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LabVIEW with Fuzzy Logic Controller Simulation Panel for Condition Monitoring of Oil and Dry Type Transformer

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***Abstract*—**Condition monitoring of electrical power equipment has attracted considerable attention for many years. The aim of this paper is to use Labview with Fuzzy Logic controller to build a simulation system to diagnose transformer faults and monitor its condition. The front panel of the system was designed using LabVIEW to enable computer to act as customer-designed instrument. The dissolved gas-in-oil analysis (DGA) method was used as technique for oil type transformer diagnosis; meanwhile terminal voltages and currents analysis method was used for dry type transformer. Fuzzy Logic was used as expert system that assesses all information keyed in at the front panel to diagnose and predict the condition of the transformer. The outcome of the Fuzzy Logic interpretation will be displayed at front panel of LabVIEW to show the user the conditions of the transformer at any time.

***Keywords*—**LabVIEW, Fuzzy Logic, condition monitoring, oil transformer, dry transformer, DGA, terminal values.

I. Introduction

THE actual working condition of transformers in power grid is an important aspect viewing the stability of the power supply. Economic pressure forces power utilities to introduce efficient maintenance strategies carrying out only the most important jobs. In order to conserve transformers "health" additional control devices are necessary. A monitoring system offers the possibility to measure transformers working condition over a long period of time. Trends, which point out a degradation of transformers condition can be detected early by generating alarms and warning message. Slowly developing faults can be detected and repaired before they lead to damages.

There are several advance surveillance and diagnosis techniques of transformer fault such as dissolved gas-in-oil analysis (DGA), partial discharge (PD), furan analysis (FA), frequency response analysis (FRA), recovery voltage measurement (RVM), peak load and thermal dynamic[1]. However all these diagnosis techniques cannot provide a final conclusion of the fault type and position, besides, it may be intensive to subtle incipient fault. Because of that, expert system was added to the system to assess all the information to classify the possible fault type and its position.

In this project, Fuzzy Logic was used as an expert system that assesses all the information to diagnose and predict the type of faults for two types of transformer: oil-immersed type transformer and dry type transformer. The window that connects the user with the system was developed using LabVIEW. By using this window user can select to monitor and diagnose the condition of oil or dry type transformer. In this project, to monitor dry type transformer the current and voltage analysis method was used. Meanwhile, for oil-immersed type transformer DGA method was used.

II. Methodology

This research investigates the feasibility of using Fuzzy Logic method to predict and detect faults at early stage in distribution transformer. The Fuzzy Logic based detector has been developed to monitor and predict faults at an early stage on particular section of the transformer. The detector for this early warning faults detection device only requires external measurement taken from the input and output nodes of the transformer.

The measurements taken from the transformer will be processed by the Fuzzy Logic Controller using Simulink MATLAB. The results of the controller will be an input to the LabVIEW for the comparison and processes to display the faults analysis and monitoring condition. Besides having online data from the controller, the analysis done in LabVIEW also used the historical data of the transformer as additional information in doing the analysis for the faults prediction of the transformer. In this research LabVIEW used as user interface with the system. Off line testing and analysis of the transformer can be done using this program.

Dry transformer that usually insulated by epoxy resin has advantages that environment precautions are not required and need only minimum services. However, dry-type transformer is sensitive to different destruction phenomena due to the characteristic of their solid insulation [2]. For this type of transformer, voltage and current analysis were used to give

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early warning for faults prediction and detection. Research on the behaviors of current and voltage for each type of transformer faults have been studied and analyzed.

There are many methods available for diagnosis of oil transformer. Those are DGA, breakdown voltage test, the water content test, the tan (delta) test, resistivity test, acidity test, sludge test and interfacial tension test. Out of these, DGA was selected as it gives the present status of the transformer and provides information regarding faults that are growing inside the transformer. DGA approaches identify faults by considering the ratio of specific dissolved gas concentration.

III. Expert System: Fuzzy Logic

The Fuzzy Logic controllers built by using MATLAB will process inputs data of the DGA and terminal values gathered by the LabVIEW. The controllers will distinguish and predict the condition of the transformer. The fuzzy system used the max-min interference with centroid defuzzification. The union of the membership function resulting from rules develop is used to produce the aggregated output [3]. The outputs of the controllers for this project are the type of faults for the transformer.

Fuzzy Logic and Artificial Neural Networks are traditional methods used in diagnosis of transformer faults. Both can generalize; both produce correct responses despite minor variations in the input vector. There are, however, fundamental differences between the techniques, some of which weigh heavily in favor of fuzzy systems in certain applications as stated by Song et al [4]

> ….although a large number of AI techniques have been employed in power systems, Fuzzy Logic is a powerful tool in meeting challenging problems in power systems. This is so because Fuzzy Logic is the only technique, which can handle imprecise vague or 'fuzzy' information [4]

Fuzzy Logic was found to have superior performance in developing the diagnosis systems and in identifying the practical transformer fault cases [5-7]. Besides using AI techniques, transformer inductance during saturation, flux and voltage restraints, wavelet packet transform and improved frequency response analysis are the other approaches in protection of the power transformer [6, 8]. However, all these methods cannot withstand the complexity and influence by unexpected events and noise introduced during the transformer faults [4].

IV. Simulation Panel: LabVIEW

LabVIEW is a graphical programming language, which was, develops in 1986 by National Instruments [9]. LabVIEW was used as simulation panel as this software enable simulation, data capture, data analysis and circuit animation [10]. In this paper, the simulation panel is a graphical user interface used to key in the inputs and display the result of the transformer condition by the controller and also display the history data of transformer.

As in traditional, text-based programming languages, LabVIEW contains structures that control the block diagram function execution. Program control structures for LabVIEW include Sequence, Case statement, For Loop, and While Loop. These structures are graphically depicted as border structures. Just as you would imbed code into the lines of a structure in a conventional programming language, you place icons within the borders of LabVIEW graphical structures. LabVIEW features a graphical compiler that generates optimized compiled code. Virtual Instrument (VIs) execute at speeds comparable to those of compiled programs. In addition, you can execute your VIs with the LabVIEW Run-Time System, a low-cost, compact form of the LabVIEW development system [10].

V. System Implementation

A. System Structure

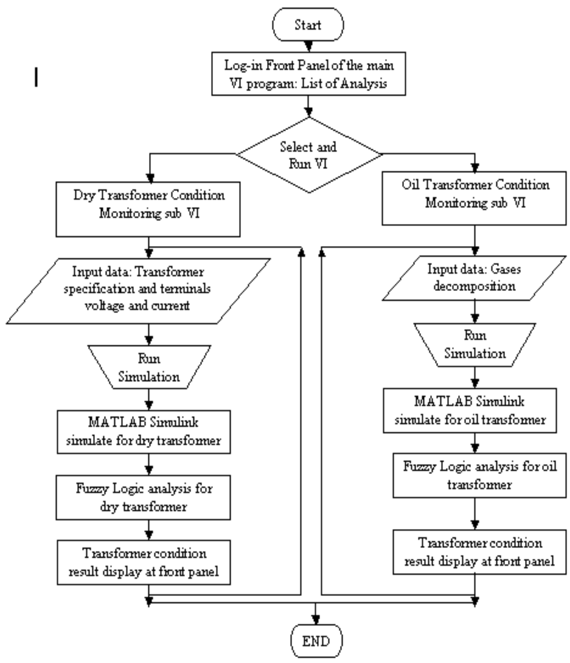

Fig. 1 Structure of the system

B. Voltage and Current Analysis

Terminal value, primary and secondary currents and voltages of the transformer convey the information that can be used to detect internal transformer failures. Experiments done by Karen L et al [11] on single phase 7200V/240V/120V, 25kVA, 60 Hz distribution transformer has shown the behaviors of the terminal values during internal short circuit and incipient faults. The behaviors of the faults are show in Table I below.

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TABLE I
INTERPRETATION OF THE FAULT BEHAVIOR

Short Circuit Type	Terminal behaviors
1. Primary winding with earth	Primary Voltage : No change Secondary Voltage : No change Primary Current : Increase higher than health value (3 times higher). Secondary Current : No change
2. Winding to winding at secondary	Primary Voltage : No change Secondary Voltage : Reduce to much less than health value Primary Current : Increase very higher than current health value (more than 3 time higher) Secondary Current : Increase higher than health value.
3. Arching Behavior	Primary Voltage : No change Secondary Voltage : Reduce to slightly less than health value Primary Current : Increase higher than current health value (more than 3 time higher) Secondary Current : Reduce slightly less than health value
4.Catastrophic failure	Primary Voltage : Highly reduce from health value Secondary Voltage : Highly reduce from health value Primary Current : Increase very higher than current health value (more than 3 time higher) Secondary Current : Less than health value.

C. Dissolved Gas Analysis

Like a blood test or scanner examination of the human body DGA can warn about an impendent problem, give an early diagnosis and increases the chances of finding the appropriate cure. The detection of incipient faults in oil immersed transformers by examination of gases dissolved in oil, developed from original Buchholz relay application. The Gas Chromatograph (GC) is the most practical method available to identify combustible gases. GC involves both a qualitative and quantitative analysis of gases dissolved in transformer oil [12]. There are many methods in DGA. Some among them are Norms Method, Gas Ratio Method and Key Gas method. In this project, Gas Ratio Method was used in the analysis. In condition monitoring, the advantage of using ratio method is that, they overcome the issue of volume of oil in the transformer by looking into the ratio of gas pairs rather than absolute values. The ratio methods considered in this project are Roger Ratio Method and IEC Method.

The Roger's method utilizes four ratios, CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4. Diagnosis of faults accomplished via a simple coding scheme based on ranges of ratios. Tables below show codes for gas ratios and faults diagnose used in this method.

TABLE II
GAS RATIO CODES

Gas Ratios	Ratio Codes
CH_4/H_2	i
C_2H_6/CH_4	j
C_2H_4/C_2H_6	k
C_2H_2/C_2H_4	l

TABLE III
ROGER'S RATIO CODES

Ratio Code	Range	Code
i	<=0.1	5
	>0.1,<1.0	0
	>=1.0,<3.0	1
	>=3.0	2
j	<1.0	0
	>=1.0	1
k	<1.0	0
	>=1.0,<3.0	1
	>=3.0	2
l	<0.5	0
	>=0.5,<3.0	1
	>=3.0	2

TABLE IV
GAS RATIO CODES

i	j	k	l	Diagnosis	Code
0	0	0	0	Normal deterioration	n
5	0	0	0	Partial discharge	o
1-2	0	0	0	Slight overheating <150°C	p
1-2	1	0	0	Overheating 150°C -200°C	q
0	1	0	0	Overheating 200°C -300°C	r
0	0	1	0	General conductor overheating	s
1	0	1	0	Winding circulating currents	t
1	0	2	0	Core and tank circulating currents, overheated joints	u
0	0	0	1	Flashover without power flow through	v
0	0	1-2	1-2	Arc with power flow through	w
0	0	2	2	Continuous sparking to floating potential	x
5	0	0	1-2	Partial discharge with tracking (note CO)	y

For diagnosis scheme recommended by IEC originated from Roger's method, except that the ratio C_2H_6/CH_4 was dropped since it only indicated a limited temperature range of decomposition. Four conditions are detectable, i.e. normal ageing, partial discharge of low and high-energy density, thermal faults and electrical faults of various degrees of severity. In this method three gas ratios are used to interpret the faults. Tables V and VI shows the codes for different gas ratios depending on the range of gas ratio and their interpretation.

TABLE V
IEC RATIO CODES

Ratio Code	Range	Code
i	<=0.1	5
	>0.1,<1.0	0
	>=1.0,<3.0	1
	>=3.0	2
k	<1.0	0
	>=1.0,<3.0	1
	>=3.0	2
l	<0.5	0
	>=0.5,<3.0	1
	>=3.0	2

TABLE VI
IEC FAULT DIAGNOSIS TABLE

l	i	k	Diagnosis	Code
0	0	0	Normal ageing	a
*	0	0	Partial discharge of low energy density	b
1	1	0	Partial discharge of high energy density	c
1-2	0	1-2	Discharge of low energy (Continuous sparking)	d
1	0	2	Discharge of high energy (Arc with power flow through)	e
0	0	1	Thermal fault <150^{o}C	f
0	2	0	Thermal fault 150^{o}C -300^{o}C	g
0	2	1	Thermal fault 300^{o}C -700^{o}C	h
0	2	2	Thermal fault >700^{o}C	m

But, the drawback of these ratio methods is that it fails to cover all range of data and quite fall outside the scope of tables. To overcome this problem, in this project Fuzzy Logic was used to overcome the drawback and combine both codes.

D. Simulation Panel

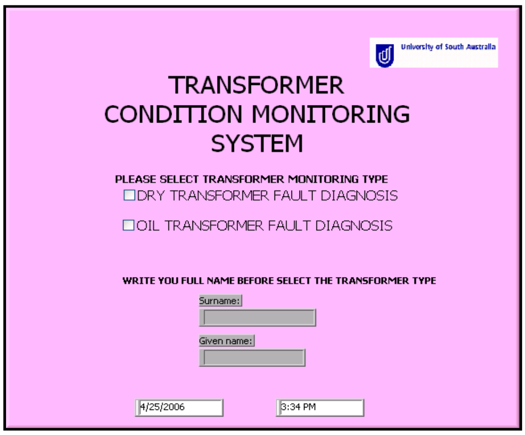


Fig. 2 Main Front Panel of the condition monitoring system

At the main simulation panel, user must select what type of transformer to be monitored and to predict the fault. Here, user must write the name and select whether to do fault diagnosis of dry transformer or oil transformer. Fig. 2 shows the front panel of the main simulation panel. After selecting transformer type, the system will automatically open the simulation panel for the chosen monitoring system.

Fig. 3 shows the LabVIEW front panel of the dry transformer condition monitoring system. Users need to key in all the inputs and run the program. As a result, the system will display the transformer condition. In this project, faults were analysed for each phase, so position of the fault can be located and classified. The graph will show the history of the terminal voltage and current to see the trend of the current and voltage for 24 hours.

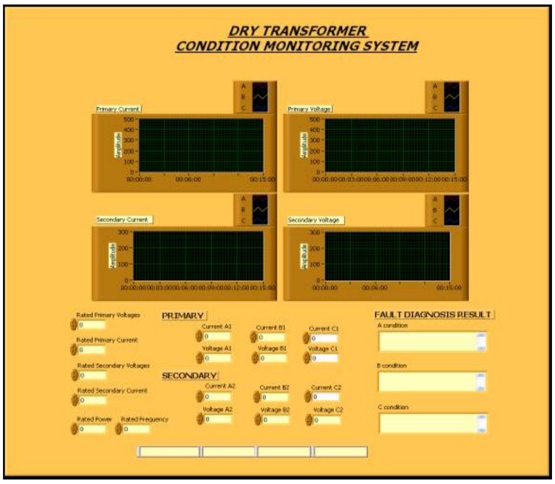


Fig. 3 Front Panel for faults diagnosis of dry transformer

The LabVIEW front panel for monitoring oil type transformer is shown in Fig. 4. Users are required to enter the value of each gas. As this system used ratio between the dissolved gases so there are no specific unit for the data entered but the data entered must be in uniform unit for all type of gases. The front panel designed will show the percentage of each gas dissolved and show the condition of the transformer base on ratio value of each gas.

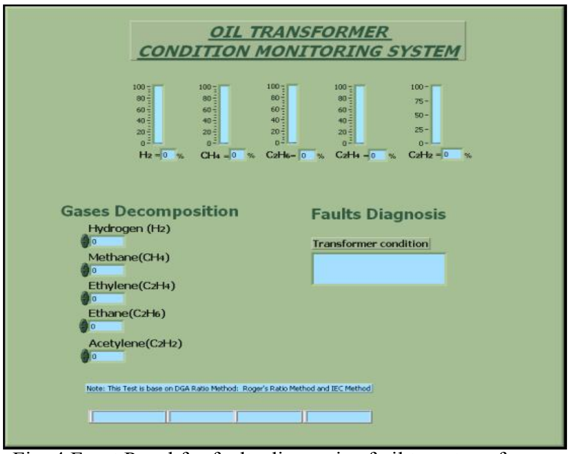


Fig. 4 Front Panel for faults diagnosis of oil type transformer

E. Fuzzy Logic Controller

Fuzzy Logic was used as the brain of the system. It was used to classify and assess the information, which are in this case the terminal voltages and currents in order to make a decision. The Fuzzy Logic system was built from the following four main parts:

i. Membership function

In building Fuzzy Logic system, membership functions are used to translate verbal judgements or linguistics into numeric expression [13]. In this project, the membership function was developed using MALAB Fuzzy Logic Toolbox. For dry type transformer the three controllers have inputs; each phase terminals voltage and currents (phase A, B and C) and the output; fault types for each phase.

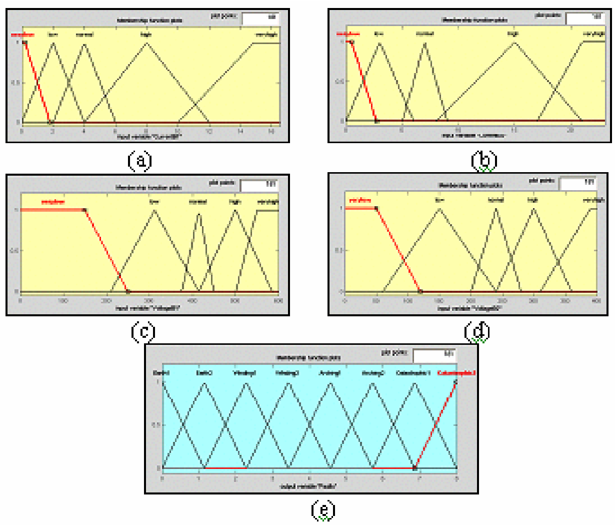


Fig. 5 Membership function for dry type transformer controller Inputs: (a) I1 (b) I2 (c) V1 (d) V2. Output: (d) Fault type

Controller for oil type transformer has inputs of the combination of Roger's Ratio Codes and IEC Ratio Codes. Meanwhile the output of the controller is a diagnosis result that will give transformer condition.

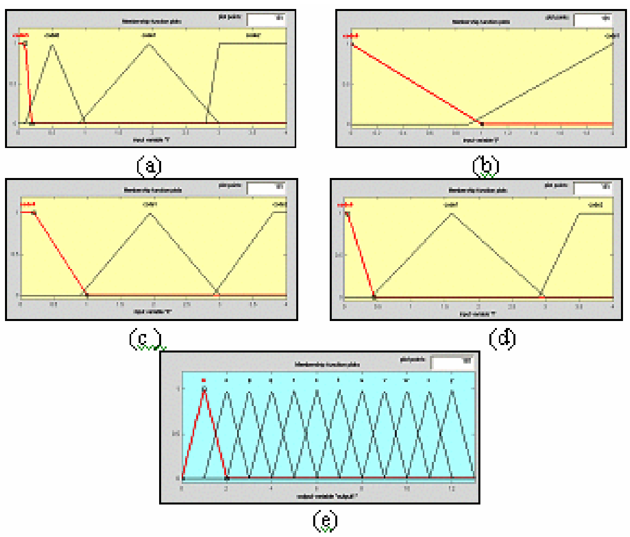


Fig. 6 Membership function for oil type transformer controller, inputs: (a) code 'i' (b) code 'j' (c) code 'k' (d) code 'l'. Output: (d) Fault type code

ii. Fuzzy rules

The linguistic control rules of the fuzzy system were expressed in IF-THEN form. This rule establishes the relationship or association between the propositions. In monitoring the dry type transformer, there are three set of rules based on the phases, which duplicate each other. The propositions involve on each set of rules are primary current (CURRENT A1 or CURRENT B1 or CURRENT C1), secondary current (CURRENT A2 or CURRENT B2 or CURRENT C2), primary voltage (VOLTAGE A1 or VOLTAGE B1 or VOLTAGE C1), secondary voltage (VOLTAGE A2 or VOLTAGE B2 or VOLTAGE C2) and faults type. Sample of eight rules develop base on membership function for each phases controller are as below:

IF currentA1 *very high* AND currentA2 *normal* AND voltageA1 *normal* AND voltageA2 *normal* THEN faults is *Earht1*

The rules developed for the oil type transformer condition monitoring controller combine the IEC Ratio Code diagnosis and Roger's Ratio Code diagnosis. There are seventeen rules have been develop for diagnosis the faults of the oil type transformer. Sample of rules developed is as below

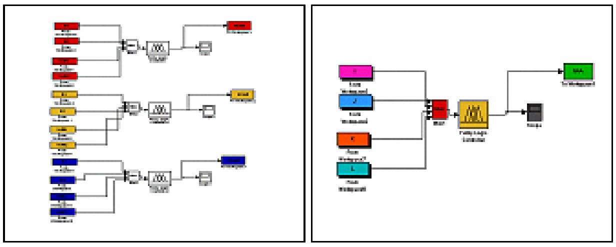
IF i *code0* AND j *code0* AND k *code0* AND l *code0* THEN ouput1 is *n*

iii. Fuzzy inference and defuzzification

In this paper, the min-max inference with centroid defuzzification method was used to build the controller. This type of inference make the union of membership function resulting from the rules developed can be used to produce the aggregated output. The centroid method favours the rule with the output of greatest area. . Each rule provides a result as a truth-value of a particular membership function for the output variable. In centroid defuzzification, if the rule specifies an AND relationship between the mappings of the two input variables, as the examples above do, the minimum of the two is used as the combined truth value; if an OR is specified, the maximum is used.

iv. Fuzzy controller simulation

MATLAB Simulink was used to develop the simulation panel for the Fuzzy Logic system. This simulation connects the data from LabVIEW panel to the Fuzzy Logic controller as an input. Meanwhile, the output of the controller will be send back to the LabVIEW panel to display the transformer diagnosis result.



(a) (b)

Fig. 7 Controller Simulation (a) dry system (b) oil system

VI. Simulation Test Results

A. *Dry Type Transformer Condition Monitoring Tests*

Test conducted to see whether the system built successfully monitor the condition of the dry type transformer. Tests were conducted for several cases with different values of the terminal voltage and current to see the variety of the faults diagnosis. Table VII shows the transformer specification used for the tests:

TABLE VII
DRY TRANSFORMER SPECIFICATION

Transformer specification	Value
Rated Power	3 KVA
Rated primary voltage	415V
Rated secondary voltage	240V
Rated primary current	4A
Rated secondary current	7A
Rated Frequency	50Hz

TABLE VIII
RESULTS FOR TESTING DRY TYPE MONITORING SYSTEM

No	ø	V 1 (V)	I1 (A)	V2 (V)	I2 (A)	Transformer Condition
1	A	415	4	240	7	Normal
	B	415	4	240	7	Normal
	C	415	4	240	7	Normal
2	A	415	15	240	7	Primary winding short with earth
	B	410	4	240	7	Normal
	C	100	9	240	23	Winding to winding short at primary
3	A	415	21	90	14	Winding to winding short at secondary
	B	350	3	240	22	Arching behavior at primary winding
	C	150	16	100	5	Catastrophic failure at secondary winding
4	A	200	3.5	90	25	Catastrophic failure at primary winding
	B	415	15	200	5	Arching behavior at secondary winding
	C	415	4	240	21	Secondary winding short with earth

B. *Oil Dry Type Transformer Condition Monitoring Tests*

Tests were conducted to see whether the monitoring system give the correct information to the user. The results were compared with the possible faults type by using the Key Gas Method. Three tests were conducted in order to make the comparison. In order to have uniform comparison, the gases values used in this test are in percentage because the Key Gas Method used the percentage in its evaluation.

TABLE IX
RESULTS FOR TESTING DRY TYPE MONITORING SYSTEM

H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	Transformer Condition	
					Tested System	Key Gas
2	16	63	19	0	Core and Tank Circulating Currents, Overheated Joints	Overheated Oil
85	13	1	1	0	General Conductor Overheating	Corona in oil
60	5	3	2	30	Flashover without Power Flow Through	Arching in oil

VII. Conclusion

This research has successfully showed that LabVIEW and Fuzzy Logic controller can be applied to develop a system for monitoring condition of the transformer. Through this system, user can monitor all size and rated of the transformer for dry and oil type transformer. The system has advantages that the designed program is user-friendly and the results can be easy to analyze by user, as the front panel is a graphical user interface. The system also successfully identifies faults type and has consistency in its interpretation as the system using Fuzzy Logic as its expert system. Fuzzy Logic has been found to have superior performance in diagnosis system and identify the transformer faults as it ability to handle imprecise vague and fuzzy information.

Indeed, only simple programming was used to develop the system. This is because the LabVIEW is graphical programming and the controller was developed using MATLAB Toolbox and Simulink panel. This can make user easy to understand the system and work on it in the future. As a last word, the system designed in this project has a capability to monitor the condition of the oil and dry type transformer. The information obtained from the transformer has successfully interpreted by the system to diagnose the faults type and predict condition of the transformer.

References

[1] Arshad M, I.S.M., Power Transformer Critical Diagnostics for Reliability and Life Extension. CCECE 2004-CCGEI 2004, 2004: p. 625-628.

[2] Gockenbach E, W.P., Borsi H, Monitoring and Diagnostic System for Dry-Transformers. IEEE 7th International Conference on Solid Dielectric Eindhoven the Netherlands, 2001: p. 291-294.

[3] Song Y.H, A.T.J., Application of Fuzzy Logic in Power System: Part 2 Comparison and integration with expert systems, neural networks and genetic algorithms. Power Engineering Journal, 1998: p. 219-222.
[4] Song Y.H, A.T.J., Application of Fuzzy Logic in Power System: Part 1 General Introduction to Fuzzy Logic. Power Engineering Journal, 1997. 11(5): p. 219-222.
[5] Huang Y.C, Y.H.T., Huang C.L, Developing a New Transformer Fault Diagnosis System through Evolutionary Fuzzy Logic. IEEE Transaction on Power Delivery, 1997. 12(2): p. 761-767.
[6] Saleh S.A, R.M.A., Modeling and Protection of a Three-Phase Transformer Using Wavelet Packet Transform. IEEE Transaction on Power Delivery, 2005. 20(2): p. 1273-1282.
[7] Zhang G, L.Y.S., Ibuka S, Yasuoka K, Isihi S., Application of Fuzzy Data Processing for Fault Diagnosis for Power Transformer. High Voltage Engineering Symposium, 1999. -(467): p. 160-163.
[8] Kim J.W, P.B.K., Jeong S.C, Kim S.W, Park P.G, Fault Diagnosis of a Power Transformer Using an Improved Frequency-Response Analysis. IEEE Transaction on Power Delivery, 2005. 20(1): p. 169-178.
[9] Higa, M.L.T., D.M; Lord, S.M.;, An Introduction to LabVIEW Exercise for An Electronic Class. 32nd Annual Frontiers in Education 2002, FIE 2002, 2002. 1: p. 6-9.
[10] Fountain, T., Software advances in measurement and instrumentation. IEE Colloquium on Software Instrumentation - Software Components,, 2004: p. 1-45.
[11] Karen L. B.P, B.M., Mausavi M.J, Peter P.B, Experimental Investigation of Internal Short Circuit Fault Leading to Advanced Incipient Behavior and Failure of Distribution Transformer. IEEE Trans., 2004.
[12] Dr. Sarma S, K.G.N.S., ANN Approach For Condition Monitoring of Power Transformer Using DGA. IEEE International Conference, 2004: p. 444-447.
[13] Islam S.M, W.T., Ledwich G., A Novel Fuzzy Logic Approach to Transformer Faults Diagnosis. IEEE Transaction on Dielectric and Electrical Insulation, 2000. 7(2): p. 177-186.