“ I hereby declare that I have read through this report entitle “Harmonic Source Identification System” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature	:	…………………………………………..
Supervisor’s Name	:	…………………………………………..
Date	:	…………………………………………..

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HARMONIC SOURCE IDENTIFICATION SYSTEM

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

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I declare that this report entitle "*Harmonic Source Identification System*" 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 : …………………………………………..

Date : …………………………………………..

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To my beloved mother and father

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ABSTRACT

The impact of harmonic distortion in modern power system became a great concern in the last decade. The problem associated with the increase usage of appliances for non-linear load allows harmonic to presence in electric power system. Harmonic distortion is not only lead to poor power quality but also can cause malfunction to sensitive electronic equipments. In order to reduce the amount of harmonic, identifying the harmonic source location between utilities and customer is an effective way for harmonic signature recognition. To evaluate the quality of the source, measurement for the single phase 240VAC source should be proposed with the capability to identify the harmonic source. Harmonic Source Identification System (HSIS) is developed to analyze the harmonic source by identifying the total harmonic distortion for voltage and current used by using both direction of active power flow and Fast Fourier Transform (FFT) method. Different load identification due to different level of harmonic distortion can be classified by conditions includes 'Excellent', 'Caution' or 'Danger' that recommended by IEEE 519-2014. The signal measured by voltage and current transducers will be converted in the form of digital signals for signal processing by using NI 6000 DAQ card. The effectiveness of HSIS is emphasized through simulation results from MATLAB. A performance test is conducted with different type of loads namely incandescent lamp, CFL lamp and synchronous motor. The notch area that occurs at the distorted waveform is presented by power spectrum. Waveform measured is identified to be less distorted for non-power electronic components and is fully distorted for power electronic components through performance test. The expected value for total harmonic distortion for voltage (THDv) and current (THDi) will be shown on monitors and users can identify the performance of the system through HSIS and safety precaution can be made if the value of harmonic exceed dangerous level.

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ABSTRAK

Kesan dari herotan harmonik dalam sistem kuasa moden menjadi kebimbangan pada dekad yang lalu. Masalah ini berpunca dari peningkatan penggunaan peralatan bukan linear membenarkan kehadiran harmonik dalam sistem kuasa elektrik. Herotan harmonik bukan sahaja membawa kepada kelemahan kualiti tenaga malah boleh menyebabkan kerosakan kepada peralatan elektronik yang sensitif. Dalam usaha untuk mengurangkan jumlah harmonik, pengenalpastian lokasi punca harmonik antara utiliti dan pengguna adalah cara terbaik bagi perolehan harmonik. Bagi menilai kualiti sumber, pengukuran berdasarkan sumber fasa 240VAU perlu dicadangkan dengan keupayaan untuk mengenal pasti sumber harmonik. Harmonic Source Identification System (HSIS) dibangunkan untuk menganalisa punca harmonik dengan mengenal pasti jumlah herotan harmonik untuk voltan dan arus yang digunakan dengan menggunakan kaedah arah aliran kuasa aktif dan Fast Fourier Transform (FFT). Pengenalpastian beban yang berbeza disebabkan kelainan tahap herotan harmonik boleh diklasifikasikan pasa kondisi 'Sangat Baik', 'Amaran' atau 'Bahaya' yang disarankan oleh IEEE 519-2014. Isyarat yang diukur dengan pengesan voltan dan arus akan ditukar dalam bentuk isyarat digital bagi pemprosesan signal menggunakan kad NI 6000 DAQ. Keberkesanan HSIS diukur melalui keputusan simulasi dari MATLAB. Ujian prestasi dilaksanakan dengan pelbagai jenis beban iaitu lampu pijar, lampu CFL dan motor segerak. Kawasan takuk yang berlaku pada gelombang terherot dikemukakan dalam bentuk spektrum kuasa. Bentuk gelombang yang di ukur kurang terherot apabila tiada komponen elektronik kuasa dan mengalami herotan yang tinggi pada komponen elektronik kuasa melalui ujian prestasi. Nilai jangkaan harmonik bagi jumlah herotan harmonik untuk voltan (THDv) dan arus (THDi) akan dipaparkan pada monitor dan pengguna boleh mengenal pasti prestasi sistem melalui HSIS dan langkah pencegahan boleh dilaksanakan sekiranya nilai harmonik melepasi tahap bahaya.

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LIST OF ABBREVIATIONS

A/D	-	Analog to digital
AC	-	Alternating current
ANSI	-	American National Standards Institute
CFL	-	Compact fluorescent lamp
CPU	-	Central processing unit
CT	-	Current transducer
DAQ	-	Data acquisition
DTFT	-	Discrete Time Fourier Transform
DWPT	-	Discrete Wavelet Packet Transform
FFT	-	Fast Fourier Transform
GND	-	Ground
GUI	-	Graphical User Interface
HSIS	-	Harmonic Source Identification System
Hz	-	Hertz
IEEE	-	Institute of Electrical and Electronics Engineers
LED	-	Light emitting diode
LV	-	Low voltage
MATLAB	-	Matric laboratory
NI	-	National Instrument
PC	-	Personal computer

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PCC	-	Point of common coupling
PQ	-	Power Quality
rms	-	Root mean square
TDD	-	Total Demand Distortion
THD	-	Total harmonic distortion
THDi	-	Total current harmonic distortion
THDv	-	Total voltage harmonic distortion
USB	-	Universal Serial Bus
VS2015	-	Visual Studio 2015
VT	-	Voltage transducer
WPT	-	Wavelet Packet Transform

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CHAPTER 1

INTRODUCTION

1.1 Research Background / Motivations

In present days, power distribution system became highlighted in the growth of technology for availability, reliability and quality of a system. Power electronic components that apply in digital circuitry such as computer and television create power line disturbance namely harmonic distortion [1]. Harmonic distortion became the major contributor to poor power quality due to excessive draw of reactive power from non-linear loads such as nonlinearity of transformer, arching device, rotating machines, and inverter fed AC drives [2]. Non-linear loads are caused by a drawn of non-sinusoidal current, thus inducing voltage distortion and affecting on consumer equipment. Based on the IEEE 519 - 2014 Task Force on the Effect of Harmonic on Equipment, the harmonic can lead to problem in central processing unit (CPU) frequency problem and can change the size and brightness for television. Hence, this justifies that modern electronic devices in electrical systems are sensitive to harmonic issues than those from the olden days.

Harmonic source problems need to be monitored to identify the locations of distortion of voltage and current between non-linear loads (customer) and the network (utility). This is important to ensure the safety of the equipment in term of lifespan, malfunctioning and error. The maximum allowable for total harmonic distortion (THD) recommends by IEEE Standard 519-2014 where %THDv must be not be greater than 8%, while %THDi must not be greater than 50% of the rated current [3]. This project is capable to identify the source of harmonic for the single phase 240VAC system by taking a reference point known as point of common coupling (PCC). Through the classification of harmonic source at PCC, the source of harmonic

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can be traced by minimizing the area where PCC is located. Figure 1.1 shows the location of the harmonic source at Area 3 that can be identified by placing the voltage transducers (VT) and current transducers (CT) at each PCC. HSIS is capable to identify the harmonic source by taking the parameters of rms voltage, current, real power, reactive power and apparent power of the measured system. Hence, the detection of harmonic source at Area 3 is classified as a customer fault and the word "Customer" will be displayed in the graphical user interface (GUI).

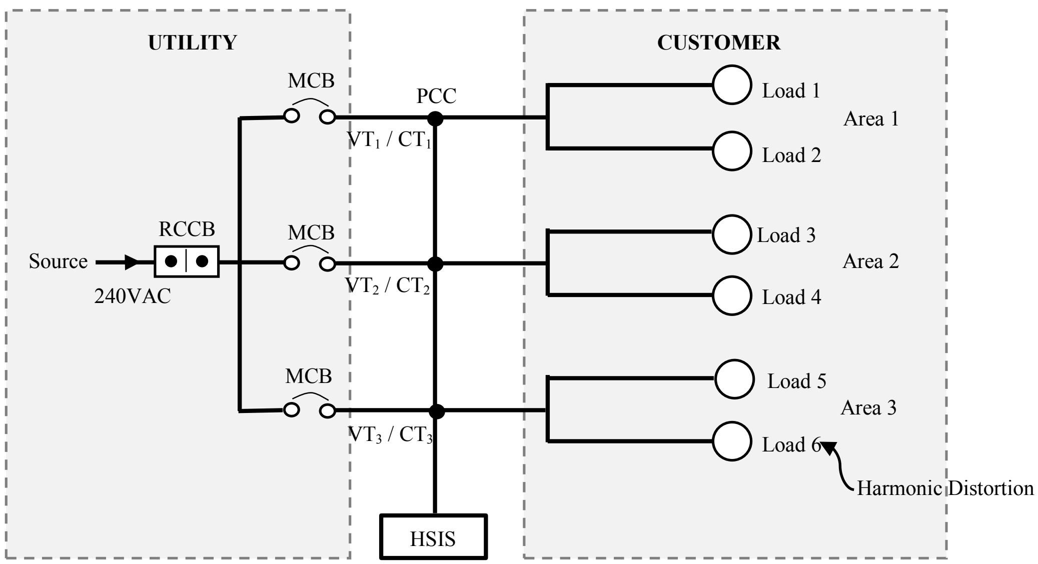

Figure 1.1: Identification of Harmonic Source Using HSIS

Mainly, the harmonics have varied with time according to the load conditions. From such point of view, a method based on time varying signal in an option to monitor the harmonic distortion [4]. HSIS is developed based on time domain where the value of voltage due to the time is measured by using FFT. Through the load measured in single phase system, the expected waveform with harmonic is as shown in Figure 1.2 (a). The harmonic occur in a single phase system for voltage and current is not a clean sinusoidal waveform due to non-linear loads. This signal will be analyzed and converted in term of FFT spectrum as shown in Figure 1.2 (b).

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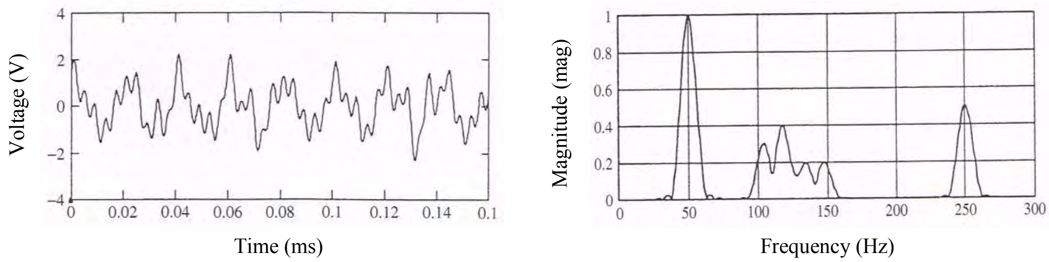

(a) (b)

Figure 1.2: (a) Waveform with Harmonic Components

(b) FFT Spectrum [4]

HSIS is proposed to serve as an alternative to the pricy monitoring systems available, so the performance test is conducted to ensure the capability of HSIS. Different type of loads is measured for the system performance verification due to different level of harmonic. In addition, it is well known that harmonic source detection popularity is increased because of the amount of harmonic has gained. Thus, the significant way is to monitor the level of harmonic distortion so that immediate action can be taken such as installing the filter to reduce the amount of harmonic.

1.2 Problem Statement

Harmonic distortion is mainly caused by non-linear loads supplied from the electrical appliances. This condition will form large oscillatory currents and voltage that can damage the equipment and insulation from the single phase 240VAC system. User having problems to identify the locations of the load that produced large amounts of harmonic. The capability of HSIS is able to monitor the harmonic distortion of current and voltage supplied. If the large amount of harmonic occur in a supply source, an action can be taken by the user. Different level of harmonic can be identified with different load identification in the system due to the different load demand by the user. This project is made as a safety purpose for the user to avoid using appliances than can be damaged by harmonic distortion.

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1.3 Objective

This project embarks on the following objectives:

1. To simulate the voltage and current for harmonic distortion using MATLAB based on Fast Fourier Transform (FFT).
2. To develop Harmonic Source Identification System to identify the harmonic distortion from single phase 240VAC source supply.
3. To analyze the performance of the system with different load identification from single phase 240VAC source supply.

1.4 Scope of Work

Harmonic Source Identification System is developed to identify the total harmonic distortion for voltage (THDv) and current (THDi) from single phase 240VAC source supply using Fast Fourier Transform (FFT) method. Voltage and current transducer will be used to measure the harmonic distortion from single phase system with different load identification. Simulation based on voltage and current will be conducted using MATLAB and level of harmonic distortion will be presented in form of FFT spectrum. VS2015 will be used to measure the performance of the system with different load identification.

1.5 Report Outlines

The outline of this report represent by 5 chapters. Brief explanation for the cause of harmonic distortion and how these harmonic can harm the equipment are discussed in introduction part. In this chapter, it has been stated that HSIS is developed to identify the location harmonic source. The objectives and scope are clearly stated for a project guidelines. Other chapters in this report are summarized as follows:

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Chapter 2 presents the background theories related to the project. This includes the explanation of basic method used to measure the THD and harmonic source locations. The summary and discussion of the proposed methods of HSIS have also explained in this chapter.

Chapter 3 discusses the project methodology used in developing HSIS. Acceptable methods used in accomplishing this project are explained in details. With the help of a particular figure and block diagram, the hardware and software implementation in developing HSIS are shown. Three different loads are considered for performance test of the system.

Chapter 4 shows the results of simulations from MATLAB based on the method proposed. The effectiveness of HSIS in measurement and harmonic source identification are discussed in accordance with the results recorded by the performance test for three different types of loads.

Chapter 5 concludes the achievement of the desired objectives based on simulation, project development and performance test. Some future work recommendations are also suggested for improving the method used in determining the harmonic distortion.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to gain enough information to recommend the appropriate method that can be used to complete the research, comparison between certain techniques is required to measure the harmonic distortion in single phase system. The outlines in this chapter related to the theory and basic principles, review of previous related work, and summary of this project. In the first section of the research covered the definition from Institute of Electrical and Electronics Engineers (IEEE) where PCC, Total Demand Distortion (TDD), harmonic measurement methods, and voltage and current distortion limits. Besides, this section reviews on harmonic distortion occur in the single phase power system by analyzing different types of waveform for different harmonic order in the following sequence.

Reviews of previous related works on harmonic distortion focused on certain methods such as Wavelet Packet Transform (WPT), direction of active power flow and FFT designed by respective researchers. Each method is explained based on three sections, i.e. the analog input and signal conversion, signal processing and computational calculation, and GUI. The performance is verified for improvising the existing harmonic distortion monitoring system for the convenience of users.

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2.2 Theory and Basic Principles

Institute of Electrical and Electronics Engineers (IEEE) 519-2014 stated that the measurement of harmonic distortion is recommended at PCC whereby the point is on the LV side of the distribution transformer [5]. As stated in [6], the loads contain harmonic can be pure resistive, inductive, capacitive or single phase rectifier. Nowadays, measurement of harmonic is proposed where the harmonic source is located between the utility and costumer using several methods. There will be disadvantage in measuring the harmonic at PCC for single point due to lack in accuracy. In terms of economics, PCC can increase the level of investment for harmonic measurement in power system for optimization [7].

In PCC measurement, TDD is considered as a percentage of average maximum voltage or current over a demand interval for certain time [8]. IEEE 519 stated that the demand interval in [9] is typically between 15 to 30 minutes and larger voltage or current demand will produce large distortion and vice versa. As mentioned above, TDD is not covered for interharmonics component as the main objective focused on harmonic distortion as mentioned in [6]. Based on consideration stated in [10], data taken for harmonic distortion represent best in average values for the performance of the system.

Harmonic distortion becomes the main culprit in power quality (PQ) system now. Under certain condition stated in [11] where nonlinear loads such as rectifier and arc furnace increases with the increases uses of power electronic component. This condition leads to the disturbance in a system allow appliances to operate under loss condition and increases maintenance cost. Harmonic distortion that occurs in single phase will become influenced to other appliances and leads to further damages. For example, a device like a computer that sensitive to disturbance can cause data error. The supplier will become the victim due to the loss interested in customer for their utilities. Due to this issue, researchers come with certain method that will be discussed later.

Voltage and current distortion limit measured is recommended based on rated value between 120V to 69kV. Through this recommendation, harmonic distortion at PCC can be measured and proper solution can be made if the value exceeds the limits. In terms of harmonic distortion, there may be a problem due to the increased use of the capacitor banks that can

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increase power factor, but may lead to the worst scenario such as harmonic [12]. In accordance, proper measuring system is the best option to monitor the performance of a system and hypothesis can be made based on the situation occur where HSIS is proposed.

2.2.1 Total Harmonic Distortion

Harmonic distortion is one of the main indices that affect the power quality. Harmonic distortion is represented in a complex time and frequency domain [12] and expressed in rms values. As mentioned in [13], due to the increases use of power electronic components, new type of harmonic source is traced. Harmonic effect can be measured either voltage or current and this distortion may lead to the increases of frequencies in the waveform [14]. Figure 2.1 presents the harmonic waveform for single phase systems.

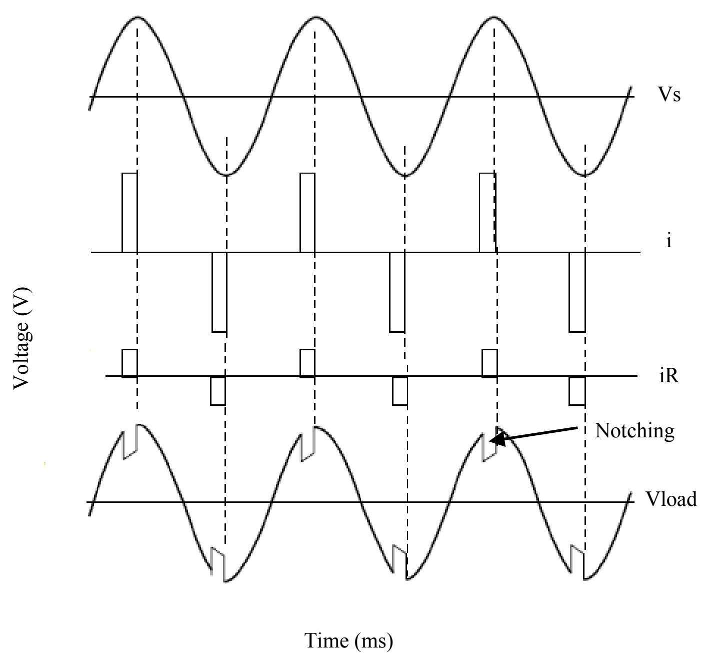

Figure 2.1: Harmonic Signal Occur Inside Sinusoidal Signal [12]

As shown in Figure 2.1, the distortion occurs at the pure sinusoidal waveform is called notching. Notch area may affect the quality of the system. The percentage of notch depth is

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measured to monitor the distortion in a source. The ratio between non-fundamental frequencies to fundamental frequency is called total harmonic distortion and can be expressed as given below [15].

$$THD = \frac{\sqrt{\sum_{n=2}^{N} {V_n}^2}}{V_1} \tag{2.1}$$

Where V_n = Single frequency r.m.s

n = Harmonic voltage

N = Maximum harmonic

V_1 = Fundamental line to neutral r.m.s

Based on recommendation of American National Standards Institute (ANSI) standard in [16], the THD truncation is at 5kHz, but in practical application, the value will not exceed that much due sensitivity on hardware implementation. THD may come to simple in term of measurement based on equation (2.1) but the detailed information in the power spectrum analysis for every harmonic order became the main issue.

2.2.2 Harmonic Level

Different harmonic level gives a different shape of harmonic waveform. Harmonic level can be classified into 3 different sequences which are positive, negative and zero. As mentioned above, a harmonic is measured at PCC where the studies include the modelling of two winding transformers. As stated in [17], most distribution transformer cannot propagate and leads to zero sequence harmonics. As the result, the low voltage system will suffer greater damage if small unbalances happen as the zero sequence harmonic involve at neutral wire. Table 2.1 indicates the level of harmonic for positive, negative and zero sequence.

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