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.
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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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).

Checked and Approved by

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Project Supervisor

School of Electrical System Engineering
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May 2011
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-arah kan 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.
IMPLEMENTATION OF PASSIVE AND ACTIVE POWER FILTERS FOR HARMONIC MITIGATION

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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<td>Adjustable-speed Drive</td>
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<tr>
<td>VFD</td>
<td>Variable-frequency drive</td>
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<td>PWM</td>
<td>Phase-width modulation</td>
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<td>VSI</td>
<td>Voltage-source inverter</td>
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<td>SPWM</td>
<td>Sinusoidal PWM</td>
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<td>PPF</td>
<td>Passive Power Filter</td>
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<td>APF</td>
<td>Active Power Filter</td>
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<td>PCC</td>
<td>Point of Common Coupling</td>
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<td>PSIM</td>
<td>Powersim</td>
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<td>EDA</td>
<td>Electronic-Design Automation</td>
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<td>THD</td>
<td>Total Harmonic Distortion</td>
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<tr>
<td>THDV</td>
<td>Total Harmonic Voltage Distortion</td>
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<tr>
<td>THDI</td>
<td>Total Harmonic Current Distortion</td>
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<td>PF</td>
<td>Power Factor</td>
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<td>Distortion Factor</td>
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<td>Individual Harmonic Distortion</td>
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<td>IHDV</td>
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<td>IHDI</td>
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\( IHC_i \)  \hspace{1cm} \text{Individual Harmonic Current Isolation}

\( V-f \)  \hspace{1cm} \text{Voltage-to-frequency ratio}

IEEE  \hspace{1cm} \text{Institute of Electrical and Electronics Engineers, Inc.}

\( Q \)  \hspace{1cm} \text{Quality Factor}

\( \beta \)  \hspace{1cm} \text{Bandwidth}

\( h \)  \hspace{1cm} \text{Harmonic order}

\( r \)  \hspace{1cm} \text{Tuning coefficient}

\( m \)  \hspace{1cm} \text{Modulation index}

EMI  \hspace{1cm} \text{Electromagnetic Interference}

\( n_{\text{sync}} \)  \hspace{1cm} \text{Synchronous speed (in rpm)}

\( \omega_{\text{sync}} \)  \hspace{1cm} \text{Synchronous speed (in rad/s)}

\( n_m \)  \hspace{1cm} \text{Motor speed (in rpm)}

\( \omega_m \)  \hspace{1cm} \text{Motor speed (in rad/s)}

\( \tau_{\text{ind}} \)  \hspace{1cm} \text{Induced torque (in N.m)}

\( \tau_{\text{load}} \)  \hspace{1cm} \text{Load torque (in N.m)}

\( P_{\text{out}} \)  \hspace{1cm} \text{Output power (in W)}

\( P_{\text{mech}} \)  \hspace{1cm} \text{Mechanical power (in W)}

\( P_{\text{conv}} \)  \hspace{1cm} \text{Converted power (in W)}

\( P_{\text{AG}} \)  \hspace{1cm} \text{Air-gap power (in W)}

\( f_e \)  \hspace{1cm} \text{System frequency (in Hertz)}

\( f_r \)  \hspace{1cm} \text{Rotor frequency (in Hz)}

\( P \)  \hspace{1cm} \text{Number of poles}

\( V_h \)  \hspace{1cm} \text{Harmonic voltage component (in V)}
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<tbody>
<tr>
<td>$I_h$</td>
<td>Harmonic current component (in A)</td>
</tr>
<tr>
<td>$V_1$</td>
<td>Fundamental frequency voltage component (in V)</td>
</tr>
<tr>
<td>$I_1$</td>
<td>Fundamental frequency current component (in A)</td>
</tr>
<tr>
<td>$B_S$</td>
<td>Magnetic field</td>
</tr>
<tr>
<td>$\epsilon_{\text{ind}}$</td>
<td>Induced voltage (in V)</td>
</tr>
<tr>
<td>$s$</td>
<td>Slip</td>
</tr>
</tbody>
</table>
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 tend 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.