International Journal of Electronics and Electrical Engineering

Volume 2 | Issue 4 Article 13

April 2014

FUZZY BASED CASCADED MULTILEVEL SHUNT ACTIVE POWER FILTER FOR POWER LINE CONDITIONERS

B. SOUJANYA YADAV
Electrical and Electronics dept, Sreendhi Institute of Science and Technology , Hyderabad A.P ,India.,
Soujanya788@gmail.com

L. RAMADEVI
Electrical and Electronics dept, Sreendhi Institute of Science and Technology , Hyderabad A.P ,India.,
ramadevi2006@gmail.com

DR. P. S. R. MURTHY
Electrical and Electronics dept, Sreendhi Institute of Science and Technology , Hyderabad A.P ,India.,
murtypsr39@yahoo.com

FUZZY BASED CASCADED MULTILEVEL SHUNT ACTIVE POWER FILTER FOR POWER LINE CONDITIONERS

B. SOUJANYA YADAV[1], L.RAMADEVI[2] & DR.P.S.R.MURTHY[3]

[1,2&3]Electrical and Electronics dept, Sreendhi Institute of Science and Technology , Hyderabad A.P ,India.
E-mail:Soujanya788@gmail.com, E-mail:ramadevi2006@gmail.com, E-mail:murtypsr39@yahoo.com

Abstract: In this paper shunt active power filter is used to improve the power quality at distribution system. Due to non-linear loads, current harmonics, unbalanced voltages and current and reactive power problems will be created in the network. The Instantaneous real power theory (IRPT) provides the real power calculation with PI controller will not provide accurate result and good performance under both steady state and transient state. Compensating above problems by using fuzzy based on Cascaded multi-level voltage source inverter. The inverter switching signals are generated based on the triangular sampling current controller provides power line conditioning. The Paper deals with three phase, five level cascaded multi level voltage source inverter based shunt active filter with PI and Fuzzy controller by using MATLAB/Simulink

Keywords*: Shunt active filter, Instantaneous power theory, power quality, Triangular-sampling current, fuzzy controller*.

I. INTRODUCTION

Rapid variation of non-linear loads like arc furnaces, rectifiers and SMPS etc. They change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental component) AC current.So far, shunt passive filters, which consist of tuned LC filters and/or high-pass filters, have been used to improve power factor and to suppress harmonics in power systems. However, shunt passive filters have such problems as to discourage their applications. Shunt passive filter exhibits lower impedance at a tuned harmonic frequency than the source impedance to reduce the harmonic currents, rowing into the source. In principle, filtering characteristics of the shunt passive filter are determined by the impedance ratio of the source and the shunt passive filter. Therefore, the shunt passive filter has the following problems.

The source impedance, which is not accurately known and varies with the system configuration, strongly influences filtering characteristics of the shunt passive filter. The shunt passive filter acts as a sink to the harmonic current flowing from the source. In the worst case, the shunt passive filter falls in series resonance with the source impedance. At a specific frequency, an anti resonance or parallel resonance occurs between the source impedance and the shunt passive filter, which is the so-called harmonic amplification.

Active power line conditioners, which are classified into shunt and series ones, have been studied to compensate for reactive power, negative-sequence and harmonics in industrial power systems since their basic compensation principles were proposed in the 1970's [1]-[3]. Active power filters can perform one or more of the functions required to compensate power systems and improving power quality

This paper explores design and analysis of a novel controller that uses instantaneous power theory along with fuzzy logic controller for cascaded multi level active power filter. The shunt APLC is investigated under steady state and transient state and found to be effective for power factor correction and additionally reduces ripple voltage of the dc capacitor with the proposed fuzzy logic controller.

II. INSTANTANEOUS REAL POWER THEORY

In three-phase circuits, instantaneous currents and voltages are converted to instantaneous space vectors. In instantaneous power theory, the instantaneous three-phase currents and voltages are calculated as following equations. These space vectors are easily converted into the α–β orthogonal coordinates [3]

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

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (2)$$

Considering only the three-phase three-wire system, the three-phase currents can be expressed in terms of harmonic positive, negative and zero sequence currents. In Equations (1) and (2), α and β are orthogonal coordinates. v_α and i_α are on α axis, v_β and i_β are on β axis. In three-phase Conventional instantaneous power is calculated as follows:

$$p = v_\alpha i_\alpha + v_\beta i_\beta \quad (3)$$

In fact, instantaneous real power (*p*) is equal to following Equation

$$p=v_a i_a + v_b i_b + v_c i_c \quad (4)$$

Instantaneous real and imaginary powers are calculated as Equations (5):

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (5)$$

In Equation (5), $v_\alpha i_\alpha$ and $v_\beta i_\beta$ are instantaneous real (*p*) and imaginary (*q*) powers. Since these equations are products of instantaneous currents and voltages in the same axis. In three phase circuits, instantaneous real power is *p* and its unit is watt. In contrast $v_\alpha i_\beta$ and $v_\beta i_\alpha$ are not instantaneous powers. Since these are products of instantaneous current and voltages in two orthogonal axes, *q* is not conventional electric unit like W or Var. *q* is instantaneous imaginary power and its unit is Imaginer Volt Ampere (IVA). The real power is the sum of the ac power loss and dc power loss. Similarly, the reactive power is also ,these power quantities given below for an

$$p=\bar{p}+\tilde{p} \quad (6)$$

$$q=\bar{q}+\tilde{q} \quad (7)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix} \quad (8)$$

From Equation (8), in order to compensate harmonics so, instantaneous compensating currents ($ic\alpha$ and $ic\beta$) on α and β coordinates are calculated by using real power (p) and reactive power is zero as given below.

$$\begin{matrix} i_{c\alpha} \\ i_{c\beta} \end{matrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ 0 \end{bmatrix} \quad (9)$$

III .SHUNT ACTIVE POWER FILTER

The three-phase supply source connected with non-linear load and these nonlinear loads currents contains fundamental and harmonic components. If the active power filter provides the total reactive and harmonic power, $i_s(t)$ will be in phase with the utility voltage and would be sinusoidal. At this time, the active filter must provide the compensation current $i_c(t) = i_L(t) - i_s(t)$ therefore; active power filter estimates the fundamental components and compensating the harmonic current and reactive power.

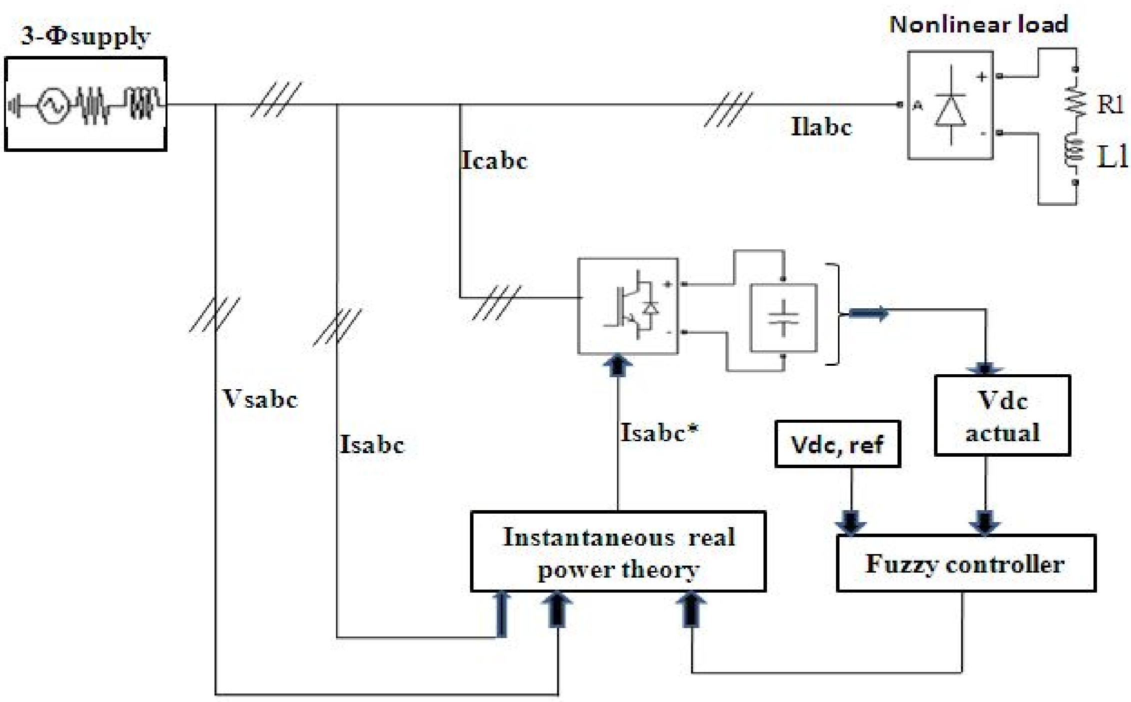


Fig1: shunt active power line conditioner

Instantaneous real-power theory based cascaded active filter for power line conditioning system is connected in the distribution network at the PCC through filter inductances and operates in a closed loop. The shunt active filter system contains a cascaded inverter, RL-filters, a compensation controller (instantaneous real-power theory) and switching signal generator (proposed triangular-sampling current modulator) as shown in the Fig 1

A. Power Converter:

A cascaded multilevel active power filter is constructed by the conventional of H-bridges.

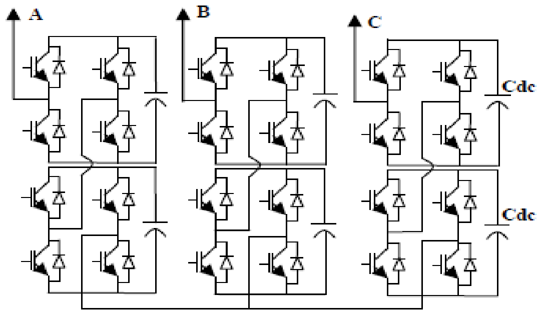


Fig 2: cascaded multilevel active power filter

The three-phase active filter comprises of 24-power transistors with diodes and each phase consists of two-H-bridges in cascaded method for 5-level output voltage, shown in Fig 2. Each H-bridge is connected a separate dc-bus capacitor and it serves as an energy storage elements to supply a real-power difference between load and source during the transient period [4-5].

B. Reference Current control strategy

The control scheme of the shunt active power filter must calculate the current reference signals from each phase of the inverter using instantaneous real-power compensator. The block diagram as shown in Fig.3, that control scheme generates the reference current required to compensate the load current harmonics and reactive power. The fuzzy controller is tried to maintain the dc-bus voltage across the capacitor constant of the cascaded inverter. This instantaneous real-power compensator with fuzzy-controller is used to extracts reference value of current to be compensated.

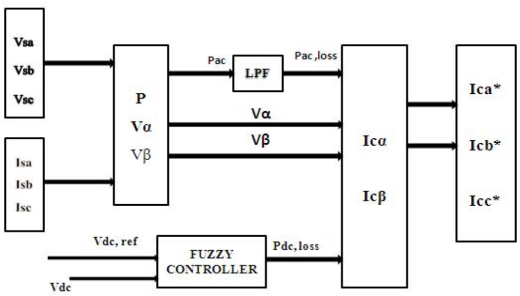


Fig3: Reference current generator using IRPT

In order to obtain the reference compensation currents in the *a–b–c* coordinates the inverse of the transformation given in expression (10) is applied [6]:

$$\begin{bmatrix} i_{ca}^{*} \\ i_{cb}^{*} \\ i_{cc}^{*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & \sqrt{3}/2 \end{bmatrix} \qquad \textbf{(10)}$$

C. Control loop using conventional (pi) controller

Dc voltage ripples controlling is done by modifying the small dc power flowing into the dc components which are combination of conduction losses and switching losses. the PI controller is used to reduce the steady state error and transient error of the cascaded inverter .the transfer function of control loop is

$$\text{H(s)}=[V_{dcref} - V_{dc}][K_P + KI/S] \qquad \textbf{(11)}$$

In this paper introducing new controller that is fuzzy logic, to overcome the disadvantages of conventional controller and to improve the accuracy of the system under steady and transient state.

IV. IMPLEMENTATION OF FUZZY LOGIC CONTROLLER

Since power system dynamic characteristics are complex and variable, conventional control methods cannot provide desired results. Intelligent controllers can be replaced with conventional controllers to get fast and good dynamic response in load frequency control problems .If the system robustness and reliability are more important, fuzzy logic controllers can be more useful in solving a wide range of control problems since conventional controllers are slower and also less efficient in nonlinear system applications. Fuzzy logic controller is designed to minimize fluctuation on system outputs . FLC designed to eliminate the need for continuous operator attention and used automatically to adjust some variables the process variable is kept at the reference value. A FLC consists of three sections namely, fuzzifier, rule base, and defuzzifier as shown in Fig 4.

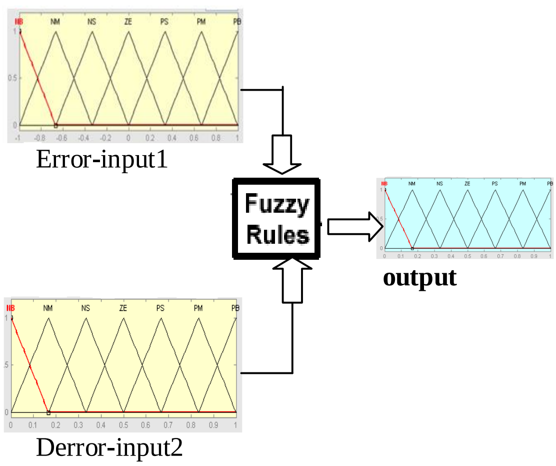


Fig4 Implementation of fuzzy logic controller

The error, e and change in error, de are inputs of FLC. Two input signals are converted to fuzzy numbers first in fuzzifier using seven membership functions: Positive Big (PB), Positive Small (PS), Positive medium,Zero (ZE), Negative Small (NS), Negative Big (NB), negative Medium (NM). Triangular membership functions are used in this paper since it is easier to intercept membership degrees from a triangle. Then they are used in the rule table shown in Table I to determine the fuzzy number of the compensated output signal

TABLE I: fuzzy rules

error/ derr	NB	NM	NS	ZE	PB	PM	PS
NB	PB	PB	PM	PM	ZE	PS	PS
NM	PB	PM	PM	PS	NS	ZE	PS
NS	PM	PM	PS	PS	NS	NS	ZE
ZE	PM	PS	PS	ZE	NM	NS	NS
PB	ZE	NS	NS	NM	NB	NB	NM
PM	PS	ZE	NS	NS	NB	NM	NM
PS	PS	PS	ZE	NS	NM	NM	NS

V .SIMULATION RESULTS

The system performance by the proposed fuzzy based cascaded multilevel inverter shunt active filter using instantaneous real power theory is evaluated through Mat lab/Simulink tools. Simulation of the six pulse rectifier load current or source currnets by using PI controller is presented in Fig 5(a)

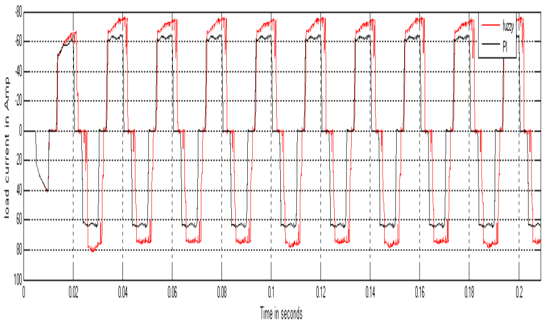


Fig 5(a)

The reference fundamental current is extracted from the distorted wave form 5(b)

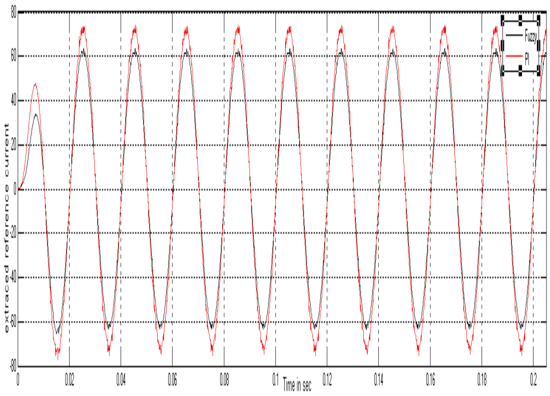


Fig 5(b)

By using cascaded multilevel inverter based active filter provides harmonic filter or compensationin belowFig6(a)

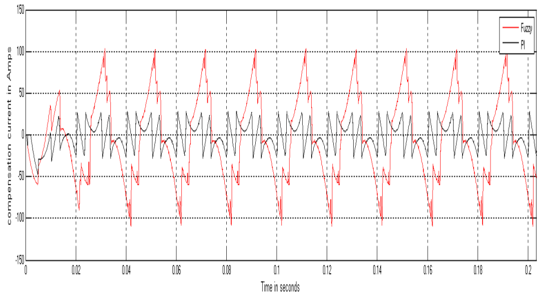


Fig6(a)

The source current after compensation indicates the sinusoidal waveform in Fig 6(b) additionally achieved power factor correction in6(c) that result indicates a-phase voltage is in phase with a-phase current .the other phase s is just 120^0 phase shifted

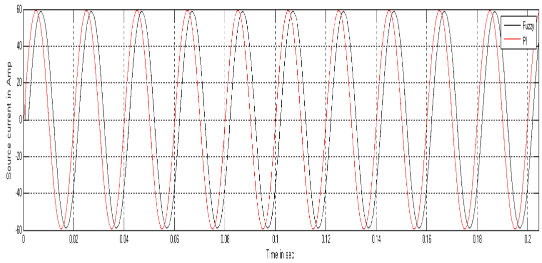


Fig 6(b)

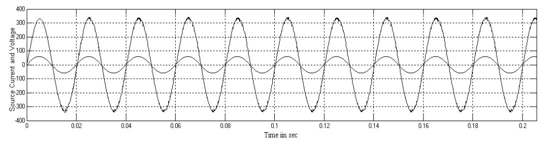


Fig 6(c)

The DC-bus capacitors voltage of the cascaded multilevel inverter is controlled by fuzzy logic controller that is shown in Fig 6(d)

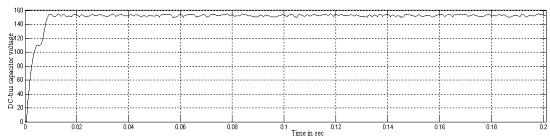
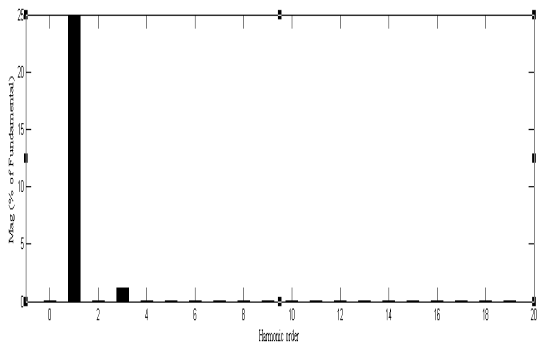
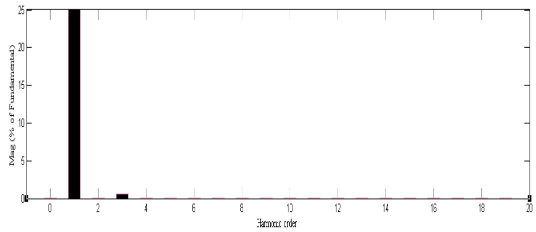


Fig 6(d)

The fast Fourier (FFT) is used to determine the order of harmonics shown in Fig7



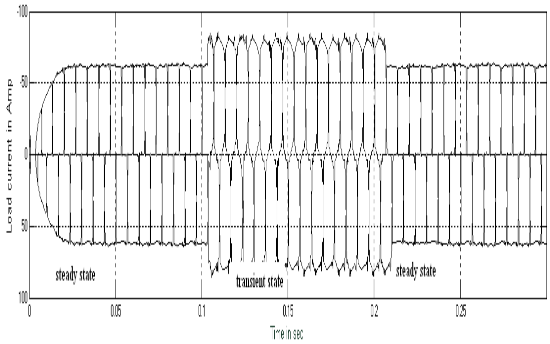
(a)



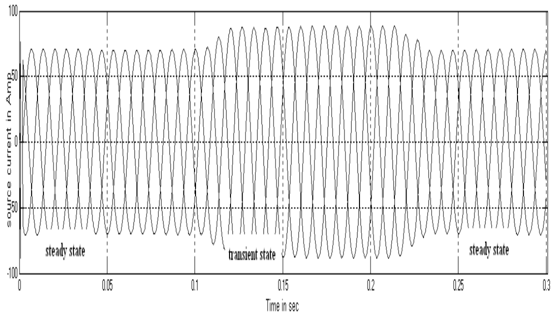
(b)

Fig 7 :instantaneous real power compensator based Cascaded shunt active power filter (a) the source current with PI controller(THD=2.06%) (b)with proposed controller of APF (THD=1.07%)

The three phase source currents and load currents under steady and transient state behavior of waveforms are shown below in Fig 8(a)and 8(b)



(a) Load currents



(b) source currents

The total harmonic distortion(THD)is measured under steady state and transient state conditions ,the THD parameters with PI and Fuzzy logic controller are presented in below table II

Conditions (THD)	With PI	With proposed controller
Steady state	2.06	1.07
transient	5.08	1.99
Power factor	0.9508	0.998

REFERENCES

[l] H. Sasaki and T. Machida, "A new method to eliminate ac harmonic currents by magnetic compensation-Considerations on basic design," ***IEEE Trans. Power Appl. Syst.*** vol. PAS-90, p. 2009, 1971.

[2] **L.** Gyugyi and E. C. Strycula, "Active ac power filters," in ***ZEEEIZAS Ann. Meeting,*** 1976, pp. 529.

[3] H. Akagi, A. Nabae, S. Atoh, Control strategy of active power filters using multiple voltage-source PWM converters, IEEE Trans. Ind. Appl. 1A-22 (1986) 460–465

[4] Rajesh Gupta, Arindam Ghosh and Avinash Joshi "Switching Characterization of Cascaded Multilevel-Inverter-Controlled Systems" IEEE Trans on Industrial Electronics, Vol.55, No.3, pp 1047-1058, March-2008

[5] Mariusz Malinowkski, K.Gopakumar, Jose Rodriguez and Marcelo A.Perez "A Survey on Cascaded Multilevel Inverters" IEEE Trans on Indus. Electronics, Vol.57, No7, pp.2197-2205, July-2010.

[6] J. Afonso, et al., Active filters with control based on the *p–q* theory, IEEE Ind. Electron. Soc. Newsletter 47 (3) (2000) 5–11.

APPENDIX

Line to line voltage-=440v;
System frequency=50HZ;
Source impedence of Ls=1mH;
Filter impendece R_C ,L_C =0.1Ω;
Diode rectifier load R_L =20Ω;L_L =100mH;
Dc capacitance=2100µF;
Reference voltage=200v;
Power devices are IGBT'S

◈◈◈