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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

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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 Feed-forward 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].

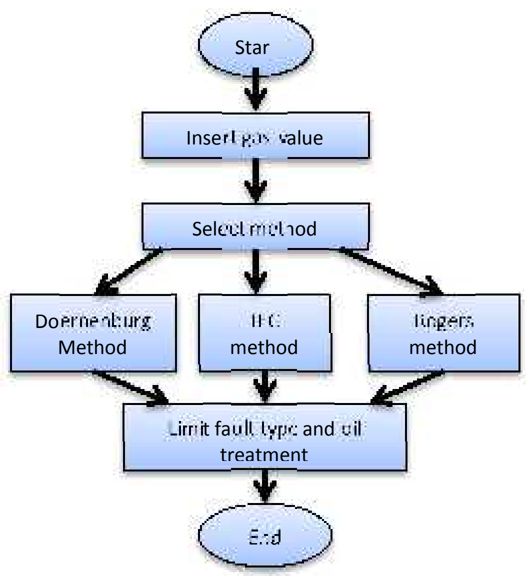

Figure 1: Methodology flowchart

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:

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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

Method	Number of inputs	Inputs
Roger's Ratio Method	4	CH4/H2 C2H6/CH4 C2H4/C2H6 C2H2/C2H4
IEC 60599 Method	4	C2H2/C2H4 CH4/H2 C2H4/C2H6
Doernenburg Ratio Method	10	CH4 H2 C2H6 C2H4 C2H2 CO CH4/H2 C2H2/C2H4 C2H2/CH4 C2H6/C2H2

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 network. For each identifiable fault, only one 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 network is shown in Tables 2, 3, and 4, respectively.

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

Output									Fault Diagnosis
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	
1	0	0	0	0	0	0	0	0	NO FAULT
0	1	0	0	0	0	0	0	0	PARTIAL DISCHARGES OF LOW ENERGY DENSITY
0	0	1	0	0	0	0	0	0	PARTIAL DISCHARGES OF HIGH ENERGY DENSITY
0	0	0	1	0	0	0	0	0	DISCHARGES OF LOW ENERGY
0	0	0	0	1	0	0	0	0	DISCHARGES OF HIGH ENERGY
0	0	0	0	0	1	0	0	0	THERMAL FAULT OF LOW TEMPERATURE < 150 °C
0	0	0	0	0	0	1	0	0	THERMAL FAULT OF LOW TEMPERATURE RANGE 150 °C–300 °C
0	0	0	0	0	0	0	1	0	THERMAL FAULT OF MEDIUM TEMPERATURE RANGE 300 °C–700 °C
0	0	0	0	0	0	0	0	1	THERMAL FAULT OF HIGH TEMPERATURE > 700°C

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

Output												Fault Diagnosis
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	
1	0	0	0	0	0	0	0	0	0	0	0	NORMAL DETERIORATION
0	1	0	0	0	0	0	0	0	0	0	0	PARTIAL DISCHARGE
0	0	1	0	0	0	0	0	0	0	0	0	SLIGHT OVERHEATING - BELOW 150 °C
0	0	0	1	0	0	0	0	0	0	0	0	OVERHEATING– 150 °C – 200 °C
0	0	0	0	1	0	0	0	0	0	0	0	OVERHEATING– 200 °C – 300 °C
0	0	0	0	0	1	0	0	0	0	0	0	GENERAL CONDUCTOR OVERHEATING
0	0	0	0	0	0	1	0	0	0	0	0	WINDING CIRCULATING CURRENTS
0	0	0	0	0	0	0	1	0	0	0	0	CORE AND TANK CIRCULATING CURRENTS, OVERHEATED JOINTS
0	0	0	0	0	0	0	0	1	0	0	0	FLASHOVER WITHOUT POWER FOLLOW THROUGH
0	0	0	0	0	0	0	0	0	1	0	0	ARC WITH POWER FOLLOW THROUGH
0	0	0	0	0	0	0	0	0	0	1	0	CONTINUOUS SPARKING TO FLOATING POTENTIAL
0	0	0	0	0	0	0	0	0	0	0	1	PARTIAL DISCHARGE WITH TRACKING

Table 4: Output of the Doenrenburg Ratio Method-Based Neural Network

Output				Fault Diagnosis
Q1	Q2	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)).

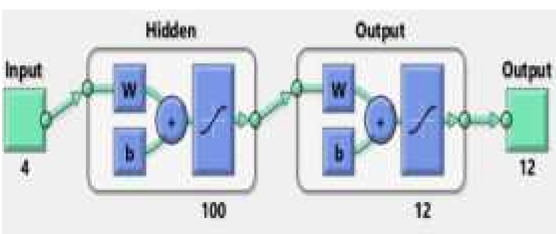

Figure 2 (a): Architecture of the Rogers ratio method

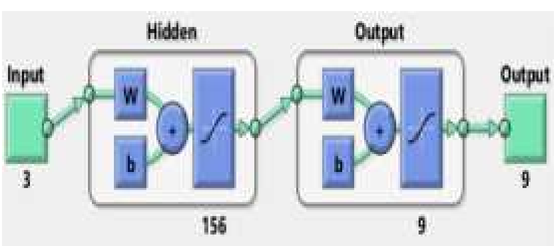

Figure 2 (b): Architecture of the IEC ratio method

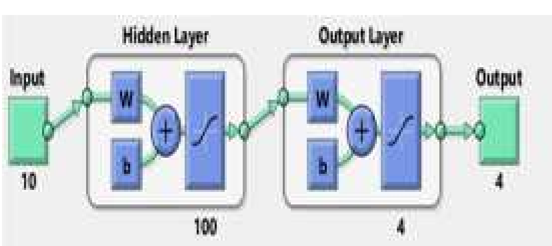

Figure 2 (c): Architecture of the Doernenburg ratio method

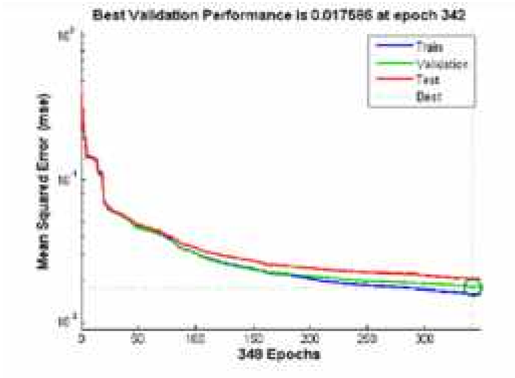

Figure 3 (a)

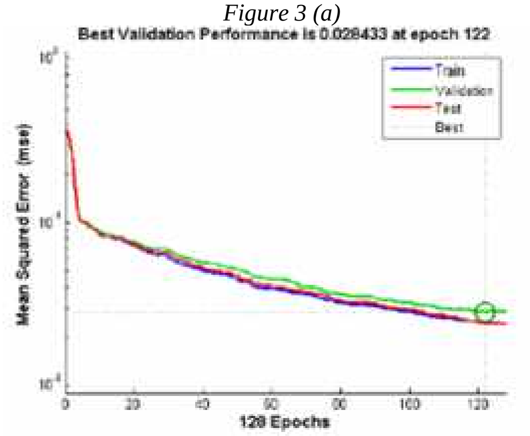

Figure 3 (b)

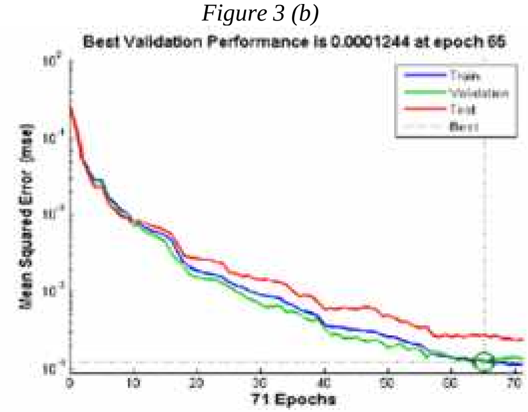

Figure3(c)

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

Table 5: Dissolved gas values from six substations

No.	Values of gases						
	CH4	H2	C2H6	C2H4	C2H2	CO	CO2
1	4	2	5	3	0.001	152	6608
2	11	0.001	4	3	0.001	96	4188
3	2	11	2	2	0.001	124	2664
4	3	11	2	3	0.001	92	1657
5	7	5	6	0.01	0.001	78	1177
6	0.01	0.01	0.001	0.01	0.001	23	1043
7	49	25	69	10	0.01	343	1309
8	65	40	87	12	0.01	408	1456
9	0.1	1	0.1	13	0.01	151	1909
10	27	10	49	4	0.01	146	683
11	109	789	11	156	873	515	5347
12	90	647	10	129	638	428	2439
13	44	144	12	118	583	192	3946
14	38	379	7	46	198	150	2287
15	4	0.1	1	8	0.001	64	1158
16	0.001	12	0.01	26	0.002	234	2696
17	4	4	1	25	0.001	221	2122
18	31	10	89	7	0.001	165	1065
19	9	190	25	3	0.01	393	3029
20	8	199	20	3	0.01	256	1886
21	8	149	17	3	0.01	215	1861
22	8	40	2	1	0.001	41	855
23	2	10	5	2	0.0001	154	4297
24	2	12	3	1	0.0001	129	2333
25	0.01	0.01	3	1	0.0001	82	2585
26	2	28	5	1	0.001	100	2991
27	4	22	6	2	0.002	132	2246
28	1	2	0.0001	1	0.0001	81	1369
29	0.01	0.01	5	2	0.0001	139	2189
30	1	1	0.01	0.001	0.001	109	1167
31	0.01	0.1	1	0.001	0.001	79	2696
32	1	0.1	0.01	4	17	117	3011
33	7	12	2	13	53	211	2171
34	10	58	2	13	61	216	1812
35	10	12	2	13	56	153	1692
36	0.01	41	18	0.001	0	65	136
37	5	4	6	2	0	35	722
38	0.001	36	17	0.001	0.0001	39	1343
39	0.1	16	2	1	0	138	1410
40	2	4	2	1	0	104	799
41	9	98	22	3	0.001	157	2100
42	10	94	33	2	0.001	209	2354
43	10	293	16	3	0.0001	444	2605
44	7	28	12	2	0	222	1699
45	8	113	13	5	0.0001	322	2160
46	6	188	9	3	0	151	964

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Table 6: Result of the data from the 70 samples

47	7	3	1	0.001	0.0001	542	3099
48	7	3	3	11	0.001	312	2503
49	3	1	5	4	0	186	1197
50	73	8	60	11	0.01	771	2974
51	50	5	63	9	0.001	404	1861
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
55	0.01	0.1	0	0.01	0	8	133
56	35	0.001	56	6	0.001	851	1191
57	12	1	7	42	0	260	1865
58	16	7	6	42	0.001	123	967
59	323	186	61	519	4	27	323
60	17	14	3	29	0.01	9	57
61	28	6	19	54	0.001	618	1860
62	26	5	22	72	0	444	1719
63	11	0.1	12	50	0.0001	649	958
64	17	0.01	20	108	0	259	570
65	29	5	10	3	0.001	431	1572
66	46	7	23	7	0.001	745	2519
67	41	6	24	7	0.002	648	1951
68	31	5	26	7	0.002	413	1740
69	14	0.1	17	3	0.001	680	992
70	13	0.1	18	2	0	175	468

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.	Fault Type			Oil Treatment
	Rogers Method	IEC Method	Doernenburg Method	
1	OVERHEATING-150 °C~200 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
2	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
3	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
4	GENERAL CONDUCTOR OVERHEATING	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
5	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
6	CORE AND TANK CIRCULATING CURRENTS	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
7	OVERHEATING-150 °C~200 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C~300 °C	NO FAULT	SINGLE FILTERING AND DEGASSING
8	OVERHEATING-150 °C~200 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C~300 °C	NO FAULT	SINGLE FILTERING AND DEGASSING
9	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
10	OVERHEATING-150~200 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C~300 °C	NO FAULT	GOOD OIL NO FILTERING
11	CONTINUOUS SPARKING TO FLOATING POTENTIAL	UNIDENTIFIABLE	ARCING (HIGH-INTENSITY PD)	DOUBLE FILTERING AND DEGASSING
12	CONTINUOUS SPARKING TO FLOATING POTENTIAL	UNIDENTIFIABLE	ARCING (HIGH-INTENSITY PD)	DOUBLE FILTERING AND DEGASSING
13	CONTINUOUS SPARKING TO FLOATING POTENTIAL	FAULT IN CELLULOSE INSULATING PAPER	ARCING (HIGH-INTENSITY PD)	DOUBLE FILTERING AND DEGASSING
14	CONTINUOUS SPARKING TO FLOATING POTENTIAL	FAULT IN CELLULOSE INSULATING PAPER	ARCING (HIGH-INTENSITY PD)	DOUBLE FILTERING AND DEGASSING
15	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
16	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
17	NORMAL DETERIORATION	UNIDENTIFIABLE	NO FAULT	GOOD OIL NO FILTERING
18	OVERHEATING-150 °C~200 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C~300 °C	NO FAULT	SINGLE FILTERING AND DEGASSING
19	OVERHEATING-200 °C~300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	SINGLE FILTERING AND DEGASSING
20	OVERHEATING-200 °C~300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	SINGLE FILTERING AND DEGASSING
21	OVERHEATING-200 °C~300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	SINGLE FILTERING AND

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22	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
23	OVERHEATING-200 °C–300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
24	OVERHEATING-200 °C–300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
25	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
26	OVERHEATING-200 °C–300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
27	OVERHEATING-200 °C–300 °C	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
28	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
29	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
30	FLASHOVER WITHOUT POWER THROUGH	UNIDENTIFIABLE	NO FAULT	GOOD OIL NO FILTERING
31	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
32	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	UNIDENTIFIABLE	GOOD OIL NO FILTERING
33	CONTINUOUS SPARKING TO FLOOTING POTENTIAL	DISCHARGES OF LOW ENERGY	ARCING (HIGH-INTENSITY PD)	GOOD OIL NO FILTERING
34	CONTINUOUS SPARKING TO FLOOTING POTENTIAL	DISCHARGES OF LOW ENERGY	ARCING (HIGH-INTENSITY PD)	SINGLE FILTERING AND DEGASSING

36	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
37	NORMAL DETERIORATION	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
38	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
39	UNIDENTIFIABLE	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	GOOD OIL NO FILTERING
40	NORMAL DETERIORATION	NO FAULT	NO FAULT	GOOD OIL NO 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	UNIDENTIFIABLE	SINGLE FILTERING AND DEGASSING
44	OVERHEATING-200 °C–300 °C	NO FAULT	NO FAULT	GOOD OIL NO FILTERING
45	OVERHEATING-200 °C–300 °C	PARTIAL DISCHARGES OF LOW ENERGY DENSITY	NO FAULT	SINGLE FILTERING AND DEGASSING
46	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 °C	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	UNIDENTIFIABLE	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	UNIDENTIFIABLE	SINGLE FILTERING AND DEGASSING
51	UNIDENTIFIABLE	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	NO FAULT	SINGLE FILTERING AND DEGASSING

52	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
53	NORMAL DETERIORATION	UNIDENTIFIABLE	NO FAULT	GOOD OIL NO FILTERING
54	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
55	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
56	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	THERMAL DECOMPOSITION	GOOD OIL NO FILTERING
57	NORMAL DETERIORATION	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
58	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
59	CORE AND TANK CIRCULATING CURRENTS	FAULT IN CELLULOSE INSULATING PAPER	THERMAL DECOMPOSITION	DOUBLE FILTERING AND DEGASSING
60	CORE AND TANK CIRCULATING CURRENTS	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
61	WINDING CIRCULATING CURRENTS	THERMAL FAULT OF MEDIUM TEMPERATURE AT 300 °C–700 °C	NO FAULT	SINGLE FILTERING AND DEGASSING
62	UNIDENTIFIABLE	THERMAL FAULT OF HIGH TEMPERATURE > 700 °C	NO FAULT	GOOD OIL NO FILTERING
63	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
64	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	UNIDENTIFIABLE	SINGLE FILTERING AND DEGASSING
65	OVERHEATING-BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	NO FAULT	GOOD OIL NO FILTERING
66	OVERHEATING-BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	UNIDENTIFIABLE	GOOD OIL NO FILTERING
67	OVERHEATING-BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	NO FAULT	GOOD OIL NO FILTERING
68	OVERHEATING-BELOW 150 °C	THERMAL FAULT OF LOW TEMPERATURE AT 150 °C–300 °C	NO FAULT	GOOD OIL NO FILTERING
69	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING
70	UNIDENTIFIABLE	FAULT IN CELLULOSE INSULATING PAPER	NO FAULT	GOOD OIL NO FILTERING

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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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