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A Novel Fuzzy Logic Controller Based Shunt Active Power Filter for Power System Harmonic Mitigation

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ABSTRACT:- Most of the pollution issues created in power systems are due to the non-linear characteristics and fast switching of power electronic equipment. Due to this harmonics are produced and reactive power compensation is required, so that system efficiency is less and power factor is poor. Active power filters have been developed over the years to solve these problems to improve power quality. Among which shunt active power filter is used to eliminate and load current harmonics and reactive power compensation. In this work both PI controller based and fuzzy logic controlled, three-phase shunt active power filter to compensate harmonics and reactive power by nonlinear load to improve power quality is implemented for three-phase three wire systems. The advantage of fuzzy control is that it is based on linguistic description and does not require a mathematical model of the system. A MATLAB program has been developed to simulate the system operation. Various simulation results are presented under steady state conditions and performance of fuzzy and PI controllers is compared. Simulation results obtained shows that the performance of fuzzy controller is found to be better than PI controller.

Keywords:-*Active power filter, PI controller, Fuzzy logic controller(FLC), Harmonic distortion*

I. INTRODUCTION

In modern electrical distribution systems there has been a sudden increase of single phase and three-phase non-linear loads. These non-linear loads employ solid state power conversion and draw non-sinusoidal currents from AC mains and cause harmonics and reactive power burden, and excessive neutral currents that result in pollution of power systems. Pollution has been introduced into power systems by nonlinear loads such as transformers and saturated coils.Due to its nonlinear characteristics and fast switching, PE create most of the pollution issues. Most of the pollution issues are created due to the nonlinear characteristics and fast switching of PE. Increase in such non linearity causes different undesirable features like

- Low system efficiency
- Poor power factor
- Causes disturbance to other consumers and
- Interference in nearby communication networks

The effect of such non-linearity may become sizeable over the next few years. Hence it is very important to overcome these undesirable features. Active power filters have been developed to overcome these problems. Shunt active filters based on current controlled PWM converters are seen as viable solution. There are two approaches to the mitigation of power quality problems. The first approach is called load conditioning, which ensures that the equipment is made less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line-conditioning systems that suppress or counteract the power system disturbances. Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems. They are usually custom designed for the application. However, their performance is limited to a few harmonics, andthey can introduce resonance in the power system. Among the different new technical options available to improve power quality, active power filters have proved to be an important and flexible alternative to compensate for current and voltage disturbances in power distribution systems.

The active power filter topology can be connected in series for voltage harmonic compensation and in parallel for current harmonic compensation. Mostly need current harmonic compensation, so the shunt active filter is used than series active filter. The shunt active power filter has the ability to keep the mains current balanced and sinusoidal after compensation regardless of whether the load is non-linear and balanced or unbalanced.

Recently, fuzzy logic controllers (FLC's) have generated a good deal of interest in certain applications. The advantages of FLC's over the conventional controllers are:

- It does not need accurate mathematical model
- It can work with imprecise inputs
- It can handle nonlinearity, and
- It is more robust than conventional nonlinear controllers.

In this work both PI and fuzzy logic controlled shunt active power filter for the harmonics and reactive power compensation of a nonlinear load are implemented. Both controllers performance under certain conditions and different system parameters is studied.

II. PRINCIPLE OF BASIC COMPENSATION

Figure (a) shows the basic compensation principle of a shunt active power filter. It is controlled to draw / supply a compensating current ic from / to the utility, so that it cancels current harmonics on the AC side, and makes the source current in phase with the source voltage. Figure (b) shows the different waveforms. Curve A is the load current waveform and curve B is the desired mains current. Curve C shows the compensating current injected by the active filter containing all the harmonics, to make mains current sinusoidal.

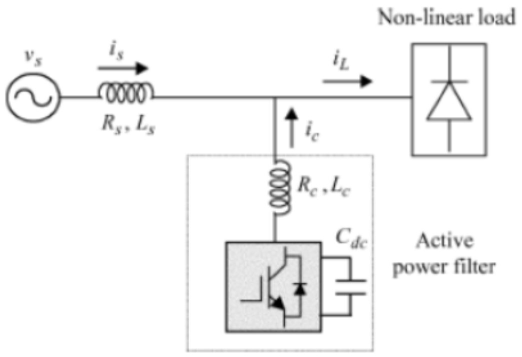


Figure.(a) Shunt active power filter Basic compensation principle.

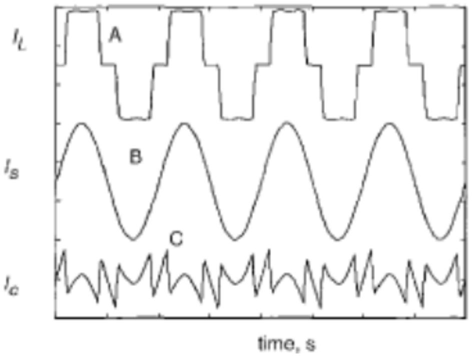


Figure.(b) Shunt active power filter-Shapes of load, source and desired filter current wave forms.

A. Current supplied by source

From Figure.(a) the instantaneous currents can be written as

$$i_s(t)=i_l(t)-i_c(t)(1)$$

Source voltage is given by

$$v_s(t)= V_m sin\omega t(2)$$

If a non-linear load is applied, then the load current will have a fundamental component and harmonic components which can be represented as

$$I_L(t)= \sum^{\infty}_{n=1} I_n \sin(n\omega t+\Phi_n)$$
$$= I_1\sin(\omega t+\Phi_1) +\sum^{\infty}_{n=2} I_n \sin(n\omega t+\Phi_n) \qquad (3)$$

The instantaneous load power can be given as

$P_L(t)= v_s(t)*i_l(t)$

$= V_m I_1\sin^2\omega t*\cos\Phi_1 + V_m I_1\sin\omega t*\cos\omega t*\sin\Phi_1$

$+ V_m\sin\omega t*\sum^{\infty}_{n=2} I_n \sin(n\omega t+\Phi_n) \qquad (4)$

$=P_f(t) + P_r(t) + P_h(t) \qquad (5)$

From (4), the real (fundamental) power drawn by the load is

$$P_f(t)=V_m I_1\sin^2\omega t*\cos\Phi_1 = v_s(t)* i_s(t)(6)$$

From (6), the source current supplied by the source, after compensation is

$$i_s(t)= P_f(t)/ v_s(t) =I_1\cos\Phi_1\sin\omega t =I_{sm}\sin\omega t$$

Where $I_{sm}= I_1\cos\Phi_1$

The total peak current supplied by the source is

$$I_{sp}= I_{sm} + I_{sl}(7)$$

If the active filter provides the total reactive and harmonic power, then $I_s(t)$ will be in phase with the utility voltage and purely sinusoidal. At this time, the active filter must provide the following compensation current.

$i_c(t)=i_L(t) – i_s(t)$

Hence, for accurate and instantaneous compensation of reactive and harmonic power it is necessary to estimate, i.e. the fundamental component of the load current *as* the reference current.

B. Estimation of reference source current

The peak value of the reference current I_{sp} can be estimated by controlling the DC side capacitor voltage. Ideal compensation requires the mains current to be sinusoidal and in phase with the source voltage, irrespective of the load current nature. The desired source currents, after compensation, can be given as

$$I_{sa}^{*}= I_{sp}\sin\omega t$$
$$I_{sb}^{*}= I_{sp}\sin(\omega t–120^0)$$
$$I_{sc}^{*}= I_{sp}\sin(\omega t+120^0)$$

Where $I_{sp}(=I_1\ \mathrm{COS}\Phi_1+I_{sl})$ the amplitude of the desired source current. This peak value of the reference current has been estimated by regulating the DC side capacitor voltage of the PWM converter.

C. Function of dc side capacitor

The DC side capacitor serves two main purposes:

(i) it maintains a DC voltage with small ripple in steady state,

(ii) serves as an energy storage element to supply real power difference between load and source during the transient period.

In the steady state, the real power supplied by the source should be equal to the real power demand of the load plus a small power to compensate the losses in the active filter. Thus, the DC capacitor voltage can be maintained at a reference value. However, when the load condition changes the real power balance between the mains and the load will be disturbed. This real power difference is to be compensated by the DC capacitor.the peak value or the reference source current can be obtained by regulating the average voltage of the DC capacitor The active filter produces a fundamental voltage which isin-phase with fundamental leading current of the passivefilter. A small amount of APF is consisting due to the leadingcurrent and fundamental voltage of the passive filter and itdelivers to the dc capacitor. Therefore, the electrical quantityadjusted by the dc-voltage controller is consequently. TomaintainV$_{dc}$ equal to its reference value, the losses throughfilter‟s resistive-inductive branches will be compensated byacting on the supply current.

III. *DESIGN OF POWER CIRCUIT OF A SHUNT ACTIVE POWER FILTER*

The design of the power circuit includes three main parameters:
- Selection of filter inductor, L_c.
- Selection of DC side capacitor, C_{dc}.
- Selection of reference value of DC side capacitor voltage, $V_{dc,ref}$

A. Selection of L_c and $V_{dc,ref}$

The design of these components is based on the following assumptions:
1. The AC source voltage is sinusoidal.
2. To design of Lc, the AC side line current distortion is assumed to be 5%.
3. Fixed capability of reactive power compensation of the active filter.
4. The PWM converter is assumed to operate in the linear modulation mode (i.e. $0 \leq m_a \leq 1$).

As per the compensation principle, the active filter adjusts the current i_{c1} to compensate the reactive power of the load. If the active filter compensates all the fundamental reactive power of the load, is1 will be in phase and i_{c1} should be orthogonal to V_s, as shown in Fig.b. (the 1 stands here for the fundamental component).

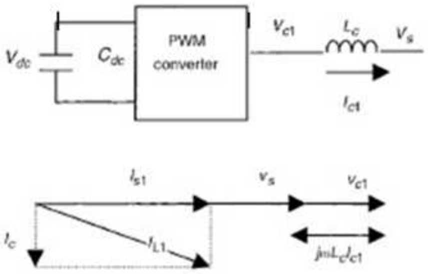


Figure.2.5. Active power filter and its phasor diagram

The three-phase reactive power delivered from the active filter can be calculated from a vector diagram

$Q_{c1} = 3V_sI_{c1} = 3V_sV_{c1}/\omega L_c(1-(V_s/V_{c1}))$ (8)

i.e. the active filter can compensate the reactive power from the utility only when $V_{c1} > V_s$.

If the PWM converter is assumed to operate in the linear modulation mode (i.e. $0 \leq m_a \leq 1$), the amplitude modulation factor ma is

$$m_a = v_m/(V_{dc}/2)$$

wherevm=$\sqrt{2}V_c$, and hence $V_{dc} = 2\sqrt{2}\ V_{c1}$ for m_a=1.

The filter inductor Lc is also used to filter the ripples of the converter current, and hence the design of $L_c$is based on the principle of harmonic current reduction. The ripple current of the PWM converter can be given in terms of the maximum harmonic voltage, which occurs at the frequency mf ω:

$$I_{ch(mf\omega)} = V_{ch(mf\omega)}/\ m_f\omega Lc(9)$$

Where mf is the frequency modulation ratio of the PWM converter.

By solving (8) and (9) simultaneously, the value of L_c, and V_{c1} (i.e.V_{dc}) can be calculated. V_{c1}, and hence V_{dcref}, must be set according to the capacity requirement of the system (i.e. $V_s \leq V_{c1} \leq 2V_s$). As the switching frequency is not fixed with the hysteresis controller, a practically feasible value of 10 kHz has been assumed.

B. DC side capacitor(C_{dc}) Design

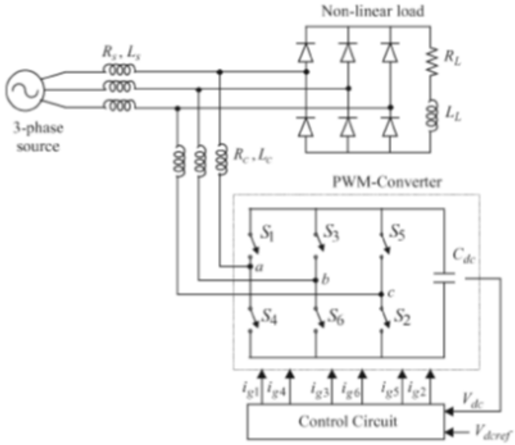
The design of the DC side capacitor is based on the principle of instantaneous power flow. The selection of C_{dc} can be governed by reducing the voltage ripple. As per the specification of the peak to peak voltage ripple ($V_{dc,p-p(max)}$) and rated filter current ($I_{c1,rated}$), the DC side capacitor C_{dc} can be found from equation

$$C_{dc} = (\prod * I_{c1,rated})/(\sqrt{3}\omega V_{dc,p-p(max)}) \qquad (10)$$

The value of C_{dc} depends on the maximum possible variationin load and not on the steady state value of load current. Hence, proper forecasting in the load variation reduces the value of C_{dc}. Further, filter inductor can be calculated as:

$$L_{c,min} = m_a V_{dc,ref}/(2\sqrt{2}), \Delta I_{SW,P-P}.K_L.f_{SW,max}$$

IV. PI CONTROL SCHEME



Figure(a). Schematic diagram of shunt active filter.

The complete schematic diagram of the shunt active power filter is shown in figure (a). While figure (b).gives the control scheme realization. The actual capacitor voltage is compared with a set reference value.

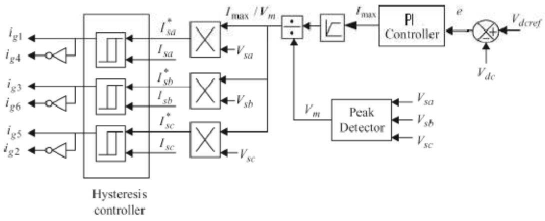
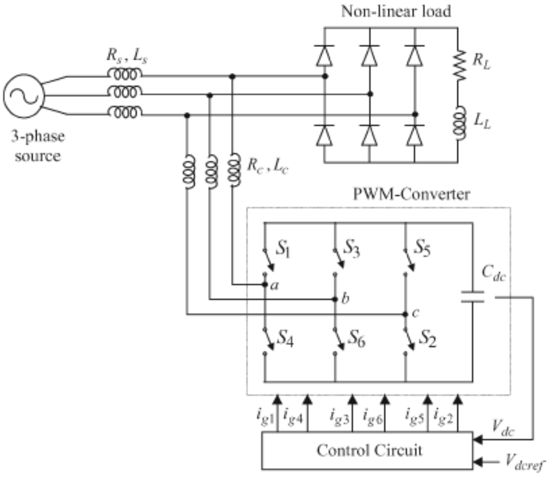


Figure (b). APF Control scheme with PI controller

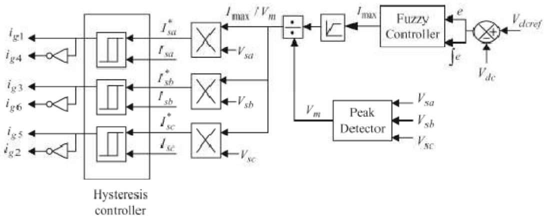
The error signal is fed to PI controller. The output of PI controller has been considered as peak value of the reference current. It is further multiplied by the unit sine vectors (u_{sa}, u_{sb}, and u_{sc}) in phase with the source voltages to obtain the reference currents (i_{sa}*, i_{sb}*, and i_{sc}*). These reference currents and actual currents are given to a hysteresis based, carrierless PWM current controller to generate switching signals of the PWM converter. The difference of reference current template and actual current decides the operation of switches. To increase current of particular phase, the lower switch of the PWM converter of that particular phase is switched on, while to decrease the current the upper switch of the particular phase is switched on. These switching signals after proper isolation and amplification are given to the switching devices. Due to these switching actions current flows through the filter inductor L_c, to compensate the harmonic current and reactive power of the load, so that only active power drawn from the source.

V.FUZZY CONTROL SCHEME

Fuzzy logic control is deduced from fuzzy set theory in1965;where transition is between membership and non membership function. Hence, limitation of fuzzy sets can beundefined and ambiguous; FLC"s are an excellent choicewhen precise mathematical formula calculations areimpossible.



Figure(a). Schematic diagram of closed loop fuzzy logic controlled shunt active power filter



Figure(b).Fuzzy Control scheme

Fig. (a) shows the block diagram of the implemented fuzzy logic control scheme of a shunt active power filter. Fig. (b) shows the schematic diagram of the control algorithm.

In order to implement the control algorithm of a shunt active power filter in closed loop, thee DC side capacitor voltage is sensed and then compared with a reference value. The obtained error e (=$V_{dc,ref}$-$V_{dc,act}$) and the change of error signal ce(n)=e(n)-e(n-1) at the nth sampling instant as inputs for the fuzzy processing. The output of the fuzzy controller after a limit is considered as the amplitude of the reference current Imax takes care of the active power demand of load and the losses in the system.

The switching signals for the PWM converter are obtained by comparing the actual source currents (i_{sa}, i_{sb}, and i_{sc}) with the reference current templates (i_{sa}*, i_{sb}*, and i_{sc}*) in the hysteresis current controller. Switching signals so obtained, after proper amplification and isolation, are given to switching devices of the PWM converter.

A. 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 internal structure of the fuzzy controller is shown in Fig.(c).

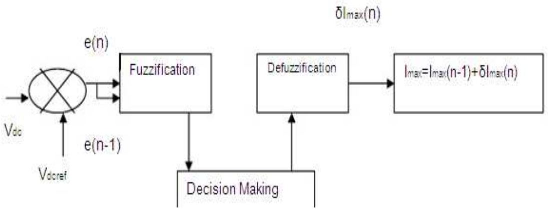


Figure (c). Internal structure of fuzzy logic controller.

A fuzzy inference system (or fuzzy system) basically consists of a formulation of the mapping from a given input set to an output set using fuzzy logic. This mapping process provides the basis from which the inference or conclusion can be made. A fuzzy inference process consists of the following steps:

- Step 1:Fuzzification of input variables
- Step 2: Application of fuzzy operator (AND,OR,NOT) in the IF(antecedent) part of the rule
- Step 3: Implication from the antecedent to the consequent(THEN part of the rules)
- Step 4: Aggregation of the consequents across the rules
- Step 5: Defuzzification

The crisp inputs are converted to linguistic variables in fuzzification based on membership function (MF). An MF is acurve that defines how the values of a fuzzy variable in a certain domain are mapped to a membership value μ (or degree of membership) between 0 and 1. A membership function can have different shapes, as shown in figure. The simplest and most commonly used MF is the triangular-type, which can be symmetrical or asymmetrical in shape.

The basic properties of Boolean logic are also valid for Fuzzy logic. Once the inputs have been fuzzified, we know the degree to which each part of the antecedent of a rule has been satisfied. Based on the rule, OR or AND operation on the fuzzy variables is done.

The implication step helps to evaluate the consequent part of a rule. There are a number of implication methods in the literature, out of which Mamdani and TS types are frequently used. Mamdani, proposed this method which is the most commonly used implication method. In this, the output is truncated at the value based on degree of membership to give the fuzzy output. Takagai-Sugeno-Kang method of implication is different from Mamdani in a way that, the output MFs is only constants or have linear relations with the inputs.

The result of the implication and aggregation stpes is the fuzzy output which is the union of all the outputs of individual rules that are validated or “fired”.

Conversion of this fuzzy output to crisp output is defines as defuzzification. There are many methods of defuzzification out of which

- Center of Area (COA) and
- Height method

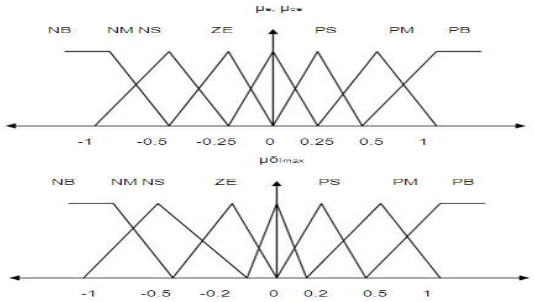
are frequently used.

Here in this scheme, the error e and change of error ce are used as 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).

The fuzzy controller is characterized as follows:

- Seven fuzzy sets for each input and output.
- Triangular membership functions for simplicity.
- Fuzzification using continuous universe of discourse.
- Implication using Mamdani's 'min' operator.
- Defuzzification using the 'height' method.

The below Figure.shows the normalized triangular membership functions used in fuzzification



(a)Membership functions for e and ce
(b)Membership function for δI_{max}

B. Design of Control Rules

The fuzzy control rule design involves defining rules that relate the input variables to the output model properties. The input variables of the FLC are the error e and the change of error ce.The output is the change of the reference current (δI_{max}). The time step response of a stable closed loop system should have a shape shown in figure (a). and figure (b). shows the phase plane trajectory of the step response, which shows the mapping of the error against the change in error.

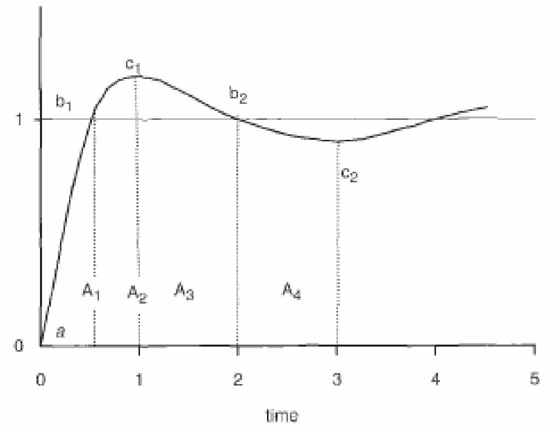
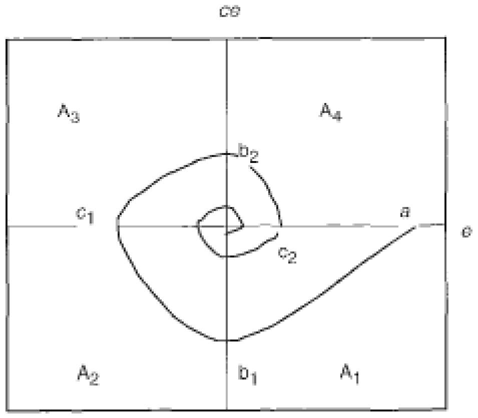


Figure.(a). Time step response of a stable closed loop system



Figure(b). Phase plane trajectory of step response.

The system equilibrium point is the origin of the phase plane. The time response has been divided into four regions A1,A2,A3, and A4 and two sets of points - cross-over (b1, b2) and peak (c1, c2). The index used for identifying the response area is defined as

A1: if e>0&ce<0, A2: if e<0&ce<0

A3:if e<0&ce>0, A4: if e>0&ce>0
The cross over index:
b1 : e>0 to e<0,ce<0
b2 : e<0 to e>0,ce>0
and the peak valley index:
c1: ce=0,e<0, and c2: ce=0,e>0

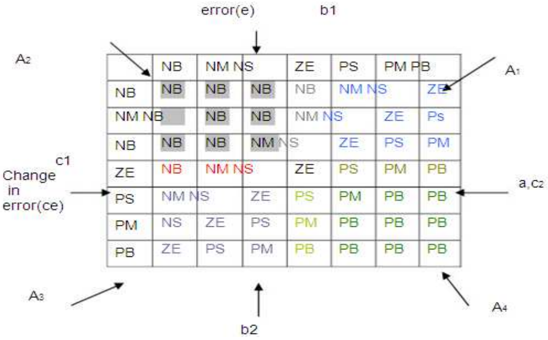
Based on these four areas, two sets of points and phase plane trajectory of e and ce, the rule base is framed. The corresponding rule for the region 1 can be formulated as rule R_1 and has the effect of shortening the rise time

R_1 : if e is + ve and ce is - ve, then $\delta I_{max}$is +ve

Rule 2 for region 2 decreases the overshoot of the system response, which can be written as

R_2 : if e is - ve and ce is - ve; then δI_{max} is – ve

Similarly, rules for other regions can be formed. For are determined based on the theory that in the transient better control performance finer fuzzy partitioned sub- state, largeerrors need coarse control, which requires spaces (NB, NM, NS, ZE, PS, PM, PB) are used, and coarse input/output variables; in the steady state, are summarized in Table. The elements of this table however, small errors need fine control, which requires fine input/output variables. Based on this, the elements of the rule table are obtained from an understanding of the filter behavior and modified by simulation performance.



	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	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
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table.1.Control rule table

VI. MODELLING OF THE SYSTEM

A program is developed to simulate the fuzzy logic based shunt active power filter in MATLAB. The complete active power filter system is composed mainly of three-phase source, a nonlinear load, a voltage source PWM converter, and a fuzzy controller or a PI controller. All these components are modeled separately, integrated and then solved to simulate the system.

A. Modelling of non linear load

A three-phase diode rectifier with input impedance and R-L load is considered as a nonlinear load. Due to the presence of source inductance, six overlapping and six non-overlapping conduction intervals occur in a cycle. During a non-overlapping interval only two devices will conduct while during an overlapping interval three devices of the bridge will conduct simultaneously. The dynamic equations during non-overlap and overlap intervals are given in (1) and (2) respectively:

$$Pi_d= (V_0-(2R_S + R_L)i_d- 2v_d)/(2L_s + L) \qquad (11)$$

$$Pi_d = (V_0-(1.5R_S + R_L)i_d- 2v_d)/(1.5L_s + L) \quad (12)$$

Where $R_s$andL_s are the elements of the source inductance, v_d is the voltage drop across each device, R_L and L are the elements of load impedance, i_d is the load current flowing through the diode pairs and p is the differential operator d/dt). V_0 is the AC side line voltage segment (v_{ac}, v_{bc}, v_{ba}, v_{ca}, v_{cb}, v_{ab} during non-overlap, and $v_{bc}+v_{ac}/2$, $v_{ba}+v_{bc}/2$, $v_{ca}+v_{ba}/2$, $v_{cb}+v_{ca}/2$, $v_{ab}+v_{cb}/2$, $v_{ac}+v_{ab}/2$ during overlap intervals) based on diode pair conduction. The phase currents i_{sa}, i_{sb}, and i_{sc} are obtained by i_d, considering the respective diode pair conduction.

B. Modelling of PWM Converter

The PWM converter has been modeled as having a three phase AC voltage applied through a filter impedance (Rc,Lc) on its input, and DC bus capacitor on its output. The three phase voltages vfa, vfb, and vfcreflected on the input side can be expressed in terms of the DC bus capacitor voltage Vdcand switching functions stating the on/off status of the devices of each leg Sa, Sband Sc as

$$\begin{aligned} vfa &= (Vdc/3)(2Sa-Sb-Sc) \\ vfb &= (Vdc/3)\,(-Sa+2Sb-Sc) \qquad (13) \\ vfc &= (Vdc/3)\,(-Sa-Sb+2Sc \end{aligned}$$

The three phase currents i_{fa}, i_{fb}, and i_{fc} flowing through impedances (R_c, L_c) are obtained by solving the following differential equations

$$\begin{aligned} P_{ifa\,=}&\ (1/L_c)(R_c i_{fa}+ (v_{sa} - v_{fa}) \\ P_{ifb\,=}&\ (1/L_c)\,(R_c i_{fb}+ (v_{sb} - v_{fb}) \qquad (14) \\ P_{ifc\,=}&\ (1/L_c)\,(R_c i_{fc}+ (v_{sc} - v_{fc}) \end{aligned}$$

The DC capacitor current can be obtained in terms of phase currents i_{fa}, i_{fb}, and i_{fc} and the switching status (1 for on and 0 for off) of the devices $S_{a,}S_b$ and S_c

$$I_{dc} = i_{fa}S_a + i_{fb}S_b + i_{fc}S_c$$

From this, the model equation of the DC side capacitor voltage can be written as

$$pV_{dc} = (1/C_{dc})(\ i_{fa}S_a + i_{fb}S_b + i_{fc}S_c) \qquad (15)$$

C. Estimation of peak supply current

The peak value of the reference current I_{max} is estimated using fuzzy controller by controlling the DC side capacitor voltage in closed loop. The output of fuzzy control algorithm is change in peak current $\delta I_{max(n).}$ The peak reference current $I_{max(n),}$ at the nth sampling instant is determined by adding te previous peak current $I_{max(n-1)}$ to the calculated change in reference current:

$$I_{max}(n) = I_{max}(n-1) + \delta I_{max}(n)$$

In classical control theory this is integrating effect, which increases the system type and improves steady state error.

D. Hysteresis Controller

The current controller decides the switching patterns of the devices in the APF. The switching logic is formulated as

Ifi_{sa}< (i_{sa}* - hb) upper switch is OFF and lower switch is ON in leg “a” of the APF;

Ifi_{sa}> (i_{sa}* - hb) upper switch is ON and lower switch is OFF in leg “a” of the APF.

Similarly, the switches in the legs “b” and “c” are activated. Here, hb is the width of the hysteresis band around which the reference currents. In this fashion, the supply currents are regulated within the hysteresis band of their respective reference values.

The performance of active filter is analyzed by solving set of differential equations (11)-(15), with other expressions by a fourth order Rungakutta method.

VII. SIMULATION RESULTS

The system studied has also been modeled using simulink and performance of PI and Fuzzy controllers is analyzed. The system parameters selected for simulation study are given in table 7.1. Figures 7.1-7.10 shows the simulation results of the implemented system with PI controller and fuzzy controllers with simulation parameters mentioned in table 7.1. The source voltage waveform of the reference phase only (phase-a, in this case) is shown in fig.7.1. A diode rectifier with R-L load is taken as non-linear load. The THD of the load current is 27.88%. The optimum values (Kp and Ki) are found to be 0.2 and 9.32 respectively.

Table7.1.System parameters for simulation study.

S.No	**System Parameters**	**Values**
1	Source voltage(V_s)	100V(peak)
2	System frequency(f)	50Hz
3	Source impedance(R_s,L_s)	0.1Ω;0.15mH
4	Filter impedance(R_c,L_c)	0.4Ω;3.35mH
5	Load impedance(R_1,L_1)	6.7Ω;20mH
6	DC link capacitance	2000µF
7	Reference DClink voltage($V_{dc,ref}$)	220V

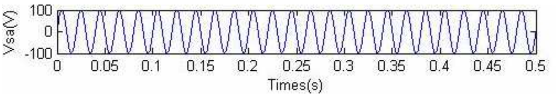


Figure.7.1. Source voltage.

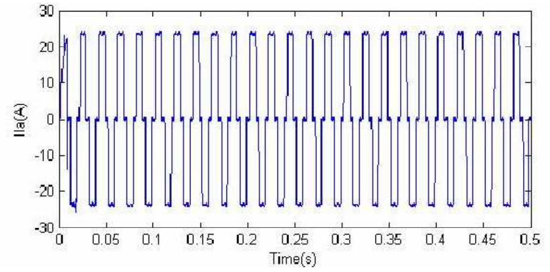


Figure.7.2.Load current.

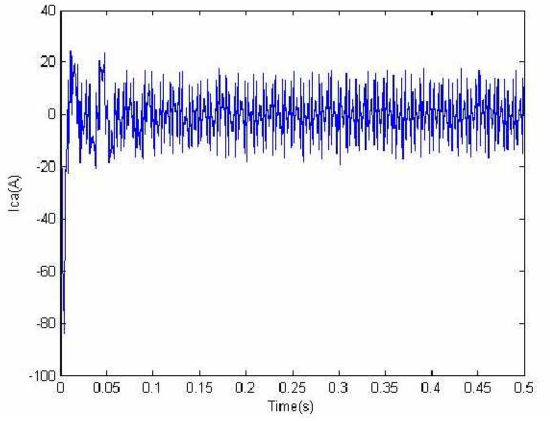


Figure.7.3. Compensating current with PI controller.

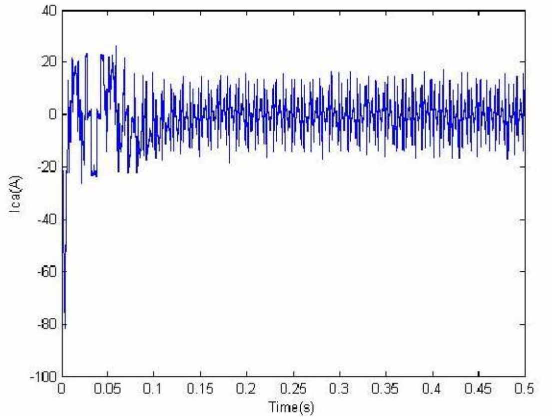


Figure.7.4. Compensating current with fuzzy controller.

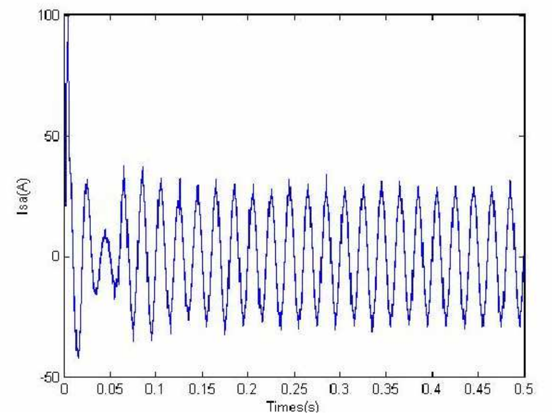


Figure.7.5. Source current with PI controller.

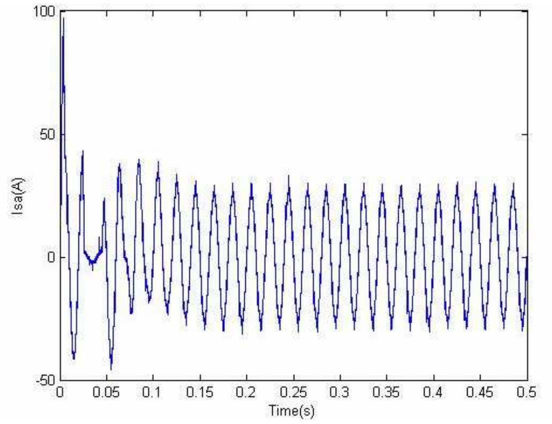


Figure.7.6. Source current with fuzzy controller.

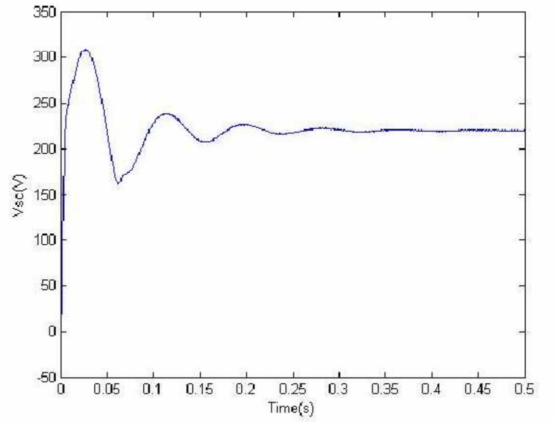


Figure.7.7. DC side capacitor voltage with PI controller.

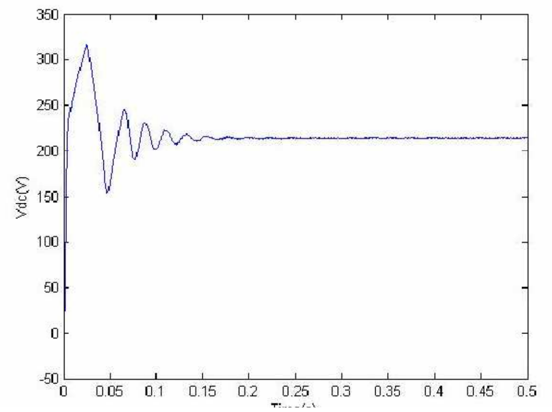


Figure.7.8. DC side capacitor voltage with Fuzzy controller.

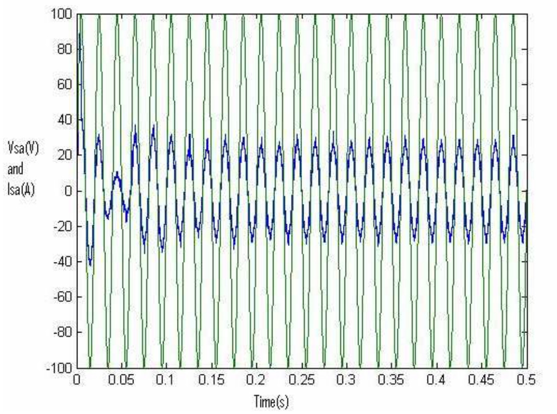


Figure.7.9. Voltage and current in phase with PI controller after compensation.

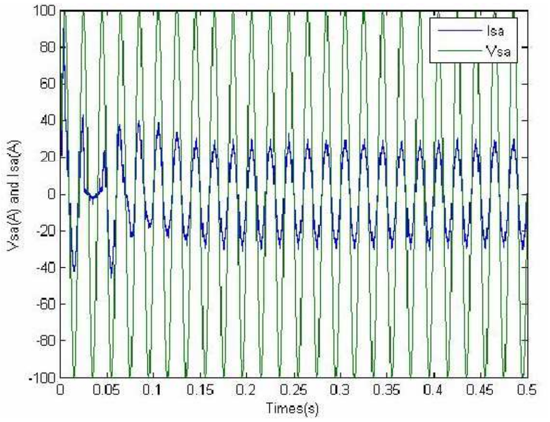


Figure.7.10. Voltage and current in phase with fuzzy controller after compensation.

From the responses it is depicted that the settling time required by the PI controller is approximately 8 cycles whereas incase of fuzzy controller is about 6 cycles. The source current THD is reduced form 27.88% to 2% incase of PI controller and 2.89% incase of fuzzy controller which is below IEEE standard with both the controllers.

VIII. CONCLUSION

A shunt active power filter has been investigated for power quality improvement. Various simulations are carried out to analyze the performance of the system. Both PI controller based and fuzzy logic controller based Shunt active power filter are implemented for harmonic and reactive power compensation of the non-linear load.A model has been developed in MATLAB SIMULINK and simulated to verify the results.The performance of both the controllers has been studied and compared.The fuzzy controller based shunt active power filter has a comparable performance to the PI controller in steady state except that settling time is very less in case of fuzzy controller.The proposed controller based shunt active power filter performs perfectly for mitigate the harmonics and FLC is better than other controllers.The THD of the source current is below 5%, the harmonics limit imposed by IEEE standard.

REFERENCES

[1] AlirezaJavadi, Handy Fortin Blanchette, Kamal Al- Haddad “An advanced control algorithm for series hybrid active filter adopting UPQC behavior”, 38th annual conference on IEEE industrial electronics society, 2012, pp 5318-5328.

[2]. F. Z. Peng, H. Akagi, and A. Nabae, “Study of active power filters using quad series voltage source PWM converters for harmonic compensation,” IEEE Transactions on Power Electronics, vol. 5, no. 1, Jan. 1990, pp. 9–15.

[3] G. Jayakrishna, K.S.R.Anjaneyulu “Fuzzy Logic Control based Three Phase Shunt Active Filter for Voltage Regulation and Harmonic Reduction” International Journal of Computer Applications (0975 – 8887), vol 10– No.5, November 2010.

[4]. H. Akagi, Y. Kanazawa, and A. Nabae, “Instantaneous reactive power compensators comprising switching devices without energy storage components,” IEEE Transactions on Industry Applications, vol. IA-20, no. 3, May/Jun. 1984, pp. 625–630.

[5]. H.Akagi, “Trends in active power line conditioners,” IEEE Transactions on power Electronics, vol 9, no 3, 1994, pp 263-268.

[6] G. Jayakrishna, K.S.R.Anjaneyulu “Fuzzy Logic Control based Three Phase Shunt Active Filter for Voltage Regulation and Harmonic Reduction” International Journal of Computer Applications (0975 – 8887), vol 10– No.5, November 2010.

[7] Karuppanan P and KamalaKantaMahapatra “PI, PID and FLC for Reactive Power and Harmonic Compensation” IEEE on Power Electronics, Drives and Energy Systems (PEDES), 2010, pp: 1 – 6.

[8] Karuppanan P and KamalaKantaMahapatra, “PLL with PI, PID and FLCs based Shunt Active Power Line Conditioners” IEEE PEDES- International Conference on Power Electronics, Drives and Energy Systems, 2010.

[9] Nitin Gupta and S. P. Singh, S. P. Dubey “Fuzzy logic controlled shunt active power filter for reactive power compensation and harmonic elimination” IEEE on Computer and Communication Technology (ICCCT), 2011 , pp: 82 – 87.

[10] ParagKanjiya, VinodKhadkikar and Hatem H. Zeineldin “A non-iterative optimized algorithm for shunt active power filter under distorted and unbalanced power supply” IEEE transactionl on industrial electronics, 2011.

[11] SakshiBangia, P R Sharma, ManeeshaGarg“Simulation of Fuzzy Logic Based Shunt Hybrid Active Filter for Power Quality Improvement” MECS, I.J. Intelligent Systems and Applications, vol 02, 2013, pp 96-104.

[12] ShilpyAgrawal, Vijay Bhuria “ Shunt active power filter for Harmonic Mitigation by Using Fuzzy Logic Controller” international journal of Advanced Research in Computer Engineering & Technology, Volume 2,Issue6, June 2013.

[13]. S. Jain, P. Agarwal, and H. O. Gupta, “Design simulation and experimental investigations on a shunt active power filter for harmonics and reactive power compensation,” Electrical Power Components and Systems, vol. 32, no. 7, Jul. 2003, pp. 671–692.

[14]. S. K. Jain, P. Agrawal, and H. O. Gupta, “Fuzzy logic controlled shunt active power filter for power quality improvement,” Proceedings of Institute of Electrical Engineers, Electrical Power Applications, vol. 149, no. 5, 2002.

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