Enhancement of Power Quality with Single Phase Hybrid Series Active Power Filter by Using Fuzzy Logic Controller

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ABSTRACT

This paper describes different power quality problems in distribution systems. And solution with hybrid filter configuration to suppress harmonic current distortion in the source current. This Hybrid filter is controlled by using the Mamdani inference method of Fuzzy Controller. This HSAPF are described showing their compensation characteristics and principles of operation. The system is modeled by using MATLAB/SIMULINK software and performance is observed.

Keywords**:** *Active Power Filter, Instantaneous Reactive Power Control Algorithm, Power quality enhancement.*

1. Introduction

In today's environment, electronic loads are very sensitive to harmonics, sags, swells and other disturbances. Among these parameters, current harmonics have become a growing power quality concern. One more power quality issue is reactive power compensation. Reactive power is required to maintain the voltage to deliver active power. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines. Though reactive power is needed to run many electrical devices, it can cause harmful effects on electrical appliances. So the reactive power compensation is very important in electrical power system. So, power quality become important in the power system. In the mid-1940s, passive power filters (PPFs) have been widely used to suppress current harmonics and compensate reactive power in distribution power systems.

This technique is simple and less expensive. But it has many drawbacks such as there is no isolation b/w input and output, These circuits cannot provide any gain. Circuit becomes bulky if inductors are used. In this frequency response is not sharp as no sudden change in the output when switching from pass band to stop band. Source loading can take place. As a better option of complete compensation of distortions, active power filters[2, 3] have been researched and developed. Active filters overcome drawbacks of passive filter by using the switched mode power converter to perform complete harmonic current elimination. Shunt active power filters are developed to suppress the harmonic currents and reactive power compensation simultaneously by suitable control techniques to generate a compensating current in equal and opposite direction so that source current becomes harmonic free

However, Construction cost of Active Power filter is too high. To avoid this limitation, hybrid filter topologies have been developed. Using low cost passive filters with the active filter, the power rating of active converter is reduced compared with that of pure active filters. This hybrid filter retains the advantages of active filters and passive filters. Also hybrid filters are cost effective and become more practical in industry applications [5-9].

2. Harmonic Elimination Using a Hybrid Series Active Filter (HSAF)

The active filters can be classified into pure active filters and hybrid active filters in terms of their circuit configuration. Most pure active filters as their power circuit can use either a voltage-source pulse width-modulated (PWM) converter equipped with a dc capacitor or a current-source PWM converter equipped with a dc inductor. At present, the voltage source converter is more favorable than the current-source one in terms of cost, physical size, and efficiency. Hybrid active filters consist of single or multiple voltage-source PWM converters and passive components such as capacitors, inductors, and/or resistors. The hybrid filters are more attractive in harmonic filtering than the pure filters from both viability and economical points of view, particularly for high-power applications. However, single-phase active filters would attract much less attention than three-phase active filters because single phase versions are limited to low-power applications except for electric traction or rolling stock [17].

Figure 1 shows the configuration of the HSAF and nonlinear load proposed in this paper and, its parameters are given in Table I. The HSAF consists of a series active filter and two parallel single tuned passive filters in series with the active filter. Two passive filters are tuned in dominants harmonic frequencies of 3rd and 5th. The effectiveness of the proposed method in harmonic elimination and reactive power compensation is shown using HSAF for a nonlinear load. In the following sections, the control method, the design process and simulation results are given.

3. Compensation Strategy

One of the key points for proper implementation of an APF is to use a reliable method for current/voltage reference generation. Currently, there is a large variety of practical implementation supported by different theories (either in time or frequency domain). The control method should extract the harmonic components with minimum phase shift and attenuate the fundamental component. In this paper discrete Fourier transformation (DFT) is used to extract the source current harmonics with assuming N samples in a cycle, as:

$$X_1 = \sum_{k=0}^{N-1} x_k \, e^{\frac{j2\pi k}{n}} \qquad (1)$$

$$X_{k1} = \frac{1}{N} X_1 e^{\frac{-j2\pi k}{n}} \qquad (2)$$

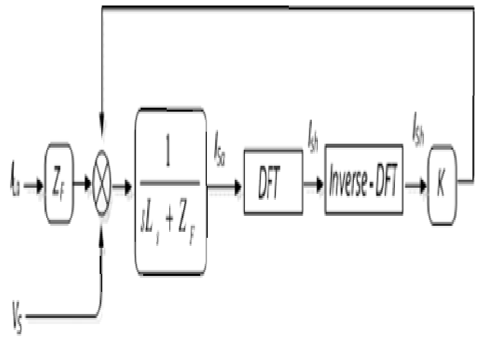

Fig1 .Block diagram of the whole system

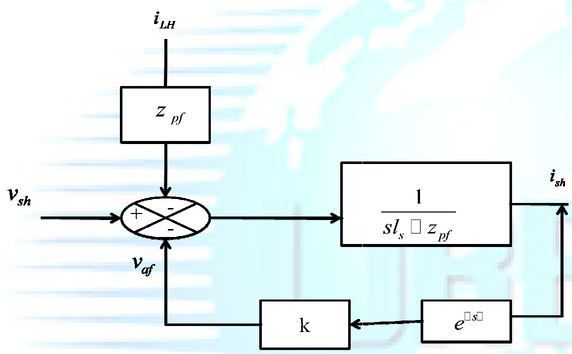

Fig.2 Control diagram of the system with constant delay τ

where (1) is DFT and (2) is inverse DFT. After extracting the fundamental component, it is subtracted from source current to extract harmonic components as:

$$i_{Sh} = i_S - i_{S1} \qquad (3)$$

Figure3. shows the Block diagram of hybrid series active filter. A method was proposed by Akagi [17] to control the dc voltage capacitor. Based on this method, if active filter is along the passive filter, an extra voltage reference should be added to q component. As seen in this figure, a component with 90 degree lead the load terminal voltage is added to reference voltage in order to control the dc link voltage capacitor.

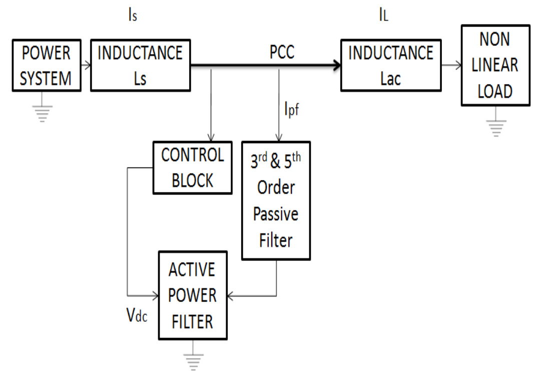

Figure 3: Block Diagram of Hybrid Series Active Filter

4. Frequency Characteristics of the System

The voltage source harmonics are modeled by Vsh, and itis in series with the Thevenin impedance (Zs) of the power system. Also, nonlinear load is a diode rectifier by a resistive –capacitive load on its output. This load has usually a voltage source characteristic because an inductor is on rectifier input, and this makes it as a current source type load characteristic. The load is modeled by harmonic voltage VLhv in series with inductor LAC. The series active filter behaves as a damping resistor which can eliminate resonance between the parallel passive filter and the source impedance. It also prevents flowing of harmonic currents to the power source by presenting zero impedance at the fundamental frequency and a high resistance K at the power source or load harmonics.

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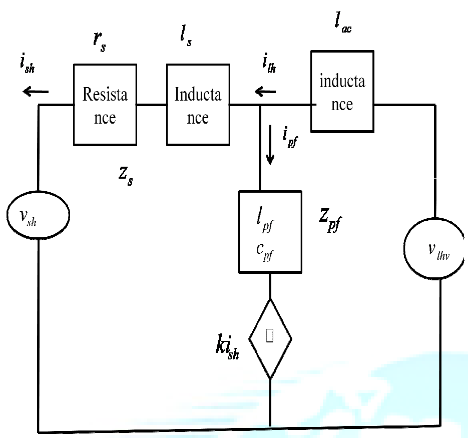

Fig.4. Harmonic equivalent circuit of single phase system

So, the series active filter can be modeled by a resistor, K, and its output reference voltage as:

$$V_{af} = Ki_{sh} \quad (4)$$

the harmonic current of the power source is calculated as:

$$I_{sh} = \frac{Z_{pf}}{Z_s + Z_{pf} + K} I_{lh} + \frac{V_{sh}}{Z_s + Z_{pf} + K} \quad (5)$$

Where Zs and Zpf are power source and passive filter equivalent impedance, respectively

4.1. Basic Fuzzy Algorithm

In a fuzzy logic controller, the control action is determined from the evaluation of „*a'* set of simple linguistic rules. The development of the rules requires „*a'* thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The design of a fuzzy logic controller requires the choice of membership functions. The membership functions should be chosen such that they cover the whole universe of discourse. It should be taken care that the membership functions overlap each other. This is done in order to avoid any kind of discontinuity with respect to the minor changes in the inputs. To achieve finer control, the membership functions near the zero region should be made narrow. Wider membership functions away from the zero region provides faster response to the system. Hence, the membership functions should be adjusted accordingly. After the appropriate membership functions are chosen, a rule base should be created. It consists of a number of Fuzzy If-Then rules that completely define the behavior of the system. These rules very much resemble the human thought process, thereby providing artificial intelligence to the system. The internal structure of the fuzzy controller is shown in Fig. 5. The error *e* and change of error *Ce* are used numerical variables from the real system. To convert these numerical variables into linguistic variables, the following seven fuzzy levels or sets are chosen as: NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big) and presented in input and output normalized membership functions (Figs. 6 and 7). The fuzzy controller is characterized as follows: (i) Seven fizzy sets for each input and output. (ii) Triangular membership functions for simplicity. (iii) Fuzzification using continuous universe of discourse. (iv)Implication using Mamdanis 'min' operator. (v)Defiizzification using the 'centroid' method.

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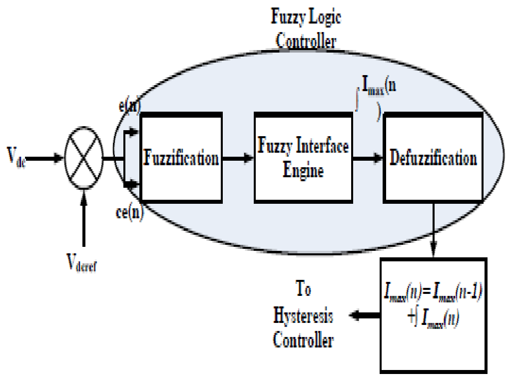

Figure 5: Internal Structure of Fuzzy controller.

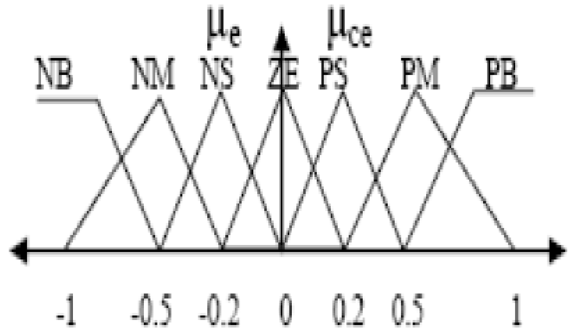

Figure 6: Input normalized membership function.

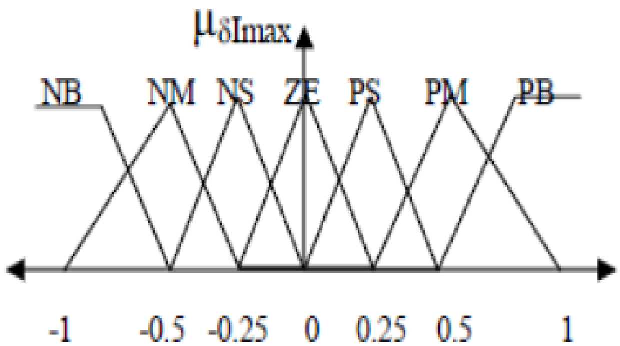

Figure 7: Output normalized membership function.

Table.I Control Rule Base

ce / e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
N	NB	NB	NB	NM	NS	ZE	PS
NB	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
P	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

4.2. Rule Base

The elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse input/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in TableI.

5. Simulation Results:

Harmonic elimination and reactive power compensation by HSAF is shown in this section through simulation. A HSAF with the process presented above is simulated in MATLAB. As per recommended value of THD as per IEEE 519-1992[21] and IE C61000[22] is 5%. To decrease value of the THD of Is, Hybrid filter is employed with the dc capacitor voltage of 84V. The THD of the power source current (Is) is 2.2%. Corresponding Simulated results shown in below figures.

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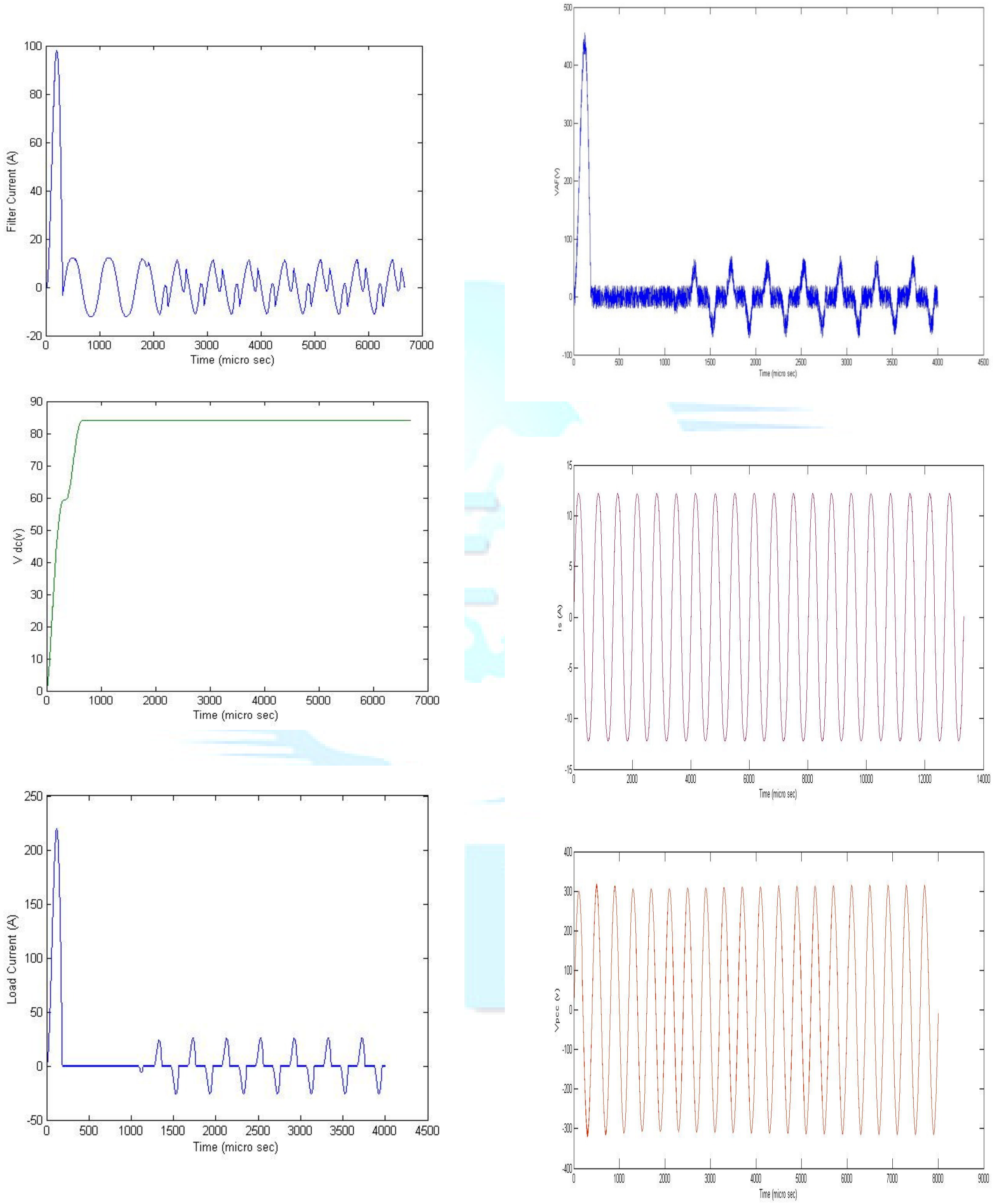

Fig 7. Simulated waveforms of HSAPF

6. CONCLUSION

This paper presents a fully digitally controlled HSAF for harmonic elimination and reactive power compensation in a single phase system with a control method for series active filter by using fuzzy logic. This method is applicable in both singe and three phase systems. Simulation results show the effectiveness of the presented method .

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