MODELLING OF CURRENT TRANSFORMER FOR THE APPLICATION OF ERROR ESTIMATION, ESTIMATION FACTOR AND RATIO ERROR

by

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LIST OF ABBREVIATIONS

CT	Current Transformer
THD	Total Harmonic Distortion
PSCAD	Power Systems Computer Aided Design
JA	Jiles Atherton
EMTP	Electromagnetic Transient Program
KCL	Kirchhoff's Current Law
RCF	Ratio Correction Factor
H	Magnetic Field
B	Magnetic Induction
IGBT	Insulated Gate Bipolar Transistor
RMS	Root Mean Square
E	Sinusoidal Voltage
W	Active Power
VAR	Reactive Power
IEEE	Institute Electric and Electronic Engineering
ANSI	American National Standards Institute
MMF	Magnetomotive Force
AC	Alternating Current

LIST OF SYMBOLS

Ω	Ohm
Δ	Magnetic core hysteresis and eddy current losses
β	Phase angle error
ℓ	Magnetic core path length
λ	Peak value
ε	Ratio error

PEMODELAN TRANFORMER ARUS UNTUK APLIKASI ANGGARAN RALAT, ANGGARAN FAKTOR DAN RALAT NISBAH

ABSTRAK

Kajian ini menyumbang dalam penyelidikan mengenai prestasi transformer arus dengan gangguan harmonik. Selainb itu, kajian ini juga menyumbang dalam meningkatkan kecekapan transformer arus dengan pengiraan kesalahan sudut fasa dan kesalahan nisbah. Dalam tesis ini, faktor pembetulan juga telah ditaksir bagi meningkatkan prestasi dan ketepatan transformer arus. Melalui projek ini, transformer arus 15/1A dan 7.5/1A diuji dengan peratus jumlah gangguan harmonik yang berbeza. Bahagian pertama ujikaji dilakukan menerusi simulasi perisian PSCAD apabila transformer arus dimodelkan bersama beban yang berbeza. Perbandingan dijalankan oleh PSCAD dari aspek arus masukan dan keluaran, arus harmonik, nisbah transformer arus dan beban. Dengan menggunakan PSCAD, peratus jumlah arus gangguan harmonik yang berbeza disalurkan bagi menguji pelaksanaan transformer arus. PSCAD juga digunakan untuk menjalankan simulasi bagi melihat keadaan ketepuan transformer arus apabila beroperasi dengan nilai impedans magnetik yang berbeza. Unsur kajian perbandingan telah dimasukkan ke dalam sebahagian simulasi dengan melakukan perbandingan dengan model dari Universiti Manitoba dan penyelidik lain. Bahagian kedua projek adalah perbandingan yang dilakukan di makmal iaitu perbandingan antara beban linear dan tidak linear yang digunakan bersama transformer arus. Dalam bahagian ini, mentol-mentol digunakan sebagai beban linear manakala komputer-komputer peribadi sebagai beban tidak linear. Tindak balas dan kecekapan transformer arus diuji apabila disambung dengan kedua-dua jenis beban itu dan arus masukan dinaikkan. Meter Analisa Kuasa (PM300) dan perisian VPAS disambung ke litar bagi mendapatkan bentuk gelombang arus dan mengukur kesalahan sudut fasa. Perbandingan seterusnya adalah antara transformer arus kelas 1 dan kelas 3 yang diuji dengan beban 0.5 ohm, 10 ohm and 25 ohm kerana ketersediaan yang dimiliki oleh bank perintang. Daripada keseluruhan eksperimen baik perisian mahupun ujian makmal, keputusan menunjukkan bahawa peratus harmonik yang berbeza akan membawa kesan kepada transformer arus dari aspek kecekapan, kesalahan sudut fasa, dan kesalahan nisbah. Kesan-kesan ini juga diambil kira dari nilai bebanan di bahagian primer. Kesan harmonik ke atas transformer arus diuji sehingga terhasilnya ketepuan dalam transformer arus itu. Hal ini disebabkan oleh kenaikan arus primer, komponen DC, harmonik dan perubahan frekuensi. Selain itu, kesilapan dalam transformer arus juga sangat dipengaruhi oleh ketaklelurusan arus kemagnetan. Akhir sekali, kajian dalam bidang ini menyumbang ke arah peningkatan prestasi transformer arus dalam sistem kualiti kuasa.

MODELLING OF CURRENT TRANSFORMER FOR THE APPLICATION OF ERROR ESTIMATION, ESTIMATION FACTOR AND RATIO ERROR

ABSTRACT

The research contributed in the investigation of current transformer performance with harmonic distortion. Besides that, the research also contributed in enhances the current transformer efficiency by estimation the phase angle and ratio errors. In this thesis, the correction factors have been estimated to work up the current transformer performance and accuracy. Throughout this project, the current transformer 15/1A and 7.5/1A are tested with different percentages of total harmonic distortion. The first part of testing is done with software simulation using PSCAD when current transformer modeled with different burden. The PSCAD simulation is compared in terms of primary and secondary current, harmonic current, current transformer ratio and burden. Different percentage of total harmonic distortion current is supplied to test the current transformer performance by using PSCAD software. PSCAD also simulate to see the current transformer saturation when operates with different values of magnetizing impedance. Element of comparative studies was included in the simulation part by doing the comparison with the model from University of Manitoba and other researcher. The second part is the hardware comparison between the linear and non-linear loads used in current transformers. In this part, the bulbs used as linear loads and personal computers as non-linear loads. Reaction and efficiency of current transformer are tested when connected with both types of loads and increasing the input current. Power meter analyzer (PM300) and VPAS software connected to the circuit to plot current waveform and measured phase angle error. The next comparison is between current transformer class 1 and class 3 tested with burden 0.5ohm, 10 ohm and 25 ohm due to the availability of the resistor banks. From the overall experiment of software and hardware, results shows that different percentage of harmonics bring effects to the current transformer in terms of efficiency, phase angle error and ratio error. The effect also counted on the values of secondary burden. The harmonic effects on the current transformer tested presence until the current transformer saturate. These are due to the increment of primary current, DC component, harmonic and frequency changed. Otherwise, current transformer error is strongly influenced by the non-linearity of the magnetizing current. Finally, the study in this field is contributed to enhance current transformer performance in power quality system.

CHAPTER 1

INTRODUCTION

1.1 Introduction

A Current Transformer (CT) is a type of transformer that is designed to measure high current in a power system. CT are basically of two general type, those are used for over current, relay protection applications and those are used for metering applications. In protection applications one is concerned about the performance and errors of the CT (B.S. Guru & H.R. Hiziroglu).

The performance and accuracy of the current transformer can be analyzed when excited with non sinusoidal currents. When the CT operates under non sinusoidal condition, two errors are known to occur that are phase angle error and ratio error. These errors can affect the CT accuracy and performance (Emanuel A.E & Orr J.A, 2007).

The CT with a non linear load will have harmonic distortion. This harmonic distortion gave a major effect to the transformer those increasing transformer losses (Said D.M & Nor K.M, 2008).

This thesis is a concern of the research work that titled “Modelling of Current Transformer for the Application of Error Estimation, Estimation Factor and Ratio Error”. The first aim of this research is to use the PSCAD software in modeling the characteristics of the current transformer. The research will also investigate the effects of harmonic distortion to the current transformer applied in the single phase and three

phase system. Moreover, the study will estimate the correction factor due to level of harmonic distortion by adjusting the THDi.

1.2 Problem Statement

Installation of current transformer for transformer protection purpose in the distribution system with nonlinear load will have some error at current transformer itself. The problems are current ratio error, phase angle error and accuracy error. These errors will affect the differential relay for transformer protection which differential relay will trip even though no fault. These errors will cause the current transformer goes to saturate. Saturation of current transformer under fault conditions produces harmonics in the secondary circuits. As the CT saturation increases, the secondary harmonics will also increase before CT goes into a completely saturated mode (J.Das, 2002).

The main problem are the effects of harmonic to the current transformer performance when the harmonic distortion is supplying over limit or range that is set in current transformer. This harmonic distortion will increase the transformer losses and may cause transformer core to go into saturation. Meanwhile, these effects will increase the temperature and sound level resulting core overheating and transformer damaging (S.P. Kennedy & C.L.Ivey). So, the main point for the problem statement that need to solve is to reduce the harmonic effects on the current transformer in terms of loads and burdens choosing. Then, to select better utilization of current transformer in ratio and class aspects. This problem will be briefly discussed in Chapter Three.

1.3 Aims and Objectives

This project is to study the effects of harmonic distortion on the current transformer used for differential transformer protection. Overall, the research objectives are :

- To model and simulate current transformer using PSCAD software to implement the current transformer performance in harmonic condition.
- To estimate ratio and phase angle error in increasing the current transformer efficiency
- To estimate the correction factor due to level of harmonic distortion to work up the current transformer performance and accuracy.

1.4 Scope of the Project

The project begins with the development of current transformer model using PSCAD software. Investigation of the effect of harmonic distortion to the current transformer is conducted prior to the model development. The project requires the understanding of current transformer and harmonic distortion characteristics. The relationship and the effects of harmonic distortion to the CT also need to be understood. Basically this project will develop within the scope; software model of a current transformer characteristics using PSCAD, mathematically calculation of the current transformer, harmonic and its effects especially in terms of current transformer ratio error and phase angle error. The testing is including the measurement of current transformer performance use as protection element in single phase and three phase systems with different total harmonic distortion (THD).

1.5 Thesis Outline

The thesis is broken down into five chapters. Chapter one provides the introduction of the project which includes general introduction, problems statement, aims and objectives, scopes and thesis outline.

Chapter Two discusses the literature review and characteristics of current transformer and harmonic. This chapter also produce theoretical point of view of the harmonic effects to the current transformer in protection system and other related information with critical review from other researchers.

Next chapter, Chapter Three presents the research methodology. This describes the mathematical modeling, current transformer modeling using PSCAD software and testing and experiment process in the laboratory.

Contents for Chapter Four are the results and discussion. This chapter discusses the results according to the simulation and hardware testing which explain current transformer modeling and performance with non linear load and harmonic distortion in single and three phase systems.

Finally, Chapter Five consists of the conclusion and recommendation for future improvement in the current transformer performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a survey that is conducted to review the current transformer characteristics, harmonic characteristics and effects of harmonic to the current transformer performance. In addition, this chapter also covered the critical review from other researchers.

2.2 Critical Review of Other Researcher

A lot of researchers around this world have conducted their own experiments with different materials and techniques either to determine the current transformer performance within the harmonic distortions or to obtain the effects of harmonic pollution to the current transformer or to determine the current transformer's efficiency. Harmonic issued is very much debated these days because of their impacts on the equipments and measurements system. Therefore, the current transformer used as the protection tools in protecting the equipments from over current and harmonic distortion. However, harmonics injection also gives the change in current transformer performance. Many of the researcher's works in the current transformer and harmonics have been simplified as below;

2.2.1 Current Transformer and Harmonic Relationship

Alexander E. Emanuel and John A. Orr (2007) in their paper "*Current Harmonics Measurement by Means of Current Transformers*", have analyzed the accuracy of current transformers when excited with non-sinusoidal currents. The phase angle error affects the accuracy of the measurement when harmonic powers are measured. When the ferromagnetic core permeability become lower, then the magnetizing current and the phase angle error becomes larger. In addition, the larger air-gap of a clamp on the CT, then larger magnetizing current and harmonic current present in the secondary current will be reflected in the spectrum of the magnetizing current even for a perfectly linear CT (Emanuel A.E & Orr J.A, 2007).

A. Cataliotti, D. Di Cara, A.E. Emanuel and S.Nuccio (2008) in their paper "*Characterization of Current Transformers in the Presence of Harmonic Distortion*", proposed a new way to characterize current transformers, closer to real operative conditions which harmonic phase angle and ratio errors are measured when the CT are excited with a non-sinusoidal current composed of a fundamental and one harmonic, with adjustable phase shift. This way results was compared with the results that obtained in the frequency response test. The errors measured using the new approaches are larger than the ones found with the frequency response. So, the frequency response is not a reliable method to evaluate the CT performance under distorted conditions (A. Cataliotti, D. Di Cara, A. E. Emanuel & S. Nuccio , 2008).

Cataliotti, D. Di Cara, P.A. Di Franco, A.E. Emanuel and S.Nuccio (2008) in another their paper "*Frequency Response of Measurement Current Transformers*", have demonstrate that for the frequency range analyzed the transformer equivalent circuit is a