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Power Quality Improvement using Intelligent Fuzzy-VLLMS Based Shunt Active Filter

J. Vara Lakshmi, L. Shanmukha Rao

Abstract*: The power quality problem in the power system is increased with the use of non-linear devices. Due to the use of non-linear devices like power electronic converters, there is an increase in harmonic content in the source current. Due to this there is an increase in the losses, instability and poor voltage waveform. To mitigate the harmonics and provide the reactive power compensation, we use filters. There are different filters used in the power system. Passive filters provide limited compensation, so active filters can be used for variable compensation. In this paper, a shunt active filter has been made adaptive using a Variable Leaky Least Mean Square (VLLMS) based controller. Proposed adaptive controller can be able to compensate for harmonic currents, power factor and nonlinear load unbalance. DC capacitor voltage has been regulated at a desired level using a PI controller and a self-charging circuit technique. But, this scheme has two disadvantages such as, tuning issues of current controller pre-requisites the traditional PI controller, which is controlled by intelligent based Fuzzy-Logic controller for achieving good performance features. The design concept of proposed intelligent Fuzzy controller for shunt active filter has been verified through simulation analysis and results are presented with proper comparisons.

Keywords* : Active Power Filter, Self-Charging DC-Capacitor Circuit, Adaptive Hysteresis Current Controller, Fuzzy-Logic Controller.

I. INTRODUCTION

The utilization of electrical power is intensified by several bounds and leaps in order to enhance the standard living at present days. The eminent provocations are required for generation of highly qualified energy with respect to greater reliability and standard limits at decent consequences. Now-a-days the increased attention on Power Quality (PQ) concerns is affected the end-user level commercial and industrial consumers. Majorly, power distribution system is deteriorated from the current/voltage related power quality concerns, which includes current harmonics, reactive power compensation, power factor correction, un-balance loading effects, and sag/swell. In that harmonic content creates major effects, due to the presence of non-linear characterization of power-electronic load apparatus [1].

These power quality concerns in power distribution systems are not new, but the awareness of these issues has been increased recently by end-user consumers. Non-linear load devices stimulus the impressive harmonized current components with non-unity power factor, which initiates the crucial obstacles at PCC level. Classical, power quality mitigation schemes are available in older days consisting of passive power filters and static capacitors, which are integrated in parallel to the PCC/load. Several demerits are illustrated in [1]-[3], such as only fixed harmonic mitigation, massive size, low response and may form the resonance issues with the line impedances. An advanced custom power device based active compensation scheme is utilized for enhancement of above mentioned power quality concerns [4].

The solution to above mentioned problem can be realized using a shunt active power filter[5]-[9].APF performance basically depends on the way of estimating the reference compensating signal. Instantaneous Reactive Power (IRP) theory [10], synchronous reference frame (SRF) theory [11] and modified p-q theory [12] etc. are the well-known methods of generating current reference by maintaining dc link voltage. These above cited methods are very attractive for their simplicity and ease of implementation but they are incapable in providing appropriate solution in presence of more harmonics, reactive power and unbalance or their combinations with limited power rating of Voltage Source Inverter (VSI) used as APF. Soft computing techniques such as neural network have been discussed in[13]-[14].So it can be seen that the use of artificial intelligence has been used very often as a controller in shunt active filter. A Model Reference Adaptive Sliding Mode Control (MRASMC) using radial basis function (RBF) [15] has been used as a controller in single phase Active Power Filter (APF). An adaptive sliding mode control with a Double Loop Recurrent Neural Network (DLRNN) [16] structure has been used for nonlinear dynamics system. Anew control using sliding mode control-2 [17] has also been implemented in Hybrid Series Active Power Filter(HSAPF)for making it robust and stable.

So far as signal processing techniques are concerned, Least Mean Square (LMS) is a favorable choice. Because of fixed step size in conventional LMS technique, it has slower rate of convergence.

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This can be overcome using time varying step size [18]. Since Least Mean Square of error is taken as the cost function in LMS algorithm, weights are not bounded and it takes more time to respond because of stalling effect [18]. To overcome this, leaky LMS algorithm is employed where magnitudes of weights are also included in cost function to nullify the stalling and parameter drifting effect [19], [20].

A novel VLLMS based technique for shunt active filter. Harmonic currents and reactive component of nonlinear load can be extracted using a circuit based on the above technique. Both harmonic and reactive current of nonlinear load together with signal from self-charging circuit [21] form the reference injection current of adaptive hysteresis controller for generating switching signal of three phase voltage source inverter. It will compensate unbalanced load currents and bring the power factor of the supply side to become unity. DC capacitance is also maintained at a desired level using a self-charging circuit. The main contribution of the paper is on the implementation of VLLMS in active power filter circuit for faster adaptation of active filter to any variations in operating conditions. Conventional weight updating algorithm is modified by replacing with VLLMS based weight updating algorithm, which greatly enhances the speed of algorithm and extraction. Another contribution of this paper is the use of Adaptive Hysteresis Band Current Control technique for avoiding acoustic noise uneven switching frequency in hysteresis band current control.

The self-charging PI controller never regulates the DC-link voltage under sudden interruptions, parameter variations, moderate PQ compensation characteristics etc. For this a new intelligent based Fuzzy-Logic Controller is pre-requisite for enhancing better performance of APF with improved PQ compensation characteristics with a good stability index. This paper proposes, a novel VLLMS-Fuzzy Logic based control function is used for generating optimal reference voltage and current generation scheme to proposed APF to acquire improved PQ features in a multi-feeder distribution system. The performance of APF is evaluated under the presence of classical PI and proposed Fuzzy Logic controllers by using MATLAB/SIMULINK tool, simulation results are conferred with comparative studies.

II. PROPOSED ACTIVE POWER FILTER DRIVEN BY VLMMS CONTROL TECHNIQUE

A. Active Power Filter

The current source i_L is used to model the instantaneous current of the nonlinear load that can be represented by

$$i_L(t) = i_{L1}\sin(\omega t + \phi_{L1}) + \sum_{n=2}^{\infty} i_{Ln}\sin(n\omega t + \phi_{L1})$$

$$i_L = i_{L1}\sin\omega t\cos\phi_{L1} + i_{L1}\sin\phi_{L1}\cos\omega t + \sum_{n=2}^{\infty} i_{Ln}\sin(n\omega t + \phi_{L1})$$

$$i_L = i_{L1,p} + i_{L1,q} + i_{Ln} \qquad (1)$$

Where i_{L1} is the peak value of the fundamental component and i_{Ln} is the peak value of the harmonic component. ϕ_{L1} and ϕ_{Ln} are the phase angles of the fundamental and the harmonic components. Fig. 1 shows the circuit for shunt APF. Voltage source v represents the instantaneous supply voltage at the PCC with i_s as its instantaneous supply current. The injection current of the shunt active filter is denoted by i_{inj}. The first order low-pass filter in series with the VSI output is represented by inductor L_{sh} with resistor R_{sh} as the inverter losses. V_{dc} /2 denote the voltage of each capacitor unit. In (1) above, the instantaneous current of the nonlinear load is expanded into 3terms.The first term is the load instantaneous fundamental phase current $i_{L1,p}$ which is always in phase with the supply voltage. The second term $i_{L1,p}$ is the load instantaneous fundamental quadrature current which is always 90° out of phase with the supply voltage. The third term i_{Ln} is the load instantaneous harmonic currents. From Fig.1,it can be shown that

$$i_s + i_{inj} = i_{L1,p} + i_{L1,q} + i_{Ln} \qquad (2)$$

In order to have i_s that is almost in phase with v and at the same time consists only of the fundamental component, from (2)

$$i_{inj} = i_{L1,p} + i_{Ln} \qquad (3)$$

The dc voltage of each capacitor V_{dc} /2 is also measured and passed to the self-charging circuit to regulate to its reference voltage level $V^*/2$.The output signal from the self-charging circuit i_{dc} together with $i_{L1,p}$ and i_{Ln} will form the reference injection current of the adaptive shunt active filter i^*.

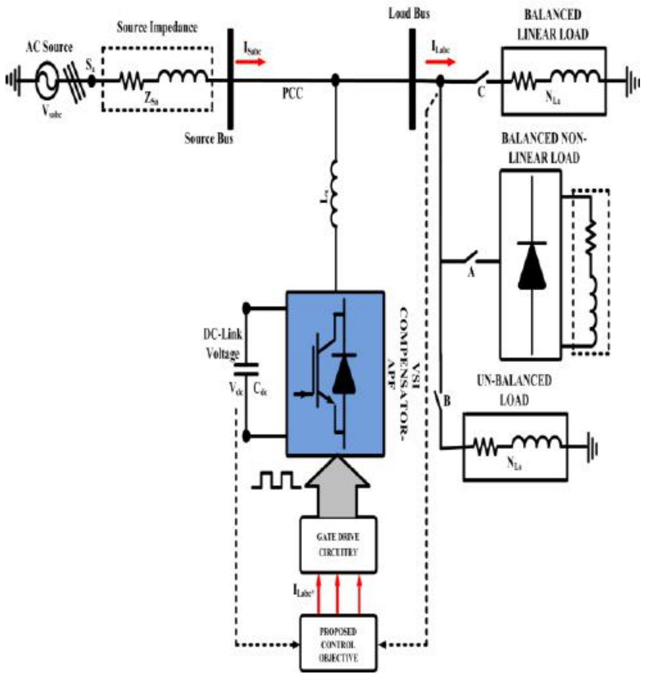

Fig.1. Block Diagram of Proposed APF Compensation Scheme

A. Proposed VLLMS Algorithm

Here a VLLMS algorithm is used for extraction of fundamental active component of current from load current. For that, signal can be modeled as

$$y(t) = \sum_{n=2}^{\infty} A_n \sin(n\omega t + \phi_{L1})$$
$$y(k) = \sum_{n=2}^{N} [A_n \sin(n\omega kT)\cos\phi_n + A_n \cos(nwkT)\sin\phi_n] \quad (4)$$

Equation (4) can be rewritten in Parametric form as follows

$$y(k) = H(k)X \quad (5)$$
$$H(k) = [\sin(\omega kT)\cos(\omega kT)\sin(n\omega kT)\cos(n\omega kT)] \quad (6)$$

The vector of unknown parameter

$$X = [A_1\cos(\phi_1)A_1\sin(\phi_1)....A_n\cos(\phi_n)A_n\sin(\phi_n)]^T \quad (7)$$

The VLLMS algorithm is applied to estimate the state. The algorithm minimizes the square of the error recursively by altering the unknown parameter X_k at each sampling instant using (8) given below

$$\hat{X}_{k+1} = (1 - 2\mu_k\gamma_k)\hat{X}_k + 2\mu_k e_k \hat{y}_k$$
$$\hat{y}_k = H(k)\hat{X}_k \quad (8)$$

Where the error signal is

$$e_k = y_k - \hat{y}_k \quad (9)$$

Step size μ_k is varied for better convergence of the VLLMS algorithm in the presence of noise.

$$\mu_{k+1} = \lambda\mu_k + \gamma_k R_k^2 \quad (10)$$

Where Rk represents the autocorrelation of e_k and e_{k-1}. It is computed as

$$R_k = \beta R_{k-1} + (1-\beta)e_k e_{k-1} \quad (11)$$

Where β is an exponential weighting parameter and $0<\beta<1$, and $\lambda(0<\lambda<1)$ and $\gamma > 0$ control the convergence time. The variable leakage factor γ_k can be adjusted as

$$\gamma_{k+1} = \gamma_k - 2\mu_k \rho e_k \hat{y}_k X_{k-1} \quad (12)$$

After the updating of the vector of unknown parameter using VLLMS algorithm

$$i_{L1,p} = X_1 H_{11} \quad (13)$$

As seen from Fig. 1, the current output of the VLLMS based fundamental extraction circuit is subtracted from the load current. The subtracted output serves as a major component in reference current generation. Fig. 2 shows the flow chart of the active component of fundamental current extraction scheme using VLLMS algorithm.

B. Self-Charging DC-Capacitor Circuit

To regulate the dc capacitor voltage at the desired level, an additional real power has to be drawn by the adaptive shunt active filter from the supply side to charge the two capacitors. The energy E stored in each capacitor can be represented as

$$E = \frac{1}{2}C\left(\frac{V_{dc}}{2}\right)^2 \quad (14)$$

If the value of the dc capacitor voltage changes from V_{dc} to V the change in energy is represented by

$$\Delta E = \frac{1}{2}C\left[\left(\frac{V_{dc}^1}{2}\right)^2 - \left(\frac{V_{dc}}{2}\right)^2\right] \quad (15)$$

The charging energy delivered by the three-phase supply side to the inverter for each capacitor will be

$$E_{ac} = 3Pt$$
$$= 3(V_{rms} I_{dcrms}\cos\phi)t$$

P -additional real power required
t -charging time
V_{rms} -value of instantaneous supply voltage v
I_{dc-rms} -value of the instantaneous charging current
I_{dc} -phase difference between supply voltage and charging current

$$E_{ac} = 3\frac{V}{\sqrt{2}}\frac{I_{dc}}{\sqrt{2}}\frac{T}{2} = \frac{3VI_{dc}T}{4} \quad (16)$$

Neglecting the switching losses in the inverter and according to the energy conservation law, the following equation holds from(15) and (16).

$$\Delta E = E_{ac}$$
$$\frac{1}{2}C\left[\left(\frac{V_{dc}^1}{2}\right)^2 - \left(\frac{V_{dc}}{2}\right)^2\right] = \frac{3VI_{dc}T}{4} \quad (17)$$
$$I_{dc} = \frac{2C\left[\left(\frac{V_{dc}^1}{2}\right)^2 - \left(\frac{V_{dc}}{2}\right)^2\right]}{3VT}$$

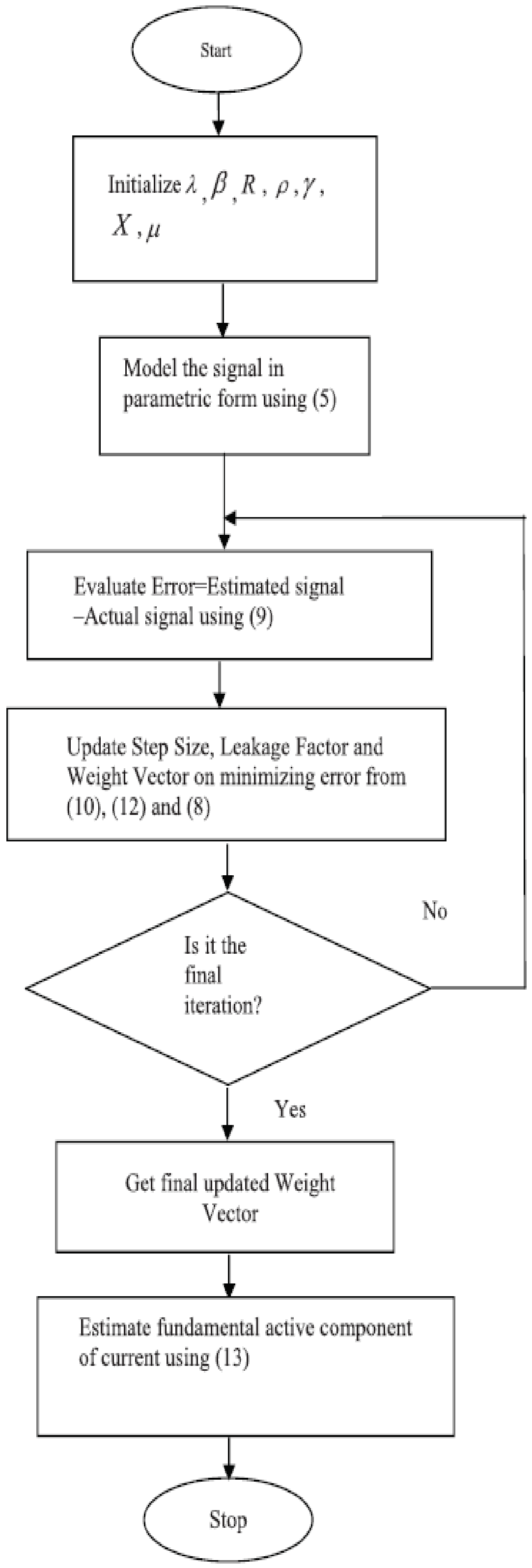

Fig. 2. Flow chart of the active fundamental current extraction scheme of

VLLMS algorithm

To maintain the value of each dc capacitor voltage at the reference level $V^*dc/2$, $Vdc/2$ is measured and fed back to a PI controller as shown in Fig. 3 to manipulate $V'dc/2$. So that it can be used in (17) to compute the required peak value of the charging current I_{dc} from the supply side. The PI controller also helps in reducing the steady state offset between the reference $V^*dc/2$ and the actual $Vdc/2$. The PLL synchronizes itself with the supply voltage of phase a i.e V_a and gives three output sine-waves which are 120° out of phase with each other. These sine waves are multiplied with I_{dc} to obtain three phase i_{dc}. In order to force the supply side to deliver i_{dc}, a term consisting of this i_{dc} is added to the three phase injection currents i_{inj} that can be represented by

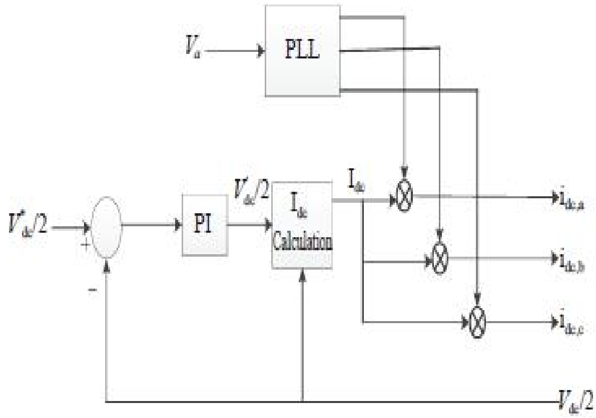

Fig.3. Three phase self-charging circuit with PI controller

$$i_{inj,a} = i_{L1,qa} + i_{Ln,a} - I_{dc}\sin\omega t$$
$$i_{inj,b} = i_{L1,qb} + i_{Ln,b} - I_{dc}\sin(\omega t - 120)$$
$$i_{inj,c} = i_{L1,qc} + i_{Ln,c} - I_{dc}\sin(\omega t + 120) \quad (18)$$

Fig. 3 shows the schematic of three phase self-charging circuit with PI controller. The negative sign indicates the flow of charging current into the VSI. For each phase it lags by an angle of 120°. The reference currents calculated shows that the adaptive shunt APF injects i_{Ln} and $i_{L1,q}$ into the line to compensate the harmonic currents and the reactive power respectively, and at the same time it receives the charging current i_{dc} from the supply to regulate the dc capacitor voltage. An inductor which acts a low pass filter is connected in between the filter and the PCC to eliminate the higher order harmonics. The compensating signals along with the original injecting currents are given to a adaptive hysteresis current controller to generate the switching pulses for the IGBTs or switches in the inverter to produce the required currents.

D. Adaptive Hysteresis Current Controller

Adaptive hysteresis control has been used in this paper to actualize (18) at the output of VSI. The mathematical expression derived in (18) has been used as the reference signal i^*_{inj} for the adaptive hysteresis control [22]. The injected current i_{inj} at the output of VSI is measured and fed back to the adaptive hysteresis control as it's another input. The adaptive hysteresis control will take the difference between i^*_{inj} and i_{inj} as given by

$$\Delta i_{inj} = i^*_{inj} - i_{inj}$$

(19)

Taking into account the value of Δi_{inj}, the adaptive hysteresis control will switch the IGBT of VSI as per the expression given in (20).

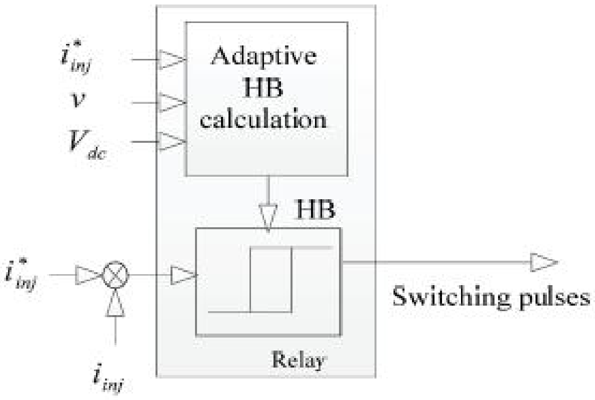

Fig.4. Adaptive hysteresis band current controller

$$Sw = adaptive\ hys(\Delta i_{inj}) = \begin{cases} 1 \ if\ \Delta i_{inj} > HB \\ 0\ if\ \Delta i_{inj} < -HB \end{cases} \quad (20)$$

Where *HB* is the hysteresis band and *Sw* is the status of the IGBT, "1" represents on and "0" represents off. The value of "*u*" shown in Fig. 1 will be "1" if *Sw*= "1" and "-1" if *Sw*= "0". In hysteresis band current control, it has a fixed hysteresis band due to which the switching frequency is not constant, are uneven in nature. Due to this uneven switching frequency acoustic noise is produced. To overcome these drawbacks, an Adaptive Hysteresis Band Current Control technique has been used which adaptively changes the hysteresis band according to system parameters such as reference source current, source voltage, switching frequency and DC Capacitor voltage, so that the switching frequency is maintained almost constant. The hysteresis band [18] can be calculated according to the following equation.

$$HB = \frac{0.125V_{dc}}{f_c L}\left[1 - \frac{4L^2}{V_{dc}^2}\left(\frac{v}{L} + m\right)^2\right] \quad (21)$$

In adaptive hysteresis band current controller, since modulation frequency *fc*, almost remains constant, this improves the PWM performances and APF substantially. Calculated hysteresis band using above (21), is applied to hysteresis band current controller as shown in Fig. 4 for switching pulse generation to be fed back to inverter.

C.Fuzzy-Logic Controller

The Fuzzy-Logic (FL) controllers authorize based on knowledge system which includes Fuzzy member-ship functions and Fuzzy rule-base to assimilate the human knowledge for getting subjective decisions. Some efforts have been developed to attain improved characteristics on system performance by integrating learning mechanism by regulating membership functions and/or rule-base system of the Fuzzy-controller [23]. The heart of the Fuzzy controller is a knowledge system which comprises of information unit for providing linguistic variables and fuzzy rule base. The system associated with database is used to characterize the fuzzy-rule functions and manipulation of fuzzy data in a Fuzzy-Logic controller and the heuristic rules of the knowledge are highly influencing the controller performance [24]. The inference mechanism decides how the fuzzy-logical operations are accomplished, and knowledge base is simultaneously determines the output of fuzzy logic controller based on IF-THEN rules.

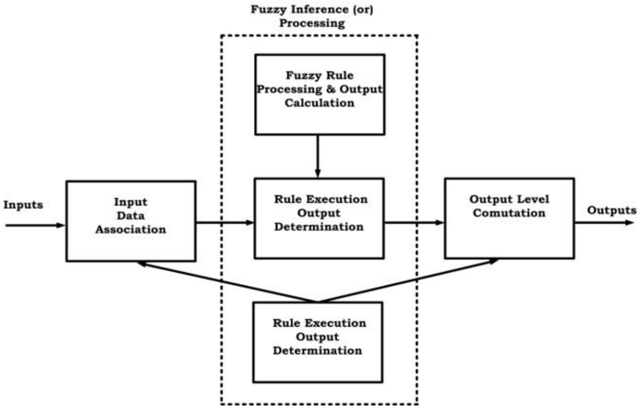

Fig.5 Fuzzy Logic Inference

The Fuzzy-Logic controller is used to furnishing the reference voltage/current signal for generation of optimal switching states to compensator based on mamdani structure. For better enhancement a combination of proposed Fuzzy controller with a VLLMS controller is used which increases the stability index and overall compensation characteristics. As well as, shunt-VSI is used to compensate current harmonics, reactive power compensation, power factor correction, etc. The error is attained from comparison of actual and reference components in terms of current and voltage imperfections are considered as input/output for FL controller with seven linguistic variables. All the membership functions of error, change in error and output are considered as triangular functions because of simple control functions as linearity principle. These membership functions are transformed to fuzzy data by using fuzzification process for making the favourable decisions as rule-base system and provide the output signals and again re-transformed into general data by using centroid method of defuzzification process. The utilized membership functions are Zero (ZE), Positive-Large (PL), Positive-Medium (PM), Positive-Small (PS) and Negative-Large (NL), Negative -Medium (NM), Negative -Small (NS), respectively as depicted in Fig.6 and the rule-base is depicted in Table.1.

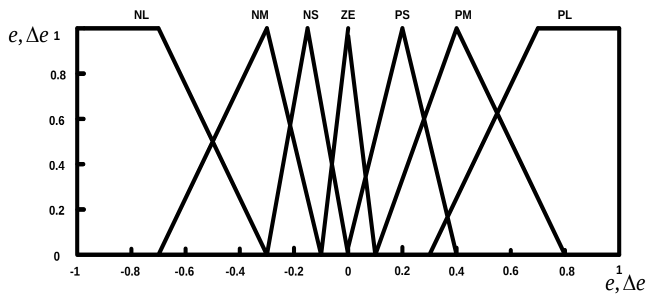

Fig. 6 Membership Functions of Hybrid FLC

Table.1 Rule-Base of FLC

e / Δe	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	ZE	NM	NS	EZ	PS	PM	PL

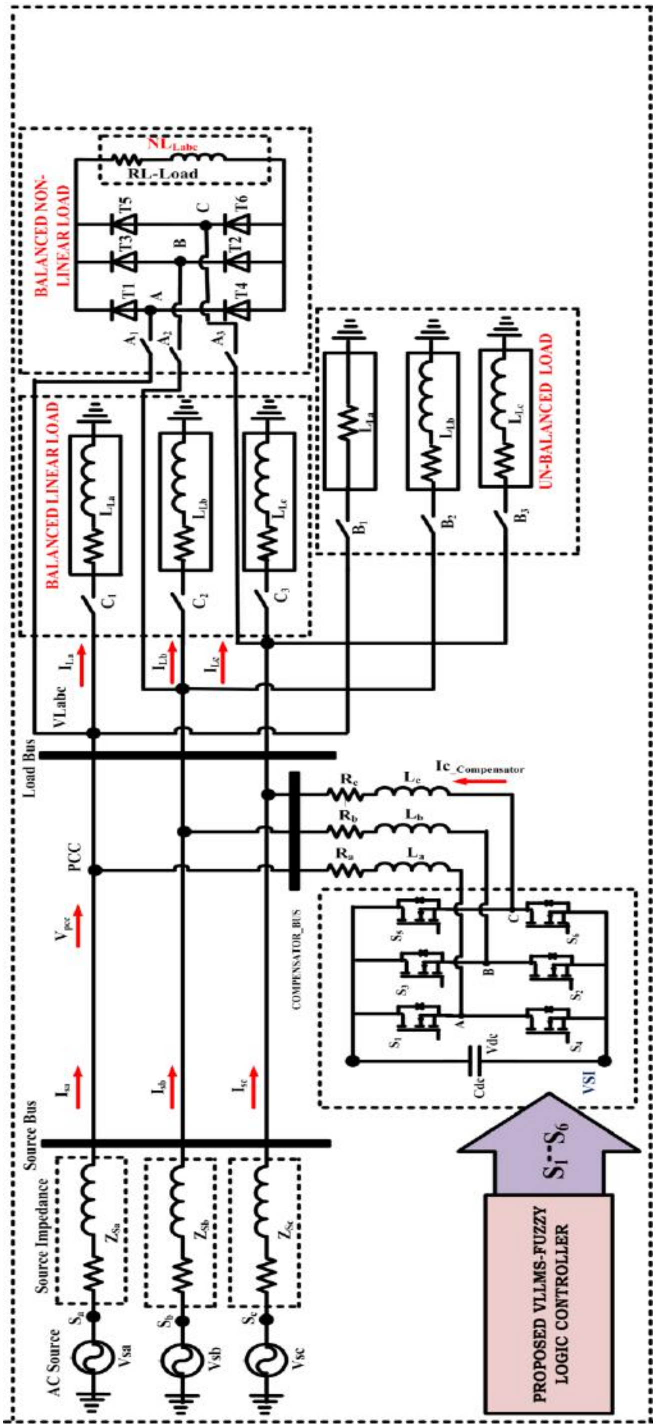

Fig.7 Over-all Schematic Diagram of Proposed VLLMS-Fuzzy Logic Controller Driven APF for PQ Enhancement

III. MATLAB/SIMULINK RESULTS

The simulation analysis is conveyed by implementation of Active-Power Filter by using proposed VLLMS-Fuzzy Logic Control scheme in a three phase power systems under several load situations with the help of system parameters, system parameters are shown in below Table.2.

Table 2. System Parameters

Parameters	Values
Source Voltage	220V, 50Hz
Source Impedance	0.1+j0.282Ω
Load Impedance	2+3jΩ
DC-Link Capacitor	1500µF
VSI Filter Units	R-0.001; L-10mH
PI Controller Gains	Kp-0.8; Ki-0.5

Case A: Without Presence of any Active-Power Filter

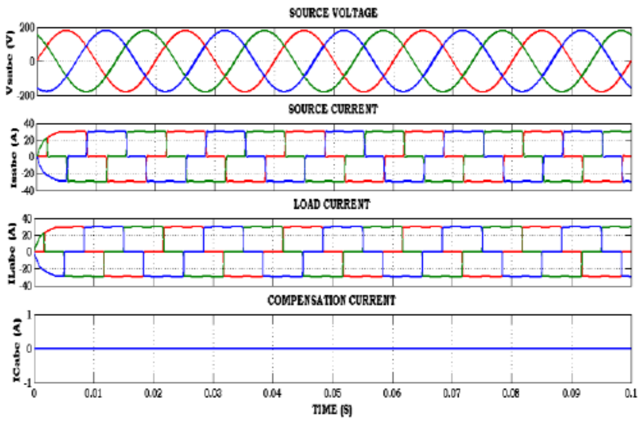

Fig.8 Simulation Results of Three Phase Power System under Non-Presence of APF

Fig.8. illustrates the various simulation outcomes of three phase power system non-presence of APF, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the balanced non-linear load, due to the NL-load device the PCC currents goes to affects as a harmonized components which is reflected the PQ concerns. Without APF compensator load parameters is always equal to source parameters, that's why both are stared as same.

Case B: Presence of VLLMS Driven APF under Balanced Linear Load

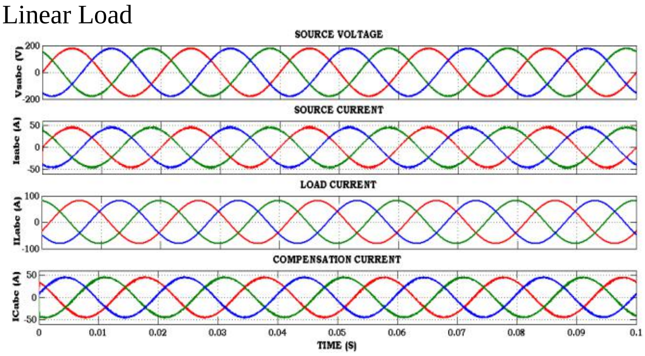

Fig.9 Simulation Results of Three Phase Power System Presence of VLLMS driven APF under Balanced Linear Load

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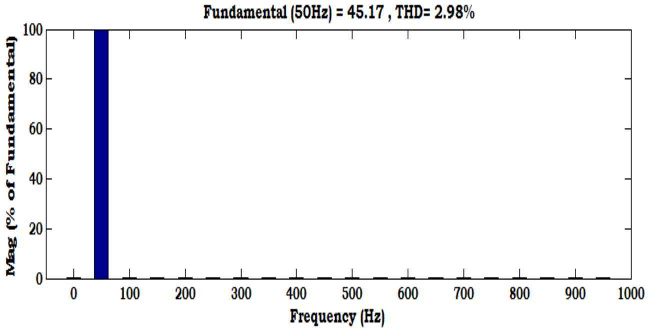


Fig.10 THD analysis of Source Current

Fig.9 illustrates the various simulation outcomes of three phase power system presence of VLLMS driven APF under balanced linear load device, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the balanced linear load, due to the linear-load device the PCC currents maintains as constant and THD of source current well within standards as depicted in Fig.10, attains 2.98%.

Case C: Presence of VLLMS Driven APF under Un-Balanced Linear Load

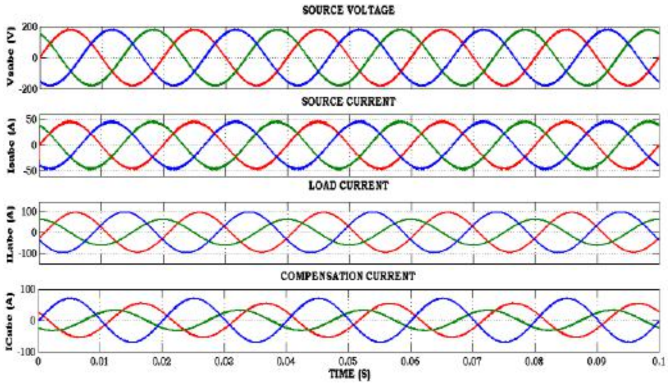


Fig.11 Simulation Results of Three Phase Power System Presence of VLLMS driven APF under Un-Balanced Linear Load

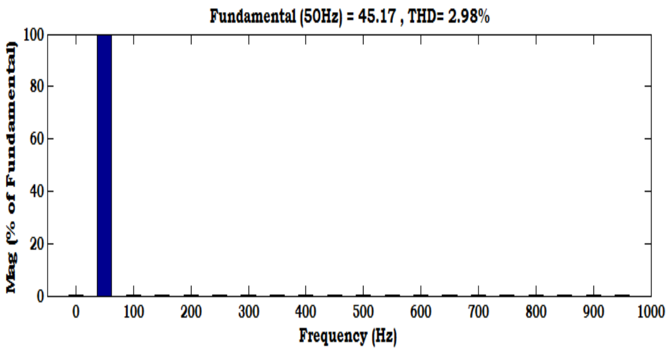


Fig.12 THD analysis of Source Current

Fig.11 illustrates the various simulation outcomes of three phase power system presence of VLLMS driven APF under unbalanced linear load device, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the unbalanced linear load, due to the unbalanced linear-load device the PCC currents are maintains as constant due to presence of APF. But load currents are maintained as unbalanced, as well as the APF injects compensated current to power system which regulates balanced nature and THD of source current well within standards as depicted in Fig.12, attains 2.98%.

Case D: Presence of VLLMS Driven APF under Balanced Non-Linear Load

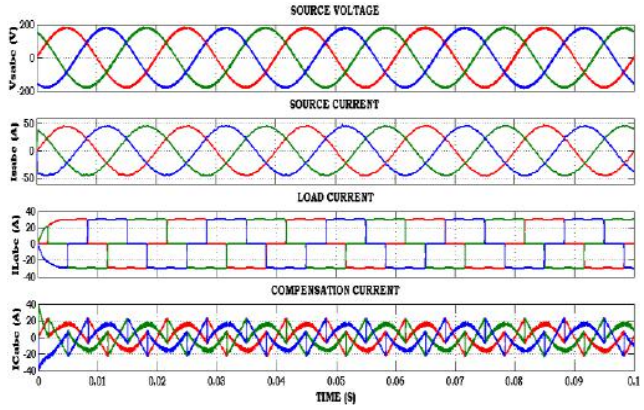
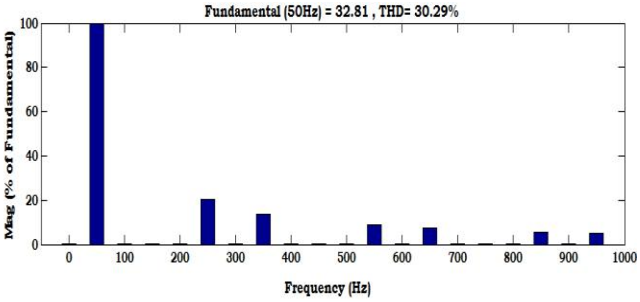
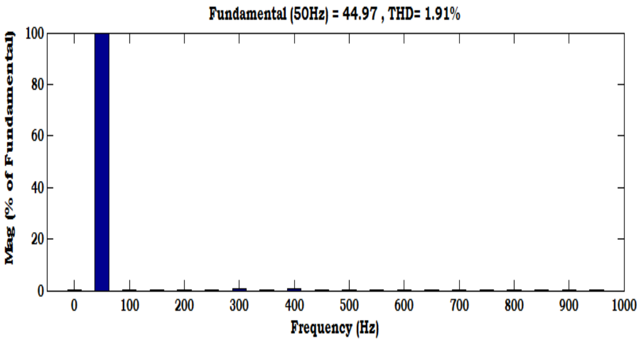


Fig.13 Simulation Results of Three Phase Power System Presence of VLLMS driven APF under Balanced Non-Linear Load



(a) THD Analysis of Source Current without Compensation (without APF)



(b) THD Analysis of Source Current with Compensation Device (with APF)

Fig.14 THD Analysis of Source Current with and without APF

Fig.13 illustrates the various simulation outcomes of three phase system presence of APF with proposed VLLMS control strategy under balanced non-linear load device, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the balanced non-linear load, due to this load device load currents are harmonized components. But source currents maintain as harmonic-free and well with in IEEE standards by using APF compensator by using attractive fundamental frequency based compensation currents.

The THD of source current without APF is 30.29% have more harmonic values and THD of source current is 1.91% have low harmonics well compensated by APF and within a IEEE-519 standard's as depicted in Fig.14.

Case E: Presence of VLLMS Driven APF under Un-Balanced Non-Linear Load

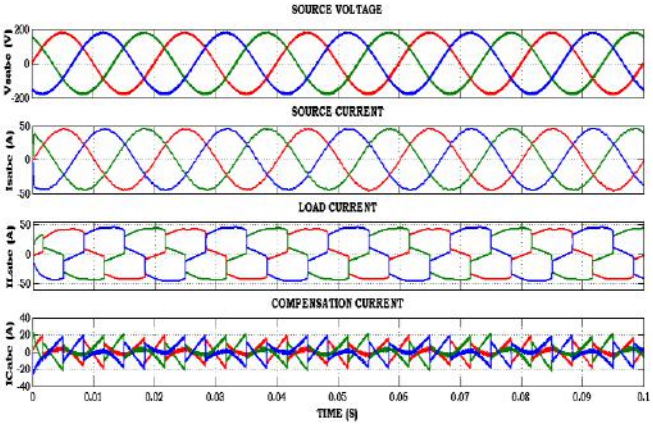
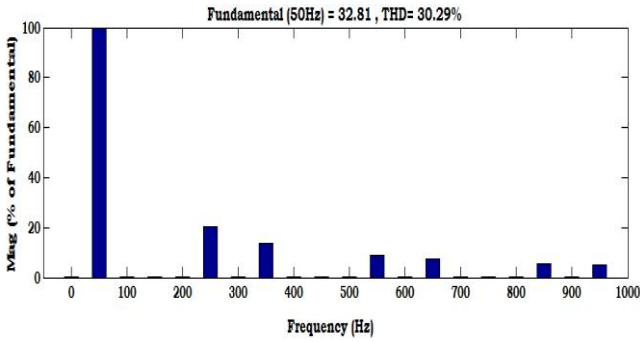
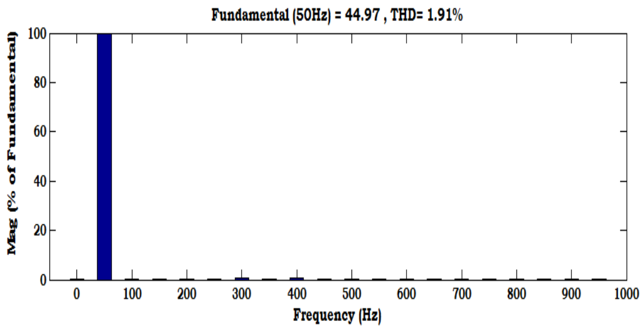


Fig.15 Simulation Results of Three Phase Power System Presence of VLLMS driven APF under Un-Balanced Non-Linear Load



(c) THD Analysis of Source Current without Compensation (without APF)



(d) THD Analysis of Source Current with Compensation Device (with APF)

Fig.16 THD Analysis of Source Current with and without APF

Fig.15 illustrates the various simulation outcomes of three phase system presence of APF with proposed VLLMS control strategy under unbalanced non-linear load device, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the unbalanced non-linear load, due to this load device load currents are unbalanced and harmonized components. But source currents maintain as harmonic-free and balanced nature well with in IEEE standards by using APF compensator by using attractive fundamental frequency based compensation currents. The THD of source current without APF is 30.29% have more harmonic values and THD of source current is 1.91% have low harmonics well compensated by APF and within a IEEE-519 standard's as depicted in Fig.16.

Case F: Presence of Fuzzy-Logic Controller based VLLMS Driven APF under Balanced Non-Linear Load

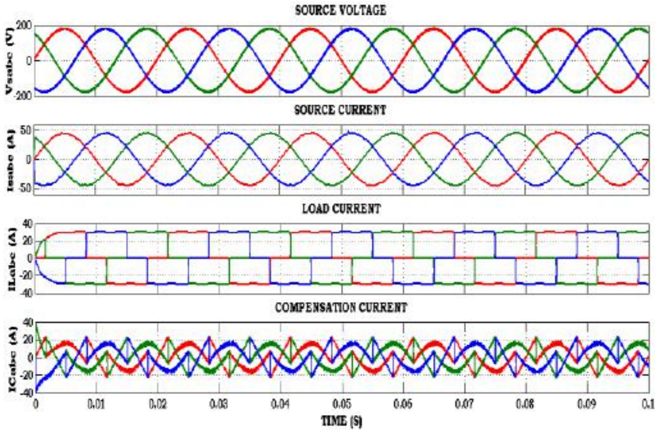


Fig.16 Simulation Results of Three Phase Power System Presence of Fuzzy-VLLMS driven APF under Balanced Non-Linear Load

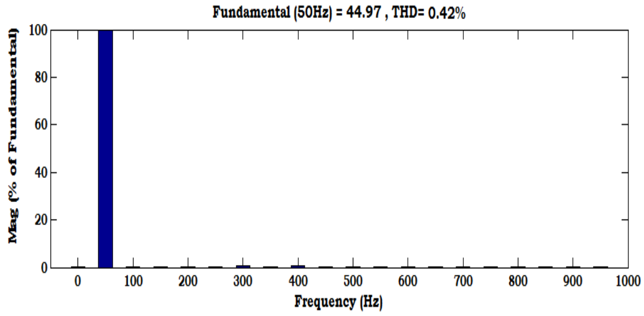


Fig.17 THD Analysis of Source Current with Compensation Device (with APF)

Fig.16 illustrates the various simulation outcomes of three phase system presence of APF with proposed Fuzzy-VLLMS control strategy under balanced non-linear load device, in that (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, respectively. In this case load is treated as the balanced non-linear load, due to this load device load currents are harmonized components. But source currents maintain as harmonic-free and well with in IEEE standards by using APF compensator by using attractive fundamental frequency based compensation currents. The THD of source current with Fuzzy-VLLMS controller driven APF is 0.42% have low harmonics well compensated by APF and within a IEEE-519 standards as depicted in Fig.17.

IV. CONCLUSION

In this paper, a new control design for the shunt active power filter has been presented. The controller design is based on Fuzzy-Logic controller based VLLMS algorithm for fundamental current extraction.

With the use of this proposed algorithm, the performance of shunt active filter has been enhanced in various load conditions like balanced and unbalanced nonlinear load currents. Self-charging capability has also been integrated into the proposed shunt active power filter for regulating the DC Capacitor voltage. Simulation results under various system operating conditions have verified the effectiveness and robustness of the proposed adaptive shunt active filter.

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