IMPLEMENTATION OF PASSIVE AND ACTIVE POWER FILTERS FOR HARMONIC MITIGATION

by

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Report submitted in partial fulfillment
of the requirements for the degree
of Bachelor of Engineering

MAY 2011

IMPLEMENTATION OF PASSIVE AND ACTIVE POWER FILTERS FOR HARMONIC MITIGATION

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2011

ACKNOWLEDGEMENT

Alhamdulillah and praise be to Allah S.W.T, as He is the main contributor towards the success of this project completion.

I also wish to express my appreciation to all those who had been willing to support me throughout the progress of this project. I would like to express my gratitude to my supervisor, En. Muzaidi bin Othman @ Marzuki for all the advices and guides given towards the successful completion of this project.

I am also grateful to all the lecturers and panels involved towards encouraging me on conducting this project within the two semester periods.

Also not to forget, my utmost thanks to my parents, brothers, friends and each of those, whom without them, this project would not probably be at its best form.

May God bless you all until the end of time. Wassalam and thank you.

DECLARATION SHEET

I, Mohd Arif bin Mat Omar, hereby declare that my Final Year Project Thesis is the result of my research work under supervision of Mr. Muzaidi bin Othman @ Marzuki. All literature sources used for the writing of this thesis have been adequately referenced.

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APPROVAL AND DECLARATION SHEET

This project report titled Implementation of Passive and Active Filter for Harmonic Mitigation was prepared and submitted by Mohd Arif bin Mat Omar (Matrix Number: 081070532) and has been found satisfactory in terms of scope, quality and presentation as partial fulfillment of the requirement for the Bachelor of Engineering (Industrial Electronic Engineering) in Universiti Malaysia Perlis (UniMAP).

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PELAKSANAAN PENAPIS PASIF DAN AKTIF DALAM MENGURANGAN HARMONIK

ABSTRAK

Pemanfaatan beban bukan linear telah menjadi perhatian utama terutama dalam industri sistem kuasa. Operasi beban mampu menghasilkan arus dan voltan harmonik yang muncul pada rangkaian am titik utiliti-pelanggan (PCC). Tambahan pula, jika harmonik terjadi pada frekuensi yang sama ketika sistem elektrik dalam keadaan resonans, ia mampu mengakibatkan amplifikasi terhadap herotan harmonik, atau dikenali sebagai resonans harmonik. Peranti pembolehubah kelajuan (ASD) merupakan sumber utama harmonik. Variasi modulasi indeks yang dihasilkan oleh pengawal fasa modulasi lebar (PWM) akan menyebarkan frekuensi harmonik dalam kabel elektrik utama. Keseluruhan komponen harmonik bertambah buruk disebabkan oleh kemasukan komponen penyambung arus terus (DC link) bagi proses penyatu-arahan arus. Pengenalan penapis pasif (PPF) dan aktif (APF) mampu mengurangkan herotan harmonik secara keseluruhan yang berlaku pada kabel elektrik utama. Penapis pasif penalaan tunggal mampu mengasingkan herotan harmonik relatif terhadap frekuensi penalaan bagi resonans harmonik, walaupun mereka memperkenalkan pembatasan terhadap pemampasan kuasa reaktif. Penapis aktif pirau melitupi ruang lingkup pemampasan harmonik yang luas pada frekuensi harmonik yang tinggi. Penapis aktif pirau mempunyai prestasi yang lebih baik dalam hal peningkatan faktor kuasa berbanding penapis pasif penalaan tunggal.

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ABSTRACT

The utilization of non-linear loads has become a major concern especially in the industrial power system. The operation of the loads could draw harmonic currents and voltages which appear at the utility-consumer point of common coupling (PCC). In addition, if the harmonic occurs at the same frequency when the power system is at resonance, it could result in amplification of the harmonic distortion, or known as harmonic resonance. Three-phase Adjustable Speed Drives (ASDs) are a common source of harmonics. The variation of modulation index of a specific phase-width modulation (PWM) controller thus distributes harmonic frequencies within the main power lines. The overall harmonic components are further aggravated by the inclusion of DC link components for rectification process. The introduction of passive and active power filters (PPFs and APFs) thus reduces the overall harmonic current distortion occurring within the main power lines. Single-tuned passive filters provide fair harmonic isolation relative to its tuning frequency for harmonic resonance, although they introduce limitations on reactive power compensation. Shunt active filters cover greater range over harmonic compensation at wide harmonic frequencies. Shunt active filters provide greater performance in terms of power factor improvement compared to single-tuned passive filters.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURES

ASD	Adjustable-speed Drive
VFD	Variable-frequency drive
PWM	Phase-width modulation
VSI	Voltage-source inverter
SPWM	Sinusoidal PWM
PPF	Passive Power Filter
APF	Active Power Filter
PCC	Point of Common Coupling
PSIM	Powersim
EDA	Electronic-Design Automation
THD	Total Harmonic Distortion
THD_V	Total Harmonic Voltage Distortion
THD_I	Total Harmonic Current Distortion
PF	Power Factor
DF	Distortion Factor
IHD	Individual Harmonic Distortion
IHD_V	Individual Harmonic Voltage Distortion
IHD_I	Individual Harmonic Current Distortion

IHC_I	Individual Harmonic Current Isolation
V-f	Voltage-to-frequency ratio
IEEE	Institute of Electrical and Electronics Engineers, Inc.
Q	Quality Factor
β	Bandwidth
h	Harmonic order
r	Tuning coefficient
m	Modulation index
EMI	Electromagnetic Interference
n_{sync}	Synchronous speed (in rpm)
ω_{sync}	Synchronous speed (in rad/s)
n_m	Motor speed (in rpm)
ω_m	Motor speed (in rad/s)
τ_{ind}	Induced torque (in N.m)
τ_{load}	Load torque (in N.m)
P_{out}	Output power (in W)
P_{mech}	Mechanical power (in W)
P_{conv}	Converted power (in W)
P_{AG}	Air-gap power (in W)
f_e	System frequency (in Hertz)
f_r	Rotor frequency (in Hz)
P	Number of poles
V_h	Harmonic voltage component (in V)

I_h	Harmonic current component (in A)
V_1	Fundamental frequency voltage component (in V)
I_1	Fundamental frequency current component (in A)
B_S	Magnetic field
e_{ind}	Induced voltage (in V)
s	Slip

CHAPTER 1

INTRODUCTION

1.1 Overview

The term ‘power quality’ refers to the purity of the voltage and current waveform, and a power quality disturbance is a deviation from the pure sinusoidal form. Harmonics superimposed on the fundamental are one cause of such deviations. The widespread and increasing use of solid state devices in power systems is leading to escalating ambient harmonic levels in public electricity supply systems [9]. These devices tends to draw currents and voltages with frequencies that are integer multiples of the fundamental frequency.

The effect of harmonic distortion is slightly different between single-phase and three-phase loads in terms of troublesome harmonic components. The single phase non-linear loads are most likely to generate triplen harmonics. The triplen harmonics are the 3^{rd} and odd multiples of the 3^{rd} (9^{th}, 15^{th}, etc.) of the harmonic components. These harmonics could also cause overload on the neutral conductor of a 3-phase 4-wire system and circulating current on the delta winding of a delta-wye transformer configuration [10]. On the other hand, 3-phase non-linear loads such as three-phase Adjustable Speed Drives (ASDs) are most likely to generate primarily 5^{th} and 7^{th} current harmonics and some of the higher order harmonics.