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Performance Improvement in Active Power Filter Using Fuzzy Controller

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ABSTRACT

Solar photovoltaic (SPV) is one of the most widely recognized sustainable power sources utilized as of now. The significant issue with sustainable power assets is power quality to fulfill the developing energy need. As of late dependability and adaptability of energy supply are likewise connected with the nature of force. The issues appended with line shortcomings, voltage hang/enlarge, sounds in supply and gleam are the critical worries for unfortunate power quality. The new situation is intended to challenge electrical assets like age, transmission and conveyance. Taking into account sustainable power in the current power framework requires extra examination and examination to synchronize new parts. Starting here of view, many power hardware converters and exchanging gadgets are intended to build the dependability and effectiveness of the framework. Essentially, sun based PV framework requires a most extreme power direct tracker toward remove the power upto the greatest degree. It comprises of two phases: DC to DC converter and Heartbeat Width Balance controlling stage. A staggered inverter (MLI) is utilized to improve the power nature of the general framework. It diminishes the music contortion and settles the framework close to the solidarity power factor. This paper exhaustively investigations the flowed H-span Staggered Inverter related with the fluffy rationale regulator (FLC) and SPV framework. The reproduction results are contrasted and the 3-level and five levels Inverter.

1. INTRODUCTION:

Since the past few decades, there has been intensive increase in the use of power converters and switching devices, various nonlinear loads and equipment's which draw highly non-linear current from the source and thereby inject harmonics in the system. These harmonics are perilous and greatly pollute the power system. They degrade power quality by increasing total harmonic distortion (THD) and reactive power consumption and also by causing poor power factor, voltage flicker, bad voltage regulation, voltage sags and swells, unbalanced load etc.[1]-[4]. Harmonics also cause electromagnetic interference (EMI) in communication network present within certain proximity. Issues pertaining to power quality are increasing steeply, therefore, tackling these problem become an indispensable task for maintaining a good power system.

Power channels came up as a practical answer for giving clean-consonant free power at shopper closes. Traditionally, detached L-C channels were utilized for music alleviation and capacitors for power factor improvement. In any case, continuously they got supplanted by dynamic power channels (APFs) on the grounds that they are related with specific intrinsic hindrances like cumbersome size, mistuning, unsteadiness, reverberation with load impedance or utility impedance and absence of adaptability [5]-[7]. APFs give dynamic and flexible answer for the issue of force quality. Research on APF innovation blast up and an enormous number of control strategies are being proposed and carried out. At present there is an obviously enormous number of control techniques utilized for power remuneration by APFs. In this paper, a line conditioner is planned utilizing overflow H-span Staggered inverter in which traditionally input wellspring of excitation is supplanted by SPV framework related with Fluffy rationale control for separating the greatest power. The proposed line conditioner creates a repaying current inverse in bearing of line current to limit the impact of sounds present in the composite framework. The Reproduction results are contrasted and the 3-level and 5-level inverters intended for a similar composite framework. The complete music contortion (THD) and power misfortunes are significant boundaries for the assessment and expansion of execution investigation of proposed framework.

Key components and advancements in the field of environmentally friendly power-based power molding compensators are staggered inverters, most extreme Power Point Following (MPPT), and sun oriented photovoltaic (SPV) frameworks. Each is vital for working on the exhibition, reliability, and effectiveness of the frameworks. The importance of SPV frameworks lies in their capacity to outfit sun oriented energy. MPPT guarantees the proficient use of the accessible sun based power by upgrading the working mark of sun powered chargers. Staggered inverters go about as power conditioner to change over the DC power produced by sunlight based chargers into top notch AC power for dissemination in the electrical framework, adding to generally speaking framework effectiveness and security. Together, these advances improve the presentation and suitability of the proposed frameworks.

Curiosity of the proposed line compensator has dynamic capacity for improving the nature of force by following the heap current sounds content. Proposed compensator utilizes Sun powered PV framework rather than DC voltage source in ordinary CHBMLI [8]-[10]. The fluffy rationale based MPPT regulator is carried out to follow the greatest power from SPV framework. Hysteresis current control conspire is applied for creating the reference current to infuse the dynamic power part through PV upheld VSC. Followed load current containing consonant part goes through low pass channel for getting the smooth sinusoidal current which is utilized as blunder sign and render from genuine burden current for creating a repaying current in such way that is inverse in gradually work succession of symphonious current present in the framework with same extent to delivering the symphonious impact.

2. PROPOSED TECHNIQUE

The work studied about in the paper contains the power quality improvement of 3-stage supply by infusion of remunerating current in inverse heading of examined consonant current at reason behind normal coupling. The entire cycle is executed in a successive way. The methodology followed this approach of execution displayed in fig.1. It obviously explains the bit by bit course of thought about framework. The philosophy of current work accumulates data of force nature of existing framework and examination the symphonious current part present in the framework [11]-[14]. The electrical cable conditioner planned utilizing CHBMLI produces a repaying flow backward way to kill the impact of music present in the framework. Recreation results, FFT and THD examination portrayed and approved the entire cycle.

Power line conditioner involves a Sun oriented PV framework for excitation, utilizes fluffy rationale based most extreme power point regulator. It is carried out by three roles as, Fuzzification, Connection point and De-fuzzification. Contribution of the fluffy rationale is sun oriented temperature (Tx) and sun based irradiance (Sx) and yield is found as voltage. This voltage is utilized as a kind of perspective voltage (Vref) for computing the force of the board. Figure 2 shows the result of fluffy system [15]-[17].

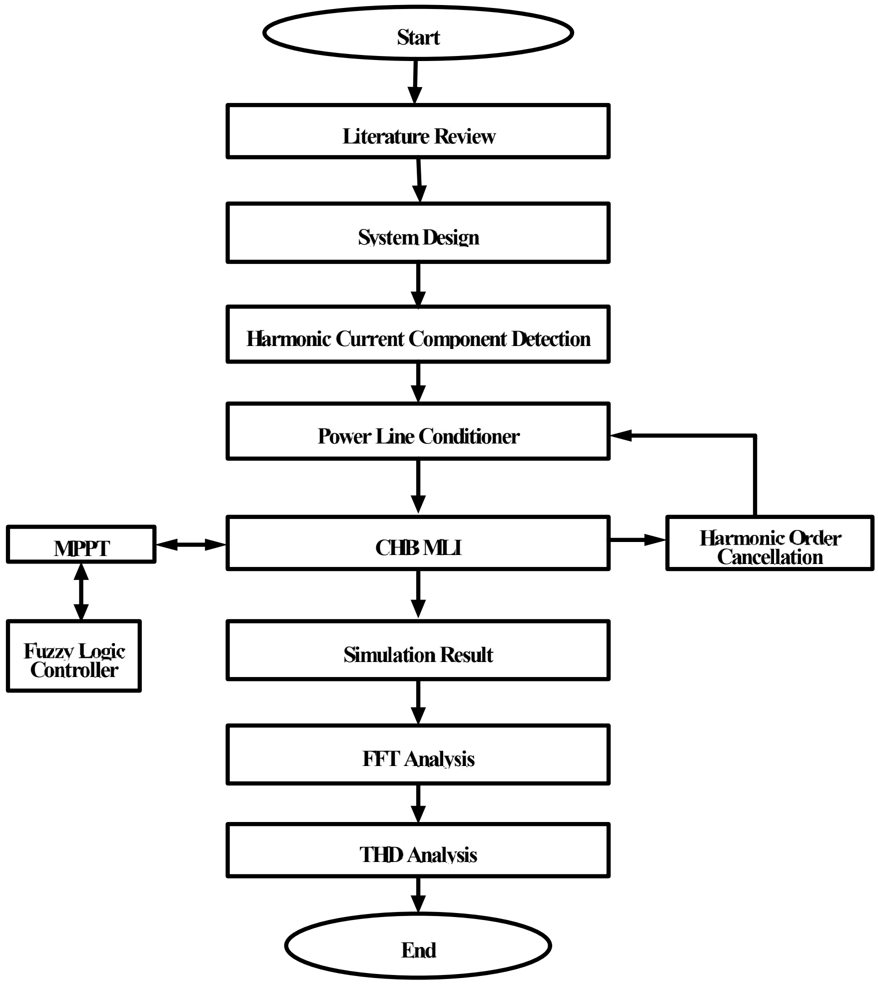


Fig.1 Methodology Implication

The multilevel inverter efficiently converts DC power to AC power with reduced harmonic distortion, while the fuzzy logic controller adapts the inverter's operation based on real-time conditions using fuzzy logic reasoning. This collaborative approach enhances the overall efficiency, reliability, and adaptability of the solar power system.

3. COMPOSITE DESIGN

The interfacing of SPV Board and CHBMLI is displayed in fig.2, where energy cushion includes battery or some other stockpiling gadget [18-19]. It is utilized for congruity in supply when the sun powered energy isn't free generally in overcast or evening. This power is benefited from the staggered inverter (MLI) in which voltage source converter (VSI) is utilized as compensator which limit the wave of current. To decrease the sounds, shunt dynamic power channel (SAPF) [20]-[23] is intended to accomplish the result voltage close to the sinusoidal way. It likewise diminishes the channel size and cost. The structure of 5 levels MLI is shown in fig. 9. The output of the system is V_α, V_β and V_0 [24]-[28].

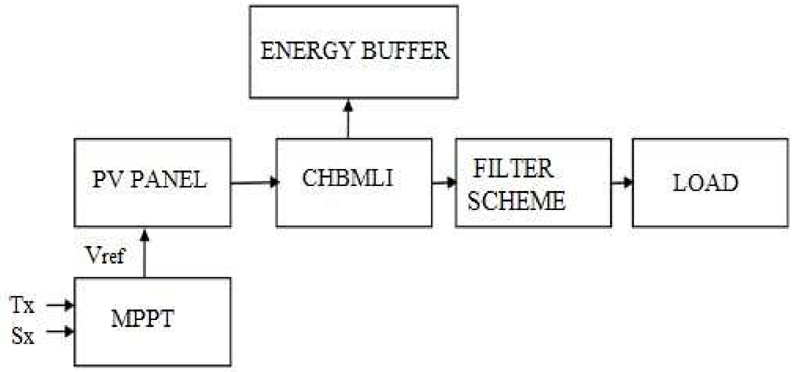


Fig.2.PV panel and CHBML1 interfacing

The outpouring H-span Staggered Inverter is chosen because of its ability to support voltage, lower consonant twisting, particular plan, and effectiveness. The determination of the Fluffy Rationale Regulator depends on its adaptability in managing nonlinear frameworks, low execution intricacy, strength to vulnerability, and viable energy preservation. These components cooperate to improve a sun oriented power framework's general steadfastness and execution.

The presentation measurements utilized for assessing a sun oriented power framework, especially while integrating an Outpouring H-span Staggered Inverter (MLI) and a Fluffy Rationale Regulator (FLC), can be different and rely upon the particular objectives and needs of the framework. Here are some key presentation measurements regularly utilized for assessment:

Energy Conversion Efficiency:

Energy conversion efficiency is a measure of how effectively the solar power system converts sunlight into usable electrical energy. It is typically calculated as the ratio of the electrical energy output to the solar energy input, expressed as a percentage.

Total Harmonic Distortion (THD)**:**

THD quantifies the distortion in the output waveform, indicating how closely the inverter output resembles a pure sinusoidal waveform. It is expressed as a percentage and is calculated based on the amplitudes of harmonics relative to the fundamental frequency.

Maximum Power Point Tracking (MPPT) Efficiency:

MPPT efficiency measures how well the MPPT algorithm tracks and maintains the solar panels at their maximum power point under varying environmental conditions. It is the ratio of the actual power output to the maximum power available from the solar panels.

Response Time:

Response time measures how quickly the solar power system, including the Fuzzy Logic Controller, can adapt to changes in environmental conditions or system parameters. It is often measured in seconds and indicates the system's agility in responding to dynamic conditions.

Modulation Index Control:

The modulation index controls the amplitude of the output waveform in multilevel inverters. Efficient control of the modulation index is crucial for optimizing the inverter's performance. It involves assessing the ability of the Fuzzy Logic Controller to adjust the modulation index dynamically.

3.1 CASCADED MULTILEVEL INVERTER

The multi-level inverter consisting of a series of single complete H- bridge converters, each with a separate dc bus. Conventionally it used to convert DC to AC source as shown in fig.3 [29]-[32]. In the proposed work it is used to replicate the compensating current.

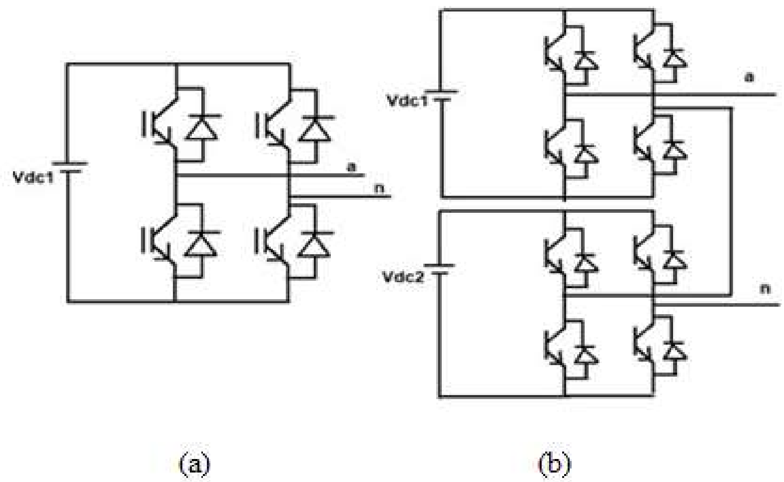


Fig.3. Cascaded inverter (a) 3-level (b) 5-level

Comparing cascade H-bridge multilevel inverters with 3-level and 5-level multilevel inverters involves evaluating various criteria to determine their performance, efficiency, and suitability for specific applications. Here are several criteria consider:

- Capable of achieving a high number of voltage levels by cascading multiple H-bridge inverters.
- THD depends on the number of cascade stages and modulation technique. 3-level inverter: Typically, lower THD compared to 2-level inverters. 5-level inverter: Generally lower THD compared to 3-level inverters.
- Cascade H-bridge: May have higher switching losses due to multiple stages. 3-level inverter: Lower switching losses compared to cascade H-bridge for similar power ratings. 5-level inverter have higher switching losses than 3-level inverters but still lower than cascade H-bridge.
- 5 level inverter has more efficiency as compared to 3 level inverter.

1.1 3.2 MPPT

The fuzzy logic based MPPT controller is implemented to fulfill the voltage demand of $_{\text{line}}$ compensator as shown in fig.4. Mamdani's-based constant voltage (CV) method is used for extracting the maximum power which automatically adjusts the reference voltage at various environmental conditions [33-36]. The fuzzy logic controller toolbox is simulated in the MATLAB/Simulink environment to determine the open circuit voltage (Voc).

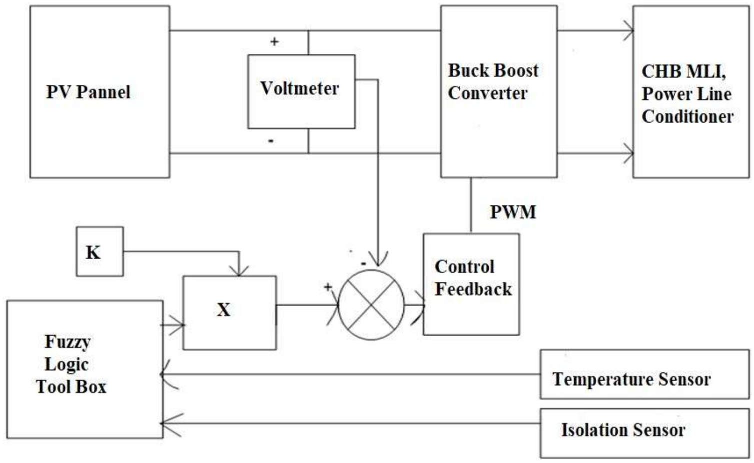


Fig.4 Fuzzy logic based MPPT controller

1.2 3.3 Shunt Active Power Filter

Shunt active power filters inject an equal-but-opposite harmonic compensation current to balance out current harmonics. In this instance, the shunt active power filters functions as a current source, injecting the phase-shifted harmonic components produced by the load. Any kind of load regarded as a harmonic source can be used according to this approach [37]-[38]. The compensation approach is shown in fig. 5.

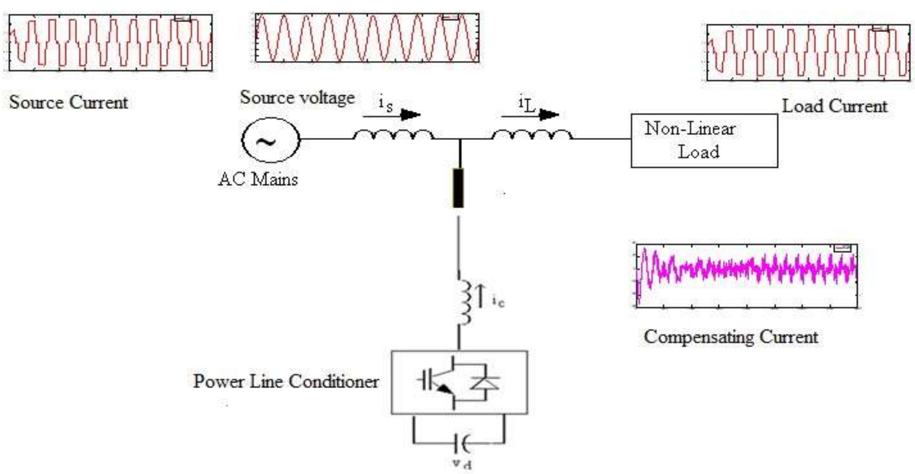


Fig.5 Current compensation characteristic of the shunt active power filter

4. POWER QUALITY PROBLEMS IN COMPOSITE SYSTEM

The broad categories of power quality problems of composite power system are categorized in Table.1 [27].

4.1 Mathematical modeling of Power Quality Compensation

By specifying zero sequence power, the p-q theory emphasizes a three-phase, four-wire system. The goal of this simulation is to examine the performance of the compensation procedure in generalized power quality enhancements such as reactive power compensation, harmonic elimination, and imbalance compensation [39]-

[42]. This is done by using the instantaneous p-q theory to verify the compensation technique. The next section contains the required transformation formulae.

1.3 4.2 Compensation with p-q Theory

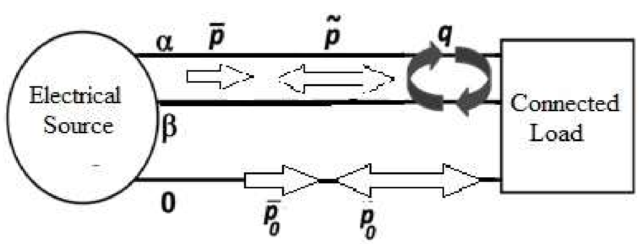
The algebraic conversion of the currents and voltages in three-phase to two-phase sequences based on p-q theory instantaneous power components is rendered as follows.

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

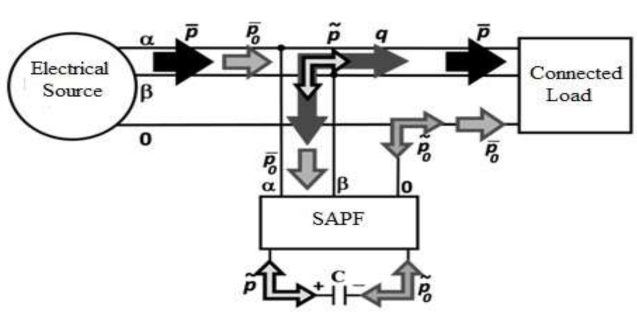
i_0, i_α, i_β are zero sequence current along α axis and β axis current respectively.

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

$v_0\ v_\alpha\ v_\beta$, are zero sequence voltage, α axis, β axis voltage respectively. p, q, p_0 are instantaneous real, reactive and zero sequence power and depicted in Figure 6(a) and 6 (b) evinced that the active filter capacitor is sufficient to recompense the alternating unusual active and zero sequence power [20-26].



(a)



(b) Fig. 6. (a) p-q power components (b) Compensation of power components.

Instantaneous zero-sequence power is recompensed using active filter capacitor, so $i_{c0}^* = i_0$. The reference compensating currents in two and three phase sequence respectively is deduces as,

$$\begin{bmatrix} i_{c\alpha}^* \\ i_{c\beta}^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_x \\ p_y \end{bmatrix}$$

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c0}^* \\ i_{c\alpha}^* \\ i_{c\beta}^* \end{bmatrix}$$

$$i_{cx}^* = -(i_{ca}^* + i_{cb}^* + i_{cc}^*)$$

Where.

P_0 = mean value of the instantaneous zero-sequence power

$P_0\sim$ = alternated value of the instantaneous zero-sequence power

p = mean value of the instantaneous real power

$p\sim$ = alternated value of the instantaneous real power

q = instantaneous imaginary power

5. SIMULINK MODEL AND RESULTS

Simulation were implemented during the execution of the electrical cable conditioner to concentrate on its conduct under different working circumstances and to tune some regulator boundaries related to the advancement of the dynamic channel part esteems. The Power Framework Block set and MATLAB/Simulink has been achieved in this case as reenactment apparatuses, which is displayed in Fig. 7.

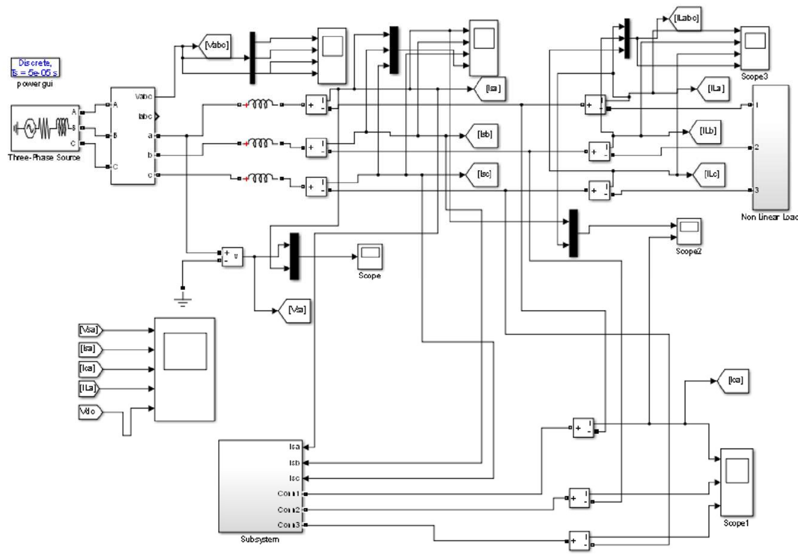
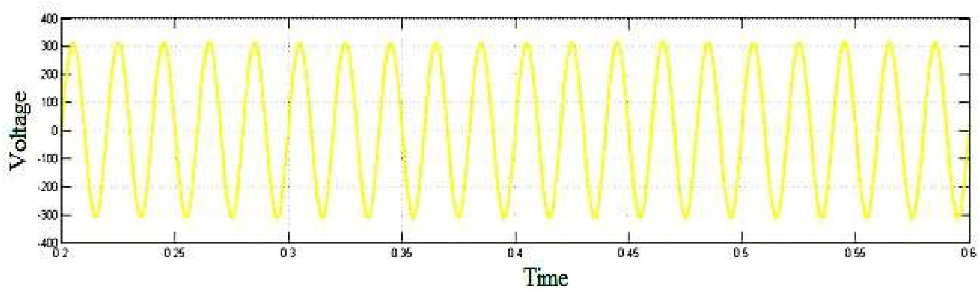
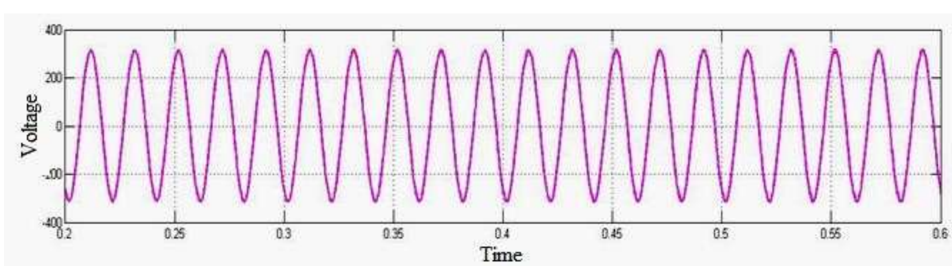


Fig.7. Simulink model of composite system with proposed power line conditioner

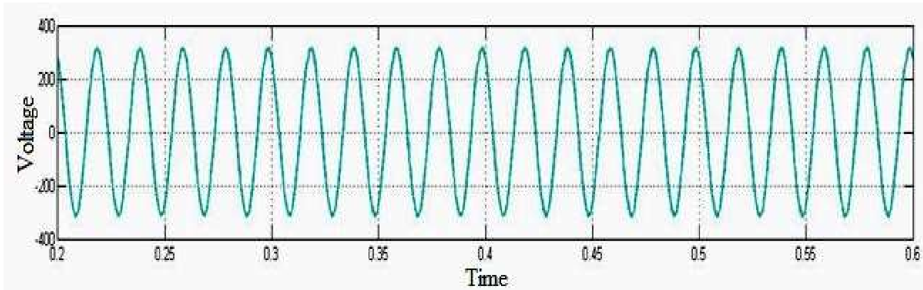
A power line conditioner is simulated in MATLAB/Simulink environment and results are discussed in this section. Simulation results showed that distortion comes into picture when a non-linear load is connected to the system. Source side compensation is done at point of common coupling. The source voltage waveforms of all three phases are shown in fig. 8(a), 8(b), 8(c) and 8(d) respectively. The waveform is pure sinusoidal, the concern of power quality issue comes into picture when non-linear load is integrated with system configuration as it distorted the voltage waveform.



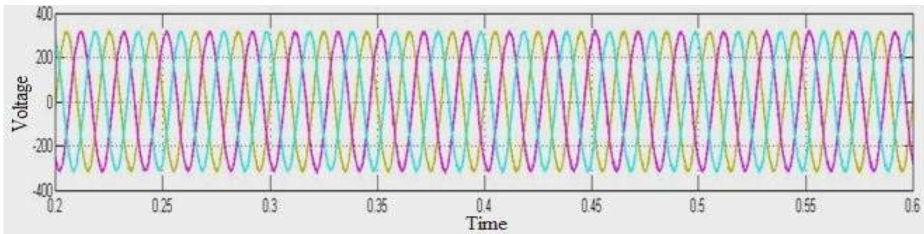
(a)



(b)



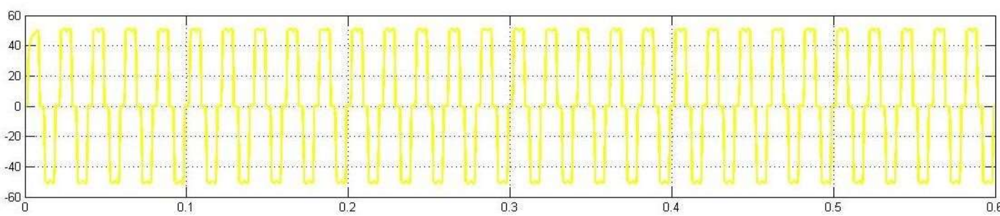
(c)



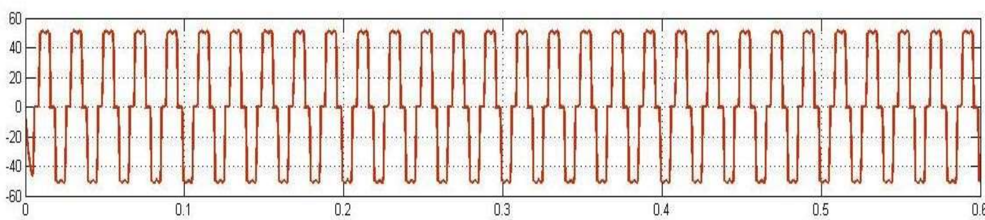
(d)

Fig.8. Source voltage (a) Phase-a (b) Phase-b (c) Phase-c (d) Phase-a-b-c-d

Current waveform of all three phases before compensation is shown in fig. 9(a)-(c) after integrating the non-linear load in the system. Result analysis depicted that waveform contain 29.84% THD. A fuzzy logic based and solar power supported multi-level inverter is designed as shunt compensator to intending the PQ-issue.



(a)



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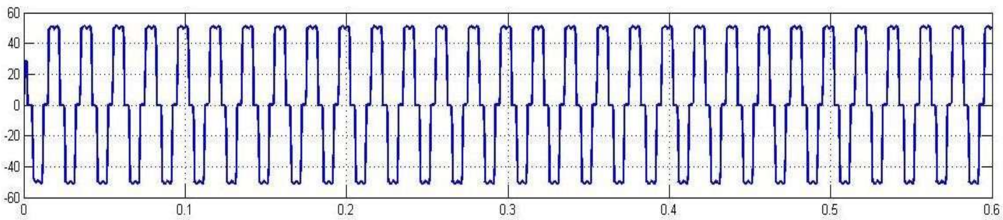
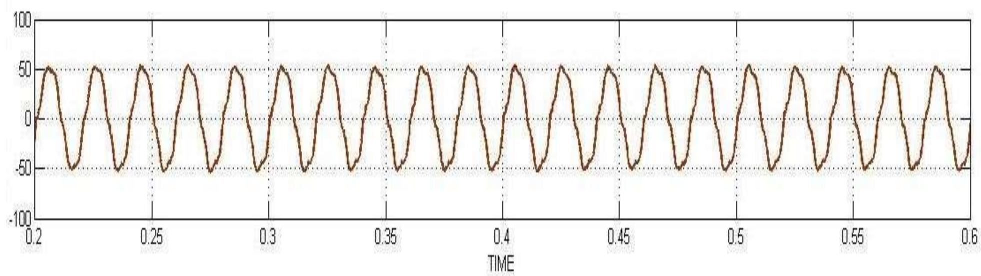


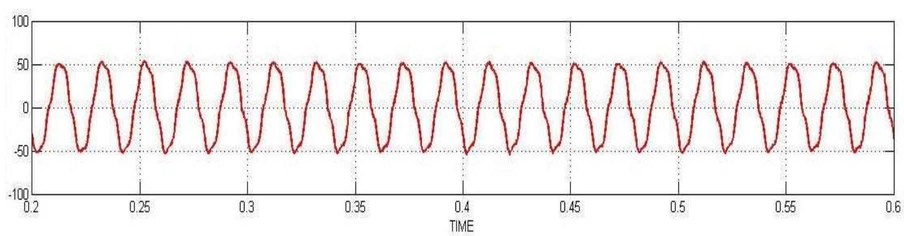
(c)

Fig. 9. Source current before compensation (a) Phase-a (b) Phase-b (c) Phase-c

As shown in fig. 10(a)-(c) wave form shows that quality is improved and THD content in source side currents are 2.96% which is in permissible limit as per IEEE standard and PV based 5 level MLI is acted as power line conditioner. Compensating current generated to ameliorate the source side response as delineating in Figure 12.



(a)



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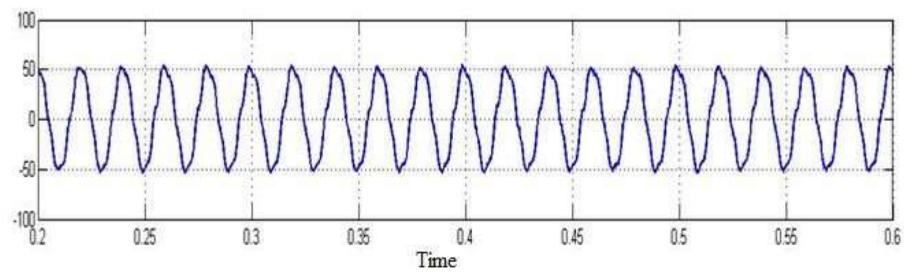
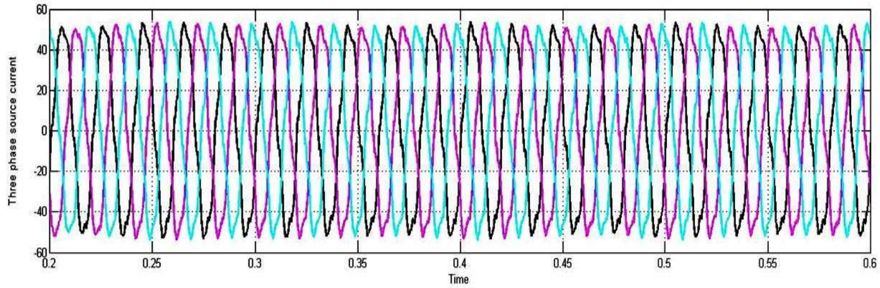
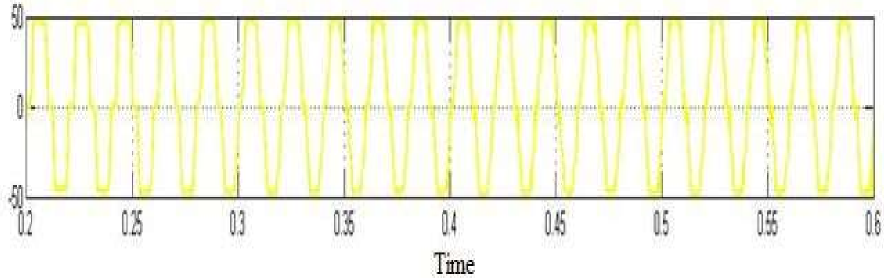


(c)

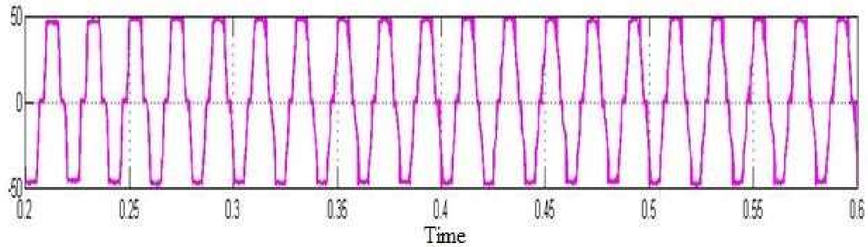


(d)

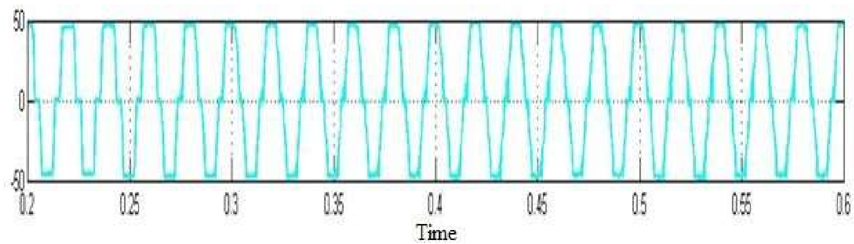
Fig.10. Source current after compensation (a) Phase-a (b) Phase-b (c) Phase-c (d) Phase a-b-c-d



(a)



(b)



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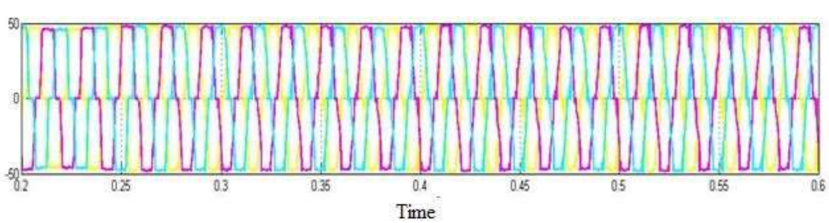


(d)

Fig.11. Load current wave form of respective phases that contain harmonics

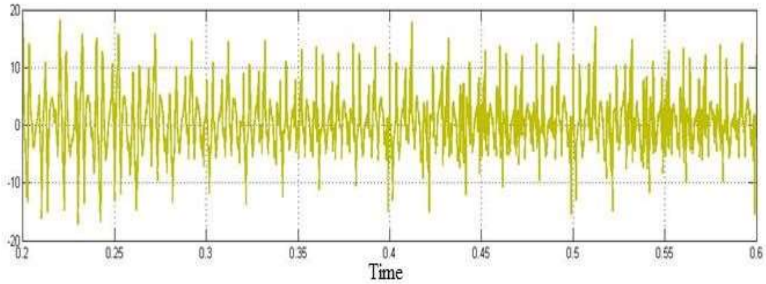


Fig.12. Compensating current

Fig. 13 illustrated the ripple less voltage extracted from solar panel and act as a constant voltage source through fuzzy logic based MPPT algorithm. The conventional capacitors used in a voltage source inverter are replaced through optimized self-generating solar supported constant voltage source.

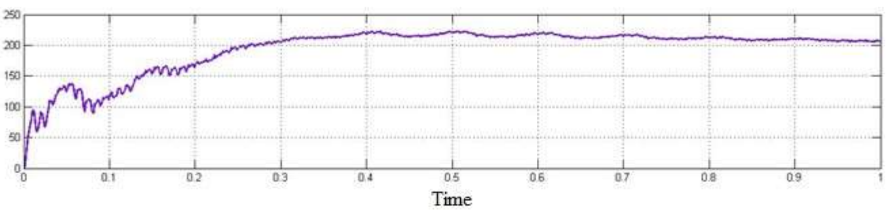
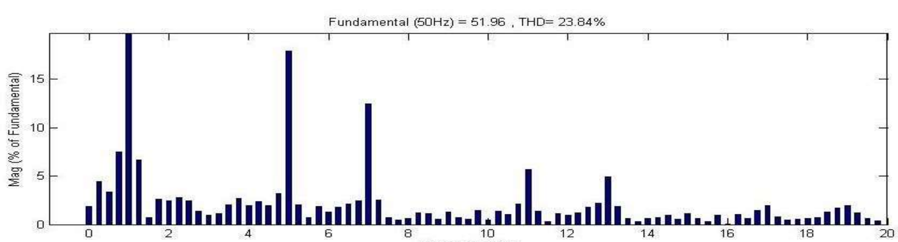


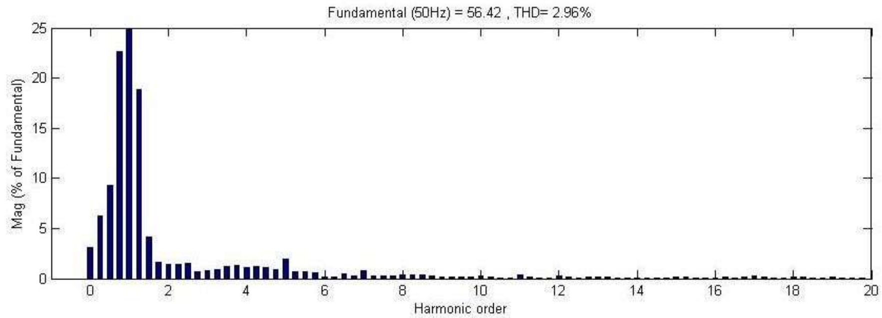
Fig. 13. PV module DC output voltage

1.4 5.1 FFT ANALYSIS

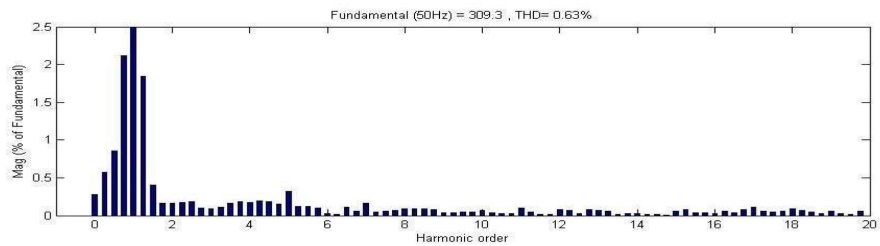
The detailed FFT analysis is cultivated in Table 1 which is reflection of fig. 14(a)-(c) to cope the overall objective of work done.



(a)



(b)



(c)

Fig. 14.FFT analysis (a) before compensation (b) 3 level cascaded inverter (c) 5 level cascaded Inverter.

Comparative analysis of 3-level and 5-level MLI based power line conditioner is finished on Table 1 and results show that the remunerating limit of line conditioner is straightforwardly relative to the exchanging levels in inverter and 5-level MLI based shunt power compensator is enhanced and independent on thinking about the framework intricacy.

Table 1: Comparison to Total Harmonic Distortion of Source Current

Method	THD %	1st	5th	7th	11th	13th
PV based 3-Level Cascaded MLI	Before compensation After compensation	100 100	18.68 4.51	12.47 3.72	6.52 3.01	4.72 2.09
PV based 5-Level Cascaded MLI	Before compensation After compensation	100 100	18.68 1.91	12.47 0.87	6.52 0.39	4.72 0.23

6. CONCLUSION

A FLC based PV upheld flowed staggered inverter is portrayed as shrewd electrical cable conditioners. Under different conditions, the exhibition of the shunt power channel is contemplated and effective in any event, when the stockpile voltages are imbalanced and mutilated; limits THD in source current to levels significantly beneath as far as possible set as principles. The source current turns out to be totally sinusoidal, absent any trace of sounds, and in stage with the fundamental stock voltage, holding solidarity power factor in every one of the cases explored. Various non-straight loads have been used in every reproduction to look at the dynamic channel's fleeting reaction. It has been seen for each situation that the separating game plan follows the example after one power cycle when the heaps fluctuate. The speculation functioned admirably after the major positive arrangement voltage was recovered. The fundamental positive grouping voltage locator is sought after when voltage unevenness and bends both introduced.

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