SVM BASED HYSTERESIS CURRENT CONTROLLER FOR A THREE PHASE ACTIVE POWER FILTER

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ABSTRACT

A space vector modulation (SVM) based hysteresis current controller (HCC) technique for a three phase shunt active power filter is proposed. The proposed SVM based HCC is implemented in a closed loop control system. The reference input to the control system is the reference compensating harmonic current. The reference compensating harmonic current is obtained from the harmonic extraction tool or called as the harmonics isolator. The harmonics extraction is based on the instantaneous active and reactive power theorem in time domain to calculate the reactive power compensation in the power system. The error current is the difference between the reference and the actual compensating harmonic current from the power compensation. Three error currents are obtained and compared by using the hysteresis tolerance band comparators to obtain the information about the region and voltage vector. The switching control algorithms of the proposed SVM based HCC manages to generate appropriate switching gates to the active power filter. The active power filter generates the actual compensating harmonic current based on the switching gates provided by the controller. The actual compensating harmonic current is generated based on the reference compensating harmonic current. The actual compensating harmonic current is then injected back into the line to cancel the harmonic components in the distorted line. By implementing this control strategy, the active power filter (APF) manages to generate better compensated harmonics currents to the line. The proposed active power filter is able to improve about 67% of the total harmonic distortion (THD) for the distorted line current caused by an uncontrolled rectifier as the nonlinear load.

ABSTRAK

Pengawal arus histerisis (HCC) berasaskan teknik pemodulatan vector ruang (SVM) dicadangkan dalam projek ini untuk mengawal pensuisan penapis kuasa aktif pirau. HCC berasaskan SVM yang dicadangkan adalah diimplikasikan dalam satu sistem kawalan gelung tertutup. Isyarat rujukan kepada sistem kawalan gelung tertutup ini adalah arus harmonik pemampas rujukan yang dihasilkan oleh pengasing harmonik. Pengasing harmonik ini adalah berdasarkan teori kuasa aktif dan reaktif ketika yang beroperasi dalam domain masa untuk memdapatkan pemampasan kuasa reaktif dalam sistem kuasa. Arus ralat yang diperolehi dalam sistem kawalan ini adalah merupakan perbezaan antara isyarat arus harmonik pemampas rujukan dengan arus harmonik pemampas sebenar. Ralat ini akan dibandingkan dengan menggunakan pembanding jalur toleransi histerisis untuk mendapatkan maklumat mengenai bahagian atau kawasan dan vector ruang. Algoritma bagi kawalan pensuisan yang dihasilkan oleh pengawal HCC berasaskan SVM berupaya untuk menghasilkan denyutan suis yang benar kepada penapis kuasa aktif. Penapis kuasa aktif akan mengeluarkan arus harmonik pampasan sebenar berasaskan pensuisan yang dihasilkan oleh pengawal yang dicadangkan. Arus harmonik pemampas sebenar dihasilkan berdasar isyarat masukan yang diberikan kepada sistem kawalan tersebut. Arus harmonik pemampas sebenar akan dimasukkan semula ke arus talian untuk menghapuskan komponen harmonik yang menyebabkan herotan dalam arus talian. Dengan mengimplikasikan strategi kawalan ini, penapis kuasa aktif ini dapat mengurangkan peratus jumlah herotan harmonik (THD) yang terkandung dalam sistem kuasa yang disebabkan oleh penerus diod sebanyak 67%.

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CHAPTER I

INTRODUCTION

Since the rapid development of the semiconductor industry, power electronics devices have gained popularity in our daily used electrical house-hold appliances. Although these power electronics devices have benefited the electrical and electronics industry, these devices are also the main source of power harmonics in the power system. These power harmonics are called electrical pollution which will degrade the quality of the power supply. As a result, filtering process for these harmonics is needed in order to improve the quality of the power supply. Thus, active power filter seems to be a viable alternative for power conditioning to control the harmonics level in the power system nowadays.

1.1 Project Background and Reviews

Power system normally operates at 50 or 60 Hz. However, saturated devices such as transformers, arching loads such as florescent lamp and power electronic devices will produce current and voltage components with higher frequencies into the power line. These higher frequencies of current and voltage components are known as the power harmonics. The harmonics disturbances in the power supply are caused by the nonlinearity characteristic of the loads. Due to the advantages in efficiency and controllability of power electronic devices, their applications can be found in almost all power levels. Hence, power harmonics has become a serious problem.

The power harmonics caused by the saturated devices which are mainly due to the operating modes of the transformers and machines are usually laid on the iron core saturation curve. On the other hand, the current distortion caused by the florescent lamp is related to the arc and the magnetic ballasts. Both currents of these devices are peaked and rich in third order harmonics. As for the power electronic devices, these loads control the flow of power by supplying the voltages and currents in certain intervals of the fundamental period. Thus, the current drawn by the load is no longer sinusoidal but appears chopped or flattened [1], [2].

The impact of harmonics on the power system can be categorized into two group; short term effects and long term effects. The short term effects are usually noticeable and are related to excessive voltage distortion such as nuisance tripping of sensitive loads or overheating of transformer. However, the long term effects will show the impact after certain period and it is undetected. This long term effects are usually related to increased resistive losses or voltage stress. Capacitors in power systems might fail or capacitor fuses may blow due to the overvoltage stress on dielectric [2]. The existence of harmonics in power system can cause overheating of conductor and increase losses. Besides that, harmonics can cause low power factor and lead to higher losses in power system. Moreover, the high cost caused by the poor power quality is an important issue too [3], [5].

1.1.1 Control of Power Harmonics

The impacts and effects of harmonics cause the power system to be unreliable and bring damage to the power system components. There are solutions employed in order to overcome the problems caused by the harmonics.

One of the solutions is to limit the harmonic current injection from nonlinear loads by implementing delta transformer connection to yield a net 12-pulse operation to block the third harmonic current. Another solution is by introducing standards such as IEEE Standard 519 to the end-users and the electric utilities to attempt reasonable harmonics goals. The end-users have to limit the harmonic currents by controlling their loads and the utilities should limit the harmonic voltages by controlling the power system impedances. This is to ensure that both parties carry their responsibility on controlling the harmonics level in the power system.

However, it is hard to implement the above solution methods as the public have no basic knowledge about power system. As a result, filters are introduced to compensate the harmonics in the power system. Filters can be simple passive filter consists of RLC component or as complex as an active power filter to eliminate the harmonic currents in the system [2], [3].

1.1.2 New Harmonics Elimination Method

Traditionally, passive filters such as tuned harmonics filter has been used to improve the power factor of the system and suppress the harmonics. However, this passive filter has some problems that discourage its implementation. The problems which occur, such as the unknown source impedance can influent the filtering characteristic as the system configuration varies and at specific frequency, anti-resonance can occur between the source impedance and the filter, which will cause harmonics amplification [4].

As a matter of fact, active power filters which are more flexible and viable have become popular nowadays. The basic compensation principles of the active filter were proposed around 1970 by Bird, B. M. *et al.* in 1967 and Gyugyi, L. *et al.* in 1976. These active power filters are able to compensate harmonics continuously, regardless of the changing of the applied loads. However, active power filters configurations are more complex and require appropriate control devices to operate. As there are various topologies of active power filter, researches are done in order to design and develop better control strategies and filter configurations [3], [4].

1.2 Objective and Scope of Project

The main objective of the project is to develop and design a current controller of a closed loop control system for a three phase active power filter. To develop a current controller utilizing instantaneous active and reactive power (pq) theorem, space vector modulation and hysteresis current control method that generate appropriate switching gates to the three phase active power filter. The system is able to monitor the changing of harmonics in the power system within a range of loads continuously.

At the end of this project, harmonic currents of a three phase system with a nonlinear load will be reduced by utilizing a space vector modulation (SVM) based hysteresis current controller (HCC) for a three phase active power filter

The scope of the project based on the objective above is; firstly, to identify and determine the used nonlinear load and its current waveform patterns. Secondly is to study and research on the harmonics extraction method and the controller design. Thirdly is to develop and design a harmonics extraction algorithm and current controller for a closed loop power system. Finally is to simulate the designed harmonics extraction algorithm and controller by using digital simulation tool.

1.3 Project Overview

The overall block diagram represents the proposed SVM based HCC for an active power filter is shown in Figure 1.1. A three phase power supply with 240V, 50Hz, which is connected to a full bridge diode rectifier as the nonlinear load in this project to produce a distorted source current. Due to the nonlinear characteristic of the diodes, the sinusoidal current waveform for the supply is distorted.

The distorted current is fed into the harmonics isolator to produce the desired compensated harmonic currents which is the inversed of the original harmonics in the line. The harmonics isolator algorithms are based on the instantaneous active and reactive theorem in time domain. The desired compensated harmonic currents, i_h^* is used as the reference current to the closed loop control system. Error is the difference between the desired compensated harmonic currents, i_h^* with the actual compensated harmonic currents, i_h produce by the active power filter.

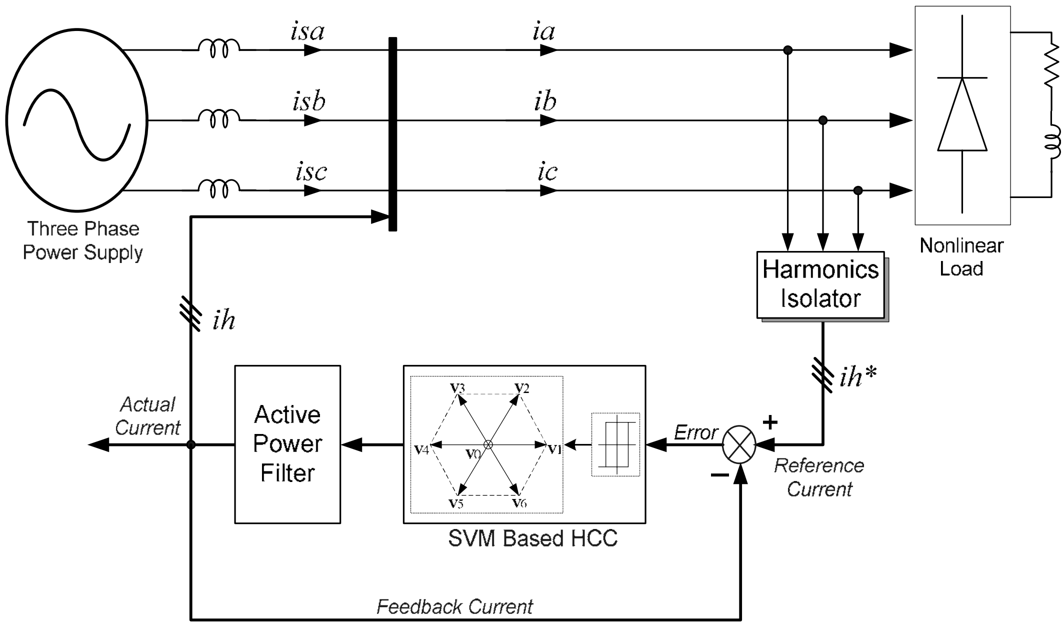

Figure 1.1 Block diagram of proposed active power filter

The compensation system continuously monitors the harmonics produced by the filter and compares it with the reference current. The actual compensated harmonic currents are injected back into the power line to cancel the original harmonic current. The distorted current i_a, i_b and i_c of each phase will be compensated when i_h are injected into each phase. The sinusoidal supply currents, i_s are the summation of the distorted currents and compensated harmonic currents of the active power filter.

Figure 1.2 shows the distorted current waveform of phase A, i_a when the power system is without any filtering process. The degree of current distortion is represented by the percentage of total harmonics distortion (THD) which is 30.01%. The distorted current, i_a is no longer a sinusoidal waveform. However, when the compensated harmonic currents, i_h are added into the distorted line, a sinusoidal waveform is expected to be obtained.

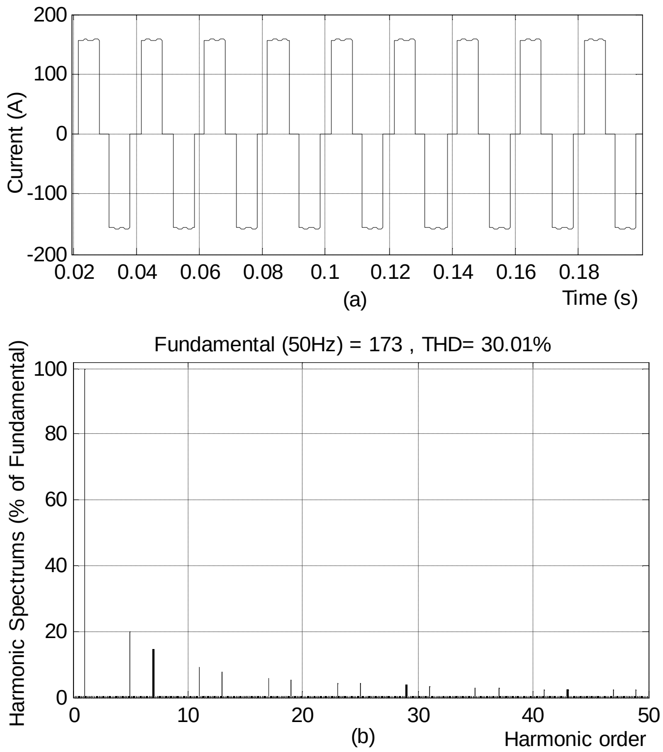

Figure 1.2 Phase A; (a) distorted current, (b) harmonic spectrums

The formation of the distorted currents is caused by the diodes which act like switches and conduct in certain intervals of the fundamental period. The supply currents are chopped into shapes similar to the waveform shown above.

1.4 Problems Statement and Solutions

The main problem that needs to be solved is to reduce the harmonics level in the line current. As a result, active power filter is used to implement in the power system for harmonics compensation purpose.

As there are various topologies of active power filter, good control strategy needs to be designed and must be compatible with the proposed active power filter. Fast response and direct closed loop control strategy is considered in this research. The harmonics compensation techniques in time domain and frequency domain are studied. Comparison between these two domains is done to determine to best compensation techniques.

After determining the suitable control strategy to use, the related compensated techniques have to be designed and transformed into appropriate control algorithms. Therefore, the basic of the equations derivation of each related techniques are study in details. Suitable control algorithms are then developed for the proposed active power filter.

1.5 Organization of Thesis

The thesis is organized into six chapters namely the introduction, literature reviews, active power filter topologies, simulations and results analysis, discussion and future works and conclusion.

Chapter I discuss the background and general idea of the proposed project. Besides that, the objective and scope of the project are stated too in this chapter.

Chapter II discuss the reviews of the literature which includes the principles of each techniques implemented in the active power filters. The brief reviews of the control strategy used in the proposed active power filters are mentioned in this chapter too.

Chapter III shows the research methodology of each design stage. The details of the topology of the proposed active power filters are discussed in this chapter with the derivation of the equations and the operations of the system.

Chapter IV shows the simulation design and the results of each stage. Troubleshooting of each design block in the closed loop control system is discussed in this chapter too. The results obtained and problems are analyzed.

Chapter V consists of the overall discussion on the design project, future works and improvements that can be done for this system.

Chapter VI provides the summary of the overall proposed active power filter and the concluding remarks for this thesis.

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