MITIGATION OF FERRORESONANCE IN POWER TRANSMISSION SYSTEM USING STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

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In the name of Allah, the Most Merciful and the Most Beneficent.

"To my beloved father, mother, brother and friends, thanks for being there throughout this journey"

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ABSTRACT

Nowadays power quality becomes critical issue in power electrical system. The connection of three-phase transformer through underground cables is growing fast in residential, commercial, industrial and rural applications. Due to this increasing situation, the possibilities of having a series connected capacitance and a non-linear inductance, prone to ferroresonance, become more probable. Not only the cable capacitance (and consequently its length) is an important factor to take into consideration in the transformers ferroresonance, but also other elements are completely necessary for ferroresonance to appear. All these factors affect the ferroresonance appearance in several ways, producing the phenomenon just as well as making some damaging consequences appear. Because of that, it is necessary to have a general idea about what would be the best preventive decisions to take in order to avoid unexpected surprises. First of all it is necessary to have accurate model consist of ferroresonance then we should apply any device to smooth the sharp effect of it. In this project one of the FACTS devise has been applied, static synchronous series compensator (SSSC) to palliate ferroresonance. It is shown that the performance of system becomes better than before and maintain at its acceptable rated value.

ABSTRAK

Pada masa kini, kualiti kuasa menjadi isu kritikal dalam sistem kuasa elektrik. Sambungan pengubah tiga fasa melalui kabel bawah tanah berkembang pesat di kediaman, aplikasi komersil, industri dan luar bandar. Oleh kerana keadaan ini semakin meningkat, kemungkinan mempunyai kemuatan sambungan siri dan kearuhan bukan linear, seterusnya terdedah kepada ferroresonance, menjadi lebih tinggi. Bukan sahaja kemuatan kabel (dan seterusnya panjang) satu faktor penting untuk mengambil kira dalam ferroresonance transformer, tetapi juga unsur-unsur yang lain adalah perlu untuk ferroresonance untuk muncul. Semua faktor yang mempengaruhi penampilan ferroresonance dalam beberapa cara, menghasilkan fenomena yang sama juga membuat beberapa akibat merosakkan muncul. Oleh kerana itu, adalah perlu untuk mempunyai idea umum mengenai apa yang akan menjadi keputusan pencegahan yang terbaik untuk mengambil untuk mengelakkan kejutan yang tidak diduga.Simulasi telah dilaksanakan menggunakan perisian ATP-EMTP. Adalah perlu untuk mempunyai model ferroresonance yang tepat seterusnya menentukan peranti yang sesuai bagi menghalang atau mengurankan kesan ferroresonance. Dalam projek ini salah satu komponen FACTS telah digunakan iaitu pemampas siri segerak statik (SSSC) untuk meredakan ferroresonance. Prestasi sistem menjadi lebih baik daripada sebelumnya dan berjaya mengekalkan tahap voltan pada nilai kadaran.

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LIST OF ABBREVIATIONS

DC	-	Direct Current
AC	-	Alternating Current
ATP	-	Alternative Transient Program
EMTP	-	Electro Magnetic Transient Program
HV	-	High Voltage
LV	-	Low Voltage

LIST OF SYMBOLS

C	-	Capacitance
L	-	Inductance
R	-	Resistance
E	-	Voltage source
F	-	Frequency
w	-	Frequency
Z	-	Impedance
C_s	-	Coupling Capacitance
$R_m(v)$	-	Transformer Core Losses
$L_m(\varphi)$	-	Nonlinear Inductance
X_L	-	Impedance of Inductor
X_C	-	Impedance of Capacitor
L_{sat}	-	Non-linear Inductor Saturation
h_C	-	Coercive Magnetic Field
h_m	-	Last Return Point of the Magnetic Field
M_{rev}	-	Reversible Component of Magnetizing
M_{irr}	-	irreversible Component of Magnetizing
M_s	-	Saturation Magnetizing
H_e	-	External applied Field
α	-	Molecular field parameter

CHAPTER 1

INTRODUCTION

1.1 Introduction to Power Quality

There is no doubt the enhancement of power quality and stability in power system are critical issues. Any reasons which lead to distortion must be considered and mitigated. Transients occur on power systems due to a variety of reasons. Ferroresonance is a mysterious phenomenon [2-4-7].

The issue of electricity power sector delivery is not confined to only energy efficiency and environment issues and also it depends on quality and continuity of supply. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. Power quality may also be defined as the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment.

Other terms used for power quality are supply reliability, service quality, voltage quality, current quality, quality of supply, and quality of consumption According to IEEE Standard 1159-1995, the definition of power quality is given as :

"the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment Power quality problems concerning frequency deviation are the presence of harmonics and other departures from the intended frequency of the alternating supply voltage." On the other hand, PQ problems concerning voltage magnitude deviations can be in the form of voltage fluctuations, especially those causing flicker . Furthermore, due to the power system impedance, any current (or voltage) harmonic will result in the generation and propagation of voltage (or current) harmonics and affects the entire power system.

1.1.2 Unpredictable Events

Both electric utilities and end users agree that more than 60% of power quality problems are generated by natural and unpredictable events. Some of these are faults, lightning, resonance, and ferroresonance.

Ferroresonance is a resonance situation with nonlinear inductance which is equal of capacitance in the network. The inductive reactance not only depends on frequency, but also on the magnetic flux density of an iron. Core coil (transformer iron- core). High overvoltage due to Ferroresonance can cause failures [2-9-10].

1.2 Problem statement

A good power system should possess the ability to regain its normal operating condition after a disturbance. Since ability to supply uninterrupted electricity determines the quality of electric power supplied to the load, stability that is regarded in the current study is one of the important topics in power system. Power system stability is critical issue at the event of possible disturbances such as ferroresonance and load switching; Consequence power system may experience sustained oscillations.

Practically, in electrical system we use transformer at generation and distribution parts as well as transmission part of the system, in case of ferroresonance hence; the step up transformers are used, the abnormal rates of harmonics and over current and over voltage which is produced in transformer due to ferroresonance transmit to whole entire system and the rest of system sense abnormal situation because of that. Reduction of the oscillation is also important. Damping has to be provided to the system in order to avoid this. The availability and successfully of FACTS devices such as SSSC to damp these oscillations have been applied in this project. This project will also illustrate the effective ways of SSSC to damp the effect of ferroresonance in the power system.

1.3 Objectives of this project

The objectives of the project are:

i. The main objective of this project is to simulate the ferroresonance phenomenon on power system. An alternative Transient Program-Electromagnetic Transient Program (ATP) is used to carry out this project.
ii. To determine methods to minimize/ reduce the risk of ferroresonance also modeling of ferroresonance by detailed model to show transient behavior of the output voltage waveform.

iii. To model SSSC and coupling capacitance.
iv. To design a time switching controller for SSSC function.
v. To investigate the harmonic effect with and without connecting SSSC.
vi. To determine Fourier series once Ferroresonance occur.
vii. To compare performance with/without apply SSSC.

1.4 Scopes of the project

The scopes of the project are:

i. The aim of this research is to create ferroresonance situation, because at the ferroresonance time; nonlinear inductance of transformer combine with the capacitance of line and current will jump up.

ii. To prove that ferroresonance can cause disturbance in terms of power quality issue; and transient situation in the system.

iii. The main scope of this project is to identify method to minimize the impacts of ferroresonance on power system. Using compensator such as SSSC will lead to decrease in the sharp attack of ferroresonance into system. In terms of power quality issue we have to have the voltage and current in standard rate, the investigation of harmonic problem which is directly related to power quality is another goal of this project.

1.5 Methodology

i. **First,** to construct a complete model of our project, ferroresonance was created based on actual B-H curve data.

ii. **Second**, the effect of ferroresonance into the power system configuration will be considered.

iii. **Third**, SSSC was designed and the output waveform was analyzed with/without SSSC.

iv. **Finally**, the whole of modelling should carry out in ATP software. The results show mitigation or smooth the shock and sharp effects of ferroresonance.

1.6 Report Organization

This thesis consists of five chapters describing all the work done in the project. The thesis outline is generally described as follows.

Chapter 1: This chapter explains the introduction of the project. Brief general background is presented. The objectives of the project are clearly phased with detailed. The research scope implementation plan and methodology are also presented.

Chapter 2: This chapter discusses the project background and some previous literature review.

Chapter 3: this chapter describes the methodology and stages which is implemented to model a ferroresonance and compensator during this project.

Chapter 4: This chapter discusses and analyzes the results of output waveform once ferroresonance occurs and the comparison of using SSSC and without it.

Chapter 5: This chapter presents the conclusion based on the analysis and comparison of results in chapter 4. Recommendations for future works are also provided.

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