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Bachelor of Electrical Engineering (Industrial Power)"

Signature :……..
Supervisor's Name : Mr. Imran Bin Sutan Chairul
Date :……..

LIFE ASSESSMENT FOR POWER TRANSFORMER IN DISTRIBUTION ELECTRICAL NETWORK

MUHAMMAD NAIM BIN ABDUL MUTHALIB

A report submitted in partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle

"*Life Assessment for Power Transformer in Distribution Electrical Network* "

is the result of my own research except as cited in the references.

The report has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature :……...

Name : MUHAMMAD NAIM BIN ABDUL MUTHALIB

Date :……

Dedicated with deepest love to:

My beloved family and fiancee for their support, guidance and love.

My dearest friends for being there whenever I need them.

My supervisor for his support and aid.

ACKNOWLEDGEMENT

First of all, I would like to thank Allah for His firm hands in guiding me in the course of completing this thesis writing. Alhamdulillah.

I would like to show my deep gratitude to my supervisor, Mr. Imran Bin Sutan Chairul for his invaluable support, patient, assistance and especially his encouragement to this projet. I truly have learnt a lot and all this would not be without his guidance.

I also would like to thank all my friends for their contribution in giving me moral support throughout my project development period. Most of all, I am fully indebted to my beloved family and fiancée for their understanding, comfort, patience, enthusiasm, and encouragement and for pushing me farther than I though I could go.

Lastly, I really appreciate to have this responsibility to finish this project. This task has taught a lot of lesson and knowledge which is much valuable for me in the future.

ABSTRACT

Power transformers are one of the most essential and important equipment of the electrical power system, which ensure stable and reliable energy delivery. Transformer operational life depends on its insulation system, which are insulating oil and solid insulating material. The degradation of the insulation occurs as the operating time of the transformer increases. Paper insulation is the most critical component of the transformer insulation system. Experimental and simulation studies on paper insulation showed that temperature, oxygen and moisture contents contributed to its degradation. In this study, level of parameters such as dissolved gases, coil temperature and oil temperature were obtained from transformers in Malakoff Prai Power Plant (PPSB). Then each parameter were differentiate and categorize for end-of-life analysis. The data will be analyse by using Unreliability for a Given Operating Time method in Weibull++ 7 software and Microsoft Excel.

ABSTRAK

Transformer kuasa adalah salah satu peralatan yang paling penting dalam sistem kuasa elektrik, yang memastikan penghantaran tenaga yang stabil dan boleh dipercayai. Jangka hayat transformer bergantung kepada sistem penebat, iaitu penebat minyak dan bahan penebat pepejal. Kemerosotan penebat berlaku sebagai masa operasi transformer meningkat. Penebat kertas adalah komponen yang paling penting dalam sistem penebat transformer. Kajian eksperimen dan simulasi mengenai penebat kertas menunjukkan suhu, oksigen dan kelembapan kandungan menyumbang kepada kemerosotan itu. Dalam kajian ini, tahap parameter seperti gas terlarut, suhu gegelung dan suhu minyak diperolehi daripada transformer di Malakoff Prai Power Plant (PPSB). Maka setiap parameter akan dibezakan dan dikategorikan untuk analisa jangka hayat. Data ini akan dianalisa dengan menggunakan kaedah "Unreliability for a Given Operating Time" dalam perisisan Weibull++ 7 dan juga perisian Microsoft Excel.

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NOMENCLATURE

DGA	Dissolved Gas Analysis
DP	Degree of Polymerization
kV	Kilo Volt
MVA	Mega Volt Ampere
CO	Carbon Monoxide
CO2	Carbon Dioxide
HPLC	High Performance Liquid Chromatography
GC	Gas Chromatography
GSUT	Generator Step-Up Transformer
UAT	Unit Auxiliary Transformer
PPB	Part Per Billion
PPM	Part Per Million
^{O}C	Degree Celcius
PPSB	Prai Power Sdn. Bhd.

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.0 Research Background

Power transformers are one of the most essential and important equipment of the electrical power system, which ensure stable and reliable energy delivery. The operational life of a common power transformer is usually depends on its insulation system, which consist of insulating oil and solid insulating material.

The insulation oil is a highly refined mineral oil that is stable at high temperature and has excellent electrical insulating properties. Its usefulness is to insulate, suppress corona and arcing, and to serve as a coolant. Meanwhile, the solid insulation material that being used are types of paper that are used as electrical insulation due to pure cellulose having exceptional electrical properties.

Under normal operational conditions, gradual aging of insulation oil and solid insulating material will occur due to the joint effect of the electrical, thermal, chemical, humidity, and oxidation. The condition of oil-paper insulation system is the main diagnostic indicator that influences the operational of transformers.

This project focused on paper insulation condition and its life assessment based on the parameters levels of dissolved gases, coil temperature and oil temperature.

1.1 Project Motivation

As a student which is studying electrical engineering, I have been interested in this field since my interest in engineering began. My own experience of doing power transformer routine check during my time at Malakoff Prai Power Plant (PPSB) for industrial training has led me to ponder many questions as to why there are so many type of transformer with different functions and why is the transformer is very important to the power plant . This

project has given me the opportunity to explore the world of electrical to find out the answer to my questions.

My knowledge of this field at the start of the project was casual. I knew generally about the main function of the transformer and its working principle without knowing anything specific about the insulation system, effect of temperature to the insulation and overall structure of the transformer lifetime. As this is a subject I am interested in making my career in, studying the insulation system and lifetime analysis of the transformer seemed a natural choice of study which I knew would be both challenging and interesting.

Form the theory aspect, I have done much research into the transformer insulation system and its related to the degradation o the transformer lifetime. The challenging part and most interesting is collecting real data from the transformer in Malakoff Prai Power Plant (PPSB) and perform the life assessment of the power transformer.

1.2 Problem Statements

Power transformer in every power plant is custom-made based on the plant power output capacity which means that it is only made upon request. Power transformer failure will force a power plant to shut down for a long period of time because it is one of the most important equipment of the electrical power system, which ensure stable and reliable energy delivery. Due to that, the power transformer needs to be monitored and well maintained. In this study, the parameters of dissolved gases, coil temperature and oil temperature from the power transformers in Malakoff Prai Power Plant (PPSB) were collected. The effect of each parameter on the condition of paper insulation were investigated and the transformers life assessment was conducted.

1.3 Objectives of Study

The objectives of this study are:

1. To obtain the level of dissolved gases, coil temperature and oil temperature from transformers in Malakoff Prai Power Plant (PPSB).
2. To differentiate and categorize the condition of each parameter either acceptable (S) or not acceptable (F).
3. To assess the life of power transformer using Weibull plot.

1.4 Scope of Works

The scopes of this thesis are:

1. Parameters levels were obtained from 2 different units of in-service Malakoff's power transformer in Malakoff Prai Power Plant (PPSB). The specifications of these transformers are 463600KVA, 132/19kV for the Generator Transformer and 23000KVA, 19/6.6kV for the Auxiliary Transformer with both liquid and solid insulation.
2. The parameters obtained are dissolved gases, coil temperature and oil temperature.
3. Statistical techniques conducted are in term of unreliability for a given operating time and parameter estimation technique.

1.5 Thesis Outline

This thesis is divided into five chapters, which consists of:
Chapter 1 : Introduction
Chapter 2 : Literature Review
Chapter 3 : Research Methodology
Chapter 4 : Result and Discussion
Chapter 5 : Conclussion and Recommendation

Chapter 1 describe background, problem statement, objective, and scope of the project.

Chapter 2 presents the literature review of the project. This chapter explain what type of analysis that available and which is the best type that can be use to conduct the projet.

Chapter 3 discuss the methodology adopted for this research work. It involves dissolved gas analysis and Weibull analysis using Reliasoft and Microsoft Excel.

Chapter 4 show the result obtain from the data collected with the discussion of the project.

Chapter 5 explain the conclusion achieved in this project and suggest recommendation for future work.

CHAPTER 2

LITERATURE REVIEWS

Introduction

The basic insulation materials used in the oil filled transformers are paper and pressboard. The advantages of these materials are they have good electrical and thermal properties. The winding of the transformers is wrap using the paper. Under large oil gap, breakdown may happen at a lower voltage. This is known as volume effect. In order to enhance the dielectric strength of oil gaps, pressboard is used as spacer and barrier to divide the oil volumes into smaller oil gaps. If flashover occurs in an oil gap, the total breakdown can be avoided since the voltage is taken by the rest of oil gaps [1].

Pressborad and paper are made from cellulose. One of the weakness of cellulose insulation is that the ageing is restored. The transformer performance could be affected as the paper undergo ageing process. Conductor fault can occur and brittle paper can break away from the winding and block the ducts due to the overheating, The overheating occurs because of the increasing of the local carbonising of the paper. On top of it, moisture and acidity which are the by-products of paper ageing could accelerate the degradation of the paper.

The catastrophic failure of a transformer can be avoid by monitoring the condition of the paper. The property that is affected by the ageing state of the paper is mechanical

strength while others property such as electrical is not affected. Due to that, the best technique to determine ageing state of paper is the mechanical strength measurement. However, paper samples from in-service transformers is impossible to obtain. Due to that, non-intrusive methods are used to determine the condition of the paper by measuring by-products of paper ageing from Furanic Compound Analysis (FCA), Degree of Polymerization (DP), and Dissolved Gas Analysis (DGA).

2.1 Paper Degradation Monitoring Techniques

2.1.1 Furan Compound Analysis

The molecular formula of grain is C_4H_4O. Based on the molecular formula, it represents four carbons and one oxygen in a five membered ring with each of the carbons having a hydrogen attached. Franc compounds are normally arise due to paper oxidation and hydrolysis processes can be directly extracted from the oil to classify the thermal decomposition of insulation paper. Furan concentration in transformer oil depends on the mass ratio between oil and cellulose. The five most common derivatives of green that produced by the degradation of the cellulose and that are soluble in oil are 2-Fulfural (2FAL), 2-Fulfurol (2FOL), 5-Hydroxy methyl-2-furfural (5HMF), 5-Methyl-2-furfural (5MEF), and 2-Acetyl furan (2ACF) as shown in figure 2.1 [2].

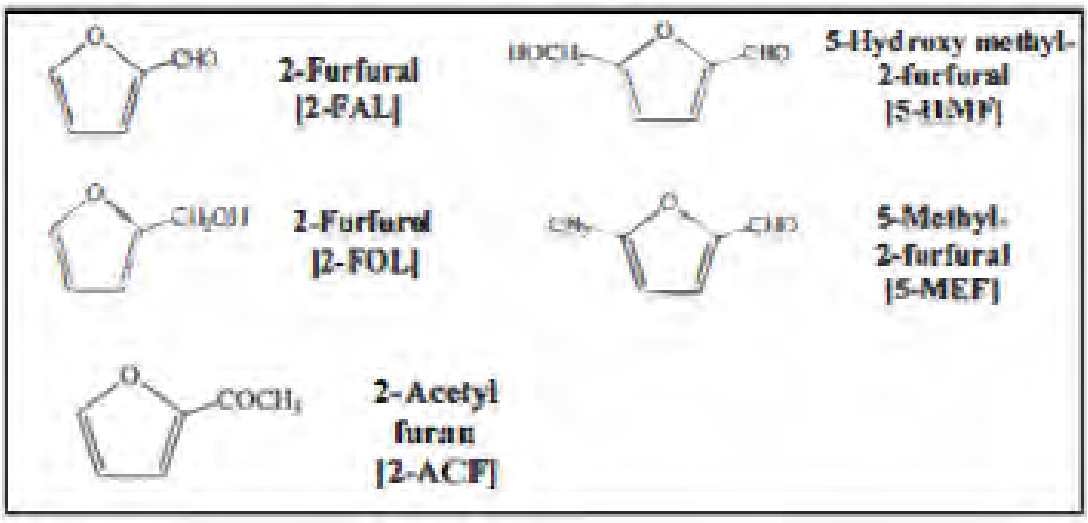

Figure 2.1: Derivatives of Furan From Degradation of Cellulose [2

Furan concentration in transformer oil depends on the mass ratio between oil and cellulose. Franc concentration in oil can be quantified by using High Performance Liquid Chromatography (HPLC) or Gas Chromatography-Mass Spectrometry (GC/MS) based on American Society for Testing and Material (ASTM D5837-Standard Test Method for Furanic Compounds in Electrical Insulating Oil by Gas Chromatography). Both techniques qualified to provide accurate and reliable measurement of grain derivative concentration in transformer oil [2].

Figure 2.2: High Performance Liquid Chromatography (HPLC) [3]

There are several methods being used to extract the five most common derivatives of grain that produce by the degradation of the cellulose from the insulating oil. The reason this deravatives was extracted from the insulating oil instead of the insualting paper is because sample of paper could not be obtained from in-service power transformer. Due to that, the deravatives is extracted from the transformer insulating oil. This method is valid because the deravatives of furan that produce by the degradation of the cellulose is soluble in oil.

Based on study that had been done by P Verma [4], the furanic compounds that exist in the aged oil smaples have been analysed by HPLC, after extraction with solvent

mixture as per IEC 61198. The samples are tested at 120°C, 140°C and 160°C and at electric stress 2.5 kV for 360, 720, 1080 and 1440 hours. A special test cell has been design for accelearated thermal and electrical ageing treatment on paper. Figure 2.3 shows the schematic diagram of the test cell.

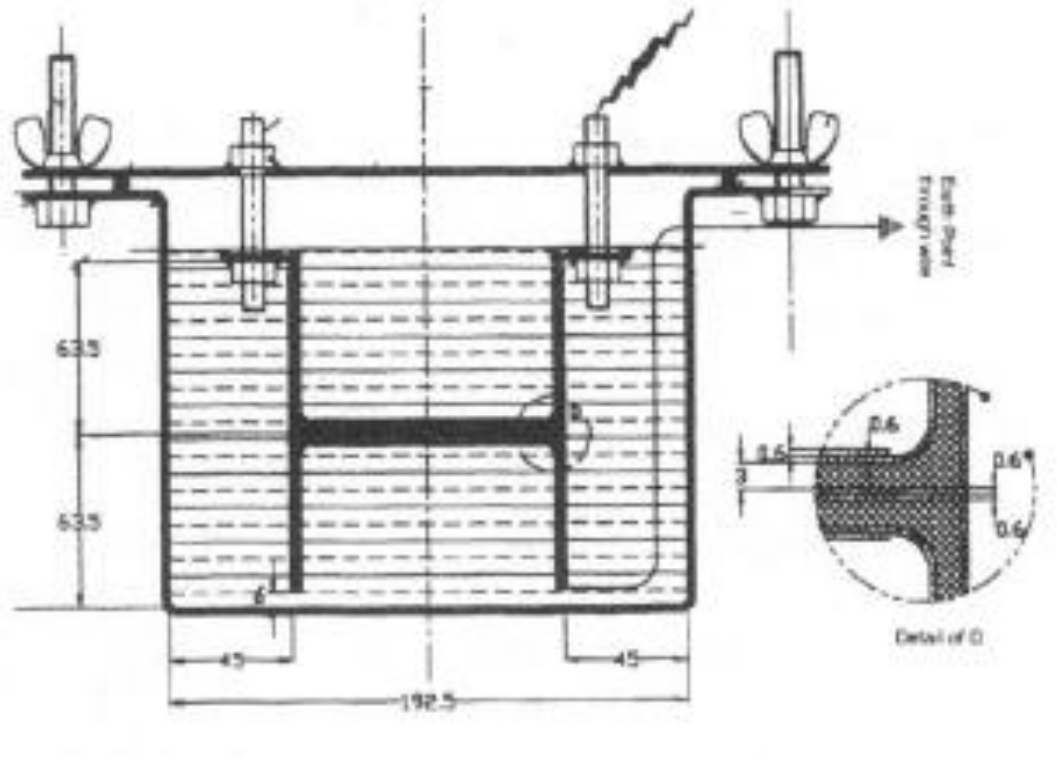

Figure 2.3: Test Cell[4]

The test cell had be made by using a mild steel of 3.5 mm thickness with a capacity of three litres. A high temperature resistant enamelled paint was used to polished the inner surface of the test cell. In order to prevent the leakage of gases at high temperature, the silicon sealing has been provided in between the top cover. Two copper strips covered with paper joined together were placed in the cell when the paper was tested in the presence of oil. The paper and oil were put in the ratio of 20:1 by weight. The temperature control of the oven was within $\pm 2^{o}$C. The paper and oil samples were taken periodically from the test cell at 120°C/2.5 kV, 140°C/2.5 kV and 160°C/2.5 kV after 360, 720, 1080 and 1440 hours.

Standard solution was prepare by using high purity furan compounds. UV detector is used to identify the furan derivatives after separation at two different wave lengths, 220 nm and 276. Samples peaks are identified by comparing the elution times with respect to standard samples of furans and concentration calculations are made in parts per billion

taking into account the concentration of standard furan compounds injected. These are calculated from standard and sample peaks. Table 2.1 shows the results.

Table 2.1: Furfural Compound Formation[4]

Aging condition		2-Furfuraldehyde (ppb)	2-Acetyl Furan (ppb)	5-Methyl Furfuraldehyde (ppb)	5-hydroxy Methyl Furfural Dehyde (ppb)
1.	120°C 2.5 kV 360hrs	41	12	16	22
2.	120°C 2.5 kV 720hrs	54	19	23	29
3.	120°C 2.5 kV 1440hrs	76	27	38	51
4.	140°C 2.5 kV 360hrs	106	41	54	82
5.	140°C 2.5 kV 720hrs	116	42	57	90
6.	140°C 2.5 kV 1440hrs	150	48	59	97
7.	160°C 2.5 kV 360hrs	480	154	135	265
8.	160°C 2.5 kV 720hrs	4920	155	140	267
9.	160°C 2.5 kV 1440hrs	5600	162	151	290

As per Mr. S.D Mayers Co.[5], For evaluation of remnant life using 2-FAL and DP as given in Table 2.2. This gives general guidelines to analyse the power transformers life aging based on the fural compounds.

Table 2.2: Guidelines for life aging based on 2-FAL[5]

55 °C Rise Transformer 2FAL (ppb)	Evaluated Degree of Polymerization (DP)	Evaluated Percentage of Remaining Life	Suggested Interpretation
58	800	100	Normal Ageing Rate
130	700	90	
292	600	79	
654	500	66	Accelerated Ageing Rating
1,464	400	50	
1,720	380	46	
2,021	360	42	
2,374	340	38	Excessive Ageing Danger
2,789	320	33	
3,277	300	29	Zone
3,851	280	24	High Risk of Failure
4,524	260	19	
5,315	240	13	End of Expected Life of Paper Insulation and of the transformer
6,245	220	7	
7,337	200	0	

The table above shows that for a range of 2-FAL from 0-292 ppb, the power transformer has normal ageing rate. For range between 654-2012 ppb, the transformer has accelerated ageing rate. For range between 3851-4524 ppb, the transformer has high risk of failure. Tha tarnsfomer was expected to totally damage at the range of 2-FAL above 5315 ppb.

The reason furan analysis is used to analyse the insulation paper degradation in power transformer is because the aging process of the power transformer oil does not produce furfurol. In contrast, molecule of furfurol in liquid form, with the formula (C4H3OCHO) and dissolved in oil, is the principal resultant from the paper insulation decomposition. Bases on previous researched, the state and condition of paper insulation aging can be quickly and accurately diagnosed by measuring the content of furfurol with HPLC (High Performance Liquid Chromatography) method. Nevertheless, other evidences should be used to accurately determine the condition of solid insulating aging because other factors may affected the resulting furfurol [6].