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# ANN EXPERT SYSTEM FOR DIAGNOSING FAULTS AND ASSESSING THE QUALITY INSULATION OIL OF POWER TRANSFORMER DEPENDING ON THE DGA METHOD

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# ABSTRACT

Dissolved gas analysis is a common method for diagnosing faults in electrical transformers and determining the type of faults early on, depending on the specific standards used. Applying dissolved gas analysis methods can be used in diagnosis and in the evaluation process. There are many methods used in the diagnosis of faults in power transformers, including traditional and intelligent .The use of an intelligent expert system relies on dissolved gas analysis using artificial neural networks, and it gives excellent results in diagnosing faults and assessing the quality of insulating oil during service and the application of appropriate treatment.

Keywords: ANN Expert System, Fault Diagnosis, Insulation Oil, Dissolved Gas Analysis, Power Transformer

# 1. INTRODUCTION

The subject of transformer maintenance is important, and it should be considered in economic terms and in the continuity of work in transformers with high efficiency. High-power transformers will work more reliably if periodical and repeated maintenance and procedures are performed by the system. In particular, oil-immersed transformers need more attention than dry transformers, as the presence of chemical reactions in the insulating oil can lead to the loss of some of its chemical properties and efficiency [1].

Dissolved gas analysis (DGA) is a valuable tool for maintenance engineers in substations in diagnosing potential faults and evaluating oil quality during the service of the adapters in life expectancy. The generation of combustible gases in the insulating transformer oil occurs as a result of different factors, including high temperature, spark, and electric arc. Gas rates vary according to the influential factors that indicate the presence of faults, which are also expected from the assessment of the separation of oil for transformer quality. Gas ratios are calculated using the method used for analysis as stipulated in the standard specifications (IEC standard 60599 and IEEE standard C57-104)[2][3].

Dissolved gases depend on the gas values generated in the insulating oil and gases, such as methane, hydrogen, ethane, ethylene, acetylene, carbon monoxide, and carbon dioxide, in many and varied ways. Each method of analysis depends on the specific percentages in the process of fault diagnosis and the process of quality assessment of the used oil. Some hydrocarbon gases are present in most transformers that are in service for long periods. Oil and gases in these transformers operate normally, but when these percentages are increased, they become a threat to the transformer and cause the deterioration of the oil insulation process [4][5].

In this study, we used an expert system to diagnose faults and assess the quality of insulating oil in power transformers based on DGA. The expert system design used the artificial neural network (ANN) technology through the graphical user interface (GUI) in the MATLAB program to achieve accuracy in the diagnosis and in the assessment process. Rogers ratio, IEC ratio, and Doernenburg ratio were used in the analysis. These methods diagnosed the faults and assessed the quality of oil during the service ISSN: 1992-8645

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# 2. DGA INTERPRETATION METHODS

When a person is sick, he/she goes to the doctor, who takes a sample of his/her blood for analysis and determination of the disease. Electrical transformers rely on the same technique to distinguish early and unavoidable faults that may occur. Using a sampling of insulating oil in the transformer process, DGA determines the ratio of gases generated in the oil. Electrical insulating oils under high pressure and high temperature generate varying amounts of flammable and non-flammable gases. The types of faults are determined, and the quality of oil separation is assessed. Numerous methods are used in dissolved gases, and they depend on both gas-to-gas ratio analysis and the values of individual gases. The most commonly used methods for the diagnosis of faults and oil quality evaluation have been used and examined [6].

# 2.1. Rogers Ratio Method

Rogers's method adopts five gas values (CH4, H2, C2H4, C2H6, and C2H2) and identifies specific the ratios of these gases (CH4/H2, C2H6/CH4, C2H4/C2H6, and C2H2/C2H4). Faults in oil-immersed power transformers are diagnosed early on using these ratios. The potential faults are determined using the ratio values [7].

# 2.2. IEC Ratio Method

The IEC ratio method uses three gas ratios instead of four (C2H4/C2H6, C2H2/C2H4, and CH4/H2) and compares these levels with the faults in a specified standard table (IEC 60599) to determine the potential of the falling fault type. Before the three ratios are identified, the ratio of carbon dioxide to carbon monoxide is calculated. If the ratio is between 3:11, the expense ratios of the three should be checked to determine the type of fault. If the ratio exceeds 3:11, then the insulating paper has a problem [8][9].

# 2.3. Doernenburg Ratio Method

Doernenburg ratio method uses four ratios (CH4/H2, C2H2/CH4, C2H4/C2H6, and C2H2/C2H4) equal to twice the value specified in the IEEE standard C57.104-1991. The ratio of the concentration of any of the gases (CH4, H2, C2H4, C2H6, C2H2, and CO) is used. A schedule is set for the faults based on the four ratios. The following three major faults are used: thermal decomposition, partial discharges of low-intensity PD, and arcing high-intensity PD [10].

#### 2.4. Total Combustible Gas Method

A sudden increase in the concentration of combustible gases or gas space generation rate with blindsided internal failures is expected. Periodic screening procedures are performed by taking oil samples and analyzing them to determine the value of gas ratios. The oil deterioration coefficient is also obtained; less oil means insulation efficiency and cooling hand. The IEEE standard C57.104 league table is used for examining and repeating transformers [11].

# 3. METHODOLOGY

This study aimed to develop an intelligent expert system for the diagnosis of faults, assessment of the quality of insulating oil, and treatment of power transformers. The system is designed on the basis of the DGA method in insulating oil. The expert system uses three Feedforward Back-propagation ANN technology in the diagnosis and the evaluation process through the back propagation algorithm. The user interface for expert system is designed using the GUI in the MATLAB software shown figure (1) [12][13][14].



*Figure 1: Methodology flowchart* 

#### 3.1. Modeling of the ANN Expert System

To develop the expert system, three feed-forward back-propagation ANNs are created. Each ANN is based on each of the following DGA algorithms: Rogers's ratio method, IEC method, and Doernenburg ratio method. Modeling the ANN involves the following: 20<sup>th</sup> August 2015. Vol.78. No.2

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### 3.1.1. Input definition

The input of the Rogers ratio method-based neural networks uses gas ratios, and that of the IEC and Doernenburg ratio methods use four gas ratios and six gas values plus four gas ratios, respectively. Table 1 presents the inputs for all three constructed neural networks.

Table	1.	Inputs	of the	Expert	System	for DGA
ruoic		Inpuis	<i>oj inc</i>	DAPCH	<i>bysicm</i>	<i>joi D</i> 011

Mrthod	Number of inputs	inputs
Roger's Ratio Method	- 4	CH4/H2 C2H6/CH4 C2H4/C2H6 C2H2/C2H4
EC 60599 Method	4	C2H2/C2H4 CH4/H2 C2H4/C2H6
Doemenburg Ratio Method	10	CH4 H2 CH4 CH4 CH4 CH4 C0 CH4 CH4 CH4 CH4 CH4 CH4 CH4 CH4 CH4 CH4

# 3.1.2. Output definition

The number of neurons in the output layer of each artificial network is equal to the number of faults identified by the method on which the network is based: 12 for the Rogers ratio-based neural network, 9 for the IEC 60599-based neural network, and 4 for the Doenrenburg ratio-based neuron output in the output layer of the network is equal to one, and all the other outputs are zero. The codification of the outputs of the IEC-based neural network, Rogers ratio-based neural network and Doenrenburg ratio-based neural network is shown in Tables 2, 3, and 4, respectively.

 Table 2: Output of the IEC Ratio Method-Based Neural

 Network

FAUX LARGED HIS	Crack.			#	Orther				
10000000000000000000000000000000000000	Q9	QS	Q7	Qfi	Q5	Q4 ]	QI	Q2	QL
NOFAULT	0	0	0	0	0	0	0	0	T
PARTIAL DISCHARGES OF LOW ENERGY DENSITY	0	0	0	0	0	0	0	1	0
OF HIGH ENERGY DENSITY	0	0	0	0	0	0	1	0	0.0
DISCHARGES OF LOW ENERGY	0	0	0	0	0	1	0	0	0
DISCHARGES OF HIGH ENERGY	0	.a.	0	0	1	0	0	0	0
THERMAL FAULT OF LOW TEMPERATURE - 150 °C	0	0	0	1	0	0	0	0	0
THERMAL FAULT OF LOW TEMPERATURE RANGE 150 °C-300 °C	0	9	÷	0	0	0	0	0	0
THERMAL FAULT OF MEDIUM TEMPERATUR RANGE 300 °C-700 °C	0	1	0	0	0	0	0	0	0
THERMAL FAULT OF HIGH TEMPERATURE : 700°C	-F	0	0	0	ġ	0	0	0	0

#### Table 3: Output of the Rogers Ratio Method-Based Neural Network

					0	utput						Full Diamonia
QI.	101	03	101	105	06	07	05	09	010	011	012	
1	0	0	0	0	0	0	0	g	0	0	0	DETERIORATION
0	1	0	. 0	. 0	0.1	0	0	0	0	0.	0	PARTIAL DESCHARGE
0	0	1	а. (	0	0	0	0.:	0	a	0	0	SEJGHT OVERHEATING- BELOW 150 °C
0	0	0	-1	0	0	0	0.	0	0	0	.0	OVERHEATING-
0	9	0	3	1	0.	0	0	0	a	0	0	OVERHEATING-
0	0	•	3	9	1	D	0	0		0	0	GENERAL CONDUCTOR OVERHEATING
0	0		0	0	9	1	0	9	0	9	0	WINDING CIRCULATING CURRENTS
0	0	4	9	0	0	0	-j.	0	0	0	0	CORE AND TANK CIRCULATING CURRENTS, OVERHEATED JODNTS
0	0	0	.0	0	R.:	0	0	15	0	0	0	FLASHOVER WITHOUT POWERFOLLOW THROUGH
0		0	.0	0	P.)		0.	0	1		.0	ARC WITH POWERFOLLOW THROUGH
9	9		9	Ð	0	9				1	9	CONTINUOUS SPARKING TO FLOATING POTENTIAL
0	0			0	0	0	0	0	0	0	상	PARTIAL DISCHARGE WITH TRACKING

 Table 4: Output of the Doenrenburg Ratio Method-Based

 Neural Network

	0.	tput		Fault Diagnosis		
Ql	Q1	Q3	Q4			
1	0	0	0	NO FAULT		
0	1	0	0	THERMAL DECOMPOSITION		
0	0	1	0	PARTIAL DISCHARGES (LOW- INTENSITY PD)		
0	0	0	1	ARCING (HIGH-INTENSITY PD)		

#### **3.2.** Architecture of the ANN

In this work, ANN models are constructed using the MATLAB software. Multilayer feed forward back propagation is chosen as the network architecture because of its popularity and applicability to this scope of work. The work involves constructing several two-layer networks. Each network consists of one input layer, one hidden layer, and one output layer. Generally, the process of developing an ANN is divided into the training stage and the testing stage. During the training stage, the network is fed with data consisting of three ratios of gases and transformer conditions as the targeted output. The training stage is the most crucial process in designing ANN. Many factors may affect the performance of a network, such as the network parameters, architecture, and learning algorithm. In the training stage, the control parameters vary

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heuristically. Problems of under fitting and over fitting may occur during neural network training. Overheating occurs when the network has the capability to memorize the network, but cannot generalize the new data feed. Early stopping is applied to the developed network to avoid overheating. Data for the training stage is divided into three subsets, training set, validation set, and testing sets. The training set computes the gradient and updates the network's biases and weight. The validation set monitors the condition of the training stage. Validation and training errors normally decrease in the early stage of the training phase, but when overheating occurs, the validation error increases. Three ANNs are developed: one based on Rogers ratio method with four gas ratios as inputs and 12 transformer conditions as outputs, one of the IEC method with three gas ratios as inputs and nine transformer conditions as outputs, and the Doernenburg ratio method with 10 gas ratios as inputs and four transformer conditions as outputs shown Figure(2 (a, b, c)) and Figure (3 (a, b, c)).



Figure 2 (a): Architecture of the Rogers ratio method



Figure 2 (b): Architecture of the IEC ratio method



Figure 2 (c): Architecture of the Doernenburg ratio method



Figure 3 (a, b, c): Performance of the training stage. (a) Roger's ratio method-based ANN, (b) IEC ratio methodbased ANN, (c) Doernenburg ratio method-based ANN.

#### 3.3. Design of the Interface System for the ANN Expert System

The interface system of the ANN expert system is designed using the GUI access provided in the MATLAB environment. As depicted in Figure 4, the user input interface allows several items to be entered, including gas values, analysis methods (Rogers ratio method, IEC ratio method, or

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Doernenburg ratio method ), gas ratios, fault type diagnosis, and oil treatment.



Figure 4: Interface system of the ANN ES

# 4. RESULTS AND DISCUSSION

The data used in this study were taken from the Malaysian National Company for Electricity (TENAGA) through six different substation adapter types. The adapters operate at 132 KV transformers that have served for more than 10 years and are still in servicing the following stations: Kota Tinggi, Larkin, Pasak, Kangkar, Tebrau, Seelong, and Cahaya Baru. The data for the set of dissolved gases in oil were collected through samples taken from the oil of these transformers. The samples were analyzed to determine the value of dissolved gases such us (CH4, H2, C2H4, C2H6, C2H2, CO, and CO2). The dissolved gas values of 70 samples taken from the power transformers are presented in Table 5. The results were evaluated with the results obtained from the Malaysian National Electricity according to international standards.

CH4         H2         C2H4         C2H4         C2H4         C2H4         C2H4         C2H4         CCH4         CC	No.		1977		-			
1         4         2         5         3         0.001         152         4           2         11         0.001         4         3         0.001         96         4           3         2         11         2         2         0.001         124         4           4         3         11         2         3         0.001         92         5           5         7         5         6         0.01         0.001         23         7           4         3         11         2         3         0.001         23         7           6         0.01         0.01         0.01         343         7         8         65         40         87         12         0.01         408         7           10         27         10         49         4         0.01         146         11         108         873         515         12         90         647         10         129         638         428         1         14         38         379         7         46         188         180         180         180         180         180         180         181		CH4	HZ	C2H6	C2H4	C2H2	co	CO2
2         11         0.001         4         3         0.001         96         3           2         11         2         2         0.001         124         3           4         3         11         2         3         0.001         92         5           5         7         5         6         0.01         0.001         78         6           6         0.01         0.01         0.01         0.01         0.01         23         7           49         25         69         10         0.01         1408         7           5         0.1         1         0.3         13         0.01         151         16           10         27         10         49         4         0.01         146         11           11         109         789         11         156         873         515         12           12         90         647         10         129         638         428         1           14         38         379         7         46         198         150         1           15         4         0.1         1	1	4	2	5	3	0.001	152	6601
1         0         0         0         0         0         0         1         1         0         0         0         0         1         1         0         0         0         0         1         1         0         0         0         0         1         1         0         0         0         1         1         0         0         1         1         0         0         1         1         1         0         0         1	-		0,001	4		0.001	30	4188
3 $7$ $5$ $6$ $0.01$ $0.001$ $0.001$ $0.001$ $78$ $6$ $6$ $0.01$ $0.001$ $0.001$ $0.001$ $0.001$ $23$ $7$ $8$ $65$ $40$ $87$ $12$ $0.01$ $408$ $9$ $9$ $0.1$ $1$ $0.1$ $13$ $0.01$ $146$ $11$ $109$ $789$ $11$ $156$ $873$ $515$ $3$ $12$ $90$ $647$ $10$ $129$ $633$ $428$ $2$ $13$ $44$ $144$ $12$ $113$ $583$ $192$ $3$ $14$ $38$ $379$ $7$ $466$ $198$ $190$ $2$ $15$ $4$ $0.11$ $1$ $8$ $0.001$ $221$ $3$ $15$ $9$ $190$ $25$ $3$ $0.01$ $383$ $3$ $20$	-	-		2	2	0.001	92	1647
6         0.01         0.01         0.001         0.01         0.001         23           7         49         25         69         10         0.01         343         3           8         65         40         87         12         0.01         408         5           9         0.1         1         0.1         13         0.01         146         1           10         27         10         49         4         0.01         146         1           11         109         789         11         156         873         515         3           12         90         647         10         129         633         428         3           14         38         379         7         46         198         190         3           15         4         0.1         1         8         0.001         221         3           16         0.001         12         0.01         26         0.001         221         3           15         9         190         25         3         0.01         383         3           20         8         1	5	7	5	6	0.01	0.001	78	1177
7         49         25         69         10         0.01         343           8         65         40         87         12         0.01         408           5         0.1         1         0.1         13         0.01         151           10         27         10         49         4         0.01         146           11         109         789         11         156         873         515         3           12         90         647         10         129         638         428         3           14         38         379         7         46         196         150         2           15         4         0.1         1         8         0.001         211         2           16         0.001         12         0.01         25         3         0.01         393         3           20         3         199         20         3         0.01         21         3           21         8         149         17         3         0.01         129         2           22         8         40         2         1	6	0.01	0.01	0.001	0.01	0.001	23	1043
8         65         40         87         12         0.01         408           5         0.1         1         0.1         13         0.01         151           10         27         10         49         4         0.01         146           11         109         789         11         156         873         515         3           12         90         647         10         129         638         428         3           14         38         379         7         46         198         190         2           15         4         0.1         1         8         0.001         64         1           16         0.001         12         0.01         26         0.002         234         3           16         31         10         89         7         0.001         166         1           15         9         190         25         3         0.01         216         1           21         8         149         17         3         0.01         129         2           23         2         10         5         2	7	49	25	69	10	0.01	343	1309
s $0.1$ 1 $0.7$ $13$ $0.01$ $151$ 10         27         10         49         4 $0.01$ $146$ 11         109         789         11         156         873         515         9           12         90         647         10         129         638         428         9           13         44         144         12         118         583         192         9           14         38         379         7         46         198         150         16           15         4         0.1         1         8         0.001         64         1           16         0.001         12         0.01         26         0.002         234         1           16         31         10         89         7         0.001         166         1           15         9         190         25         3         0.01         215         1           20         8         17         3         0.01         216         2         2         2         1         2         2	8	65	40	87	12	0.01	408	1456
10       27       10       49       4       0.01       146         11       109       789       11       156       873       515       3         12       90       647       10       129       638       428       3         14       38       379       7       46       198       150       3         14       38       379       7       46       198       150       3         15       4       0.1       1       8       0.001       64       3         16       0.001       12       0.01       26       0.002       234       3         16       31       10       89       7       0.001       165       3         20       8       199       20       3       0.01       216       3         21       8       149       17       3       0.01       118       3         22       8       40       2       1       0.001       100       2         23       2       10       5       2       0.0001       129       2         26       2       28 <td< td=""><td>9</td><td>0.1</td><td>.1</td><td>0.1</td><td>13</td><td>0.01</td><td>151</td><td>1909</td></td<>	9	0.1	.1	0.1	13	0.01	151	1909
11         109         789         11         156         873         515         3           12         90         647         10         129         638         428         3           14         38         379         7         46         198         150         3           14         38         379         7         46         198         150         3           15         4         0.1         1         8         0.001         64         3           16         0.001         12         0.01         26         0.002         234         3           17         4         4         1         25         0.01         383         3           20         8         199         20         3         0.01         383         3           20         8         199         20         3         0.01         383         3           21         8         140         2         1         0.001         41         3           23         2         10         5         2         0.0001         129         2           26         2	10	27	to	49	4	0.01	146	683
12       90       647       10       129       638       428       13         14       144       144       12       118       583       192       3         14       38       379       7       46       198       150       2         15       4       0.1       1       8       0.001       64       16         16       0.001       12       0.01       26       0.002       234       2         17       4       4       1       25       0.01       26       0.001       21       3         16       31       10       89       7       0.001       165       1       1       1       3         20       8       199       20       3       0.01       216       1       1       1       3         21       8       149       17       3       0.01       154       4         23       2       10       5       2       0.0001       129       2         26       2       28       5       1       0.001       100       2         27       4       22       6	11	109	789	11	156	873	515	5347
13         44         144         12         118         583         192         3           14         38         379         7         46         198         150         3           15         4         0.1         1         8         0.001         64         3           15         4         0.1         1         8         0.001         64         3           16         0.001         12         0.01         26         0.002         234         3           17         4         4         1         25         0.01         383         3           20         8         199         20         3         0.01         383         3           21         8         149         17         3         0.01         215         3           23         2         10         5         2         0.0001         129         2           26         0.01         0.01         3         1         0.001         82         2           26         2         28         5         1         0.001         100         2           27         4	12	90	647	10	129	638	428	2435
14         38         379         7         46         198         180         3           15         4         0.1         1         8         0.001         64         1           16         0.001         12         0.01         26         0.002         234         3           17         4         4         1         25         0.001         221         2           18         31         10         89         7         0.001         165         1           19         9         190         25         3         0.01         383         3           20         8         199         20         3         0.01         215         3           21         8         40         2         1         0.001         1129         2           23         2         10         5         2         0.0001         129         2           24         2         12         3         1         0.001         100         2           26         2         28         5         1         0.001         100         2           28         1 <td< td=""><td>13</td><td>44</td><td>144</td><td>12</td><td>118</td><td>583</td><td>192</td><td>3945</td></td<>	13	44	144	12	118	583	192	3945
15         4         0.1         1         8         0.001         64           16         0.001         12         0.01         26         0.002         234         2           17         4         4         1         25         0.001         221         3           18         31         10         89         7         0.001         165         1           18         31         10         89         7         0.001         165         1           20         8         199         20         3         0.01         216         1           21         8         149         17         3         0.01         215         1           22         8         40         2         1         0.001         114         3           23         2         10         5         2         0.0001         129         2           25         0.01         0.01         3         1         0.001         82         2           26         2         28         5         1         0.001         81         1           29         0.01         0.01	14	38	379	7	46	198	150	2287
16 $0.001$ 12 $0.01$ 286 $0.002$ 234       3         17       4       4       1       25 $0.001$ 221       3         18       31       10       89       7 $0.001$ 165       1         19       9       190       25       3 $0.01$ 393       3         20       8       199       20       3 $0.01$ 256       1         21       8       149       17       3 $0.01$ 215       1         23       2       10       5       2 $0.001$ 129       2         24       2       12       3       1 $0.001$ 82       2         26       2       28       5       1 $0.001$ 100       2         27       4       22       6       2 $0.002$ 132       2         28       1       2 $0.0001$ 1 $0.0001$ 109       1         30       1       1 $0.001$ $0.001$ $109$ 1       3         31<	15	4	0.1	1	8	0.001	64	1158
17 $4$ $4$ $1$ $25$ $0.001$ $221$ $2$ 15         31         10         89         7 $0.001$ 166 $1$ 20         8         199         20         3 $0.01$ 383 $3$ 20         8         199         20         3 $0.01$ 256 $2$ 21         8         149         17         3 $0.01$ 215 $3$ 22         8         40         2         1 $0.001$ 41 $3$ 23         2         10         5         2 $0.0001$ 129 $2$ 25         0.01         0.01         3         1 $0.0001$ 82 $2$ 26         2         28         5         1 $0.001$ 100 $2$ 27         4         22         6         2 $0.002$ 132 $2$ 30         1         1 $0.01$ $0.001$ $109$ $1$	16	0.001	12	0.01	26	0.002	234	2696
10 $30$ $10$ $30$ $7$ $0.001$ $100$ $30$ $100$ $30$ $100$ $300$ $100$ $300$ $100$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $3000$ $30000$ $30000$ $30000$ $30000$ </td <td>17</td> <td>-</td> <td>4</td> <td></td> <td>25</td> <td>0.001</td> <td>221</td> <td>2122</td>	17	-	4		25	0.001	221	2122
15 $15$ $150$ $25$ $5$ $0.01$ $255$ $150$ $255$ $150$ $255$ $1256$ $1256$ $125$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $132$ $122$ $133$ $112$ $122$ $133$ $112$	10		10	50		0.001	100	3000
22 $3$ $149$ $17$ $3$ $0.01$ $200$ $221$ $8$ $149$ $17$ $3$ $0.01$ $215$ $223$ $2$ $10$ $5$ $2$ $0.001$ $154$ $4$ $24$ $2$ $12$ $3$ $1$ $0.0001$ $129$ $2$ $25$ $0.01$ $0.01$ $3$ $1$ $0.0001$ $82$ $2$ $26$ $2$ $28$ $5$ $1$ $0.001$ $100$ $2$ $27$ $4$ $22$ $6$ $2$ $0.002$ $132$ $2$ $28$ $1$ $2$ $0.0001$ $1$ $0.001$ $811$ $1$ $29$ $0.01$ $0.01$ $5$ $2$ $0.0001$ $139$ $2$ $30$ $1$ $1$ $0.001$ $0.001$ $1001$ $199$ $1$ $31$ $0.01$ $0.11$ $1$ <	20		199	20		0.01	366	1854
22         8 $40$ $2$ 1 $0.001$ $41$ $3$ $23$ $2$ $10$ $5$ $2$ $0.0001$ $154$ $4$ $24$ $2$ $12$ $3$ $1$ $0.0001$ $129$ $2$ $25$ $0.01$ $0.01$ $3$ $1$ $0.0001$ $82$ $2$ $26$ $2$ $28$ $5$ $1$ $0.001$ $100$ $2$ $27$ $4$ $22$ $6$ $2$ $0.002$ $132$ $2$ $28$ $1$ $2$ $0.0001$ $1$ $0.001$ $811$ $1$ $29$ $0.01$ $0.01$ $5$ $2$ $0.0001$ $139$ $2$ $30$ $1$ $1$ $0.01$ $0.001$ $0.001$ $79$ $2$ $32$ $1$ $0.1$ $1$ $0.001$ $0.001$ $79$ $2$ $34$ $10$ $58$ <td>21</td> <td>8</td> <td>145</td> <td>17</td> <td>3</td> <td>0.01</td> <td>215</td> <td>1861</td>	21	8	145	17	3	0.01	215	1861
24 $2$ $12$ $3$ $1$ $0.0001$ $129$ $2$ $25$ $0.01$ $0.01$ $3$ $1$ $0.0001$ $82$ $2$ $26$ $2$ $28$ $5$ $1$ $0.001$ $100$ $2$ $27$ $4$ $22$ $6$ $2$ $0.002$ $132$ $2$ $28$ $1$ $2$ $0.0001$ $1$ $0.001$ $81$ $1$ $29$ $0.01$ $0.01$ $5$ $2$ $0.0001$ $810$ $1$ $29$ $0.01$ $0.01$ $5$ $2$ $0.0001$ $139$ $2$ $30$ $1$ $1$ $0.01$ $0.001$ $0.001$ $199$ $1$ $31$ $0.01$ $0.1$ $1$ $0.001$ $0.001$ $79$ $2$ $32$ $1$ $0.1$ $1$ $0.001$ $0.001$ $79$ $2$ $34$ $10$	22	8	40	5	1	0.001	41	855 4297
24 $2$ $12$ $3$ $1$ $0.0001$ $129$ $2$ $25$ $0.01$ $0.01$ $3$ $1$ $0.0001$ $82$ $2$ $26$ $2$ $28$ $5$ $1$ $0.001$ $100$ $2$ $27$ $4$ $22$ $6$ $2$ $0.002$ $132$ $2$ $28$ $1$ $2$ $0.0001$ $1$ $0.001$ $811$ $1$ $29$ $0.01$ $0.01$ $5$ $2$ $0.0001$ $139$ $2$ $30$ $1$ $1$ $0.01$ $0.001$ $0.001$ $109$ $1$ $31$ $0.01$ $0.1$ $1$ $0.001$ $0.001$ $79$ $2$ $32$ $1$ $0.1$ $1$ $0.001$ $0.001$ $79$ $2$ $34$ $10$ $58$ $2$ $13$ $61$ $216$ $1$ $35$ $10$	23	2	10	5	2	0.0001	154	4297
25         0.01         0.01         3         1         0.0001         82         2           26         2         28         5         1         0.001         100         2           27         4         22         6         2         0.002         132         2           28         1         2         0.0001         1         0.0001         81         1           29         0.01         0.01         5         2         0.0001         139         2           30         1         1         0.01         0.001         0.001         109         1           31         0.01         0.1         1         0.001         0.001         79         2           32         1         0.1         0.01         4         17         117         3           33         7         12         2         13         53         211         2           34         10         58         2         13         61         216         1           35         10         12         2         13         56         153         1           36         0.01	24	2	12	3	1	0.0001	129	2333
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	25	0.01	0.01	3	1	0.0001	82	2585
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	26	2	28	5	. 1	0.001	100	2991
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	27	4	22	6	2	0.002	132	2246
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	28	1	2	0.0001	1	0.0001	81	1369
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	29	0.01	0.01	5	2	0.0001	139	2189
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	30	1		0.01	0.001	0.001	109	1167
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.01			0.001	0.004	70	nene
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	31	0.01	0.1		0.001	0.001	18	2090
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	34	1	0,1	0.01		W	117	3011
34         10         58         2         13         61         216         1           35         10         12         2         13         56         153         1           36         0.01         41         18         0.001         0         65         1           37         5         4         6         2         0         35         1           38         0.001         36         17         0.001         0.0001         39         1           39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         3           41         9         96         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	33	7	12	2	13	53	211	2171
35         10         12         2         13         56         153         1           36         0.01         41         18         0.001         0         65         1           37         5         4         6         2         0         35         1           38         0.001         36         17         0.001         0.0001         39         1           39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         1           41         9         98         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	34	10	58	2	13	61	216	1812
36         0.01         41         18         0.001         0         65         1           37         5         4         6         2         0         35         1           38         0.001         36         17         0.001         0.0001         39         1           39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         1           41         9         98         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	35	10	12	2	13	56	153	1692
37         5         4         6         2         0         35         7           38         0.001         36         17         0.001         0.0001         39         1           39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         7           41         9         96         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	36	0.01	41	18	0.001	0	65	136
38         0.001         36         17         0.001         0.0001         39         1           39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         7           41         9         96         22         3         0.001         157         2           42         10         84         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	37	5	4	6	2	0	35	722
39         0.1         16         2         1         0         138         1           40         2         4         2         1         0         104         3           41         9         96         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	38	0.001	36	17	0.001	0.0001	39	1343
40         2         4         2         1         0         104         1           41         9         98         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	39	0.1	16	2	1	0	138	1410
41         9         96         22         3         0.001         157         2           42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	40	2	4	2	1	0	104	799
42         10         94         33         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	41	9	98	22	3	0.001	157	2100
10         04         05         2         0.001         209         2           43         10         293         16         3         0.0001         444         2           44         7         28         12         2         0         222         1	47	10	0.4	22	2	0.001	209	2254
10         255         10         3         0.0001         444         2           44         7         28         12         2         0         222         1	12	10	300			0.001	205	2004
44 7 28 12 2 0 222 1	43	10	233	10	3	0.0001	444	2005
45 8 113 13 5 0.0001 322 2	44	7	28	12	2	0.0001	322	1699

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Table 6:	Result	of the	data	from	the	70	samp	les

47	7	3	1	0.001	0.0001	542	3099	No.
48	7	3	3	11	0.001	312	2503	
49	3	1	5	4	0	186	1197	
50	13	0	00	- 11	0.01	1/1	2814	1
51	50	5	63	9	0.001	404	1861	1
52	21	0.1	51	5	0	565	973	-
53	4	2	1	21	0.001	264	1370	
54	6	4	2	14	0.01	316	1409	1
55	0.01	0.1	0	0.01	0	8	133	•
55	35	0.001	55	6	0.001	851	1191	
57	12	1	1	42	0	260	1865	,
58	16	7	6	42	0.001	123	967	L
59	323	186	61	519	4	27	323	
60	17	14	3	29	0.01	9	57	1
61	28	6	19	54	0.001	618	1860	10
62	26	5	22	72	0	444	1719	
63	11	0.1	12	50	0.0001	649	958	11
64	17	0.01	20	108	0	259	570	
65	29	5	10	3	0.001	431	1572	12
66	45	7	23	7	0.001	745	2519	
67	41	6	24	7	0.002	648	1951	11
68	31	5	26	7	0.002	413	1740	
69	14	0.1	17	3	0.001	680	992	34
70	13	0.1	18	2	0	175	468	

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The resulting values after the gases were introduced into the program are presented in Table 6. Note that from the results, a disparity exists in the use of the three methods as some of the faults discovered using the Rogers ratio method were not detected in other methods, and vice versa. The quality assessment of insulating oil and the appropriate treatment results agree with the used oil treatment and the extent of efficiency of use. Three ways must be used to ensure the safety of the transformers from early-occurring faults

No.	ā — .	Tevil Type		Oil tradmont
	Augus Michod	ISC Nished	Osonotium Method	
1	CVERHEAT/NG-150 10-200 10	NAULT IN CELICUOSE INSULATING PAPER	NO NAULT	RUTSKING
2	UNICENTIAASUE	NAULT IN CELULIOSE INSULATING PAPER	NO NULT	6000 O/L NO FUTERING
3	UNICENTIAASUE	NAULT IN CELLUIDSE INSULATING PAPER	NO MULT	ACCO OL NO
	CONDUCTOR CONDUCTOR	NAULT IN CELLUIDSE INSULATING PAPER	NO FAULT	AUTORIALS
3	UNIDENTIFIABLE	NAULT IN COLUMNSE INSULATING PAPER	NO FAULT	ACCORDING
0	CORE AND TANK CIRCULATING CURRENTS	MULTIN CELLUIOSE	NO NAULT	ALTERING
	CVER-BATING-150 10-500 10	THERMAL PALLY OF LOW TEMPERATURE AT 150	NO NAULT	SINGLE MUTERING AND DECASSING
	015-00149570 2, 005-3,	THERMAL MALLY OF LOW TEMPERATURE AT 150 'CHIOD 'C	NO FAULT	SINGLE NUTERING AND DEGASSING
8	UNICENTRASLE	INSULATING PAPER	NO NAULT	ADOD OIL NO FUTERING
10	CV51-647ING-150- 200 °C	THERMAL PAULT OF LOW TEMPERATURE AT 150 10-500 10	NO MULT	ACTOR ING
11	CONTINUOUS SPAREING TO RUDOTING ROTENTIAL	UNICENTRADIE	ANDING (HOH- INTENSITY PO)	DOUSLE MUTERING AND DESASSING
12	CONTINUOUS SPARKING TO AUDOTING POTENTIAL	UNICENTRASIS	ARCING (HON- INTENSITY FC)	DOUBLE AUTEMING AND DEGASSING
11	CONTINUOUS SPARCING TO RUDOTING POTENTIAL	NAULT IN COLUMNSE INSULATING PAPER	AACING (HON- INTENSITY FO)	ODUBLE NUTERING AND DESASSING
34	CONTINUOUS SPARKING TO RUDOTING POTENTIAL	NAULT IN COLUMNSE INSULATING PAPER	ARCING (HOH- INTENSITY FO)	DOUBLE PLITEMING AND DECASSING
15	UNICENTIFIASUE	FAULT IN CELICLOSE INSULATING PAPER	NO NAULT	BOOD OIL NO ALTERING
38	UNICENTIAASUE	NAULT IN CELLULOSE INSULATING PAPER	NO NULT	SOOD OLL NO NUTERING
73	NORVAL OFTEN ORATION	UNICENTALSLE	NO PAULY	0000-0% NO AUTER/NO
38	2, 005-0,	THERMAL PAULT OF LOW TEMPERATURE AT 250 "CHOO"C	NO TAULT	SINGLE ALTERING AND DEGASSING
-15	C-100 /C	PARTIAL DISCHARGES OF LOW EVENOY DENSITY	NO NAULT	SINGLE AUTERING AND DECASE/NO
20	C-400 C	PARTIAL DISCHARGES OF LOW EVENDY DENSITY	NO FAULT	SINGLE FUTEFING AND DECASSING
33	OVERHEATING-200	FARTAL DISCHARDES OF	NO MULT	5/10,2



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	LINE PROFILE AND	FAURT IN PRILLEOSE	MO FAULT	6000.000.000
	Green and the transfer	INSULATING PAPER	The Factor	FILTERING
23	OVERHEATING-200	FAULT IN CELLULOSE	NO FAULT	GOOD OIL NO
	°C-300 °C	INSULATING PAPER		FILTERING
24	OVERHEATING-200	FAULT IN CELLULOSE	NO FAULT	GOOD OIL NO
	°C~300 °C	INSULATING FAPER		PILTERING
25	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
26	OVERHEATING-200	FAULT IN CELLULOSE	NO FAULT	GOOD OIL NO
	D-300 T	INDULATING PAPER		FILIERING
	0VERHEATING-200	INSULATING PAPER	NO FAULT	PILTERING
25	UNDENTIFIABLE	FAULT IN CELLULOSE	NO FAULT	GOOD OIL NO
29	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING FAPER	NO FAULT	GOOD OIL NO FILTERING
30	FLASHOVER WITHOUT POWER THROUGH	UNDENTIFIABLE	NO FAULT	SOOD OIL NO FILTERING
31	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
52	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	UNDENTIFIABL E	GOOD OIL NO FILTERING
33	CONTINUOUS SPARKING TO FLOOTING POTENTIAL	DISCHARGES OF LOW ENERGY	ARDING (HIGH- INTENSITY PD)	GOOD OIL NO FILTERING
54	CONTINUOUS SPARKING TO FLOOTING POTENTIAL	DISCHARGES OF LOW ENERGY	ARCING (HIGH- INTENSITY PD)	SINGLE FILTERING AND DEGASSING

21-1	114/05/04/14/04 01 0	EALUTIN PETITIONE	NO 2011	20000 70-110
24	CONDENTITIABLE	INSULATING PAPER	NO PAULI	PILTERING
53	DETERIORATION	UNIDENTIFIABLE	NOTAULT	GOOD OIL NO PILTERING
54	CORE AND TANK ORCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	PILTERING
55	UNICENTIMABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO PLITERING
56	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	THERMAL DECOMPOSITI ON	6000 DK NO PLTERING
\$7	NORMAL DETERIORATION	THERMAL FAULT OF HIGH TEMPERATURE > 200 %	NO FAULT	GOOD OIL NO FILTERING
58	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE + 700 °C	NETAULY	READE OF NO
59	COREAND YANK CIRCULATING CURRENTS	FAULT IN CELLULOSE INSULATING PAPER	THERMAL DECOMPOSITI ON	DOUBLE PLTERING AND DEGA33/NG
60	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	SOOD OLL NO ALTERING
61	WINDING CIRCULATING CURRENTS	THERMAL FAULT OF MEDRIM TEMPERATURE AT 300 °C-700 °C	NO FAULT	SINGLE PILTERING AND DEGASSING
62	UNIDENTIFIABLE	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
63	UNICENTRABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO PILTERING
64	UNIDENTIFIABLE	HAULT IN CELLULOSE	UNIDENTIFIABL E	SINGLE PILTERING AND DEGASSING
65	OVERHEATING- BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 "C+500 %C	NO PAULT	GOOD OIL NO PILTERING
64	OVERHEATING- BELOW 150 °C	THERMAL FAULT OF IDW TEMPERATURE AT 150 10-300 10	UNIDENTIFIABL	PILTERING
87	OVERHEATING- BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 *C-500 *C	NO FAULT	GOOD OIL NO PILTERING
68	OVERHEATING- BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 "C-500 °C	NOVAULT	SOOD OIL NO PILTERING
43	UNIDENTRIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OL NO FILTERING
20	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OLL NO PLITERING

	Shirt Children and Children	INCLUMTING BADED	IND PAGES	ENTEDING
		INCOMPTING PAPER		TILILINING
37	OETERIORATION	INSULATING PAPER	NOFAULT	FILTERING
38	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
39	UNIDENTIFIABLE	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO PAULT	GOOD OIL NO FILTERING
40	NORMAL DETERIORATION	ND FAULT	NO FAULT	GOOD OIL ND FILTERING
41	OVERHEATING-200 "C-300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	SINGLE FILTERING AND DEGASSING
42	OVERHEATING-200 "C-300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	SINGLE FILTERING AND DEGASSING
43	OVERHEATING-200 °C-300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	UNDENTIFIABL E	SINGLE FILTERING AND DEGASSING
44	OVERHEATING-200 *C-300 *C	NO PAULT	NO FAULT	GOOD OIL NO FILTERING
45	OVERHEATING-200 "O-300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENGITY	NO FAULT	SINGLE FILTERING AND DEGASSING
45	OVERHEATING-200 "C-300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	SINGLE FILTERING AND DEGASSING
47	OVERHEATING- BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 "C-300 °C	NO FAULT	GOOD OIL NO FILTERING
48	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 %	NO FAULT	GOOD OIL NO FILTERING
49	OVERHEATING-150 "C-200 "C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C-300 °C	NO FAULT	GOOD OIL NO FILTERING
50	UNDENTIFIABLE	THERMAL FAULT OF LOW TEMPERATURE AT 150 "C-500 "C	UN DENTIFIABL É	SINGLE FILTERING AND DEGASSING
51	UNIDENTIFIABLE	THERMAL FAULT OF LOW TEMPERATURE AT 150 "C-300 °C	NO FAULT	SINGLE FILTERING AND DEGASSING

# 5. CONCLUSION

Maintenance teams in secondary stations always need information about the functioning of transformers and the early conservation of faults that may occur. Intelligent expert systems effectively help maintenance teams in the detection of potential faults, assessment of the quality of insulating oil used in transformers, and determination of the appropriate treatment process that needs to be addressed. The use of the intelligent expert system in order to be accurate results and easy to use by maintenance teams in the secondary stations. The results obtained from the intelligent expert system's work in the diagnosis of faults for transformers through the DGA methods based on the ANN process were effective in identifying the fault types and giving the appropriate treatment for insulating oil. The multiplicity of the methods used clearly contributes to the diagnosis of faults. In case the Rogers method is unable to detect the faults, the IEC and Doernenburg methods can be used in the same program to obtain an accurate diagnosis of the failures that may occur in the process of power transformers. There are many previous studies, but only in the diagnosis of faults where there are no previous studies works two ways at the same time.

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