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Research Article

# REFINEMENT OF HARMONICS USING APF WITH SINUSOIDAL PULSE WIDTH MODULATION TECHNIQUE

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### ABSTRACT

This research paper presents harmonics reduction using active power filter based on sinusoidal pulse width modulation technique. The Sinusoidal Pulse Width Modulation controlled active filter is used for the enhancement of the power quality and power factor in three phase power systems. Active power filters are widely used for the elimination of non-sinusoidal currents. The pulse width modulated control of the active filter allows independent control of lower order harmonics for improvement of the power quality and power factor. The active PWM rectifier acts directly on the main line currents, forcing them to be sinusoidal and in phase with the main voltage supply. Thus the proposed method highly reduces the total harmonic distortion and enhances the power quality and power factor of the three phase system.

**Keywords:** Active power filter, Sinusoidal pulse width modulation.

### INTRODUCTION

In the recent years, the use of power semiconductor switching devices in computers, television and other microprocessor based power electronic equipment are increased. Harmonics filters play a vital role in the power quality enhancements. Filters are classified into two types; passive and active filters. When we are comparing the efficiency, the active filters are more efficient than the passive filters. The main role of active filters is to synthesize a current (or) voltage distortion. The common application of active filtering combines the tasks of harmonic filtering and power factor compensation.

Abaali et al., stated that the modified synchronous detection is used to determine the reference compensating currents of the shunt active power filter under non sinusoidal voltage conditions<sup>1</sup>. The active filters for power conditioning is to provide the following malfunction like reactive power compensation, harmonics and cost effective in power conditioning. But in Non-linear loads, especially power electronic loads create harmonic currents and voltages in the power systems. For many years, various active power filters (APF) have been developed to suppress the harmonics, as well as compensate for reactive power, so that the utility grid will supply sinusoidal voltage and current with unity power factor<sup>2</sup>. Conventionally, the shunt type APF acts to eliminate the reactive power and harmonic currents produced by non-linear loads from the grid current by injecting compensating currents

intended to result in sinusoidal grid current with unity power factor. This filter has been proven to be effective in compensating harmonic current sources, but it cannot properly compensate for harmonic voltage sources. Many electronic appliances, such as switch mode power supplies and electronic ballasts, are harmonic voltage sources. A voltage sourcing series active power filter is suitable for controlling harmonic voltage sources, but it cannot properly compensate for harmonic current sources<sup>3</sup>.

A. Chandra et al., explains about the control algorithm of shunt active filter for voltage regulation, harmonic elimination, power-factor correction, and balancing of nonlinear loads<sup>4</sup>. In the similar manner, weichmann et al., describes in detail about the generalized functional model for three-phase PWM inverter/rectifier converter<sup>5</sup>. Recently researchers are more focused towards single (or) multiple phase active power filters, since it is more efficient in the case of distributed power factor and harmonics corrections<sup>(6-8)</sup>. In this present paper the Sinusoidal Pulse Width Modulation controlled active filter is used for enhancement of the power quality and power factor in three phase power systems. The active PWM rectifier acts directly on the main line currents, forcing them to be sinusoidal and in phase with the main voltage supply.

The active filter is controlled using a PWM AC-to-DC converter (rectifier topology) occupying six bi-directional switches. The series resonant tank circuit consists of  $L_0$  and  $C_0$

is tuned to a high resonant frequency. The six-switch converter is applicable to PWM controlled to generate an output current,  $I_0$ , at the resonant frequency. The output current,  $I_0$ , is reflected onto the filter input side, as a function of the PWM switching functions controlling the bi-directional switches. Therefore, the preferred current harmonics are generated at the input of the filter to cancel the nonlinear load generated harmonics at the point of common coupling (PCC) between the industry and the utility, as shown in Figure.1.

**A. CIRCUIT DIAGRAM OF TEST SYSTEM**

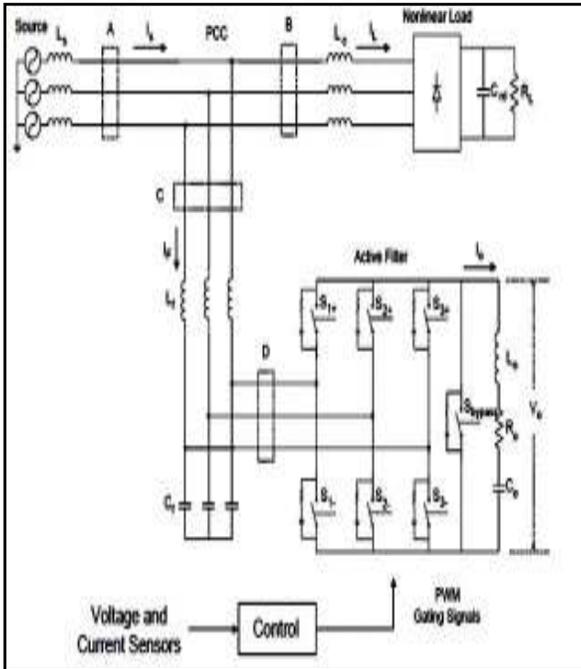


Figure 1: Represents the schematic diagram of Circuit of test system

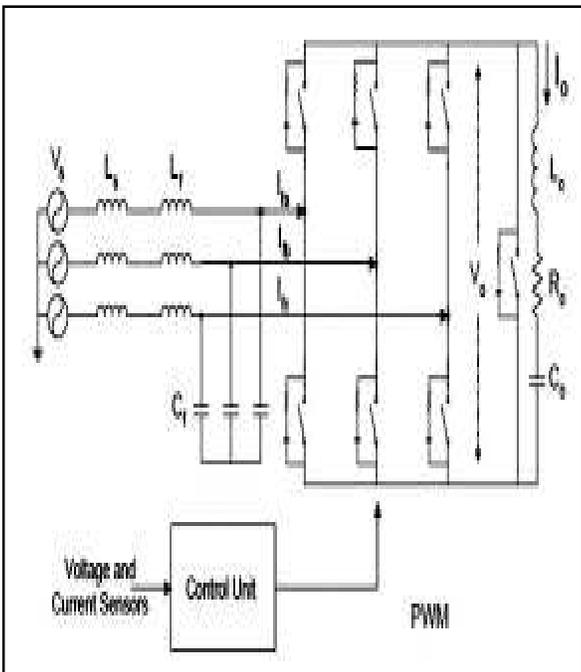


Figure 2: Represents the schematic diagram of proposed active power filter

The PWM approach provides active cancellation of lower-order harmonics by controlling the input currents  $I_{fa}$ ,  $I_{fb}$ , and  $I_{fc}$  to be at the desired harmonic frequencies, with variable amplitude and phase, and opposite to the load generated harmonics ( $I_{La}$ ;  $I_{Lb}$ ;  $I_{Lc}$ ). The PWM switching frequency is chosen to be high and the switching frequency harmonics in  $I_{fa}$ ,  $I_{fb}$ , and  $I_{fc}$  are filtered by the  $L_f$  and  $C_f$  components composing a small input low-pass filter. The resonant tank ( $L_0$  and  $C_0$ ) losses are represented by the resistance 'R' in Fig.2,

**(i) Sinusoidal Pulse Width Modulation Technique:** In sinusoidal pulse width modulation (SPWM) control, the gate pulse of the inverter is generated by comparing the triangular reference wave with carrier half sinusoidal wave. The triangular reference wave and carrier half sinusoidal wave are represented as  $V_r$  and  $V_c$  respectively. In triangular reference wave amplitude ( $A_r$ ) is fixed in carrier half sinusoidal wave amplitude ( $A_c$ ) is variable with frequency  $f_r$  and  $2f_s$  respectively.  $V_s$  and  $V_c$  voltages are in phase with double the supply frequency. The modulation index,  $M$  is  $A_c/A_r$  and amplitude is  $A_r$  by changing it width of the pulse is varied. It may be noted that the width of the pulses obtained are variable. The width is smaller at the centre of the carrier signal (sinusoidal), and increases as one goes to the start and end of the above signal. In SPWM control, the power factor is improved and the lower order harmonics reduced.

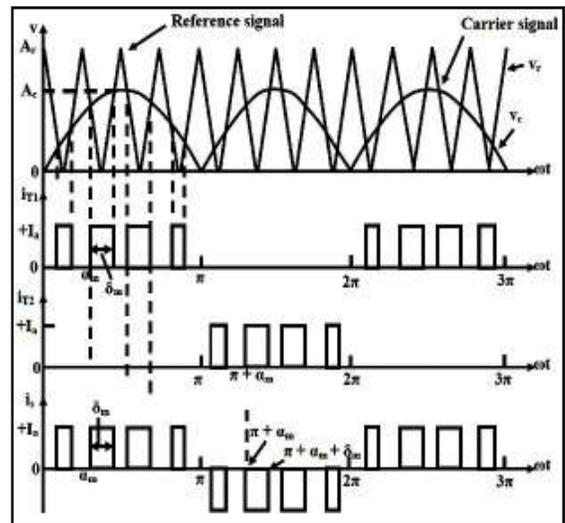


Figure 3: Represents the schematic diagram of Sinusoidal pulse width modulation

Figure.3 shows the waveform of sinusoidal pulse width modulation technique. The carrier signal is modified and triangular waveforms are kept same, up to some point from the start and end of the cycle, and then the pulse widths can be made uniform. The distortion factor is significantly reduced compared to that of multiple pulse modulations.

**(ii) Analysis of Proposed Method**

The proposed three-phase active filtering method was shown in the Figure. 2. The PWM control of the six bi-directional converters switches yields an output voltage,  $V_0$ , given by equation 1.

$$V_0 = SW_1 * V_{ab} + SW_2 * V_{bc} + SW_3 * V_{ca} \rightarrow [1]$$

Where  $SW_1$ ,  $SW_2$ , and  $SW_3$  are line-to-neutral switching functions, and  $V_{ab}$ ,  $V_{bc}$ , and  $V_{ca}$  are line-to-line input voltages. The output current, through the filter series resonant circuit, is given by equation 2.

$$I_0 = \frac{V_0}{Z} \rightarrow [2]$$

Where  $Z$  is the resonant circuit impedance

The resulting input current is given by equation 3.

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} (SW_1 - SW_3) * I_0 \\ (SW_2 - SW_1) * I_0 \\ (SW_3 - SW_2) * I_0 \end{bmatrix} \rightarrow [3]$$

Where  $S_1$ ,  $S_2$ , and  $S_3$  were line-to-line switching functions, representing input line currents. By seeing the equation 3, output current  $I_0$  is reflected onto the input side according to the line-to-line switching functions  $S_1$ ,  $S_2$ , and  $S_3$ .

The series resonant active filter is used for the cancellation of lower-order harmonic currents by generating and injecting, harmonic currents of the same magnitude and frequency, and 180 degree out of phase with the unnecessary harmonics on an

ac system. This objective is realized by PWM control of the active filter, and the tuning of the series resonant frequency. The product of the switching functions and the resulting output current will reflect the desired harmonic currents onto the input side.

**B. SIMULATION MODEL OF A TEST SYSTEM**

**Table 1: Represents the Design Specification and Circuit Parameters**

Design Specification and Circuit Parameters		
Sl. No	Simulation Parameters	Range
1.	Source voltage	220 volt
2.	Fundamental frequency	50 Hz
3.	Filter capacitance	12 μF
4.	Filter inductance	1.81mH
5.	Switching frequency	7.5 kHz
6.	DC voltage	48 volt

**A. Sinusoidal pulse with modulation system**

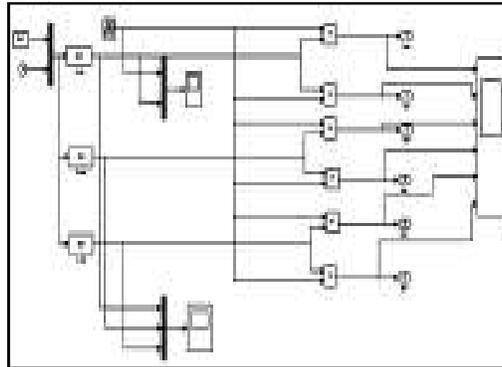


Figure 4: Represents the schematic diagram of SPWM technique

**Complete Test System**

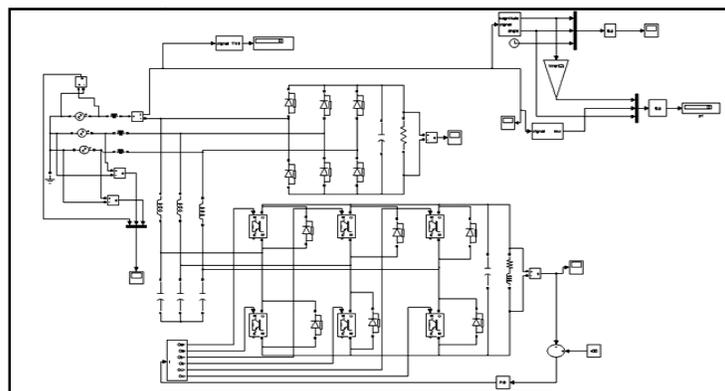


Figure.5: Represents the schematic diagram of Test system

**RESULTLS AND DISCCSION**

**C. SIMULATION RESULTS**

The simulation is performed using MATLAB Simulink platform for three phase nonlinear load and the test system specification are shown in table.1.

Table.2 shows that total harmonic distortion is highly reduced after introducing the proposed test system. In phase A, B and C the total harmonic distortion was reduced from 33.4% to 3.9%, 32.1% to 3.8% and 31.09% to 3.7% respectively

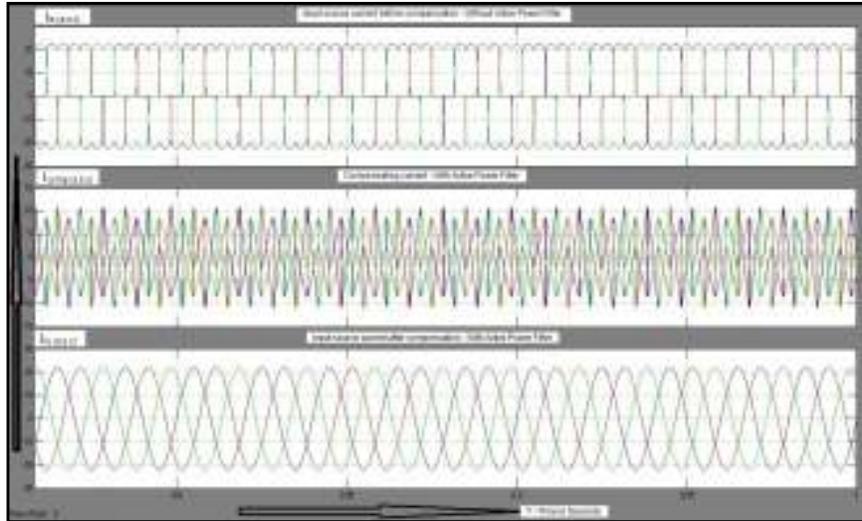


Figure.6: Represents the schematic diagram of  $I_{is}$  (a,b,c) Input source current before compensation  $I_{comp}$  (a, b,c) compensating current;  $I_{is}$  (a,b,c) Input source current after compensation

Table.2: Represent the Total Harmonic Distortion-THD

Total Harmonic Distortion-THD			
Sl. No	Input Source Current	Without Active Power Filter	With Active Power Filter
1.	Phase-A	33.49	3.903
2.	Phase-B	32.10	3.833
3.	Phase-C	31.09	3.724

### CONCLUSION

In this paper we can conclude that sinusoidal pulse width modulation controlled active filter reduces the lower order harmonics generated in the power systems. The active filter topology is realized by the three phase rectifier. The input current harmonics is reduced and the power factor of the system is improved by injecting the currents of the opposite phase into the point of common coupling. The simulation result shows that total harmonic distortion is highly reduced and power quality enhancement is achieved using proposed method.

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### BIOGRAPHIE



Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. His research interests are power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.

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