

raf

TJ153 .A94 2009.



0000065713

Investigation on relationship between ultrasound faults
with hot spots on incoming cable at distribution
transformer / Azizul Hakim Mohamud.

**INVESTIGATION ON RELATIONSHIP BETWEEN ULTRASOUND
FAULTS WITH HOT SPOTS ON INCOMING CABLE AT
DISTRIBUTION TRANSFORMER**


AZIZUL HAKIM BIN MOHAMUD

MAY 2009

“I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature :
Supervisor's Name : EN. HIDAYAT BIN ZAINUDDIN
Date : 12/5/09

“I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references.”

Signature :.....
Name : **AZIZUL HAKIM BIN MOHAMUD**
Date : **13 MAY 2009**

**INVESTIGATION ON RELATIONSHIP BETWEEN ULTRASOUND FAULTS WITH
HOT SPOTS ON INCOMING CABLE AT DISTRIBUTION TRANSFORMER**

AZIZUL HAKIM BIN MOHAMUD

**This Report Is Submitted In Partial Fulfillment of Requirements For The Degree of
Bachelor In Electrical Engineering (Industry Power)**

**Fakulti Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka**

May 2009

DEDICATION

Special dedicated to my beloved parents and family

**For my supervisor, Mr. Hidayat bin Zainuddin
Universiti Teknikal Malaysia Melaka**

**And lastly to my beloved friends and who have encouraged, guided and inspired me
throughout my journey in education**

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my highest gratitude to my supervisor, Mr Hidayat bin Zainuddin who has helped me a lot in sharing his knowledge and experiences and giving me useful advised in doing this project. During the duration of this final year project, Mr Hidayat bin Zainuddin has helped to guide me in order to write a good report and develop the project.

Besides that, I would like to express my deepest appreciation to all the lecturers who has shared their knowledge and skills with me which enable me to do my research on case studies.

Last but not least, I would like to thank to my family who have been giving me support and motivation throughout final year project. Lastly thank you to all my friends who given me tremendous support duration of the project. Thanks to all of you.

ABSTRACT

Condition monitoring is among the most important component in vast of engineering and exacting demand are made upon their carrying capacity and reliability. Consequently, by examining fault, it is possible, in majority of cases, to form an opinion on the cause of the fault and to take the requisite action to prevent a recurrence. Ultrasound and infrared thermography is one of the condition monitoring. It has been known for some time that ultrasound and infrared technologies complement each other when conducting inspections of transformer over 1000 volts. Fortunately, the combined use of ultrasound and infrared can improve a transformer inspection program by providing early detection of both heating and non-heating problems. Hence, this study will fine the condition that cause ultrasound and hot spot problems. The main purpose of this study is to fine the relationship between ultrasound faults and hot spot on distribution transformer incoming cable. Thermograms and ultrasound audio files will be integrated into this research to show their relationship to problems that occur in this type of electrical equipment.

ABSTRAK

Kaedah pemantauan keadaan adalah menjadi kepentingan dalam kejuteraan pada masa kini. Tidak hairanlah permintaan yang tinggi dalam kaedah pemantauan ini menjadikannya satu benda yang penting bagi menjadikan lebih berkuliti dan dinamik. Sebagai contoh, sesuatu masalah pada peralatan elektrik dapat di kesan dengan cepat sebelum peralatan elektrik itu gagal untuk berfungsi. Kaedah ultrabunyi dan suhu inframerah adalah contoh kaedah pemantauan keadaan pada peralatan elektrik. Pada sesuatu masa teknologi ultrabunyi dan inframerah digunakan bersama ketika melakukan pemeriksaan pada transformer 1000V ke atas. Penggunaan kedua-dua kaedah ini secara serentak pada sesuatu masa mempu mengesan lebih awal masalah panas dan tidak panas pada pengubah. Oleh itu kajian ini akan mencari faktor yang menyebabkan masalah ultrabunyi dan titik panas. Tujuan sebenar kajian ini adalah untuk mencari perhubungan antara kerosakan jenis titik panas pada kabel masukan pengubah pengagihan. Segala data dalam bentuk foto inframerah dan graf ultrabunyi akan di gunakan bagi mendapatkan kesahihan perhubungan antara masalah bunyi dan titik panas.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	SUPERVISOR RATIFICATION	i
	DECLARATION	ii
	PROJECT TITLE	iii
	DEDICATION	iv
	ACKNOWLEDGEMENTS	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xv
	LIST OF APPENDICES	xvi
1	INTRODUCTION	1
	1.1 Project Overview	1
	1.2 Problem Statement	2
	1.3 Project Objective	2
	1.4 Project Scope	3
	1.5 Thesis Outline	3

2	LITERATURE REVIEW	4
2.1	Introduction	4
2.2	Transformer Failures	5
2.3	Factors on cable insulating material deterioration	5
2.3.1	Treeing	5
	2.3.1.1 History of treeing	6
	2.3.1.2 Water trees	6
	2.3.1.3 Electrical Trees	7
2.3.2	Partial Discharge	9
2.3.3	Defect in the Semiconducting Screen	10
2.4	Importance of Electrical Fault Inspection	11
2.5	Introduction of Condition Monitoring	12
2.5.1	Partial Discharge Analysis	13
2.5.2	Ultrasound	14
	2.5.2.1 Corona	16
	2.5.2.2 Tracking	17
	2.5.2.3 Arc	17
2.5.3	Infrared Thermography	18
	2.5.3.1 Infrared Energy	19
	2.5.3.2 Electrical Energy to Thermal Energy	20
	2.5.3.3 Electrical Load	20
	2.5.3.4 Temperature and Electrical Load	21
	2.5.3.5 Radiation	21
	2.5.3.6 Infrared Camera	22
	2.5.3.7 Advantages of Thermal Imaging Over Contact Instrumentation	22
	2.5.3.8 Infrared Applications	23
	2.5.3.9 Palettes	23
2.6	Study case of ultrasound and infrared thermography on transformer	24
2.6.1	Case 1	24

	2.6.2 Case 2	25
	2.6.3 Case 3	26
3	METHODOLOGY	27
	3.1 Project Development	27
	3.1.1 Literature Review	27
	3.1.2 Data Collection	28
	3.1.3 Data Analysis	29
	3.1.4 Suggestion Corrective Action	29
	3.2 Condition Monitoring Procedure on Incoming Cable of Distribution Transformer	30
	3.2.1 Ultrasound Inspection Collecting Data Procedure	30
	3.2.2 Infrared Thermography Inspection Collecting Data Procedure	32
	3.3 Software Used	33
	3.3.1 UE Spectralyzer EZ Tomas	34
	3.3.2 Thermacam Reporter 2000	37
4	RESULT AND ANALYSIS	41
	4.1 Introduction	41
	4.2 Case of Cable Condition	42
	4.2.1 Case 1	42
	4.2.2 Case 2	44
	4.2.3 Case 3	45
	4.2.4 Case 4	46
	4.3 Comparison Between Cases	47
	4.3.1 Comparison between Case 1 and Case 2	47
	4.3.2 Comparison between Case 2 and Case 3	49
	4.3.3 Comparison between Case 4 and others case	50

4.4	Discussion on Problem	51
4.4.1	XLPE Cable and Problem	51
4.5	Source in Effect Problem	55
4.5.1	Bad splice/termination	55
4.5.2	Shield corrosion or missing shield	56
4.5.3	Overload and defect in insulation	59
4.5.4	Water trees/electrical tress	60
5	CONCLUSION AND RECOMMENDATION	62
5.1	Conclusion	62
5.2	Recommendation	64
	REFERENCES	66
	APPENDICES A-F	69

LIST OF TABLES

NO.	TITTLE	PAGE
3.1	Cable Transformer Severity Criteria for Ultrasound	35
3.2	Cable Transformer Severity Criteria for Infrared Thermography	39
4.1	Case 1 Cable condition with detection of both ultrasound and hot spot (ultrasound and hot spot high)	47
4.2	Case 2 Cable condition with detection of both ultrasound and hot spot (ultrasound and hot spot low)	47
4.3	Cable condition without detection of ultrasound with detection of hot spot	49
4.4	Case 4 Cable condition with detection of ultrasound and without detection of hot spot	50
4.5	Comparative properties of some cable insulating materials	53
5.1	Newly Proposed Classification Severity Criteria with Combination Problem between Ultrasound and Hot Spot	63
5.2	Recommendation for TNB related to the case study	64

LIST OF FIGURES

NO.	TITLE	PAGE
2.1	Example of shape of treeing	6
2.2	Water trees	7
2.3	Water tree (WT) and electrical tree (ET) growing into each other from opposite screens	8
2.4	Example of electrical treeing at incoming cable of transformer (ring pattern)	9
2.5	Discharge Inception Stress vs. Cavity Size [37]	10
2.6	Conductor Screen Damage	11
2.7	Partial discharge analysis technique on cable insulator	13
2.8	The ultrasonic instrument detects the high-frequency noise	14
2.9	Ultrasound detection using ultrasound instruments	15
2.10	Physically effect on corona that form on insulators that have dust	16
2.11	Example of visible sign of corona by ultrasound wave	17
2.12	Example of visible sign of tracking by ultrasound wave	17
2.13	Example of visible sign of arching by ultrasound wave	18
2.14	Environment waveform	20
2.15	Infrared Thermography camera	22
2.16	Types of Thermography palette	23
2.17	Dust and residue on cable from breakdown	25
2.18	Conductive corona powder / dust bushing supporting arcing conditions	26
3.1	Ultraprobe 2000 and Thermography camera	28
3.2	Flow of ultrasound inspections procedure	30
3.3	Example of UE Spectralyzer EZ Tomaz report for ultrasound inspection	36
3.4	Six panes of IR object settings dialogue box	38

3.5	Example of Thermacam Reporter 2000 report for infrared thermography Inspection	40
4.1	Example of cable condition with detection of both ultrasound and hot spot (ultrasound and hot spot high)	43
4.2	Cable condition with detection of both ultrasound and hot spot (ultrasound and infrared low)	44
4.3	Cable condition without detection of ultrasound with detection of hot spot	45
4.4	Cable condition with detection of ultrasound and without detection of hot spot	46
4.5	Condition of cable is clean from dust or white powder	51
4.6	3 cores XLPE Cable	52
4.7	Crosslink for XLPE 11 kV cable	53
4.8	Distribution transformer at substation for 11kV/ 415 V	54
4.9	Problem at cable that near the incoming terminations of transformer	54
4.10	Hot spot between terminations sites at transformer	55
4.11	Stress enhancement areas, sites of possible shielding damage	57
4.12	White powder on surface cable	58
4.13	Tracking on Surface of Insulator	58
4.14	Overload and defect at insulation	60
4.15	Trapped charges bore a tunnel from one void	60
4.16	Transformer outside substation that uncovered	61

LIST OF ABBREVIATION

TNB	-	Tenaga Nasional Berhad
TNBD	-	Tenaga Nasional Berhad Distribution
IR	-	Infrared Thermography
dB	-	Decibel
PD	-	Partial Discharge
PDA	-	Partial Discharge Analysis
XLPE	-	Polyethylene
UTeM	-	Universiti Teknikal Malaysia Melaka
PPE	-	Personal Protective Equipment
°C	-	Degree Celcius
PE	-	Electrical Substation

LIST OF APPENDICES

NO.	TITTLE	PAGE
A	Gantt Chart	69
B	Cable condition with detection of both ultrasound and hot spot (ultrasound and hot spot high)	71
C	Cable condition with detection of both ultrasound and hot spot (ultrasound and hot spot low)	79
D	Cable condition without detection of ultrasound with detection of hot spot	86
E	Cable condition with detection of ultrasound and without detection of hot spot	99
F	Cable Transformer Severity Criteria for Infrared Thermography and Ultrasound	102

CHAPTER 1

INTRODUCTION

1.1 Project overview

It has been known for some time that ultrasound and infrared technologies complement each other when conducting inspections of transformer over 1000 volts. At this voltage and higher, the electrical potential field is such that corona and tracking conditions can occur. Electrical discharge in the form of corona and tracking has caused many failures in transformer with little advanced warning or understanding of the cause. This is especially frustrating for the end-user when infrared technology is being utilized as a predictive tool to prevent such occurrences. Because corona and tracking conditions are voltage problems that not produce heat, it goes undetected during an infrared thermography inspection. Fortunately, the combined use of ultrasound and infrared can enhance a transformer inspection program by providing early detection of both heating and non-heating problems.

Otherwise, this study will find the condition that cause ultrasound and thermography problems from the physically shape. The presence of ultrasound and thermography in transformer is a serious problem that should be addressed as soon as possible. Therefore, this research is carried out to study what condition that more to cause ultrasound and infrared thermography effect.

1.2 Problem Statement

Generally, Tenaga National Berhad (TNB) has to face problem in their equipment like switchgear, transformers, cable compartment and etc. Therefore, TNB conducts inspection to their equipment according to a certain time. From this inspection like ultrasound and infrared thermography inspection they find the problem at their equipments. Example of ultrasound problems are corona and tracking while infrared thermography problem like heating on transformers bushing.

After examining fault at their equipments, TNB forms an opinion on the cause of the fault and take the requisite action to prevent a recurrence. Sadly, some of the task could not be solved after the action taken. Therefore, this study is done to learn the relationship between ultrasound faults with infrared thermography effect on power transformers so that a better appropriate preventive action can be taken. However, this project is only focused on the incoming cable of distributions transformer.

1.3 Project Objectives

1. To carry out a research on relationship between ultrasound faults effect on infrared thermography at transformers in order to understand what condition that cause it.
2. To determine the suitable value of temperature that can cause ultrasound from the sample of infrared thermograph image and ultrasound respond collected under loading transformers
3. To propose the possible solution to be used in over coming the problems.

1.4 Project Scope

The target for this study is on 11kV incoming cable of TNB's distribution transformer. This study will go to find out the amount of ultrasound fault in power distribution transformer that related with infrared thermography by presents on case studies. The physical condition at incoming cable of distributions transformer can be seen via infrared thermogrphy image and photo image. On the other hand ultrasound can detect electrical discharges from the cable insulator.

1.5 Thesis Outline

Chapter 1 briefly summarizes the project background and problem statements as well as elaborates the objectives and scope of the project. This chapter describe for the hole of the project.

In Chapter 2, the literature review includes condition monitoring technique, likes ultrasound and infrared thermography application to power distributions transformer inspection.

Chapter 3 is a project operation or project methodology. For this project there are several steps should be taken in order to achieve the project objectives scope.

Chapter 4 details the results and the analysis of the project. All the data from the field is collected and analyzed by using chosen software. The problem from data is related to the theoretical.

Finally, the Chapter 5 discusses the conclusion of the project and necessary recommendations are stated early.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss in detail about the literature review that related to this case study. Several concepts of cases will be explained. This is because the understanding of all concepts is necessarily important to conduct this research. This work is a part of ongoing project that focuses on relationship between ultrasound faults with infrared thermography effect using data from field study.

Therefore in the following section, a brief overview about condition monitoring, ultrasound and infrared thermography situation that can be used on power transformer inspection. The researches that have been done in developing this project involve research on transformer incoming cable, faults that always occur on transformer cable, and effectiveness in using ultrasound and infrared thermography on transformer cable inspection.

2.2 Transformer Failures

Manufacture fault, short circuit faults, abnormal transient fault, premature insulation fault, and aging of the insulation materials are major causes of transformer failures [3]. There are two major classes of transformer failures, it is internal faults and external faults [2]. Internal faults could be faults between two adjacent turns, between a segment of turns, parts of coils, or between a turn and a grouped part of the transformer. External faults include overloads, over-current, over-voltage, reduced system frequency, and external short circuits such as a short circuit created on the secondary windings [2],[4]. Recent record suggests about 70% to 80% of transformer failures are due to internal faults [5]. The internal faults of transformers can be divided into loose connection or contact of internal conductors and poor quality insulation [10]. Thus insulation failure comes from the internal faults.

Among internal faults, incipient fault is caused by gradual deterioration of insulating materials, so they develop slowly, and they require a relative long time for the incipient behaviors to develop into a short circuit which will lead to a catastrophic failure [6]. Therefore, in the following section will discuss on several factors that contribute to gradual deterioration of insulating materials.

2.3 Factors on cable insulating material deterioration

2.3.1 Treeing

Treeing at the dielectric cable insulation is the term of a type of electrical pre-breakdown deterioration that path through the wall of cable insulation [11]. Treeing has been demonstrated as one of the most important factors involved in loss of life for medium voltage cables. There are two types of treeing ie; water trees and electrical trees. Figure 2.1 shows example of shape of treeing.



Figure 2.1: Example of shape of treeing

2.3.1.1 History of treeing

The phenomenon known as treeing in dielectrics was first described by Raymer in 1921 [1]. He had been investigating electrical breakdown in the presence of discharges in paper-insulated cables. The tree-like appearance of Lichtenberg figures was well known during 1920s. These “trees” are totally different from what is seen in extruded dielectric cables because those older trees were carbon paths burned into the paper insulation that proceed concentrically around the insulating wall.

Treeing in extruded dielectric cables was described by Whitehead [24] in 1932 in his work on electrical breakdown. The development of corona detection equipment in 1933 by Tykociner, Brown, and Paine [25] made quantitative studies possible. Kreuger [25] thoroughly described methods for detection methods for detection and measurement of discharges in 1965. Previous reported results, especially by the Japanese [26] that they called sulfide trees, now become required reading.

2.3.1.2 Water Trees

Water trees form at a slow rate that may take many years to propagate and grow. Water trees can occur in all solid dielectric materials [3]. It is also known to be associated with reduction of dielectric strength and eventual failure of polyethylene

insulated cable which does not incorporate an effective moisture barrier [1, 2]. However, past studies of this phenomenon often correlated poorly with data gathered from field-aged cable [3, 4].

Water trees are initiated and grow at much lower electric fields than do electrical trees. They can extend from one electrode to the other without a service failure. They can be so large that they extend from shield to shield without resulting in breakdown. Some moisture is required. If partial discharge is present, we are not able to detect it at this time. They disappear when allowed to dry unless stained. They reappear when placed in boiled water. They have some method to minimize water treeing. The most effective method to avoid the formation of water trees is to keep the insulation absolutely dry. The shape of water trees is illustrates in Figure 2.2.

Figure 2.2: Water trees

2.3.1.3 Electrical Trees

Electrical trees in extruded dielectric cables are the result of internal electrical discharges that decompose the organic materials. No moisture is needed for this process. Partial discharges that decompose the organic material in insulations are generally