I hereby declare that I have read through this report and found that is comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

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PERFORMANCE EVALUATION OF ACTIVE AND PASSIVE FILTERS FOR HARMONIC REDUCTION IN ELECTRICAL DISTRIBUTION SYSTEM BASED ON SYNCHRONOUS REFERENCE FRAME (SRF)

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A project report submitted in partial fulfilment of the requirement for the award of Bachelor of Electrical Engineering (Industrial Power)

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I declare that the project report entitled "Small Wind Energy Converter" is the results from my own research except as cited in the references.

Signature: ....

Name : Muhammad Asyraf bin Mohd Hanafi

Date : ....

To my beloved mother and father.

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In the name of Allah, the Most Beneficent and The Most Merciful. It is a deepest sense gratitude of the Almighty that give me strengh and ability to complete this Final Year Project report.

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ABSTRACT

The wide use of controlled power appliances such as personal computer, switch mode power supply, adjustable stepped drive inject a significance harmonic distortion in power system. These harmonic cause an increase in level of rms supply current which results an increase of power loss, heating of equipment and also deteriorates the quality of power. Passive filter have been used to suppress harmonics current conventionally. This kind of filter cannot modify their compensation due to non-linear loads and the filtering characteristics of active filters are affected by source impedance. To overcome the disadvantages of passive filter and active power filter combination with shunt active filter are introduced.

The project is to investigate the performance of active and shunt passive filters for harmonic reduction for power quality improvement in in electrical distribution system. The proposed system comprises of a power circuit of the shunt active filter. It involves the construction of the proposed filter topologies consists of transformer, Voltage Source Inverter (VSI) and shunt series passive filters. The main aim of this project is to cover design, modelling, construction and of active power combination with series passive filters using MATLAB/SIMULINK. The proposed controller based on Synchronous Reference frame (SRF) transformation technique is applied to the active power filter. The proposed system is capable to reduce current harmonics generated by non-linear loads.

ABSTRAK

Penggunaan meluas peralatan kuasa dikawal seperti komputer peribadi, suis mod bekalan kuasa, pemacu melangkah laras menyuntik herotan harmonik kepentingan dalam sistem kuasa. Ini menyebabkan harmonik peningkatan dalam tahap rms membekalkan arus yang menyebabkan peningkatan kehilangan kuasa, pemanasan peralatan dan juga merosot kualiti kuasa. penapis pasif telah digunakan untuk menindas konvensional semasa harmonik. Ini jenis penapis tidak boleh mengubah suai pampasan mereka kerana beban bukan linear dan ciri-ciri penapisan penapis aktif dipengaruhi oleh sumber galangan. Untuk mengatasi kelemahan penapis pasif dan gabungan penapis kuasa aktif dengan shunt penapis aktif diperkenalkan.

Projek ini adalah untuk menyiasat prestasi aktif dan shunt penapis pasif untuk mengurangkan harmonik untuk peningkatan kualiti kuasa di dalam sistem pengagihan elektrik. Sistem yang dicadangkan terdiri daripada litar kuasa penapis shunt aktif. Ia melibatkan pembinaan topologi penapis dicadangkan terdiri daripada pengubah, Voltan Source Inverter (VSI) dan siri shunt pasif penapis. Tujuan utama projek ini adalah untuk menampung reka bentuk, model, pembinaan dan gabungan kuasa aktif dengan siri penapis pasif menggunakan MATLAB / SIMULINK. Pengawal yang dicadangkan berdasarkan kerangka rujukan (SRF) teknik transformasi segerak digunakan untuk penapis kuasa aktif. Sistem yang dicadangkan mampu untuk mengurangkan harmonik semasa yang dijana oleh beban bukan linear.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Research background

The one of the most power quality problem in electrical power system is the harmonic current pollution and voltage distortion. A circuit filter configuration is needed to solve and give the outstanding or superb power supply. The power quality is to make crucial thing in the distribution system. Other than that, the cause is because of various phenomena that can be an interruption and disturbance harmonic, voltage sags, overvoltage, and voltage surges.

In this report, due to the distribution system the current harmonic will be discovered. Not less than that, which the meaning of harmonic usually compares to the power quality in ideal world. Moreover how pure is the current and how clean is the voltage waveform is in the sinusoidal developing from the supply can be seen. For extra info, to have a perfect sinusoidal waveform is ideally electrical power supply should be zero variety of distortion.

Harmonic distortion in the system can be revealed when current or voltage waveform is of form from its ideal sinusoidal form. More than that, there are many problems that give harmonic distortion result. Nowadays, it becomes major challenge for an engineer to perform a something that related with this field to maintain or to find a new way for reducing the harmonic distortion. A further study of a good designs in the industry harmonic distortion will improved very excellently.

1.2 Problem statement

The problem the usually rise in the distribution is the harmonic due to the great number of non-linear load or static power switches [2]. Beyond that, disturbance of harmonic distortion will effect several electrical equipment. So with a combination of active filter and passive filter together will limit the harmonic distortion allowed on the electrical distribution system. Evaluation of the combination both filters is crucial to ensure that it is the optimum design for the circuit configuration. Overall of this project is to make sure the efficiency and power handling deliver in the electrical distribution system network is according to standard. It is most important in power transmission and distribution system.

1.3 Objectives

The objective of this project is to evaluating the performance of active and passive filter by analyzing the harmonic distortion that causes harmonic source in distribution system. Objectives that identified are as follows:

1. To study of active filter and passive shunt filter for harmonic reduction in electrical distribution system.
2. To model active power filter based on Synchronous Reference Frame (SRF) and shunt active filter using MATLAB/SIMULINK
3. To evaluate and analyse the performance of harmonic current for active and shunt passive active in electrical distribution system.

1.4 Scope of work

On this project the main focus is to study about harmonic source in distribution system. This project is a combination of active and shunt passive filter to reduce harmonic distortion. Not less than that, the total harmonic distortion (THD) had been discussed. Another focus has been made is to determine harmonic current that occur in distribution

system by manipulating total harmonic distortion of the current and voltage as the primary measures and as well wants to reduce the harmonic distortion caused by current and voltage waveform that occurs. In the meanwhile, to discover the finest result is to mitigate distortion in the current and voltage waveform by use up the selected technique. In addition, MATLAB Software is used to design the simulation circuit and analysis based on the result. This project as well is been used to the gather up the data and compare to the simulation result.

1.5 Expected project outcomes

The proposed topologies is capable to reduce harmonic contents generated by non-linear load in electrical distribution system that can give an excellent performance in improving power quality.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and basic principles

2.1.1 The Concept of Harmonics Theory

A periodic waveform can be described as a sum of sine waves with the frequency being multiple of the fundamental frequency.

$$f_h = (h) \times \text{fundamental frequency} \qquad (2.1)$$

Where h is an integer.

For example, a fifth harmonic would yield a harmonic component:

$$f_h = (5) \times (50\text{Hz}) = 250\,\text{Hz} \text{ in 50Hz Systems} \qquad (2.2)$$

The non-fundamental components are called "harmonic distortion". In another view, the combination of any sine wave of simple multiplication of fundamental frequency with the fundamental waveform is a harmonically distorted waveform. Harmonic voltage distortion can be classified as voltage harmonic distortion and current harmonic distortion. Figure 2.9 (a) shows the fundamental frequency waveform component (f1) with the third harmonic frequency waveform (f3) and the fifth harmonic frequency waveform component (f5), the resultant of the above three waveforms, which is the major deviation from the fundamental waveform (f1), is shown in Figure 2.9(b).

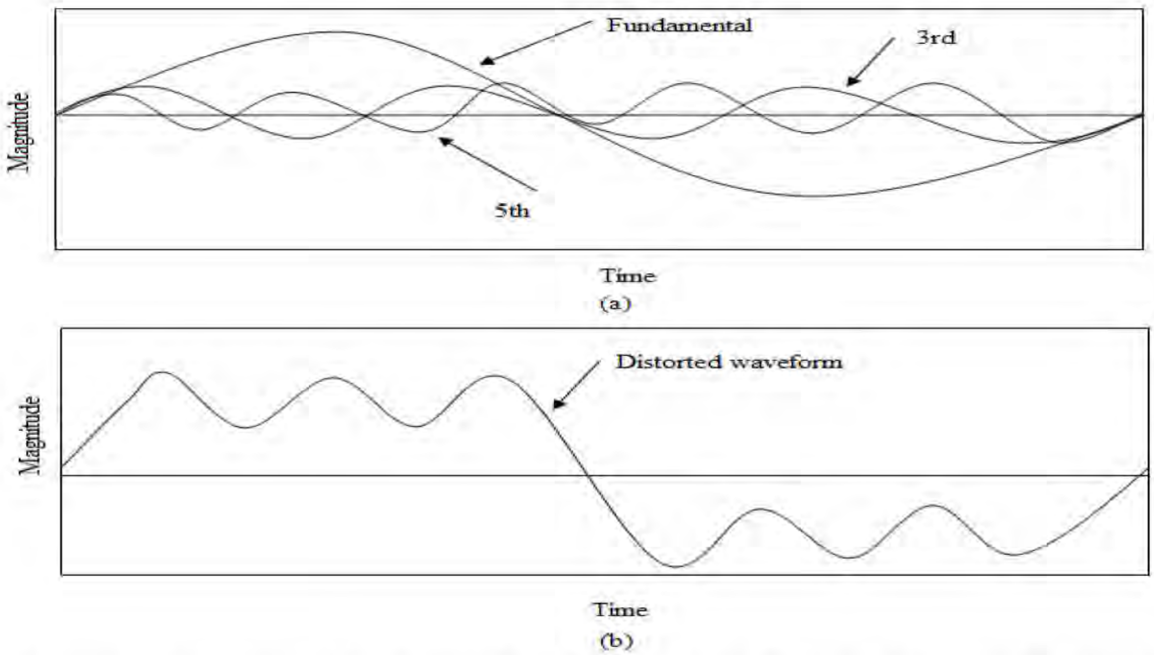

Figure 2.1: (a) Separated fundamental and harmonic waveforms, and (b) waveform resulting from summation.

2.1.2 Definition of Total Harmonics Distortion

Harmonics distortion is caused by non-linear devices in the power system. A non-linear device is one in which the current is not proportional to the source voltage. Harmonic distortion levels are described by the complete harmonics spectrum with magnitude and phase angle of each individual harmonic component. Besides, it is also common to use a single quantity, known as Total Harmonic Distortion (THD), as a measure of effective value for harmonic distortion (Roger et al., 2002). THD is defined for voltage and current signals, respectively, as follows:

$$\%THD = \left[\frac{1}{a_1^2}\sum_{n=5}^{\infty}\left(a_n{}^2\right)\right]^{\frac{1}{2}} \text{ x } 100 \quad (2.7)$$

where n = 6i ± 1(i = 1,2,3….)

This means that the ratio between RMS values of signals, including harmonics and signals; considering only the fundamental frequency, define the THD.

2.2 Harmonic Sources

The harmonics cause disturbances to the utility, such as voltage distortion, power factor correction, capacitor parallel resonance, overheating, overloading power transformer, and communication line interference (Maset et al., 1996). Besides, there are many sources for the harmonics in the power utility. The main sources of harmonics in conventional power systems are summarised below (Nguyen et al., 2000):

• **Power Electronic Devices**: With the recent advances in power semiconductor technology, more electronics devices, such as phase controllers, inverters, and variable speed drivers, are widely used in the industry. These devices are sensitive to harmonics, and at the same time, they are a source of a high percentage of harmonic currents.

• **Electronic Switching Devices**: Electronic power processing equipment utilises switching devices. In general, a switching process in electronic devices are synchronized to the AC voltage, but this is unnecessary.

• **The voltage-current relationships with non-linear devices**: Two examples of such devices are Iron-core reactors and arcing loads. The non-linear V-I curve leads to produce harmonic currents when excited with a periodic input voltage.

• **Transformer and saturable reactors**: the non-linear magnetizing current of transformers and saturable reactors make them the major harmonic sources from the utility. They have a more pronounce impact during light load.

• **Arc Furnaces and Electric Arc Welders**: These non-continuous loads result in significant current distortion and the appearances of even harmonics in the transmission and distribution systems.

Harmonic standard level, IEEE 519-1992, is the recommended practices and requirements for the harmonics control of electrical power systems. It sets maximum THD limits on voltages and currents that a power system is allowed; therefore, the power conversion system cannot inject harmonics into the grid that causes the system to go above these limits set forth by the standard, and if at all possible; the power conversion system should filter these harmonics.

2.2.1 Effect of Harmonic

The RMS current level is increased due to harmonics, which can lead to an increase in power loss, equipment heating, and voltage sags, as well as the reduction of power factor, communication system interference, error in meter reading, mis-operation of utility relay, and also distortion of power quality (Don et al., 2000; Bhim et al., 1999). The conductors may cause heat as a result of the main effect of harmonics.

The conductors are heated as the current flows in it and this leads to an increase in temperature, due to additional current from the skin effect. Besides conductors, skin effect is also available in transformer due to its eddy current losses.

2.2.2 Harmonic Measurement

Ideally, power supplied by the utility should be a perfect sine wave of standard frequency and magnitude, but power converters add harmonic distortion to the system (Yukihiko et al., 1996). This disturbance has a certain limit for load and utilities. Hence, non-linear load current, I(t), can be represented by the following equation:

$$i(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \varphi) \tag{2.8}$$

The total RMS current,

$$I = \sqrt{\frac{1}{T}\int_0^T i(t)dt} \tag{2.9}$$

$$= \sqrt{I_1^2 + \sum_{n=2}^{\infty} I_n^2}$$

Where, I_1 and I_n are the fundamental and harmonic component respectively, so the total harmonic current

$$I_{harmonic} = \sqrt{\sum_{n=2}^{\infty} I_n^2} \tag{2.10}$$

2.2.3 Harmonic Spectrum

When the contributions of individual frequency components of the composite wave are expressed in a graph, it is known as a harmonic spectrum. Harmonic contents are usually described as a percent of the fundamental for a certain component, as shown in Figure 2.10.

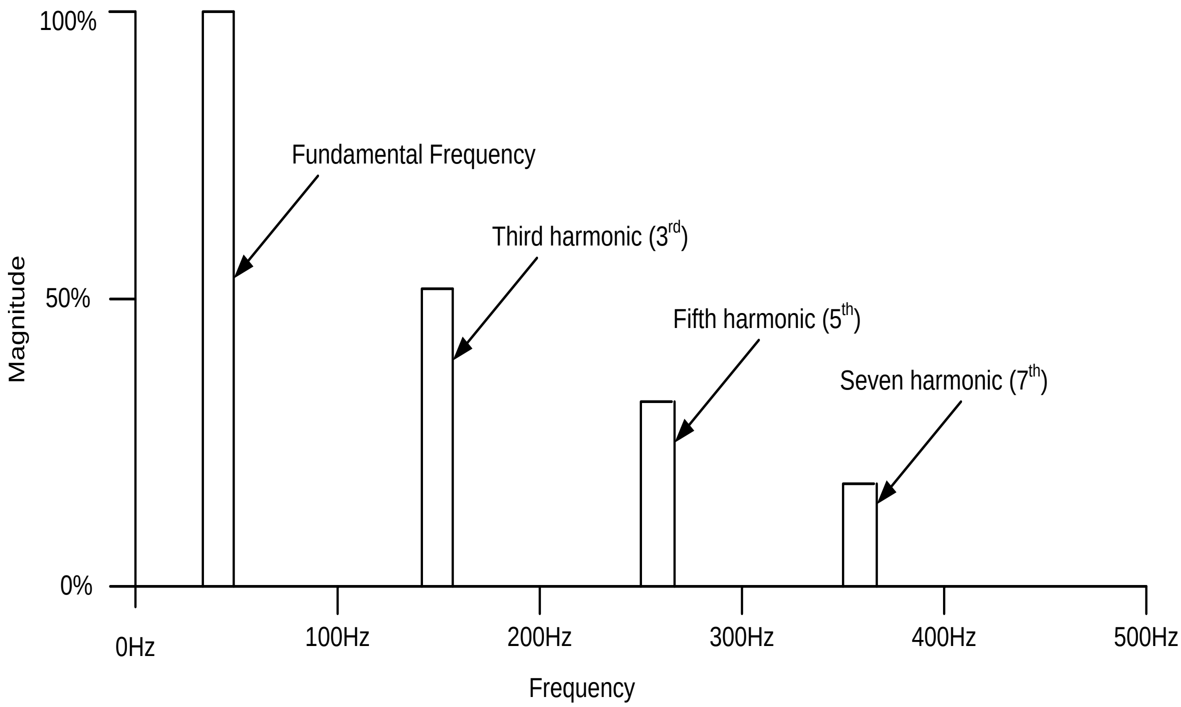

Figure 2.10: Harmonic spectrum of a sample with distorted wave.

2.3 Theory and basic principles

2.3.1 Advantages of active filter over shunt passive filter

1. When the active filter already in the circuit it not easier to perform both filter just injects the passive filter.
2. Both filters can work independently with several of load characteristic and together it are able to use up in demanding condition where passive filter cannot work excellently due to the parallel resonance problems.
3. Both filter can be used to reduce harmonic over one at a time and perform in power quality
4. Active and passive filter is important to reduce harmonic and also power factors.

2.3.2 Comparison of active filters and shunt passive filter

Table 2.1: Comparison between active filter and passive filter.

	Active filter	Passive filter
Harmonic control by command	Possible via parameters	Very hard
Harmonic current control	Simultaneously monitors many frequencies	Requires filter for each frequency
Dimension	Small scale	Large scale
Weight	Low	High
Encouragements of a frequency variation	No effect	Decrease the performance

2.4 Review of previous related works

2.4.1 Active power filter

To improve the power quality in harmonic reduction technique is using active filter, by injecting equivalent current or voltage distortion keen on the system, but in diametric value, which spontaneously offsets overcome the genuine distortion appeared on the lap. Active Power filter make use of fast-switching insulated gate bipolar transistors (IGBTs) bridge, which generates an output current of the preferred profile such that every time they are injected into the distribution system or AC lines, it offsets the fundamental load-generated harmonics. The controller part is the most important of the active power filter [3]. The execution and stability of the filter gate will improve when separate control strategies are put into operation to the active power filter. Moreover there are two types of active harmonic filter are designed fpr control scheme.

1. The filter will perform a fast Fourier transforms to calculate the amplitude and phase of each order of harmonics. The power device is use to produce a same or equal of current amplitude but indifferent phase angle for specific harmonic order.