Improving TDGC on Oil Dissolved Tranformator Gas Using Fuzzy Logic

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***Abstract*— Maintenance of transformator, especially in power transformers is a part that must be carried out continuously. Transformator oil has a functions to isolating and cooling the transformer. Testing the condition of the transformer oil which is carried out in the laboratory from the results of the test data will know the condition of the transformer oil. Dissolved gas identification is a test that is often used in analyzing transformer oil conditions. Dissolved gas identification itself has several testing methods such as TDCG (Total Dissolved Combustible Gases). Fuzzy logic is a rule-based decision making system that aims to solve problems. Making fuzzy logic programs with TDCG method of transformer oil testing can make the diagnosis of transformer oil conditions more effective and can be used as supporting data for laboratory tests.**

Keywords*— *Transformator Oil, TDCG, Fuzzy Logic

I. Introduction

The high demand for electricity in Indonesia must be able to provide electricity needs for the community. The substation is a node in the electric power system, which consists of the arrangement and sequence of a number of equipment installed in a particular location to receive and distribute electricity, increase and decrease the voltage in accordance with the level of its working voltage, the place of work for switching the circuit of an electric power system and to support the reliability of the electric power system. One of the main components in an electric power system is a transformer.

The importance role of this transformer, it is necessary to conduct research relating to the transformer, especially on transformer oil which serves as insulation and cooling. Considering the high price of transformer oil, it is necessary to carry out maintenance and treatment of transformer oil, one form of treatment on transformer oil is the dissolved gas analysis (DGA) test. Testing the condition of the transformer oil which is carried out in the laboratory from the results of the test data will know the condition of the transformer oil. Dissolved gas analysis is a test that is often used in analyzing transformer oil conditions. Dissolved gas analysis itself has several testing methods such as TDCG (Total Dissolved Combustible Gases), key gases, ratio gases (Doernenburg and Roger), and duval triangles. This DGA test can be interpreted as an analysis of the condition of the transformer based on the amount of dissolved gas (fault gas) on the transformer. This DGA test uses fuzzy logic methods, fuzzy logic as a rule-based decision making system that aims to solve problems. Making fuzzy logic programs with the key gas method and gas transformer oil ratio testing can make the diagnosis of transformer oil conditions more effective and can be used as supporting data for laboratory tests at intervals every 3 months.

The DGA results at the Gunung Salak PLTP in Indonesia only consider the results of the TDCG (Total Dissolved Combustible Gases) method or the total flammable dissolved gas to determine the state of the tansformator. The state of the insulating oil will be solved by using Fuzzy Logic. It is expected that the DGA testing using fuzzy logic to analyze the state of the insulating oil will be more accurate than if done by only analyzing the TDCG gas concentration. The purpose of this research is the creation of a fuzzy logic system to determine the state of transformer insulation oil by considering the gases dissolved in the insulating oil detected by the transformer type conditions based on TDCG method.

II. Literature Review

A. Maintenance of Transformer Oil (DGA)

Dissolved Gas Analysis (DGA): Transformers as high voltage equipment cannot be separated from the possibility of experiencing abnormal conditions, where the trigger can come from internal or external transformers.

This abnormality will have an impact on the performance of the transformer. In general, these impacts / effects can be in the form of overheat, corona and arcing. One method to find out whether there is abnormality in the transformer is to know the impact of the transformer abnormality itself. To determine the impact of abnormalities on the transformer, the DGA (Dissolved gas analysis) method is used.

In the event of abnormalities in the transformer, the insulating oil as a hydrocarbon chain will decompose due to the abnormality of energy and will form hydrocarbon gases which are soluble in the insulating oil itself. Basically DGA is a process for calculating the levels / values of hydrocarbon gases that are formed due to abnormalities. From the composition of the levels / values of the gases, it can be predicted what the effects of abnormalities are in the transformer, whether overheat, arcing or corona. The gases detected from the DGA test results are H2 (hydrogen), CH4 (Methane), N2 (Nitrogen), O2 (Oxygen), CO (Carbon monoxide), CO2 (Carbondioxide), C2H4 (Ethylene), C2H6 (Ethane), C2H2 (Acetylene).

B. Transformer Oil Testing Method

TABEL I. DISSOLVED GAS CONSENTRATIONS [1]

Status	Dissolved key gas concentration limits (μL/L (ppm)[a]							
	Hydrogen (H_2)	Methane (CH_4)	Acytlene (C_2H_2)	Ethylene (C_2H_4)	Ethane (C_2H_6)	Carbon Monoxide (CO)	Carbon dioxide (CO_2)	TDCG[b]
Condition1	100	120	1	50	65	350	2500	720
Condition2	101-700	121-400	2-9	51-100	66-100	351-570	2500-4000	721-1920
Condition3	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

Assuming that no previous test on the transformer for dissolved gas analysis has been made or there is no recent test. If the previous analysis exists, it must be reviewed to determine whether the situation is stable or unstable. The results of the gas analysis obtained from several laboratories can be different. TDCG values do not include CO2 which is not a type of combustible gas.

Condition 1, the transformer is operating normally. However, it is still necessary to monitor the condition of these gases. Condition 2, TDCG level starts to be high. There is a possibility of symptoms of damage that must begin to watch out for. More routine oil sampling is needed. Condition 3, TDCG at this stage indicates the decomposition of the insulation and / or transformer oil. One or many damages might have occurred. In this condition the transformer must be watched out for and need further treatment. Condition 4, TDCG at this level indicates a decomposition / damage to the paper insulation and / or transformer oil that has been expanded.

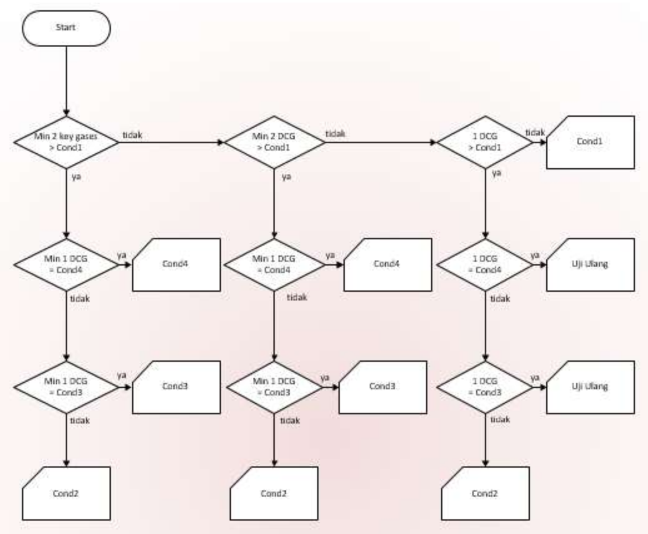

Fig 1. DGA Testing Flowchart[2]

C. Fuzzy Logic

Fuzzy Logic is a way to present and deal with the problem of uncertainty (doubt, inaccuracy, lack of complete information, and partial truth). Fuzzyfication process is a process to change non-fuzzy variables (numerical variables) into fuzzy variables (linguistic variables), in other words fuzzyfication aims to identify inputs that will describe a system [3]

The membership function (membership function) is a curve that shows the mapping of data input points into the membership value (often also called the degree of membership) which has an interval between 0 to 1. One way that can be used to obtain membership values is through an approach function [4] Fuzzy rules are the link between all inputs that will produce the target output. Defuzzyfication is the process of changing fuzzy information that is processed by the fuzzyfication process in the form of input and output as well as the implementation of the existing rules in the fuzzy [5].

Membership function (membership function) is a curve that shows the mapping of data input points into the membership value (often also called the degree of membership) that has an interval between 0 to 1. One way that can be used to obtain membership values is through function approach. There are several functions that can be used.

III. DESIGN SYSTEM

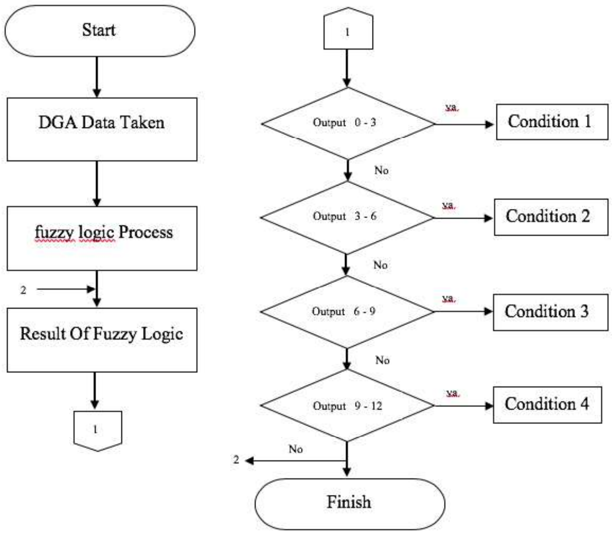

Fig 2. System Flowchart

A. Fuzzy Logic Design

Fuzzy logic theory is used to develop the dissolved gas membership function to determine the actual state of the transformer insulation oil to prevent failure of the transformer.

DGA data retrieval uses a PAS (Photo Acoustic Spectroscopy) tool where this tool serves to detect gases dissolved in transformer oil. Furthermore, fuzzy logic programming is made in the MATLAB application for data processing. After the fuzzy logic program is finished, data processing uses simulink to be able to determine the results of the transformer conditions.

Transformer conditions are divided into 4 conditions :

Condition 1, the transformer is operating normally. However, it is still necessary to monitor the condition of these gases.

Condition 2, TDCG level starts to be high. There is a possibility of symptoms of damage that must begin to watch out for. More routine oil sampling is needed.
Condition 3, TDCG at this stage indicates a decomposition of the insulation and / or transformer oil. One or many damages might have occurred. In this condition the transformer must be watched out for and need further treatment.

Condition 4, TDCG at this level indicates a decomposition / damage to the paper insulation and / or transformer oil that has been expanded.

The degree of membership is the degree contained in the transformer oil which will be input and illustrated into several levels of membership according to each method. By using the triangle membership function, use the following equation:

1. Hydrogen (H2) membership

a. Degrees a = 0; b = 50; c = 100, then the membership function for C1 (condition 1) can be solved by the equation:
- $b \leq x \leq c$
$0 \leq x \leq 50$
- $x \geq d$
$50 \leq x \leq 100$

b. Degrees a = 100; b = 400; c = 700, then the membership function for C2 (condition 2) can be solved by the equation:
- $b \leq x \leq c$
$100 \leq x \leq 400$
- $x \geq d$
$400 \leq x \leq 700$

c. Degree a = 700; b = 1250; c = 1800, then the membership function for C3 (condition3) table 2.1 can be solved by the equation:
- $b \leq x \leq c$
$700 \leq x \leq 1250$
- $x \geq d$
$1250 \leq x \leq 1800$

d. Degree a = 1800; b = 1900; c = 2000, then the membership function for C4 (condition4) can be solved by the equation:
- $b \leq x \leq c$
$1800 \leq x \leq 1900$
- $x \geq d$
$1900 \leq x \leq 2000$

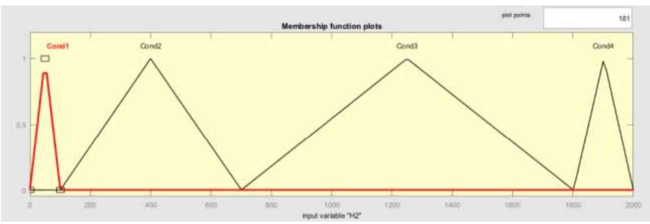

Fig 3. Hydrogen (H2) membership Fucntion

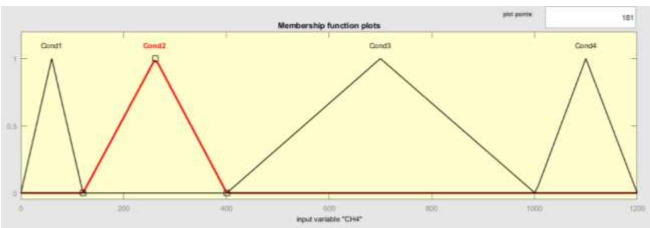

Fig 4. CH4 membership Fucntion

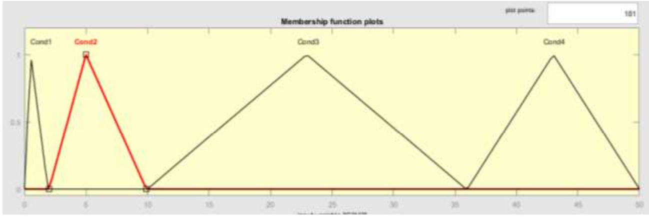

Fig 5. C2H2 membership Fucntion

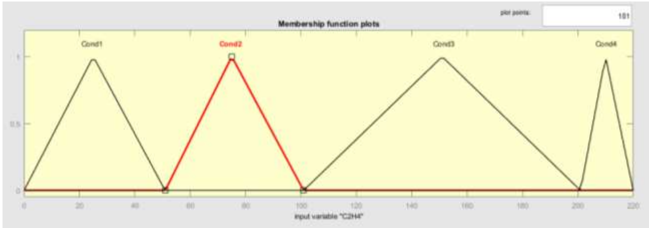

Fig 6. C2H4 membership Fucntion

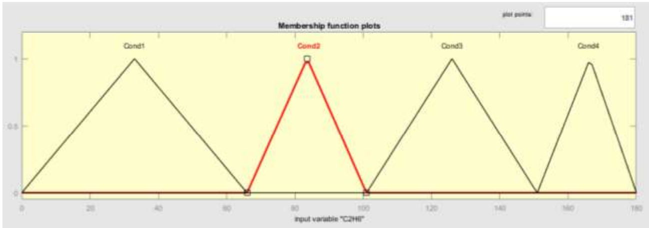

Fig 7. C2H6 membership Fucntion

B. *Output Membership*

1. Degrees a = 0; b = 1.5; c = 3, then the output membership function for C1 (condition1) is:
- $a \leq x \leq b$
$0 \leq x \leq 1.5$
- $b \leq x \leq c$
$1.5 \leq x \leq 3$

2. Degree a = 3; b = 4.5; c = 6, the membership function for C2 (condition2) is:
- $a \leq x \leq b$
$3 \leq x \leq 4.5$
– $b \leq x \leq c$
$4.5 \leq x \leq 6$

3. Degrees a = 6; b = 7.5; c = 9, the membership function for C3 (condition3) is:
- $a \leq x \leq b$
$6 \leq x \leq 7.5$
- $b \leq x \leq c$
$7.5 \leq x \leq 9$

4. Degree a = 9; b = 10.5; c = 12, the membership function for C4 (condition4) is:
- $a \leq x \leq b$
$9 \leq x \leq 10.5$
- $b \leq x \leq c$
$10.5 \leq x \leq 12$

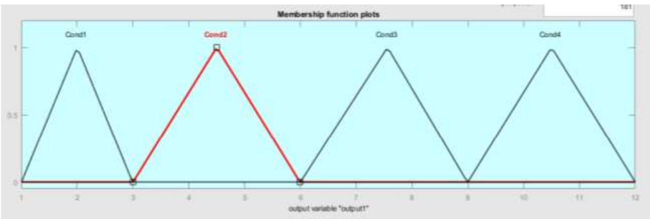

Fig 7. Output Membership Function

C. Fuzzy Logic Rules

1. If (H2 is C1) and (CH4 is C1) and (C2H2 is C1) and (C2H4 is C1) and (C2H6 is C1) then (output1 is C1) (1)
The fuzzy rule above explains if all gases are in condition 1, the output will be in condition 1.

2. If (H2 is C2) and (CH4 is C2) and (C2H2 is C2) and (C2H4 is C2) and (C2H6 is C2) then (output1 is C2) (1)
The fuzzy rules above explain if all gases are in condition 2, the output will be condition 2.

3. If (H2 is C2) and (CH4 is C2) and (C2H2 is C3) and (C2H4 is C2) and (C2H6 is C2) then (output1 is C3) (1)
The fuzzy rule above explains that if there are at least two gases in condition 2 and one gas in condition 3, the output will be condition 3.

4. If (H2 is C2) and (CH4 is C1) and (C2H2 is C4) and (C2H4 is C2) and (C2H6 is C1) then (output1 is C4) (1)
The fuzzy rule above explains that if there are at least two gases in condition 2 and one in condition gas 4 then the output will be worth condition 4.

D. Simulation

Simulink is used to help design the simulation this time by using a block diagram that has been adapted to the method used. Simulink data input is adjusted to the DGA test results that have been obtained, then processed with fuzzy logic controls that have been made it will appear on the simulink display of the outputs with fuzzy logic rules.
This simulink simulation uses constanta, demux, fuzzy logic controller, and display components.

1. Constanta: a component used to enter input data that has been created and arranged accordingly from fuzzy logic programming.
2. Demux: a component used to receive all existing input into one output.
3. Fuzzy Logic Controller: a component that will process and identify data in accordance with programs created in fuzzy logic and programs exported to workspaces so that the fuzzy logic controller can function.
4. Display: the component that displays the output in the form of an appropriate nominal number we have programmed to determine the conditions of the results of data processing.

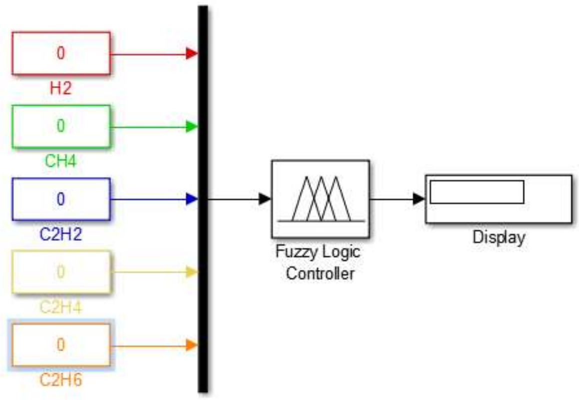

Fig 8. Simulink Simulation

IV. Result

In the test scenario, the simulation is designed based on the system analysis and diagnosis of transformer oil quality with fuzzy logic using DGA with the TDCG method. The input data is based on the results of the DGA power transformer testing at PLTP Gunung Salak with a capacity of 150KV each. Gas is detected by DGA testing where the gas will be input in this simulation. DGA Simulation Test Results DGA Test Results Data at PLTP Gunung Salak Transformer: 1BAT01 / 2BAT01 / 3BAT01 Capacity: 150KV Place / Year: PLTP Gunung Salak.

TABEL II. TRANSFORMATOR TESTING

NO	Combustible gas	Consentrate (ppm)		
		1BAT01	2BAT02	3BAT01
1	Hidrogen (H2)	132	16	5
2	Metana (CH4)	4	6	1
3	Karbon monoksida (CO)	423	395	70
4	Karbon dioksida (CO2)	2580	3920	1245
5	Etana (C2H6)	6	21	10
6	Etilen (C2H4)	25	44	8
7	Asetilen (C2H2)	0,5	1	0,5

A. Trasformer 1BAT01 Testing

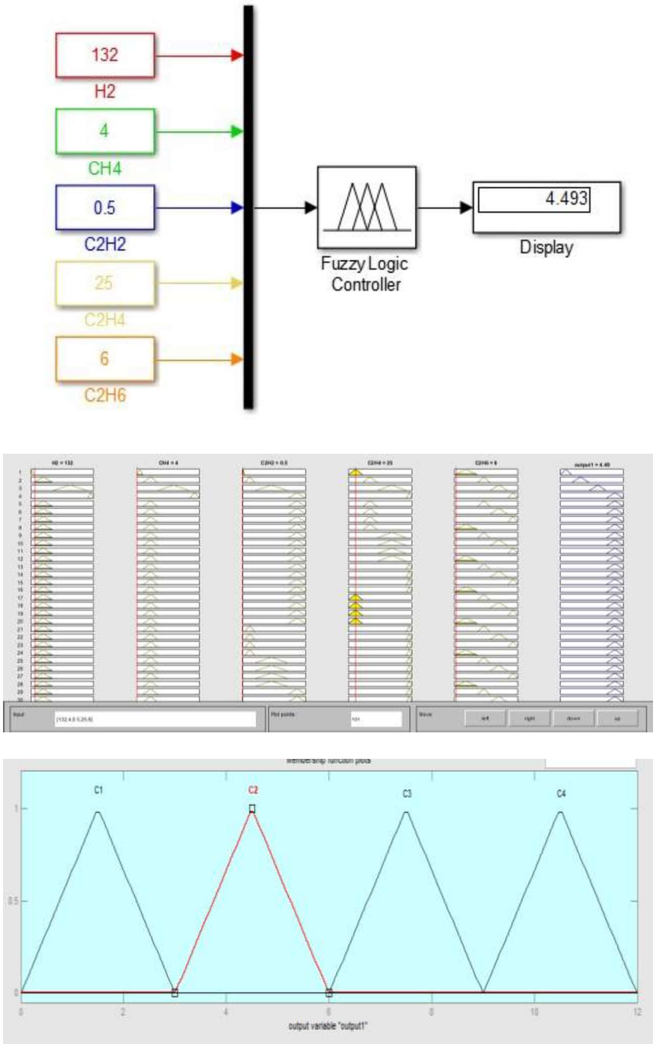

Fig 9. Tranformator 1BAT01 test and Output

From the simulation results of simulink and rules in figures 9 get the nominal output of 4,493 and 4.49, where the output points to the condition point 2. According to figure 9 the value of condition 2 from 3 to 6. This condition 2 is because H2 gas is in condition 2, according to TDCG flowchart that if one of the DCG shows output condition 2, then the result is condition 2. The test results on transformer 1BAT01 show the results of output in condition 2 ie TDCG level starts high there is a possibility of symptoms of failure that must be watched out which means oil sampling needs to be done more regularly and often. And these results are in accordance with the simulink and rules that have been made namely one of the gas conditions 2 and H2 appear in condition 2.

B. Trasformer 2BAT01 Testing

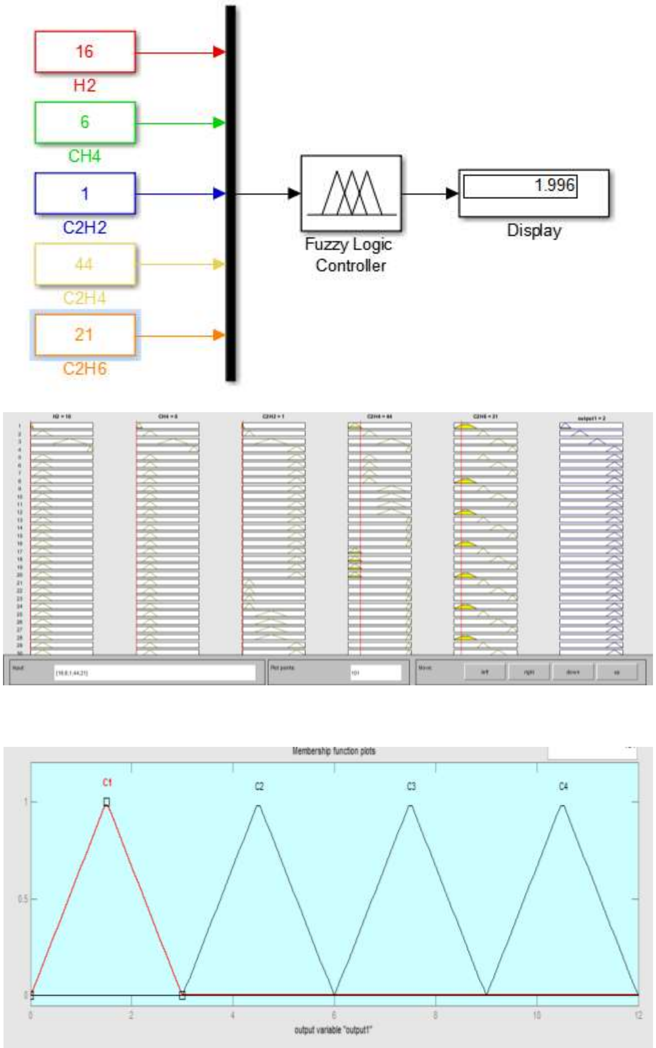

Fig 10. Tranformator 2BAT01 test and Output

From the simulation results of simulink and rules in figures 10 get nominal output of 1,996 and 2, where the output refers to the point condition 1. According to figure 10 condition values 1 from 0 to 3. This condition 1 is because all gases are in condition 1, according to TDCG flowchart that if all DCG gases show output condition 1, then the result is condition 1. The test results on this 2BAT01 transformer show the output results in condition 1 ie the transformer is operating normally. However, it is still necessary to monitor the condition of these gases. And these results are in accordance with the simulink and rules that have been made namely all the gases that appear in condition limits 1.

C. Trasformer 3BAT01 Testing

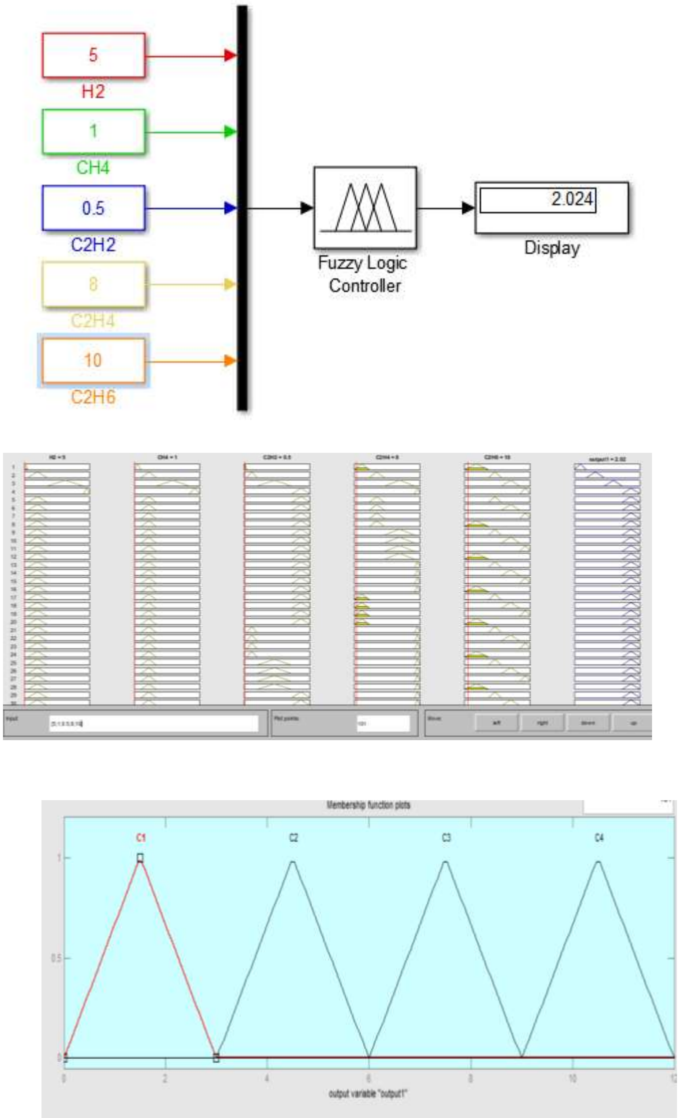

Fig 11. Tranformator 3BAT01 test and Output

From the simulation results of simulink and rules in figures 4.7 and 4.8 get nominal outputs of 2.024 and 2.02, where the output refers to the point condition 1. According to figure 4.9 condition values 1 from 0 to 3. This condition 1 is because all gases are in condition 1, according to TDCG flowchart that if all DCG gases show output condition 1, then the result is condition 1. The test results on this 3BAT01 transformer show the output results in condition 1 ie the transformer is operating normally. However, it is still necessary to monitor the condition of these gases. And these results are in accordance with the simulink and rules that have been made namely all the gases that appear in condition limits 1.

V. Conclusion

From the results of identification of TDCG (Total Dissolved Combustible Gas), it can be concluded that: This fuzzy logic system functions properly in accordance with the program, TDCG flowchart, and the boundary standards of the IEEE. Simulink as a tool to identify the condition of the transformer using the TDCG method. The TDCG method is the first step to determine the transformer monitoring conditions. • The transformer 1BAT01 shows the output of condition 2, that is, the TDCG level starts to be high, there is a possibility of failure symptoms that must be watched, which means that oil sampling needs to be done more routinely and frequently. And these results are in accordance with the simulink and rules that have been made namely one of the gas conditions 2 and H2 appear in condition 2. • The transformer 2BAT01 shows the output at condition 1, that is, the transformer is operating normally. However, it is still necessary to monitor the condition of these gases. And these results are in accordance with the simulink and rules that have been made namely all the gases that appear in condition limits 1. • The transformer 3BAT01 shows the output at condition 1, that is, the transformer is operating normally. However, it is still necessary to monitor the condition of these gases. And these results are in accordance with the simulink and rules that have been made namely all the gases that appear in condition limits 1.

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