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Mitigation of Current Harmonics in Power System using Fuzzy Based Shunt APF Controller

V. Keerthi Sree[*] and P. Srinivasa Varma[**]

Abstract: The main aim of this paper is to compensate a current harmonics in power system using Fuzzy Logic Controller. A 3-Φ 3-wire system is proposed in this paper which consists of power system along with three phase VSC to act as APF and Non-Linear Load. The main theme of this INC MPPT is to efficiency from the PV system. For reliable performance of active power filter and better harmonic compensation this paper propose a concept of instantaneous power theory. Also, a comparison analysis is performed for improving THD by PI/Fuzzy controllers. This system is experimentally verified and tested using Simulink.

Keywords: Harmonic Current, Total Harmonic Distortion, PV system, Power Quality.

1. INTRODUCTION

In the present scenario, power quality and power supply are the main problems in power system. So that, the DG systems has got lot of importance because of the limitation of conventional power generation. The main advantage of DG system, it is more productive, high quality, and provide power to loads to maintain continuous administration

The maximum utilization of power electronic systems can produce nonlinearity in network, and its effects on overall system performance [1]. To mitigate problems caused by harmonics, some filter components are used inside the system.

Generally, passive filters is a solution to reduce the harmonics. But these passive filters are responsible for resonance type problems occurred in grid. So that, active power filter is the better solution as compared to general filters for compensating harmonics.

In this paper, APF system is proposed which produces an UPF supply to utility and non-harmonic current to the loads.

2. STRUCTURE OF APF SYSTEM

The effective utilization of generated power with more flexible can be achieved by the concept of Grid interconnected system. The utilization of DG system is rapidly increased in distribution network and also power quality problems have been detected that may affect the operation of the network. Generally, Harmonics are main responsible for creating distortions in the power system network, due to this the quality of power delivered to the customers reduces. In, order to overcome these type of power quality problems the basic compensation technique is filters [2]. The combination of Fuzzy-APF has been implemented for several years. This APF system has capable to compensate power factor, unbalances in current, current harmonics, and also to inject power developed by solar system with low THD.

[*] P.G Student, K.L. University, Vaddeswaram, Guntur, India. *Email: vasalikeerthib1@gmail.com*

[**] Associate Professor, K.L. University, Vaddeswaram, Guntur, India. *Email: pinnivarma@kluniversity.in*

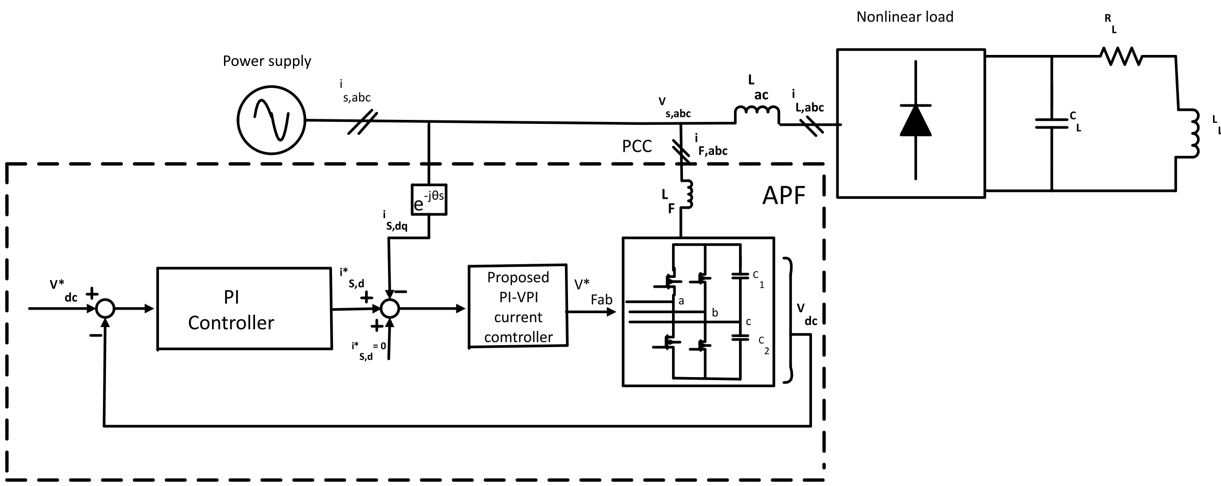

Figure 1: Configuration of Proposed Grid Connected APF System

According to customer point of the main problem for reduction of power quality is to production of harmonics because of utilization of non-linear loads. Generally, Filters are commonly used to mitigate the harmonics in a system. Here, in this paper we proposed a concept of shunt active power filter for better compensation as shown in Figure 1. And also proportional integral controller and vector based proportional integral controllers is proposed for regulation of common dc link voltage. This VPI controller has a capable of providing better control performance [3]. Thus, PI plus VPI controllers and implemented in the fundamental reference frame and the utility currents are measured and controlled to be sinusoidal by an effective harmonic compensator. Owing to the effectiveness of the proposed PI-VPI controller, the harmonic currents produced by the nonlinear load can be accurately compensated without the demand of a load current measurement and harmonic detector [4].

A. P-Q Theory for Reference Current Generation

The VSC integrated by APF should give better solution for harmonic elimination along with reactive power compensation and simultaneously inject the maximum power generated by the solar system. In order to control this system an instantaneous power theory is proposed in this paper. The reference signals for this controller is generated by using grid voltages, non-linear load currents [5]-[6], output currents of VSC, injected currents by APF and dc-link voltages.

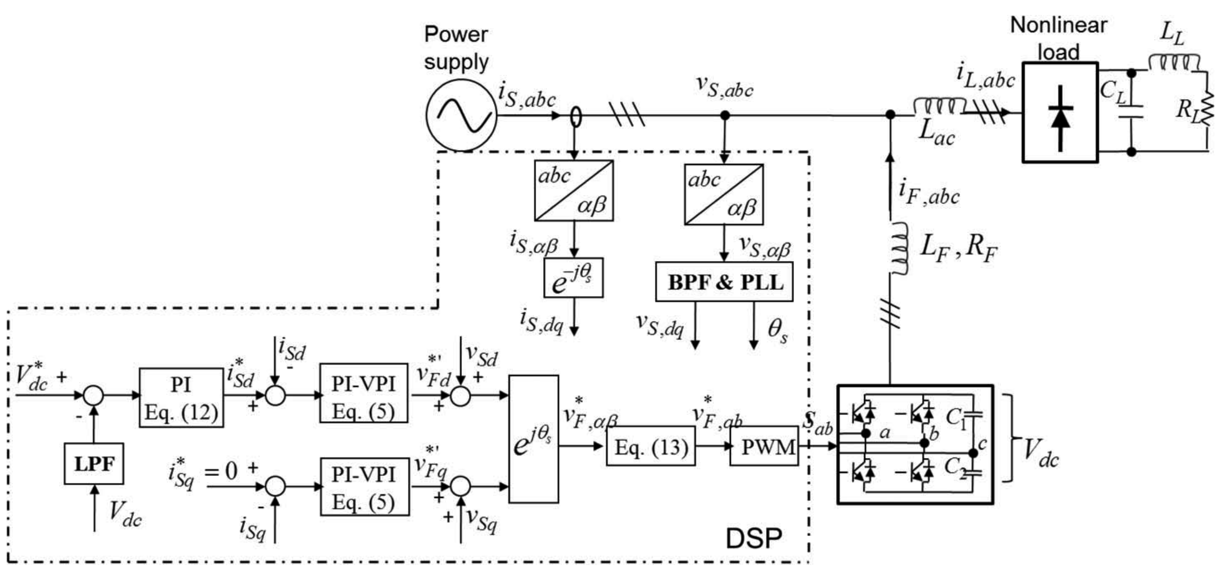

Figure 2: Control Diagram for Proposed APF system

The instantaneous active and reactive powers of load current and voltages can be obtained by using Clarks transformation technique [7].

$$\begin{bmatrix} V_a \\ V_{\hat{a}} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_{\hat{a}} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -0.5 & \sqrt{3/2} \\ -0.5 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_{\hat{a}} \end{bmatrix}$$

B. PI Controller

The oscillations produced by the system is damped with the help of PI controller. In this proportional controller helps to produce the reference signal which is proportional to error signal [8]-[9]. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

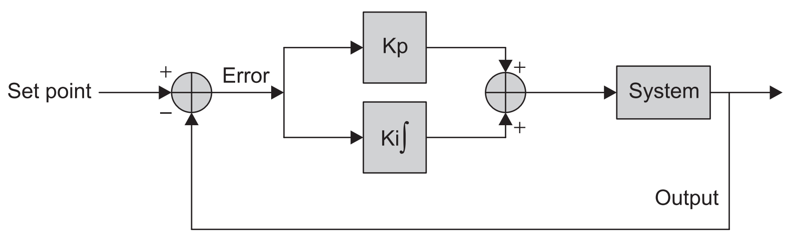

Figure 3: Configuration of PI controller

C. Fuzzy Logic Controller

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 4 [10]. Generally, the FLC is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions.

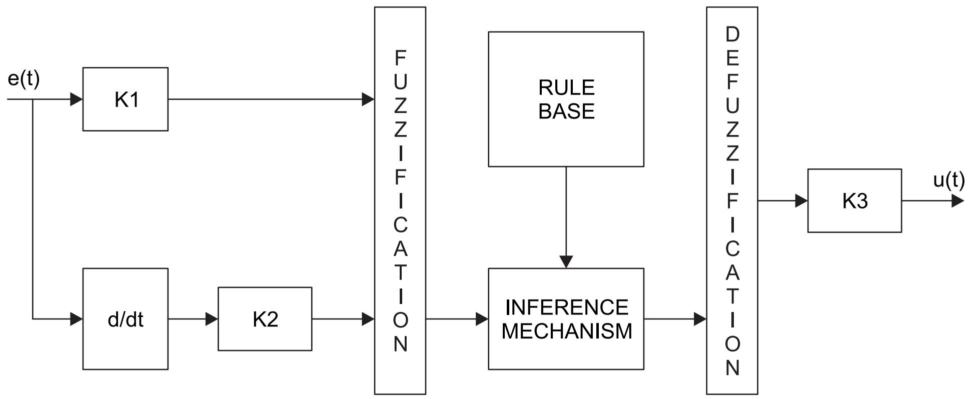

Figure 4: Basic structure of fuzzy logic controller

In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3.The numbers of rules are formed as 9 [11]. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the output as maximum value of input.

3. SIMULATION DIAGRAM AND RESULTS

The proposed system shown in Figure 1 can be tested and verified using simulation toolbox in Matlab. The system parameters for the proposed system is represented in Table 2. In addition with, this system is also implemented using Fuzzy based shunt active power filter for better damping of harmonics caused by the non-linear loads.

Case 1: With PI Controller

In this case the proposed system can be simulated using PI controller for compensating the current harmonics. The performance results for this proposed system and its total harmonic distortions are shown below.

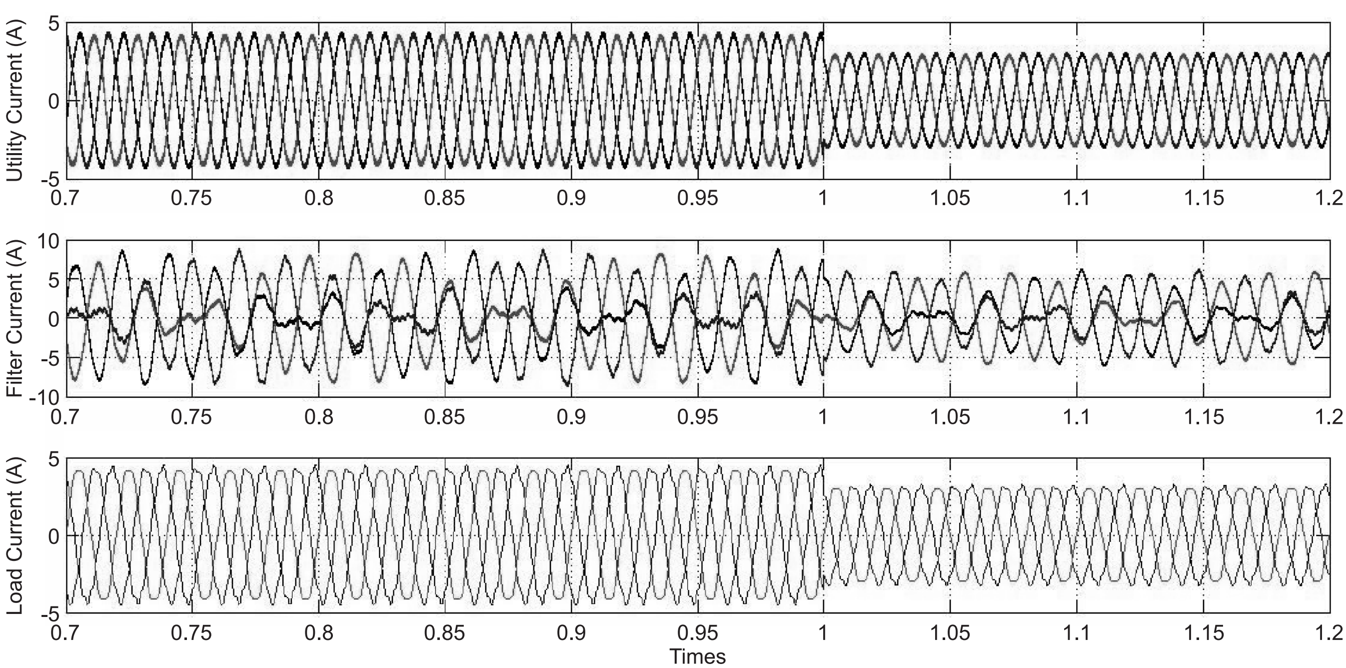

Figure 5: Waveforms for (a) Source Current. (b) Non-Linear Load current. (c) APF current with PI controller

Figure 5 shows the simulation result for (a) grid current, (b) load current and (c) filter current. As we know, because of non-linear load presence in the system the load current is effected by unwanted harmonics. In order to compensate these problem an APF is proposed under three cases as explained above and the filter grid current is also shown.

Case 2: With Fuzzy Controller

In this case the proposed system can be simulated using Fuzzy controller instead of conventional PI controller for compensating the current harmonics. The performance results for this proposed system and its total harmonic distortions are shown below.

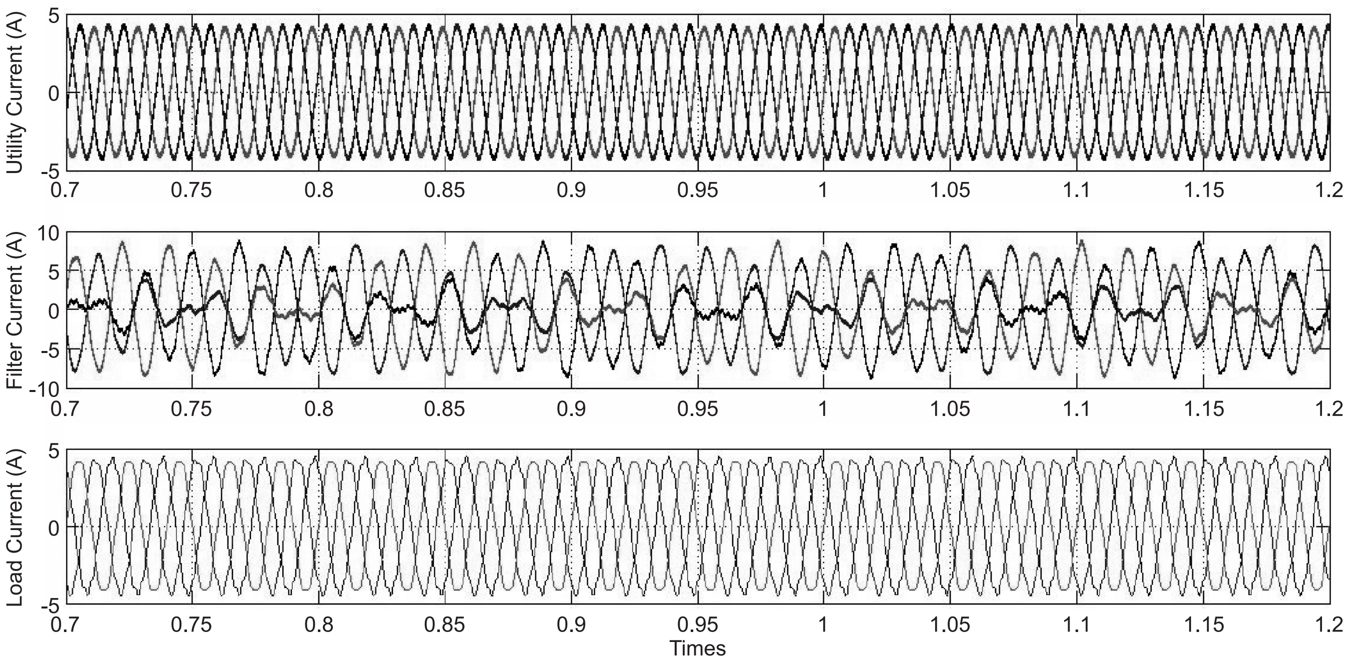

Figure 6: Waveforms for (a) Source Current. (b) Non-Linear Load current. (c) APF current with fuzzy controller

Figure 6 shows the simulation results of (a) grid current, (b) load current and (c) filter current. As we know, because of non-linear load presence in the system the load current is effected by unwanted harmonics. In order to compensate these problem a Fuzzy based APF is proposed under three cases as explained above and the filter grid current is also shown. And the comparison of total harmonic distortion for the two cases such as PI and Fuzzy controller is formulated in table.

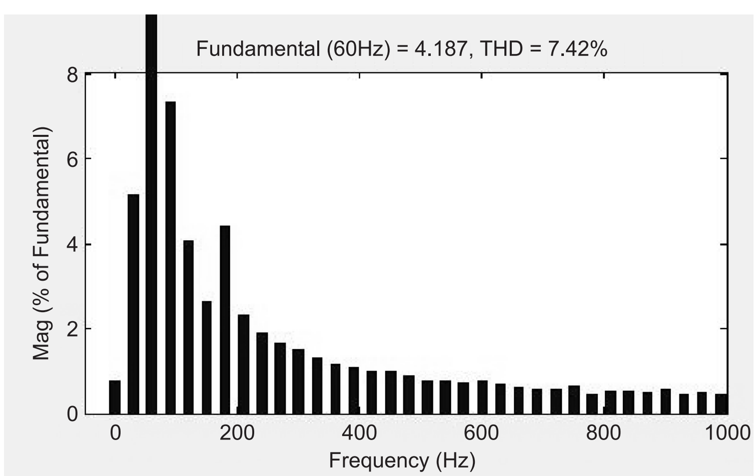

Figure 7: Total Harmonic Distortion factor for Utility Current under PI Controller

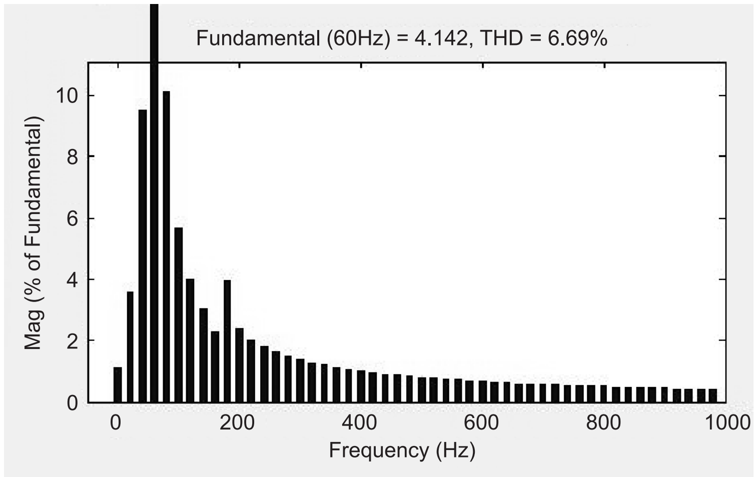

Figure 8: Total Harmonic Distortion factor for Utility Current under Fuzzy Controller

Table 1
%THDs Evaluation

Modes→ Type↓	*Utility Current*
PI Controller	7.42
Fuzzy Controller	6.69

Table 1 shows the comparison of Total Harmonic Distortion for filtered utility current under two different cases such as (a) Conventional PI controller and (b) Fuzzy Logic Controller. From the above analysis the proposed system with Fuzzy Controller gives better THD as compared with Conventional PI controller.

4. CONCLUSION

This paper proposed concept of Fuzzy based active power filter for power quality improvement using instantaneous power theory controller. This controller implemented in this paper is for filtering the harmonics caused by non-linear load. In this paper PI, Fuzzy Controllers are developed for controlling Dc link voltage. The performance of this system can be tested and verified in Matlab/Simulink. From the results we conclude that, Fuzzy Logic Controller shows better performance over conventional controller.

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