PIC Based Controller Single Phase AC/DC Converter for Harmonic Control

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Abstract— **PIC Based Controller Single Phase AC/DC Converter purposely deals to control harmonic current components. Proportional–integrative (PI) controller is used to control the Pulse Width Modulation (PWM) signal generated. By using PWM technique, the input current will be forced to follow the generated current created by the Active Power Filter (APF) in order to maintain low harmonic distortion while supplying the non-linear load. One-level two pulses PWM circuit topology was used in this study. Computer simulation was implemented to confirm the operational circuit. Comparison in harmonic percentage before and after the implementation of APF will be presented.**

Keyword:* *Active Power filter (APF), Passive Filter, PWM, PI controller

I. INTRODUCTION

Owing to the growth of non-linear loads, such as switching mode power supplies and computers used in the utility side, serious power pollution is produced and reflected into the distribution and transmission networks. All of this contribute current harmonic and result is an increase in losses and interference with power equipment.

One of the most important issues for the power electronic designer is to reduce current or voltage harmonics created by the converters. Harmonics actually have a negative effect on the operation of the electrical system and, therefore, increasing attention is paid to their generation and control [9]. Yet, recent research efforts have shown that this field of investigation, with different lies of thought, first idea is using power passive filter, which are basically consisted of capacitors and inductors with constant values.

Some disadvantages such as constant reactive power independent on the load and resonance effect between the filter and source impedance [1] have been limited the application of these filters and become continuously remaining unresolved question.

Recently, researcher [1-12] comes out with the power active filters based on high frequency inverter PWM techniques have been raised rapidly. Depending on the way of inverter connection between Source and load the active filter can be of type series, parallel, combined series-parallel or associated passive active filter. Figure 1 show APF topology frequently uses.

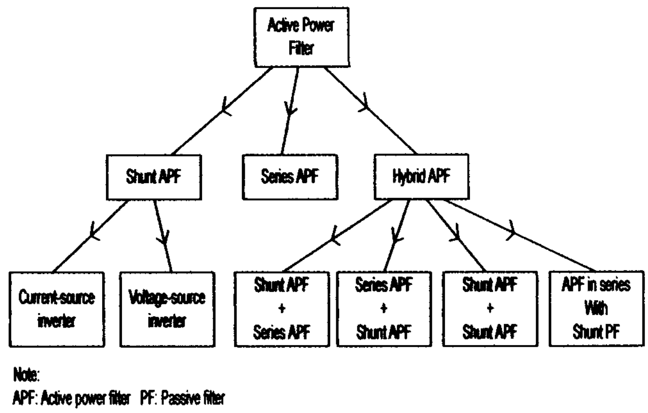


Figure 1: Active power Filter topology

References [1-10] illustrate an example of parallel active power filter in able to reduce harmonic distortion. There are operating using PWM technique to inject the non-sinusoidal current required in non-linear loads [3] to circuit. However these active filters technique are relatively new and a number of different topologies are being proposed [1-12]. Figure 1 shows several topology of APF has been use [10]. Within each topology, there are issues of required component ratings and suitable methods to rating the overall filter for the loads to be compensated. To overcome such situation the passive filters [8] is use as harmonic oscillator.

To give an additional contribution in this field this paper also propose using active power filter in control strategy which maintain the input current with low harmonic distortion. Although the use of parallel active power filter was presents and have some difficulties. This approach was chosen because the basic aim here is to verify the feasibility of the proposed control strategy. In this paper, the simulation using MATLAB/SIMULINK program is presented.

II. ACTIVE POWER FILTER

Remarkable progress in power electronics had spurred interest in APF for harmonic distortion mitigation. The basic principle of APF is to utilize power electronics technologies to produce specific currents components that cancel the harmonic currents components caused by the nonlinear load. The active filter configuration investigated in this paper is based on a PWM voltage source inverter (VSI) [1, 3]. The principle of operation of the APF consists of injecting at the point of common coupling an equal but opposite distorted current, thus cancelling the harmonic content of the original AC current [2]. Figure 2 illustrates the concept of harmonic current cancellation [1, 6]. This APF use short circuit straight line and it can switch at high frequency to generate signal that will cancel harmonic in non-linear loads. Consequently, the current being supplied from the source is sinusoidal I_s. The inverter will inject current I_f to the source current. Total current I_L is equal to current inject from APF I_f and source current I_s [1][3] [7].

$$I_L = I_f + I_s. \quad (1)$$

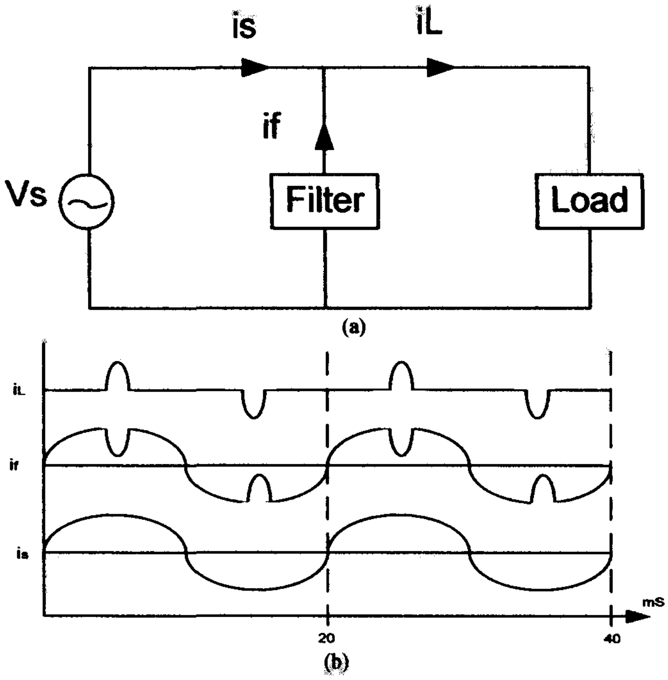


Figure 2: (a) Full circuit diagram; (b) expected current waveform

$$v_s(t) = v_p \sin(\omega t) \quad (2)$$

$$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (3)$$

$$i_L(t) = I_1 \sin(\omega t + \theta_1) + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (4)$$

$$i_{L1}(t) = I_{11} \sin(\omega t + \theta_1)$$

$$= I_{11} \sin \omega t \cos\theta + I_{11} \cos \omega t \sin\theta \quad (5)$$

$$i_L(t) = I_{1q} \sin(\omega t) + I_{1q} \cos(\omega t)$$

$$+ \sum_{n=2}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (6)$$

$$i_F(t) = I_{1f} \sin(\omega t) - I_{1p} \sin(\omega t) - I_{1q} \cos(\omega t)$$

$$+ \sum_{n=2}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (7)$$

$$i_F(t) = -I_{1q} \cos(\omega t) + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \theta_n) \quad (8)$$

$$i_s(t) = i_L(t) + i_F(t) = I_{Lp} \sin(\omega t) \quad (9)$$

Where;

$I_{Lp} = I_{Lp}\cos\theta_1$; real part of $i_{L1}(t)$

$I_{Lq} = I_{L1}\sin\theta_1$; reactive part of $i_{L1}(t)$

$\sum_{n=2}^{\infty} I_n \sin(n\omega t + \theta_n)$; distortion component

v_p ; peak source voltage

ω ; angular frequency ot the fundamental

θ_n ; phase of the nth order harmonic of the load current

The active filter consists of a relatively large isolation inductance to convert the voltage signal created by the inverter to a current signal for cancelling harmonics. The rest of the active filter provides smoothing and isolation for high frequency components. The desired current waveform is obtained by accurately controlling the switching of the insulated gate bipolar transistors (IGBTs) in the rectifier. Control of the current wave shape is limited by the switching frequency of the inverter and by the available driving voltage across the interfacing inductance as in Figure 3.

Figure 4 illustrates the configuration of active filter as a boost converter. Operational Boost converter is by voltage source (Vs) supply energy to inductor and makes inductance fully charge. Charging processes at inductor occur with slowly and causes current linearly increase in inductor until reach rated condition. The energy stored in the inductor can be used for compensation purposes [3]. The active filter does not need to provide any real power to cancel harmonic currents from the load. The harmonic currents will be cancelled show up as reactive power [8]. Reduction in the harmonic voltage distortion occurs because the harmonic currents flowing through the source impedance are reduced [6].

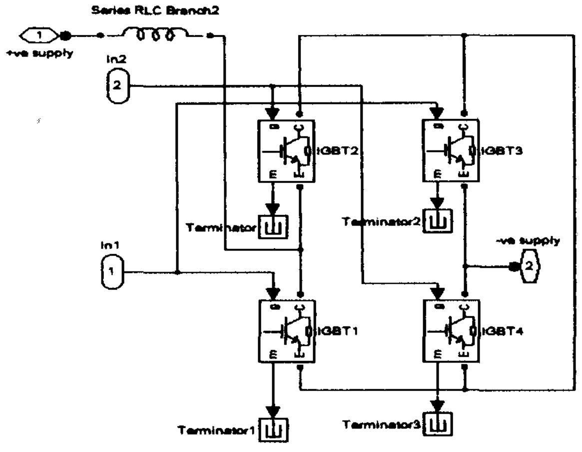


Figure 3: Active filter

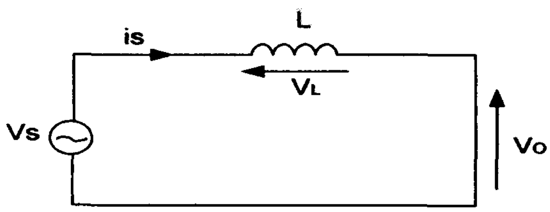


Figure 4: Boost converter operation

$$v_L = L\frac{di_s}{dt} = v_s(t) \qquad (10)$$

The Input current increase or decrease its value depending of *Vs*. This allows for a complete control of the input current [9].

The IGBT is controlled by the control loop, which consists of a peak detector and a Supply Current Control Loop (SCCL). The peak detector is connected to a point just after the main supply terminal before the APF and the load. The components in the SCCL are as shown in Figure 5 [3]. The PWM technique is used to synthesize the injected current (see Figure 6). The controlling output of the SCCL provides gating signals to the IGBT, which in turn, provides the switching functions to compensate the distorted supply current into a sinusoidal form.

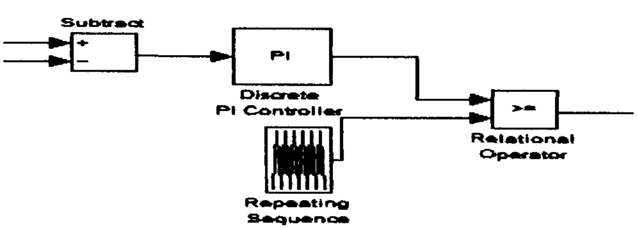


Figure 5: Supply current control loop (SCCL)

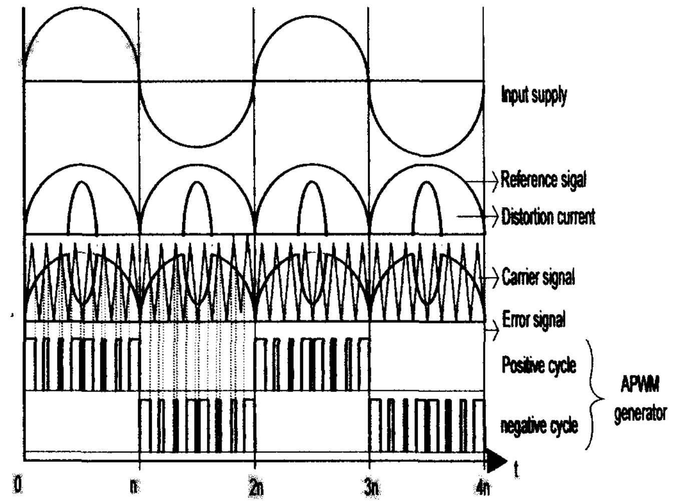


Figure 6: switching pattern PWM

III. OPERATION OF APF

Main proposed APF used to inject the required current into the system is as shown in Figure 3. When IGBT2 & IGBT4 is turned ON, V_L is equal to V_s. When the IGBT2 & IGBT4 is turned OFF, there exists a change in current. Since the current in the inductor cannot change instantaneously, voltage in the inductor reverses its polarity in an attempt to maintain constant current. At this stage, the current will flows through the inductor *L* in the APF.

Control is required in the design such that the inductor does not completely discharge the energy so that some residual energy remains in the inductor. Thus, when the IGBT2 & IGBT4 is turned ON at this stage, the current ramp rides on a pedestal with a magnitude proportional to the remaining energy in the inductance. Energy stored in the inductor is transferred. Due to this requirement in operation, the boost voltage VL must always be greater than the DC supply voltage VS since the APF is intended to inject an opposite reactive current into the system

The same concept is applied to negative cycle where IGBT1 & IGBT3 take part on and off stage.

IV. PASSIVE FILTER

Since having problem to find exact component rating in APF, the passive filter is introduced. The passive filter is tuned to low cut off frequency, such that only fundamental component will pass from the input to the output [5]. Thus the output filter has to be designed to have resonances above this frequency in order to avoid unstable situations as show in figure 7. However resistor parallel with capacitor introduce in simulation to limit the transient voltage in capacitor its self.

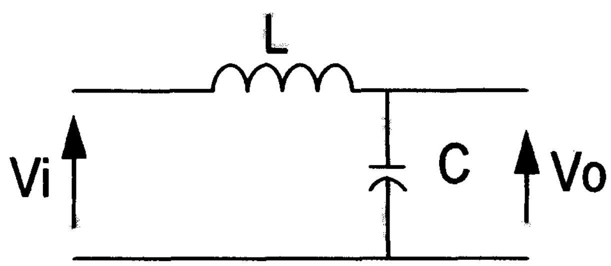


Figure 7: LC filter

Resonance:

$$f_{s,} = \frac{1}{2\pi\sqrt{LC}} \tag{11}$$

V. PWM TECHNIQUE

In power electronics, various pulse width modulation (PWM) techniques are widely used to control the output of static power converters. The reason for using PWM techniques is that; they provide voltage and/or current wave shaping customized to the specific needs of the application under consideration. The active pulse width modulation (APWM) operates by comparing the harmonic that was used to determine a new magnitude with the carrier signal to produce the required PWM control. The harmonic current is obtained by subtraction the mains fundamental current from the measured current. This is done by changing the modulation ratio of the PWM (defined as the amplitude ratio of the modulating signal to the carrier signal); thus changing the width of pulse in accordance to the error detected.

The higher the switching capacity of the converter 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.

VI. PI CONTROLLER

In control theory, a controller is a device to monitor and give effect to the operational condition in systems. The operational condition is normally referred as output variable can give effect to the input by adjusting certain variable. In PI Controller variable K_p and K_i are take part. Where K_p is proportional gain and K_i is integrated gain. The idea 3rd harmonic component then feedback around the loop to produce 5th, 7th and other odd harmonic, by elimination 3rd will reduce other odd harmonic will apply [9,12]. However calculation of the line current harmonic level is difficult by the non-linear feedback nature in the systems. In this case the ratio of Ki/Kp is keep equal to 25 [12] and for maintain of less harmonic distortion it would not be possible to rise the proportional gain above 0.8.

VII. FLOW CHART

Figure 8 describes the overall processes involved in this project.

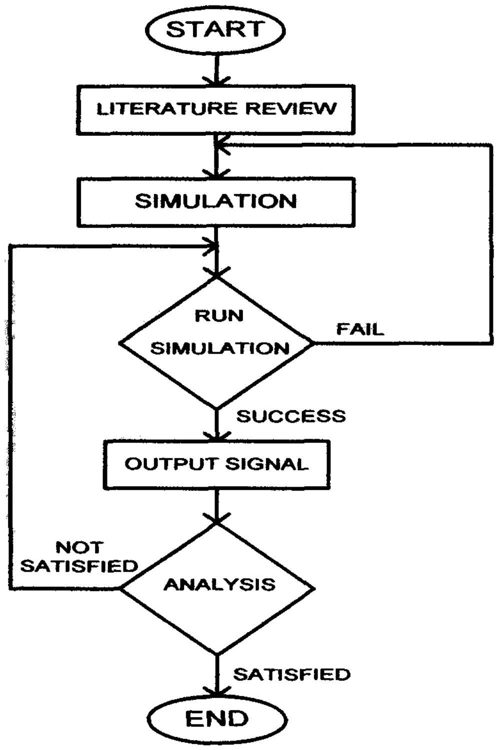


Figure 8: Overall project flow chart

VIII. SIMULATION

Using same idea in Figure 2, Simulation using MATLAB/Simulink is setup as in Figure 9. This model shown parallel active filter is connected to the main rectifier circuit and RC circuit use as load. This experiment is dividing in three categories there are rectifier circuit, APF circuit and control circuit.

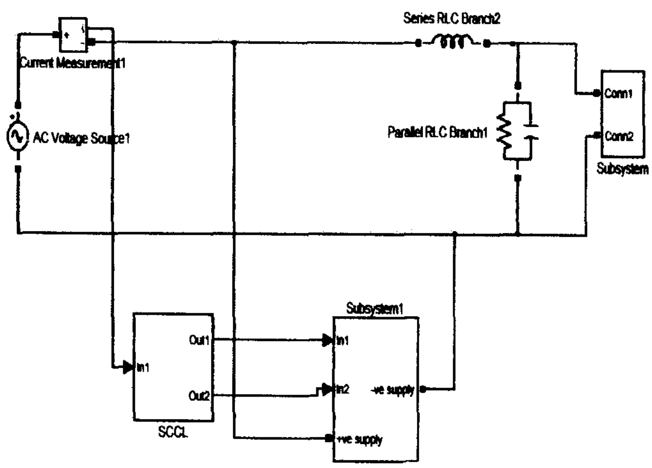


Figure 9: Simulation circuit

A. First stage is build rectifier circuit. Show in figure 10. In rectifier circuit four normal diodes is use, this diode is to convert AC voltage to DC voltage. The load is use is RC circuit as a non-linear loads, value R=300Ω and C= 2200 µF, this load will create harmonic current as shown in figure 13(a).

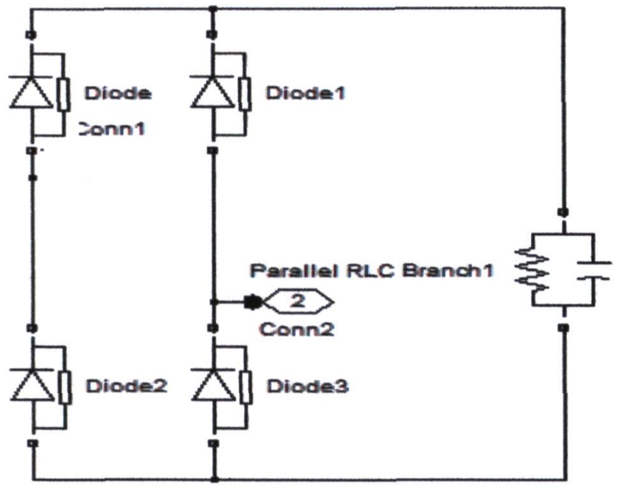


Figure 10: Rectifier circuit

B. Second stage is developed active filter, the active power filter is use is same as figure 3, there are boost IBGT inverter. In this circuit four IGBT diodes is use and short circuit use as a load is to maintain V_O is always lower than V_L.

C. At third stage is develop control, the control circuit is using same as figure 5. Some modification doing in this circuit to obtain 2 different output pulse. Result in this modification is show in figure 11.

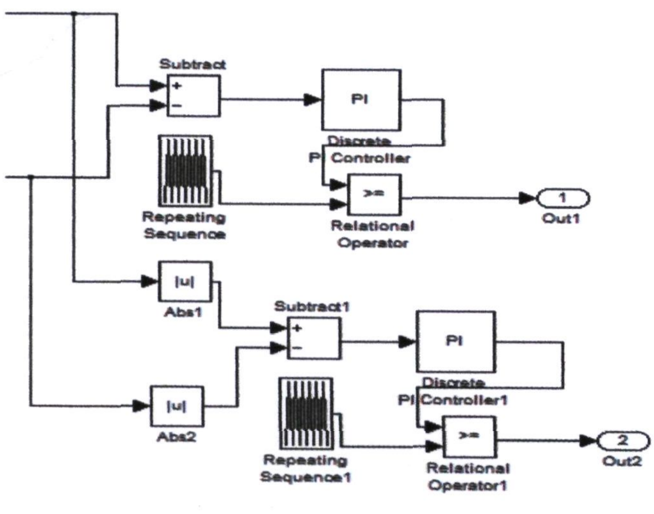
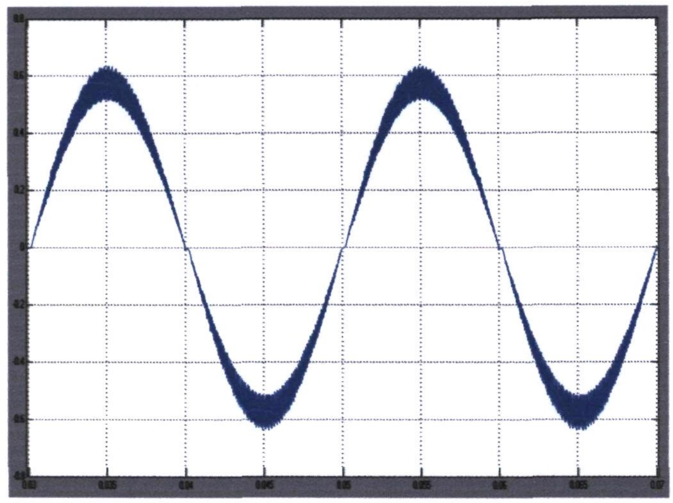


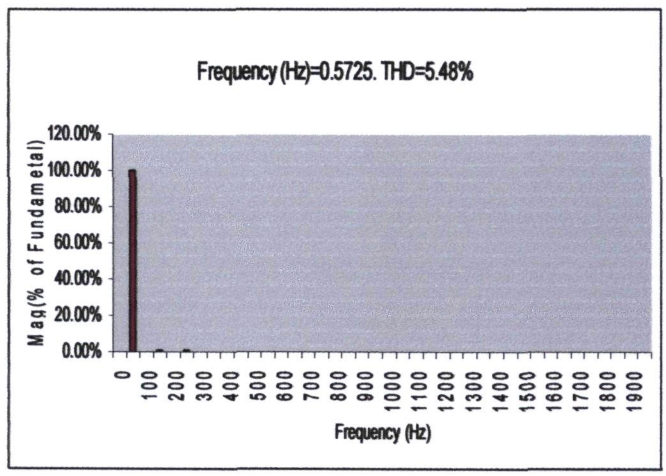
Figure 11: New output SCCL

IX. SIMULATION RESULT AND DISCUSSION

Figure 12, 13, & 14 show the result simulation from MATLAB/Simulink software. Figure 12(a) shows the injection current to the main circuit. This harmonic is proportional with the harmonic current created by non-linear loads. Figure 12(b) describes the total harmonic current measured at injection current.



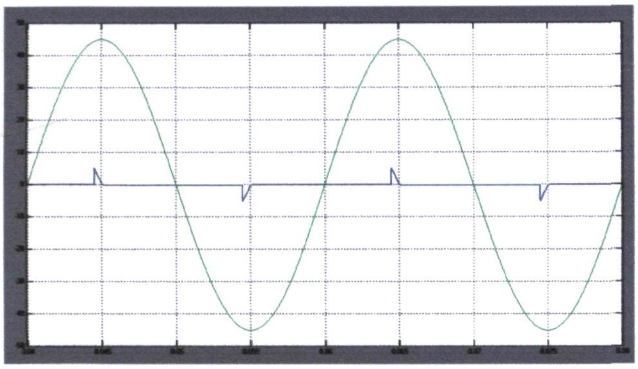
(a)



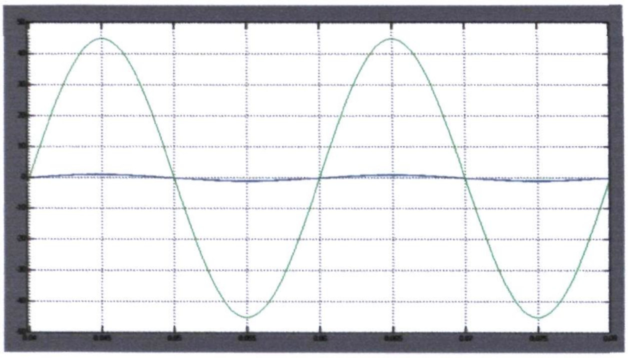
(b)

Figure 12; (a): Current injection; (b): Harmonic injection

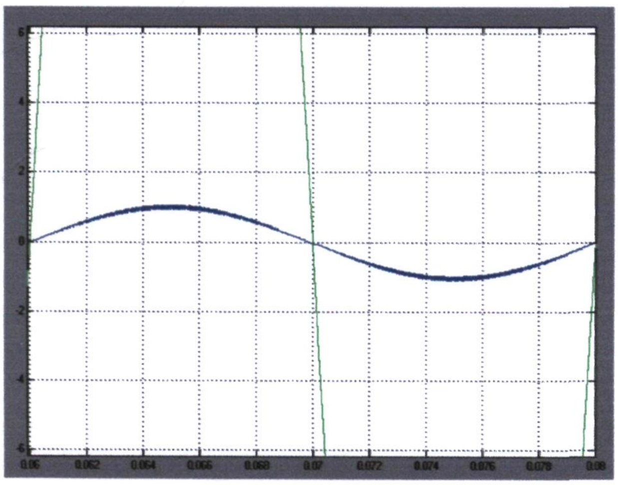
Figure 13 describes the current at main line. Figure 13(a) shows current with highly harmonic before composite with injection current. This current is feedback from non-linear loads in rectifier circuit. Figure 13(b) shows the current after composites with injection current, this current is more sinusoidal and also in phase with voltage supply. Figure 13(c) is same waveform as figure 13(b) but this current is zooming in to one cycle.



(a)



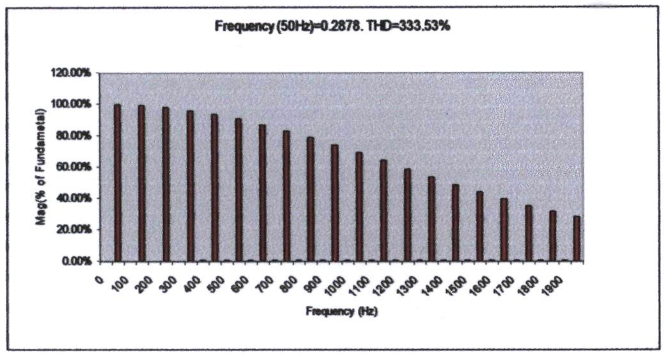
(b)



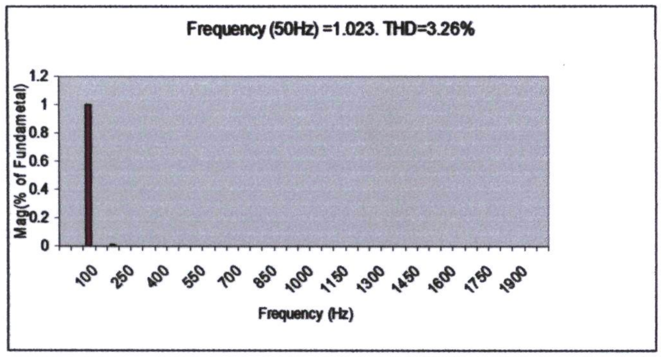
(c)

Figure 13; (a): Current before composite (b): Current after composite (c); current after composite zoom in one cycle.

Figure 14 shows the total harmonic current distortion. Figure 14(a) is the THD before composite with APF current and figure 14(b) is THD after composite with AFP current. The THD percentage is decreases from 333.53% to 3.26% after composition. Table 1 tabulate the result and summary parameter use in this simulation.



(a)



(b)

Figure 14; a: Harmonic before composite, b: Harmonic after composite

Table 1: compilation of result

Parameter	Non-linear load	After APF
Supply voltage(Vs)	45p-p	
Non-linear load (capacitor/resistor)	2200uF 300 Ω	
Passive filter (capacitor/resistor/inductor)	1uF 100 Ω 1 mH	
Boost inductance	10mH	
THD	333.53%	3.26%

X. CONCLUSION

PIC Based Controller Single Phase AC/DC Converter is most suitable for rectifier and harmonic elimination in single phase system. By using suitable *Kp* and *Ki* value this controller will eliminate the harmonic current up to 3.26%. This value is satisfied IEE 519-92 regulation. Current waveform after compensated with injection current also in phase with voltage waveform this illustrate power factor (pf) also improve. From this paper we obtain not only the active filter take importance part but also the controller itself are also importance.

XI. RECOMMENDATION AND FUTURE DEVELOPEMENT

For future development several element will be use as a DC sources despite sort circuit line. Other method is by connecting permanent DC supply, permanent DC will get from DC source, capacitance component or PV systems. Nowadays green energy a dispute to whole world; to support current green policy PV supply is more preferable. Example connection for PV systems is show in figure 15.

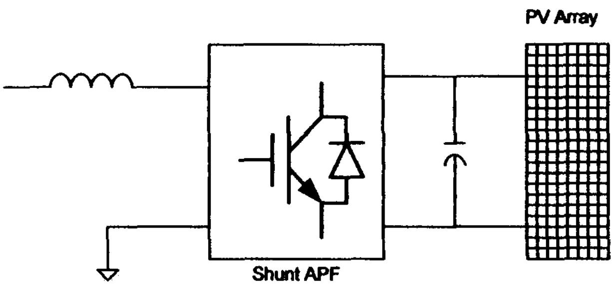


Figure 15: PV connection.

XII. ACKNOWLEDGEMENT

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