A STUDY OF HARMONICS EFFECT ON ELECTROMECHANICAL OVERCURRENT RELAY

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Bachelor of Electrical Engineering (Industrial Power)

May 2010

" I hereby declare that I have read through this report entitle a study of harmonics effect on electromechanical overcurrent relay and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ....

Supervisor's Name : AZHAR BIN AHMAD

Date : 12 May 2010

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

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2010

I declare that this report entitle a study of harmonics effect on electromechanical overcurrent relay 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 : ZAWANI BINTI ABDUL HADI

Date : 12 May 2010

Dedicated to my beloved father, mother, my siblings
and all my friends
for their love and sacrifice.

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ABSTACT

This project is the starting point for detail research in the harmonics effect on electromechanical overcurrent relay. The main purpose of this project are to study about the harmonics current effect on the Miniature Circuit Breaker (MCB) and to characterized the harmonics current versus MCB tripping characteristic. Nowadays, most of the MCB set on the fundamental current and neglected the harmonics current that exist in normal distribution system. In addition, there is always the problem faced by the consumer where the MCB tripping occurred before the rated current value because that is taken by using common brand of clamp meter. In this project, experiment was conducted on the MCB which was injected with harmonics rich current by programmable AC source. Two types of clamp meter, common brand and good brand were used to measure the current from the experimental. Then, the new tripping characteristic of the MCB which included harmonics current will be characterized. It will be compared to original tripping characteristic (without harmonic) and new tripping characteristic (with harmonic).

ABSTRAK

Projek ini adalah titik permulaan penyelidikan secara terperinci mengenai kesan harmonik pada geganti arus lebih. Tujuan utama projek ini adalah untuk mengkaji kesan arus harmonik pada pemutus litar kenit (MCB) dan seterusnya merekod ciri-ciri arus harmonik melawan MCB. Pada masa sekarang, kebanyakan MCB telah disetkan pada arus asas dan mengabaikan arus harmonik yang wujud pada sistem pengagihan. Selain daripada itu, terdapat masalah yang selalu dihadapi oleh pengguna di mana MCB akan *trip* sebelum kadaran arus yang sepatutnya kerana pengukuran arus yang dibuat oleh pengguna adalah menggunakan *clamp meter* berjenama biasa. Dalam projek ini, eksperimen telah dijalankan pada MCB di mana harmonik telah dimasukkan pada bekalan arus ulang alik. Dua jenis *clamp meter* di mana yang berjenama biasa dan bejenama baik digunakan untuk mengukur arus pada eksperimen yang dijalankan. Kemudian, *tripping characteristic* dengan harmonik yang baru dapat diplotkan.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
ELCB	-	Earth Leakage Circuit Breaker
MCB	-	Miniature Circuit Breaker
MCCB	-	Molded Case Circuit Breaker
PCs	-	Personal Computer
RCCB	-	Residual Current Circuit Breaker
RMS		Root Mean Square
SMPS	-	Switch Mode Power Supplies
THD		Total Harmonics Distortion
UPS	-	Uninterruptible Power Supplies

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CHAPTER 1

INTRODUCTION

1.1 Background

Three-phase four-wire distribution systems are widely used to deliver electrical power at low voltage levels. The live and neutral conductors are design to operate with sinusoidal voltages and currents. However, the operating conditions have changed dramatically because of nonlinear and electronic loads. These loads will distort the steady state sinusoidal AC voltage and current waveforms.

In the past, most electrical equipment were using balanced linear load. A linear load in a power system distribution is a component in which the current and voltage are perfect sinusoidal. The non-linear load connected to the power system distribution will generate harmonics current and voltage. Harmonic currents can cause some problems in electromechanical overcurrent relays that provide protection and reliability to the power systems. Most of the electromechanical overcurrent relays manufacturers design their overcurrent relays for pure sinusoidal currents. The well known characteristics of overcurrent relays may not valid under distorted waveforms. Each harmonic frequency component could produce an independent and cumulative effect, causing the overall value to change depending on the magnitudes of harmonic components. Therefore, the overcurrent relays cannot protect the lines or transformers reliably when harmonics are involved. The presence of the harmonics causes the difference on the voltage and current. So, this can cause false tripping of overcurrent relays, let the overcurrent relays to operate slower and/or at higher pickup values and overcurrent relays cannot operate when required. In this research, a detail study will be conducted on the effect of harmonics current to common electromechanical overcurrent relay. It will also include harmonics current effect on the neutral voltage and current, and supply voltage and current in the system.

1.2 Problem Statement

This project has four problem statements. The problem statements for this project are shows below :

i. Harmonic may caused overcurrent relays to operate improperly or to not operate when required. Overcurrent relays exhibit a tendency to operate slower or with higher pickup under harmonic.
ii. The presence of excessive zero sequence third harmonic current can cause ground overcurrent relays false trip.
iii. Harmonics can impair high speed operation for relays and can affect the current interruption capacities.
iv. This research wishes to characterize the harmonics current that would be trip the electromechanical overcurrent relays.

1.3 Objectives

The objective of this project is to conduct a detail study of the effect of harmonics current on common electromechanical overcurrent relay. The project objectives can be broken into four phases:

i. To study about the electromechanical overcurrent relays (ABB MCB) characteristic.
ii. To test and prove about the harmonics current can be effected on the distribution system (overcurrent relays, supply voltage and supply current).
iii. To characterized the harmonics current versus overcurrent relay characteristic.
iv. To compare and analyze between tripping characteristic (with and without harmonic), measurement equipment (FLUKE and ALL-SUN clamp meter) and brand of MCB (ABB and WYNEX).

1.4 Scope of Project

These projects consist of four scopes. The first scope, study about the harmonics and 6A rated current of Miniature Circuit Breaker (ABB MCB). Second scope, prove that the harmonics current will be effected on MCB tripping where to prove this, experiment will be carried out and the data will be taken during the experiment. Third scope, characterize the harmonics current tripping characteristic on the MCB where the tripping characteristic with harmonics current depends on the tripping current and tripping time. The last scope, this project used resistance loads and programmable AC source will be generated the 3^{rd}, 5^{th}, 7^{th}, 9^{th} and 11^{th} harmonic.

1.5 Outline of Progress Report

This progress report consists of six chapters. The first chapter of progress report are discusses about the background, problem statement, objective and scope of this project. The second chapter consists more on the theory and literature review that has been done. It is also discusses about the theory on harmonic and overcurrent relay. The third chapter will be explained about the methodology of this project. Chapter 4 will be present about the results of the project. Chapters 5 consist of analysis and discussion about the project. In the discussion part, it is explained the problem occur when doing the project. Chapter 6 will be discusses about the conclusion and recommendation of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a summary of previous research on a topic. The purpose of a literature review is to convey what knowledge and ideas have been established on a topic and what are the strengths and weaknesses. Literature review has been conducted prior to undertaking this project to obtain the information on the technology available and the methodologies that used by the other researchers on the same topic around the world. This chapter provides the summary of literature reviews on key topics related to the harmonics current effect on electromechanical overcurrent relay.

2.2 Harmonic

Before twentieth century, the predominant use of electricity for business and industry was power motors, lights and heating devices. These uses have little effect on the fundamental frequency. They are called linear loads, because the current rises and falls in proportion to the voltage wave. In recent years, few industries use devices such as rectifiers or converters, power supplies and other device to improve product quality [6]. All of these make the current sinusoidal waveform distorted, because the current flow was not directly proportional to the voltage. These loads are called non-linear loads. Non-linear loads cause waveforms that are multiples of the fundamental frequency sine wave to be superimposed on the base waveform. These multiples are called harmonics [19].

In power system, the definition of a harmonics is a sinusoidal component of a periodic wave having a frequency that is odd multiple of fundamental frequency [9]. Harmonics are actually a mathematical model of the real world distorted sinusoidal waveforms. It is simply a technique to analyze distorted AC waveforms. All complex AC voltage or current waveforms can be represented by a series of sinusoidal waves of various frequencies that are integer multiples of the fundamental frequency [17]. On a 50 Hz fundamental frequency system, this could include the 3rd order harmonics (150 Hz), 5th order harmonics (250 Hz), 7th order harmonics (350 Hz) and so on.

In an electrical distribution system, utilities normally generate almost perfect sinusoidal voltage and current. However, these perfect sinusoidal waveforms do not hold at consumer ends due to the widespread utilization of non-linear loads that draw decidedly non-sinusoidal current [1]. These loads have distorted our electrical system's voltage and current waveforms; they introduce harmonics into the electrical system. Unlike the fundamental, harmonics provide no usable power to do work. They simply take up the capacity of electrical system. When presented in sufficient quantities, harmonics do not only disturb loads that are sensitive, but also may cause many undesirable effects to the power system [2].

Furthermore, harmonics are being introduced into the electrical distribution system at an increasing rate due to the introduction of electronic power conversion in industrial plants, commercial complexes, manufacturing facilities and private dwelling. In his publication, indicates that all of US Command, Control, Communication and Intelligence sites have its electrical system strained largely due to the high numbers of switch mode power supplies (SMPS) and uninterruptible power supplies (UPS) inside these facilities. Forecasts indicate that this trend will continue for the foreseeable future.

Harmonics in power distribution system are current or voltage that are integer multiples of fundamental frequency. For example if the fundamental frequency 50 Hz, the third harmonic is 150Hz, then the fifth harmonic is 250 etc [6]. Figure 2.1 shows a fundamental sine wave with third and fifth harmonics and Figure 2.2 shows a fundamental with 70 % third harmonic and 50 % fifth harmonic added.

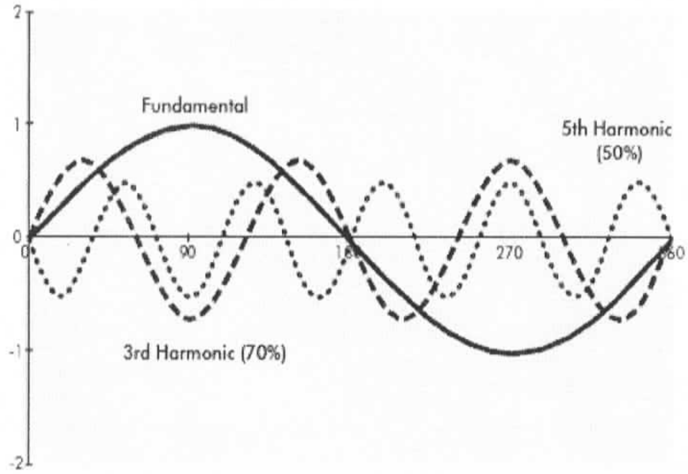

Figure 2.1 : Fundamental with third and fifth harmonics

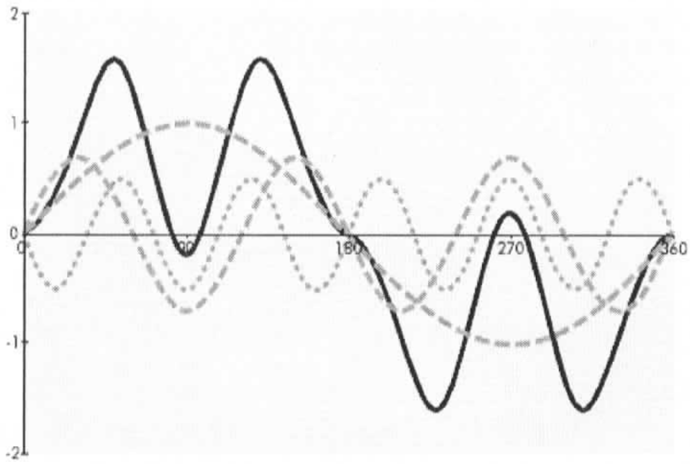

Figure 2.2 : Distorted current waveform

Harmonics in voltage or current waveforms can be conceived as perfectly sinusoidal components of frequencies multiple of the fundamental frequency [6].

Harmonics frequency, $f_h = (h) \times (fundamental\ \ frequency)$ (2.1)

Harmonics are created by nonlinear loads because current does not vary smoothly with voltage as it does with simple resistive and reactive, each time the current is switched on and off, a current pulse is created and harmonic waveforms are characterized by their amplitude and harmonic number. The origins of harmonics are well known though the effects are different in each network [2]. The most common source of harmonics are fluorescent lamp, television, computer and printer, UPS and adjustable speed drive [3].

The combination of these different nonlinear loads can result in high voltage distortion levels throughout the facility, neutral conductor overload, motor heating, transformer heating, increased losses and frequent false tripping [15].

Most electrical equipment is using balance linear load. A linear load in a power system distribution is a component in which the current and voltage are perfect sinusoidal [19]. Examples of linear loads are induction motor, heaters and incandescent lamps. But the rapid increase in the electronics device technology such as diode, thyristors, etc cause industrial loads to become non-linear. These components are called solid state electronic or non-linear load [2]. The non-linear load connected to the power system distribution will generate harmonics current and voltage.

2.3 Harmonics Current

Basically, harmonics in power installations it is the current harmonics that are of most concern because the harmonics originate as currents and most of the ill effects are due to these currents. The harmonics current generate by the load or more accurately converted by the load from fundamental to harmonic current have to flow around the circuit via the source impedance and all other parallel paths. Harmonic currents can cause some problems in electromechanical overcurrent relays that provide complete protection and reliability for the power systems. Most of the relay manufacturers design their relays for pure sinusoidal currents. The well known characteristics of relays are not valid under distorted waveforms [14]. When presented in sufficient quantities, harmonics do not only disturb loads that are sensitive, but also may cause many undesirable effects to the power system.

The harmonics current injected on power distribution system caused by non-linear load, and they can damage equipment overtime by sustained overheating or cause sudden failures due to resonant conditions. In order to control harmonics, IEEE Standard 519, "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems," was adopted. IEEE Standard 519 limitations on voltage and current harmonics in order to ensure that harmonic distortion levels throughout the entire electrical distribution system, from utility to consumer, will remain low enough for the system to function properly. Harmonic currents not only disturb loads that are sensitive to waveform distortion, but also cause many undesirable effects on power system elements. There are several common problem areas caused by harmonics such as overloading of neutrals, overheating of transformers, nuisance tripping of circuit breakers, over-stressing of power factor correction capacitors and skin effect [9]. Two typical problems are overloading [16] and elevated neutral voltage [20] problem harmonics present into the electrical system, poses additional danger to overload the neutral wire. The harmonics current injected on power distribution system caused by non-linear load, and they can damage equipment.

The harmonic current on three-phase three wires power distribution system is dominated by the fifth and seventh harmonics that are generated from the three phase bridge diode rectifiers [7]. The main problem of harmonics current on three phase distribution power system is harmonic resonance. The harmonic resonance is accurse in the fifth and seventh order harmonics frequency between power factor improvement capacitor and source inductance [21]. Two forms of resonance which must be considered. Those are series resonance and parallel resonance. For the series resonance, the total impedance at the resonance frequency reduces to the resistance component only. For the case where this component is small, high current magnitudes at the exciting frequency will flow. It may lead to large oscillating currents and consequently high harmonics voltage.

For the parallel resonance, frequency the impedance is very high and when excited from a source at this frequency, a high circulating current will flow in the capacitance-inductance loop [21]. Harmonic Resonance occurs when the capacitor reactance and the system reactance are equal. These currents will result in greater voltage distortion. This provides a higher voltage across the capacitor and potentially harmful currents through all capacitor equipment. Harmonic resonance may occur at any frequency but the fifth seventh are the frequencies with most concerned. Some indicators of resonance are overheating, frequent circuit breaker tripping, unexplained fuse operation, capacitor failure, electronic equipment malfunction, flicking lights and telephone interference.