# Single Phase Rectifier Using Single Switch of Shunt Active Power Filter

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***Abstract*—This paper presents the result of single phase rectifier system using shunt active power filter (APF) technique. The shunt APF is used to compensate the harmonic current components when a non-linear load is connecting to the rectifier. The technique involves injecting equal but opposite current to shape the distortion supply current to be sinusoidal and in-time phase with supply voltage. The boost rectifier circuit is employed as a shunt active power filter which consists of one power switch for cost minimizing as well as reducing switching losses. Computer simulation and hardware are presented in this paper.**

***Keywords- Rectifier; Active Power Filter; Boost Converter; Harmonics***

## I. INTRODUCTION

Electronic equipment application has been important due to demands from industry application. The non linear loads [7] contains of power switching devices appear to be prime sources of harmonic distortion. A non-sinusoidal current being drawn from the supply, containing harmful harmonic components which are then injected back to the supply system were creating various problems.

Various methods have been proposed to solve these problems. The conventional method of harmonic filtering is passive filter [3,4,6]. Among the more commonly used passive filter are the shunt LC filter and shunt low pass LC filter. They have some advantages such as simplicity, reliability, efficiency and cost [4]. However the harmonics problem is not solved because their performance is limited to a few harmonics and they can introduce resonance in the power system. Also, a separate filter is necessary for each harmonic frequency [4].

In recent years, various active power filter (APF) have been an effective way to compensate harmonics component in non linear load.[6]. Many studies have been carried out on various aspect of active power filter implementation [3,4,6,7]. APF can be connected in several power circuit configurations. In general, they are divided into three main categories, namely shunt APF, series APF and hybrid APF [3,4].

In many cases, parallel active power filters (PAF) have been used for harmonic current filtering [6]. It is based on a "Pulse-width modulated, PWM". It means that in these devices," Direct Current, DC" is converted to form the harmonic currents of the load which is then injected into AC line [4].

The research in this field has proposed various improvements in compensation algorithms, switching techniques and etc [3,9]. Normally for the circuit topology, voltage source inverter (VSI), current source inverter (CSI) and half-bridge rectifier circuit was employed but required a number of power switches used [1,6].

Boost rectifier circuit is one of the techniques used in series active filter (SAF) which is a modification of a basic bridge-diode circuit by insertion of a boost switch and an inductor [5].

In this paper, the boost rectifier circuit is used as a shunt active power filter in feeding a non linear load to reduce total harmonic distortions as well as improving the power factor. Only one switch is used instead of using the VSI and CSI to reduce the switching losses. On the other hand, it also can minimize the cost for hardware implementation.

The compensation process occurred by injecting equal but opposite current to shape the distortion supply current to be sinusoidal and in-phase with supply voltage.

The result of proposed filter was analyzed with computer MATLAB Simulink and experimental hardware verification.

## II. METHODOLOGY

### A. *BOOST RECTIFIER CIRCUIT*

The concept of boost rectifier circuit is to shape the supply current to be sinusoidal as well as power factor correction. This concept achieved by using a switch and an inductor added to basic bridge rectifier circuit to act as shunt active power filter.

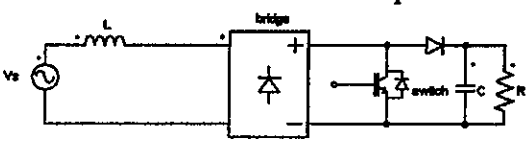



Figure 1: Basic boost rectifier circuit

## B. PROPOSED SYSTEM

The system consists of single phase rectifier connected to RC load (non-linear load) and an inductor (input filter) as shown in Figure 2. The boost rectifier circuit that shown in Figure 1 represents the APF that connected in parallel with the voltage supply. The APF is connected before the input filter.

The IGBT used in the APF is controlled by the Current Control Loop (CCL). The gating signal from IGBT provides the switching functions to generate equal but opposite current of distorted supply current.

This current will be injected back into the circuit to compensate the distorted supply current into a sinusoidal form.

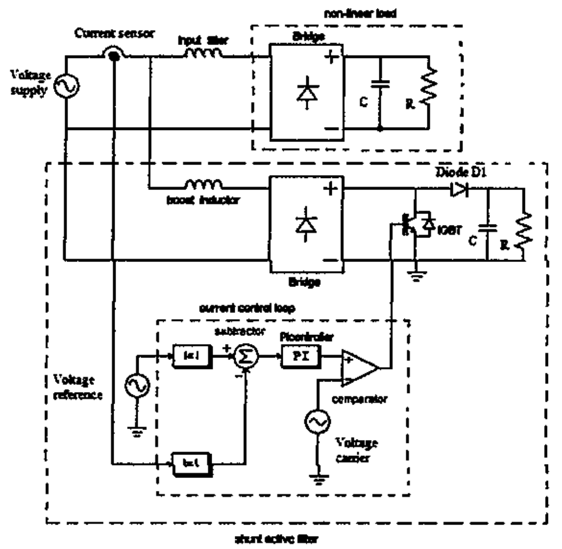



Figure 2: APF System

## C. APF OPERATION

The APF used to inject the required current into the system. The operation can be explained in two conditions; during 'ON' and 'OFF' of power switch. During turn 'ON' (Figure 3), diode D1 reversed biased. The inductor is supplied by the input and inductor current will increase. The energy stored in the inductor is used for the compensation process. When the switch is 'OFF' (Figure 4), the voltage in the inductor will reverse it polarity to get constant current. Current will flows through inductor, diode D1 and RC circuit in the APF. The energy stored in the inductor is used for charging the capacitor to be transferred. Vo will be higher than Vs to let APF injecting current to the system.

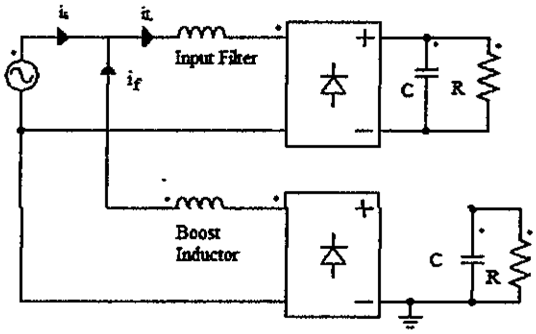



Figure 3: Switch ON

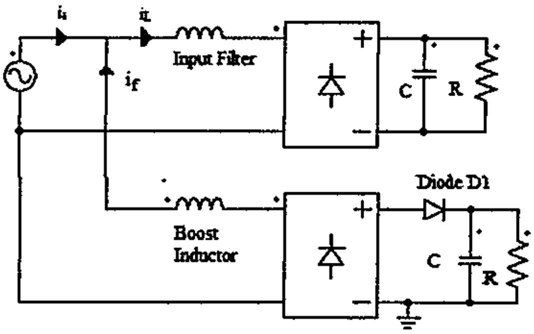



Figure 4: Switch OFF

## D. CURRENT CONTROL LOOP

Based on Figure 5, the distorted supply current is sensed by current sensor then fed to absolute block for enable zero crossing detection in order to get positive waveform only. Then, it will be subtracted with reference signal for synchronization.

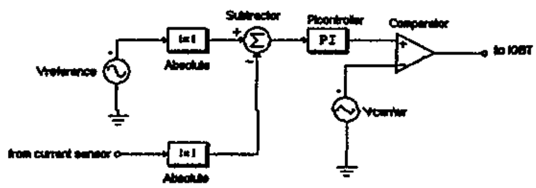



Figure 5: Current Control Loop

A discrete proportional integral (PI) controller is used to regulate the error. From Figure 6, the PWM signal is generated by comparing the error signal with the carrier signal to produce PWM control in order to synthesize the injected current. Due to single switch application, only the positive waveform will be considered. The gating signal will be generated using unipolar switching technique.

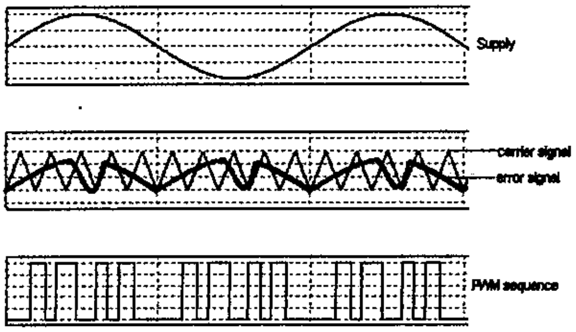



Figure 6 : Generating PWM

### E. SIMULATION CIRCUIT

The configuration of the shunt APF system is simulated using MATLAB Simulink (MLS) model. Figure 7 shows the proposed system.

The result of the compensating circuit is measured using the scope connected to the supply voltage and current. The graphical user interface (Powergui) is used in performing the harmonic analysis (FFT).

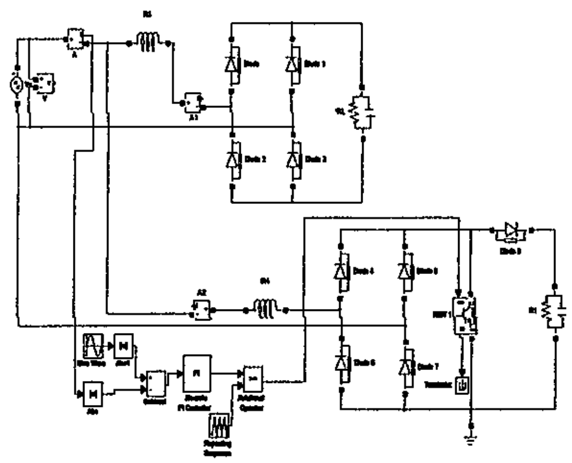


Figure 7 : Shunt APF using MLS

### F. HARDWARE TEST RIG

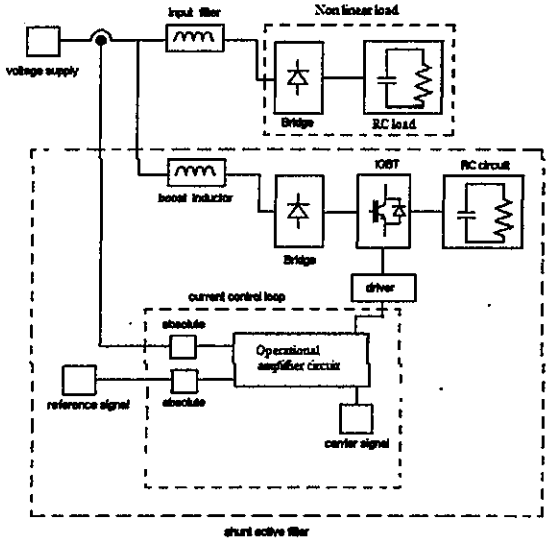



Figure 8 : Hardware set-up

Figure 8 shows the hardware set-up for shunt APF configuration. The non-linear load constructed using single phase diode bridge rectifier KBPC 804 feeding a resistor that connected in parallel with capacitor with inductor as a line filter.

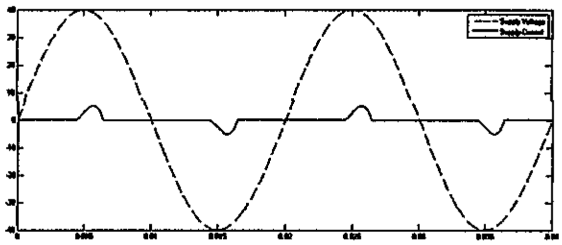
The APF circuit consists of an inductor that connected in series with diode bridge rectifier feeding a resistor and shunt capacitor. The IGBT used as a switch which is controlled using driver circuit.

The current control loop use the current sensor to sense the amplitude of distorted supply current and then subtracting with reference signal. Both are fed to absolute block to enable zero crossing detection that is only positive waveform considered. The reference signal is fed from signal generator and the operational amplifier (op amp) UA741 is used for absolute function.

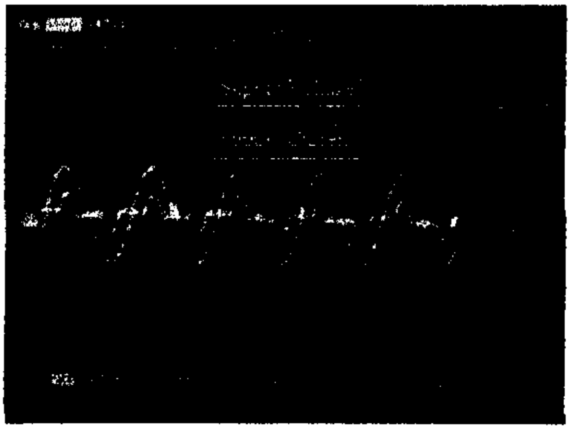
Then the error signal is compared with the carrier signal to generate the PWM signal. The operational amplifier (op amp) UA741 is used for subtractor and comparator circuit. The carrier signal is supplied from signal generator. The controlling output is used to provide gating signal to gate driver circuit then fed to IGBT for current compensation.

## III. RESULTS AND DISCUSSION

Figure 9 and 10 shows the input current waveform before and after the compensation process. It shows that power factor correction occurs after using shunt APF. It can be clearly seen that the waveform of the supply current is fully sinusoidal and in phase with supply voltage after the compensation.

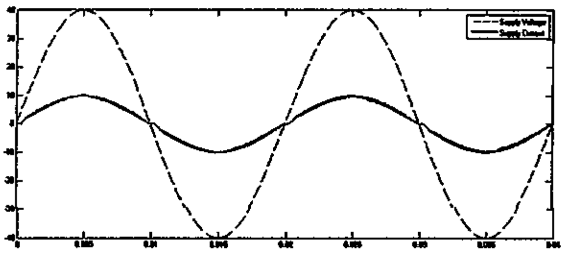


(a)

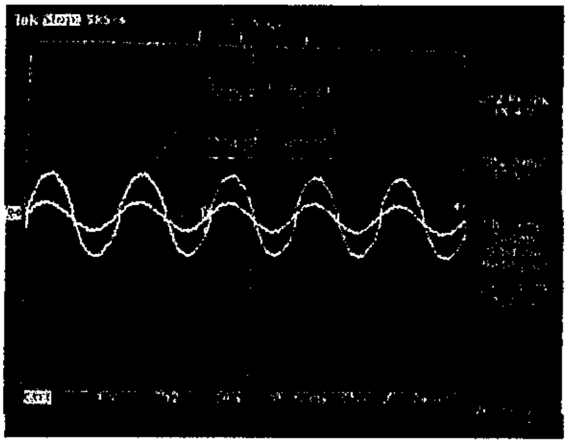


(b)

Figure 9 : Supply Voltage and Current before using shunt APF (a) Simulation result (b) Hardware result



(a)



(b)

Figure 10 : Supply Voltage and Current after using shunt APF (a) Simulation result (b) Hardware result

Figure 11 and 12 shows the THD level before and after using the filter. Before the compensation, the total harmonic distortion (THD) is 149.90%. The THD level reduced to 4.12% with almost unity power factor.

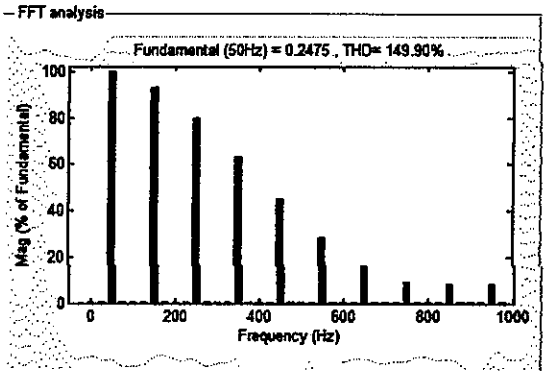



Figure 11 : MATLAB/Simulink Harmonics Spectrum before using shunt APF

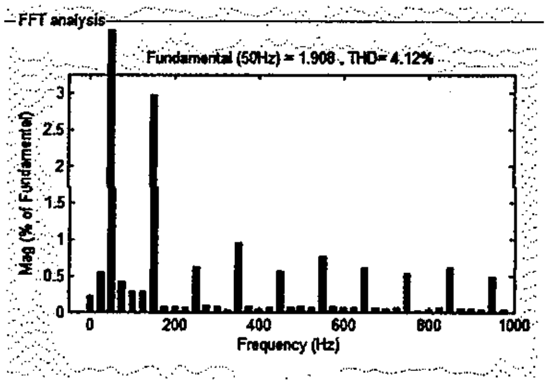



Figure 12 : MATLAB/Simulink Harmonics Spectrum after using shunt APF

## IV. CONCLUSION

This paper shows that the proposed shunt APF is sufficient in compensating the distorted supply current in order to reduce total harmonic distortion as well as power factor correction. The technique involves injecting equal but opposite current to shape the distortion supply current to be sinusoidal and in-time phase with supply voltage.

Table 1: Parameters

| | |
|---|---|
| Supply Voltage | 40(p-p) |
| Non linear loads(R/C) | 300Ω / 2200μF |
| RC circuit(APF) | 1000Ω / 500μF |
| Input filter(L) | 1mH |
| Boost Inductor(L) | 3.5mH |

Table 2: Comparison between before and after using shunt APF

| Compensation | Power Factor(pf) | THD(%) |
|---|---|---|
| Before | 0.55 | 149.90% |
| After | 0.99 | 4.12% |

## V. FUTURE WORK AND RECOMMENDATION

For the hardware test rig, the controller for the current control loop (CCL) that contains the discrete proportional integral (PI) controller, subtractor and comparator circuit can be improved by using other controller. Peripheral Interface Controller (PIC) microcontroller can be done in term of programming in order to generate the PWM for the compensating current.

As for the filter, this work can be done by using hybrid filter that contains passive and active filters.

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