

STUDY ON THE NON LINEAR CHARACTERISTIC OF POWER
TRANSFORMER AND THEIR EFFECT FERRORESONANCE

SALIZAWATI BT HJ. SHAMSUDDIN

A project report submitted in partial fulfilment
of the requirement for the award of the degree of
Master of Engineering (Electrical Engineering)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

May 2008

ABSTRACT

Ferroresonance can occur in electrical power system and consequently can cause damage such as due to voltage transformer overheating or power transformer overvoltages. This study involves simulation work to simulate various conditions under which ferroresonance can occur in typical extra high voltage substations. The ATP-EMTP simulation program was used to model various power system components and simulate the ferroresonance phenomena. The effects of the non-linear characteristics of power transformers are also studied. Methods to prevent the ferroresonance conditions from occurring and hence avoiding equipment damages and losses were also proposed based on the simulation work.

ABSTRAK

Feroresonan berlaku ke atas sistem kuasa elektrik yang boleh menyebabkan kerosakan pada sistem tersebut. Contohnya kejadian pemanasan lebihan pada pengubah voltan ataupun voltan lampau pada pengubah kuasa. Kajian ini melibatkan kerja simulasi bagi pelbagai keadaan yang boleh berlakunya feroresonan pada pencawang elektrik EHV. Program ATP-EMTP merupakan satu program simulasi yang berkeupayaan untuk menghasilkan pelbagai model komponen sistem kuasa dan seterusnya melakukan simulasi ke atas sistem. Kajian simulasi ini melaporkan kesan sifat tak lurus keluli pengubah kuasa terhadap feroresonan dan kaedah untuk mengelakkan berlakunya feroresonan. Justeru itu, kerosakan dan kerugian komponen dapat dihindarkan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xv
	LIST OF SYMBOLS	xvi
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Objectives	2
	1.3 Scope of Work	2
	1.4 Project Flow Chart	3
	1.5 Organisation of Thesis	4
2	LITERATURE REVIEW	5
	2.1 Introduction	5
	2.2 Case Study by Zia Emin and Yu Kwong Tong: Ferroresonance Experience in UK: Simulation and Measurement	5

2.2.1 Objective	5
2.2.2 Voltage Transformer	6
2.2.2.1 Comparison Field Measurement and Simulation	7
Result	
2.2.3 Single Phase Traction Supply Transformer	8
2.2.3.1 Comparison Field Measurement and Simulation	9
Result	
2.2.4 Conclusion	9
2.3 Case Study by YK Tong: NGC Experience on Ferroresonance	10
In Power Transformer and Voltage on HV Transmission	
System	
2.3.1 Introduction	10
2.3.2 Power Transformers	10
2.3.3 Voltage Transformer	11
2.3.4 Measurement to Predict or Prevent Ferroresonance	11
2.4 Case Study by David A.N. Jacobson: Example of	12
Ferroresonance in High Voltage Power System	
2.4.1 Objective	12
2.4.2 Wound Potential Transformer-Circuit Breaker	12
Grading Capacitor	
2.4.2.1 Description of Disturbance	12
2.4.2.2 Simulation Result	13
2.4.2.3 Mitigation Options	13
2.4.3 Transformer – Circuit Breaker Grading Capacitor	14
2.4.3.1 Description of Disturbance	14
2.4.3.2 Simulation Result	14
2.4.3.3 Mitigation Options	15
2.4.4 Open Delta Potential Transformer	15
2.4.4.1 Description of Disturbance	16
2.4.4.2 Simulation Result	16
2.4.4.3 Mitigation Options	17
2.4.5 Conclusion	17
2.4 Summary	17

3	FERRORESONANCE	19
3.1	Basic of Ferroresonance	19
3.2	Main Characteristic	22
3.2.1	Sensitivity to System Parameter Value	22
3.2.2	Sensitivity to Initial Condition	24
3.3	Classification of Ferroresonance Mode	25
3.3.1	Fundamental Mode	25
3.3.2	Sub harmonic Mode	25
3.3.3	Quasi Periodic Mode	26
3.3.4	Chaotic Mode	26
3.4	Power System Ferroresonance	28
3.5	Symptoms of Ferroresonance	28
3.5.1	Audible Noise	29
3.5.2	Overheating	29
3.5.3	Arrestor and Surge Protector Failure	29
3.5.4	Flicker	30
3.5.5	Cable Switching	30
4	METHDOLOGY	32
4.1	System Modeling	32
4.2	ATP-EMTP Simulation	32
4.3	Selected model and Validation	33
4.4	Resistor and Capacitor Model	34
4.5	Overhead Transmission Lines	34
4.6	Transformer Model	34
4.6.1	Nonlinear and frequency Dependent Parameter	36
4.6.1.1	Modelling of Iron Core	36
4.6.1.2	Modelling of Eddy Currents Effects	37
5	SIMULATION: 400kV DOUBLE CIRCUIT CONFIGURATION	38
5.1	Introduction	38
5.2	Simulation Procedures	38
5.3	Circuit Description	39
5.4	Simulation Model	40

5.4.1 Typical Overhead Line Spacing for 400kV	42
5.4.2 BCTRAN Transformer Model	44
5.4.3 Non-linear Inductance	47
5.4.4 Resistor and Capacitor Model	48
5.5 Result of Simulation for 400kV Double Circuit	48
5.6 Simulation by Changing the Magnetization Characteristic	51
5.6.1 Simulation Model	51
5.6.2 Simulation Result	56
5.6.2.1 Simulation Result for Curve 1	56
5.6.2.2 Simulation Result for Curve 2	58
5.6.2.3 Simulation Result for Curve 3	59
5.6.2.4 Simulation Result for Curve 4	60
5.7 Mitigation Technique	62
5.7.1 Simulation Model	64
5.7.2 Simulation Result	64
6 CONCLUSION AND RECOMMENDATION	70
6.1 Conclusion	70
6.2 Recommendation	71
REFERENCES	72

CHAPTER 1

INTRODUCTION

1.1 Introduction

A power quality is a term used to describe electrical power that motivates an electrical load and the load's ability to function properly with that electric power. With a poor power quality, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor power quality.

As a general statement, any deviation from normal of a voltage source (either DC or AC) categorized as a power quality issue. Power quality issues can be high-speed events such as voltage impulses / transients, high frequency noise, wave shape faults, voltage swells and sags and total power loss. Power quality issues will affect each type of electrical equipment differently. By analyzing the electrical power and evaluating the equipment or load, we can determine if a power quality problem exists.

Power quality problems manifest themselves in variations in the voltage has been obtained. This variation can be in the form of transients due to switching or lightning strikes, sags or swells in the amplitude of the voltage, a complete interruption in the supply, or harmonic distortion caused by non-linear loads in the system which may likely lead to the occurrence of ferroresonance.

1.2 Objective

The main objectives of this project is to simulate the ferroresonance event on extra high voltage substation power transformer based on parameters, features, components and arrangements of the substation power system. An alternative Transient Program- Electromagnetic Transient Program (ATP-EMTP) will be used to carry out the simulation in order to study the phenomenon and therefore to determine methods to minimize or reduce the risk of ferroresonance to power transformers.

1.3 Scope of Work

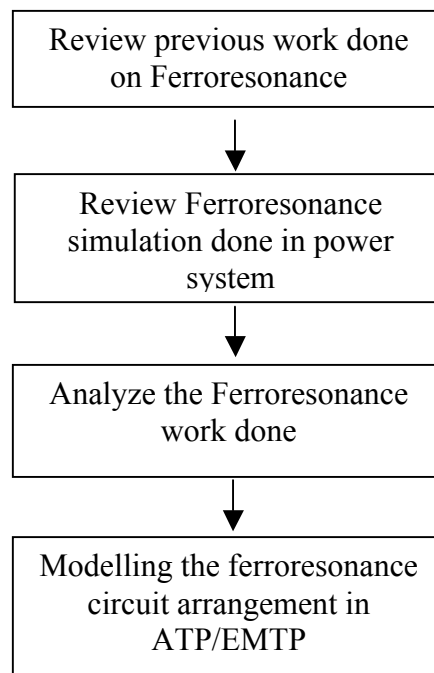
The main scope of this project is to simulate the various conditions of ferroresonance, which include:

- i. To prove or otherwise that ferroresonance can occur at 400kV double circuit substation;
- ii. To identify the effect of magnetization characteristic of power transformer on ferroresonance;

- iii. To identify method to minimize the impacts of ferroresonance on power transformers.

1.4 Project Flow Chart

To solve the problem, one has to first study the problem and come up with the process flow chart, which will guide the simulator throughout the project. It is also to give the simulator the basic overview of the system and what is required before simulations be completed. The flow chart of this project is as shown in Figure 1.1.



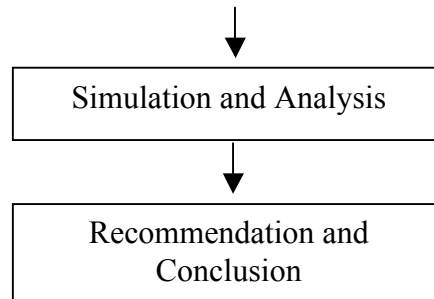


Figure 1.1: Project Flow Chart

1.5 Organisation of Thesis

Chapter 2 illustrates previous work done related on ferroresonance phenomenon in voltage transformer and power transformer. Besides, it is also includes some techniques for avoiding or mitigating ferroresonance. Chapter 3 describes the basics of ferroresonance, characteristics and types of ferroresonance. Chapter 4 describes the methods that are used for the simulation. Therefore, all information related the simulation is explained in detail with the operation. Chapter 5 presents the circuits that were used in the simulation and explains how the simulations techniques are implemented. Lastly, chapter 6 describes the conclusion and recommendation that is related to the project done.

List of References

1. Zia Emin,, Yu Kwong Tong.(2001). Ferroresonance Experience in UK: Simulations and Measurements IPST '01 - Rio de Janeiro, Brazil, June 24-28,Paper 006.2
2. Y K Tong (1997) NGC Experience on Ferroresonance in Power Transformer and Voltage Transformer on HV Transmission Systems. IEE
3. David A. N. Jacobson, Examples of Ferroresonance in a High Voltage Power System Member, IEEE
4. Electrical Engineering Tutorials: Ferroresonance- Introduction, Classification and Characteristic 20 March, 2007
5. Technical Bulletin — 004a. Ferroresonance, (2002)
6. ATPDRAW version 3.5 for Windows 9x/NT/2000/XP Users' Manual (2002)
7. Juan A. Martinez-Velasco. Bruce A.Mork, Transformer Modeling for Low Frequency Transient- The State of the Art IPST 2003, International Conference on Power Systems Transients.
8. Hans.K. Hokaidan, Laszlo Pikler, Bruce A. Mork, New Features in ATPDraw Version 3.5. EEUG Meeting 9-10th Hungary
9. Charalambos Charalambous, Z.D. Wang, Jie Li, Mark Osborne and Paul Jarman.(2007)Validation of a Power Transformer Model for Ferroresonance with System Tests on a 400 kV Circuit. IPST
10. B. Peter Daay. Ferroresonance Destroy Transformers (1191). IEE
11. M.R Iravani, Chair, A. K. S. Chaudhary, W. J. Giesbrecht, I. E. Hassan, A. J.F.Keri, K. C. Lee,J. A. Martinez, A. S. Morched, B. A. Mork, M. Parniani, A. Sharshar, D. Shirmohammadi, R. A. Walling, and D. A. Woodford.(2000) Modeling and Analysis Guidelines for Slow

12. Transients—Part III: The Study of Ferroresonance. IEEE Transactions, Vol 15. No.1
13. S. Mozaffari, M.Sameti, A.C.Soudack. Effect of initial conditions on chaotic ferroresonance in power transformers. IEE no. 19971459
14. ZhuZhu Xukai, Yang Yihan, Lian Hongbo, Tan Weipu.(2004) Study on Ferruresonance due to Electromagnetic PT In Ungrounded Neutral System . IEEE
15. Bernard C. Lesiutre, Jama A. Mohamed, Aleksandar M. Stankovic, (2000) Analysis of Ferroresonance in Three-Phase Transformer.IEEE Percon
16. S. Mozaffsri, M. Samet, A.C Soudack. (1997) Effect of Initial Conditions on Chaotic Ferroresonance in power transformer. IEE .Proceeding online no. 1971459
17. Bruce A.Mork., Parameters for Modeling Transmission Lines and Transformers in Transient Simulations. (2001) IEEE
18. Marta Val Escudero,Ivan Duduryah, Miles Redfm.: Understanding Ferroresonance ESB International, Ireland
19. P. Ferracci: Ferroresonance, Cahier Technirue 190 (1998). Group Schneider.
20. Dr. D.A.N. Jacobson , Dr. R. W. Menzies (2001). Investigation of Station Service Transformer Ferroresonance in Manitoba Hydto's 230kV Dorsey Converter Station. IPST