UNIVERSITI TEKNIKAL MALAYSIA MELAKA

HARMONIC DETECTION OF RECTIFIER LOAD IN POWER DISTRIBUTION SYSTEM

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

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I hereby, declared this report entitled "A Harmonic Detection of Rectifier Load in Power Distribution System" is the results of my own research except as cited in references.

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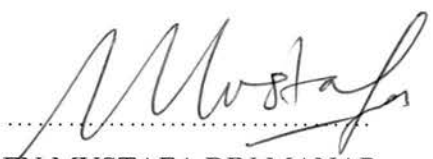
APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:



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ABSTRACT

Nowadays, harmonic distortion has been known as a significant problem to maintain power quality. Some harmonics in the power signals are dangerous to sensitive equipment and also cause to power loss. Therefore important to detect harmonics and use different harmonic mitigation techniques to get clean or pure signal for safe operation of the connected equipment and minimize power loss. This project is about modeling/simulation and the effect of using 6 pulses and 12 pulse rectifier circuit commonly found in power distribution system. The model was implemented using MATLAB/Simulink with the SimPowerSystem Block Set. The 6 pulse rectifier circuit is involving most AC drives because of its low cost and simplest structure. The 12 pulse rectifier circuit is known to be more expensive, but produces the reduced input current harmonics and voltage ripples. The aim of this research is to detect the harmonic by using 6 pulses and 12 pulse rectifier circuit and analyze the harmonic by using Fast Fourier Transform (FFT) method, plot the stylized spectrum of distorted signal in software MATLAB with power system frequency and calculate the total harmonic distortion that will be useful for solving problems that related to the power quality.

DEDICATION

To my beloved parents,
Darminah Binti Sar and Zulkifli Bin Mohamad,

siblings,
Ainol Adha, Intan Nadia, Nur Ashiqin

supervisor,
En Mustafa Bin Manap,

lecturers, teachers and friends;

Who educated me and enabled me to reach at this level.
Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
DC	-	Direct Current
RMS	-	Root Mean Square
THD	-	Total Harmonic Distortion
PCC	-	Point of Common Coupling
IEEE	-	Institute of Electrical and Electronics Engineering
FFT	-	Fast Fourier Transform
VFD	-	Variable Frequency Drive

CHAPTER 1
INTRODUCTION

1.0 General Background

The reliability of power electronic system such as three phase rectifier is very important in various applications. Rectifier is one of nonlinear loads that produce an adverse impact on the electrical system. It is very common term in power electronics sector where an AC signal is converted into a DC signal. For obtaining the most suitable quality power the measured voltage or current signal must be purely sinusoidal. But in real scenario, it gets degenerated due to power quality problems such as harmonics. According to IEEE, harmonics is a sinusoidal voltage or current having frequency that are integer multiples of the fundamental frequency at which the power system is designed to operate. Harmonics are the major source of sine waveform distortion and always present in electrical power system. It can cause many problems such as malfunctions in stabilities and reducing the lifetime of the equipment. The increased uses of nonlinear equipment have caused problems such as harmonics to become common. The method that will be used is using Fourier transform method. This method can improve the rectifier power factor (PF). Hence detection and identification of the equipment in industry play a big role.

1.1 Problem Statement

Power quality is main role to electricity consumers at all level usage in this modern power distribution. Usually, this problem is causing by harmonic producing loads. The harmonic distortion is very old phenomenon though it has been discovered since 19th century (Al-bayaty et al. 2016). Rectifier is one of nonlinear load model. These nonlinear devices have the problem of power quality in terms of distortion waveform and the biggest cause of harmonics generation on power lines. Various methods are used to reduce these problems in rectifiers.

This crucial issue lead to safety issue, power trip and has been identified as a major and frequent problem in industry. Harmonic can cause the equipment has problems with the operation and also lead to increase losses and heating in numerous electromagnetic devices. To reduce the harmonic effect by follow the standard harmonic indices (current and voltage), IEEE standards 519-2014 is recommended for harmonic occur in electrical power system and focuses on the point of common coupling (PCC) with the consumer utility interface.

1.2 Objectives

The objectives are to:

a) To detect the harmonic for 6 pulse diode rectifier and 12 pulse diode rectifier in power distribution system
b) To analyse the harmonic by using the Fast Fourier Transform (FFT) method.
c) To observe and calculate the total harmonic distortion (THD) between 6 pulse and 12 pulse in the input current waveform and the output voltage waveform

1.3 Scope Project

The scope of this project is the flow plans to make the project successfully arranged and organized. This research will study and detect the harmonic in three phase rectifier in power distribution system by using Fast Fourier Transform method, plot the spectrum for total harmonic distortion (THD) in MATLAB software. The 6 pulse diode rectifier and 12 pulse diode rectifier models will be use to compare their input current harmonics, output voltage ripples at the PCC and also THD. The amount of total harmonic distortion produced should be under recommended value of IEEE standard 519-2014. The criteria specify for harmonics should be equal or less than 5% and total harmonic distortion (THD) should be equal or less than 8%.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

There are two types of loads within the power system which are the linear load and nonlinear load. However non-linear load devices on the power system produce harmonics. There are many devices that generate harmonics and can be connected to the power system at every level voltage such as inverter and rectifier. These loads can cause voltage distortion and current distortion (Muthukumarasamy et al. 2017). The harmonic distortions can make the equipment failure. The increase use of a nonlinear load makes the result more stringent in the IEEE standard. Such both of them are limited by international standards IEEE and that has led to the necessity of limiting according to standards. (Ellis & Eng 2001)

This chapter presents an overview about the theoretical and methodological of harmonic detection for rectifier load in power distribution system. Firstly, the literature review of related topics and an overview about harmonics is presented. Then, the standard harmonic distortion limits for voltage and current that follow IEEE standard is presented. The basics of harmonics extraction including several signal processing techniques such as Fast Fourier transform theory are explained briefly. Fourier analysis can be used to help determine Total Harmonic Distortion (THD) and how much of the distortion of a voltage or current present harmonics in the signal.

2.1 Power Quality

Power quality issue is common happen in industry. It is an important branch in power system engineering to ensure that industrial customer receives the best supply power quality. The issue of power quality is becoming serious because of the increasing use of load which sensitive to current irritation. It depends on whether you supply or consume energy. Power quality interruption is categorized into harmonic, transient, voltage sag, voltage swell, voltage notch, and flicker (Schneider Electric 2010)

Power quality in modern society has been an important factor that can cause a major problem throughout the industry. Electrical energy is an important resource for modern society. Recently, the demand for power was dramatically increased. Increase of power demand has lead to a decrease in the power quality.

To measure electrical power performance the widely use is power quality. It refers to the delivery of a sufficiently high grade of electric energy to suit the needs of the equipment utilizing the electric energy. Power quality is becoming important as electronic equipment is increasingly used in industrial (Mukherjee et al. 2016).

Power disturbance can make the equipment to damage and shorten its lifetime because the affect in current and voltage on the distribution system. So that the sensitive equipment cannot function well as it was designed. The use of poor power quality can effect the lost productivity, damaged the equipment, and reduce power efficiency.

2.2 Definition of Harmonic

The knowledge of understanding about harmonics has been around for a long time. Harmonic is a non sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency (Handbook n.d.). According to IEEE, harmonics are a sinusoidal waveform of voltage or current that having frequency integer multiples of the fundamental frequency at which the power system is function to work (Committee et al. 2014). Harmonics are the main origin of sine wave distortion and raise a heavy batch of problems. They are usually caused by non linear load devices such as rectifier and inverter. Harmonics are a mathematical way of form distortion of a voltage or current waveform that happens at an integer multiple of the fundamental frequency being 50 or 60Hz (Ingale 2014).

Harmonics in power system network shortens the lifetime of the equipment. The harmonic exist does not signify that the factory cannot function well. Like other power quality problem, the power of the equipment when operating in the presence of harmonic depends on the power distribution system.

The most common range frequencies measured in an electrical distribution system is from 3^{rd} to 25^{th}.Nonlinear load draw non-sinusoidal current from a sinusoidal voltage because of harmonic. Combined with the value of fundamental, harmonics creates distortion in waveform. It occurs due to the nonlinear characteristics of devices and loads to the power system (Committee et al. 2009).

The levels of harmonic distortion can categorize with magnitude and phase angles of each individual harmonic component by the complete harmonic spectrum. In power systems, existing harmonics are mostly odd integer multiple of the power frequency. The most common harmonic is in the odd orders. Figure 1 shows harmonic distortion example.

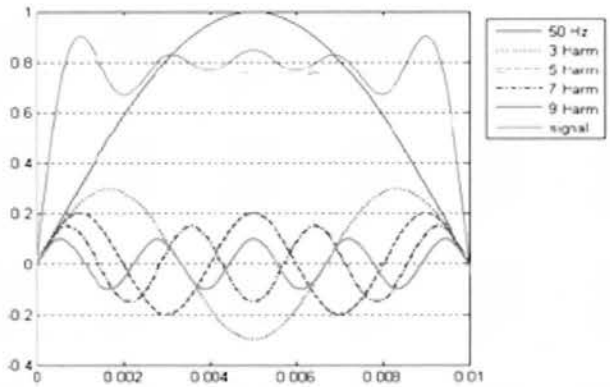

Figure 2.1 Example of harmonic distortion.

2.2.1 Cause/Effect of Harmonic

Harmonic problem occur because the use of nonlinear load devices like adjustable speed drive, electronic ballast, switching power supply and etc. The main reason for poor power quality is the proliferation of the electronic devices.

Harmonic created many unwanted effects in the power system. The increase use of the equipment heating can make the copper losses and iron losses become increase. It is the most prominent effect that occurs in the industrial machine. Single phase nonlinear loads present the peak to peak voltage magnitudes and increase the stress on the rectifiers.

The symptoms of harmonics problem to the equipment are considerably as the tripping of circuit breakers and loss of synchronization on timing circuit. For equipment impact, harmonic current flow from the loads into the utility supply system can cause harmonic voltage distortions to show also the voltage supply of utility system.

Table 2.1 The effect of harmonic on equipment.

Equipment	Harmonic effects	Results
Capacitors	• Breakdown of dielectric material • Dry capacitors cannot run through heat very well, and therefore harmonic will occur and the equipment will damage • The capacitors used in computers are mostly susceptible, since they are being unprotected by a fuse or relay	• Short circuits • Heating of capacitors due to increased dielectric losses • Capacitor explosion • Fuse failure
Transformers	• Voltage harmonics gives the higher transformer voltage and insulation stress and normally it is not a significant problem	• Increased copper and iron losses • Transformer heating • Stress • Reduce life
Motors	• Increased losses • Magnetic fields rotate at a corresponding speed and produces harmonics problem	• Mechanical vibrations and noise • Motor heating • Pulsating torque • Reduces efficiency • Reduce life

2.2.2 Types of harmonic

Harmonics can classify into two types which is harmonics order in odd and even numbers. Usually in supply voltage and load current, harmonic in odd order distortion become highest. The increase or decrease of amplitude can effect the odd harmonics. Normally in the crest factor, a third harmonic is lead to transform. In the positive and negative sine wave, the distortions that occur are same.

In the electrical equipment, it should not generate any even harmonic because it produce normally small in the modern rule of harmonic distortion. They only happen in the presence of a direct current (DC) component. The Total Harmonic Distortion is most usually used to measure the detection of harmonic content of the waveform.

2.3 Nonlinear load

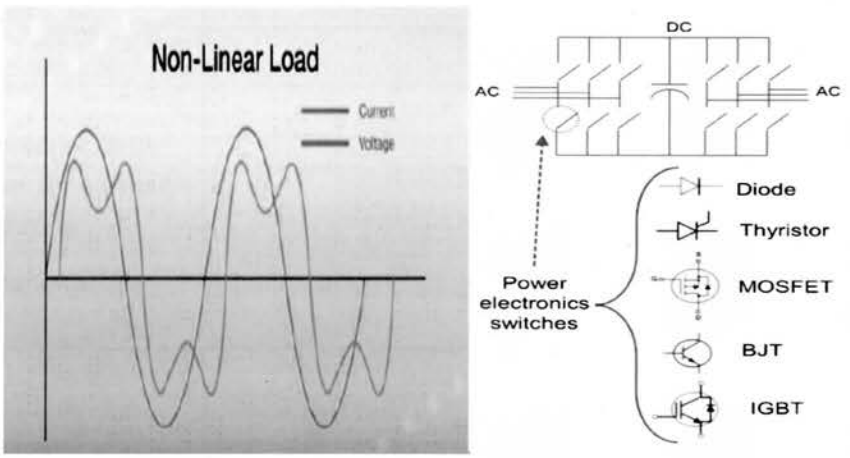

Figure 2.2 Distortion waveform and switching devices causing by nonlinear load.

2.3.1 The effect on current distortion

Table 2.2 Distortion of current waveform.

Types of load	Typical waveform	Current Distortion
Single Phase Power Supply		80% (High 3rd)
Semiconductor		High 2nd, 3rd, and 4rd at partial loads
6 pulsed converter, capacitive smoothing, no series conducting		80%
6 pulsed converter, with large inductor for current smoothing		28%
12 pulsed converter		15%

2.4 Harmonic Configuration and Distortion Factor

Harmonic of the converter characteristic is the harmonic that generate by any device equipment in a steady state form. These conditions are expressed as:

$$h = kv \pm 1$$

Where, h = order of harmonics

k = value integer 1,2,3,...

v = number of pulses per cycle

For three phase rectifier, if the number of pulses v = 6 per line frequency the dominant harmonics are:

$h = k.6 \pm 1 = 5, 7, 11, 13, 17, ...$

Same goes to the characteristic harmonic currents for 12-pulse rectifier will be:

$h = k.12 \pm 1 = 11, 13, 17, ...$

2.5 Harmonic Standard

The most important standard for IEEE 519 problem of power quality in electrical power system is discussed in power quality standards (IEEE & Institute of Electrical and Electronic Engineers 2009). Harmonic limits are recommended for both voltages and currents.