DECLARATION

I declare that this report entitled “Reduction of Harmonic Using Single Phase Shunt Active Power Filter Based on Fast Fourier Transform Method for PWM Cascaded Multilevel Inverter” 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 : Nur Izzati Binti Zolkifri

Date : 10/06/2016

DECLARATION

"I hereby declare that I have read through this report entitle "Reduction of Harmonic Using Single Phase Shunt Active Power Filter Based on Fast Fourier Transform Method for PWM Cascaded Multilevel Inverter" and found that it has comply the partial fulfilment for awarding the Bachelor Degree of Electrical Engineering (Industrial Power)."

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FINAL YEAR PROJECT REPORT

Submitted by:

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This report is submitted to Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka in partial fulfilment for Bachelor of Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

(2016)

To my beloved mother and father

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to my supervisor, Mr. Musa Bin Yusup Lada for his patience guidance, motivation, enthusiasm and immense knowledge. The supervision helped me in all the time of research and writing of this report. Besides, I would like to express my thanks to Universiti Teknikal Malaysia Melaka (UTeM) for giving me the chance to pursue my study in Bachelor of Electrical Engineering.

Next, I would like to extend my thanks to all my course mates for their supports and time during completing this project. Last but not least, a special thanks to my family especially my parents who always give their support and motivation to me. Without support from them I am not able to complete this project.

ABSTRACT

The usage of power electronic device has been widely used in industrial as well as in domestic system. Consequently, it will develop power quality problem in distribution system. High Total Harmonic Distortion (THD) and low power factor is a main problem that caused by non-linear loads. This is because non-linear load generate a non-sinusoidal waveform passes through the distribution system which leads to voltage and current harmonics. Indirectly, current harmonic can cause problem to the load itself such as losses, overheating and overloading. The main objective of this project is to improve the power quality as well as to simulate and analyze the performance of single phase shunt Active Power Filter (APF) based on Fast Fourier Transform (FFT) method. In this project Photovoltaic solar panel is the power supply and converted to alternating current (AC) by cascaded H-bridge Multilevel Inverter (MLI) which uses Pulse Width Modulation (PWM) technique as controller. Furthermore, MLI with PWM control scheme produced less harmonic output. However, non-linear loads installed in the system will causes increasing of harmonic. Thus, this project is about implement a single phase APF based on FFT to filter the harmonic and directly improve the power quality. The performance of APF based on FFT was evaluated in term of total harmonic distortion at line current with connection to the R, RL, RC and rectifier loads. The MATLAB/Simulink simulation has been used in this project in order to simulate and prove that the FFT technique is capable to reduce the harmonics generated by loads. At the end of this project, the performances of APF based on FFT technique were analysed. The simulation result shows that by injecting APF in the system, the THD line current was improved below than 5% even though THD load current show the high percentage of THD. In addition, the simulation result shows that THD line current of Unipolar MLI with R load and rectifier indicate lower percentage of THD at 0.24% after APF based on FFT technique was applied. The highest THD line current after injecting APF is trinary MLI with RC load and rectifier which is 4.81% and it still under the limit of IEEE 519 harmonic standard.

ABSTRAK

Penggunaan peranti elektronik kuasa telah digunakan secara meluas dalam industri dan juga di dalam sistem domestik. Oleh yang demikian, ia akan menyebabkan satu masalah yang besar iaitu kualiti kuasa dalam sistem pengedaran. Jumlah harmonik yang tinggi dan faktor kuasa yang rendah adalah masalah utama yang disebabkan oleh beban bukan linear. Ini kerana beban bukan linear menjana gelombang yang bukan berbentuk sinusoidal melalui sistem pengagihan yang akan membawa kepada harmonik voltan dan arus elektrik. Secara tidak langsung, harmonik arus elektrik boleh menyebabkan masalah kepada beban itu sendiri seperti kehilangan kuasa, suhu berlebihan dan terlebih bebanan. Objektif utama projek ini adalah untuk meningkatkan kualiti kuasa dan juga untuk mensimulasikan dan menganalisis prestasi satu fasa APF berdasarkan teknik FFT. Dalam projek ini mengambil kira tenaga solar sebagai sumber tenaga utama, dan PWM digunakan untuk mengawal MLI. Tambahan pula, MLI dengan skim kawalan PWM menghasilkan output yang kurang harmonik. Walau bagaimanapun, beban bukan linear yang dipasang dalam sistem telah menyebabkan peningkatan harmonik. Oleh itu, projek ini mengaplikasikan satu fasa APF menggunakan teknik FFT untuk menapis harmonik dan secara tidak langsung meningkatkan kualiti kuasa. Prestasi APF menggunakan teknik FFT dinilai dari segi jumlah ganguan harmonik di arus hantaran dengan menyambung kepada R, RL, RC dan beban penerus.MATLAB / Simulink telah digunakan dalam projek ini untuk mensimulasikan dan membuktikan bahawa teknik FFT ini mampu untuk mengurangkan harmonik yang telah dijana oleh beban. Di akhir projek ini, prestasi APF berdasarkan teknik FFT dianalisis. Hasil THD arus hantaran bertambah baik iaitu berada di bawah daripada 5% walaupun THD arus beban menunjukkan peratusan yang tinggi. Di samping itu, hasil simulasi menunjukkan bahawa THD arus hantaran unipolar MLI dengan beban R dan penerus menunjukkan peratusan THD yang lebih rendah dengan 0.24% selepas APF berdasarkan teknik FFT yang telah digunakan. THD arus hantaran yang tertinggi selepas menyuntik APF adalah trinary MLI dengan beban RC dan penerus iaitu 4.81% dan ia masih di bawah had IEEE 519 standard harmonik.

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MLI – Multilevel Inverter

CHB-MLI – Cascaded H-Bridge Multilevel Inverter

AC - Alternating Current

DC - Direct Current

PWM - Pulse Width Modulation

VSI - Voltage Source Inverter

CSI - Current Source Inverter

APF - Active Power Filter

PPF - Passive Power Filter

FFT - Fast Fourier Transform

VSAPF – Voltage Source Active Power Filter

CSAPF – Current Source Active Power Filter

CHAPTER 1

INTRODUCTION

1.1 Overview

Solar energy is one of renewable energy that has been widely used in recent years. The solar panels were converted into electrical energy in the form of Direct Current (DC). The rising demands of solar energy from several industrial companies have triggered industrial engineer to come up with ways to convert DC voltage into AC voltage for direct use with AC loads. Thus, electrical power inverter has been introduced and it was described as a circuit that convert Direct Current (DC) input signal into Alternating Current (AC) by which both magnitude and frequency can be controlled. There are several type of inverters exist and multilevel inverters (MLI) is one of the inverter that produce less harmonic compared to the two-level inverter that consists of four switches [1]. Multilevel inverter is a power electronic system that functions to synthesize a sinusoidal voltage from several levels of DC voltages.

The main purpose of MLI is to have better sinusoidal voltage and current in the output by applying switches in series. There are three types of MLI which are Cascaded H-Bridges MLI, Diode Clamped MLI, and Flying Capacitor MLI [3]. The concept of PWM Cascaded H-Bridges multilevel inverter is applied. Besides, by using pulse width modulation (PWM) technique, multilevel inverter (MLI) will generate better output power quality. Even though MLI can be design in harmonic less, the non-linear load current might undermine quality of energy supply in the system. Nonlinear loads are the reasons for the increasing harmonics and it causes very serious damage in power distribution system. The effects of harmonic are low power factor, overheating of neutral wire and overloading to the system [1]. Previously, passive filter is used to reduce the total harmonic distortion but there are several disadvantages in passive filter like resonance that affect the stability and fixed compensation [3]. Thus, Active Power Filter (APF) becomes a solution to improve grid power quality. Since APF have two major control techniques which are time domain and frequency domain, this project is dealing with frequency domain based on Fast Fourier Transformation (FFT) method by connected to MLI system. The APF performs the filtering action by injecting harmonic components which eliminate those from the load, thus the line current becomes less of harmonic distortion. The frequency methods that based on FFT are used because it provides accurate individual and multiple harmonic detection of load current. This model is simulating in MATLAB/Simulink, to mitigate harmonics of the load current.

1.2 Motivation

Since late 1980s power quality problem has become priority in the distribution system. Harmonic distortion in power system has been a significant problem in order to maintain power quality. Furthermore, harmonic distortion have been presented for a decades. However, in these recent years Total Harmonic Distortion (THD) was increasing rapidly due to widely used of electronic device. High value of THD can causes overheating, overloading and losses in distribution system [2]. Electronic device such as home appliance, diodes, and silicon controlled rectifier (SCR) was categorized as non-linear loads. These non-linear loads contribute to high percentage of THD in the system. Since power electronic device have its own advantage in efficiency and controllability, it was expected to be on high demand in the future. Moreover, non-linear loads can be used for low-voltage appliance and high voltage. As for solar energy that have been converted to the electrical energy by using Multilevel Inverter (MLI) with harmonic less still drawn high percentage of THD whenever it connected to the non-linear load. Therefore, in order to maintain power quality and follow the standard of IEEE 519-1992 which is THD must be below than 5% in the distribution system with the presence of non-linear load, filter is needed [3].

1.3 Problem Statement

In recent years, solar energy is one of the most popular renewable energy. Hence, multilevel inverter (MLI) is used to convert variable direct current (DC) source from Photovoltaic solar panel into alternating current (AC). Even though MLI could be designed in harmonic less, but by connecting to the non-linear loads current may weaken quality of energy supply in the system. Electronic devices are well known as a non-linear load and generate current harmonic pass through the grid. Electrical power system which is power quality will face a serious damage in such situation. The characteristic of the power quality of the AC power system are divided into two which is Total Harmonic Distortion (THD) and Power Factor (PF). Harmonic distortion can cause long term effect and short term effect on power distribution system. Long term effects are related to excessive voltage distortion while short term effect are usually related to increased resistive losses or voltage stresses. Depending upon level of the harmonics, the non-linear load current may lead to the power quality problem. Harmonics can also be categorized as pollutant that pollutes the entire power system. Hence, harmonic filter is needed in order to eliminate them from the AC supply. There are various techniques for harmonics elimination that has been studied throughout the years. So far, using passive filter are not the best solution due to many demerits like fixed compensation, increased losses, and bulky in size. Therefore, APF become an applicable method to improve grid power quality. APF has fundamental competence to effectively adjust itself to reducing power line harmonics and at the same time minimizing effect of parasitic problems. Furthermore, improving power factor using APF would not change fault level of power system grid [5].

1.3 Objective

The objectives of this project are:

i. To improve the power quality using single phase shunt active power filter based on Fast Fourier Transform method for PWM cascaded multilevel inverter.
ii. To simulate and analyze a single phase shunt Active Power Filter based on Fast Fourier Transform method for PWM cascaded multilevel inverter by using MATLAB/Simulink software.
iii. To verify the performance of single phase shunt active power filter based on Fast Fourier Transform method for PWM cascaded multilevel inverter follow the requirement of harmonic standard IEEE 519 which is below than 5%.

1.4 Scope

The scope of this project is to conduct simulation of the conventional single phase shunt active power filter based on Fast Fourier Transform method for PWM cascaded multilevel inverter. The MATLAB/Simulink software is used to simulate and analyse the performance of single phase shunt active power filter for PWM cascaded Multilevel Inverter (MLI) using Fast Fourier Transform method. The control switching scheme was applied for MLI in this project are trinary seven levels, bipolar, and unipolar. The block simulator was developed based on FFT method algorithm and tested with several of non-linear loads which are R-load, RL-load, RC-load and Rectifier. Furthermore, this project aims to reveal the concept of harmonics reduction process and improving grid power quality in a single phase power system grid. This project deals with frequency domain which is Fast Fourier Transform method to reduce the THD and at the same time eliminate effect of the parasitic problems.

1.5 Report Outline

There are five chapters in this report. It is started with the introduction of the project and five others chapter are sorted as follows:

Chapter 1 is about the short explanation of this project, problem statement, objective and scope.

Chapter 2 cover the theoretical background of this project such as type of filter, topologies of APF, types of inverter, power quality, and total harmonic distortion.

Chapter 3 focuses in the project methodology. This chapter consist of flowchart of the project, milestone, Gantt chart, block diagram of the project, simulation model, and the switching method used in this project.

Chapter 4 contains all the simulation result and the discussion of the simulation result by using different non-linear loads.

Chapter 5 covers the summary of this project and the recommendation for the further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Total Harmonic Distortion (THD) have been detected increasing rapidly due to the widely used of non-linear loads. Moreover, non-linear loads will generate harmonic even though MLI switching scheme is good enough in producing less harmonic output. Thus, this chapter reviews the previous work on filtering harmonic. Filtering is one of the solutions in order to mitigate the current and voltage harmonic. Filtering is important to improve power quality, power factor and reduce harmonic. Filtering can be done by using passive or active power filter. Since passive filter is limited in eliminating the harmonic, this project comes out with the most popular technique which is Active Power Filter [5].

2.2 Power Quality

Power quality is a general term used to represent the interaction of electrical power with electrical equipment. It is defined in the IEEE 100 Authoritative Dictionary of IEEE Standard Term as the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment [2]. Since late 1980s power quality problem has become priority in the distribution system. There are three parties that concern about power quality such as utility companies, equipment manufacturers and electric power consumers. The characteristic of the power quality of the AC power system are divided into two which is Total Harmonic Distortion (THD) and Power Factor (PF). Besides, there are two terms that widely used in power systems about the power quality. First it is called as good power quality which can be used to define a power supply that is always available, consistently within the voltage and frequency tolerance then any load connected to it will run smoothly and efficiently. In addition, having a pure noise-free sinusoidal wave shape is one of the characters of the good power quality. Whereas, the poor power quality in power system is define when the load connected to it fail or have a reduced lifetime and efficiency of the electrical installation [1]. Besides, poor power quality can affect the accuracy of utility metering and the equipment in use is vulnerable to damage or service disturbance which will cause equipment miss operation and premature failure.

Indeed, power quality is an important point in the relationship between suppliers and consumers [3]. The ideal power quality consist of two sorts of frequency that are utilized in power system which are 50 Hz and 60 Hz because these frequency are most minimal resonance frequencies and also acknowledge as fundamental frequency as shown in Figure 2.1 and Figure 2.2. The ideal power quality is represented by the waveform in single-phase and three phases.

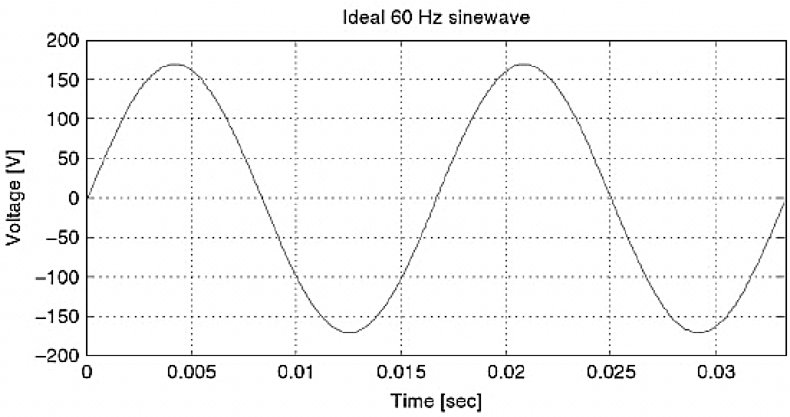

Figure 2.1: Ideal single-phase voltage waveform

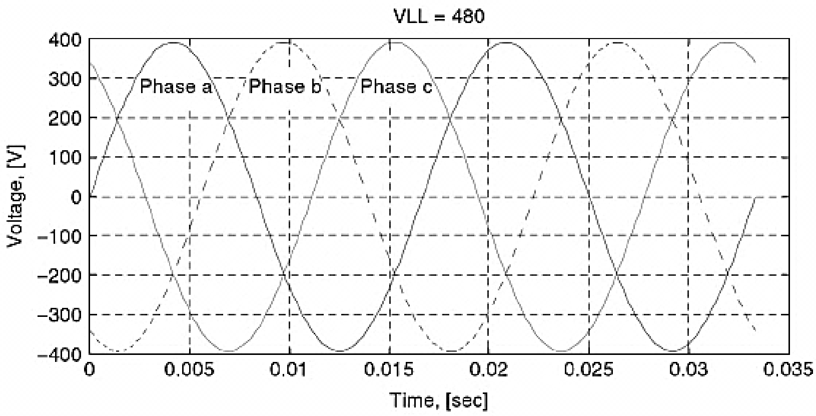

Figure 2.2: An ideal three-phase voltage waveform.

2.2.1 Harmonic Distortion Definition

The increasing usage of non-linear load will tend toward to the power quality issues with much attention in harmonic distortion. Harmonic distortion has been gaining endless attention due to the increasing of non-linear loads that use in daily life. The main source of voltage and current harmonic is power electronic device that have been widely use in electric component such as chopper, rectifier and cyclo-converter which is characterized as non-linear. The non-linear loads affected the flow of power by drawing currents only during certain intervals of the fundamental period [4]. Thus the current supplied are not drawn linearly as in sinusoidal waveform and will draw higher percentage of harmonic distortion.

Figure 2.3 shows that the sum of the pure sinusoids that can produce non-sinusoidal signal. Harmonic distortion also can be classified as pollution in the electrical system which causes problems if the sum of the harmonic currents exceeds certain limits [5]. The summation of sinusoids is indicating in Fourier series form. By using Fourier analysis that was presented by the French mathematician Jean Baptiste Joseph Fourier (1768-1830), a periodic distorted waveform can be decomposed into an infinite series containing DC component, fundamental component and its integer multiples called the harmonic components [4]. Equation 2.1 and Equation 2.2 shows the Fourier series equation for current and voltage respectively.

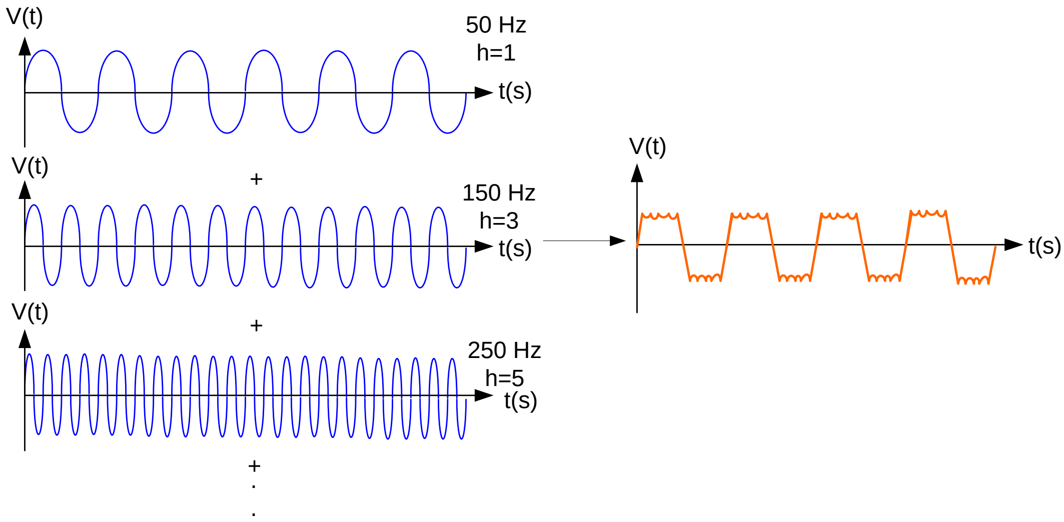

Figure 2.3: The sum of the pure sinusoids that can produce non-sinusoidal signal

$$i(t) = I_0 + \sum_{n=1}^{\infty} I_n \cos(nw_0t + \emptyset_{I_n}) \tag{2.1}$$

$$v(t) = V_0 + \sum_{n=1}^{\infty} V_n \cos(nw_0t + \emptyset_{V_n}) \tag{2.2}$$

The summation of all harmonic component of the voltage or current waveform is defined as the root-mean-square (rms) value divided by the rms value of the fundamental component of the voltage or current wave and multiplied by 100% is presented as total harmonic distortion (THD). THD frequently use as the measurement index of measuring harmonic distortion. Equation 2.3 and Equation 2.4 shows the fundamental of THD in voltage and current form.

$$THD\ in\ voltage = \frac{\sqrt{(V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1}\ x\ 100\% \tag{2.3}$$

$$THD\ in\ current = \frac{\sqrt{(I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}}{I_1}\ x\ 100\% \tag{2.4}$$

2.2.2 Harmonic Source on Power System Distribution

Harmonic distortion is caused by non-linear loads that connected to the power system. Hence, everything that has non-linear characteristic will cause harmonic distortion in power system. Non-linear loads also can be determined through waveform which is loads