Faculty of Electrical Engineering

SHUNT ACTIVE POWER FILTER EMPLOYING KALMAN FILTER ESTIMATOR FOR HARMONICS REDUCTION

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DECLARATION

I declare that this thesis entitled "Shunt Active Power Filter Employing Kalman Filter Estimator for Harmonics Reduction" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Ahmad Shukri Bin Abu Hasim

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature	:	……...
Supervisor Name	:	Prof. Dr. Zulkifilie Bin Ibrahim
Date	:	……...

DEDICATION

Dedicated to my beloved parents, wife and family members for their love, patience and support throughout my life

ABSTRACT

The wide use of non-linear loads, such as front-end rectifiers connected to the power distribution systems for DC supply or inverter-based applications, causes significant power quality degradation in power distribution networks in terms of current or voltage harmonics, power factor, and resonance problems. Many techniques have been proposed by the researchers to overcome these problems. One of the method is by using shunt active power filter (APF). This technique is an effective solution for reducing the current harmonics for low to medium power applications. Therefore, this research is targeted to design and implement a three-phase shunt APF employing Kalman filter estimator. The first step is designing the shunt APF circuit by deploying voltage source inverter (VSI). However, when using VSI the DC voltage needs to be maintained because its influence the real power conversion hence degrades the performance of the APF. Two methods are used to overcome this problem namely are conventional PI and PI-improved method. Both methods have been simulated under voltage variation and open circuit test. The results show that PI-improved voltage regulator produce better performance in reduction of the THD as the results reduce the surge current. On the other hands, three common controllers of the shunt APF for generation of reference current are compared and analysed to determine the best performance of THD reduction. Based on the results, the *d-q* reference current generator produces the lowest THD among others. Conventionally, low-pass filter (LPF) is used to filter out the unwanted DC component of the non-linear load to produce the sinusoidal waveform called reference current. However, when applying LPF it contribute with the phase shift and high transient at the supply current. Therefore, to reduce these problems, the digital Kalman filter estimator is used to replace the LPF for generating the reference current. Details investigation between conventional and proposed method under simulation based on Matlab simulink platform and experimental are made for three types of load namely three-phase rectifier with R-load, three-phase rectifier with RC-load and three-phase induction motor are presented. The performance criteria of the shunt APF are determined by the supply current waveform, THD, harmonics spectrum and power quality measurements were also obtained by simulation and experimental. In conclusion, by employing Kalman filter estimator for generating the reference current it reduce the time delay and high transient current at the power supply thus, improved the overall THD from 0.15% to 0.42% compared to the LPF.

ABSTRAK

Penggunaan meluas beban tidak linear, seperti penerus hadapan dihubungkan dengan sistem pengagihan kuasa untuk bekalan DC atau aplikasi berasaskan inverter, menyebabkan kemerosotan kualiti kuasa ketara dalam rangkaian pengagihan kuasa dari segi harmonik pada arus atau voltan, faktor kuasa, dan masalah resonans. Banyak teknik yang digunakkan untuk mengatasi permasalahan ini. Salah satu teknik ialah dengan menggunakan penapis aktif jenis selari (APF). Teknik ini dianggap sebagai penyelesaian yang paling berkesan untuk mengurangkan arus harmonik bagi aplikasi kuasa rendah dan kuasa sederhana. Oleh itu, kajian ini disasarkan untuk mereka bentuk dan melaksanakan tiga fasa APF dalam keadaan selari menggunakan penganggar penapis Kalman. Kaedah penyelidikan ini adalah bermula dengan mereka bentuk APF selari menggunakan sumber voltan inverter (VSI). Walau bagaimanapun, apabila menggunakan VSI, voltan DC perlu dikekalkan kerana ianya mempengaruhi penukaran kuasa sebenar dengan itu merendahkan prestasi APF. Dua kaedah yang digunakan untuk mengatasi masalah ini. Pertama dengan menggunakan PI-konvensional dan kaedah PI-penambahbaikan. Kedua-dua kaedah telah disimulasi di bawah keadaan perubahan voltan dan ujian litar terbuka. Keputusan menunjukkan bahawa kaedah PI-penambahbaikan pengatur voltan menghasilkan prestasi yang lebih baik dalam pengurangan THD serta mengurangkan lonjakan arus. Selain daripada itu, tiga jenis pengawal biasa untuk APF selari bagi penjanaan arus rujukan di bandingkan dan di analisis untuk menentukan jenis yang terbaik dalam menghasilkan THD yang paling rendah. Berdasarkan hasil keputusan, penjana semasa d-q telah menghasilkan THD paling rendah di kalangan yang lain. Penapis konvensional, laluan rendah (LPF) digunakan untuk menapis komponen DC yang tidak diingini bagi beban bukan linear bagi menghasilkan bentuk gelombang sinusoidal yang dipanggil arus rujukan. Walau bagaimanapun, LPF menyumbang kepada perubahan fasa dan lonjakkan arus yang tinggi pada arus bekalan. Oleh yang demikian, bagi mengurangkan masalah tersebut, penapis digital penganggar Kalman digunakan bagi menggantikan LPF untuk menjana arus rujukan. Butiran siasatan antaranya kaedah konvensional dan dicadangkan di bawah simulasi berasaskan Matlab simulink platform dan eperimental dibuat untuk tiga jenis beban iaitu beban R, beban RC dan motor aruhan. Prestasi kriteria APF selari adalah ditentukan oleh bentuk gelombang arus bekalan, THD, spektrum harmonik dan pengukuran kualiti kuasa juga diperolehi oleh simulasi dan eksperimen. Kesimpulannya, dengan menggunakan penapis Kalman rujukan penganggar penjana arus ianya mengurangkan kelewatan masa dan lonjakkan arus pada bekalan dan secara langsung menambah baik keseluruhan THD antara 0.15 % sehingga 0.42 % berbanding dengan LPF .

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AC	-	Alternating Current
ANN	-	Artificial Neural Network
APF	-	Active Power Filter
ARAMA	-	Autoregressive Moving Average
CMLI	-	Cascaded Multi Level Inverter
CZT	-	Chirp z-transform
DC	-	Direct Current
DFT	-	Discrete Fourier Transform
DSP	-	Digital Signal Programming
ESPRIT	-	Estimation of Signal Parameter
GA	-	Genetic Algorithm
HB	-	Hysteresis Band
HCC	-	Hysteresis Current Control
HHT	-	Hilbert-Huang Transform
IGBT	-	Insulating Gate Bipolar Transistor
LPCM	-	Linear Peak Current Mode
MUSIC	-	Multiple Signal Classification
NLC	-	Non-linear Carrier
NLL	-	Non-linear Load
PC	-	Personal Computer
PCC	-	Point of Common Coupling
PFC	-	Power Factor Correction

PHD	-	Pisarenko harmonics decomposition
PI	-	Proportional Integral
PLL	-	Phase Lock Loop
PWM	-	Pulse Width Modulation
RTI	-	Real Time Interface
RTW	-	Real Time Workshop
SHE	-	Selective Harmonics Elimination
SRF	-	Stationary Reference Frame
STATCOM	-	Static Synchronous Compensator
SVM	-	Space Vector Modulation
THD	-	Total Harmonics Distortion
VSI	-	Voltage Source Inverter
WT	-	Wavelet Transform