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Power Quality Improvement with a Shunt Active Power Filters using Fuzzy Logic

SK. Ershad Sameeer[1], T. Krishnam Raju[2], Y. Kartheek[3], SK. Mohammad Nazeer[4], V. Dega Rajaji[5] , A.V.S. Ramanjaneyulu[6]

[1,2,3,4]IV/IV B. Tech, EEE , Acharya Nagarjuna University College of Engineering & Technology, Acharya Nagarjuna University, Guntur

[5,6]Assistant Professor EEE Department,Acharya Nagarjuna University College of Engineering & Technology, Acharya Nagarjuna University, Guntur.

Abstract: Along with the increasing demand on improving power quality i.e generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment, the most popular technique that has been used is Active Power Filter (APF); This is because Passive filters performance is limited to a few harmonics and they can introduce resonance in the power system. Passive filters are larger component sizes and therefore Costs high. So APF can easily eliminate unwanted harmonics, improve power factor and overcome voltage sags and eliminate any harmonic frequencies. This paper will discuss and analyze the simulation result for a three-phase three wire shunt active power filter using MATLAB program. This simulation will implement a non-linear load, to compensate line current harmonics under balanced and unbalance loads. As a result of the simulation, it is found that an active power filter is the better way to reduce the total harmonic distortion (THD)

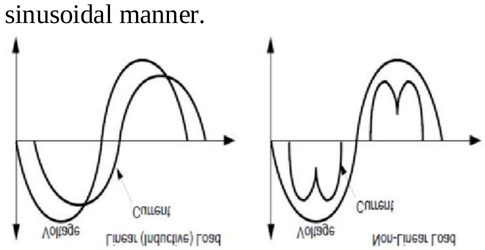
Keywords: APF, PWM converter, fuzzy logic, THD, Power Quality, Instantaneous Power theory

I. INTRODUCTION

A harmonic is a component of a periodic wave having a frequency that is an integral multiple of the fundamental power line frequency of 60 Hz. Harmonics are the multiple of the fundamental frequency. Total harmonic distortion is the contribution of all the harmonic frequency currents to the fundamental.

II. HOW HARMONICS ARE PRODUCED

Harmonics are the by-products of modern electronics. They occur frequently when there are large numbers of personal computers (single phase loads), uninterruptible power supplies (UPSs), variable frequency drives (AC and DC) or any electronic device using solid state power switching supplies to convert incoming AC to DC. Non-linear loads create harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner.



Linear load Nonlinear load

The terms “linear” and “non-linear” define the relationship of current to the voltage waveform. A linear relationship exists between the voltage and current, which is typical of an across-the-line load. A non-linear load has a discontinuous current relationship that does not correspond to the applied voltage waveform. h = (n x p) ±1 where: n = an integer (1, 2, 3, 4, 5…) p = number of pulses or rectifiers

For example, using a 6 pulse rectifier, the characteristic harmonics will be: h = (1 x 6) ±1 5th &7th harmonics h = (2 x 6) ±1 11th &13th harmonics h = (3 x 6) ±1 17th &19th harmonics

Harmonic is defined as “a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency”. Harmonic is turn out of several of frequency current or voltage multiply by the fundamental voltage or current in the system. Previous technique used to compensate load current harmonics is L-C passive filter; as a result the filter cannot a d a p t f o r various r a n g e o f load current a n d sometimes produce undesired resonance.

Efficiency and controllability is increasing the concern for harmonic distortion levels in end user facilities and on the overall power system". The harmonic standard was invigilated with the objective of this standard is to provide general harmonic evaluation procedures for different classes of customer such as industrial, commercial and residential. Illustrated methods for evaluating of harmonics control at the customer level and the utility system. Expert devices such as ovens that produce heat are commonly sensitive to harmonics. There are many problems caused by harmonics in the power system and electrical loads such as a Disturbance to Electrical and Electronics Devices, Higher Losses, Extra Neutral Current, Improper Working of Metering Devices, De-Rating of Distribution.

III. ACTIVE POWER FILTERS

Active power filters are basically of two types i.e. shunt active power filter and series active power filters. Here we are mainly concentrate on the shunt active filters.

A. *Shunt Active Filters*

The concept of shunt active filtering was first introduced by Gyugyi and Strycula in 1976. Nowadays, a shunt active filter is not a dream but a reality, and many shunt active filters are in commercial operation all over the world. Their controllers determine in real time the compensating current reference, and force a power converter to synthesize it accurately. In this way, the active filtering can be selective and adaptive. In other words, a shunt active filter can compensate only for the harmonic current of a selected nonlinear load, and can continuously track changes in its harmonic content The shunt active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180^0

Active filter have been designed, improved, and commercialized in past three decades. They are applicable to compensate current-based distortions such as current harmonics, reactive power and neutral current. They are also used for voltage-based distortion such as voltage harmonics, voltage flickers, voltage sags and swells, voltage imbalances.

They are two categories of active filter such as single- phase and three-phase. Three-phase active filters may be with or without neutral connection and single phase active filters are used to compensate power quality problems caused by single-phase loads such as DC power supplies. Three-phase active filters are used for high power nonlinear loads such as adjustable speed drive (ASD) and Ac to DC converters. Based on topologies, they are two kinds of active filter such as current source and voltage source active filters. Current source active filters (CSAF) employ an inductor as the DC energy storage device as shows in Fig. 1. In voltage source active filter (VSAF), a capacitor acts as the storage element .VSAF are

inexpensive, lighter, and easier to control compare to CSAF . There are types of connection that can be used for active filter such as shunt active filter, series active filter, parallel active filter.

Harmonic currents are generated mainly due to the presence of: Nonlinear loads

Harmonic voltages in the power system

A nonlinear load draws a fundamental current component I_{LF} and a harmonic current I_{Lh} from the power system. The harmonic current I_{Sh}, is induced by the source harmonic voltage V_{Sh}. A shunt active filter can compensate both harmonic currents I_{Sh} and I_{Lh}, however the principal function of a shunt active filter is compensation of the load harmonic current I_{Lh}, this means that the active filter confines the load harmonic current at the load terminals, hindering its penetration into the power system. For simplicity the power system is represented only by an equivalent impedance X_L in Fig.4.1. If the load harmonic current I_{Lh}, flows through the power system, it produces an additional harmonic voltage drop equal to $V_T = X_L * I_{Lh}$, that further degenerates the load terminal voltage V_T. The principle of shunt current compensation shown in Fig.4.1 is very effective in compensating harmonic currents of loads. However, a shunt active filter that realizes this principle of shunt current compensation should also draw an additional harmonic current in order to keep the load terminal voltage sinusoidal and equal to $V_T = V_{SF} – X_L * I_{LF}$. The harmonic voltage drop appearing across the equivalent impedance becomes equal to the source harmonic voltage if $V_{Sh} = X_L * I_{Sh}$. In this case, the harmonic voltage components cancel each other, so that the terminal voltage V_T ,is kept sinusoidal.

Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

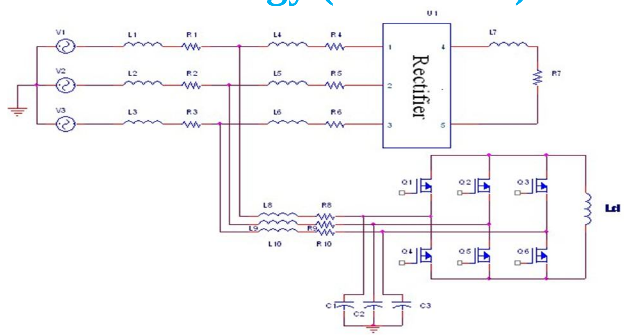


Fig. 1. A typical three-phase current source active filter (CSAF)

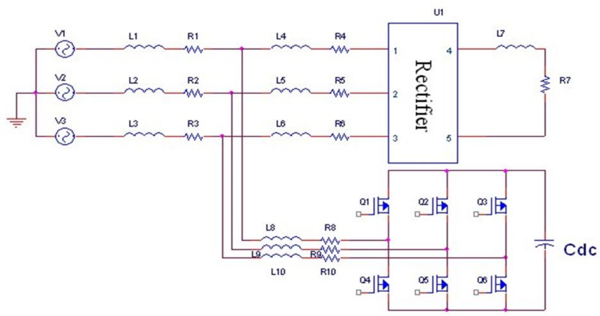
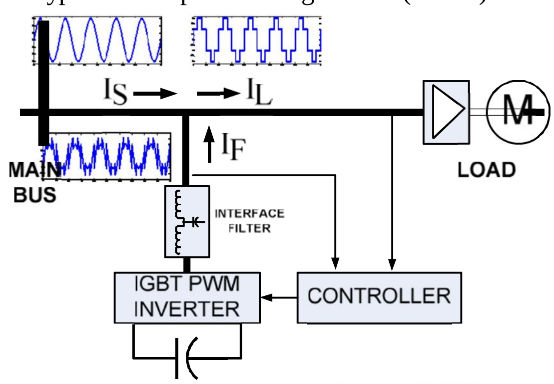
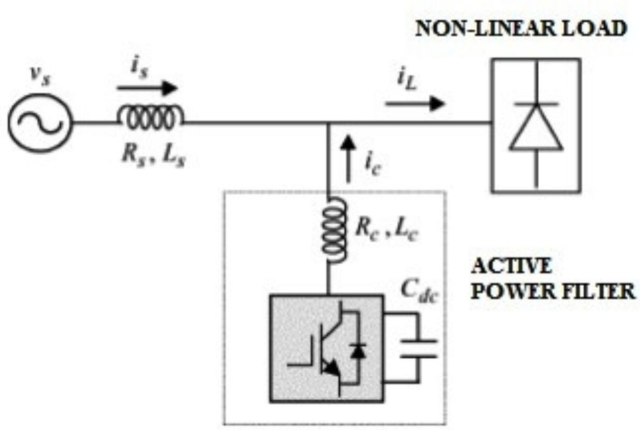


Fig.2 A typical three-phase voltage source(VSAF)





IV. GENERATION OF REFERENCE CURRENTS

Basic block diagram of shunt APF shows the basic compensation principle of shunt active power filter. The supply current is drawn and an equal and opposite compensating current(ic) is generated and given at the point ofcommon coupling which cancels out the

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

harmonics and make the supply currents to be sinusoidal.

The instantaneous p-q theory is used for the generation of reference currents. Equation (1-2) indicates the transformation of the phase voltages Va, Vb, Vc and load currents from a, b, c coordinates to _ – _ coordinates.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{L_a} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (2)$$

\

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} 0 & v_\alpha & v_\beta \\ 0 & v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (3)$$

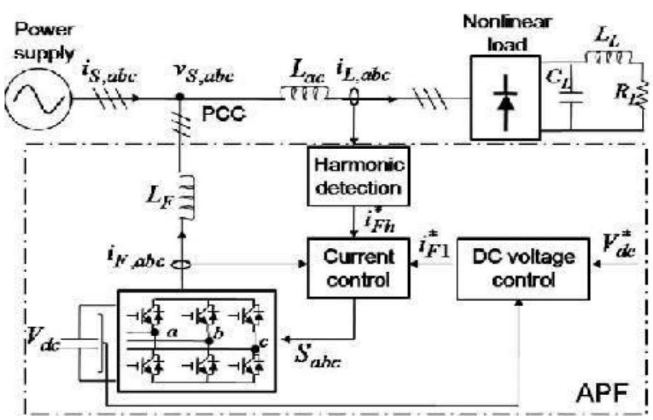
Small high pass filter is used in the system to avoid high frequency between the source impedance. Equation (3) describes the power calculation. Each power comprises of two components, ac power component and dc power component. For harmonic compensation both the powers are used as reference powers. The reference currents in coordinates are given by equation (4).

$$\begin{bmatrix} i_{c\alpha}{}^* \\ i_{c\beta}{}^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} -\tilde{p} + \Delta\bar{p} \\ -q \end{bmatrix} \quad (4)$$

$$\Delta\bar{p} = \bar{p}_0 + \bar{p}_{Loss}$$

PLL (Phase locked loop) employed in shunt filter tracks automatically, the system frequency and fundamental positive–sequence component of three phase generic input signal. Proper operation of the shunt filter under distorted and unbalanced voltage conditions is made by proper and exact design of PLL. The id-iq currents obtained after transformation is given into two low pass filters respectively. The filter to which the id current is given filter outs the positive ripples and the filter to which the iq current is given filters out the negative ripples. The main advantage of this method is that the angle is calculated from the main voltages.

A. PI-VPI Control Strategy [3]

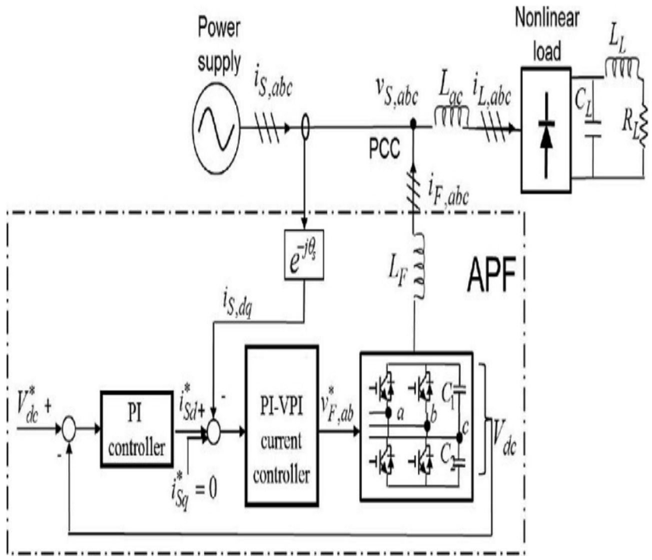


Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

B. Typical control scheme of a shunt APF

Three-phase diode rectifiers are widely used as the front-ends of industrial ac drives [3]–[5]. These types of loads introduce harmonic currentsinto the networks, which have odd orders: $6n \pm 1(n = 1, 2, 3 \ldots)$ of the fundamental frequency. Since these harmonic currents cause serious problems and deteriorate the power quality of the distribution networks, the shunt APF was developed to compensate those harmonic currents and consequently to improve the power quality. As illustrated in Fig. 2, a shunt APF is basically a three phase voltage source inverter (VSI) connected in parallel with a nonlinear load at the point of common coupling through an inductor *LF*. The energy storage of the APF is a large capacitor located at the dc-link side of the inverter. The nonlinear load can be presented as a RL or RLC load connected to the power supply through a three phase diode rectifier as shown in Fig. 2. As stated earlier, the APF must generate the harmonic currents to compensate harmonics produced by the nonlinear load and to make the supply currents

sinusoidal.To fulfil these demands, the traditional control scheme requires a harmonic detector and current controller where both loops must be designed properly to achieve good control performance.However, it may cause excessive complexity in the design process.



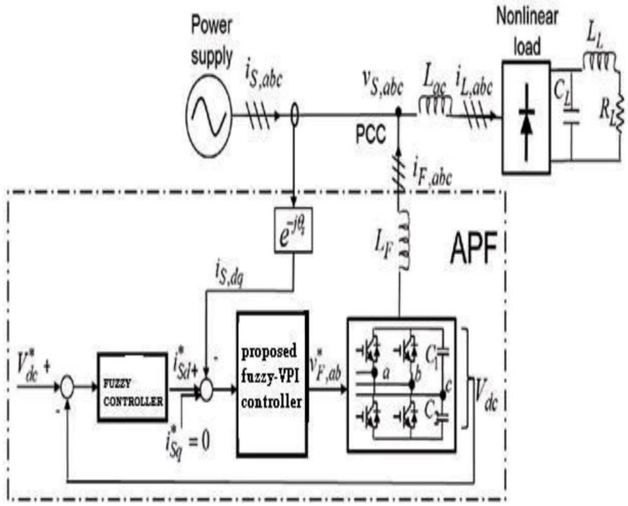
Structure of the PI-VPI control scheme for three-phase shunt APF

In order to simplify the control scheme and to enhance the accuracy of the APF, an advanced control strategy is pi-vpi control is applied, as shown in Fig. 3. In Fig. 3, the pi-vpi control scheme is implemented by using only the supply current (*iSa* and *iSb*) without detecting the load current (*iL,abc*) and filter current (*iF,abc*). Thereby, the load current sensors and filter current sensors in the typical shunt APF shown in Fig. 2 can be eliminated. And also, the harmonic current detection is omitted. Due to the absence of harmonic detection, the pi-vpi control scheme can be implemented with only two loops: the outer voltage control and the inner current control. The outer loop aims to keep dc-link voltage of the APF constant through a PI controller, which helps the APF deal with load variations. The output of this control loop is the reference active current in the fundamental reference frame (*i*Sd*). Meanwhile, the reference reactive current (*i*Sq*) is simply set to be zero, which ensures the reactive power provided by the power supply to be zero. And, the reactive power caused by loads is supplied by the shunt APF. The inner loop is then used to regulate the supply current in the fundamental reference frame (*iS,dq*) by using the PI-VPI current controller. The output of this loop becomes the control signal (*v*F,ab*) applied to the four-switch APF which is implemented by the FSTPI. Since the current control is executed without the harmonic detector, the control performance of the APF only relies on the current controller. In the next section, the analysis and design of the proposed current controller will be presented.

C. Proposed Control Strategy To Improve The Performance Of Shunt Active Power Filter

The proposed control strategy makes the use of fuzzy-VPI controller to improve the performance of shunt active power filter. The structure of proposed control scheme is shown in figure below.

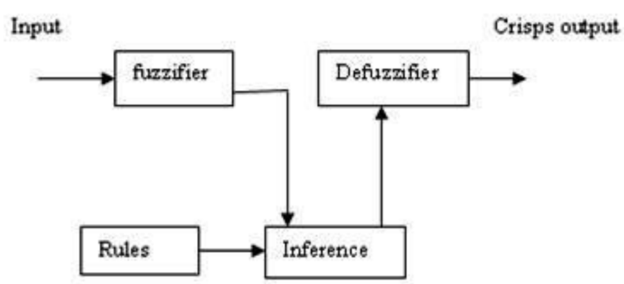
Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)



Structure of the proposed control scheme for three-phase shunt APF

D. Fuzzy Logic Controller

Fuzzy logic controllers (FLC) are suitable for systems that are structurally difficult to model due to naturally existing non linearity's and other model complexities. The main drawback of using repetitive current control is, there is no control action, to avoid the distortion from the grid voltage. In-order to overcome this drawback, it needs to design a good fuzzy logic controller. The database, consisting of membership functions. Basically membership value should lies between 0 to 1. The operations performed are fuzzification, interference mechanism and defuzzification. The interference mechanism uses a collection of linguistic rules to convert the input conditions into a fuzzified output. Finally defuzzification is used to convert the fuzzy outputs into required crisp signals. As shown in figure below.



Fuzzy controller block diagram

1) *Fuzzification:* Fuzzification is an important concept in the fuzzy logic theory. Fuzzification is the process where the crisp quantities are converted to fuzzy (crisp to fuzzy). By identifying some of the uncertainties present in the crisp values, we form the fuzzy values. The conversion of fuzzy values is represented by the membership functions.

2) *Defuzzification:* Defuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications; hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing.

3) *FLC Design Methodology:* Design of fuzzy logic controller comprises the following steps.
   a) *Identifying the input signals to FLC.*
   b) *Determining the number of membership function, and*
   c) *Decide upon the type of membership function.*

4) *Membership function:* The number of membership function determines the quality of control which can be achieved using fuzzy logic controller (FLC). As the number of membership function increase, the quality of control improves at the cost of increased computational time and computer memory. Investigations are carried out considering seven membership function for

Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

each input and output signal. As shown in fig6 & fig7 [9]

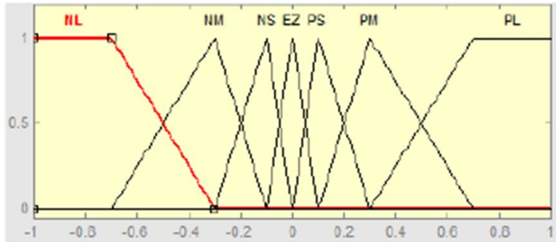


Fig.6: Membership functions for input variables (e,de).

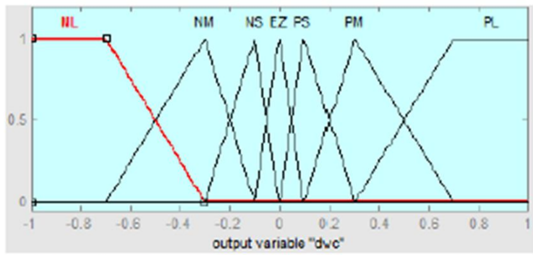


Fig.7: Membership functions for output variable (dvc)

5) *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 in-put/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 Table 1.

Table 1: Fuzzy rule Base

de \ e	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	NL	NM	NS	ZE	PS	PM	PL

6) *Fuzzy control scheme for APF:* In the fuzzy logic control algorithm for APF two inputs are required. The inputs are error and change in error. The two inputs are related by member functions. Basically forty nine rules are there. Based on the operation each rule will be used. The membership functions are expressed as negative large (NL), negative medium (NM), negative small (NS), zero(ZE), positive small(PS), positive medium(PM) and positive large(PL). Actual voltage is compared with the reference voltage, based on that error will be produced. It can be compensated by using fuzzy logic controller. Actual current is compared with the reference current, and error is compensated by fuzzy controller. Fuzzy sets support a flexible sense of membership functions. The block diagram of the fuzzy logic controller (FLC) for proposed converter is shown in fig8.[8]

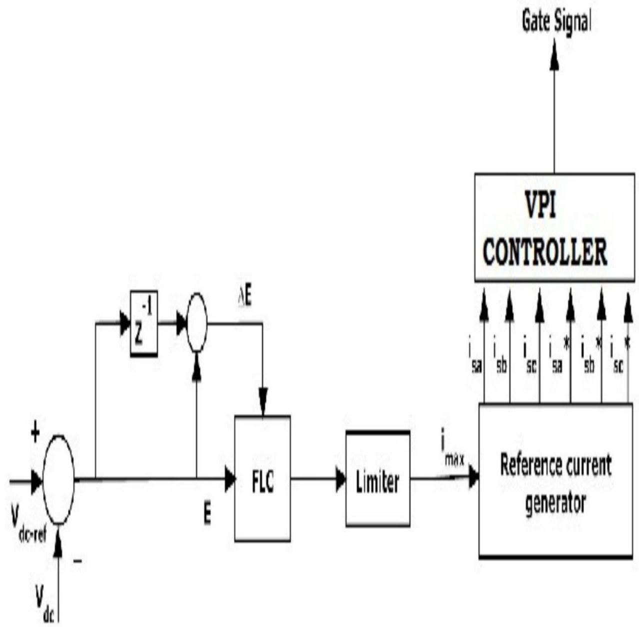


Fig.8 Block diagram of the Fuzzy Logic Controller (FLC) for proposed converter

A triangular membership function has the advantage of simplicity and easy implementation and is adopted in the application. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The centroid method of defuzzification is generally used, but the disadvantage of this method is, it is computationally difficult for complex membership functions. Here bisector method of defuzzification is used. The advantages of bisector method are, it is fast and generally produces good results.

V. SIMULATION RESULTS

Simulations are performed to show the effectiveness of the APF, by means of PI controller in series with VPI controller and fuzzy controller in series with VPI controller with RL loads. This can control the THD and improve Power factor. The simulation model of the shunt active power filter with VPI controller (RL-load) is shown in Fig.9

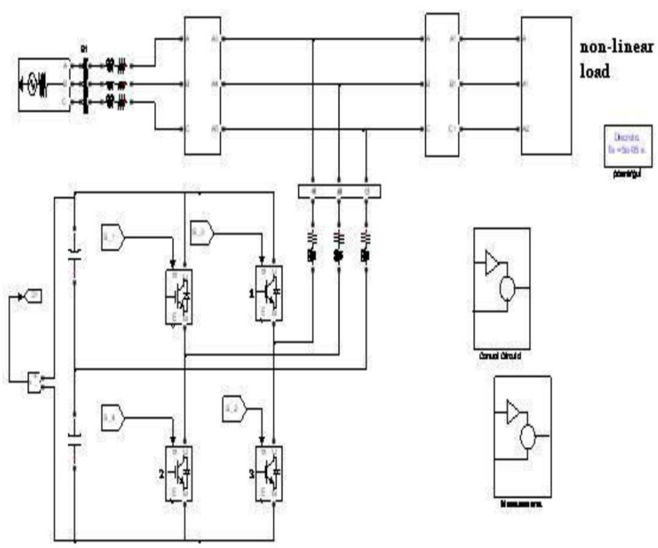


Fig.9: Matlab/Simulink Model of PI-VPI controller

Fig.9 shows the Matlab/Simulink Model of Proposed fuzzy- VPI Four Switch APF Operated under Several Control Strategies to Enhance PQ Features using Matlab/Simulink Environment.

Volume 4 Issue IV, April 2016
ISSN: 2321-9653

A. Case 1: Under PI-VPI Controller

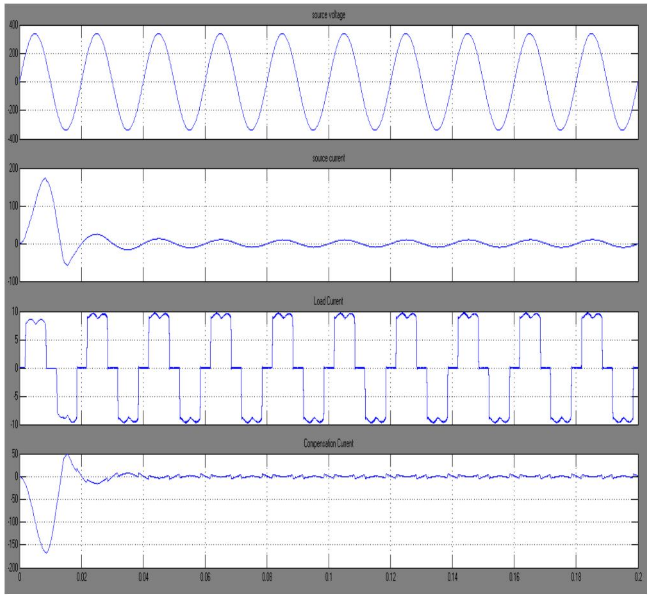


Fig.10Source Voltage, Source Current, Load Current, Compensation Current

Fig.10 shows the Source Voltage, Source Current, Load Current, and Compensation Current of APF operating under PI-VPI Controller

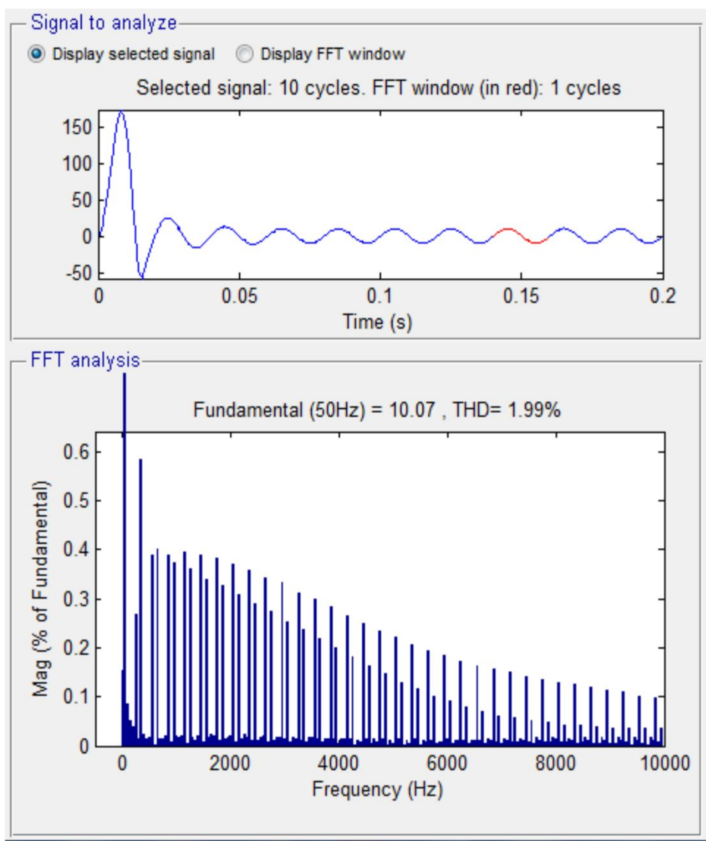


Fig.11: FFT Analysis of Source Current with PI-VPI Controller.

Fig.11 shows the FFT Analysis of Source Current with Four Switch APF with PI-VPI control strategy, the THD value is 1.99%.

B. Case 2: Proposed Four Switch APF Operated Under Fuzzy Controller

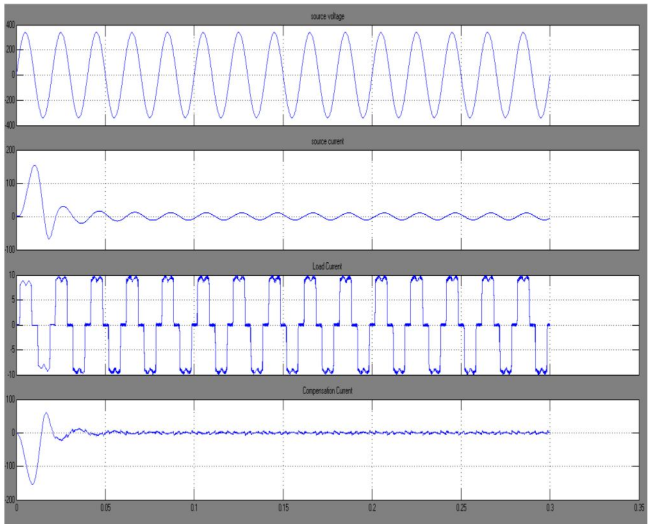


Fig.12: Source Voltage, Source Current, Load Current, Compensation Current

Fig.12 shows the Source Voltage, Source Current, Load Current, and Compensation Current of proposed Four Switch APF operating under Fuzzy Controller.

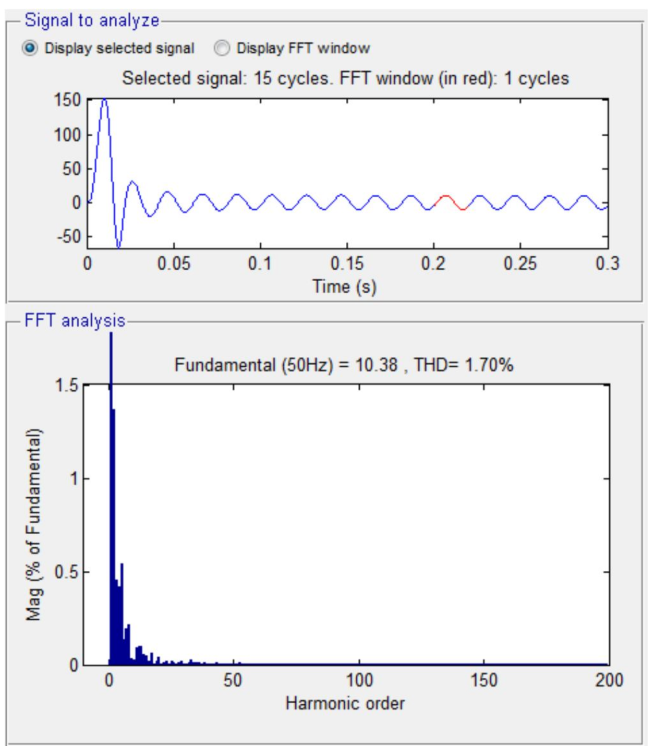


Fig.13: FFT Analysis of Source Current with Proposed Compensator

Fig.13 shows the FFT Analysis of Source Current with Proposed Four Switch APF with Fuzzy–VPI control strategy, the THD value is 1.70%.

VI. CONCLUSIONS

In this paper, an fuzzy based advanced control strategy for the three-phase shunt APF is proposed. The effectiveness of the proposed control strategy is verified through various simulation tests, The proposed control strategy presented good steady-state performance with nonlinear RL load as well as good dynamic response against load variations. The supply current is almost perfect sinusoidal and in-phase with the supply voltage even under the distorted voltage condition. The simulation results prove that the absence of a harmonic detector results in faster transient responses as well as assures notches free in steady-state performances of the supply current In all of the results, THD factor of the supply current is reduced to less than 2% by using fuzzy-VPI controller, which completely comply with the IEEE-519 and IEC-61000-3-2 standards.

REFERENCES

[1] Akagi, "New trends in active filters for power conditioning," IEEE Trans. Ind. Appl., vol. 32, no. 2, pp. 1312–1332, Nov./Dec. 1996.

[2] F. Z. Peng, "Application issues of active power filters," IEEE Ind. Appl. Mag., vol. 4, no. 5, pp. 21–30, Sep./Oct. 1998.

[3] S. Buso, L. Malesani, and P. Mattavelli, "Comparison of current control techniques for active filters applications," IEEE Trans. Ind. Electron., vol. 45, no. 5, pp. 722–729, Oct. 1998.

[4] C. Lascu, L. Asiminoaei, I. Boldea, and F. Blaabjerg, "High performance current controller for selective harmonic compensation in active power filters," IEEE Trans. Power Electron., vol. 22, no. 5, pp. 1826–1835, Sep. 2007.

[5] Quoc-Nam Trinh and Hong-Hee Lee, Senior Member, IEEE" An Advanced Current Control Strategy for Three-Phase Shunt Active Power Filters" IEEE Transactions on Industrial Electronics, Vol. 60, No. 12, December 2013.

[6] B. N. Singh, B. Singh, A. Chandra, P. Rastgoufard, and K. Al-Haddad, "An improved control algorithm for active filters," IEEE Trans. Power Del., vol. 22, no. 2, pp. 1009–1020, Apr. 2007.

[7] C. Lascu, L. Asiminoaei, I. Boldea, and F. Blaabjerg, "Frequency response analysis of current controllers for selective harmonic compensation in active power filters," IEEE Trans. Ind. Electron., vol. 56, no. 2, pp. 337– 347, Feb. 2009.

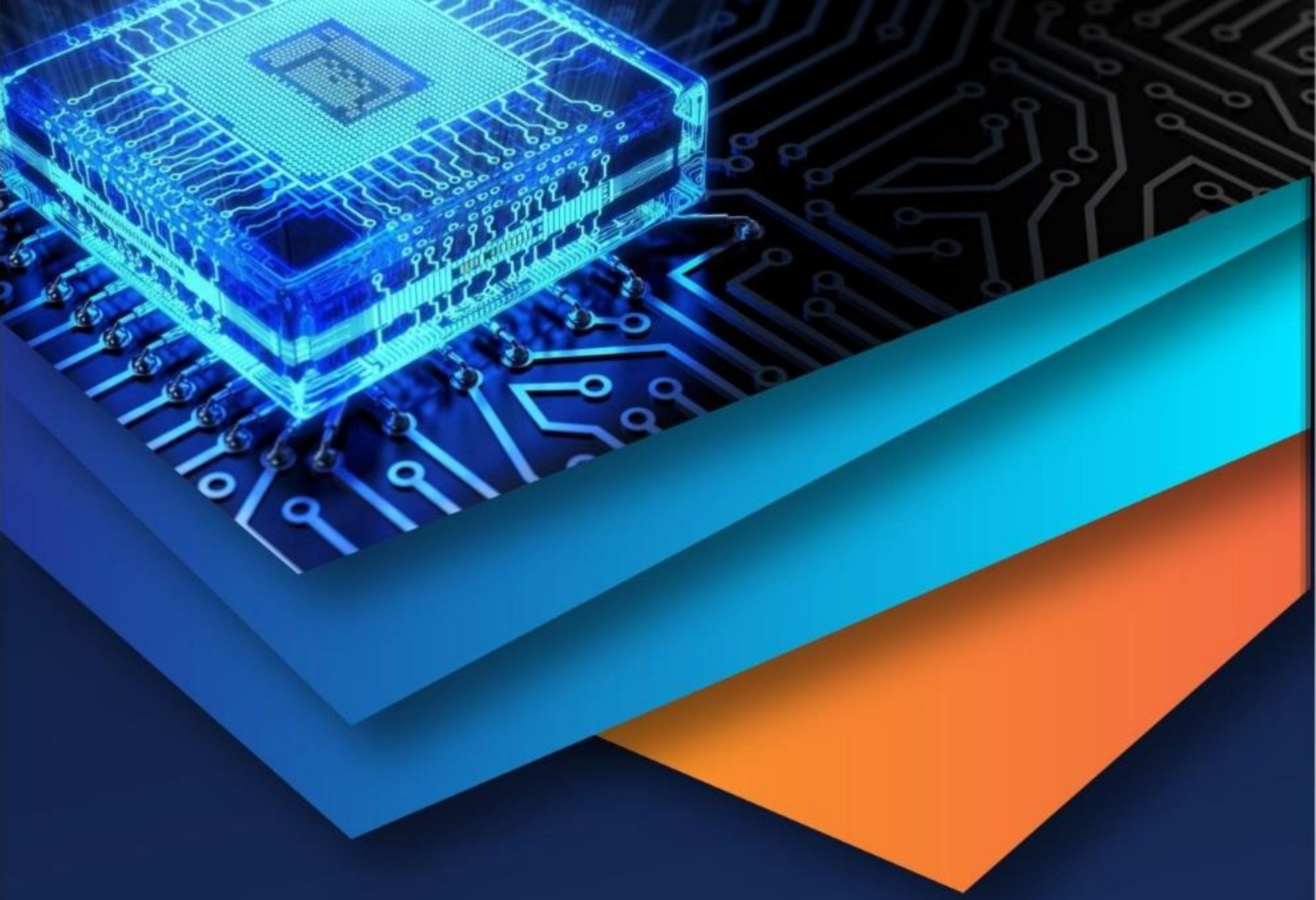
[8] Suresh Mikkili and Anup Kumar Panda "PI and Fuzzy Logic Controller Based 3-Phase 4- Wire Shunt Active Filters for the Mitigation of Current Harmonics with the Id-Iq Control Strategy" Journal of Power Electronics, Vol. 11, No. 6, November 2011.

[9] K.Sarasvathi, R.Rajalakshmi, Member, IEEE "Performance Analysis of Shunt Active Filter Using Different Controllers" International JournalEngineering Trends and Technology (IJETT) – Volume 4, Issue 5- May 2013.

[10] Ch.Ravi Kumar, Dr.P.V.Ramana Rao, "Application of Hybrid Neuro Fuzzy Controller for Automatic Generation Control of Three Area Power System Considering Parametric Uncertainties", International Journal of Electrical Engineering Technology (IJEET), Volume 4, Issue 5, pp. 104-114, 2013. ISSN Print: 0976-6545, ISSN Online: 0976-6553.

[11] Narayan G. Apte and Dr. Vishram N. Bapat, "Indirect Current Controlled Single Phase Shunt Active Filter", International Journal of Electrical Engineering Technology (IJEET), Volume 4, Issue 4, pp. 264 - 273, 2013. ISSN Print: 0976-6545, ISSN Online: 0976-6553.

[12] R.J.Motiyani and A.P.Desai, "Three Phase Shunt Active Filter with Constant Instantaneous Power Control Strategy", International Journal of Electrical Engineering Technology (IJEET), Volume 4, Issue 4, pp. 245 - 254, 2013. ISSN Print: 0976-6545, ISSN Online: 0976-6553.



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