Method

Based on the test results, possible abnormalities can be investigated using several methods according to the IEEE C57-104.2008 standard and PT PLN Decree No. 0520 K/DIR/2014, namely:

1. TDCG (Total Dissolved Combustible Gas) Method

When an abnormality occurs in a transformer, there is a sudden increase in the dissolved gas content in the transformer oil. The TDCG method calculates the total amount of flammable gases dissolved in the transformer oil. CO2 is not a flammable gas and is therefore not included in the TDCG results.

Table 1. Main Dissolved Gas Concentration Limits [UI/L (Ppm)2]

Kondisi	H_2	CH_4	CO	CO_2	C_2H_4	C_2H_6	C_2H_2	TDCG
1	100	120	350	2500	50	65	1	720
2	101-700	121-400	351-570	2500-4000	51-100	66-100	2-9	721-1920
3	701-1800	401-1000	571-1400	4001-10000	101-200	101-150	10-35	1921-4630
4	>1800	>1000	>1400	>10000	>200	>150	>35	>4630

a. Condition 1: A TDCG below this level indicates that the transformer is operating satisfactorily.
b. Condition 2: A TDCG within this range indicates a higher-than-normal level of

INFOKUM
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flammable gas. Any flammable gas exceeding this level should prompt additional investigation.

c. Condition 3: A TDCG within this range indicates a high level of decomposition. Any flammable gas exceeding this level should prompt additional investigation.
d. Condition 4: A TDCG exceeding this value indicates excessive decomposition. Continued operation could result in transformer failure.

2. Key Gas Method

The Key Gas Method is defined by IEEE C.57.104-2008 as the gases formed in oil-cooled transformers that can be used to qualitatively determine the type of failure that has occurred, based on the typical or predominant gas types formed at various temperatures.

Table 2. Types Of Failure According To The Key Gases Method

Gas Dominan	Jenis Fault
Ethylene C_2H_4	Thermal mineral oil
Carbon Monoxide CO	Thermal mineral oil and cellulose
Hydrogen H_2	Electrical low energy partial discharge (PD)
Hydrogen and Acetylene H_2, C_2H_2	Electrical high energy (arcing)

Thermal mineral oil: Decomposition products include ethylene (C2H4) and methane (CH4) with small amounts of hydrogen (H2) and ethane (C2H6). Signs of acetylene (C2H2) may form if the fault is severe or if electrical contact occurs.

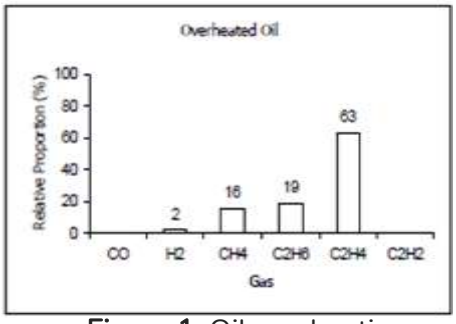

Figure 1. Oil overheating

Thermal mineral oil and cellulose: A small amount of carbon dioxide (CO) and carbon monoxide (CO2) is produced due to heating of cellulose. Hydrocarbon gases, such as methane (CH4) and ethylene (C2H4), are produced if the fault involves the oil structure.

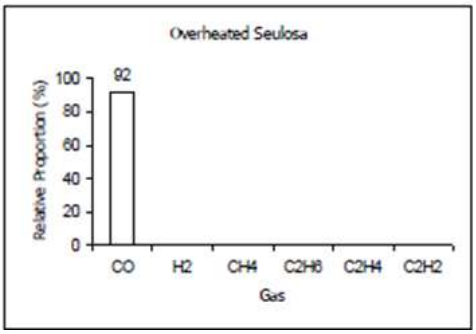

Figure 2. Excessive heat in paper

Electrical low-energy partial discharge: A low-energy electrical discharge produces

INFOKUM
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https://infor.seaninstitute.org/index.php/infokum

hydrogen (H2) and methane (CH4) with small amounts of ethane (C2H6) and ethylene (C2H4). Comparable amounts of carbon monoxide and carbon dioxide may be produced from the discharge in cellulose

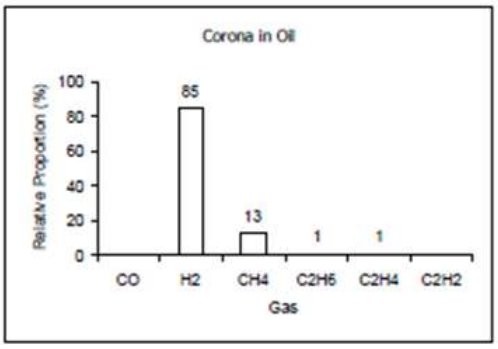

Figure 3. Partial Discharge in oil

Electrical high-energy (arcing): A small amount of hydrogen (H2) and acetylene (C2H2) are produced, along with some methane (CH4) and ethylene (C2H4). Carbon dioxide and carbon monoxide are always produced if the fault involves cellulose. The oil may be carbonized.

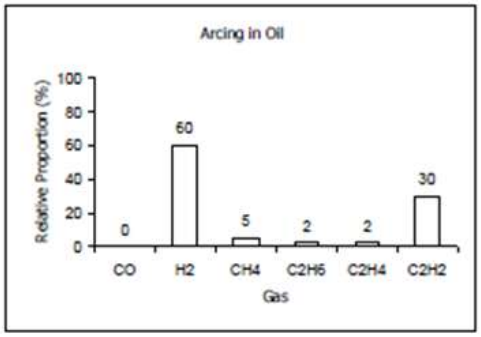

Figure 4. Arcing in oil

METHOD

This research used a laboratory experimental method with a quantitative approach. The aim was to measure and analyze the dissolved gas content in power transformer oil and to explain the measurement results based on the IEEE C57.104-2008 standard and PT PLN's Decree No. 0520 K/DIR/2014.

This research was conducted at the 150 kV Titi Kuning Substation on Jalan Suka Tirta No. 54b, Medan Johor, Medan, North Sumatra. The research objects were Power Transformers 1 and 2 of the 150 kV Titi Kuning Substation. The data in Table 3 shows the specifications of power transformers 1 and 2 of the 150 kV Titi Kuning Substation.

Table 3. Transformer Specifications

Information	Trafo I	Trafo II
Manufacture	PASTI	B&D
Year Of Manuf.	1994	2020
Standard	IEC 76	IEC 60076

INFOKUM
Volume 13, Number 06, 2025, DOI 10.58471/infokum.v13i06
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https://infor.seaninstitute.org/index.php/infokum

Rated Power	60 MVA	36/60 MVA
Cooling	ONAN/ONAF 70/100%	ONAN/ONAF
Frequency	50 Hz	50 Hz
Phases	3	3
Connection Symbol	YNyn0+d	YNyn0+d
Max Altitude	1000 m	1000 m

The Dissolved Gas Analysis (DGA) test used the Gas Chromatography method with a Morgan Schaffer Myrkoz MYR-011 Portable DGA tester to determine the levels of dissolved gases in power transformer oil. Table 4 shows the data collected from the Dissolved Gas Analysis (DGA) test results for Power Transformer 1 at the 150 kV Titi Kuning Substation, and the oil sample testing was conducted on November 23, 2023.

Table 4. Testing Results Of The Power Transformer Dga 1 At The Titi Kuning Substation

Parameter Uji	Konsentrasi (ppm)
Hydrogen H_2	70
Methane CH_4	266
Carbon monoxide CO	514
Carbon dioxide CO_2	3929
Ethylene C_2H_4	22
Ethane C_2H_6	127
Acetylene C_2H_2	0

In Table 5, the data taken are the results of the Dissolved Gas Analysis (DGA) test from the Power Transformer 2 of the 150 kV Titi Kuning Substation and oil sample testing was carried out on November 23, 2023.

Table 5. Testing Results Of Power Transformer Dga 2 Substation At Titi Kuning

Parameter Uji	Konsentrasi (ppm)
Hydrogen H_2	8
Methane CH_4	47
Carbon monoxide CO	95
Carbon dioxide CO_2	1283
Ethylene C_2H_4	2
Ethane C_2H_6	56
Acetylene C_2H_2	0

The data in tables 4 and 5 are used as a reference for determining the condition of the transformer and as analysis material to determine the appropriate steps for the transformer referring to the IEEC 57.104-2008 standard and KEPDIR No. 0520 K/DIR/2014.

INFOKUM
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https://infor.seaninstitute.org/index.php/infokum

RESULTS AND DISCUSSION

The analysis used two methods to determine the condition of this transformer: TDCG and Key Gases.

Analysis using the TDCG method

The TDCG method for Dissolved Gas Analysis (DGA) analysis involves summing the values of Hydrogen (H2), Acetylene (C2H2), Ethylene (C2H4), Ethane (C2H6), Methane (CH4), and Carbon Monoxide (CO). The following are the TDCG results obtained from the Dissolved Gas Analysis test on the power transformer at the Titi Kuning substation.

Table 6.TDCG Results For Power Transformer 1 At The Titi Kuning Substation

Gas	H_2	CH_4	CO	C_2H_4	C_2H_6	C_2H_2	TDCG
Nilai (ppm)	70	266	514	22	127	0	1001

Referring to Table 3, the TDCG calculation results in Table 6 are condition 2. The results above indicate higher-than-normal levels of flammable gas. Any flammable gas exceeding the specified levels requires immediate additional investigation.

Table 7. TDCG Results Of Power Transformer 2 At The Yellow Substation

Gas	H_2	CH_4	CO	C_2H_4	C_2H_6	C_2H_2	TDCG
Nilai (ppm)	8	47	95	2	52	0	206

Referring to Table 3, the TDCG calculation results in Table 7 are condition 1. The results above indicate that the transformer is operating satisfactorily. The transformer can operate normally.

Analysis Using the Key Gases Method

Dissolved Gas Analysis using the key gases method is a simple yet effective method for identifying the type of damage or abnormalities in a transformer based on the content of certain gases, such as Ethylene (C2H4), Carbon Monoxide (CO), Hydrogen (H2), and Acetylene (C2H2) in the transformer's insulating oil.

Table 8. TDCG Results Of Power Transformer 1 At The Yellow Substation

Indikasi	Gas Dominan	Konsentrasi (ppm)	Persentase Terhadap TDCG
Thermal Oil	Ethylene C_2H_4	22	2%
Thermal Oil – Selulosa	Carbon Monoxide CO	514	51%
Electrical – Partial Discharge	Hydrogen H_2	70	6%
Electrical – Arching	Acetylene C_2H_2	0	0%

INFOKUM
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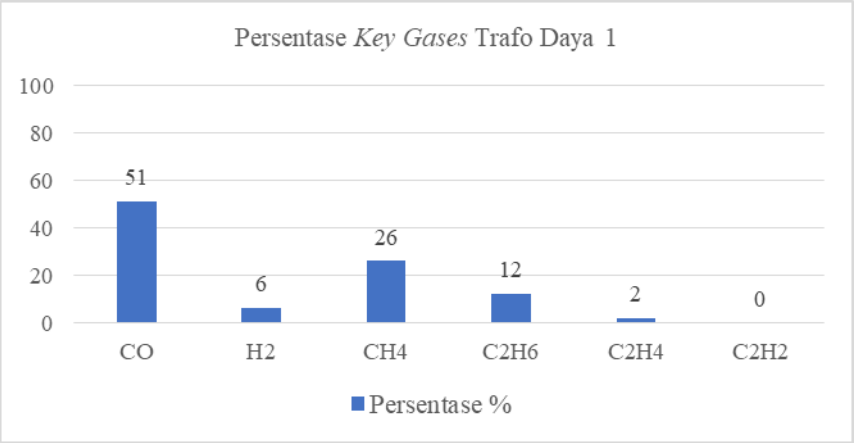

Figure 5. Percentage of Key Gases in Transformer 1

Figure 5 shows the dominant amount of carbon monoxide (CO) gas, indicating overheating in the transformer oil and insulating paper.

Table 9. Results Of The Key Gases Method For Power Transformer 2, Substation, Yellow Dots

Indikasi	Gas Dominan	Konsentrasi (ppm)	Persentase Terhadap TDCG
Thermal Oil	Ethylene C_2H_4	2	25%
Thermal – Selulosa	Carbon Monoxide CO	95	46%
Electrical – Partial Discharge	Hydrogen H_2	8	3%
Electrical - Arching	Acetylene C_2H_2	0	0%

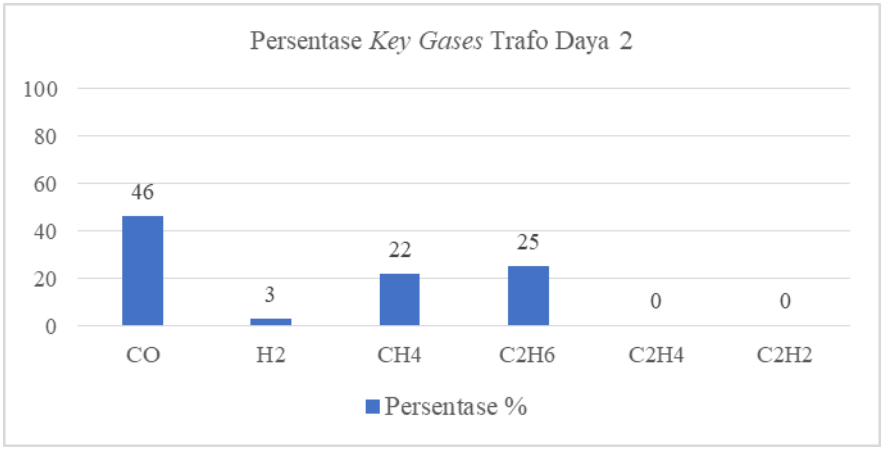

Figure 6. Percentage of Key Gases in Transformer 2

Figure 6 shows the dominant amount of carbon monoxide (CO) gas, as in Transformer 1, indicating overheating in the transformer oil and insulating paper.

INFOKUM
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ESSN 2722-4635 (Online)
https://infor.seaninstitute.org/index.php/infokum

CONCLUSION

Based on the research results and data analysis, the following conclusions can be drawn: The condition of the insulating oil sample for power transformer 1 is category 2. Abnormalities in power transformer 1 are evident from the TDCG value of 1001 ppm, and the Key Gases method found carbon monoxide (CO) gas to be dominant. This is due to excessive heat in the transformer insulating oil and insulating paper. Monthly Dissolved Gas Analysis testing is necessary to ensure the accuracy of the transformer insulating oil sample.The TDCG value for transformer 2, 206 ppm, indicates condition 1. The transformer can operate normally, but it should be noted that the Key Gases method analysis revealed carbon monoxide (CO) gas, indicating excessive heat in the transformer insulating oil and insulating paper. Retesting is necessary to confirm the actual condition of the transformer insulating oil. Dissolved Gas Analysis (DGA) testing results can assist in analyzing abnormal conditions in a transformer. If necessary, comparative testing can also be conducted using laboratories at other PLN units to confirm the results. If done correctly, transformer failures will be minimized.

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