"I hereby, declared that I have read through this report entitled "The Interpretation of Dissolved Gas Analysis (DGA) using Fuzzy Logic" and found it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : …….

Supervisor's Name : …….

Date : …….

THE INTERPRETATION OF DISSOLVED GAS ANALYSIS (DGA) USING FUZZY LOGIC

KHAIDAWATON BINTI ABD MALIK

A report submitted in partial fulfilment of the requirement for the degree of Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

I declared this report entitled “The Interpretation of Dissolved Gas Analysis (DGA) using Fuzzy Logic” is the results of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …….

Author’s Name : ……

Date : ……

TO MY BELOVED FAMILY

Abd malik bin Zakaria

Zailifah bt Md Rani

Fadhilaton

Mardhiaton

Hamizahton

Ahmad Umar

ACKNOWLEDGEMENT

Firstly, I would like to offer my gratitude to Allah S.W.T for the mercy and grace, I finally able to complete a report for the Final Year Project (FYP) based on the specified date.

Here, I would like to express my deepest appreciation and thank you to those who have helped me directly or indirectly in completing this project. In this opportunity, I would like to express my gratitude to En. Mohd Shahril Bin Ahmad Khiar as my project supervisor and Pn. Ainain Nur Binti Hanafi, who has helped me in completing this project and helped me to solve the problem in which I faced during this project. In addition, I wish to thank to Universiti Teknikal Malaysia Melaka in particular to all members of the committee for Final Year Project and all that are involved to implement this project properly. Finally I would like to show my appreciation to my parents because for their encouragement and moral support during my studies at the Universiti Teknikal Malaysia Melaka (UTeM).

In this opportunity, I hope that all my knowledge gained during the implementation of this project received a blessing from Allah S.W.T and I want to apologize if there are shortcomings and mistakes in writing of this report for FYP. Finally, the good is from Allah S.W.T and the less is from my own weakness.

ABSTRACT

This project is to design a robust and reliable intelligent diagnostic method to detect and predict incipient faults in transformer. Transformer is one of the most components in the power system network. Major fault in these transformers can cause extensive damage which is not only disturbing other features electricity supply, instead causing huge losses. In the transformer, insulation material and faulty equipment will result in the release of gas; hence can be attributed to some kind of electrical fault such as corona, pyrolysis, and arc. The resulting gas generation rate can indicate the severity of the offense and the information obtained can be very beneficial in any preventive maintenance program. By using any of the preventive maintenance programs, the identity of gas is very useful to determine that faults. The key gas considerations for evaluation are hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), and acetylene (C_2H_2). Thus, interpretation of dissolved gas analysis (DGA) is used as the preventive maintenance program to detect the incipient faults. To study on DGA related to incipient fault inside power transformer, Rogers Ratio methods of DGA will be introduced. Rogers's ratio will be reviewed before it is applied in the system. In order to automate this program, the technique of MATLAB software using the technique of fuzzy logic is developed in this study. Fuzzy logic is selected because of its ability in storing knowledge and of their functions to make decision. Fuzzy logic control system mainly consists of four major elements, which are a fuzzification unit, a fuzzy inference engine, fuzzy knowledge base and a defuzzification unit. Network all of four elements can be action to make decision based on the knowledge of the decision-maker in fuzzy decision support system. The results between DGA testing method and fuzzy decision will be analyzed to investigate the process of analyzing the oil test result henceforward to record retrieving and record keeping of large volume of transformer information as references for others researchers.

ABSTRAK

Projek ini adalah untuk merekabentuk kaedah diagnostik yang pintar dan boleh dipercayai untuk mengesan dan meramal kesalahan awal pada pengubah. Pengubah adalah salah satu komponen yang paling penting dalam rangkaian system kuasa. Kesalahan utama pada pengubah boleh menyebabkan kerosakan besar yang bukan sahaja menganggu ciri-ciri lain bekalan elektrik, bahkan menyebabkan kerugian yang besar. Dalam pengubah, bahan penebat dan peralatan yang rosak akan menyebabkan pembebasan gas; oleh itu boleh dikaitkan dengan beberapa jenis kerosakan elektrik seperti "corona", "pyrolysis", dan "arching". Kadar penjanaan gas boleh menunjukkan kesalahan pengubah dan maklumat yang diperolehi menjadi sangat berguna untuk program penyelenggaraan pencegahan. Dengan menggunakan mana-mana program pencegahan, identiti gas adalah sangat berguna untuk menentukan kesalahan yang mungkin berlaku pada pengubah. Pertimbanagan gas utama bagi penilaian adalah hydrogen (H_2), metana (CH_4), etana (C_2H_6), etilena (C_2H_4), dan asetilena (C_2H_2). Oleh itu, tafsiran analisis gas terlarut (DGA) digunakan sebagai program penyelenggaraan pencegahan untuk mengesan kesalahan awal. Untuk mengkaji DGA yang berkaitan dengan kesalahan awal dalam pengubah, kaedah "Roger's Ratio" akan diperkenalkan. Kaedah Roger's Ratio akan dikaji dahulu sebelum diaplikasikan dalam sistem. Dalam usaha untuk mengautomasikan program ini, perisian MATLAB menggunakan teknik "Fuzzy Logic" dibina dalam kajian ini. "Fuzzy Logic" dipilih kerana keupayaannya dalam menyimpan maklumat dan keupayaan membuat keputusan. "Fuzzy Logic" kawalan system terdiri daripada empat jenis elemen iaitu "fuzzification", "fuzzy inference engine", "fuzzy knowledge base", dan "defuzzification". Rangkaian kempat-empat elemen bertindak untuk membuat keputusan berdasarkan pengetahuan membuat keputusan dalam system sokongan keputusan. Keputusan diantara kaedah DGA dengan "Fuzzy Logic" akan dianalisis untuk menyiasat hasil ujian minyak dan kemudian kajian yang diperolehi direkod dan disimpan sebagai rujukan untuk penyelidik lain.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DGA	-	Dissolved Gas Analysis
FL	-	Fuzzy Logic
MF	-	Membership Function
FIS	-	Fuzzy Inference System

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Transformer is one of the most important parts of an electrical system that serves to convert electricity with a lower current and a high voltage into electricity with a high current and a low voltage (and vice versa) with almost no loss of energy [1]. However, transformers are often a lesser electrical equipment and not given adequate treatment. Even though transformers have been treated but it is inseparable from the failure due to electrical and thermal stress. If failure occurs continuously it will cause damage (breakdown). To restore the failure transformers is not easy and cannot be done in a short time. Further, it would give the impression to some very large losses.

One of the main causes of failure in the transformer is overheating. Overheating is usually caused by various factors such as excessive loading, hysteresis loss, eddy currents, the oxidation process that produces rust, water, and others. Because of that, transformer requires cooling system to escort heat arise. Excessive heat will spur a chain reaction that will accelerate the decline in working age and the qualities of a good insulation system either on oil or paper insulator, decreasing the effectiveness of the cooling system works so that will make the experience due to failure of the transformers.

Power transformers require a wide range of testing isolator, good solid insulator testing or testing oil insulator. Physical testing is done by testing the insulation material on the compact and transformer windings, while oil testing is generally done by testing the oil insulator characteristics. Pace of technological development found an alternative method for testing oil, which is the method of testing and analysis of the amount of gas dissolved in transformer oil or a known DGA (Dissolved Gas Analysis) method.

1.2 The Dissolved Gas Analysis (DGA) Methodology

Transformers are vital components in both the transmission and distribution of electrical power. The early detection of incipient faults in transformer is extremely cost effective by reducing unplanned outages. The most sensitive and reliable technique used for evaluating the health of oil filled electrical equipment is DGA.

DGA is one of the most important tools for detection of incipient faults in the equipment. Equipment in operation is subjected to chemical and electrical stresses which results in de-gradation of oil and paper generating moisture and particulate contamination. Moisture may also enter the transformer through improper breathing. Moisture in association with oxygen present in air and damages oil. All this results in deterioration of electrical and chemical properties of oil. Any abnormal thermal or electrical stress in the equipment causes decomposition of oil and paper insulation. Gases released by such decomposition, get collected in the Buchholz relay when quantity is more, whereas these gases dissolve in the oil if the quantity is less. Regular monitoring of these gases dissolved in oil gives useful information about the health of the equipment. Advance information about the type of fault can be understood by trend of the content of various gases.

Insulating oils under abnormal electrical or thermal stresses break down to liberate small quantities of gases. The qualitative composition of the breakdown gases is dependent upon the type of fault. By means DGA, it is possible to distinguish faults such as partial discharge (corona), overheating (pyrolysis) and arcing in a great variety of oil-filled equipment. Table 1.1 shows the classification of faults according to the main types of faults that can be reliably identified by visual inspection of the equipment after the fault has occurred in service in New IEC Publication 60599[2]:

Table 1.1: Types of fault detection from DGA [2]

Faults	Description
Partial Discharge (PD)	PD of the cold plasma (corona) type with possible X-wax formation, and of the sparking type inducing small carbonized punctures in paper
Discharges of low energy (D1)	Evidenced by larger punctures in paper, tracking, or carbon particles in oil
Discharges of high energy (D2)	With power follow-through, evidenced by extensive carbonization, metal fusion, and possible tripping of the equipment
Thermal faults below 300°C	If paper has turned brownish (T1), above 300°C if paper has carbonized (T2)
Thermal faults above 700°C (T3)	Evidenced by oil carbonization, metal coloration, or fusion

Interpretation of DGA is not science but also art as there is no precise interpretation methods available which can exactly pinpoint location and type of fault. DGA results only provide guidelines useful for fault investigation. It may be mentioned that DGA results may give misleading results unless certain precautions are taken during sampling procedures, Sample bottles, duration of storage, gas extraction method, good testing equipment and Skilled manpower. Information from the analysis of gasses dissolved in insulating oils is valuable in a preventive maintenance program. A number of samples must be taken over a period of time for developing trends. Data from DGA can provide [3];

(i) Advance warning of developing faults
(ii) Monitoring the rate of fault development
(iii) Confirm the presence of faults
(iv) A means for conveniently scheduling repairs
(v) Monitoring condition during overload

1.3 Motivation of Research

The most sensitive and reliable technique for evaluating the health of oil filled electrical equipment is DGA. Insulating oils under abnormal electrical or thermal stresses break down to liberate small quantities of gases. The qualitative composition of the breakdown gases is dependent upon the type of fault. By means of DGA, it is possible to distinguish faults such as partial discharge (corona), overheating (pyrolysis) and arcing in great variety of oil-filled equipment [2]. Information from the analysis of gasses dissolved in insulating oils is valuable in a preventive maintenance program. Furthermore, it has been proven that data from DGA can provide advance warning of developing faults instead of monitor the rate of fault development.

The ability to monitor dissolved gases in transformer near real time has been around for over the years and is proving its worth. Utilities not continuously monitor their critical transformer where, in this case, continuously means several times a day may be reluctant to do so now for two reasons; cost and confidence, with perhaps the bigger reason being confident.

Frequently, with rapid progress and developing over the world, DGA system should be built by using a more effective and fast way. To achieve the best performance, this intelligent fault diagnosis system must be developed to suit the natural characteristics of local transformers. However, countries with the similar environment, transformer usage and other criteria may find this system useful and applicable with minor modification. Hence, this project is motivated by two factors which are to develop a local intelligent diagnosis system to replace foreign expert so as to save maintenance cost and to predict earlier fault that enable precautionary measures to be undertaken so as to minimize the risk of transformer explosion.

1.4 Problem Statement

The power transformer is a major apparatus in an electrical network. In Malaysia there are over one thousand power transformers in service by Tenaga Nasional Berhad (TNB). This is required as transformers are highly expensive and failure in these transformers may result in the disruption of the power supply to industries. Thus, preventive techniques for early fault detection in these transformers to avoid outages are introduced. Over the years, dissolved gas analysis (DGA) has been introduced where the necessary maintenance can be carried out by the TNB maintenance team. But there is not exactly standard found to solve this problem. In order to overcome such high cost in the interpretations of the test result, MATLAB software with fuzzy logic will be develop to interpret this problem.

1.5 Objectives

The objectives of this project are:

(i) To design a robust and reliable intelligent diagnostic method to detect and predict incipient faults in transformer

(ii) To study on DGA related to incipient fault inside power transformer

(iii) To investigate the process of analyzing the oil test result, record retrieving and record keeping of large volume of transformer information as references for other researchers.

1.6 Scopes of Project

This project will be focusing on the study of DGA where Rogers Ratio method is selected. Selangor Transformer, 2009 data's that are analyzed are obtained from TNB's in service transformer. The transformers are used to interpret DGA is a transformers with 33/11kV which is carry load under 30MVA. Hundred data which selected randomly to interpret the type of incipient fault occurs in the transformer. MATLAB software will be used (Fuzzy Logic) to automate the Rogers Ratio methods.

1.7 Description Topic

This report will divide into five chapters. Chapter one describes the overview of the project, motivation of the project, objectives of the project, scope of the project and description each topic for this report. Chapter two discusses the literature review related for this project including basic theory of transformer, DGA interpretation, Rogers Ratio Method, basic information about MATLAB and so on. Chapter three explains the DGA definition and methodology of the project started from obtain data from TNB until procedure to build system through Fuzzy Logic technique using MATLAB. Chapter four discusses specific study results conducted includes a brief explanation of the results obtained from the system is built, discussion and analysis based on the data obtained by DGA. Chapter five is the closing of this report which stated conclusions from the results of studies that have been made.

1.8 Summary

This chapter presents an overview of the project. Tendency to make this project also described in the motivation of the project which encourage making something useful epoch in engineering industry. The problem of this project is defined and stated clearly. Next, with a continuation of the problems that occur, objectives and scope related for this project are presented in detail. It also gives an overview each chapter for this report.

CHAPTER 2

LITERATURE REVIEW

Dissolved Gas Analysis (DGA) is widely accepted as the most reliable technique for the earliest detection of incipient faults in transformers [4]. Although the numbers of diagnostic methods have been proposed by several researchers around the world based on DGA but these methods do not have the standards anymore. Hence, research continues need to be done to get the standards in approved and adopted. In this research, Rogers Ratio diagnostic method is selected and will be detail discussed in this chapter.

2.1 Review on Common Method Used For DGA

The Dissolved Gas Analysis (DGA) techniques are recognized as the most informative method and it is being used quite successfully throughout the world. Compared to the total combustible gases (TCG) and gas blanket analysis, DGA is selected because it can give the earliest detection of an incipient fault and it is applicable to detect the entire individual component to all units in the transformer. Although TSG is fast and applicable to use in the field and gas blanket analysis can detects the entire individual component, both methods are not applicable to the oil-filled conservator type units [5].

DGA method using fuzzy logic technique is used caused by the system has many advantages. Based Yushiko [6], stated advantages of them are rule-based inference was simple and powerful, fuzzy control was efficient technology at low cost for automation in industry and fuzzy control was easily understandable for practicing engineers and people without mathematical background. This statement can be proven through several studies made by researchers before.

References [7], Yongqiang has published a paper on the fault diagnosis method for power transformer based on Bayesian network (BN) and DGA technique. In this paper, the researchers state that by using DGA method only cannot find the clear connection between fault and content of gas. In order to analyze the fault of transformer, researchers introduced advances a new transformer fault diagnosis method on BN, statistical knowledge that offers powerful map framework to process probabilities inference. BN is used because it can give fast calculating process of probability based on already existent information. The 47 cases of transformer faults are used in this method. In order to prove the effectiveness of fault diagnosing, BN method is compare to three-ratio method. The result show that the effectiveness of BN method is better than three-ratio method with true diagnosis of 45 compare to three-ratio of 39. A weakness identified by using this method is needed to confirm the fault character and fault style. In this case, researchers introduced four style fault and modifying the coding of the three-ratio vectors with doing statistical analysis about 400 cases of transformer to interpret the diagnosis.

Reference [8], Thang has published application of self-organising map algorithm for analysis and interpretation of dissolved gases in power transformer. A novel approach for analysis and interpretation of DGA data are introduced in this paper. By using real fault-cases, the researcher's proposed self-organising map (SOM) algorithm for transformer condition monitoring (CM) based on DGA. The SOM is conducted by neurons located on a regular two-dimensional grid. The researchers conclude that advantages by using this method is it offers a more consistent and convincing diagnosis as the revealed "structure" actually originates from within the real measured DGA records. Other than that, it is easy and cost-effective to implement because it does not depend on any actual fault cases and DGA schemes for its modeling. In that case the researchers listed several reasons why they do not depend on DGA interpretation scheme.

Reference [9], Seifeddine has published power transformer fault diagnosis based on dissolved gas analysis by artificial neural network (ANN). The researchers used experimental data from Tunisian Company of Electric and Gas (STEG) to establish the power transformer fault classification. In this paper, the researchers used three of DGA method to detect incipient fault, they are Key Gas method, IEC Ratios method and the graphical representation method. In order to automation transformers fault, ANN is

applying to choose the most appropriate gas signature between the DGA traditional methods and novel method with two principal neural network are introduced, Multi-Layer Perceptron (MLP) and Radial Basis Function (RBF). The result states that RBF has a better performance than the MLP.

Reference [10], Afiqah has published a paper on fuzzy logic application in DGA methods to classify fault type in power transformer. In this paper, the researchers used two DGA methods which are Roger's Ratio and IEC Ratio. Because have multiples type of faults happened for those transformer, researchers develop fuzzy logic to diagnose such cases. In this paper, researchers classified five types of fault into fault type code such as thermal fault at low temperature (TF), overheating and sparking (OH), arching (ARC), partial discharge and corona (PD) and normal (Normal). Data was used not notified in this paper. However, wealth of diagnostic information obtained by using DGA interpretation methods followed by fuzzy logic application. Even though incipient fault can be defined by applying fuzzy logic, but researchers conclude that these two methods failed to fit the actual unclear reason. Result for Rogers Ratio and IEC Ratio approximately the same with each having 80% and 87% of accuracy.

Reference [11], Muhammad has published a paper on comparative study and analysis of DGA methods for mineral oil using fuzzy logic. In this paper, the researchers used the six DGA method; Key Gas, Rogers Ratio, Doernenburg, Logarithmic Nomograph, IEC Ratio and Duval Triangle. Description of each method is described in the journal. To automate the DGA method the researchers also develop a system using MATLAB with and without fuzzy logic. In order to compare their accuracy and consistency, researchers use the DGA interpretation method by using the six methods (Key Gas, Rogers Ratio, Doernenburg, Logarithmic Nomograph, IEC Ratio and Duval Triangle) followed by the testing method using the fuzzy logic. 69 sets of data's are used which are then classified into five types of fault (F1, F2, F3, F4 and F5). From the result, the researcher found that by applying fuzzy logic the consistencies of most methods are improved when compared to system without fuzzy logic except the Nomograph and the Key Gas method show the same result for both system.

2.2 Transformer

A transformer is an apparatus for converting electrical power in an alternate current (ac) system at one voltage or current into electrical power at some other voltage or current without the use of rotating parts [12]. A constant-voltage transformer consist essentially of three parts: the primary coil which carries the alternating current from the supply lines, the core of magnetic in which is produced an alternating magnetic flux, and the secondary coil in which is generated an electromotive force (emf) by the change of magnetism in the core which it surrounds. Sometimes the transformer may have only one winding, which will serve the dual purpose of primary and secondary coils.

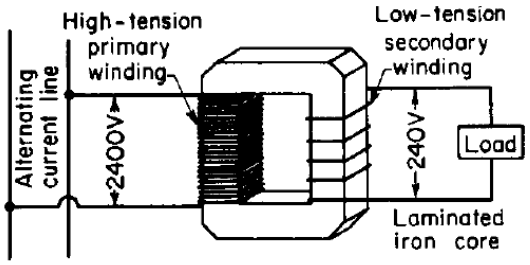

Figure 2.1: The elementary transformer

One of important part of the electric power system is called as power transformers. Power transformer can be defined as a transformer that is used to transfer electrical energy located in various portion of the electrical circuit between the generators with the primary circuit of the distribution system. Any fault in the power transformer may lead to the interruption of the power supply and accordingly [9].

2.3 DGA Interpretations

Due to reliability and order of magnitude which is larger than other gas detection methods; are listed as the factors of DGA wider acceptance in determining incipient fault of transformer [13]. The fault can occur due to the degradation of transformer oil and other insulation materials like cellulose. By increasing the rate of oil and cellulose degradation, and the type of degradation products formed will vary with the nature and severity of the fault. The composition of the gas mixture resulting from the decomposition

is energy dependent, and, since fault processes differ greatly in the energy they dissipate, different mixtures of degradation products are produced for each type of fault process.

By observing the composition of the gases produced by the degradation of the insulating media, it is possible to distinguish three basic fault processes which differ greatly in their energy characteristics; arcing, corona or partial discharge, and pyrolysis or thermal decomposition. These generate gaseous decomposition products, which dissolve in mineral oil. The nature and the amount of the individual component gases extracted from the oil may be indicative of the type and degree of abnormality. Table 2.1 state the ratios of gases that are generated and dissolved in oil for interpretation of transformer fault.

Table 2.1: Dissolved gases in oil [14]

Formula of the gas	Name of the gas
C_2H_2	Acetylene
C_2H_4	Ethylene
CH_4	Methane
H_2	Hydrogen
C_2H_6	Ethane

Based on studies that have been made by researchers is proven that gas produced in oil insulating transformer can interpret the situation either in normal or in disrepair. The following table shows the seven types of fault interpretations based on gas detected produced in oil sample in the transformer.

Table 2.2: Fault interpretation from dissolved gases [15]

S/N	Gases Detected in Oil Sample	Fault Interpretations
1	Nitrogen plus 5% or less oxygen	Normal operation
2	Nitrogen, carbon monoxide, and carbon dioxide	Transformer winding insulation overheated; key gas is carbon monoxide
3	Nitrogen, ethylene, and methane – some hydrogen and ethane	Transformer oil is overheated; minor fault causing oil breakdown. Key gas is ethylene
4	Nitrogen, hydrogen, small	Corona discharge in oil; key