DESIGN AND DEVELOPMENT OF A THREE PHASE SHUNT ACTIVE POWER FILTER FOR HARMONICS REDUCTION IN INDUSTRIAL USING MATLAB/SIMULINK

MUHAMAD NUR ARIF BIN BAHARUDIN

BACHELOR OF ELECTRICAL ENGINEERING
(INDUSTRIAL POWER)

2nd JULY 2012

" I hereby declare that I have read through this report entitle "*Design And Development Of A Three Phase Shunt Active Power Filter For Harmonics Reduction In Industrial Using Matlab/Simulink*" and found that has comply the partial fulfillment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*"

Signature : ………………………….

Supervisor's name : ………………………….

Date : ………………………….

DESIGN AND DEVELOPMENT OF A THREE PHASE SHUNT ACTIVE POWER FILTER FOR HARMONICS REDUCTION IN INDUSTRIAL USING MATLAB/SIMULINK

MUHAMAD NUR ARIF BIN BAHARUDIN

A report submitted in partial fulfillment of the requirements for the degree

of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUN 2012

I declare that this report entitle "*Design And Development Of A Three Phase Shunt Active Power Filter For Harmonics Reduction In Industrial Using Matlab/Simulink*" 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 : …………………………………….

To my beloved mother and father

ACKNOWLEDGEMENT

Firstly, I would like to offer my gratitude to Allah S.W.T for the mercy and grace, I finally able to complete a report for the Final Year Project 2 (FYP2) based on the specified date.

Here, I would like to express my deepest appreciation and thank you to those who have helped me directly or indirectly in completing this project. In this opportunity, I would like to express my gratitude to Mr. Ir. Rosli Bin Omar as my project supervisor, who has helped me in completing this project and helped me to solve the problem in which I faced during this project. In addition, I wish to thank to Universiti Teknikal Malaysia Melaka in particular to all members of the committee for Final Year Project and all that are involved to implement this project properly. Finally I would like to show my appreciation to my parents because for their encouragement and moral support during my studies at the Universiti Teknikal Malaysia Melaka (UTeM).

In this opportunity, I hope that all my knowledge gained during the implementation of this project received a blessing from Allah S.W.T and I want to apologize if there are shortcomings and mistakes in writing of this report for Final Year Project 2 (FYP2). Finally, the good is from Allah SWT and the less is from my own weakness.

ABSTRACT

Electricity consumption had been increased so rapidly once in line with the development of the country to achieve its status as the industrial countries. The large consumption of electrical energy, one thing that plays an important role in a distribution system is the quality of electrical power itself. The distribution system will have many problems related to efficiency and functionality of electrical equipment. Therefore, the entire system does not operate efficiently due to the presence of harmonic in the distribution system. Among of them, one of the disorders that cause poor power quality is harmonic. This disturbance causes electrical equipment used to heat and cannot function properly. Thereby, the aim of this project is to design and develop of a three phase shunt active power filter for harmonics reduction in industrial using MATLAB/SIMULINK. In this project, there are 4 phases of methodology have been applied to ensure that the project be completed within the prescribed time. The first phase is to find as many references related to this project. The second phase is circuit design for three phase shunt active power filter. The third phase is a simulation of the design circuit and the last phase is the final results. From the simulations carried out, it was found that the use of three phase shunt active power filters that are built can filter the harmonics in the electrical system.

ABSTRAK

Penggunaan elektrik telah meningkat begitu pesat sekali selaras dengan pembangunan negara untuk mencapai status sebagai negara-negara perindustrian. Penggunaan tenaga elektrik yang besar, satu perkara yang memainkan peranan yang penting dalam sistem pengagihan kualiti kuasa elektrik itu sendiri. Sistem pengagihan akan mempunyai banyak masalah yang berkaitan dengan kecekapan dan fungsi peralatan elektrik. Oleh itu, keseluruhan sistem tidak beroperasi dengan cekap kerana kehadiran harmonik dalam sistem pengagihan. Antara salah satu gangguan yang menyebabkan kualiti kuasa yang miskin adalah harmonik. Gangguan ini menyebabkan peralatan elektrik yang digunakan mengalami gangguan kepanasan dan tidak boleh berfungsi dengan baik. Dengan itu, tujuan projek ini adalah untuk merekabentuk dan membangunkan pirau penapis kuasa tiga fasa aktif untuk pengurangan harmonik di industri yang menggunakan MATLAB / Simulink. Dalam projek ini, terdapat 4 fasa metodologi yang telah digunakan untuk memastikan bahawa projek tersebut akan siap dalam tempoh masa yang ditetapkan. Fasa pertama adalah mencari seberapa banyak rujukan yang berkaitan dengan projek ini. Fasa kedua ialah merekabentuk litar untuk tiga fasa kuasa penapis pirau aktif. Fasa ketiga adalah menjalan simulasi bagi litar setelah proses merekabentuk dapat diselesaikan dan fasa terakhir adalah mendapat keputusan terakir. Daripada simulasi yang dijalankan, didapati bahawa penggunaan tiga fasa pirau penapis kuasa aktif yang dibina boleh menapis harmonik dalam sistem elektrik.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Power quality is important in the distribution system. To provide power supply with good quality is not easy because it depends on the type of load used. Phenomenon that causes an interruption in the electrical system such as overvoltage, voltage sags, voltage surges and harmonic [1].

Harmonic distortion problem has existed in the power system for a long time. it causes a wave of the line current and voltage in the power system to be distorted. In the past, discussions about the existence of harmonics have been discussed. However, at that time, the impact and influence of harmonic distortion is slightly lower than at present, where it only covers in the delta grounded w-ye connection of the transformer and also in some design of power transformer [1].

At present, the creation of modern equipment, especially electronic equipment and also the increased use of non-linear loads in industry has produced harmonic distortion, harmonic distortion in electrical systems became more serious because the use of electronic equipment are among the largest contributors to the formation of harmonic distortion.

Harmonic effects that occur in the electrical system depend on the harmonic source, the location of the power system and network features that allow the propagation of harmonic. The main cause leading to the generation of harmonics is the use of non-linear loads such as: -

- Office equipment such as computers and electronic equipment.
- Discharge lamps.
- Saturation and magnetic currents in the transformer.
- Frequency converter, arc furnaces, welding and voltage regulator.
- Power semiconductor switching devices such as rectifiers and inverters that can distort the sine wave.
- Motor control devices.
- Conversion and HVDC transmission.

The waveform of voltage and current in the electrical system is disturbed by harmonics usually no longer pure sine waveform. The waveform of the line voltage is usually satisfactory, but for line current harmonic distortion occurs. Harmonic distortion in the waveform of the current resulting from magnetic saturation in the core of the transformer or the effects known as eddy current or switching action of the thyristor in power electronic drives. Each of the distorted sine wave is contained harmonic. Only the fundamental components that will be consist of pure sine wave. The harmonic effects are: -

- Failure of the capacitor bank.
- Power line carrier system disorders can cause long-haul operations of switching devices, load control and metering to be less accurate.
- Heat loss in synchronous and induction machines.
- Current and voltage range of epoch in the past.
- Error in the induction watt-hour meter.
- Interference signal and the relay do not work, especially in the solid state and microprocessor systems.
- Interference in large motor controller and excitation system of power station will cause the output of the motor is not uniform.

The existence of harmonics, as informed will cause distorted current and voltage waves. Total harmonic distortion is the total current and voltage harmonic distortion. It is defined as the ratio of root mean square of all current or voltage harmonics to the fundamental of current or voltage. Equation 1.1 and Equation 1.2 assumes all even harmonic components are neglected because the effect is minimal in the three-phase system. The characteristics of the harmonic in the distribution system are a function of the harmonic source and the response of the system. For example, the transformer produces a high harmonic current from the saturation flux (harmonic voltage) and the size of the capacitor banks accounted for the propagation of frequency channels in the distribution system to the harmonic source. Harmonic currents caused by the third component in the transformer operations adversely. Harmonic currents will affect badly to the transformer and the machines that produce extreme heat. Insulation transformer and machine windings may be at risk. Harmonic voltages and currents may negatively impact the capacitor banks such as overheating, overvoltage, changes in the dielectric stress and loss [1].

$$THD_i = \frac{\sqrt{\sum_{h=2}^{\infty} I_{harmonic}^2}}{I_{1(fudamental)}} \tag{1.1}$$

$$THD_v = \frac{\sqrt{\sum_{h=2} V_{harmonic}^2}}{V_{1(fundamental)}} \tag{1.2}$$

1.2 Problem Statement

There are many disorders in electrical power systems. Harmonic is one of the disorders. Harmonic arises from the use of non-linear loads that cause wave to be inverted, distorted, or contaminate the sine wave of current or voltage as discussed in section 1.1.

Harmonic problems that are found in industry can be divided into two terms which are current and voltage. First problem can be associated with harmonic currents. Problems that may occur are as follows. Overload occurs in the neutral conductor caused by the harmonic multiples of 3 that do not have 120 in the phase shift will increase the unbalanced current in neutral conductor. It also cause overload on the transformer in which primarily caused by eddy currents, where the total loss at full load increased dramatically in line with the number of harmonics. Also the 3rd harmonic (multiples of 3) will rotate around the delta winding so the losses increase. It also it cause circuit breaker tripped due to the chaos on the ground fault. This occurs when there is a noise at the highest level associated with the harmonic generating equipment.

The next problem is related to the harmonic voltage. Presence of voltage distortion caused by interference generated by the harmonic current resulting voltage drop in the source impedance, caused damage to the sinusoidal wave of voltage, then all types of loads including linear loads will be interrupted by the harmonic that carrying by supply and will generate harmonic currents. It will also cause an increase in eddy current losses as well as in transformers. Thus, it will lead to additional losses increase as the harmonic try to turn the motor at different speed. When the harmonic currents produced in industrial load, it will lead to equality in the voltage drop in term of source impedance and current.

1.3 Objectives

Objectives of this project are to find and create solutions to the statement of the problem arising from the effects of harmonic disturbances in industrial. Objectives identified are as follows:-

- To study, identify and make analysis of the impact, causes, and how to solved the problem that created by harmonic in industrial.
- To study, identify and carry out research on methods to reduce the harmonic effects using shunt active power filters.
- To design and development of a three phase shunt active power filter for harmonic reduction in industrial using Matlab/Simulink.

1.4 Scope of Project

The scope of this project is to design a system or equipment that can be used to filter and reduce the harmonic distortion in industry. This project also includes the analysis, the review on the information and data of the harmonic distortion and its impact on the industrial and also to find the main source of how the harmonic has been generated. Design a three phase shunt power active filter and do a simulation using Matlab/Simulink to obtain the answer, solve the problem and also achieves all of the objectives for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Harmonic

In 1822, Jean Baptise (1789-1830) was one of the French mathematician, wrote in a book entitled "*Theorie de la chaleur analytique*", that any continuous function over the interval T (seconds) can be represented by the summation fundamental components of the sine and the harmonic components containing multiple frequencies of the fundamental component. Figure 2.1 shows the basic components of the waveform and the waveform of the effects of harmonic distortion [2].

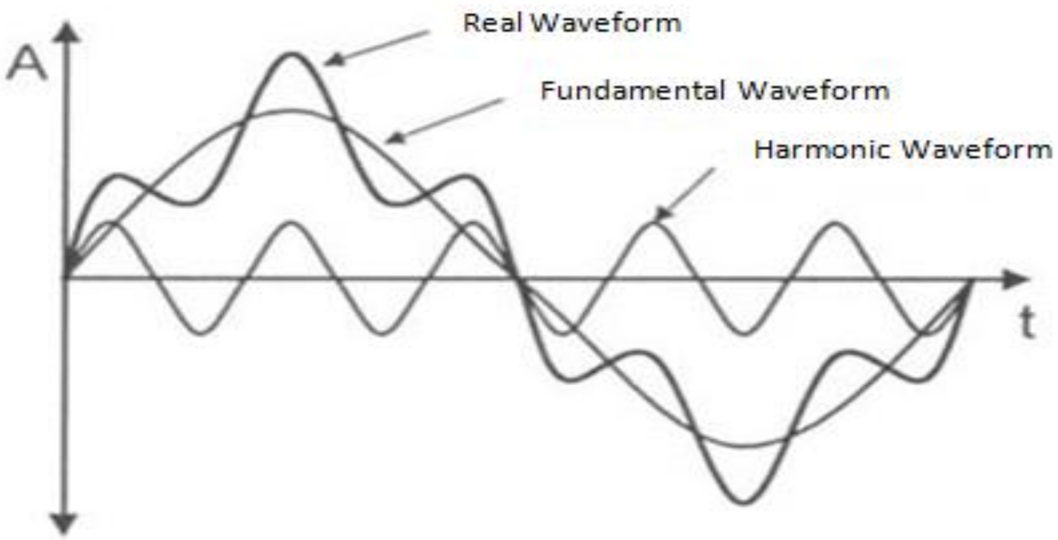

Figure 2.1: Basic Components and Waveform of The Effects Of Harmonic Distortion [3]

Harmonic content in the electrical system will cause a waveform of voltage or current in the electrical system to be distorted. This situation is very critical because it will interfere with other electrical systems. Harmonic analysis is the process of calculating the magnitude and phase angle of fundamental and harmonic waveform. Set of sine waves with the lowest frequency f Hz, while all other frequencies equal to multiples of *f (2f, 3f, 4f, 5f…).* By definition, the lowest frequency sine wave refers to the base and all the high frequency waves known as harmonics. For example a series of sine waves containing frequency of 50 Hz, 100 Hz and 150 Hz is consist of the following components, 50 Hz (fundamental frequency), the second harmonic, 100 Hz (2 x 50 Hz) and third harmonic, 150 Hz (3 x 50 Hz). By performing harmonic analysis, non-sinusoidal wave can be represented by a series of cynical wave containing multiples of the fundamental frequency and the frequency of the fundamental frequency of the harmonic components [2].

2.2 Harmonic Refer to IEEE Standard

According to IEEE standard, sinusoidal voltage or current that contains the integer of multiple frequencies are known as harmonics. It often happens in which the power supply system designed to operate in the frequency range of 50 Hz or 60 Hz, it is termed as the fundamental frequency. Harmonic will combine with base voltage or current, and produces waveform distortion. Harmonic distortion is created because of non-linear characteristics of the device and the load on the power system [4].

These equipments are generally identified as a source of harmonic currents injected current into the power system. The results of the voltage-current distortion causing non-linear voltage drop across the impedance of the system. This harmonic distortion becomes a concern for many users and for the entire power system due to the increased use of electronic equipment.

The level of harmonic distortion can be characterized by the complete harmonic spectrum with magnitudes and phase angle of each individual harmonic component [4]. Single quantity, the total harmonic distortion, as a measure the magnitude of harmonic distortion is commonly used.

Harmonic distortion produced from the use of non-linear loads in power systems. Figure 2.2 shows the waveform and harmonic spectrum for adjustable speed drive input current. Current level of distortion can be expressed by the total harmonic distortion. For example, a lot of adjustable speed drives will display high values of total harmonic distortion input current when they are operating at very light loads, but it is not a significant concern because magnitude of harmonic currents are low, even relatively high distortion [4].

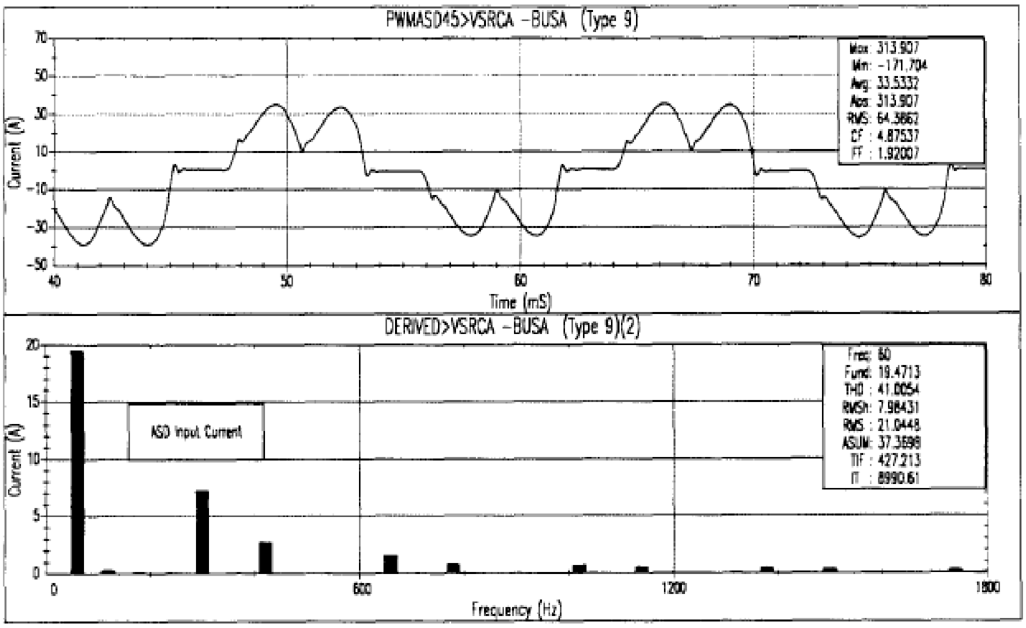

Figure 2.2: Waveform and Harmonic Spectrum for Adjustable Speed Drive Input Current [4]

To overcome this problem to characterize the harmonic currents in a manner that is consistent, IEEE Std 519-1992 has defined in other term as the total demand distortion. The term is the same as the total harmonic distortion unless the distortion stated as percent of some rated load current and not like a percentage of fundamental of the current magnitude [4].

2.3 Causes of Harmonic

This section describes the causes of harmonics in the industry. it includes the type of equipment that generate harmonics and equipment that contribute to the presence of harmonics.

2.3.1 Types of Equipment That Generate Harmonic

David Chapman has written in his book entitle "*Harmonic causes and effects*", that the harmonic currents present in the load resulting from all the non-linear loads. There is a lot of industrial equipment used in the present that produce harmonics. The equipment can be divided into two categories single-phase load and three phase load. The examples of single-phase loads are such as the switched mode power supplies (SMPS), the electronic fluorescent lighting ballasts and the small uninterruptible power supplies (UPS). While the examples of three-phase loads are such as the variable speed drives (VSD) and the large uninterruptible power supply (UPS) units.

2.3.2 Switch Mode Power Supplies (SMPS)

Many electronic devices currently use a switch mode power supplies (SMPS). In the past, step-down transformer and rectifier used to convert alternating current to direct current for electrical and electronic equipment. Now it is replaced by direct controlled rectification, where it will provide the supply to charge the reservoir capacitor to produce a direct current to the load depends on the voltage and current at the output of the load [4]. The advantages of using a switch mode power supplies (SMPS) are such as the power units can be made in almost any desired form factor, small size, less cost and light Weight. The disadvantages of using a switch mode power supplies (SMPS) are such as the power supply unit will draw a current pulse that contains a large amount of the 3rd harmonic and significantly higher frequency components as shown in Figure 2.3. Basic filtering devices has been installed at the input supply to bypass the high frequency components from the line and neutral to earth, however it does not give any effect to the Harmonic currents flowing back into the supply.

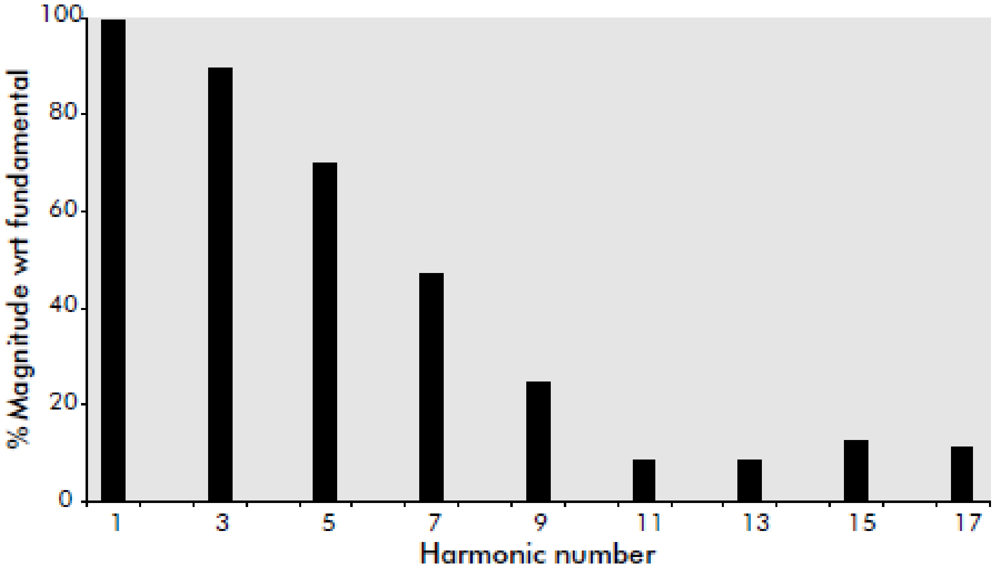

Figure 2.3: Harmonic spectrum of a typical PC [3]

2.3.3 Fluorescent Lighting Ballast

A recommendation for improving energy efficiency has resulted in demand for electronic ballasts have increased in recent years. However, the difference between the efficiency of electronic ballasts and magnetic ballasts only slightly different if more efficient magnetic ballasts used.

1) Advantages using fluorescent lighting ballasts:
   - Light levels can be maintained throughout a long life by feedback control of current flow.
2) Disadvantages using fluorescent lighting ballasts:
   - It will generate harmonics in the supply current.

Nowadays, compact fluorescent lamps are selling as a substitute of tungsten filament bulbs. Compact fluorescent lamps consists a small of electronic ballast that housed in connector casing, folded 8mm control fluorescent tube diameter. Compact fluorescent lamps rated of 11 watts are selling as a replacement for the 60 watts filament lamp and have a life period of 8000 hours. Figure 2.4 shows the graph of harmonic current spectrum. These lamps are widely used to change the light bulb filament in the state