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Power Quality Improvement Using Interleaved Boost Converter Fed Shunt Active Filter In Photo Voltaic System

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Abstract: *Interleaved Boost Converter(ILBC) is a better converter between Photo Voltaic(PV) source and shunt active power filter. This paper deals with comparison of time domain outputs of PI and Fuzzy Logic controlled ILBC fed shunt active filter in a grid connected PV system. The aim of this work is to minimize current ripple using ILBC between PV system and filter to improve the performance of shunt active filter. Closed loop monitored PI and fuzzy systems are modeled, and the corresponding results are presented. MATLAB results of load voltage, current, converter voltage and currents with Fuzzy Logic Controller exhibits enhanced dynamic response. The proposed fuzzy logic controlled ILBC Fed Shunt Active Filter system (ILBCFSAF) has advantages like low settling time, less peak over shoot and reduced steady state error in load voltage.*

Keywords*: Shunt Active Filter, Inter Leaved Boost Converter, Fuzzy Logic Controller, Non linear load*

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I. Introduction

Distribution sources such as Photo-Voltaic (PV) generation system, have become popular as green and environmental friendly power source. The Voltage Source inverter(VSI) is the principle component of PV system that can also be used as Shunt Active Filter(SAF) whose output is controlled by pulses to convert dc power of PV into ac and to inject equivalent currents to filter out harmonics. The pulses are produced by a controller that processes error signal between a reference voltage and input dc voltage of converter. Conventionally PI or PID controllers are used for this purpose but suffer from frequent tuning of their parameters for different load and disturbance conditions. In this paper knowledge based Fuzzy Logic Controller(FLC) is designed and replaced for PI controller that generates pulses according to Maximum Power Point Tracking(MPPT)Algorithm. Though there are many MPPT algorithms available a simple yet effective method known as Constant Voltage method is used for operating PV panel at a voltage corresponding to maximum power.The step up converters have drawbacks of low voltage gain and low power rating. Interleaved Boost converter has reduced ripple currents in both the input and output sides is therefore used for boosting the low voltage PV to required level demanded by SAF. Analysis and hardware implementation of two phase ILBC is proposed in [1] where in design of magnetic component i.e., inductor is studied. Two inductor boost converter systems (TIBC) are analysed in [2] and shown that it is capable of giving higher output power. High gain four stage ILBC is proposed in [3] which is a combination of two 2 phase interleaved boost converters to obtain smooth output ripple current, increase in power rating and efficiency. Boost Converter with two inductors, a resonant tank, voltage doubler circuit and a snubber circuit was proposed in[4] and is coupled to PV module which offers low current ripple, reasonable cost and high boost ability. As far as the controlling of SAF is concerned, the Instantaneous Power Theory (IPT) and its application to power conditioning given by Akagi [5] is the basis for SAF. A detailed review of SAF with respect to control techniques and topology is presented by Bhimsingh[6]. High power and high temperature studies of IL DC-DC converters were conducted in [7] where in Performance analysis based on inductor coupling type, ripple analysis and flux density analysis for CCM operation was presented. A method to evaluate the performance of utility interactive PV system is given by Abouzahr[8]. The design of SAF with output LCL filter is given by Tang[9]. The control algorithm of SAF for voltage regulation and PFC is depicted by Haddad[10]. A selection methodology for the number of phases and analysis of the input current ripple with CCM and DCM for an ILBC is given in [11]. In[12], a grid-connected PV system with Boost converter and dual four-leg inverter is presented. A study of various PV fed Active filters with respect to their circuit and control methods is presented in [13]. To investigate various Power Quality issues such as THD, phase imbalance and excessive neutral currents etc., a predictive control technique using FLC is proposed in [14] where in FLC is applied for MPPT. Basic concepts regarding design of ILBC which involves selection of inductors, input and output capacitors, power switches etc., was given in[15].Lot of research on single stage PV grid-connected system with power quality improvement has been done so far but not many studies are available on Boost Converter topologies used to boost the low magnitude PV voltages. In this paper, a novel high capacity grid-connected PV system based on Interleaved Boost converter fed Shunt active filter is proposed, which has reduced current ripple.

The problem formulation involves improving dynamic response of ILBCFSAF system. The pulse width applied to the boost converter is adjusted to obtain constant voltage at the output. The FLC is proposed to improve the dynamic response.

The content of this paper is organized as follows: Section.2 deals with description of existing and proposed system. Control schemes of the systems are described in the 3rd section. Simulation results are described in section 4.The work is concluded in section 5.

II. System Description

Block diagram of the proposed ILBCFSAF system is shown in Fig.2.1. A three phase voltage source inverter is made to work as SAF and is the key component of the system, dc required to charge the capacitor of the SAF is obtained from ILBC. Voltage of this dc Link capacitor is compared

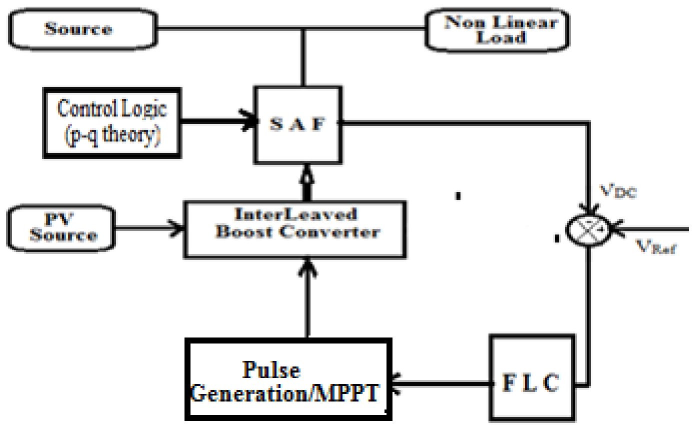


Fig.2.1 Schematic diagram of the proposed system ILBCFSAF

with the reference voltage obtained from MPPT algorithm and the voltage error is applied to the FLC. The output of the FLC controls the pulse width applied to ILBC. ILBC also takes the responsibility of boosting Dc low voltage obtained from PV Source to a suitable level required by the inverter i.e.,SAF. Instantaneous p-q theory is used to generate reference currents for SAF to compensate harmonics present in the source currents and also for power factor correction.

III. Control Schemes Of The System

3.1 . Inter Leaved Boost Converter:

Boost converters are important interfaces for PV sources that has low voltage output and require voltage boost. Interleaved concept in boost converter topology is used to improve power converter performance in terms of efficiency, size, conducted electromagnetic emission, and transient response. The benefits of interleaving include high power capability, modularity, and improved reliability. However, at the cost of additional inductors and power switching devices. The ILBCs consists of several identical boost converters connected in parallel as shown in Fig.3.1 and controlled by the interleaved method which has the same switching frequency and phase shift. An effective control of these converters is needed to improve static and dynamic performance. Though conventional PI or PID controllers are useful, tuning of these for different loads is problematic. This paper proposes a fuzzy logic controller for controlling ILBC to derive good dynamic response of the load voltage.

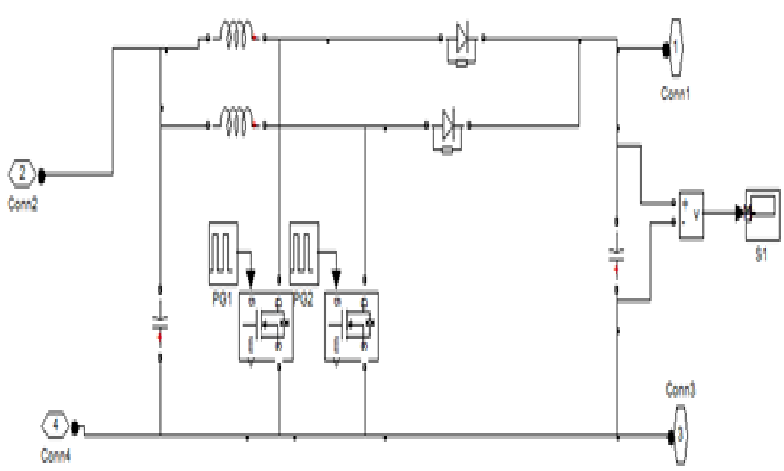


Fig.3.1 Circuit diagram of ILBC

The design considerations of ILBC are as follows

L and C for ILBC are determined using

$$L = V_i\, D/f\, I \qquad (3.1)$$

$$C = D/2.f.R \qquad (3.2)$$

L_1 and L_2 works out to 130mH and C is 470µF

3.2 Control of SAPF

p-q theory is used for controlling the three leg VSI inverter is summarized below. Conversion of source voltages in to three axis α-β-0 frame using matrix C is performed.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = C \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} ; \qquad \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = C \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{3.3}$$

$$\text{Where } C = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \tag{3.4}$$

The active and reactive power demanded by the load can be decomposed into

$$p_L = \overline{p_L} + \widetilde{p_L} ; \quad q_L = \overline{q_L} + \widetilde{q_L} \tag{3.5}$$

Finally, the reference currents in the α-β-0 frame can be calculated from the above quantities and based on the requirement that source has to supply only active power and should be relieved from supplying harmonic components, reactive power components and zero sequence components demanded by the system. These reference currents are as follows:

$$\begin{bmatrix} i_{sRf0} \\ i_{sRf\alpha} \\ i_{sRf\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_0 & 0 & v_\beta & -v_\alpha \\ v_\alpha & -v_\beta & 0 & v_0 \\ v_\beta & v_\alpha & -v_0 & 0 \end{bmatrix} \times \begin{bmatrix} \bar{p}L_{\alpha\beta} + \bar{p}L_0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$= \frac{\bar{p}L_{\alpha\beta} + \bar{p}L_0}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} 0 \\ v_\alpha \\ v_\beta \end{bmatrix} \tag{3.6}$$

Assuming L= 10mH, the capacitance of SAF is calculated by

$$f_s = 1/2\pi\sqrt{L_s\, C_s} \tag{3.7}$$

Pulse width of inverter is found to be 0.66ms

3.3 Constant Voltage Method of MPPT

Because of the nonlinear behaviour of PV system, the maximum power point (MPP) varies with solar insolation, and there is a unique PV panel operating point at which the power output is maximum , Different algorithms are available to search this MPP. Constant Voltage (CV) method is used for MPPT in this paper. According to this method, The operating point of the photovoltaic array is forced to retain near the maximum power point (MPP) by regulating the solar output voltage to match a fixed reference voltage V_{ref}. The reference voltage value is set equal to the voltage at the maximum power point V_{MPP} of the characteristic photovoltaic array. The algorithm assumes that PV panel variations, such as temperature and irradiation are not significant, and the constant reference voltage is adequateto achieve performance close to the MPP. For low insolation conditions, generally the constant voltage technique is more effective than either the perturb and observe, or the incremental conductance algorithm

3.4 Proposed Fuzzy Control Algorithm

In order to implement the control Scheme of a SAF in a closed loop, the variable that represents dynamic performance of the system to be controlled is chosen as input to the controller. In this case,the DC capacitor voltage of the converter V_{dc} is sensed and then compared with the reference value V_{dcref}. The error $e(n) = V_{dcref} - V_{dc}$ and derivative of error signal 'de(n)' are used as inputs for fuzzy processing. The proposed FLC implements mamdani"s fuzzy inference method for fuzzification and centroid defuzzification. Triangular membership functions having linguistic variable of Negative Big(NB),Negative Small(NS),Zero(ZE),positive small(PS),and Positive Big(PB) are used for input variables fuzzification. As the inputs got five subsets, a rule base formulated for this application is given in Table 3.1 below.The output of the fuzzy controller after a limit(V_{max}) is used for pulses generation of ILBC.

Table.3.1 Rule base of the Fuzzy controller

Δe/e	NB	NS	ZE	PS	PB
NB	NB	NB	NM	NS	ZE
NS	NB	NS	NS	ZE	PM
ZE	NM	NS	ZE	PS	PM
PS	NM	ZE	PS	PS	PB
PB	ZE	PM	PM	PB	PB

IV. Simulation Results

Simulation studies are done using Simulink for ILBCFSAF System as shown in Fig.4.1 with a change in solar irradiation and the results are discussed in this section. The Simulation parameters used are given in Table 4.1.

Table.4.1 parameters used for simulation

Parameter	Value	Parameter	Value
Supply Voltage	415V(Peak/Phase)	Frequency	50Hz
Source Resistance	0.01ohm	Source Inductance	50mH
Load resistance	100ohm	Load capacitance	10uF
Filter Inductance	10mH/phase	Panal Sh.ckt Current	5.15A
Panal Open Ckt.voltage	230V	Panel current at MPP	4.95A
Panel voltage at MPP	230V	No.of series cells	56
No.of panels in parallel	4		

The output voltage of solar system is shown in Fig 4.2 where in voltage decreases from 240V to 160V due to a sudden fall in its input irradiation. Both linear and non linear loads are connected at the receiving end. The output of PV is applied to the SAF through ILBC.

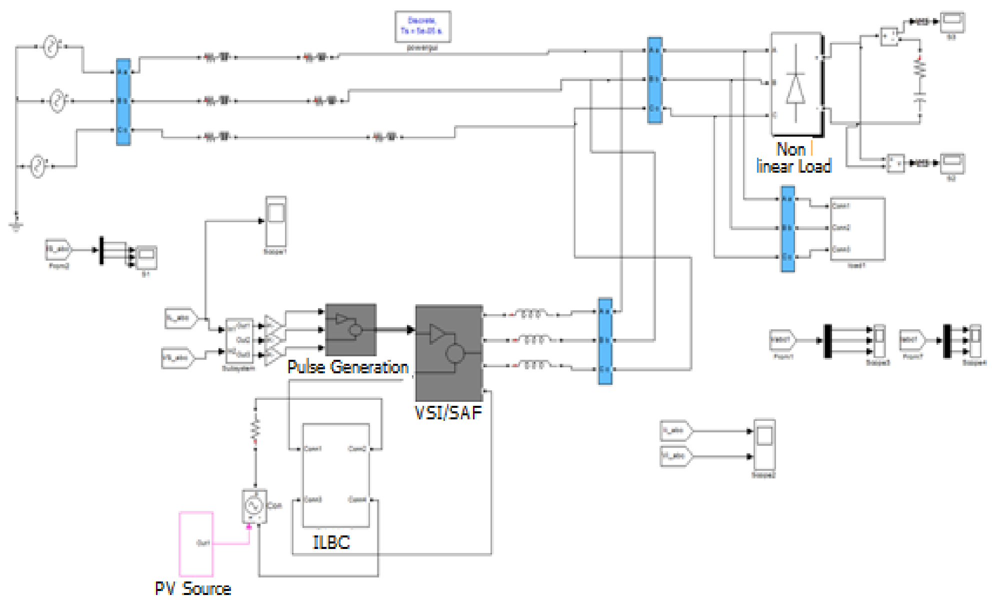


Fig.4.1 ILBC based SAF system with change in solar irradiation

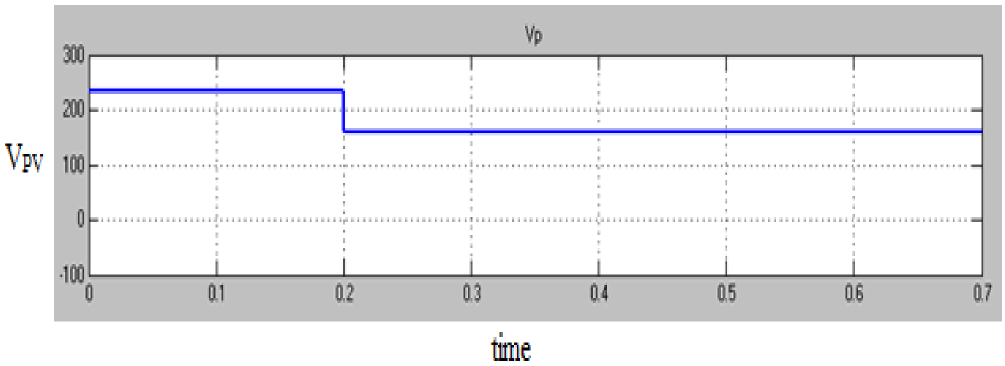


Fig.4.2 output voltage of PV system as a result of change in solar irradiation

The decrease in solar output is reflected in the output voltage of boost converter as shown in Fig.4.3.

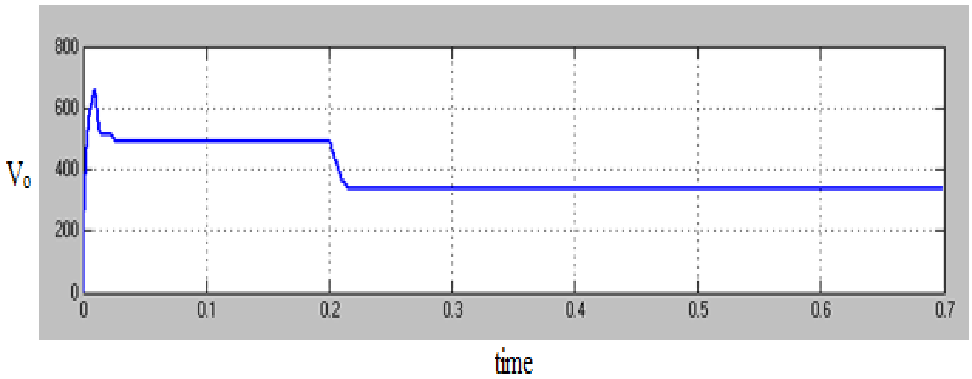
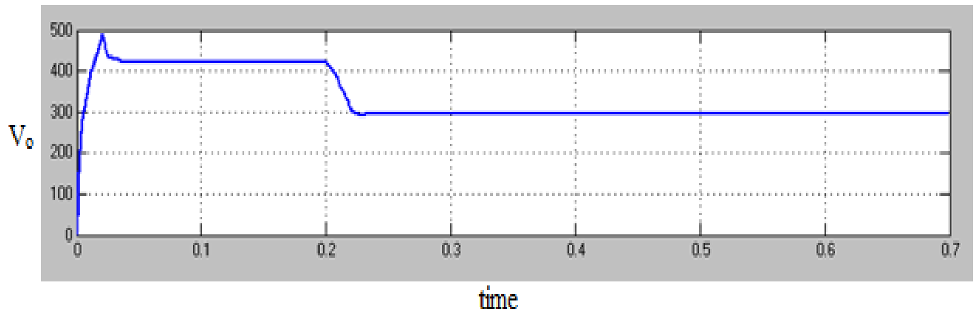
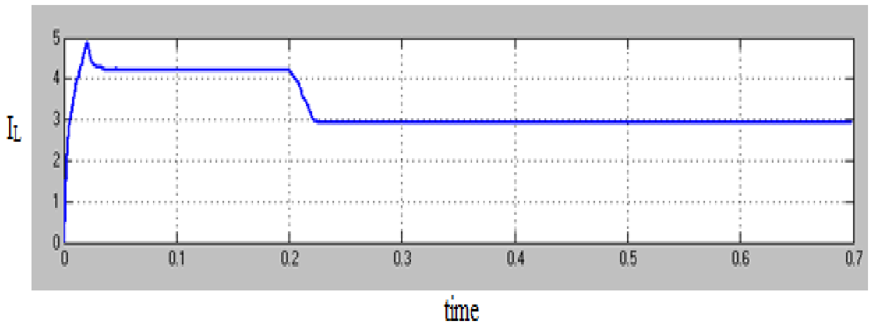


Fig.4.3 output voltage of ILBC

The rms output voltage and current values of non linear load are presented in Fig 4.4(a)and(b) respectively from which it can be observed that the voltage is decreased to 300V and current has reduced from 4.2A to 2A as a result of decrease in solar input power.



(a) RMS value of output voltage of non linear load



(b)RMS value of output current of non linear load

Fig. 4.4 output voltages and currents of non linear load due to change in solar power input

Closed loop system with PI controller is shown in Fig.4.5 The performance of ILBC in closed loop control by PI controller is examined and the results are presented. For the considered decrease in solar irradiation as in Fig.4.6, the response of load current and voltage are shown in Fig.4.7 Effective control of Boost converter using PI controller results in a considerable gain in voltage and current response of non linear load when compared to open loop mode of the system

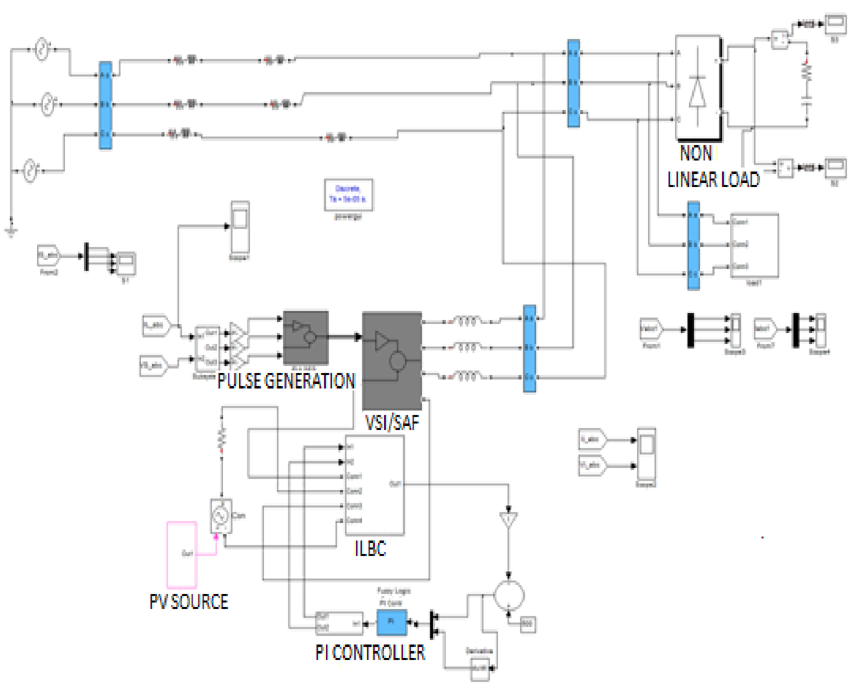


Fig.4.5 Closed loop system with PI

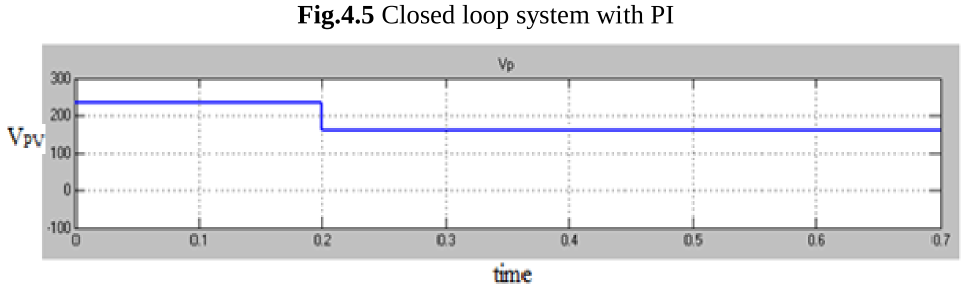
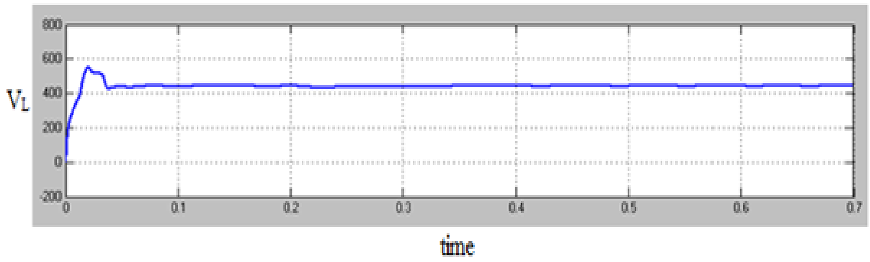
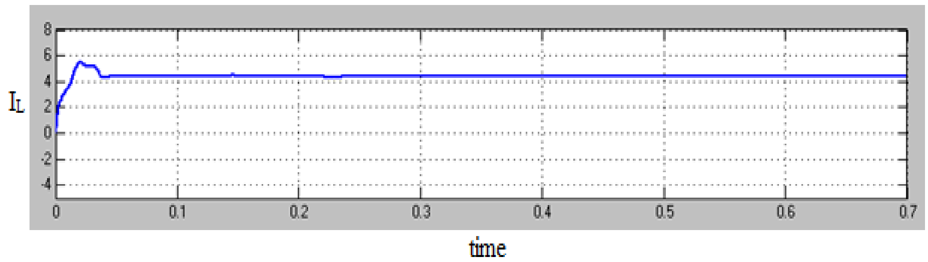


Fig.4.6 output voltage of PV system



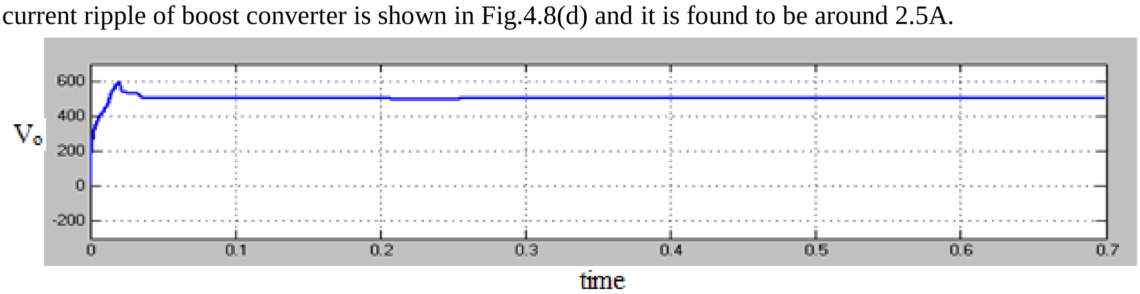
(a) voltage of non linear load



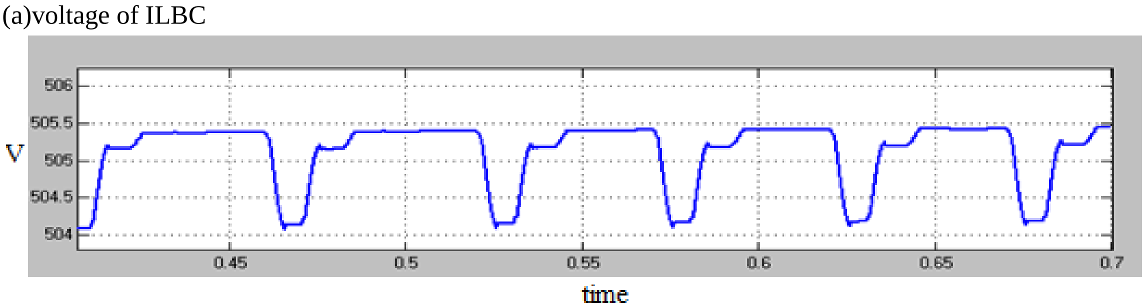
(b) Current of non linear load

Fig.4.7RMS value of output voltage and current of non linear load

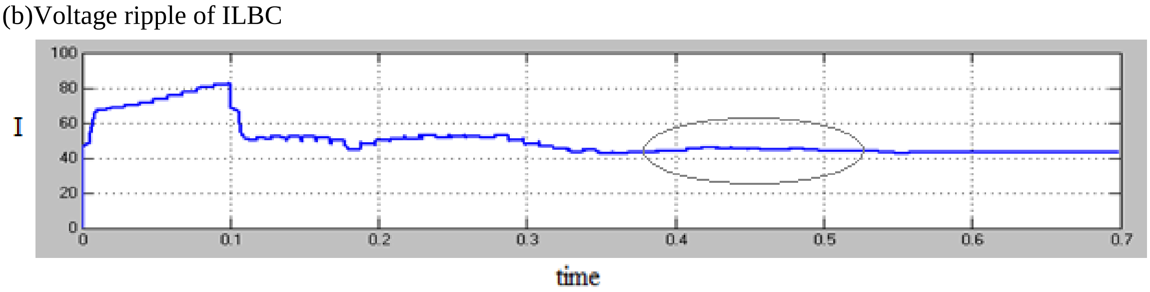
The performance of boost converter is depicted in Fig.4.8. Fig.4.8(a) is the output voltage of boost converter. Ripple in output voltage of the converter is shown in Fig4.8(b) and it is observed to be around 1.5V. Input current ripple of boost converter is shown in Fig.4.8(d) and it is found to be around 2.5A.



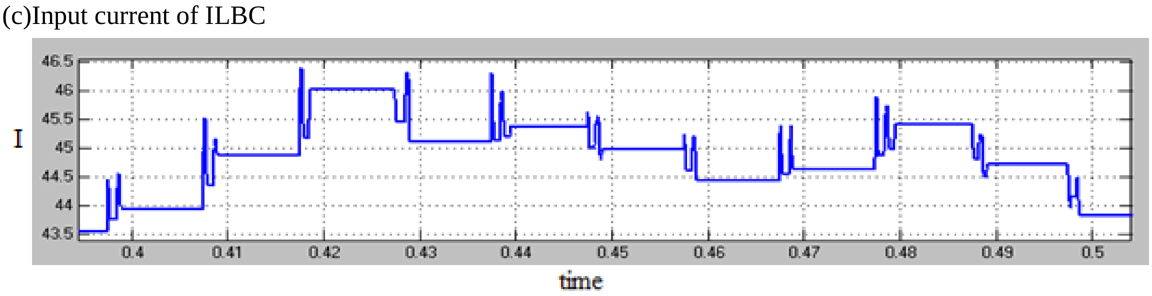
(a)voltage of ILBC



(b)Voltage ripple of ILBC



(c)Input current of ILBC



(d) Zoomed view of input current ripple of ILBC

Fig.4.8 Performance of ILBC in PI controlled system

The functioning of SAF in compensating source current harmonics for feeding non linear load is examined by source current THD and it is found to be 4.81% as shown in Fig.4.9.

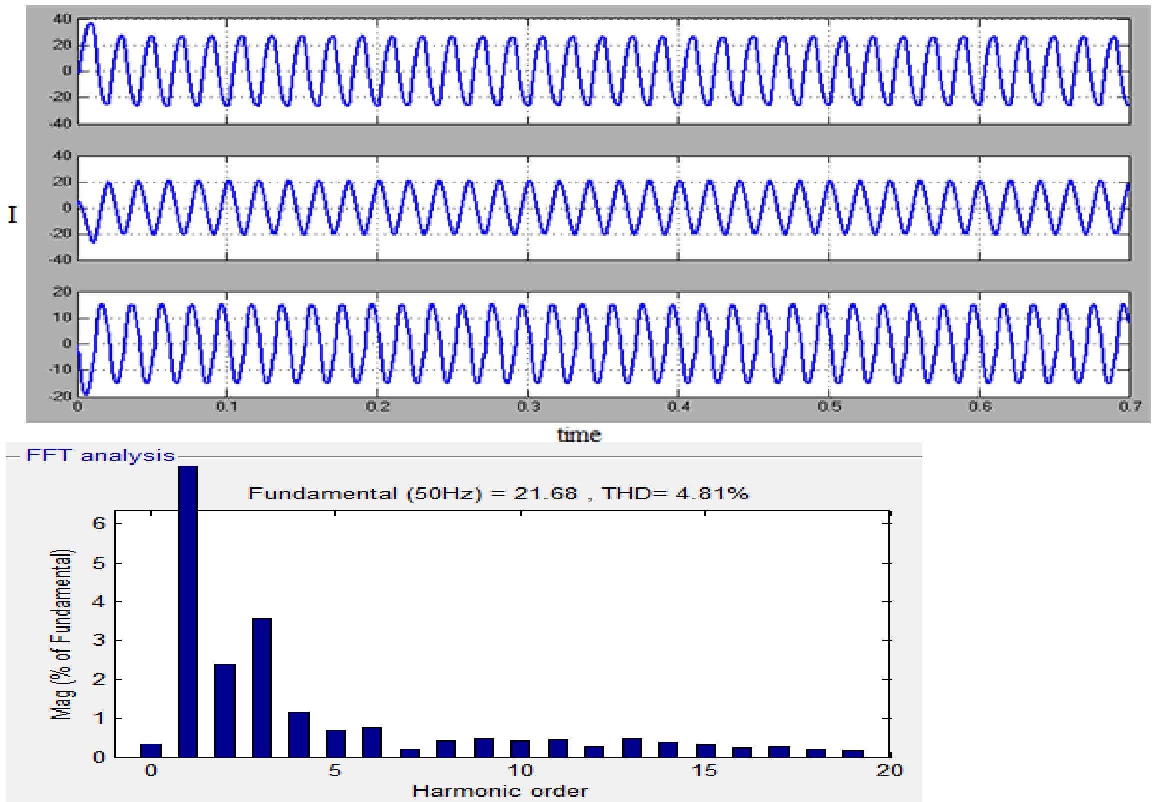


Fig.4.9 Source current and its THD spectrum for PI controlled system

PI controller of the proposed system is replaced by a fuzzy logic controller. The Simulink model of this system is shown in Fig.4.10 and the corresponding results are shown in Fig.4.11 . Voltage of boost converter is shown in Fig. 4.12. The source current and its THD value are shown in Fig.4.13. The THD is reduced to 1.9% in FL controlled ILBGFSAF system.

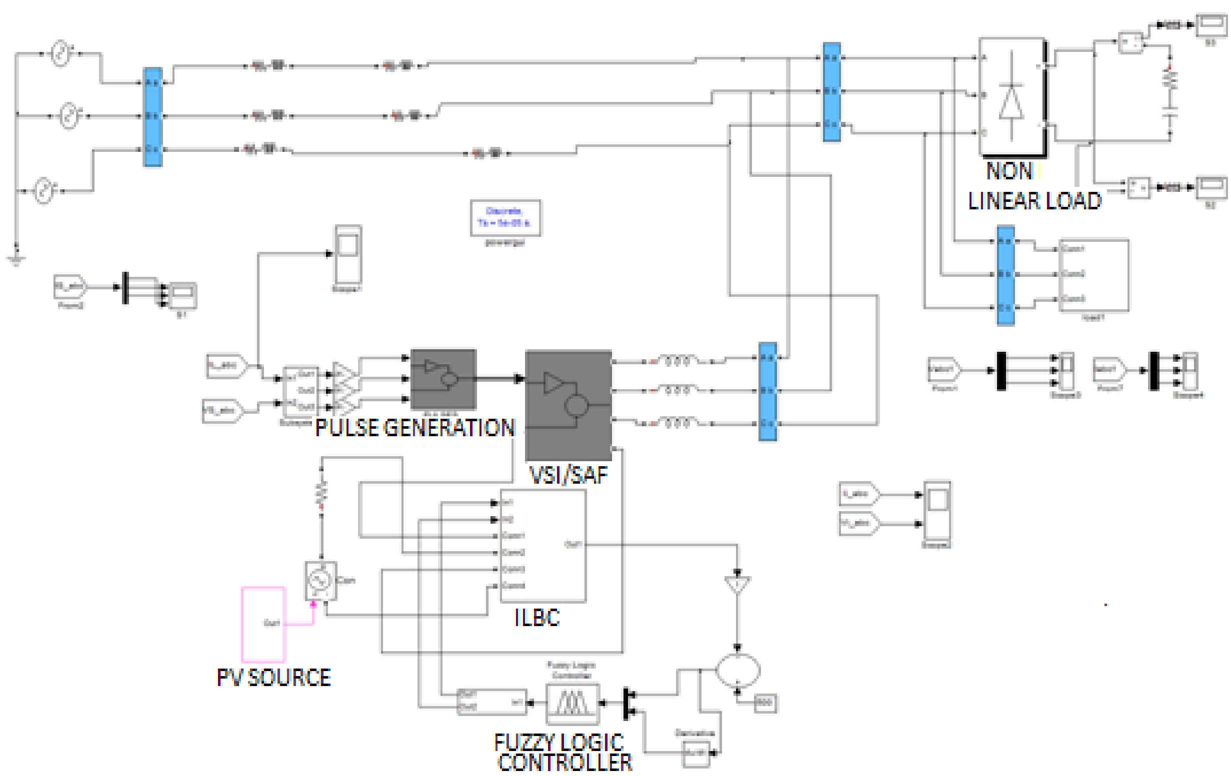
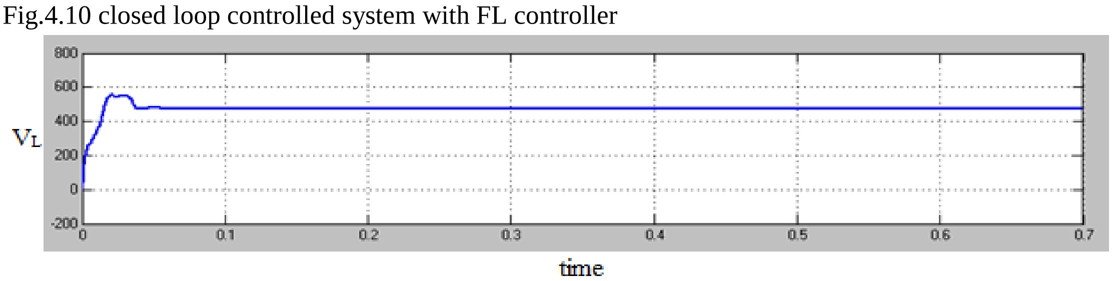
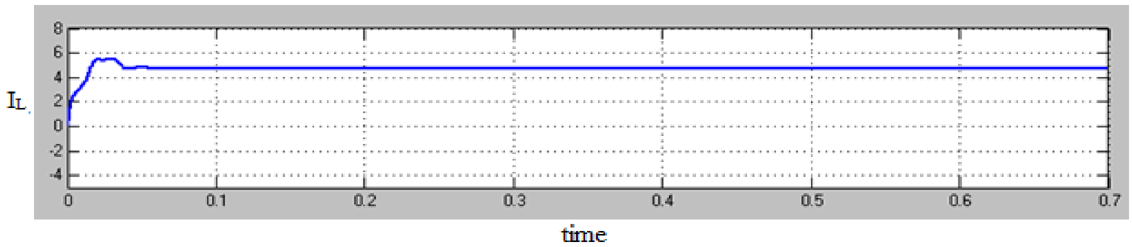


Fig.4.10 closed loop controlled system with FL controller



(a) output voltage of non linear load



(b) output current of non linear load

Fig.4.11 RMS voltage and current of non linear load

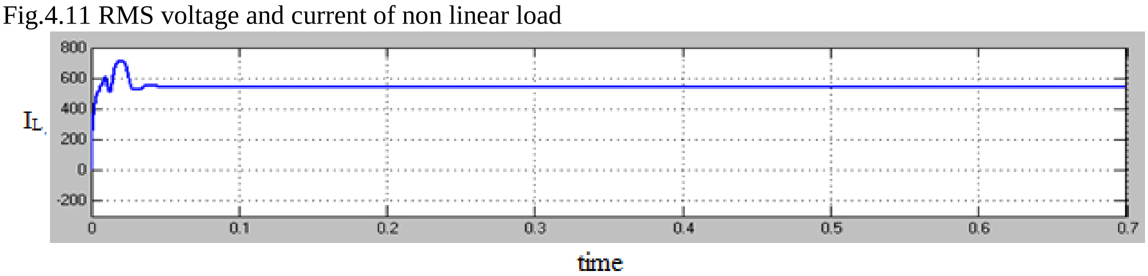
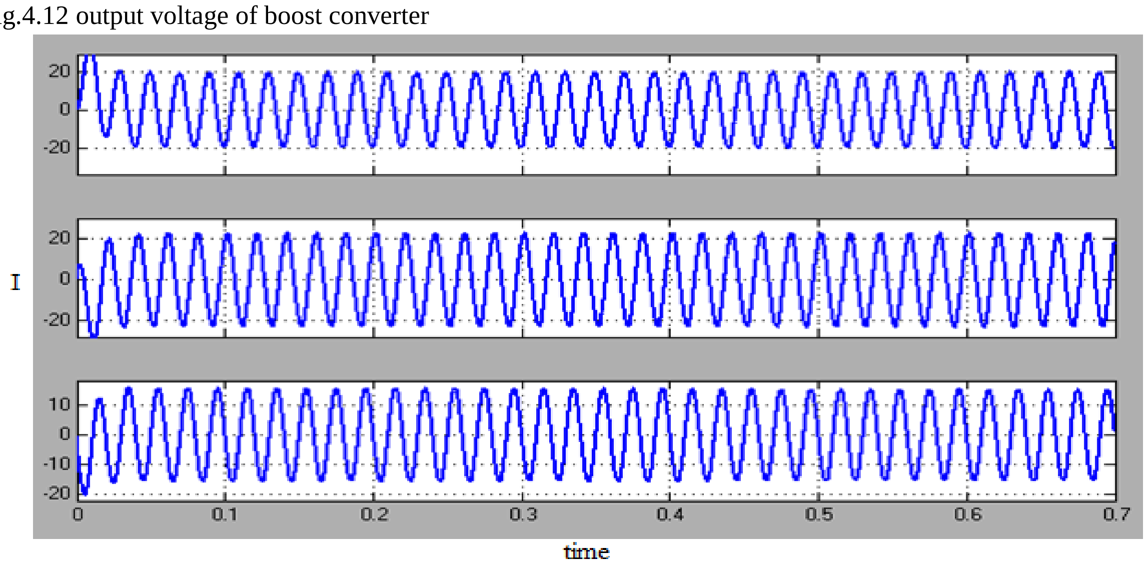


Fig.4.12 output voltage of boost converter



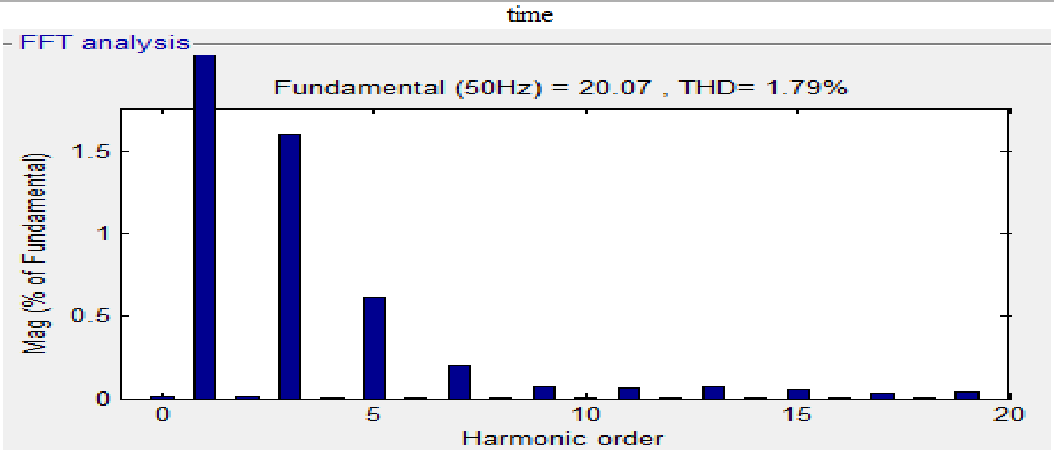


Fig.4.13 Source current and its THD spectrum for FL controlled system

The summery of time domain parameters of load current and source current THD are given in Table 4.2. Fuzzy Logic control of ILBCFSAF is superior to PI controller in terms of dynamic response for output voltage and power quality improvement of the system.

Table 4.2 Time domain parameters of load current of and THD of source current

Controller	Peak time (s)(Initial Switching)	Setting time (s)	Steady state error (V)	Source current THD
PI	0.021	0.23	9.5	4.81%
Fuzzy	0.03	0.032	1.1	1.79%

To evaluate the performance of the proposed ILBCSAF, different loading conditions are simulated by changing inductance and capacitance values of non linear load. Comparison of source current THD under these conditions are presented in Table 4.3 and 4.4

Table 4.3 is the comparison of performance of ILBC to single boost and two inductor boost from which it is evident that ILBC is offering better quality of power to the load. The increase in THD with increase in load capacitance is due to increase in the magnitude of load current. Table 4.4 below gives the comparative results of source current THD with change in load inductance from which it is clear that proposed ILBCFSAF is superior to other control methods.

Table 4.3 Comparison of Source current THD for change in Load capacitance

Capacitor	Current THD for BC	Current THD for TIBC	Current THD for ILBC
1µF	16.23%	15.33%	7.71%
25 µF	19.98%	16.33%	7.93%
50 µF	35.66%	26.54%	7.99%
75 µF	41.03%	36.93%	8.00%
100 µF	43.73%	40.79%	11.47%

Table 4.4 Comparison of Source current THD for change in Load Inductance

Inductor	Current THD for BC	Current THD for TIBC	Current THD for ILBC
1mH	29.30%	26.63%	11.67%
25mH	28.66%	26.19%	9.49%
50mH	28.15%	25.89%	8.78%
75mH	27.88%	25.72%	8.59%
100mH	27.80%	25.62%	8.20%

Inter leaved control of Boost converter has resulted in the improvement in performance of the converter. The ripple in its voltage and current are considerably reduced when compared to single and two inductor boost converters of previous work as summarized in Table 4.5.

Table.4.5 Summary of voltage and current ripple of boost converter

Shunt Active Filter System	V_{or}	I_{or}
Boost Type	20v	7A
Two Inductor Boost Type	9v	5.6A
ILBC Type	1.5v	2.5A

V. Conclusion

ILBCFSAF system controlled by PI and FLC are modeled and simulated using SIMULINK. The simulation results of PI and FL controllers are presented and analysed. The settling time with FLC for output voltage is 0.032 sec and steady state error is as low as 1.1V. Therefore the response of FLC based ILBCSAF system is better than that of PI controlled system. The advantages of proposed system are low ripple content of PV voltage and current injected at PCC and improved time domain response of load voltage. The disadvantage of proposed system is that hardware count of ILBC is twice that of normal boost converter. This work deals with comparison PI and FLC based ILBCFSAF systems.

References

[1] Nasir Coruh, Satilmis Urgun, Tarik Erfidan, Semra Ozturk," A Simple And Efficient Implemantation Of Interleaved Boost Converter" 978-1-4244-8756-1/11/$26.00 c2011 IEEE

[2] G. Kishor, D.Subbarayudu, and S.Sivanagaraju "Comparison Of Full Bridge And Two Inductor Boost Converter Systems" Journal of Theoretical and Applied Information Technology 31st December 2011. Vol. 34 No.2

[3] Weerachat Khadmun and Wanchai Subsingha "High Voltage Gain Interleaved DC Boost Converter Application for Photovoltaic Generation System" 10th Eco-Energy and Materials Science and Engineering(EMSES2012), Elsevier,Energy Procedia 34 (2013) pp.390 – 398.

[4] Krishnapriya C S, Nithin S Nair "Implementation Of Two Inductor Boost Converter For An Autonomous Photovoltaic Water Pumping System International Journal Of Electrical Engineering & Technology (Ijeet), Volume 5, Issue 12, December (2014), pp. 197-206.

[5] H. Akagi, E. Watanabe, M. Aredes "Instantaneous Power Theory and Applications to Power Conditioning: (Wiley-IEEE Press, 2007).

[6] Bhim Singh, Kamal Al-Haddad, and Ambrish Chandra "A Review of Active Filters for Power Quality Improvement" IEEE Transactions on Industrial Electronics, Vol. 46, No. 5, pp. 60 – 71, October 1999.

[7] James Scofield, Seana McNeal and Brett Jordan "Studies of interleaved dc-dc boost converters with Coupled inductors" A report submitted to Air Force Research Laboratory ,Propulsion Directorate Wright-Pattersonair Force Base, Oh 45433-7251, UNITED STATES AIR FORCE

[8] I. Abouzahr and R. Ramakumar, "An approach to assess the performance of utility-interactive photovoltaic systems," *IEEE Trans. Energy Convers.,* Vol. 8,No. 2, pp. 145–153, Jun.1993.

[9] Y. Tang, P. C. Loh, P. Wang, F. H. Choo, F. Gao, and F. Blaabjerg,"Generalized Design of High Performance Shunt Active Power Filter With Output LCL Filter" *IEEE Transactions on Industrial Electronics*, Vol. 59, No.3, pp. 1443- 1452, March 2012.

[10] Ambrish Chandra, Bhim Singh, B. N. Singh, and Kamal Al-Haddad, "An Improved Control Algorithm of Shunt Active Filter for Voltage Regulation,Harmonic Elimination, Power-Factor Correction, and Balancing of Nonlinear Loads" *IEEE Transactions on Power Electronics*, Vol. 15, No. 3, pp. 495 -507, May 2000.

[11] Gyu-Yeong Choe, Jong-Soo Kim, Hyun-Soo Kang and Byoung-Kuk Lee "An Optimal Design Methodology of an Interleaved Boost Converter for Fuel Cell Applications" *Journal of Electrical Engineering & Technology Vol. 5, No. 2, pp. 319~328, 2010*

[12] Jing Li, Fang Zhuo," A Grid-Connected PV System with Power Quality Improvement Based on Boost + Dual-Level Four-Leg Inverter"

[13] H. Patel, V. Agarwal, "Investigations into the performance of photo voltaics-based active filter configurations and their control schemes under uniform and non-uniform radiation conditions" IET Renew. Power Gener., 2010, Vol. 4, Iss. 1, pp. 12–22.

[14] Hamad, M.S, Fahmy, A.M, and Abdel-Geliel, M, "Power Quality Improvement of a Single-Phase Grid-Connected PV System with Fuzzy MPPT Controller" 978-1-4799-0224-8/13/$31.00 ©2013 IEEE.

[15] "AN-1820 LM5032 Interleaved Boost Converter" Texas Instruments Incorporated *Application Report SNVA335A–May 2008–Revised May 2013.*

P. V. Ram Kumar "Power Quality Improvement Using Interleaved Boost Converter Fed Shunt Active Filter In Photo Voltaic System." IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 13.1 (2018): 42-51.