FAKULTI KEJURUTERAAN ELEKTRIK
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LAPORAN PROJEK SARJANA MUDA

FERRORESONANCE ANALYSIS IN THREE PHASE VOLTAGE TRANSFORMER

Muhammad Asraf Bin Yusof
(B010810147)

Bachelor of Industrial Power Engineering
JUNE 2012

" I hereby declare that I have read through this report entitle "*Ferroresonance Analysis in Three Phase Voltage Transformer*" and found that it has comply the partial fulfillment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*"

Signature : .....

Supervisor's Name : .....

Date : .....

FERRORESONANCE ANALYSIS IN THREE PHASE VOLTAGE TRANSFORMER

MUHAMMAD ASRAF BIN YUSOF

This report is submitted in partial fulfillment of the requirements for the degree of Bachelor Degree of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2012

I declare that this report entitle "*Ferroresonance Analysis in Three Phase Voltage Transformer*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

ACKNOWLEDGEMENT

Alhamdulillah,

After dedicating all my hard works for this final year project report, it is finally completed smoothly. First of all, I would like to express my thankfulness and gratitude to Allah S.W.T who has given me all the strength that I needed to complete this final year project report.

I also would like to bid my greatest thank to my project supervisor, Mr. Mohd Khairi Bin Mohd Zambri of UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM) for giving me great guidance, helps, advices and being so supportive in every little aspects which have led me to a great finishing in doing my progress report of the project. I also would like to thank my final year project panels En Khairul Anwar Bin Ibrahim and Dr. Gan Chin Kim for their advice and guidance to make this project successful.

And not forgetting to my family especially to my parents, a million of thanks to them because of their support to me with their prayer and love.

Last but not least, I would like to express my appreciation to my friends for their patients, understanding and also for their undivided support that they had gave me throughout the completion of my progress report and also to all those people who helped and involved themselves in my final year project and only God can repay the favours.

ABSTRACT

The purpose of this project is to identify and analyze ferroresonance phenomenon in term of power quality issues especially in three phase voltage transformer. There are lots of power quality problems which can occur in electrical power system such as voltage swell, frequency variations, harmonic distortion, and voltage fluctuations. Ferroresonance is one of them. This project focuses on ferroresonance which will briefly describe ferroresonance phenomenon in power quality problem. Ferroresonance can be defined as a sudden overvoltage and over current at a point of transient in the electrical power system in a short period of time. Ferroresonance in voltage transformer can occur due to switching process or lightning strike activities. Ferroresonance is difficult to analyze and the occurrence of the phenomenon of ferroresonance is unpredictable. Electrical equipment such as voltage transformer, capacitor voltage transformer and switchgear that deals with ferroresonance phenomenon can cause serious damage to the equipment. Analysis of Ferroresonance in Three Phase Voltage Transformer will be conducted by using software Power System Computer Aided Design (PSCAD). To run the simulation, all the factors that can cause the ferroresonance have to be identified. During the simulation, type of fault and the tapping of transformer parameter will be analyzed. From the simulation, transient response will be obtained from PSCAD simulation and each of the transient response of ferroresonance will determine the characteristics of the ferroresonance in three phase voltage transformer. Throughout this project, ferroresonance activity will be analyzed especially in three phase voltage transformer.

ABSTRAK

Tujuan projek ini adalah untuk mengenalpasti dan menganalisis fenomena ferroresonance dari segi masalah kualiti kuasa terutamanya dalam pengubah voltan tiga fasa. Terdapat banyak masalah kualiti kuasa yang boleh berlaku dalam elektrik kuasa seperti penurunan voltage secara tiba-tiba, perubahan frekuensi, herotan harmonik dan turun naik voltan. Ferroresonance merupakan salah satu daripada masalah kualiti kuasa ini. Projek ini berfokus kepada ferroresonance di mana akan diterangkan dengan lebih lanjut lagi masalah ferroresonance ini sebagai salah satu daripada masalah kualiti kuasa. Ferroresonance boleh ditakrifkan sebagai voltan yang naik mendadak dengan secara tiba-tiba dalam masa yang singkat yang berlaku dalam sistem elektrik kuasa. Ferroresonance dalam pengubah voltan boleh berlaku disebabkan oleh proses penukaran dalam sistem elektrik kuasa atau disebabkan oleh panahan kilat. Ferroresonance sukar untuk dianalisis dan aktiviti ferroresonance ini sukar untuk di duga. Peralatan elektrik seperti pengubah voltan, pengubah voltan kapasitor, dan suis akan mengalami kerosakan teruk jika diserang oleh ferroresonance ini. Analisis ferroresonance terhadap pengubah voltan tiga fasa akan dijalankan dengan menggunakan perisian *Power System Computer Aided Design* (PSCAD) bagi mengkaji ciri-ciri ferroresonance ini. Semua faktor yang boleh menyebabkan ferroresonance haruslah dikenalpasti sebelum menjalankan simulasi. Jenis kerosakan, masa berlakunya kerosakan, dan konfigurasi alat ubah akan disimulasikan. Daripada simulasi PSCAD tersebut, bentuk gelombang tertentu akan diperolehi dan dari setiap bentuk gelombang yang diperolehi akan menentukan ciri-ciri ferroresonance dalam pengubah voltan tiga fasa. Sepanjang perlaksanaan projek ini, aktiviti ferroresonance terutamanya terhadap pengubah voltan tiga fasa akan di analisis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

TNB	-	Tenaga Nasional Berhad
VT	-	Voltage Transformer
PSCAD	-	Power System Computer Aided System
EMTDC	-	Electromagnetic Transients including DC
mA	-	miliampere
kA	-	kiloampere
kV	-	kilovolt
s	-	Second

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will cover more on introducing and identifying ferroresonance problem in power quality especially in three phase voltage transformer. From that, the conclusion will be determined based from the problem. There are lots of power quality problem that occurs in electrical power system such as frequency variations, voltage swell, harmonic distortion and interruptions. Ferroresonance phenomenon is one of them.

This project focuses on ferroresonance phenomenon as one of the power quality problems. The objectives and scope of the project are also will be explained briefly throughout this chapter. Objectives and scope are very important towards this project because it will give guidance through the whole process and with objectives and scope, it can give an overview on how to handle the project. In this project, analysis of Ferroresonance in Three Phase Voltage Transformer will be conducted by using software Power System Computer Aided Design (PSCAD). PSCAD is one of the professional's simulation tools for analyzing power system transients. PSCAD is the most suitable software that can be used for simulating the electromagnetic transients of electrical system [1].

1.2 Introduction

Ferroresonance is one of the power quality problems which can occur in any part of power system, including Malaysia. The occurrence of ferroresonance in Malaysia can be due to switching process at substation or from the lightning strike. In Malaysia, lightning strike can become the main reason contributing to ferroresonance phenomenon as Malaysia is in the second in place of the country that's have the highest number of lightning strike in the world. [2]. According to Malaysian Metrological Department, the highest mean annual number with lightning in Malaysia is recorded as many as 309 numbers of days of lightning per year at KLIA, Sepang.

In Malaysia, the effect due to lightning strike is very tremendous in damaging the equipment that had been struck by the lightning. Some of the incident involving lightning strike including the runway of the Sultan Abdul Aziz Shah airport in Subang that had been damaged seriously that caused three Firefly flights to be disrupted [3]. Other than that, in cases like in Ipoh, Perak which the struck from lightning caused the Ipoh areas went blackouts [4]. Another cases, which can relate to the ferroresonance phenomenon that occurs in Malaysia is the damaged and burned of transformer at the Tenaga Nasional Berhad (TNB) sub-station which because it had been struck by lightning. That incident had affected the power supply to the area affected [5].

Ferroresonance phenomenon in voltage transformers can occur in a condition when a nonlinear inductance that is the transformer cores is in series with the capacitance. The capacitance can be the capacitance of transmission lines, cables, capacitance voltage transformers or any shunt capacitors that is used in the power system. Other than that, is in a condition when a lightning strike the voltage transformer. The high electric current that carried by the lightning makes the voltage transformers receives a sudden high voltage that is more than the rated voltage in the voltage transformers will make the voltage transformers suffers a great external damage.

1.3 Voltage Transformer (VT)

A voltage transformers (VT) or potential transformers (PT), or known as the inductive voltage transformer is one of a type of instrument transformers that are used in power system for the purpose of measurement of the voltage output signals in medium or high voltage. It also can be used as a protective device's and relay in a medium or high voltage network because of their low costs and simple construction. Voltage transformers are designed to accurately stepping down high voltages so that protective relay and metering can be operated at a lower potential [6].

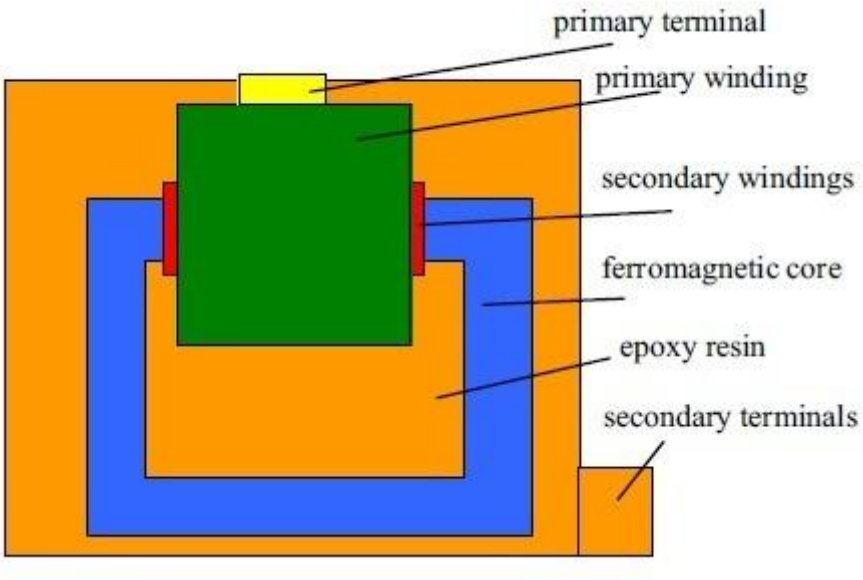

Figure 1.3.1: The basic scheme of single pole voltage transformer [6].

From figure 1.3.1, the basic constructions of the voltage transformer include the epoxy (epoxy is a type of strong glue) body, primary and secondary windings, and the magnetic circuit. The magnetic circuit of the voltage transformer is produced from the high quality silicon steel because to assure and guarantee the accuracy of the parameter in the whole range of rated voltage. Most of the magnetic circuit in the voltage transformers are using "C" shape [6].

In the secondary side of the voltage transformer, it consists of one to three winding which are used for the purposes of measuring, earth fault indicator and

also for protection purposes. Copper wire is used in the primary winding of the voltage transformer. The design of the shape and the number of primary turns are according to its specification because to meet a range of voltage values and parameters required [6]. The figure 1.3.2 below is the layout of a substation. The voltage transformer is located right after the capacitor voltage transformer. The voltage transformer is used to step down voltage for example from 132kV to 33kV/22kV/11kV. In the figure 1.3.3, it shows the voltage transformer circuit arrangement in a sub-station.

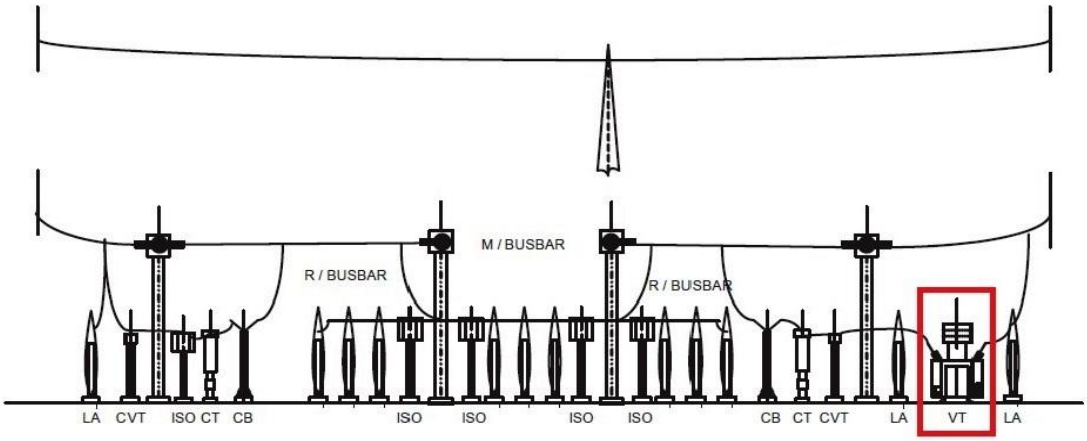

Figure 1.3.2: The location of voltage transformer in a substation [7].

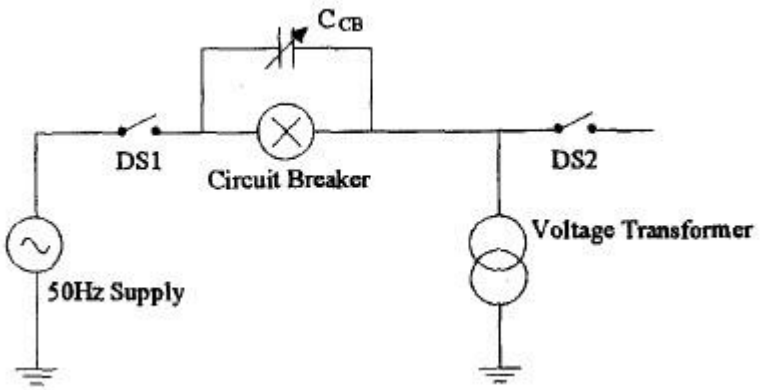

Figure 1.3.3: Sub-station voltage transformer circuit arrangement [8].

1.4 Problem Statement

Power quality and power disturbances have increasingly become an important factor throughout the electrical networks. Ferroresonance is one of these disturbances that can occur on distribution systems which can cause quality and security problems. One of the problems caused by ferroresonance is it can damage the voltage transformer and associated equipment such as switchgears, surge arrestor and capacitive voltage transformer. Apart from that, protection system failed to suppress the ferroresonance that's occurring in three-phase voltage transformer. Ferroresonance is hard to analyze because it does not occur regularly and the way of it occurrence is always unpredictable. In some cases, ferroresonance phenomena can result in false operation of the ground fault protection system. Furthermore, ferroresonance can also strike when a voltage transformer connected to an open circuit busbar in a sub-station is de-energised by opening a circuit breaker, leaving the non-linear transformer core to connect to the supply through the circuit breaker grading capacitance.

1.5 Objectives

Objective studies on Ferroresonance Analysis in Three Phase Voltage Transformer are:

- To determine and analyze the characteristics of ferroresonance in three-phase voltage transformer by using PSCAD.
- To analyze the effect of ferroresonance towards various tap changing of the voltage transformer.
- To analyze the transient of ferroresonance because of lightning and switching.

1.6 Scope of the Project

The project limits will cover simulation analysis of Ferroresonance in Three Phase Voltage Transformer by using software Power System Computer Aided Design (PSCAD). The parameter of the three phase voltage transformer will be taken from the Tenaga Nasional Berhad (TNB). The analysis of this project also limits only to the ferroresonance because of lightning and switching at tap changing 1, 7, and 16 of the three phase voltage transformer. The transformer used in this project limits only to one step down delta-star type of transformer which stepping down voltage from 33kV to 11kV with the rated power of 30MVA. Apart from that, the simulation will cover only three value of lightning only which are 34.5kA, 100kA and 200kA and will inject it only to phase A of the transmission line of this simulation. The result taken from this project will also limit only to the voltage measurement of the secondary side of the three phase voltage transformer. The result of the simulation will be analyzed to determine the characteristic of ferroresonance phenomenon in three phase voltage transformer.

1.7 Expected Result

The project research aims are:

a) To obtain better understanding about ferroresonance.
b) To obtain the characteristic of ferroresonance in three-phase voltage transformer
c) To analyze the ferroresonance activity in three-phase voltage transformer.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter will cover a lot on the analyzing the characteristics of ferroresonance, and ferroresonance in three phase voltage transformer. The factors that can cause ferroresonance in three phase transformer also will be identified. The modelling and simulation of the three phase voltage transformer are carried out by using one of the professional's simulation tools for analyzing power system transients that are the PSCAD software.

There are many past studies from the past journals in IEEE describing their studies for the transient analysis studies. (IEEE Modelling And Analysis Guidelines for Slow Transients – Part III: The Study of Ferroresonance, IEEE Transactions on Power Delivery, vol.15, no. 1, January 2000. IEEE Experimental and Numerical Analysis of Fast Transient Phenomena in Distribution Transformer, IEEE Power Engineering Society Winter Meeting, 2000, vol. 3, pp 2193- 2198) The analysis of the transient in three phase voltage transformer is basically modelled by a group of important parameters to represent the elements that can contribute to the ferroresonance phenomenon.

2.2 Voltage Transformer

In this analysis, voltage transformer that will be used in this project is the step down three phase voltage transformers 132kV/33kV or 132kV/22kV or 132kV/11kV that located in between transmission side and distribution side in main power substation (Pencawang Masuk Utama or known as PMU). Figure 2.2.1 below shows the circuit of the operating principle of the constant voltage transformer. The circuit consists of three capacitors and nine windings both from primary and secondary side [9].

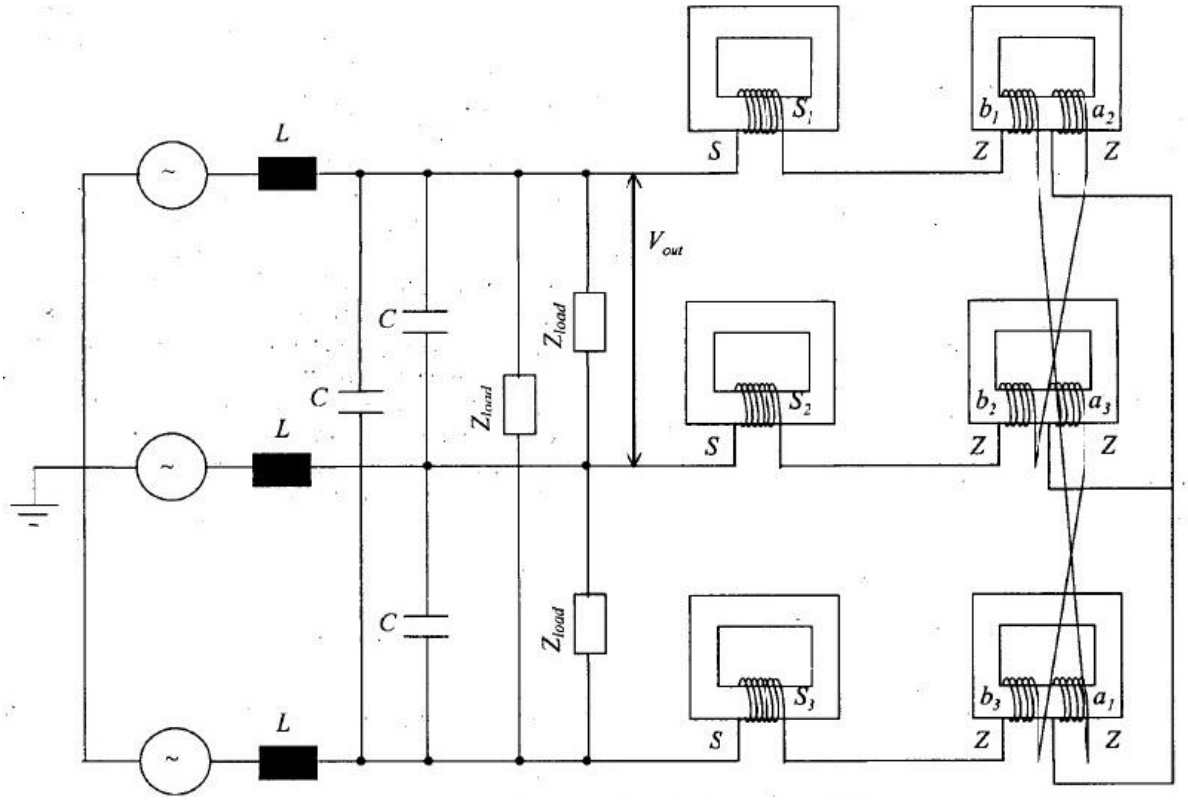

Figure 2.2.1: Circuit model of three phase constant voltage transformer [9].

2.3 Ferroresonance

The word ferroresonance was firstly used by Boucherot in 1920 in his research to describe a complex resonance oscillation in a series RLC circuit with nonlinear inductance [10]. Ferroresonance phenomenon can be defined as a condition where the occurrence of high distorted levels of overvoltage which can result to the damage of electrical power system equipment such as voltage transformer, switching device, lightning arresters and underground cable. Although ferroresonance is a phenomenon that is hard to predict, some phenomena related to the occurrences of the ferroresonance have been provided through the years via the information obtained from the past research. Some of the phenomena which can help in identifying a ferroresonance situation are over currents and over voltages, protection device failed to operate, overheating, insulation breakdown, and also the damage of electrical equipment that has been affected by ferroresonance phenomenon [11]. The ferroresonance can occur at 50Hz fundamental frequency or sub-harmonics frequencies at 33 ½ Hz, 16 2/3 Hz and 10 Hz [12].

The term ferroresonance can be referred to a condition where power system voltages resonate at the natural frequency (50Hz) with certain excited components within the systems which include a nonlinear ironclad inductance that is typically a transformer winding. For a ferroresonance to occur, a series LC circuit is excited at or near its natural frequency. Ferroresonance occurs when the components in the series circuit reach critical values which the inductance is saturate. As the ferroresonance phenomenon happen, the system voltage may surpass the rated values, which will make to the equipment damage or failure [7].

There are two types of conditions which are considered as a cause of ferroresonance:-

a) Switching;

Switching is one of the types of ferroresonance that occur in power systems. Switching transient in power systems have always been a matter of concern in studies of power equipment insulation coordination. They are generally caused by arcing faults and static discharge. Apart from that, major power systems switching disturbances that were initiated by the utilities to correct line problems might happen several times a day. These types of behaviour will automatically trigger the ferroresonance phenomena inside the power system and the equipment [7].

Figure 2.3.1 below shows the example waveform of the simulation towards ferroresonance behaviour that is caused by the switching transient. In this figure, ferroresonance occurs after the fault clearing time at 0.9 second for several cycles before it becomes stabilized.

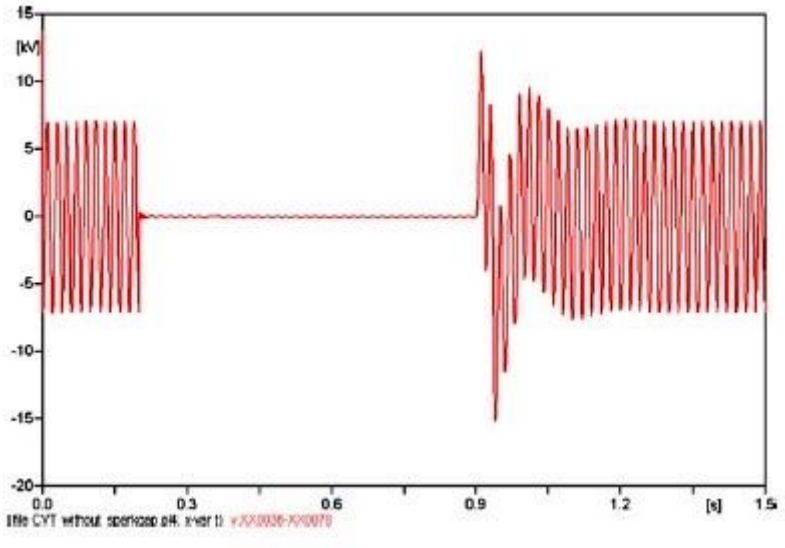

Figure 2.3.1: Ferroresonance caused by switching transient [7].

b) Lightning strike;

Lightning is one of the natural phenomenons which can cause disaster to the electrical power system in which the lightning strike caused the transient overvoltage which also can be defined as the ferroresonance phenomenon. In Malaysia, lightning activities occur regularly as Malaysia is placed second of the country which has the highest number of lightning strike in the world. According to Malaysian Metrological Department, the highest mean annual number with lightning in Malaysia is recorded as many as 309 numbers of days of lightning per year at KLIA, Sepang.

The discharges of the lightning can occur between or within clouds, or it also can occur from cloud to the ground. From both cases of the lightning discharges, only clouds to the ground flashes affect us the most. Based on the information obtain from the TNB personnel, basically the typical lightning strike will reach a mean stroke of 20kA, an average of 34.5kA and can reach up to about 200kA in about 50 to 200 nanoseconds. The equipment that had been struck by lightning suffers tremendous external damage that could lead to possible fire and explosion which mostly can occur at voltage transformers. Apart from that, lightning strike is a natural source of overvoltage that comes from natural phenomenon which can trigger ferroresonance occurrence inside equipment especially in voltage transformer in an electrical power system. Figure 2.3.2 below illustrates the example of simulation waveform of ferroresonance behaviour due to the lightning strike.

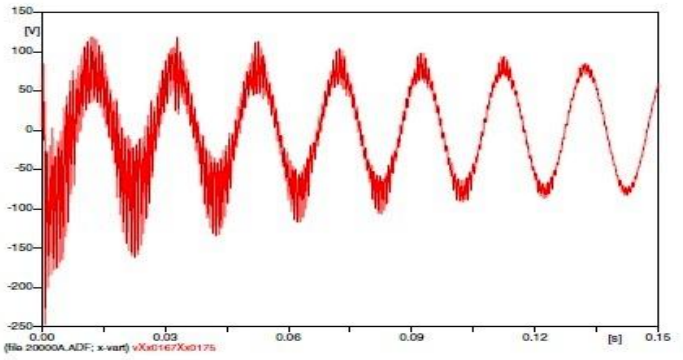

Figure 2.3.2: Ferroresonance caused by lightning strike [7].