

Single Phase Half-Bridge Inverter For Shunt Active Power Filter

Mohd Azad bin Jamaluddin
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail: MohdAzad53@yahoo.com

Abstract—This paper describes implementation of half bridge inverter as active power filter to compensate the harmonic current due to the non-linear loads to get THD less than 5% as suitable to the IEEE519-1992 standard. The active power filter consists of a half-bridge inverter, which reduces the number of switch used, compare to H-Bridge inverter. The proposed system is connected in parallel with load and at normal condition; it gives appropriate compensation to solve problems of current displacement and harmonic. Bridge rectifier is used which emulates the non-linear load characteristic. Simulation completed by using MATLAB-Simulink simulation package. Simulation and experimental result were presented to verify proposed system.

Keywords—Half-bridge Inverter; Shunt Active Power Filter; Pheripheral Interface Controller

I. INTRODUCTION

Nowadays most of the load and control equipment use computers, microcontroller, power electronic device and converters to obtain the desired control performance. These devices and controllers draw non-sinusoidal current from the supply resulting the generation of current and voltage harmonic. These distorted voltage and current result poor power factor operation, low energy efficiency, and harmful disturbance to other appliances [1]. The problems of eliminating harmonics with unity power factor operation of supply systems are receiving considerable attention to researchers worldwide [2]. Active power filter (APF), is increasingly used to mitigate harmonics in utility power lines Compared to the more established method such as the static var compensator or passive filter, APF is relatively new in the market. Much type of active power filters (APF) is design to solve harmonic problems. In recent years, various active power filter (APF) configurations has been proposed to solve harmonics problem, it is classified into series, shunt and hybrid active power filter [2-6]. Shunt active power filters is operated by using pulse width modulation (PWM) inverter techniques to inject the required non-sinusoidal current requirements of nonlinear loads. Passive filters such as LC cells cannot solve these harmonic problems adequately, due to their inability to compensate random frequency variations in the current, and tuning problems [7]. The active filter is connected in parallel with the nonlinear loads; functioned as

current sources, and cancels the current harmonic and reactive components generated by the load [8-10].

II. ACTIVE POWER FLTER

This paper is concerned on the use of a single-phase half-bridge active power filter (APF) designed with a full- bridge rectifier as a nonlinear load with simple control scheme to reduce current harmonic components and reactive power compensation. A single-phase half-bridge inverter is used IGBT as switch with an energy storage capacitor on dc side, connected in parallel with the load. The half-bridge inverter is built by two IGBT. Anti-parallel diodes are connected across these power switches in term of protection and providing power conversion in reverse direction in order to recharge the dc capacitor whenever its level goes lower than a reference value. Figure 1a shows a single-phase diode bridge rectifier act as non-linear load and the waveforms of input voltage and current drawn from the non-linear load are showed in figure 1b. The input current is distorted because of the bridge diodes conduct current only when the rectified input voltage is equal to or greater than the dc capacitor voltage.

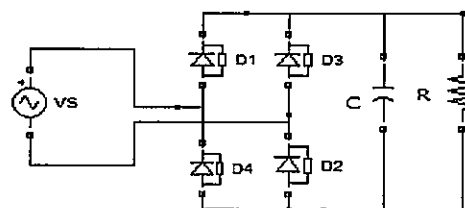


Figure 1a. Single-phase diode bridge rectifier with non linear load

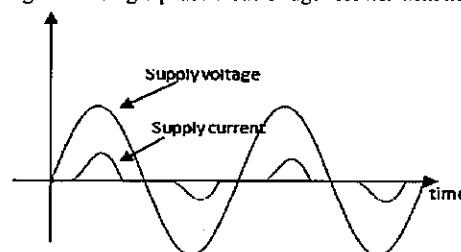


Figure 1b. Diode bridge rectifier input voltage and current waveform

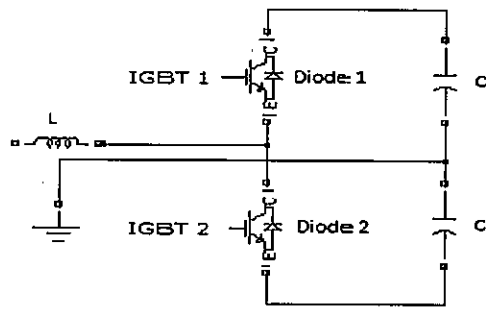


Figure 1c. Half-Bridge Inverter Circuit

Half bridge active filter concept is used power electronic switching to generate harmonic components to cancel the harmonic components of the non-linear loads, it means that in these devices, direct current is converted to form the harmonic currents of the load which is then injected into AC line. This inverter uses DC capacitor as the supply that will inject or absorb the harmonics from the nonlinear load. All this operation depends on controller circuit to control the switching. Figure 1c shows the Half-Bridge Inverter circuit topology.

The active power filter configuration uses proportional-integral (PI) controller to control the switching so that the supply line current, the non linear load, and the active power filter work together. By using the PI controller, the tendency to overshoot the set value still exists while compensating the large error. Practically the fine-tuning of PI parameter is mostly accomplished by trial-and error. To control the switching is quit hard.

III. THE PROPOSED COMPENSATION SYSTEM

Figure 2 shows the configuration of a single phase active power filter with a controller. The controller circuit connects to current sensor to measure the distorted source current. The two capacitors are used to give reactive compensation in both positive and negative half-cycle and hence capable of supplying bi-directional flow of compensation current either absorbed from or injected into the supply system similar to other APF topologies [8].

The block diagrams of current control loop (CCL) arrangements are shown in figure 3. PWM technique is used to synthesize the injected current. The output from the CCL provides gating signals to the half bridge inverter and switching functions to compensate the distorted supply current into a sinusoidal form. The subtractor, subtract the actual voltage from reference voltage and produces an error signal. The voltage error is processed in the PI current controller and after that will be entering to the comparator circuit. The error signal will act as modulation signal and will compare with carrier, which is triangular signal. The comparator process between error voltage and the triangular voltage will produce the active pulse-width modulation (APWM). The APF, is responded to these gating pulses, generating a PWM voltage at the ac side of the APF. The impressed PWM voltage causes a current to flow through the inductor for the compensation of

harmonics and reactive power of the load resulting in a unity power factor.

The higher the switching of the circuit, the more harmonics components that could be injected thus cancelling the distortion components in the supply current. A proportional integral (PI) control algorithm is used to regulate the error [6].

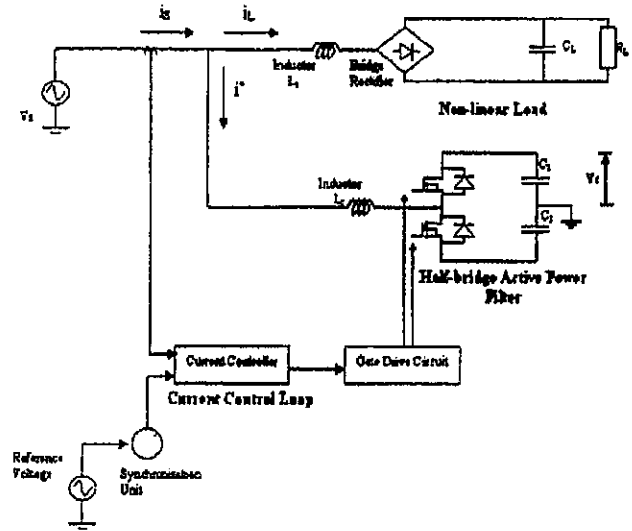


Figure 2. The Proposed Compensation system

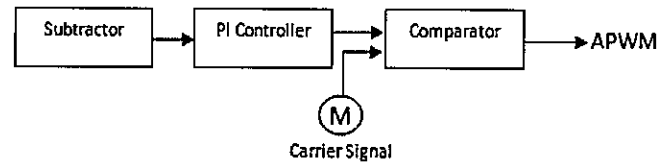


Figure 3. Controller configuration for compensation system

IV. BASIC PRINCIPLES OF OPERATION

The main task of the proposed active power filter (APF) is to reduce current harmonic components and reactive power compensation by injecting the required current into the system. The current feedback control requires proper reference current in order to eliminate current harmonics from the line and to shape the current to be in phase with the supply voltage as illustrated in fig 4. The distortion source current can be corrected by adding compensation current by using superposition principle [5]. The half bridge inverter topology that has been used in the APF makes the harmonics control possible. This inverter uses DC capacitors as the supply that can switch at high frequency to generate a signal which will cancel the harmonics from the nonlinear load. The shunt APF that connected into parallel is injected the harmonics current into the ac system with the same amplitude but not in phase with the load harmonics current.

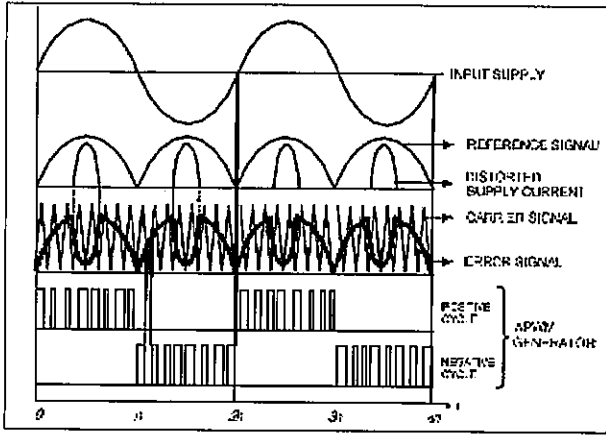


Figure 4. Switching Pattern to Generate APWM.

Figure 5 shows the switching operation of half-bridge active filter. The current flow in positive half cycle where the switch one (SW1) is open. The load current is given by $i_s = I \cos \phi + i_L$. Initially, the current i_L is equal to zero. Therefore, initially $i_s = I^*$ since the $i_L = 0$. If I^* increase in magnitude, i_s will increase accordingly.

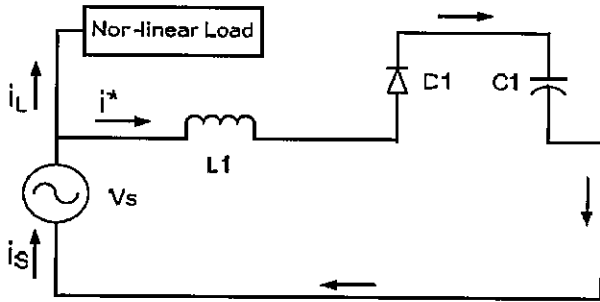


Figure 5. Switching operation in positive half cycle.

During the negative half cycle, similar operation as those of the positive half cycle is implemented but with different current direction. This is illustrated as shown in figure 6. Switch two (SW2) is closed and makes the current flow through the capacitor two (C2).

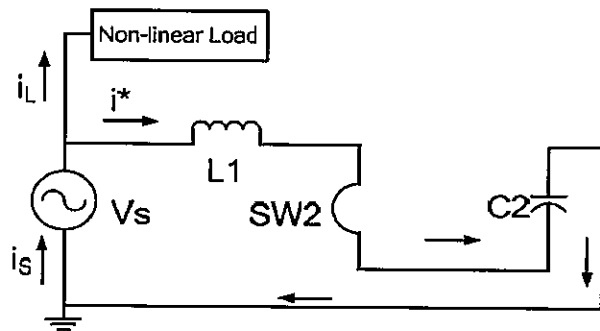


Figure 6. Switching operation in negative half cycle.

V. SIMULATION MODEL

The proposed circuit is simulated using MATLAB/Simulink. Figure 7 shows the basic circuit of single phase diode bridge rectifier with RC load in MATLAB/Simulink.

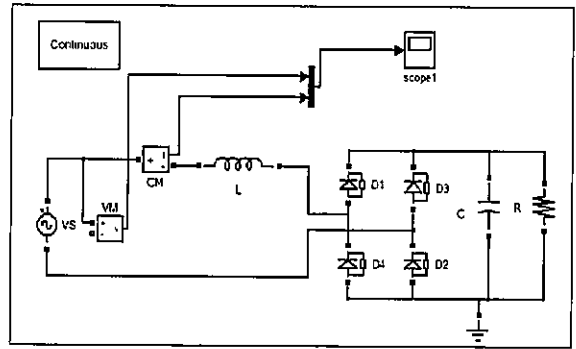


Figure 7. Basic circuit for single phase diode bridge rectifier.

Figure 8 shows the complete circuit of active power filter (APF) using half bridge inverter. The circuit is combination of power circuit and electronic circuit. Power circuit is containing single phase bridge diode rectifier and half bridge inverter circuit, while electronic circuit is containing absolute part, subtractor, PI controller and comparator.

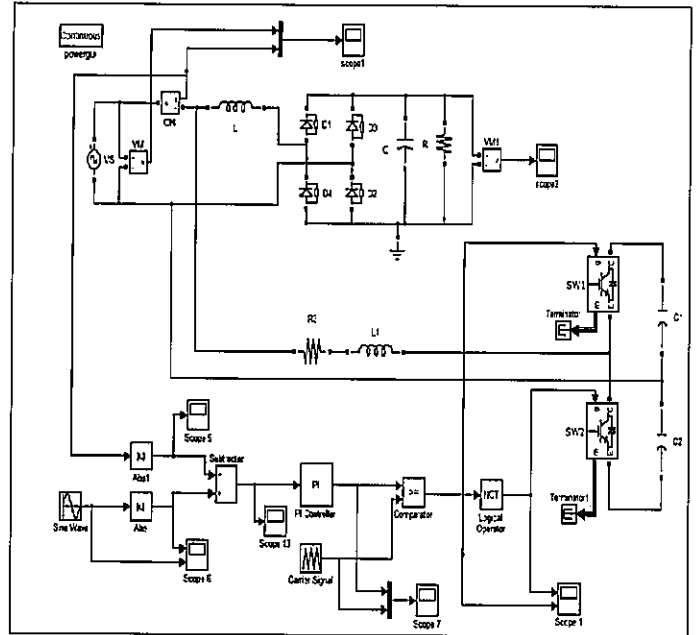


Figure 8. Complete compensating circuit using MATLAB/Simulink.

VI. HARDWARE IMPLEMENTATION

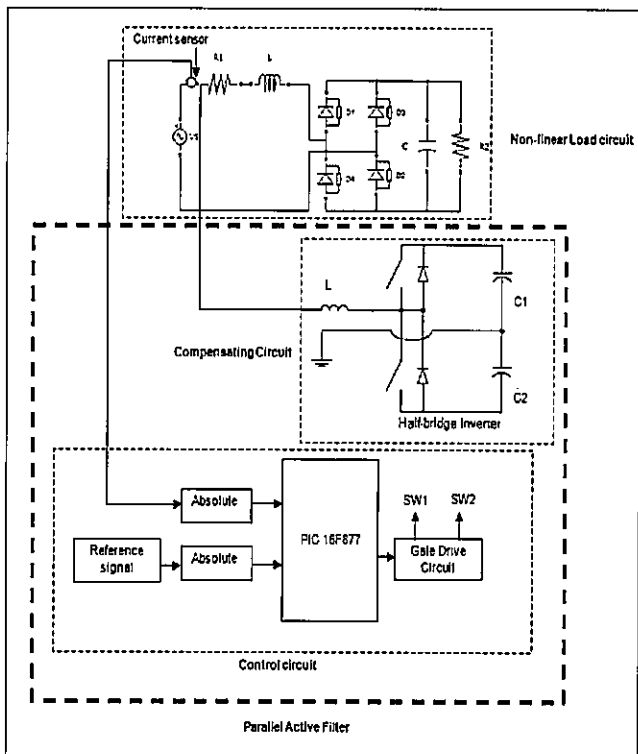


Figure 8a. Experimental test-ring.

The single-phase bridge rectifier KBPC 1504 is used to represent the non-linear load with the line input filter of 1.5mH inductance feeding a 330 Ω resistor having a shunt capacitor of 1000 μ F. The half-bridge active power filter consists of two GB14C40L IGBT switches, 2mH inductor and 10000 μ F, 50V capacitor. The IGBT is controlled by using a gate drive circuit to urge the PWM signal for appropriate level. It is also to provide electrical isolation between power and control electronics. For the implementation of the control electronics PIC16F877 microcontroller is used. Figure 8a shows the experimental test-ring while figure 8b shows the flow chart to generate the required Pulse Width Modulation (PWM).

The control electronics is a combination of analogue and digital circuits. Analogue element consists of current sensor; reference signal and absolute circuit are used. The digital system uses a peripheral interface controller (PIC) that contains the operation of subtractor, PI controller and a comparator. The function of PIC 16F877 type is to observe the current analogue form, processes and converts into digital form using a built-in analogue to digital (ADC) of the PIC. The PIC 16F877 microcontroller is used to employ discrete active PWM [10]. Figure 8b shows the flow chart to generate PWM.

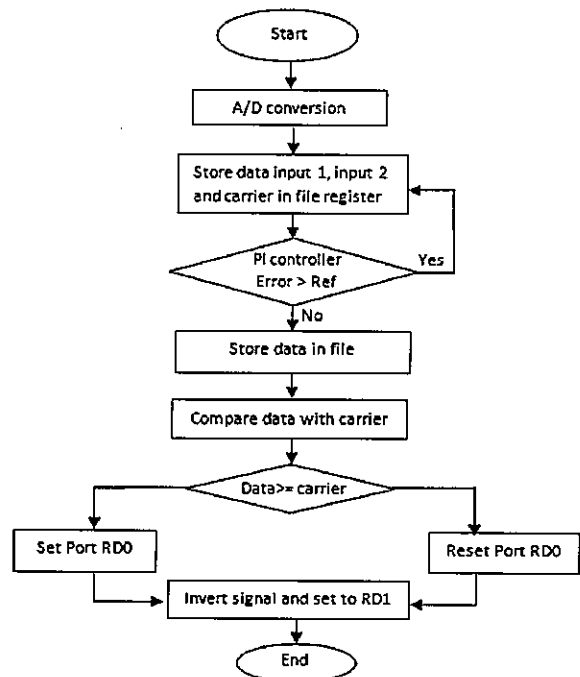


Figure 8b. Flow Chart to generate PWM.

VII. RESULT AND DISCUSSION

In this work the MATLAB/Simulink simulation is used to expound the APF system. This is followed by the description of the prototype construction. The experimental results will be presented and analyzed with reference to the simulation work.

First, the performance of the distribution system without compensation is given. Then, the result of ideal compensation will be presented. Finally, analysis on the Total Harmonic Distortion (THD) for the proposed APF is presented between simulation and experiment is carried out.

A. Simulation results

Simulation result for unfiltered system with uncontrolled rectifier load is shown in figure 8.1a. The current waveforms without any type of compensation show the distorted supply current cause of the non-linear load. Figure 8.1b shows the results of rectifier load source voltage and currents waveform after filtering. The supply current and voltage are in phase caused by the superposition of substantial harmonic current existing in the system.

Figure 8.2(a) represents the discontinuous current supply of the distorted line current while Figure 8.2(b) show the Fast Fourier Transform (FFT) synthesized from the waveform of the distorted supply current. The magnitude of odd harmonics is amplified close to the value of the fundamental, whilst the even harmonic remained relatively low. The total harmonic distortion (THD) of 157.06% is observed. Figure 8.3(a) shows the signal of simulation result when the active power filter (APF) is connected parallel to the non-linear load. THD after compensation is 2.93% are shown in figure 8.3(b). The

• waveform is now continuous, almost sinusoidal and in phase with the supply voltage.

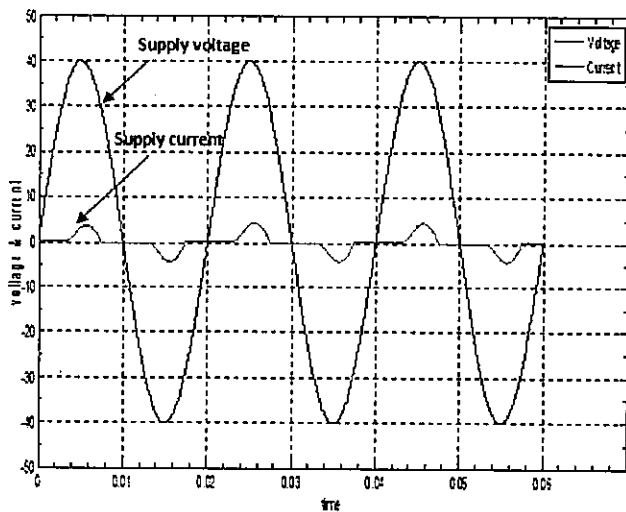


Figure 8.1a. Simulation results of non-linear load supply voltage and currents waveform without compensation

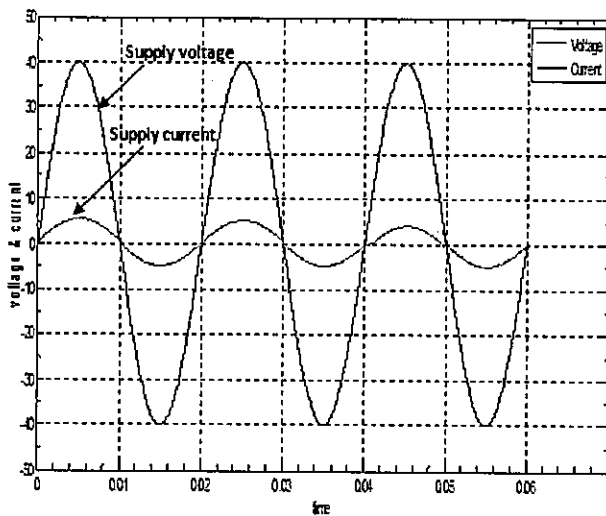
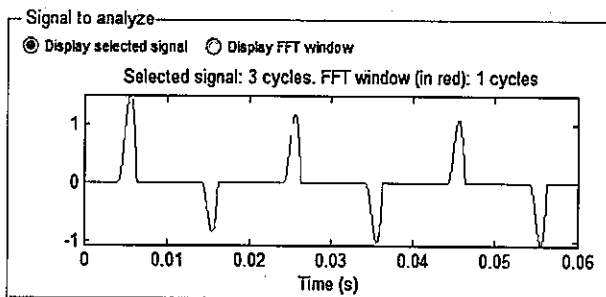
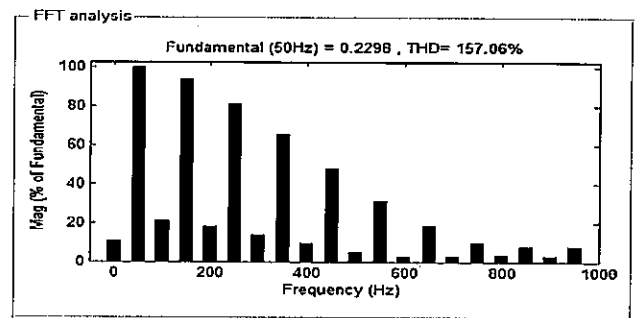


Figure 8.1b. Simulation results of non-linear load supply voltage and currents waveform with compensation



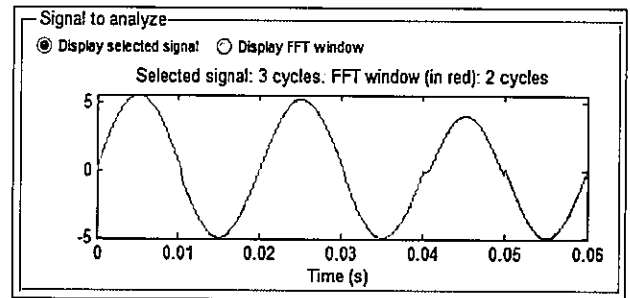
(a)
Fundamental (50Hz), THD 157.06%



(b)

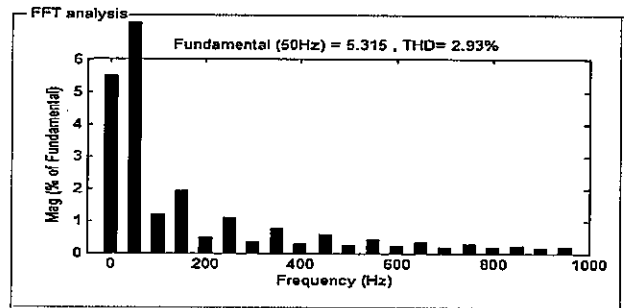
Harmonic order

Figure 8.2. Simulation results Non-linear load; (a) Discontinuous Current supply and (b) FFT on supply current without compensation.



(a)

Fundamental (50Hz), THD 2.93%.



(b)

Harmonic order

Figure 8.3. Simulation results Non-linear load; (a) Discontinuous Current supply and (b) FFT on supply current with compensation.

B. Experimental Result

Figure 9a shows the experimental result of the non linear load before filtering. Observe that the current is leading the voltage supply and the THD is 61.26%. Figure 9b shows the APF provides current injection for correction of the distorted supply current. The result observes that the supply current is in phase with the supply voltage. By implementation of the APF the Total harmonic distortion (THD) is reduced to 3.67% is archived. A result is tabulated in table 1.

The APF topology also can be improved by using fuzzy logic control on the voltage control loop to ensure the good performance of control strategy.

ACKNOWLEDGEMENTS

The author would like to thanks En. Mustafar Kamal Hamzah for guidance, advice and support in finishing this project.

REFERENCES

- [1] Sergio Sorena, Chongming Qiao, keyue M. Smedley " Single-Phase Active Power Filter with Double-Edge Integration Control" , IECON'01: The 27th Annual Conference of the IEEE Industrial Electronic Society.
- [2] H. Akagi "Active harmonics filters", Proceedings of the IEE, Vol.93, No.12, Dec. 2005, pg 2128.
- [3] F.P.d. Souza and I. Barbi, "Power Factor Correction of Linear and NON-Linear Loads Employing a Single phase Active Power Filter Based on Full-Bridge Current Source Inverter Controlled Through the Sensor of the AC Mains Current," presented at the Power Electronics Specialists.
- [4] H. Akagi, "New trends in active filters for power conditioning", IEEE Transactions on Industry Applications, Vol.32, No.6.
- [5] M.K. Hamzah " Single-phase Half-bridge Shunt Active Power Filter Employing Fuzzy Logic Control" Power Electronics Specialists Conference, 2008. PESC 2008. IEEE, On page(s): 552 – 558, 15-19 June 2008
- [6] Y. Hayashi, *et al.*, "A Novel Control of a Current-Source Active Filter for AC Power system Harmonics Compensation," vol. 27, p. 6, March/April 1997.
- [7] N. R. Hamzah, *et al.*, "Single-Phase Shunt Active Power Filter Using Single-switch Incorporating Boost Circuit," presented at the 2nd IEEE International Conference on Power and Energy (PECon 08), Johor Bahru, Malaysia, 2008.
- [8] David M.E. Ingram and Simon D. Round "A Fully Digital Hysteresis Current Controller for an Active Power Filter, page 1-30.
- [9] M.F Saidon, "Real Time Implementation Active Power Filter Using Fuzzy Logic Control". Doctorate Thesis, University of Wales Swansea, Dec 1999.
- [10] Mihail Antchev "Control Method for Single-Phase Shunt Active Power Filter". Eurocon 2005 Serbia & Montenegro Belgrade, November 22-24 2005.

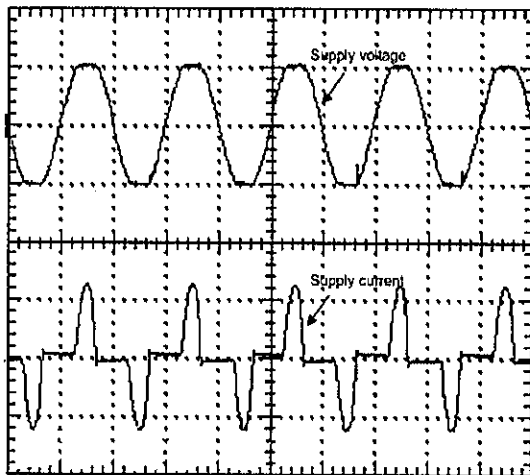


Figure 9a. Experimental results of non-linear load supply voltage and currents waveform without compensation.

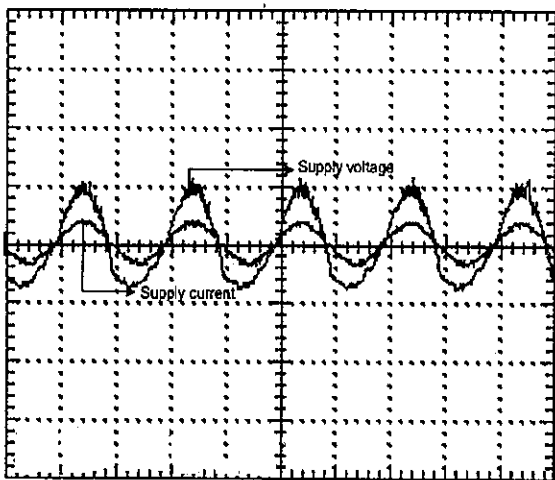


Figure 9b. Experimental results of non-linear load supply voltage and currents waveform with compensation.

TABLE I. SIMULATION RESULT AND EXPERIMENTAL RESULT BEFORE AND AFTER IMPLEMENTATION OF APF

Test	Simulation		Hardware	
	Before APF	After APF	Before APF	After APF
Total Harmonic Distortion (THD)	157.06%	2.93%	61.26%	3.67%

VIII. CONCLUSION

From the simulation and experimental result that have been presented, it is shown that the half-bridge inverter can improve harmonic compensated of the non-linear load. In this paper, it is proven that the single phase half bridge inverter can be used for the shunt active power filter which reducing the number of switch and switching losses with excellent performance. This proposed system has reduced the total harmonic distortions (THD) that satisfy the IEEE519-1992 standard.