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FINAL YEAR PROJECT REPORT II

FERRORESONANCE MITIGATION METHOD USING ACTIVE FILTER IN VOLTAGE TRANSFORMER (VT)

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

Faculty of Electrical Engineering
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I declare that this report "*Ferroresonance Mitigation Method Using Active Filter in Voltage Transformer (VT)"* 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 the candidature of any other degree.

Signature	: …….
Name	: Mohamad Azrul Nizar bin Azhar
Date	: 15th June 2017

DEDICATION

Alhamdulillah. I am fully gratitude to Allah S.W.T. with His grace. I have completed this Final Year Project with great success in 28 weeks. During this period, it would not have been possible without the help from other people surround me.

Thank you for those who helped me a lot, especially my supervisor and project teammate for giving me a guidance during these 28 weeks. A special thanks to my supervisor, Mr. Mohd Khairi bin Mohd Zambri for his guidance and monitoring.

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ABSTRACT

Ferroresonance can be defined as a sudden overvoltage and overcurrent at a point of transient in the electrical power system in a short period of time. Ferroresonance in voltage transformer can occur due to lightning strike activities. Ferroresonance is difficult to analyze and the occurrence of ferroresonance phenomenon is unpredictable. Electrical equipment such as voltage transformer and capacitor voltage transformer that deals with ferroresonance phenomenon can cause serious damage to the equipment. The lightning strike can occur for a short period of time and caused ferroresonance happened which change transient character. The increasing level of lightning source cause the increasing of sudden overvoltage and also increase the number of transient cycles on the secondary side of the voltage transformer. The purpose of this research is to investigate and analyze the mitigation method which can be used to reduce the impact of ferroresonance on three-phase voltage transformer. The analysis of ferroresonance mitigation method using active filter in voltage transformer is conducted by using Power System Computer Aided Design (PSCAD) software. To run the simulation, all the factors that can cause the ferroresonance have to be identified first. The simulation is analyzed based on the voltage reading of the transformer. The passive filter and active shunt filter are used as the mitigation method in order to mitigate the ferroresonance effect on the voltage transformer. By using the passive filter on the voltage transformer can reduce the number of ferroresonance cycle, but the sudden voltage still remains higher while the active shunt filter can reduce the number of ferroresonance cycle better than passive filter. Besides that, it is also can decrease the peak transient voltage which can cause damage at the voltage transformer.

ABSTRAK

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 panahan kilat. *Ferroresonance* sukar untuk dianalisa dan aktiviti *ferroresonance* ini sukar untuk diduga. Peralatan elektrik seperti pengubah voltan dan pengubah voltan kapasitor akan mengalami kerosakan teruk jika diserang oleh *ferroresonance* ini. Panahan kilat boleh berlaku untuk tempoh yang singkat dan menyebabkan *ferroresonance* berlaku sehingga menyebabkan berlakunya penukaran perihal transien. Peningkatan tahap sumber kilat menyebabkan peningkatan voltan secara tiba-tiba dan juga meningkatkan bilangan kitaran transien pada bahagian sekunder pengubah voltan. Tujuan kajian ini adalah untuk menyelidik dan membuat analisa tentang cara penyelesaian untuk mengurangkan impak *ferroresonance* dalam pengubah voltan tiga fasa. Analisis kaedah mitigasi *ferroreresonance* menggunakan penapis aktif dalam pengubah voltan dijalankan dengan menggunakan perisian *Power System Computer Aided Design (PSCAD)*. Semua faktor yang boleh menyebabkan *ferroresonance* haruslah dikenalpasti sebelum menjalankan simulasi. Simulasi dianalisa berdasarkan kepada bacaan pada pengubah voltan. Penapis jenis aktif yang mempunyai sambungan secara selari akan digunakan sebagai cara penyelesaian dalam kajian ini untuk mengurangkan impak fenomena *ferroresonance* pada pengubah voltan tiga fasa. Penapis pasif dan penapis pirau aktif digunakan sebagai kaedah untuk mengurangkan kesan *ferroresonance* pada pengubah voltan. Dengan menggunakan penapis pasif pada pengubah voltan boleh mengurangkan bilangan kitaran *ferroresonance*, tetapi voltan secara tiba-tiba masih kekal lebih tinggi manakala penapis pirau aktif boleh mengurangkan bilangan kitaran *ferroresonance* lebih baik daripada penapis pasif. Selain itu, ia juga boleh mengurangkan voltan transien puncak yang boleh menyebabkan kerosakan pada pengubah voltan.

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LIST OF ABBREVIATIONS

AFSC	–	Active Filter Suppression Circuit
CVT	–	Capacitive Voltage Transformer
FSC	–	Ferroresonance Suppression Circuit
PFSC	–	Passive Filter Suppression Circuit
PSCAD	–	Power System Computer Aided Design
TNB	–	Tenaga Nasional Berhad
VT	–	Voltage Transformer

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will tell about the introduction of the study and problem statement. The problem of ferroresonance cause is briefly described. Besides that, the objective and scope of the study also explained in this chapter. The purpose of this project is to analyze and design active filter of how it will affect the ferroresonance suppression circuit (FSC) to mitigate the ferroresonance phenomenon in the voltage transformer. This project will be conducted by using software Power System Computer Aided Design (PSCAD). PSCAD is the most suitable software that can be used for simulating the electromagnetic transients of the electrical system.

A 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 suffer a great external damage.

Ferroresonance suppression circuit (FSC) is installed on the primary side of the transformer to reduce the ferroresonance phenomenon. Ferroresonance is a special case phenomenon of disturbance that involve a sudden increase of voltage and current that can cause severe damage to electrical component such as the transformer in a substation. Besides that, this phenomenon will affect power quality that can cause the performance of the whole system to be affected.

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. Voltage transformers are designed to accurately stepping down high voltages so that protective relay and metering can be operated at a lower potential [1]. Voltage transformers, particularly expose to ferroresonance on account of its operating characteristics and nonlinear character, because it is designed to work under situation similar to no-load ones. Besides that, voltage transformers are even more exposed to ferroresonance, since it has a higher inductive character and also need a lower capacitance to form the ferroresonance circuit.

1.1 Problem Statement

A three-phase voltage transformer is commonly used in electrical power system for the purpose of stepping down the system voltage to a safe value in order to feed into a low rating of relays or other loads. It functions as a protective relaying purpose, to protect the electrical equipment connected to it from damaging. However, if there is any type of disturbance involving frequency waveform either current or voltage in power network which can lead to the electrical equipment damage. Ferroresonance is one of the examples of the disturbance. One of the problems caused by ferroresonance is that it can damage the voltage transformer and associated equipment such as switchgears, surge arrestor and capacitive voltage transformer. Ferroresonance is hard to analyze because it does not occur regularly and the way of its occurrence has been always unpredictable. This phenomenon will cause the protection device failed to operate as usual. In order to mitigate and protect the whole system, a mitigation method of this phenomenon needs to be designed on the primary side of the transformer to improve the voltage transformer performance.

1.2 Objectives

The objective of this project is as follows:

1) To study the characteristics of ferroresonance in voltage transformer.
2) To design and analyze the effect of active filter for ferroresonance mitigation method in voltage transformer.
3) To improve performances of voltage transformer by analyzing the ferroresonance waveform.

1.3 Scope of Works

Based on the study of the Ferroresonance Mitigation Method using Active Filter in Voltage Transformer (VT), the scopes will focus on the design of active filter mitigation methods which simulate by using Power System Computer Aided Design (PSCAD) and improvement of the ferroresonance problem by using ferroresonance suppression circuit (FSC).

1.4 Expected Project Outcome

The project research aims are:

1) To obtain a better understanding about ferroresonance.
2) To mitigate the occurrence of ferroresonance by applying the active filter for ferroresonance suppression circuit (FSC) in voltage transformer.
3) To obtain and analyze the waveforms on how the active filter effect in mitigating the ferroresonance phenomenon.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter will be analyzed further on the behavior of ferroresonance, voltage transformer and active shunt filter. The behavior or characteristics of ferroresonance which include the causes of the phenomenon, effects and investigated the mitigating solution of reducing the ferroresonance. The process of analyzing the ferroresonance phenomenon has been carried based on previous studies done by researchers. Besides that, this chapter also discusses about the active shunt filter which has been selected to be used to mitigate the impact of ferroresonance.

2.1 Voltage Transformer

A three-phase voltage transformer is commonly used in electrical power system for the purpose of stepping down the system voltage to a safe value in order to feed into a low rating of relays or a meter or other loads. The voltage transformer functions as a protective relaying purpose, to protect the electrical equipment connected to it from damaging. In Malaysia, three-phase system is used instead of single-phase or two-phase system is primarily ascribable to the economic consideration. In this research project, a step-down three-phase voltage transformer with 132 kV/11 kV in transmission substation is being applied to analyze the ferroresonance phenomenon with mitigating solution. Figure 2.1 below shows the circuit of the operating principle of the constant voltage transformer. From the figure below, it is shown that there are three capacitors and nine windings, both from primary and secondary side [2].

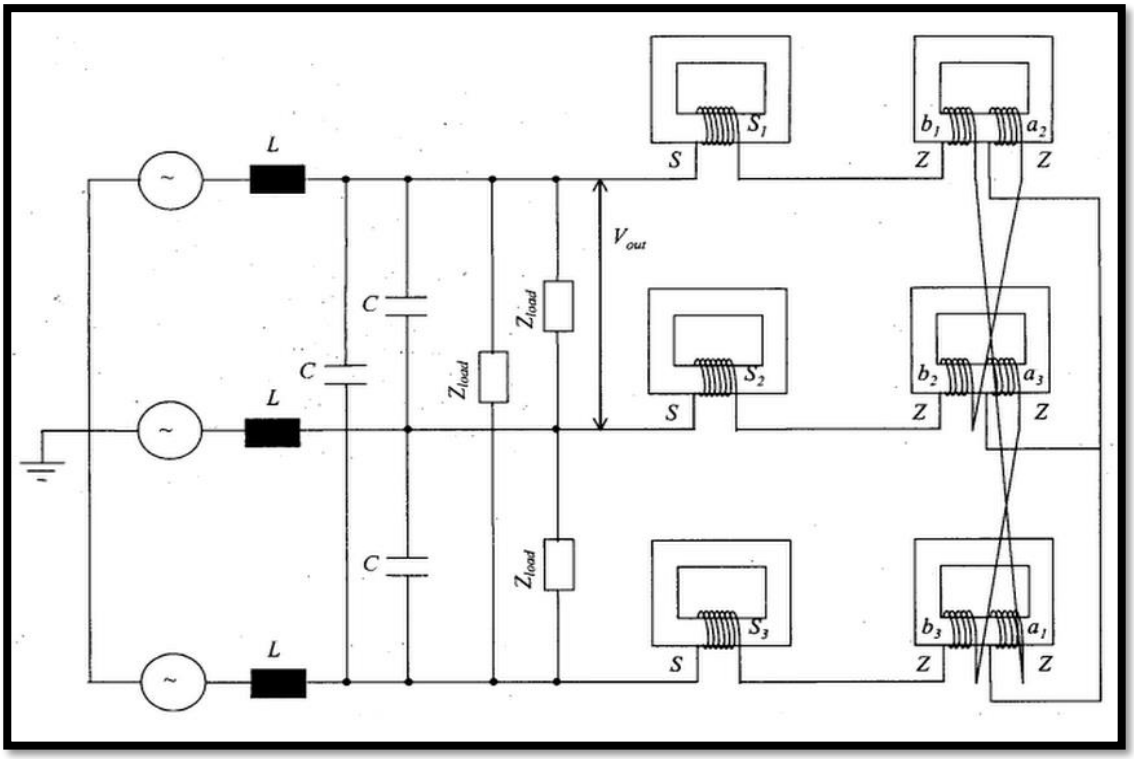

Figure 2.1: Circuit model of three phase constant voltage transformer [2].

Figure 2.2 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 132 kV to 11 kV. In Figure 2.3, it shows the voltage transformer circuit arrangement in a sub-station.

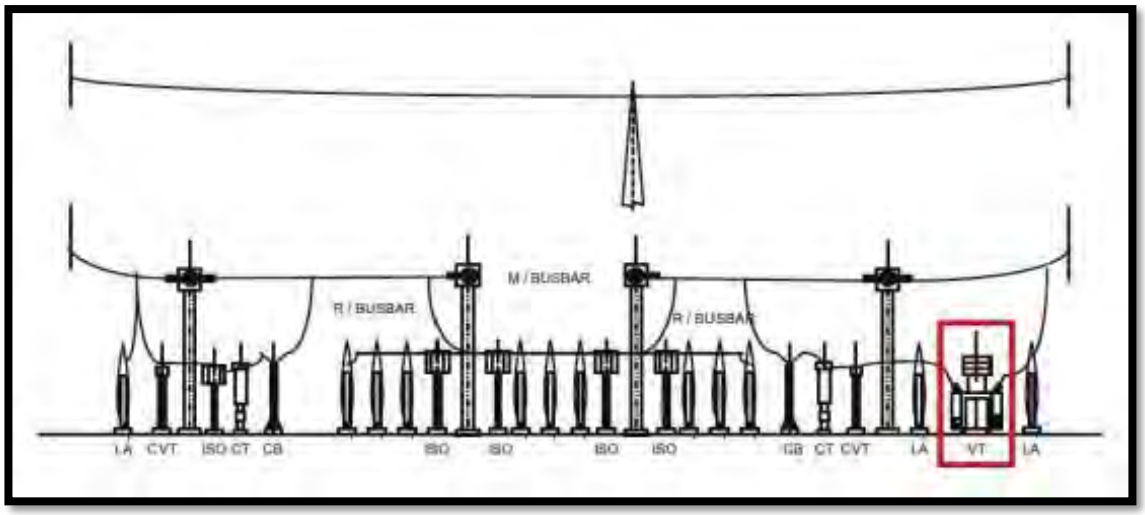

Figure 2.2: The location of voltage transformer in a substation [3].

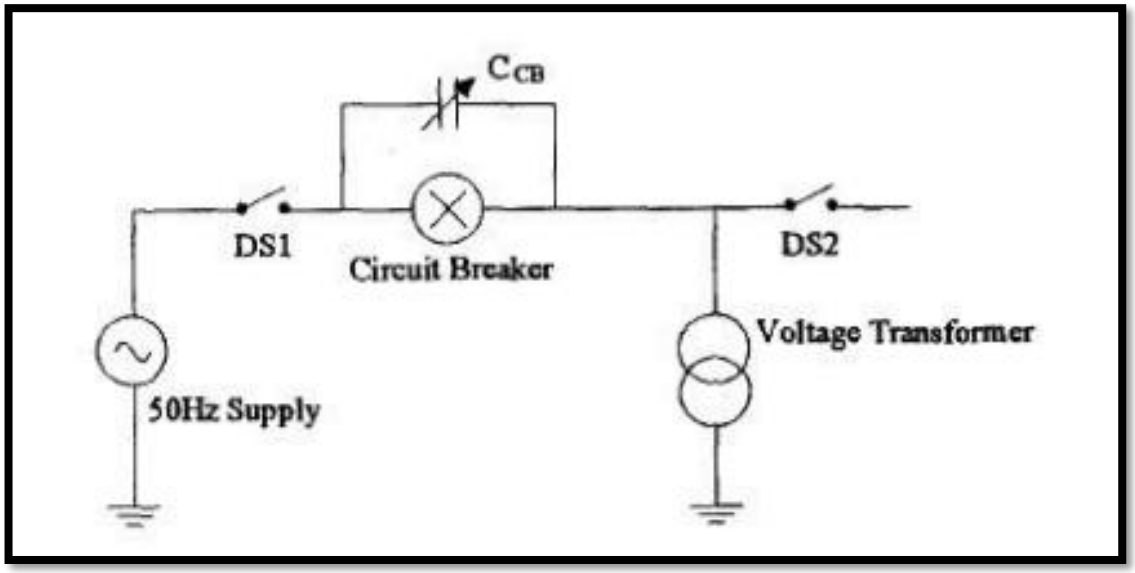

Figure 2.3: Sub-station voltage transformer circuit arrangement [4]

2.2 Ferroresonance

The word ferroresonance refers to a natural phenomenon where the resonance happens during a non-linear inductive reactance is connected in series with the capacitive reactance [5]. Ferroresonance can occur when the primary of a voltage transformer is connected line to ground in an ungrounded circuit. This configuration results in the magnetizing reactance of the VT being in a parallel loop with the coupling capacitance to ground of the system [5]. Besides that, ferroresonance occurrence in a voltage transformer occurs when it energized through grading capacitance of one or more open circuit breaker, a voltage transformer connected to an isolated neutral system, and a transformer accidentally energized in only one or two phases [5].

It was firstly introduced by a French engineer, Paul Boucherot in 1920 [6]. This phenomenon includes abnormal amounts of overvoltage and overcurrent distortion oscillating in the electrical circuit [7]. The characteristic of ferroresonance which makes it differ from the linear resonance is that the happening of the ferroresonance is caused by the sudden jumping of either a current or voltage stable operating state into an unstable state.

The occurrence of this phenomenon happens when an interruption occurs on one of the unloaded phases of the 3-phase system which consist of mainly inductive and capacitive load without or little resistive load also due to excessive current flow in the primary winding because of sustained ferroresonance between the circuit breaker grading capacitance and

non-linear magnetizing inductance of VT [7]. As a result, overvoltage may occur if the other two phases were not interrupted quickly. The factors contributing ferroresonance have two conditions in general. Firstly, is due to the switching operation. It is normally caused by arcing faults and static discharge. Secondly, due to a lightning strike it will trigger the occurrence of ferroresonance. Other causes of ferroresonance may due to low-loss transformers, single-phase operations and underground cables in the primary circuits [7].

The consequences of the occurrence of ferroresonance such as the overcurrent and overvoltage can cause severe damages to the equipment connected to the voltage transformer. The damages mentioned will be as such of the malfunction of voltage transformers, abnormal neutral-point voltage rise, incorrect earth-fault indication and etc. Subsequently, the whole power system will be facing the transmission and distribution failure which will then lead to blackouts in the vicinity.

Ferroresonance phenomenon is often be regarded as unpredictable and random. However, there are few symptoms to recognize the incident. For instance, at the point when over currents and over voltages with high levels of harmonics happen in the equipment or sustainable levels of distortion takes place in the power system would show the presence of ferroresonance [7]. When there is a sign of electrical equipment damages, disoperation of protective devices, loud noise, overheating, flicker or insulation breakdown or flicker would imply the presence of ferroresonance [7]. The discharge of lightning, which happened within few seconds of time will cause the transient overvoltage to occur [8].

The mitigation method for ferroresonance is important so as to reduce the impact of the phenomenon which can cause power losses in the distribution system. For the past decades, many researchers had been investigating many mitigating solutions to solve the problem. There are many references which can be referred for further study on the matter. The recommended approaches introduced by the past researches includes interlocking, potential transformer relocations, revises switching procedures, and adding circuit losses, for example by adding a damping resistor, a damping reactor, and active damping devices [9].

2.2.1 Ferroresonance in Voltage Transformer

Obviously, the ferroresonance occurrence in transformer can be classified into two types which are series ferroresonance and parallel resonance [10]: