HARMONICS REDUCTION USING SINGLE PHASE SHUNT ACTIVE FILTER

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ABSTRAK : *Masa kini, parameter-parameter kualiti kuasa utiliti telah menjadi isu penting di mana satu daripada parameter-parameter ini ialah kewujudan harmonik di dalam rangkaian kuasa. Cambahan beban-beban tidak linear menyumbang berbagai-bagai susunan harmonik dan herotan arus yang serius di dalam sistem kuasa elektrik. Tujuan kerja ini ialah bagi mengurangkan herotan harmonik dan membaiki faktor kuasa bagi beban tidak linear dengan menggunakan penapis aktif satu fasa terkawal digital. Penapis aktif satu fasa yang telah dibina dikawal oleh pemproses isyarat digital. Keputusan-keputusan simulasi dan eksperimen mengesahkan kebenaran penapis aktif satu fasa yang telah dibina. Keputusan-keputusan telah menunjukkan penapis aktif satu fasa yang telah dibina berupaya mengurangkan jumlah herotan harmonik bagi arus bekalan yang disebabkan oleh beban-beban tidak linear. Penapis aktif satu fasa yang dibina memerlukan pembaikan lanjutan dalam skema kawalan untuk memenuhi keperluan piawaian antarabangsa IEEE 512-1992.*

ABSTRACT : Recently, the utility power quality parameters have become an important issue. One of these parameters is the presence of harmonics in the power network. The proliferation of non linear loads contributes to various orders of harmonics and serious current distortion in the electrical power system. The aim of this work is to minimize the harmonic distortion and improve the power factor of non linear loads by using digital-controlled single phase active filter. The designed single phase active filter is controlled by the digital signal processor. Experimental and simulation results confirm the validity of the designed single phase active filter. The results indicated that the designed single phase active filter is able to reduce the total distortion harmonic of supply current due to non linear loads. The designed single phase active filter requires further improvement in the control scheme to meet the requirements of the international standard IEEE 512-1992.

KEYWORDS : Active filter, harmonic reduction

INTRODUCTION

With the development of power semiconductor and power electronics technologies, solid state power conversion techniques such as diode or thyristor rectifiers, switching mode power supplies and motor speed controller have been widely used in various applications. These power electronics equipment behave as non linear devices which generate serious input currents harmonics and result in poor input power factor. The current harmonic distortion results in overheating of the distribution transformers and motors, damage to power devices, malfunctioning of sensitive equipment and increasing power losses.

Recently, reduction of harmonics in power system has become an important issue in improving the utility power quality (Akagi, 1996). Conventionally, passive LC filters were the choice to suppress current harmonics and to improve the power factor. However, passive filter is designed to filter specific harmonic components. It is not adaptable to successfully filter varying harmonics. Any system experiencing supply or load changes can expect a change in the harmonics produced. Passive filters must be carefully sized. Undesirably large bus voltages can result from using an oversized filter, and an undersized filter can become overloaded. Finally, other complications, such as those related to resonance, are possible. In fact, interaction between the capacitance in passive filters and system impedance can result in a system resonance condition *(Zamil and Torrey, 2001)*. This resonance condition can persist even with the filter tuned slightly below the system resonant frequency. All of these points can be drawbacks to the passive filter option.

Rivas *et al* (2003) discussed the technical disadvantages of passive filters. The most critical aspects of passive filters are related to the fact that they cannot modify their compensation characteristics following the dynamic changes of the non linear load, the performance dependence they present with the power system parameters, and the probability of series resonances with the power system's equivalent reactance. Another technical disadvantage of passive filters is related to the small design tolerances acceptable in the values of L and C. Small changes in the value of L or C modify the filter resonant frequency. For example, a 5% difference in the selected value of or in a second-order filter tuned at 250 Hz (fifth harmonic) modifies the required resonant frequency of 7% with respect to the selected design value, affecting the filter current harmonic compensation performance. Also, the passive filter generates at fundamental frequency reactive power that changes the system voltage regulation, and if the filter is not designed properly or disconnected during low load operating conditions, over voltages can be generated at its terminals.

To overcome the disadvantages of the passive filter, active filters were initially proposed by Sasaki and Machida (1971) as a means of removing currents harmonics. For many years, several approaches, such as hybrid filters and multi-step inverters are reported to reduce the size of active filter. Many control concepts such as instantaneous power theory, notch filter and repetitive based controllers have also been introduced. Most of these control schemes require various transformations and are difficult to implement.

Many technical papers and articles related to active filter have been published and various types of active filters have been proposed. Classification of active filters is made from different points of view. Active filters are divided into active ac filters and active dc filters. The active dc filters have been studied to compensate for current and voltage harmonics on the dc side of thyristor converters for HVDC systems and on the dc link of a PWM rectifier or inverter for traction system *(Zamil and Torrey, 2001).*

In general, there are two types of active filters, depending on their connection to the power system as series or shunt. Shunt active filters have several advantages. They can be installed without interrupting the load and can serve multiple loads at the same time. The rating of shunt filter is usually lower than the load rating. They can easily suppress only selected harmonics, allowing them to coexist with fixed frequency LC filter banks. Furthermore, the configuration of shunt filter is more reliable which a failed active filter does not immediately affect the loads (Bolsens *et al*, 2002).

This work presents a simple algorithm to achieve the digital control of single phase active filter. The approach of single phase active filter is based on the principle of injecting harmonic current into the AC system, of the same amplitude and reverse phase to the load current harmonics. The active filter controller is implemented with a digital signal processor (DSP). The model of DSP used in this work was TMS320F2812.

Experimental and simulation results confirm the validity of the proposed digital controlled single phase active filter. The designed active filter can be able to minimize the harmonic components and reactive power supply.

SINGLE PHASE ACTIVE FILTER TOPOLOGY

Shunt active filters have several advantages. The rating of shunt filter is usually lower than the load rating. They can easily suppress only selected harmonics, furthermore, the configuration of shunt filter is more reliable which a failed active filter does not immediately affect the loads (Bolsens *et al*, 2002).

The single active filter consists of a single phase full bridge voltage source PWM inverter, DC capacitor C and an inductor L. Figure 1 shows the system under study where the active filter is connected in parallel with the non-linear load. The filter operates as current source, which cancels the current type harmonics. A single phase diode bridge rectifier feeding a series RL circuit is chosen to represent the non-linear load.

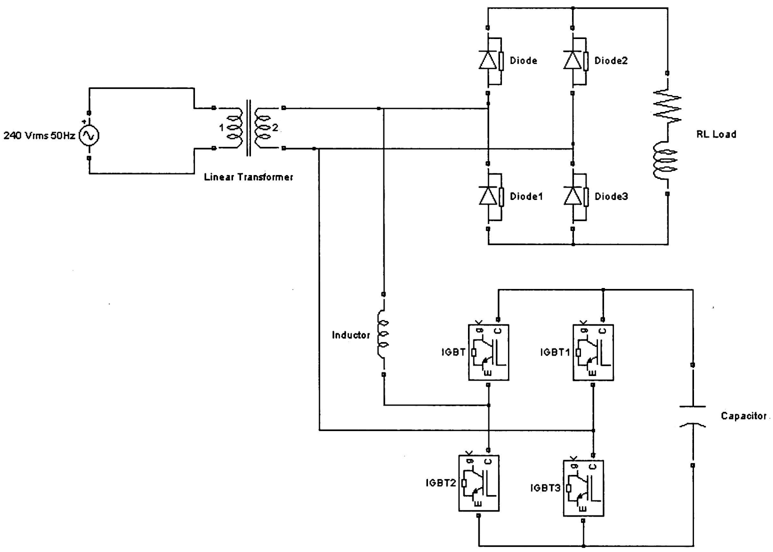

Figure 1. *Single phase active filter and load system*

Injection Inductor

The design of the inductor is based upon the two criteria; limiting the high frequency components of the injected currents and the instantaneous *di/dt* generated by the active filter should be greater than *di/dt* of the harmonic component of the load, so that proper harmonic cancellation can take place.

To cancel the harmonics perfectly, the inverter must generate a high *di/dt* which requires a small inductance, normally a few mille Henry (mH). However decreasing the inductance increases the current ripple and as a result the supply side exhibits a current with a higher total harmonic distortion.

DC Capacitor

The choice of the DC capacitor is an important criterion. The capacitors are designed to limit the dc voltage ripple to a specified value, typically 1 to 2%. A small DC capacitor value may result in large ripple during transient states. In order to actively to control output current active filter, i_f, the dc bus voltage, V_{dc} must be greater than or equal to voltage peak. Based on these two criteria, the rating of the selected capacitor is 1000 μF, with a dc voltage of 250 V.

Switching Frequency

The switching frequency must be chosen high enough to cancel harmonics up to a given frequency. First, the fixed period is calculated by the following calculus (Oliveira, *et al*, 2002):

$$P_f = \frac{1}{f_{power}} = \frac{1}{50Hz} = 0.02s \quad (1)$$

$$\frac{P_f}{N} = \frac{0.02}{2^8} = 78.125\mu s \quad (2)$$

$$f_{switching} = \frac{1}{78.125\mu s} = 12.8kHz \quad (3)$$

where f_{power} represents the frequency of the electrical power supply and N is the number of points which the signal was captured. Thus, the switching frequency of PWM can be calculated which is approximately 12.8 kHz, this frequency represents the carrier frequency of PWM.

RESULT AND DISCUSSION

Simulation Result

The simulation model of the system has been developed using Matlab software. The simulated current waveform before compensation is shown in the Figure 2, while the harmonic spectrum of the current is shown in Figure 3. The total harmonic distortion (THD) is 32.73% with the fundamental current value is equals to 5.22 A.

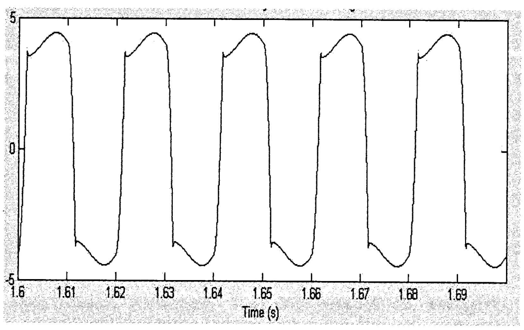

Figure 2. *Simulation result of current wave form before compensation*

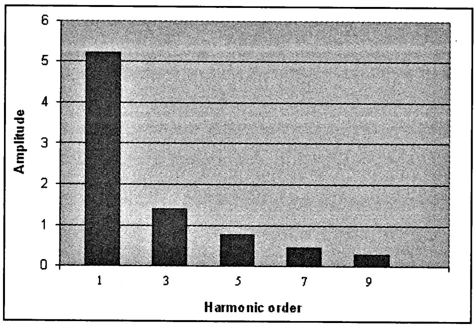

Figure 3. *Simulation result of spectrum harmonic current before compensation*

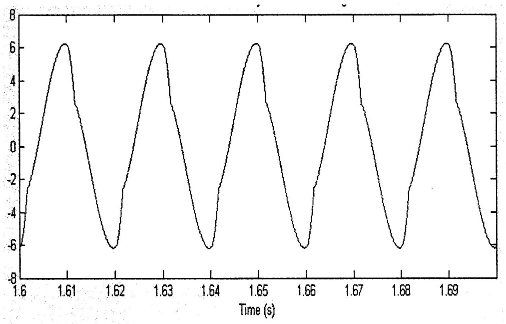

Figure 4. Simulation result of current waveform after compensation

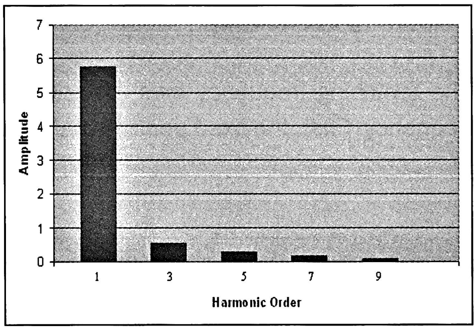

Figure 5. Simulation result of spectrum harmonic current after compensation

Figure 4 shows the source current, i_s waveform after compensation in the simulation method. With the presence of active filter, the harmonic source current is reduced from 32.73% to 11.10% with referring to the spectrum harmonic of the current after compensation which is shown in Figure 5 to reduce the THD further it is required to use another filter tuned to reduce the harmonic next in level.

Experimental Result

The experimental current waveform results of the system without the designed active filter is presented in Figure 6, while the harmonic spectrum of current without the presence of active filter is shown in Figure 7.

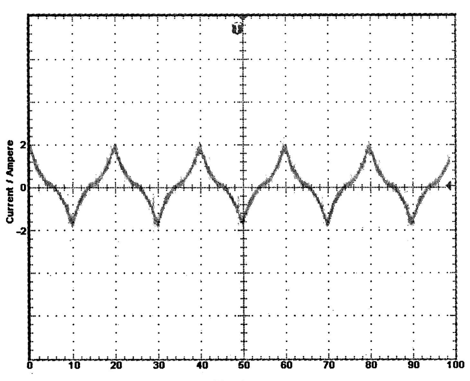

Figure 6. Experimental result of current waveform before compensation

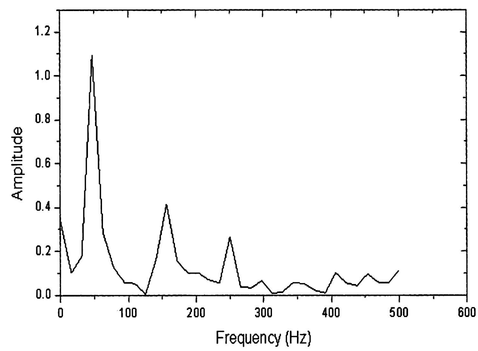

Figure 7. Experimental result of spectrum harmonic of current before compensation

In contrast, the current waveform after compensation by active filter and its harmonic spectrum which are obtained experimentally are shown in Figure 8 and Figure 9 respectively.

The measured value of THD can be given by the spectrum analyzer which showed that the THD of current waveform is minimized from 45.27% to 21.76% with the presence of the active filter.

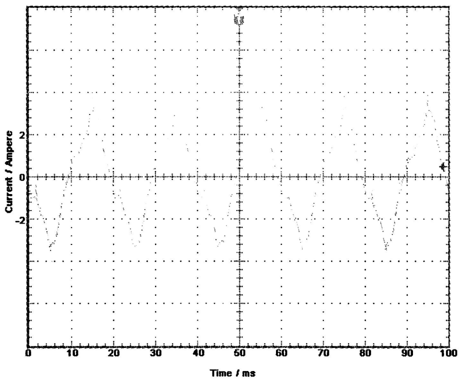

Figure 8. *Experimental result of current waveform after compensation*

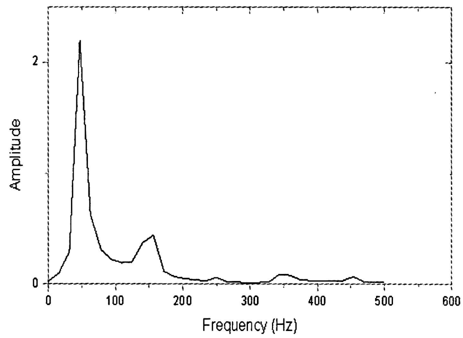

Figure 9. *Experimental result of spectrum harmonic of current after compensation*

The designed active filter is able to increase the fundamental supply current from 5.218 A to 5.753 A in the simulation results. In practical, the fundamental supply current is increased to 2.208 A from 1.10 A after compensation of active filter. It means that the fundamental active current is increased or fundamental reactive current is reduced. In other words, the reactive power in the power system is able to be minimized with the presence of the active filter.

Usually the single-phase system contains a third order harmonic which has the most affective component in the voltage and current waveforms, From the simulation result, the third order harmonic is reduced from 1.35 to 0.527 A when the filter is connected. But, in the practical, the third order harmonic is slightly increased from 0.412 A to 0.458A. It is happened because of the current injection creates its own harmonic components same reason may be extended to the increment of seventh harmonic order from 0.056 A to 0.097 A. The other harmonic orders are successfully minimized.

Based on the obtained results, the quality of the simulation and experimental waveforms are different, due to the assumption that the components used in the simulation model are ideal. This is one of the reasons for the supply current waveform before compensation of active filter is different in the simulation and experiment.

CONCLUSION

The designed active filter is able to compensate and reduced the harmonic produced by non linear load, improve the waveform of supply current, i_S and minimize the reactive power in the system. The designed active filter is able to compensate the THD from 45.27% to 21.76%. The designed single phase active filter requires further improvement in the control scheme to meet the requirement of the international standard IEEE 512-1992. Few suggestions can be mentioned, such as the method of generation PWM, the control algorithm that implemented in the DSP.

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