DETECTION OF WINDING DEFORMATION IN TNB DISTRIBUTION IN SERVICE TRANSFORMER USING CROSS CORRELATION CO-EFFICIENT ANALYSIS METHOD

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This report is submitted in partial fulfillment of requirement for the Degree of Bachelor in Electrical Engineering (Power Electronic and Drive)

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2012

“ I hereby declare that have read through this report entitle “Detection Of Winding Deformation In TNB Distribution In Service Transformer Using Cross Correlation Co-Efficient Analysis Method” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of electrical engineering (Electronic Power And Drive)”

Signature	: ………………………….
Supervisor‟s Name	: EN SHARIN AB GHANI
Date	: 22 JUN 2012

I declare that this report entitle "Detection of Winding Deformation in TNB Distribution in Service Transformer Using Cross Correlation Co-Efficient Analysis Method" is the result 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 :……………………………………………………..

Name : AHMAD FARIS FIRDAUS BIN MOHD ZAHIDI

Date : 22 JUN 2012

Specially dedicated to :

My beloved parents,
Mr Mohd Zahidi Bin Hj Ibrahim
Mrs Zaiton Binti Zawawi

My supportive family members,
Nurul Izza binti Mohd Zahidi
Ahmad Faiz Bin Mohd Zahidi

All my friends,

Thank you for the support and encouragement

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ABSTRACT

Detection of minor faults in power transformer active part is essential since minor faults may develop and become wet and finally irretrievable damages occur. Sweep Frequency Response Analysis (SFRA) is an effective low-voltage, off-line diagnostic tool used for finding out any possible winding displacement or mechanical deterioration inside the Transformer, due to large electromechanical forces occurring from the fault currents or due to Transformer transportation and relocation. In this method, the frequency response of a transformer is taken both in manufacturing industry and concern site. Then both responses are compared to predict the fault taken place in active part. But in conventional transformers, the primary reference response is unavailable. So Cross Correlation Coefficient (CCF) measurement technique can be a vital process for fault detection in these transformers. In this project, theoretical background of SFRA technique has been elaborated, the effectiveness of CCF parameter for fault detection has been represented. This project describes the use of Cross Correlation Coefficient (CCF) in conjunction with Omicron FRAnalyzer‟s software as a method. The simulations are demonstrated to apply with the purpose of frequency analysis band.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS / NOTATIONS / GLOSSARY OF TERMS

CCF	Cross-correlation Coefficient Function
H1 H2 H3	High Voltage Phase Termination of 3-Phase Transformer (Delta winding)
HV	High Voltage
IEEE	Institute of Electrical and Electronics Engineers
kHz	Kilo Hertz
kV	Kilovolt
LV	Low Voltage
MHz	Mega Hertz
MVA	Mega Volt Ampere
SFRA	Sweep Frequency Response Analysis
TNB	Tenaga Nasional Berhad
X_1,X_2,X_3,X_4	Low Voltage Phase Termination of 3-Phase Transformer (Wye winding)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.0 General background

Nowadays, reliability is an inevitable part of power system studies and operation, due to significant increase in the number of industrial electricity consumers. The power transformer is one of the major and critical elements in power system. The power transformer is specifically to withstand the mechanical forces arising from both shipping and subsequent in service event. Once a transformer is damaged either heavily or slightly, the ability to withstand further incidents or short circuit test becomes reduced. A visual inspection is costly and does not always produce the desired result. An alternative method is to implement field diagnostic technique capable of detecting damage such as Frequency response Analysis (FRA).

1.1 Problem Statement

Previously, evaluation of the transformer winding condition employed by the TNB distribution Division (transformer Performance and diagnostic) is based on graphical interpretation of SFRA measurement results. With appropriate graphical and statistical interpretation of SFRA measurement results, the transformer winding condition diagnostic could be more accurate and reliable.

1.2 Project Objectives

The project objectives of this project are:

i) To obtain SFRA measurements result from five in-service TNB distribution transformers.
ii) To analyze the SFRA measurement result by using Cross Correlation Coefficient (CCF).
iii) To verify the conditions of the transformer winding obtained from the Cross Correlation Coefficient (CCF) result by using other statistical techniques.

1.3 Project Scope

The project scope involves the following:

1) SFRA measurement conducted on five TNB"s in-service distribution transformers with two transformers already in defective condition while others are non-defect transformers.
2) The application of Omicron FRAnalyzer device is used for the SFRA measurement system.
3) SFRA measurement results are gained from comparison between phases inside transformers.
4) Only magnitude response data is taken from SFRA measurement results to be used in this study.
5) Detection of failures is only covered to transformer core and winding conditions.
6) Using SPSS Statistical software to analyze the SFRA data.
7) Verification of Cross Correlation Coefficient (CFF) result is conducted using statistical techniques such as T-Test, Absolute Sum of Logarithmic Error (ASLE) and Standard Deviation (SD).

CHAPTER 2

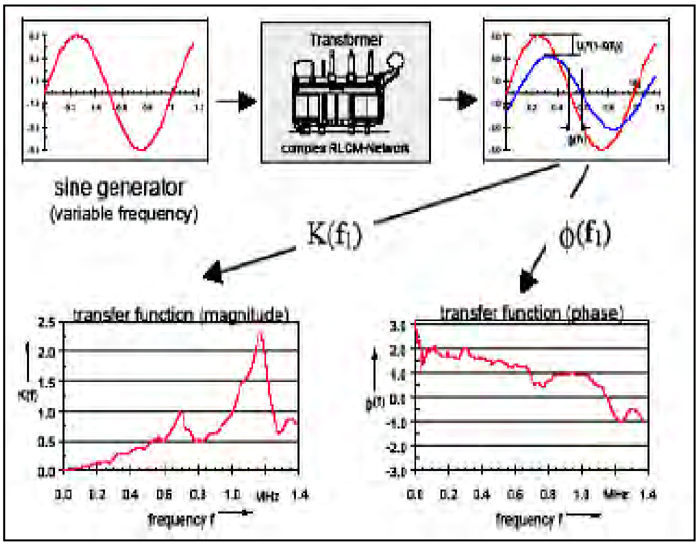
LITERATURE REVIEW

2.0 Introduction

In this chapter, some related information and previous research done by other researchers in the detecting failure of transformer are provided. It also includes type of failures in power transformer, fault diagnosis using Sweep Frequency Response Analysis (SFRA), winding deformation, frequency sub-band, Cross Correlation Coefficient (CCF) in measurement results interpretation and the other method such as T-Test, Absolute Sum of Error (ASLE) and Standard Deviation (SD).

2.1 Sweep Frequency Response Analysis (SFRA)

SFRA is able to detect a number of fault conditions, both mechanical and electrical failures. The transformer transfer function is determined in the frequency domain when the sweep frequency response method is used. The transformation in the frequency domain is performed with a network analyzer. The frequency of a sine voltage excitation can be controlled over the required bandwidth [4]. The magnitude and the angle of the complex transfer function can be obtained as shown in Figure 2.1.



[4]

Figure 2.1 Transfer function measurement by SFRA method [4]

The measured frequency range is normally very large, which can be from 20Hz up to 20MHz. The results are often presented on a graph of amplitude or phase versus frequency. The amplitude-frequency graph is often plotted or analyzed because it contains more useful information to work on [4].

2.2 Frequency Response Analysis (FRA) Technique

Frequency Response Analysis (FRA) method a transfer function of the transformer is measured in a wide frequency region and then is compared with a reference transfer function. The method is based on the fact that any power transformer can be represented by a complex network of resistance, inductances and capacitances. So, any change in these values will result in a measurable shift in the frequency response of transformer.

FRA technique there has a twofold issue. First is that obtaining a repeatable transfer function through practical measurement techniques and the second is having a correct interpretation of frequency responses in order to understand what it happened for the transformer. The conventional FRA technique is based on graphical analysis for fault diagnosis. The comparison of results make by plotting graph of the amplitude (or phase) against frequency for both sets of measurements [1].

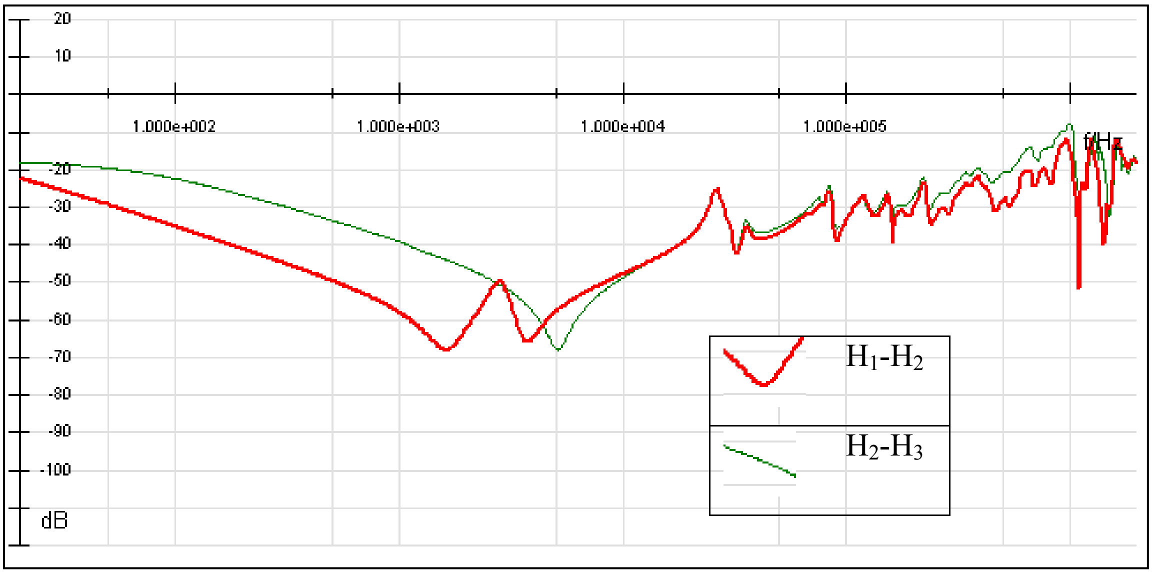


Figure 2.2: Comparison between H_1-H_2 phase and H_2-H_3 phase

Figure 2.2 shows a typical response for a high voltage star connected winding. The frequency range of interest is between 20Hz and 2MHz. Experience has shown that different sub-bands are dominated by different internal component of the transformer and are subsequently more sensitive to different types of failures.

2.3 Winding Deformation

Winding deformation may be due to mechanical and electrical faults. Mechanical faults occur in the form of displaced winding, hoop buckling, winding movement, deformations and damaged winding. They may be due to the loss of pressure, vibration during transportation and also excessive mechanical force during a close-up short circuit fault. Winding movements may also result from stresses induced by electrical faults such as an interterm short circuit as a result of lightning strikes [6, 7, and 8]. It may also result in insulation damage.

The deformation can also be due to ageing of paper. As a transformer ages the insulation shrink and the clamping pressure may be lost which reduces its voltage withstand strength. Winding deformations in transformers are difficult to establish by conventional methods of diagnostic tests like ratio, impedance/ inductance, magnetizing current etc. Deformation results in relative changes to the internal inductance and capacitance of the winding. These changes can be detected externally by low voltage impulse method or FRA method [9].

The low-voltage winding is deformed by compression towered the long-side direction. The transfer function of the deformed low-voltage winding is changed in the high frequency range. On the other hand, the transfer function of the non-deformed high-voltage winding is not changed [10]. FRA measurement results before and after a serious fault that occurred on the tap winding of a transformer, together with a photos showing the corresponding damage, where it is clear that the tap winding has collapsed partially axially and has local inter-turn damage. The FRA measurement result after the fault had occurred is clearly different from the FRA measurement result taken in the factory [11]. The following Figure 2.3 shows the windings of the phase U and the radial displacements of the windings.

Figure 2.3 Axial displacement of winding [4]

2.4 Frequency Sub-Band

Focusing on frequency ranges for interpretation of SFRA measurement, the following definitions of each frequency bands are taken from a paper published at Cigre Session 2004 [17]. Regarding to the frequency bands for SFRA interpretation [11], the frequency bandwidth can be divided into three sub-bands. With the low frequency sub-band; transformer core effects are present, in the middle frequency sub-band (10 kHz to 500 kHz) effects to the transformer winding and high frequency sub-band, detect asymmetry on the connections of windings. From the statistical result, the frequency sub-bands that related to the winding deformations are described below:

i. Local axial movement: Frequency band affected between 200 kHz - 1 MHz.
ii. Bulk radial movement: Frequency band affected between 10 kHz - 500 kHz.
iii. Influenced of SFRA test setup: Frequency band affected above 1 MHz.

2.5 Cross Correlation Coefficient (CCF)

Correlation coefficient technique stresses on the similarity in the FRA data obtained from the test windings during the measurement period. The measurements are taken from all the three phases. These measurements are compared to second set of measurements or reference measurements. The reference measurements can be from the same transformer or they can also be from different transformer [4]. Correlation coefficient is used in this study as the analyzing technique. The technique is selected to enhance the quality of the measurement so that better interpretation can be achieved.

Several attempts have been made over the years at creating automated or semi-automated SFRA analysis tools. Simplest terms, cross-correlation takes two sets of numbers and looks at how similar they are. The CCF formula is defined as:

$$CCF = \frac{\sum_{i=1}^{n}(Xi - \bar{X})(Yi - \bar{Y})^2}{\sqrt{\sum(Xi - \bar{X})^2} * \sqrt{\sum(Y - \bar{Y})^2}} \tag{2.1}$$

Where;

X_i = value from the first set of data in dB

Y_i = value from the second set of data in dB

$\bar{X}$ = value of the first set of data in dB

$\bar{Y}$ = value of the second set of data in dB

If two series of numbers such as an SFRA trace perfectly or nearly match, they would have a CCF very close to ≤1.0. If two traces have absolutely no correlation, in other words are completely random, they would have a CCF of ≥ 0.0 [5]. CCFs to analyze SFRA data first requires an understanding of what frequency sub-bands tell us about the physical health of a transformer. Once the appropriate bands are selected the CCFs can be evaluated in the context of the individual parts of a transformer.

2.6 T-Test

The T-test assesses whether the mean of two group are statistically different from each other [14]. T-Test is future in this study for the purpose of SFRA diagnostics. The test is popularly used in statistics to find deviation in the value mean of different sets data. It involves the checking of a hypothesis. A statistical hypothesis is a statement about a set of parameter of population. The T-Test is one of the hypotheses testing method. Sample variance is used in place of population variance, if the latter is unknown.

The test is used to check the equality of the means of two samples, the deviation between the means can thus be determined. In statistical its value is chosen as 95%, although other values can be selected based on specific requirement [14]. The natural property of the T-Test is that it gives a digital conclusion in term of 0 or 1. The advantage T-Test is that data sets having different sample sizes can be conveniently compared for the considered frequency interval. The formula as follow:

$$t_o = \frac{x_1 - x_2}{\sqrt{\left(\frac{s_1^{\,2}}{n_1} + \frac{s_2^{\,2}}{n_2}\right)}} \tag{2.2}$$

Where:

x_1 = sample mean of the first set data
x_2 = sample mean of the second set data
s_1 = sample variance of the first set data
s_2 = sample variance of the second set data
n_1 = sizes of sample the first set data
n_2 =sizes of sample the second set data

2.7 Absolute Sum of Logarithmic Error (ASLE)

ASLE is based on the comparison on the logarithmic vertical axis. Since the frequency responses have already been modified to be equidistant on logarithmic horizontal axis.

$$ASLE_{(x,y)} = \frac{\sum_{i=1}^{N} |20\log_{10} Y_i - 20\log_{10} X_i|}{N} \tag{2.3}$$

where:

i = the respective frequency point
X_i = the value from the first set of data in dB
Y_i = the value from the second set of data in dB
N = total number for a set of data

2.8 Standard Deviation (SD)

SD is generally defined for comparison of two data sets, a more appropriate parameter. This is being proposed for the first time as a statistical parameter for such analysis in which the differences between two data sets need to be statistically quantified. The formula is calculated as: