SIMULATION OF HARMONIC CURRENTS AND VOLTAGES DUE TO POWER ELECTRONICS EQUIPMENT

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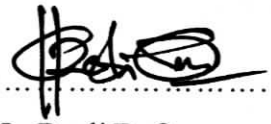
MAY 2006

" I hereby verify that I have read this report and I find it sufficient in terms of quality and scope to be awarded with the Bachelor's Degree in Electrical Engineering (Industrial Power)."

Signature : 

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"It is hereby declared that all materials in this thesis are the effort of my own work and material which are not the effort of my own work have been clearly acknowledged."

Signature : .....

Name : Siti Saleha Bt. Abas

Date : 04/05/06

For my beloved parent, Jaharah Bt. Mohmad and Abas B. Napiah. Also to my dearest siblings, Samsuri, Azmi, Noriah, Mohammat Nahri, Julliati, Mohd Riduan, AsrulAffendi and Zulhilmi.

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ABSTRACT

Harmonics can be present in voltage, current or both. Before the end of the century, it is forecast that half of electrical devices will operate with nonlinear current draw. These nonlinear load are cause of current and voltage harmonics in electrical system.. Harmonic currents cause overheating of electrical distribution system wiring, transformer overheating and shortened transformer service life. Loads that producing harmonic currents are electronic lighting ballast, electric arc furnaces, electric welding equipment, industrial process controls, saturated transformer, medical equipment, washing machine, clothes dryer, adjustable speed drives, personal computer and solid state rectifiers. While, harmonic voltages cause havoc or noise within the electrical distribution system. Noise can be picked up in computer networks, communications equipment and telephone systems when harmonics are at audio or radio frequency. Harmonic current and voltage can be eliminated by using capacitors, filters and mitigating transformer. Besides that, by making sure that the wiring size is as the equipment requirement and system need, the harmonic currents or voltages can be control or eliminate. This project is to make sure that the nonlinear equipment will produce harmonics to the system by using PSCAD simulation software.

ABSTRAK

Harmonik boleh diwakili samada oleh voltan, arus atau pun kedua-duanya sekali. Pada akhir abad ini, dijangka separuh daripada peralatan elektrik yang digunakan beroperasi dengan menghasilkan arus yang tidak linear. Beban tidak linear ini adalah penyebab kepada berlakunya arus dan voltan harmonik dalam sistem elektrik. Arus harmonik menyebabkan berlakunya kepanasan dalam sistem pendawaian pengagihan elektrik, kepanasan melampau pada transfomer da menyingkatkan jangka hayat servis transfomer. Beban yang menghasilkan arus harmonic adalah pengantap pencahayaan elektronik,relau lengkungan elektrik, peralatan kimpalan elektrik,proses kawalan industri, pemekatan transformer,peralatan perubatan,mesin basuh, pengering pakaian,computer peribadi dan sebagainya. Manakala voltan harmonik pula menghasilkan gangguan pada sistem pengagihan elektrik. Gangguan tersebut boleh diperolehi melalui rangkaian komputer, peralatan telekomunikasi dan sistem telefon apabila harmonik berada pada frekuensi audio atau radio.Voltan dan arus harmonik boleh dikurangkan dengan menggunakan kapasitor, penapis atau pun penggunaan transfomer. Selain itu, dengaN memastikan sistem pendawaian adalah menepati piawaian dan keperluan sistem, arus dan voltan harmonik dapat dikawal atau dihapuskan. Projek ini adalah untuk memastikan bahawa peralatan tidak linear akan menghasilkan harmonic kepada system elektrik dengan menggunakan PSCAD.

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LIST OF SHORTFORMS

THD	Total Harmonic Distortion
THVD	Total Harmonic Voltage Distortion
THCD	Total Harmonic Current Distortion
UPS	Uninterruptible Power Supply
AC	Alternating current
DC	Direct current
GTO	Gate turn off thyristor
RMS	Root mean square
SCR	Silicon controlled rectifier
BJT	Bipolar junction Transistor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
CPU	Central processing unit
kHz	Kilohertz
MHz	Megahertz
SMPS	Switching mode power supplies
RF	Radio frequency
PC	Personal computer
PSCAD	Power System Computer Aided Drawing Software
HVDC	High Voltage Direct Current
SSR	Sub-synchronous resonance

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CHAPTER 1

INTRODUCTION

1.1 Introduction of the Project

A widespread introduction of power electronic converters to most areas of distribution and usage of electricity is common for all developed countries [1]. Therefore over the past few years and years to come, many more sophisticated power electronic devices will be depended on to make our daily chores easier. It is estimated that by the end of the 19th century, about 60% of electric power generated in the world will flow through power electronic converters and this percentage will rise to almost 100% in the following decade [1]. But as more power electronics devices connected to the power system, the "quality" of the power becomes an important factor and this "quality" can be defined in many ways [2].

The generation of harmonic currents and voltages cause one of the most harmful power quality problems. Harmonic may affect the whole electrical environment and there are many possible ways it can further degrade the power quality at much larger distances from where it originates [3]. The efficiency of power in our homes, offices, schools, factories and power plants could also be affected by the generation of harmful harmonics.

However, to determine the limits of harmonic levels and to eliminate this problem is not a straightforward exercise [3]. Therefore there is a need to monitor the probability of harmonic presence from power electronic devices within distribution level. Harmonics can be present in voltage, current or both. It is forecast before the

end of the century, half of all electrical devices will operate with nonlinear current draw.

These non-linear loads are the cause of current and voltage harmonics. Harmonic currents cause overheating of electrical distribution system wiring, transformer overheating and shortened transformer service life.

Harmonic current and voltages can be eliminate or control by using capacitors or de-rating K factors. We can also make sure that the wiring sized is to meet the equipment and systems need, so the harmonic currents or voltages can be control or eliminate. This project is to make sure that the equipment is fulfill the required specification.

1.2 Project Objective

The aim of this thesis is to simulate harmonic currents and voltages due to power electronic equipments. The simulation for the thesis will focus into modeled problems that may affect home premises, industrial facilities and commercial buildings. All of the modeled problems will be based upon actual case studies and equipments. Simulations will be performed using sophisticated Power System Computer Aided Drawing software (PSCAD).

In proper to achieve the appropriate goals within this project, there are some objectives that this project required. The objectives of this project are :

i) To simulate harmonic currents and voltages due to power electronic equipments in home premises.
ii) Simulation will be performed using Power System Computer Aided Drawing Software (PSCAD)
iii) The modeled problem will be based on the case study.
iv) Using PSCAD simulation software based on the best information that is available.

1.3 Project Scope

Due to the objective that had been defined early, the scope for this project is stated. The common problems associated with harmonic currents and voltages have been identified and widely discussed in recent year. But little did we know that the source of harmonic currents and voltages produces comes from daily equipments used in homes, industrial facility and offices. Any device with non linear characteristics may be injecting back harmful harmonic currents and voltages into electrical system. Power electronic equipments are in the category of devices with the most non-linearity. This project is focused on the modeled problem that affected electronic equipment.

1.4 Problem Statement

Many problems occurred from harmonics effect. However, this project is based to these problems:

i) Harmonic current and voltages are common problem that had been identified recent years. However, only certain of us know about it and its sources. Harmonic current and voltages produced are comes from daily equipment that we used in homes and industries. The harmonic currents and voltages come from non-linear equipment. Any of the non-linear equipment will be injecting harmful harmonic currents and voltages to electrical system. Power electronic has the most non-linearity characteristics.

ii) Harmonic currents will cause overheating to the electrical distribution system wiring, overheating and shortened the life service of the equipment.

iii) Harmonic voltages will cause havoc or noise within the electrical distribution system.

iv) To simulate the harmonic currents and voltages, Power System Computer Aided Drawing Software (PSCAD) is used.

1.5 Methodology

There were some methods used for this project in proper to achieve the objective of this project. The methods were :

- Study about harmonics sources and the theory
- Study the Power System Computer Aided Software (PSCAD) about the environment and how it worked.
- Construct the modeled problem that will be based to the actual equipment and case study.
- Simulate the modeled problem using PSCAD program
- Relate the simulation result and the theory.

1.6 Flowchart

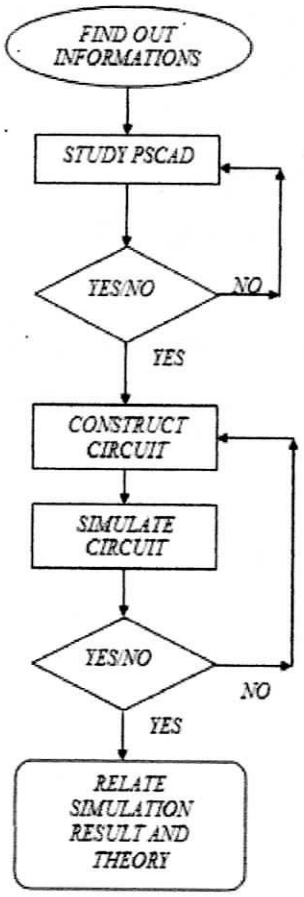

Figure 1.1 : Methodology flowchart

1.7 Overview of the Thesis

Chapter 1 introduce the thesis and explanation of objective, scope, problem statement and methodology of the project.

Chapter 2 examines the topic of harmonics theory. Explanations of harmonics along with the nature and the source of harmonics, effects and the solutions for harmonics problems based on the power electronic equipment.

Chapter 3 covers the process of power electronics for basic understanding. Exploring into its materials used, characteristics of power electronic materials and its applications.

Chapter 4 outlines the basics of the simulation software PSCAD. It briefly explains the available functions within the program and the analysis tools at hand to perform the simulations for harmonic currents and voltages.

Chapter 5 gives a description of the modeled power electronic equipments undertaken to perform the simulations. Showed the result and simulation performed.

Chapter 6 gives a summary of the findings and conclusion of the thesis. Included are some suggestions for further work in this area, as an expansion on this project.

CHAPTER 2

LITERITURE REVIEW

2.1 What is Harmonic

In an ideal electrical power system, energy is supplied at a single and constant frequency and at specified voltage levels of constant magnitudes. However, none of these conditions are fulfilled in practice [3]. The problem with voltage and frequency deviations or distortions, are no longer a new phenomenon since the start of electric power conversion. Another technical name for voltage and frequency distortion is by the term 'Harmonics'. Harmonics originates from acoustics, where it signifies the vibration of sound, which is a multiple of the basic repetition of the main frequency [3].

Harmonic is defined as a sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequency. For example, a component, the frequency of which is five times the fundamental frequency, is called a 5^{th} harmonic. The theoretical maximum amplitude of each harmonic current produced by a converter is equal to that of the fundamental component divided by harmonic order. For example, the 5^{th} harmonic is equal to 20 percent of the load current; and the 7^{th} harmonic is equal to 14.3 percent; and so on. These values are for an idealized squarewave and, in practice, will be less because of system impedance. The harmonic components are assumed to be in phase with the fundamental. The resulting waveshape will depend on the magnitude and the phase relation of each of the harmonic components.

2.2 Harmonic Analysis by Mathematic

Harmonics are actually derived from mathematical model [2], which is a technique to analyze currents and voltages. The distorted waveform, from a perfect sinusoidal is generally expressed in terms of harmonic components in the frequency spectrum. The harmonic components drawn by the frequency spectrum can then be presented in a mathematical equation. With a power frequency (fundamental frequency) of 50Hz in Malaysia, the equation representing a harmonic frequency is given by equation 1 below

$$fh = h \times 50Hz$$

Equation 1 : Harmonic frequency

Where: -

h is the harmonic order

In electrical power system, harmonic analysis not only deals with harmonic frequency but the process of deriving the magnitudes of voltages and currents must be included as well. Generally, another series of harmonic analysis in electrical power system using mathematical equation is known as Fourier analysis. Fourier analysis or better known as Fourier series, establishes a relationship between a time domain function and also that function in frequency domain. Using the Fourier series, any voltage or current waveform may be reproduced from the fundamental frequency component together with the sum of the harmonic components. The analysis is using the equation 2.

$$Vt = a0 + S\ Vh\ Sin\ (h \times 2p\mathit{ft} + qh)$$

Equation 2 : Fourier series

Where: -

a0 is the dc component

Vh is the peak voltage level

f is the fundamental frequency of 50Hz in Malaysia

t is the time of one cycle in the fundamental frequency

qh is the phase angle

Apart from representing harmonics frequency and its magnitude, Fourier series can also transform into a single periodic signal with respect to each harmonic component in particular distorted waveform. Another principle behind performing a harmonic analysis on a power system is to determine the Total Harmonic Distortion (THD). Equation 3 shows the THD formula.

$$THD = \sqrt{\frac{\text{the sum of squares of amplitudes of all harmonics}}{\text{Squares of amplitudes of the fundamental}}} \times 100\%$$

Equation 3 : THD formula

The term THD is a measure to identify the amount of harmonic distortion in a system voltage, usually expressed in percentages with respect to the fundamental voltage. Both voltage and current waveform distortion may be represented by THD, with Total Harmonic Voltage Distortion (THVD) and Total Harmonic Current Distortion (THCD) sometimes used to distinguish between the two [4].