Journal of Renewable Energy, Electrical, and Computer Engineering
Volume 4, Number 2, September 2024. 125-130
eISSN 2776-0049
Research Original Article
DOI: https://doi.org/10.29103/jreece.v4i2.17914

Determining the Appropriate use of 3 Phase 150 kV Transformer Oil Using the Fuzzy Method

Dina Maizana[✉1], **Moulando Tampubolon**[2], **Muhathir**[3], **Muhammad Fadlan Siregar**[4], **Yanawati Binti Yahya**[5]
[1] Electrical Engineering, Universitas Medan Area, Jl. Kolam. No. 1, Medan, 20223, Indonesia, maizanadina@gmail.com
[2] Electrical Engineering, Universitas Medan Area, Jl. Kolam. No. 1, Medan, 20223, Indonesia, moulanotampubolon@gmail.com
[3] Informatics Engineering, Universitas Medan Area, Jl. Kolam. No. 1, Medan, 20223, Indonesia, muhathir@staff.uma.ac.id
[4] Electrical Engineering, Universitas Medan Area, Jl. Kolam. No. 1, Medan, 20223, Indonesia, muhammadfadlansiregar@staff.uma.ac.id
[5] Electrical Engineering Section, British Malaysian Institute, Universiti Kuala Lumpur, 53100 Gombak, Selangor Malaysia, yanawati@unikl.edu.my
✉Corresponding Author: maizanadina@gmail.com | Phone: +6281362987385

Received: July 29, 2024 **Revision: August 18, 2024** **Accepted: September 20, 2024**

Abstract
Transformer is electrical power equipment that functions to convert electrical energy from one voltage value to another through the action of a magnetic field. Transformers are important electrical equipment because they are directly connected to electricity transmission and distribution lines. The aim of this research is to analyze transformer oil and its suitability standards. The type of research used is quantitative research using the Dissolved Gas Analysis (DGA) method. The data obtained for this method will be calculated by applying Fuzzy Logic to map the problem or determine variables. The mapping results will then be calculated using Matlab as the result of mathematical data analysis in graph form.
Keywords: Analysis; Transformer; Dissolved Gas Analysis (DGA); Fuzzy Logic; Matlab

Introduction
The high demand for electricity means that PT PLN, as a company operating in the field of electricity supply in Indonesia, must be able to meet the electricity needs of its consumers. In the energy system, PT PLN provides a generation system which is a source of electricity generation. The transformer is one element of the electrical system that can ensure the community's electricity needs are met on an ongoing basis. Therefore, the transformer must be maintained so that it continues to function optimally and avoid functional problems that can cause the transformer to fail.

A transformer is an electrical power device whose function is to change electrical energy from one voltage value to another through the action of a magnetic field. A transformer is an important electrical device because it is directly connected to the electricity transmission and distribution network. The role of the transformer is very important in the generating system, so it is necessary to carry out research related to transformers, especially on transformer oil which greatly influences transformer performance, where transformer oil functions as a coolant and insulator.

Due to the high price of transformer oil, maintenance and maintenance of transformer oil is very necessary. One form of maintenance and maintenance of transformer oil is the Dissolved Gas Analysis (DGA) test. The DGA test can be interpreted as an analysis of the transformer condition based on the amount of dissolved gas (fault gas) in the transformer. This DGA test is very useful in the industrial world because it can be carried out when the transformer is operating or in conditions where the transformer has voltage and is still distributing electrical power to consumers. (Bakar et al., 2014) The results of this DGA are a reference for PT PLN in carrying out transformer oil maintenance.

Previous research was conducted by (Amalia et al., 2017), it was found that the transformer was indicated to have Overheating of Cellulose, resulting in the production of toxic gases, namely CO and CO_2, which were quite high in the paper insulation. This indication was found from carrying out maintenance on the transformer in the form of oil purification (Golarz, 2016), (Arnawan et al., 2021).

The results of other research were carried out by (Anni et al., 2022) with the title Analysis of the Condition of Transformer Oil Using the Fuzzy Logic Method Based on Dissolved Gas Levels. Based on the test results, the average dissolved gas content is normal to high. The fuzzy expert system is more effective in diagnosing transformer problems and analyzing DGA, so that more optimal results can be obtained and preventative actions can be taken as quickly as possible (Hasibuan, Isa, et al., 2019).

PLN has carried out Dissolved Gas Analysis (DGA) testing on each transformer insulating oil to determine the condition of the insulating oil for each transformer. However, PLN's analysis results for determining the condition of the oil still have shortcomings regarding the condition of the insulating oil and the condition of the transformer. The analysis of the DGA results carried out by PLN only considers the results of Total Dissolved Combustible Gas (TDCG) or total flammable dissolved gas to determine the condition of the transformer without taking into account the properties. and the concentration of other gases contained in transformer insulating oil.

Based on the description above, the aim of this research is "Determining the Appropriate Use of 3 Phase 150 KV Transformer Oil using The Fuzzy Method".

Literature Review

A transformer is an electrical device whose function is to transmit electrical energy from high voltage to low voltage and vice versa. Transformers use Faraday's law of induction and Korentz's law to distribute power. In this process, alternating current flows around the iron core, the iron core will turn into a magnet, and if the magnet is surrounded by a winding, the two ends of the winding will have different potentials (Sinuhaji, 2012), (Mardiyanto, n.d.).

In the field of electric power distribution, the transformer is the distribution center of the transmission and distribution system (Hasibuan, Badrina, et al., 2019). It is hoped that the transformer can work continuously in conditions like this. Considering the intensive and almost constant operation of a transformer, it is necessary to pay attention to its operation. Transformer loading, coil temperature, transformer oil temperature and environmental temperature are factors that must be considered to ensure optimal transformer performance and prevent reducing the life of the transformer itself (Utomo, 2019).

Three-phase transformers are basically no different from single-phase transformers (Ismail et al., 2020). The most basic difference lies in the electrical system, namely one-phase and three-phase systems, so that three-phase transformers can be connected in a star, triangle or zig-zag manner. For economic reasons, three-phase transformers are more widely used in electric power transmission and distribution systems. Three-phase transformers also have disadvantages, among others, if one of the phases is damaged then the entire transformer must be moved (replaced), however, if the transformer consists of three single-phase transformers, if one of the phases is damaged the system can still be operated with an "open delta" system" (Hermawan et al., 2011), (Lin, 2014).

A three-phase transformer has six coils, three primary coils with the number of turns N_1 which are connected to the primary voltage sources VR, VS, and VT. Three secondary coils with the number of turns N_2 are connected to the primary voltage sources Vr, Vs, and Vt. For each phase, the voltage transformation ratio is the same as the ratio for a single-phase transformer, but for line to line voltage, a three-phase transformer will follow the coil connection configuration (Pandiangan et al., 2023), (Nisworo et al., 2022).

Transformer oil is a liquid produced from refining crude oil. Apart from that, this oil also comes from organic ingredients such as pyranol oil and silicone oil. Several types of transformer oil that are commonly used in the field are Diala A, Diala B, and Mectrans transformer oil. Transformer oil is a liquid insulating material used as insulation and cooling in transformers, as shown in Figure 1 (Junfithrana et al., 2019), (Sun et al., 2017).

Figure 1. Transformer insulating oil

For this reason, monitoring and maintaining the quality of transformer oil is very important to ensure the reliable operation of electrical equipment, especially transformers, and authorized experts have established instructions in the form of test standards and technical specifications such as IEC, ASTM, BS etc. New transformer oil (Unused mineral insulating oil) IEC 60296-2003 (Lukman et al., 2023) used transformer oil (mineral oil in service) SPLN 49-1:1982 IEC 422:1982 was updated to become IEC 422:1989 (Romadhona et al., 2021).

At the end of the 19th century until the end of the 20th century, probability theory played an important role in solving uncertainty problems. The methods commonly used at that time were regression analysis and multiple regressions. Rapid technological developments not only develop hardware and software technology, but also computing methods. One of the computing methods that is quite developed is intelligent systems. One method in an intelligent system that can be used to forecast is the use of fuzzy logic which was introduced by Lotfi A. Zadeh in 1965.

In general, fuzzy logic is a calculation method that uses word variables (linguistic variables) and replaces calculations with numbers. Even though the words used in fuzzy are not as precise as numbers, the words used are more in line with human intuition, for example the words unsettling, approximately, more or less and so on. With the

development of human thinking power, fuzzy logic has become popular for use in research because it is able to bridge machine language which is completely accurate with human language which is generally inaccurate. Fuzzy logic can be considered as an approach to mapping an input space into an output space.

Fuzzy logic is used as a way to map problems from input to expected output. In fuzzy sets, the membership value is between 0 and 1. A fuzzy set is a group that represents a certain condition or situation in a fuzzy variable. Fuzzy variables are variables that will be discussed in a fuzzy system, for example age, temperature, etc. The membership function is in the form of a curve that shows the mapping of input data points into membership values that have an interval between 0 and 1 (Setiawan et al., 2018).

Materials & Methods

Table 1 shows IEEE Standard C57.104-2008 Dissolved Gases bases on 3 conditions. (Lin, M. 2014) From this condition it has four classifications of transformer operating. The four classifications of transformer operating conditions are:

Condition 1 (Normal)

Total Dissolve Combustible Gas (TDCG) shows that the transformer can still operate normally and continue operation.

TDCG (720): H2 (100) + CH4 (120) + C2H2 (35) + C2H4 (50) + C2H6 (65) + CO (350) + CO2 (2,500).

Condition 2 (Up to normal)

Total Dissolve Combustible Gas (TDCG) indicates gas that is flammable and has exceeded normal limits. If one of the gases exceeds this level limit, an investigation must be carried out immediately.

TDCG (721-1.920): H2 (100-700) + CH2 (121-400) + C2H2 (36-50) + C2H4 (51-100) + C2H6 (66-100) + CO (351-570) + CO2 (2,500-4,000).

Condition 3 (Decomposition)

Total Dissolve Combustible Gas (TDCG) shows a high level of decomposition. If one of the gas values exceeds this level limit, an investigation must be carried out.

TDCG (1.921-4.630): H2 (701-1,800) + CH2 (401-1,000) + C2H2 (51-80) + C2H4 (101-200) + C2H6 (101-150) + CO (571-1,400) + CO2 (4,001-10,000).

Condition 4 (High decomposition)

Total Dissolve Combustible Gas (TDCG) shows excessive decomposition and continued operation can result in transformer failure (D. Amalia, 2017).

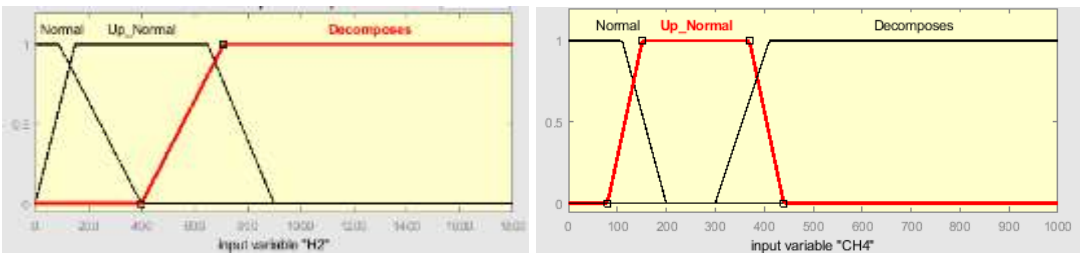
TDCG (>4.630): H2 (>1,800) + CH2 (>1,000) + C2H2 (>80) + C2H4 (>200) + C2H6 (>150) + CO (>1,400) + CO2 (>10,000).

The results are: the transformer is good if condition 1 (normal) is met, the transformer is adequate if condition 2 (up to normal) is met, the transformer is bad if it is in conditions 3 and 4 (decomposition).

Table 1. IEEE standard C57.104-2008 dissolved gases

Condition	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	CO	CO_2	TDCG
Condition 1 (normal)	100	120	35	50	65	350	2.500	720
Condition 2 (up normal)	101-700	121-400	36-50	51-100	66-100	351-570	2.501-4.000	721-1.920
Condition 3 (decomposes)	701-1.800	401-1.000	51-80	101-200	101-150	571-1.400	4001-10.000	1.921-4.630

Figure 2 is a fuzzy design using Matlab. In the picture we can see that there are 7 types of dissolved gas in transformer oil which are included in the input section, namely H_2, CH_4, CO, CO_2, C_2H_4, C_2H_6, C_2H_2 gas .and TDCG gas. The measurement results at the substation can be seen in table 2. From the table 2, the value of dissolved gas in transformer oil at GI PLN UIP3B. Data collection was carried out on three samples/units to determine the amount of gas dissolved in the oil. From the measurement results, the dissolved gas values can be obtained as in the table 2, where the gas values for the three samples are different.



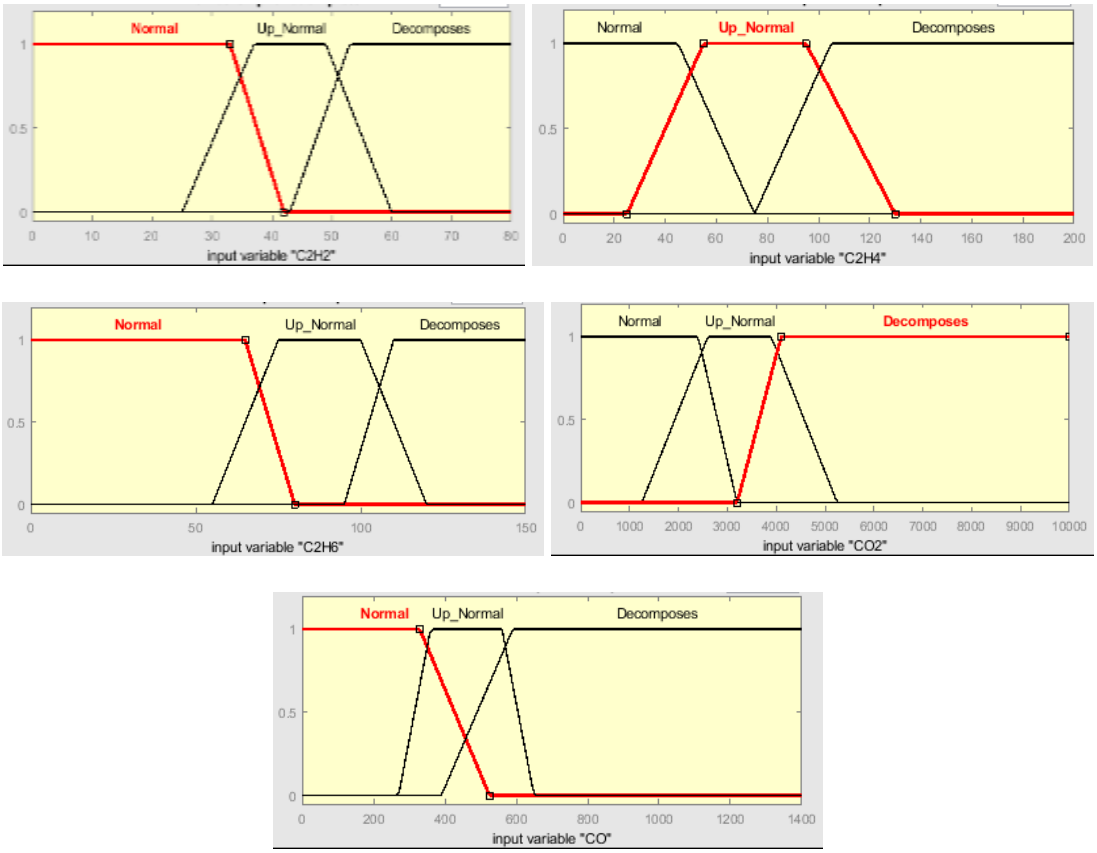


Figure 2. Fuzzy logic network in matlab for every member

Table 2. Transformer oil dissolved gas

Compound	Gas name	Value of ppm		
		Unit 1	Unit 2	Unit 3
H_2	Hydrogen	90	7,4	34
CH_4	Methane	3	3,4	4,2
CO	Carbon Monoxide	204	147	511
CO_2	Carbon Dioxide	3713	3650	3620
C_2H_4	Ethylene	9,8	5,3	8,8
C_2H_6	Ethane	16	11	11
C_2H_2	Acetylene	0,9	0,2	0

Results and Discussion

Figure 3 shows the simulation results of the Fuzzy method for measurement data in unit 1. For the gas solution values H_2, CH_4, CO, CO_2, C_2H_4, C_2H_6, C_2H_2 are still in the normal position. Meanwhile, the CO_2 gas solution is in the up normal position according to the IEEE C57.104-2008 standard. From the output of the Fuzzy simulation results, it was found that the TDCG output was still in normal conditions, namely 579.

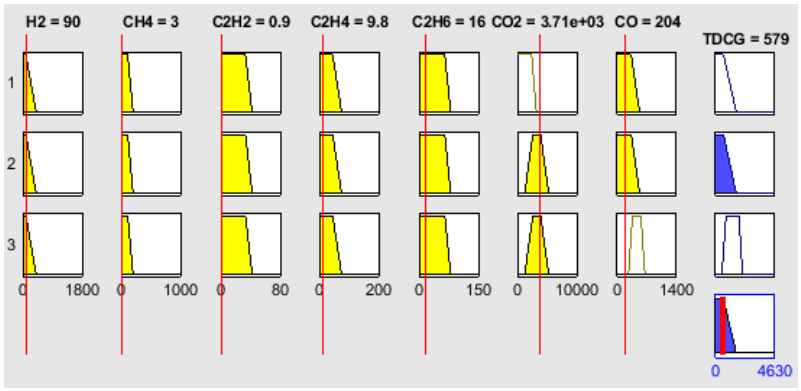


Figure 3. The test results on unit 1 obtained a TDCG value of 579 or still in the normal category

Figure 4 shows the simulation results of the Fuzzy method for measurement data in unit 2. For the gas solution

values H_2, CH_4, CO, CO_2, C_2H_4, C_2H_6, C_2H_2 are still in the normal position. Meanwhile, the CO2 gas solution is in the normal up position according to the IEEE C57.104-2008 standard. From the Fuzzy simulation results, it was found that the TDCG output still included normal conditions, namely 579. The value of the TDCG output was the same as the TDCG output in unit 1 even though the average dissolved gas value was lower than unit 1.

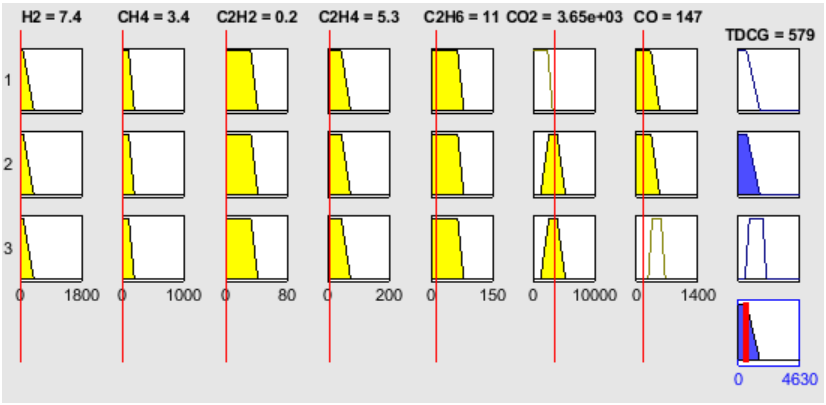


Figure 4. The test results on unit 2 obtained a TDCG value of 579 or still in the normal category

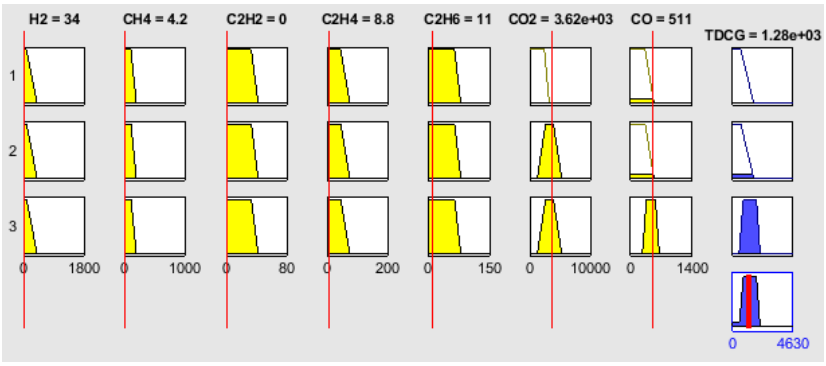


Figure 5. The test results on unit 3 obtained a TDCG value of 1280 or still in the normal category

Figure 5 shows the simulation results of the Fuzzy method for measurement data in unit 3. For the gas solution values H_2, CH_4, C_2H_4, C_2H_6, C_2H_2 are still in the normal position. Meanwhile, CO and CO_2 gas solutions dominate in the normal up position according to the IEEE C57.104-2008 standard. From the output of the Fuzzy simulation results, it is found that the TDCG output is still in normal condition, namely 1280. The value of the TDCG output is greater than the TDCG output in units 1 and 2; however, the TDCG output is still in a normal position.

From the simulation results using the Fuzzy method for the measurement data provided from the three units, namely unit 1, unit 2 and unit 3, the oil is still suitable for use in transformer operations. Even though from the third unit according to the IEEE C57.104-2008 standard, the ppm value of dissolved gas for CO and CO_2 gas is in the up-normal position compared to other dissolved gases.

Conclusions

From the simulation results using the Fuzzy method to determine the suitability of transformer oil, it was found that transformer oil is still suitable for use. This feasibility is demonstrated by the external TDCG in a normal position. Although in unit 3 the dissolved gas ppm value for CO and CO_2 gas is positioned up to normal according to the IEEE C57.104-2008 standard.

Acknowledgments

Thank you very much to the Universitas Medan Area who has supported in this research.

References

Amalia, D., Murdiya, F., & Others. (2017). Analisa Gas Terlarut Pada Minyak Transformator Daya 150 Kv Dengan Menggunakan Metode Duval Pentagon. Riau University.

Anni, R., Asran, A., & Kartika, K. (2022). Analisis Keadaan Minyak Transformator Menggunakan Metode Logika Fuzzy Berdasarkan Kadar Gas Terlarut. Jurnal Pendidikan Tambusai, 6(2), 16200–16207.

Arnawan, H., Muzamir, I., Mohd, I. Y., Siti, R. A. R., & Hadi, S. (2021). Evaluation Of 20 Kv Distribution Network Losses In Radial Distribution Systems Due To Distributed Generation Penetration. Journal Of Physics: Conference Series, 2129(1), 12085.

Bakar, N. A., Abu-Siada, A., & Islam, S. (2014). A Review Of Dissolved Gas Analysis Measurement And Interpretation Techniques. Ieee Electrical Insulation Magazine, 30(3), 39–49.

Golarz, J. (2016). Understanding Dissolved Gas Analysis (Dga) Techniques And Interpretations. 2016 Ieee/Pes Transmission And Distribution Conference And Exposition (T\&D), 1–5.

Hasibuan, A., Badrina, B., & Hasibuan, A. Z. (2019). Simulasi Analisis Aliran Daya Sub Sistem Aceh 150 Kv Menggunakan Software Powerworld Simulator. Journal Of Electrical And System Control Engineering, 3(1), 42–52.

Hasibuan, A., Isa, M., Nrartha, I. M. A., & Hardi, S. (2019). Improving Voltage Profile Of 150 Kv Transmission Line In Aceh Subsystem With Capacitor Bank Installation. 2019 3rd International Conference On Electrical, Telecommunication And Computer Engineering (Elticom), 140–144.

Hermawan, H., Syakur, A., & Iryanto, I. (2011). Analisis Gas Terlarut Pada Minyak Isolasi Transformator Tenaga Akibat Pembebanan Dan Penuaan. Teknik, 32(3), 203–211.

Ismail, R., Hasibuan, A., Nasution, E. S., Hardi, S., & Nrartha, I. M. A. (2020). Comparative Analysis Of Differential Relay Settings In Langsa Substation Transformer To Avoid Protection Failure. 2020 4rd International Conference On Electrical, Telecommunication And Computer Engineering (Elticom), 52–56.

Junfithrana, A. P., Kusumah, I. H., Suryana, A., Artiyasa, M., De Wibowo, A., & Others. (2019). Identifikasi Gas Terlarut Minyak Transformator Dengan Menggunakan Logika Fuzzy Menggunakan Metode Tdcg Untuk Menentukan Kondisi Transformator 150 Kv. Fidelity: Jurnal Teknik Elektro, 1(1), 11–15.

Lin, M.-J. (2014). A New Approach With Three Dimension Figure And Ansi/Ieee C57. 104 Standard Rule Diagnoses Transformer's Insulating Oil. Engineering, 6(12), 841–848.

Lukman, L., Arief, Y. Z., Gamayel, A., & Wilyanti, S. (2023). Performance Analysis Of Nyamplung Oil (Calophyllum Inophyl-Lum) As An Alternative Liquid Electrical Insulation Material To Replace For Power Transformer Oil. Equivalent: Jurnal Ilmiah Sosial Teknik, 5(1), 96–101.

Mardiyanto, D. C. (N.D.). Analisis Keadaan Minyak Isolasi Transformator Daya Menggunakan Metode Fuzzy Logic Berdasarkan Data Dissolved Gas Analysis (Dga).

Nisworo, S., Hasibuan, A., Daud, M., Studi, P., Elektro, T., Teknik, F., & Malikussaleh, U. (2022). Evaluasi Kondisi Belitan Generator Transformers (Gt) Dengan Sweep Frequency Response Analysis. Rele (Rekayasa Elektrikal Dan Energi) : Jurnal Teknik Elektro, 5(1). Https://Doi.Org/10.30596/Rele.V5i1.10790

Pandiangan, T. D. M., Afiqadli, A., Napitupulu, J., & Jumari, J. (2023). Analisa Unjuk Kerja Transformator Tiga Phasa Gardu Induk Pematangsiantar Pt Pln (Persero). Jurnal Teknologi Energi Uda: Jurnal Teknik Elektro, 12(1), 24–35.

Romadhona, G., Wibowo, K. M., & Royan, R. (2021). Study Of Extra Virgin Olive Oil As Liquid Insulation In Transformer. Iop Conference Series: Earth And Environmental Science, 700(1), 12030.

Setiawan, A., Yanto, B., & Yasdomi, K. (2018). Logika Fuzzy Dengan Matlab (Contoh Kasus Penelitian Penyakit Bayi Dengan Fuzzy Tsukamoto). Jayapangus Press Books, I--217.

Sinuhaji, Y. P. (2012). Analisis Keadaan Minyak Isolasi Transformator Daya 150 Kv Menggunakan Metode Dissolved Gas Analysis (Dga) Dan Fuzzy Logic Pada Gardu Induk Wilayah Sidoarjo.

Sun, C., Ohodnicki, P. R., & Stewart, E. M. (2017). Chemical Sensing Strategies For Real-Time Monitoring Of Transformer Oil: A Review. Ieee Sensors Journal, 17(18), 5786–5806.

Utomo, P. (2019). Studi Analisis Kualitas Transformator Daya Gardu Induk 150 Kv Siantan. Journal Of Electrical Engineering, Energy, And Information Technology (J3eit), 7(1).