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# Analysis Effect of Loading on the DGA Results of the UAT 2A Transformer PLTU Paiton 1&2 for Optimizing Self-Use

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**Abstract:** In this study, the analysis of the effect of loading on the DGA results of the Paiton UAT 2A transformer units 1 and 2 was carried out using the DGA (Dissolved Gas Analysis) test tool with the X-DGA kelman tool to determine the gas content contained in oil or oil. The UAT 2A transformer is a type of oil-cooled distribution transformer that uses the Nytro Libra oil type. The oil in the UAT 2A transformer is useful for insulating and cooling media so that the UAT 2A transformer does not get hot. In the oil content there is a gas content that causes transformer failure. Gas failure is called gas fault which results in thermal and electrical failure. The results of the DGA (Dissolved Gas Analysis) test analysis show that loading greatly influences the DGA test results because there are contents that are indicated to experience Low Energy Electrical Discharge, Hight Energy Electrical Discharge and Thermal Fault, namely $H_2$, $CH_4$, $C_2H_4$, $C_2H_6$, $C_2H_2$, $CO$, $CO_2$, and $H_2O$ continue to increase due to Thermal Fault.

**Keywords:** DGA (Dissolved Gas Analysis); Electrical Discharge; Energy Thermal Fault; LED lights; UAT 2A transformer

## Introduction

PT. PLN (Persero) is a national electricity company engaged in business starting from generation, transmission and distribution (Tiasmoro et al., 2021). Electrical energy is one of the main factors as an important support for the development of a region. With increasing industrial activity and population, the need for electrical energy will also increase. Based on the Decree of the Minister of Energy and Mineral Resources No. 1567k/21/MEM/2018 as of November 2017 the total installed generating capacity in Indonesia is 54577.9 MW consisting of 40285.7 MW PLN generators, 10457 MW private and 3835 MW leases, most of the power plants are in the form of Steam Power Plants (PLN, 2018).

The use of an unbalanced electricity load with a large power subscription can result in inefficiency in financing. This results in high electricity bills that are paid monthly, plus the imposition of penalty fines due to the low power factor specifically for Medium Voltage subscriptions. Low transformer efficiency which means large losses can result in losses on the power provider side, in this case PT. PLN (Persero) and consumers, especially for Medium Voltage customers, Low transformer efficiency can be caused by low power factor, as well as low loading due to the use of non-linear loads (Ermawanto et al., 2011; Faiz et al., 2015). Factors that can affect the value of transformer losses include the temperature hotspot that occurs in a transformer. The magnitude of the temperature hotspot is much influenced by changes in the magnitude of loading and changes in ambient temperature. Changes in the value of this resistance are one of the factors that affect the amount of copper loss (I2R) in the transformer (Sutjipto, 2020). The performance of the power transformer is determined through the parameters of the power that occur in the transformer (Dalila et al., 2009; Rizki & Ervianto, 2019; Yazdani-Asrami et al., 2021). If losses occur in the iron core, it can cause excessive heat and vibration in the transformer, causing the efficiency value and the transformer's lifespan (Loss of Life) to decrease (Tiasmoro et al., 2021).

The decrease in the performance of power generator engines is usually caused by the factor of excessive energy losses (Sahin et al., 2020). However, at present the efficiency of a generator is only determined

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by referring to energy efficiency based on the First Law of thermodynamics and it is felt that this method does not adequately describe the important aspects of energy utilization. Because of this, it is necessary to use a combination of exergy approaches based on Law II of thermodynamics to determine the accuracy of the efficiency of a generator (Zulmi et al., 2021). During operation, various forms of load conditions have been received by the BHT03 transformer and annual oil breakdown voltage tests have been carried out, but this condition still allows for a decrease in oil quality due to the quantity of gas content in transformer oil which has increased, so that the insulating properties of the oil do not function properly. well and can cause bigger problems, namely the transformer stops working because the GCB (Gas Circuit Breaker) experiences a trip (Sulistyo, 2016). Dissolved gas analysis (DGA) of a transformer can provide insight into the thermal and electrical stresses experienced by oil-immersed power transformers. Because it detects incipient transformer faults, DGA can help prevent further damage. In addition, DGA is a sensitive and reliable technique for detecting incipient fault conditions in oil-immersed transformers (Sun et al., 2012). From the elaboration above, it is necessary to carry out research on the effect of loading on the results of DGA (Dissolved Gas Analysis) transformer UAT 2A PLTU Paiton 1 & 2 to optimize self-use.

## Method

In this research method using research writing in the form of quantitative methods. Quantitative research is research conducted by collecting data and using a structured list of questions (questionnaire) which are compiled based on measurements of the variables studied which then produce quantitative data (Abdullah, 2015). While quantitative research is research in the form of numbers and statistical analysis (Raco, 2010). Quantitative research relies very heavily on data collection. The data in question is in the form of data obtained from the results of reading transaction points to be entered for calculation and analysis.

*DGA (Dissolved Gas Analysis) Test Method*

The DGA test was carried out by taking oil samples from the UAT 2A transformer unit and then extracting the dissolved gases. After the gas is extracted and then separated, the individual components are identified, then the quality is recorded (in units of Parts Per Million-ppm). The main advantage in DGA testing is early detection of possible failures in the transformer to be tested. However, the main drawback is the need to increase the high purity of the tested oil samples. The average DGA test tool has a high sensitivity, so that the impurity of the sample will reduce the accuracy of the DGA test (Sun et al., 2012). There are several things to note in DGA sampling, including: the tool used in sampling uses the Transport X kelman measuring instrument; how to take samples, by providing a bucket as a container for transformer oil samples, then install the oil flushing unit on the transformer main tank drain valve; and the duration of oil sampling and testing is carried out in the laboratory.

*Gas Extraction Method*

In the gas extraction method in the DGA test used to extract fault gas dissolved in transformer oil, using 2 Gas Chromatograph (GC) methods and the Photo-Acoustic Spectroscopy (PAS) method.

*Gas Chromatograph (GC)*

Gas Chromatograph is a technique for separating certain substances from a combined compound, usually these substances are separated based on their volatility (Gas Chromatograph). This method can provide qualitative information from each individual component in the sample tested. The sample being tested may already be in the form of a gas or be heated and evaporated beforehand until it is in the form of a gas.

*Photo-Acoustic Spectroscopy (PAS)*

Each type of fault gas (hydrogen, methane, oxygen, etc.) basically has a unique and unique ability to absorb electromagnetic radiation. The absorption capability of this unit is usually applied to infrared spectroscopic techniques to produce photo-acoustic effects. The absorption of electromagnetic radiation by the gas will increase the temperature of the gas. This temperature increase is directly proportional to the increase in gas pressure (with the gas being in a closed container). By vibrating the radiation source, the pressure of the gas in this closed container will fluctuate synchronously so that the amplitude of the resultant pressure wave can be detected using a sensitive microphone.

*Analysis of Transformer Oil Conditions Based on DGA Test Results*

After knowing the characteristics and the amount of dissolved gases obtained from the oil samples, it is necessary to interpret the data and then analyze the condition of the UAT 2A transformer.

*IEEE standard*

IEEE applies standardization in conducting analysis based on the amount of dissolved gas in oil samples, namely IEEE std. C57. 104-2008 (IEEE, 2009).

Table 1 lists the dissolved gas concentrations for each gas and the TDCG for conditions 1 to condition 4. This table is used to make the original assessment of the gas condition in a new or recently repaired transformer or is used if there were no previous tests on the transformer for dissolved gases or if no recent history. Users of this guide are advised that the dissolved gas concentrations contained in Table 1 are consensus values based on the experience of many companies. The transformer operator may decide to use different dissolved gas concentrations for each gas (especially acetylene) and TDCG based on engineering judgment and experience with other similar transformers.

**Table 1.** Dissolved Gas Concentration Limits in Parts Per Million (ppm) Based on IEEE std. C57. 104-2008

| Status | Dissolved key gas concentration limit (μL/L(ppm)[a]) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Hyrogen ($H_2$) | Methane ($CH_4$) | Acetylene ($C_2H_2$) | Ethylene ($C_2H_4$) | Ethane ($C_2H_6$) | Carbon Monoxide (CO) | Carbone dioxide ($CO_2$) | TDCG[b] |
| Condition 1 | 100 | 120 | 1 | 50 | 65 | 350 | 2500 | 720 |
| Condition 2 | 101-700 | 121-400 | 2-9 | 51-100 | 66-100 | 351-570 | 2500-4000 | 721-1920 |
| Condition 3 | 701-1800 | 401-1000 | 10-35 | 101-200 | 101-150 | 571-1400 | 4001-10000 | 1921-4630 |
| Condition 4 | > 1800 | > 1000 | >35 | >200 | >150 | >1400 | >10000 | >4630 |

The conditions for a particular transformer are determined by finding the highest level for each gas or TDCG in Table 1. For example, if the sample contains the following gas concentrations (in microliters/liters (ppm), vol/vol) represented by formula 1.

$$\frac{H_2}{270}\ \frac{CH_4}{253}\ \frac{C_2H_2}{5}\ \frac{C_2H_4}{17}\ \frac{C_2H_6}{75}\ \frac{CO}{524}\ \frac{TDCG}{1034} \qquad (1)$$

Gases included in the highest condition are $H_2$, $CH_4$, $C_2H_2$, $C_2H_6$, and TDCG (Furqaranda et al., 2022; Putra et al., 2023). This data therefore indicates that the transformer would be classified as Condition 2. This example can also be used to demonstrate two other factors that should be considered when using this table, namely the age of the transformer and the type of initial state.

**Table 2.** Operation Action Based on TDCG Test Conditions

| Status | TDCG Levels (μL/L) | TDCG Rate (μL/L/day) | Sampling interval and operating procedures for gas generation rates | |
|---|---|---|---|---|
| | | | Sampling Interval | Operating Procedures |
| Condition 4 | >4630 | >30 | Daily | Consider removal from service |
| | | 10 to 30 | Daily | Advice manufacturer |
| | | <10 | Weekly | Exercise extreme caution<br>Analyze for individual gases.<br>Plan outage.<br>Advice manufacturer |
| Condition 3 | 1921 to 4630 | >30 | Weekly | Exercise extreme caution |
| | | 10 to 30 | Weekly | Analyze for individual gases. |
| | | <10 | Monthly | Plan outage<br>Advice manufacturer |
| Condition 2 | 721 to 1920 | >30 | Monthly | Exercise caution. |
| | | 10 to 30 | Monthly | Analyze for individual gases. |
| | | <10 | Quarterly | Determine load dependence. |
| Condition 1 | <720 | >30 | Monthly | Exercise caution. |
| | | 10 to 30 | Quarterly | Analyze for individual gases.<br>Determine load dependence |
| | | <10 | Annual | Continue normal operation |

Table 2 shows the recommended initial sampling intervals and operating procedures for various TCG levels (in percent). After the source has been determined through analysis, inspection, consultation, or a combination thereof and the risks have been assessed, engineering judgment should be applied to determine the final sampling interval and operating procedures.

Example: A transformer has a TCG rating of 0.4% and produces gas at a constant rate of 0.035% TCG per day. Table 2 shows Condition 1. It should be sampled monthly, and the operator should be careful, analyze each gas, and determine the load dependency.

*Key Gas*

The gas key is defined by IEEE std. C57. 104-2008 as "gases formed in oil-cooled transformers which qualitatively can be used to determine the type of failure that occurs, based on the type of gas that is typical or predominately formed at various temperatures". These definitions, when associated with various cases of transformer failure that often occur, can be made into as shown in Table 3.

**Table 3.** Type of Failure Version Key Gas Analysis

| Suggested fault diagnosis | Ratio 1 CH4/CH2 | | Ratio 2 C2H2/C2H4 | | Ratio 3 C2H2/CH4 | | Ratio 4 C2H6/C2H2 | |
|---|---|---|---|---|---|---|---|---|
| | Oil | Gas space | Oil | Gas space | Oil | Gas space | Oil | Gas space |
| Thermal decomposition | >1.0 | >0.1 | <0.75 | <1.0 | <0.3 | <0.1 | >0.4 | >0.2 |
| Partial discharge (low intensity PD) | <0.1 | <0.01 | Not Significant | | <0.3 | <0.1 | >0.4 | >0.2 |
| Arcing (high intensity PD) | >0.1 to <1.0 | >0.01 to <0.1 | >0.75 | >1.0 | >0.3 | >0.1 | <0.4 | <0.2 |

## Result and Discussion

*Research Analysis Study Locations*

The location of the research in analyzing the loading on the DGA test results of the UAT 2A transformer was carried out in units 1 and 2 of the Paiton Steam Power Plant (PLTU) located in the Probolinggo Regency, East Java. The unit tested is a transformer that operates on units 1 and 2. The transformer specifications to be analyzed are as follows:

Serial Number : TSPH-91513/900
Connection : Dyn 11
Nominal Voltage : 125/50 kV
Capacity : 33.4 MVA
Tank Capacity : 11,000 kg

The UAT 2A transformer in PLTU units 1 and 2 uses Nytro Libra type oil. This oil is a new oil and has never been used. Oil type Nytro Libra is a type of nepthenic oil (Qian et al., 2012; Upadhyay, 2012). This oil has very good characteristics to be used as transformer insulating oil. The main advantage of this oil is its low viscosity at high temperatures, low solubility in water, and high oxidation stability.

The DGA test uses a syringe valve measuring instrument, which is produced by Trasport X produced by Kelman. This measuring instrument detects seven types of fault gas, namely hydrogen, methane, ethane, ethylene, acetylene, carbon monoxide, carbon dioxide, as well as the PAS method for dissolved gas extraction (Lubisi et al., 2022; Odongo et al., 2021; Sarma et al., 2021). DGA analysis is performed to detect the quantity of specific gas contained in an oil sample (Ali et al., 2023; Meira et al., 2019). Actually, during normal conditions there are gases dissolved in the oil, but when a failure occurs, it will increase the concentration of several types of gases. The composition of the increase in the concentration of these gases depends on the type of failure that occurs. The quantity/concentration of several types of dissolved gases when the oil sample is identified is then associated with various types of electrical and thermal failures/abnormalities.

*Sampling of UAT 2A Transformer Oil at PLTU Paiton Units 1 and 2*

Testing is carried out by taking oil samples using an oil collection tool and then testing them in the laboratory using the DGA (Dissolved Gas Analysis) test equipment with the X-DGA kelman tool to determine the gas content contained in the tested oil (Malik et al., 2020; Mamane et al., 2021). Two transformers tested at the Paiton Probolinggo steam power plant, East Java. Can be seen in the Table 4.

The results of the analysis of gas concentrations in Table 4 show that the gas elements CO, $CH_4$, $CO_2$, $C_2H_2$, $C_2H_4$, $H_2$, and flammable gases are on average still below the allowable limit values as shown in Table 3. The results of the analysis for $C_2H_6$ gas obtained an average amounted to 24.26 ppm, but there was an increase in concentration from 2008 to 2010. Test results showed an increase in elements that exceeded the allowable limit value of 70.9 ppm. But overall this value is still below the allowable limit value of 65 ppm. The condition of the transformer from the electrical aspect is shown through the results of measuring the electrical quality of the BHT03 transformer using the Power Quality Analyzer (PQA) as shown in Table 5. The results of this measurement are then used to calculate the current density (A/mm$^2$), secondary load line current (A) and temperature rise in transformer BHT03.

*DGA Test Data Analysis on UAT 2A Transformer*

The results of the UAT 2A transformer oil test analysis using DGA are shown in table 4. UAT 2A transformer oil sampling was carried out for 3 periods from 2017 to 2019. UAT 2A transformer oil samples were carried out in units 1 and 2 of PLTU Paiton.

**Table 4.** Results of the UAT 2A Transformer Oil DGA Test Sample

| Observation | Ethylene ($C_2H_4$) | Ethane ($C_2H_6$) | Acetylene ($C_2H_2$) | Carbon Monoxide (CO) | Carbon Dioxide ($CO_2$) | Water ($H_2O$) | TDCG | Load UAT 2A |
|---|---|---|---|---|---|---|---|---|
| I | 16 | 45 | 1 | 955 | 8479 | 19 | 1053 | 858 |
| II | 4 | 11 | 0 | 102 | 1883 | 19 | 129 | 607 |
| III | 79 | 42 | 0 | 257 | 2474 | 17 | 481 | 513 |
| IV | 47 | 27 | 0 | 336 | 3121 | 18 | 458 | 533 |
| V | 1284 | 388 | 8 | 413 | 3700 | 18 | 3890 | 899 |
| VI | 1199 | 265 | 7 | 466 | 4009 | 16 | 2747 | 648 |
| VII | 1202 | 33 | 6 | 469 | 4365 | 19 | 2693 | 611 |
| VIII | 1127 | 365 | 5 | 500 | 4717 | 19 | 2621 | 692 |
| IX | 908 | 325 | 4 | 430 | 4804 | 24 | 2118 | 646 |
| X | 1087 | 271 | 3 | 874 | 5899 | 17 | 2743 | 512 |
| XI | 1127 | 365 | 5 | 500 | 4717 | 19 | 2621 | 622 |
| XII | 1120 | 346 | 5 | 519 | 4826 | 19 | 2617 | 612 |
| XIII | 1051 | 357 | 4 | 505 | 4695 | 21 | 2502 | 612 |
| XIV | 1008 | 340 | 4 | 518 | 4991 | 20 | 2394 | 612 |
| XV | 908 | 325 | 4 | 430 | 4804 | 24 | 2118 | 636 |
| XVI | 1003 | 258 | 4 | 666 | 4692 | 20 | 2329 | 496 |
| XVII | 1086 | 290 | 3 | 716 | 4610 | 20 | 2581 | 850 |
| XVIII | 1087 | 271 | 3 | 874 | 5899 | 17 | 2743 | 512 |

The results of the analysis of gas concentrations of the gas elements $H_2$, $CH_4$, $C_2H_4$, $C_2H_6$, $C_2H_2$, CO, $CO_2$, $H_2O$ and flammable gases on average still below the allowable limit value (Mina & Kartika, 2023). The efficiency of the UAT 2A transformer of PLTU units 1 and 2 is different. Where the UAT 2A transformer of PLTU unit 1 tends to have a constant efficiency, while the UAT 2A transformer of PLTU unit 2 shows an efficiency that fluctuates along with the need for self-consumption loads.

## Conclusion

From the results of the analysis of the effect of loading on the DGA results of the UAT 2A transformer PLTU units 1 and 2 Paiton on the dissolved gas content in the oil based on DGA (Dissolved Gas Analysis) testing with the TDCG method, key gas in the Paiton Probolinggo Steam Power Plant (PLTU) East Java, It can be concluded that the UAT 2A Unit 1 at PLTU Paiton produces a DGA (Dissolved Gas Analysis) test that loading has a major influence on the DGA test results because there are ingredients that are indicated to experience Low Energy Electrical Discharge, Hight Energy Electrical Discharge and Thermal Fault namely $H_2$, $CH_4$, $C_2H_4$, $C_2H_6$, $C_2H_2$, CO, $CO_2$, and $H_2O$ continued to increase due to Thermal Fault.

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**Conflicts of Interest**
The interest in this research is to implement the tool, and as a graduation requirement for the third author.

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