Comparison of Control Strategies of an Active Power Filter for Power Quality Enhancement of Grid Connected PV System

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Abstract: ***This paper introduces an utility of power filter (APF) in photovoltaic (PV) renewable energy machine for power high-quality (PQ) improvement. The PV electricity is connected to Grid via inverter circuit, transmission line and step-up transformer. The harmonics due to the inverter circuit and non-linear neighborhood load are mitigated and reduced using shunt APF. Also the reactive power and then the voltage legislation can be tailored and adjusted the usage of APF. Design of APF is presented with control algorithms Instantaneous PQ theory and Perfect Harmonic Cancellation methods. The system under learn about is simulated using MATLAB/SIMULINK Software Package. The APF shape and its manipulate system is also presented. The simulated is subjected to loading disturbances to learn about the effectiveness of control algorithms of APF. The digital results prove the powerful of the APF in sensing of deceasing the total harmonic distortion (THD) and fast voltage regulation.***

Keywords: Distributed Generation, Photo voltaic System, Active Power Filter, Harmonics Mitigation, Power Factor Correction, Hysteresis Band Current Controller and Power Quality

1. Introduction

Connection of the standard electrical utility networks with renewable electricity sources like PV, wind, diesel Engine etc., has deliver a sequence of new challenges to PQ. The important lookup theme in the power distribution system is to improve the PQ [1]-[2]. The essential cause for bad PQ is the arrival of energy electronics based totally devices and non-linear loads in each industrial/commercial area and domestic environment [3]. Effects of negative PQ like sag swell distortion in waveform, harmonics, reactive strength technology has affected both grid as nicely as utility sectors. Therefore, efficient solutions for fixing these pollution troubles have become exceptionally critical.

Active and passive filters are used for mitigation, Elimination or reduction of these effects. Passive power filters (PPF) have many dangers [4], such as their incapability to compensate random harmonic current variation; they are designed solely for a specific frequency and the opportunity of resonance at point of common coupling (PCC), tuning problems and filter overloading. The other drawback of PPFs is that the sizes of required elements are bulky elements.

There are many research efforts to improve the efficiency of the PV system. They aimed at the presenting grid with active and reactive power, to minimize the harmonics in the system, [5]-[11]. The PV device supply actual strength from PV arrays to load and guide reactive and harmonics power simultaneously. Nowadays APFs have end up the most advantageous solution to eliminate harmonic air pollution in strength systems and have attracted a good deal attention due to the fact of their advantages; (i) Capability to compensate random various currents. (ii) Good controllability and quickly response to device variations. (iii) High control accuracy. So APFs show up to be a potential solution for controlling harmonics-associated problems.

In operation, the APF injects compensation currents at PCC into the AC traces equal but opposite route distortion as well as absorbing or producing reactive power, thereby eliminate the unwanted harmonics and compensate for energy of reactive the related load [12]. In this way, the APF cancels out the harmonic currents and leaves the fundamental cutting-edge thing to be provided by the power system and improve the gadget electricity component. [8], furthermore shunt APF can preserve the energy gadget balanced under of the unbalanced and the nonlinear loads.

By this methodology harmonic suppression is feasible within permissible standards as defined by using IEEE-519.The application of APFs for mitigating harmonic currents and compensating for reactive energy of PV renewable energy source feeding nonlinear load was once introduced in this paper.

2. PV System Context

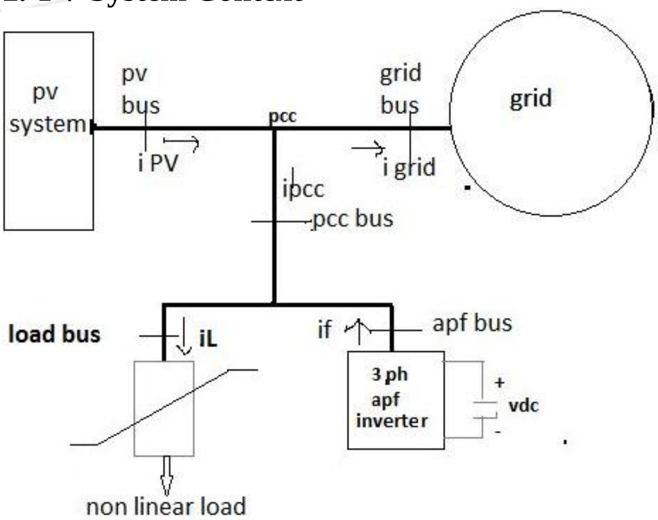

Figure 1: PV System with APF basic schematic diagram

2.1 PV Module

The fundamental power scheme of the studied machine is shown in Fig. 1. A PV system is related to a three segment utility grid with shunt APF interface and non-linear load. The PV machine used to generate strength from the solar array and feeding to each grid and neighborhood nonlinear load. The shunt APF used to beautify PQ of the photovoltaic generation and consequently the countless bus grid.

So two present day managed voltage source inverters (VSI) namely; PV inverter and APF inverter are connected to each other in the system. The PV inverter used to convert DC power to AC power and to accurate ensure a strength sharing of the load demand underneath a variety of irradiance degrees between the PV array and the grid. The APF inverter used to compensate both the reactive power and harmonics, caused with the aid of the nonlinear load at PCC of the AC mains.

Hence APF inverter reduces low-frequency ripple hassle in the system. PV and APF inverters output strength will comply with the power references. The immediately reactive strength perfect harmonic cancellation theory is used for producing reference signals for manage of power inverters [9]-[12].

The calculation of energetic and reactive components of modulating currents follows the approach of perfect harmonic cancellation concept an [11]. Hysteresis pulse width modulation approach has been applied in the control algorithm of each PV and APF invert a photovoltaic machine convert's daylight into electricity.

3. Shunt APF Configuration

3.1 Circuit Description

The proposed three section shunt APF proven in Fig.2 consists of (i) the three-leg CC-VSI energy switches having six IGBTs with anti-paralleling diodes, to grant a mechanism for bi-directional go with the flow of compensation modern to be either absorbed from or injected into the furnish system.

(ii) DC bus (Vdc) linked common to 3-Leg APF VSI, serves as an energy supply for APF. (iii) APF interface reactor (Lf) connected on the AC aspect of the VSI at PCC to regulate the maximum allowable magnitude ripple cutting-edge drift into the APF.(iv)Finally the controller, which has to be mounted in order to actively shape the furnish current to sinusoidal wave shape of a team spirit electricity factor.

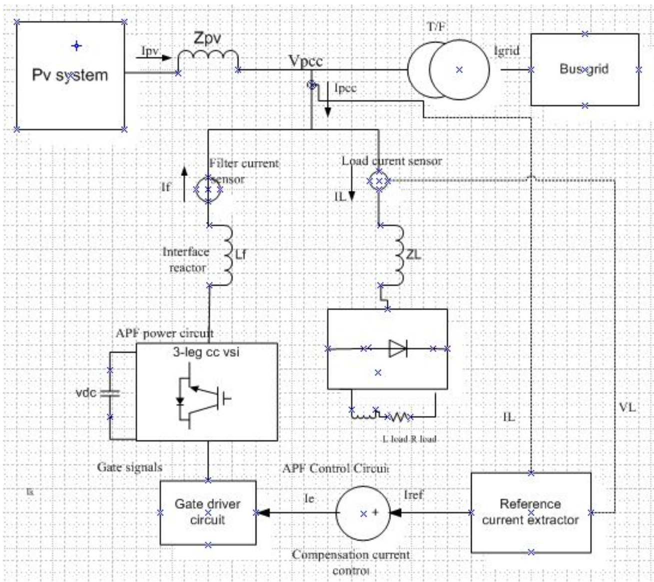

Figure 2: Structure of shunt APF system interfaced to PV system

4. Control Strategies of Shunt APF

4.1 APF Reference Compensation Current Calculation:

The spot reactive strength IRP principle that is well known as p-q control algorithm [11]-[12], is used in this study.This theorem is based totally on α-β orthogonal transformation, which transforms three phase load voltages (vLa, vLb, vLc) and load currents (iLa, iLb, iLc) into the stationary reference frame.

From these modified quantities, the immediate price of the reactive critical factor and harmonic components re-calculated. This algorithm is suitable in this case learn about because of the balanced load voltages and nonlinear line currents. The principle of harmonic current detection technique is shown in Fig.

In order to get the optimal compensation reference currents (i_{ref-a}, i_{ref-b}, i_{ref-c}), a series of calculation would be carried out as follows

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} v_{La} \\ v_{Lb} \\ v_{Lc} \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix}$$

The instantaneous real power (p) and the imaginary power (q) both include a DC component ($\bar{p}\ \bar{q}$) corresponding to harmonic current of the load current can be calculated as follows

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \bar{p} & \tilde{p} \\ \bar{q} & \tilde{q} \end{bmatrix}$$

$$\text{And } \ p = \bar{p} + \tilde{p} \ \text{ and } \ q = \bar{q} + \tilde{q}$$

In the proposed APF, the Ac components ($\tilde{p}$) is extracted from p using a low pass filter (LPF) as shown in fig 7. The compensating currents (I $c\alpha$ and I $c\beta$) which can cancel the harmonic current are derived from:

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \frac{1}{v_{\alpha}{}^2 + v_{\beta}{}^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix}$$

By taking inverse Clarke transformation matrix the APF compensating reference currents can be calculated:

$$\begin{bmatrix} i_{ref\,a} \\ i_{ref\,b} \\ i_{ref\,c} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix}$$

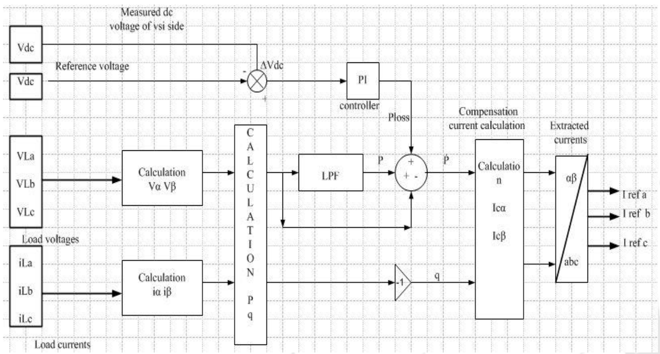

Figure 3: Block diagram of reference current generation by using p q theory

4.1.1 Simulation Result for P Q Theory

The voltage and current wave forms of phase 'a' and their associated THD is calculated at two different period cases are illustrated in the below figures.

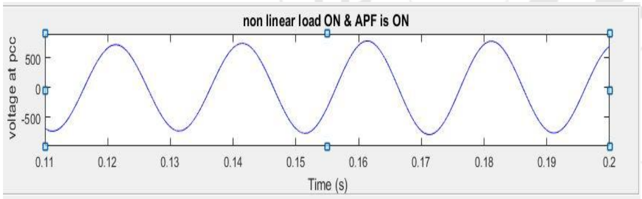

Figure 4: Voltage at PCC when Non Linear Load and APF ON

PV Output Current

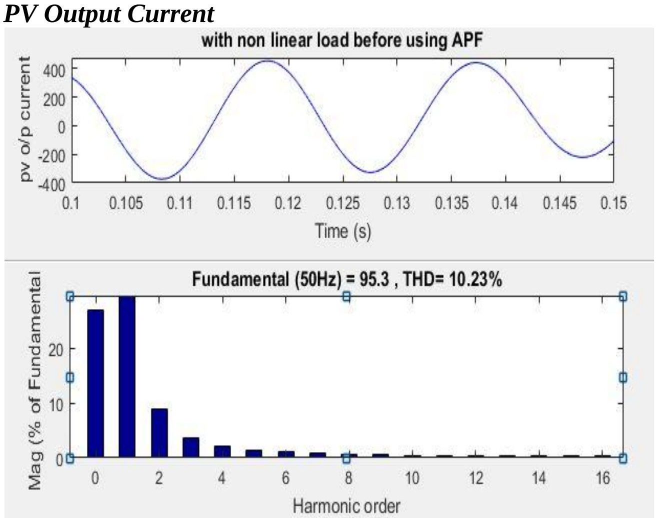

Figure 5: with Non Linear load before using APF

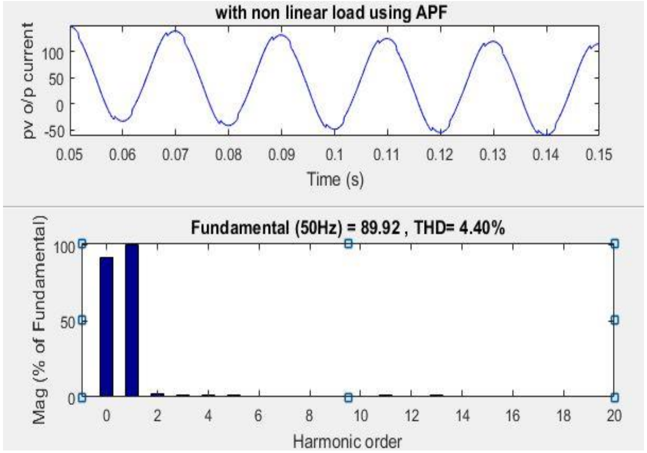

Figure 6: with Non Linear load after using APF

Grid current

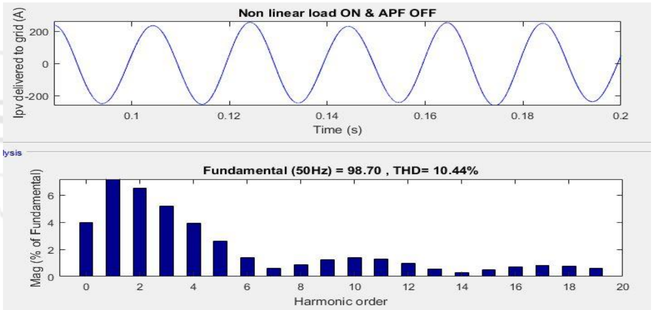

Figure 7: with Non Linear load before using APF

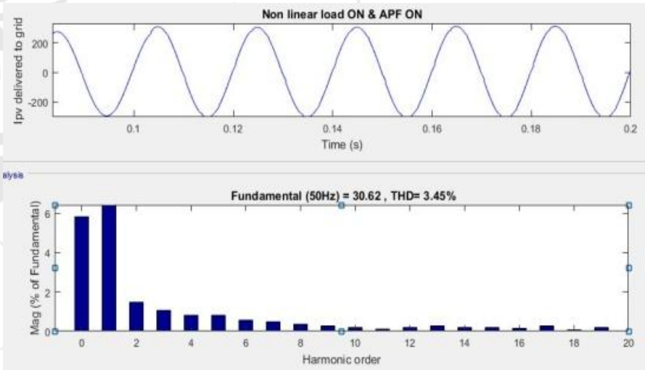

Figure 8: with Non Linear load after using APF

4.2 Perfect Harmonic Cancellation Method

The PHC control method is adopted right here to generate the required compensation currents for the shunt lively energy filter. The goal is to compensate all the harmonic currents and the fundamental reactive power demanded by using the load in addition to eliminating the imbalance.

The supply modern will be in phase with the essential nice sequence aspect of the voltage at the PCC.The required equations of the PHC control approach are explored in [5], [11].

Assume the voltages at the factor of common coupling PCC are Va, Vb, Vc, and loading currents are ILa, ILb, ILc, the immediately energy of the load is given with the aid of [12].

$$P_L = V_a I_{La} + V_b I_{Lb} + V_c I_{Lc}$$

This power as mean and oscillating values

$$p_L = \bar{p}_L + \tilde{p}_L$$

The capacitor voltage Vdc is saved constant through controlling the switch energy loss in the inverter the usage of PI controller which regulates DC capacitor voltage.

The total lively electricity fed with the aid of the supply is the sum of the inverter switching loss Psw and the lively power wanted by using the load pL.

The reference current is given by

$$I_{sref} = K_{v_1^+}$$

Where v+1 is the PCC voltage space vector with a single fundamental fantastic sequence issue obtained from the Phase-locked loop (PLL) circuit. The power delivered by the source will be

$$P_s = VI_{sref} = K_{v_1^{+2}}$$

The Average means power value is calculated by using low pass filter. The value of K parameter in the above equation is calculated by taking division of average load electricity and

Summation of the squared of the positive sequence thing of the PCC voltages.

$$k = \frac{\bar{p}_L}{V_{a1}^{+2}+V_{b1}^{+2}+V_{c1}^{+2}}$$

Once the parameter K is obtained, the reference currents are calculated by multiplying it by the positive sequence component of the voltage.

The actual currents are calculated by using inverse Clarke transformation

$$\begin{bmatrix} I_{sar} \\ I_{sbr} \\ I_{scr} \end{bmatrix} = k \begin{bmatrix} V_{a1}^+ \\ V_{b1}^+ \\ V_{c1}^+ \end{bmatrix}$$

The reference current of the APF is given by

$$i_{fr} = i_L - i_{sr}$$

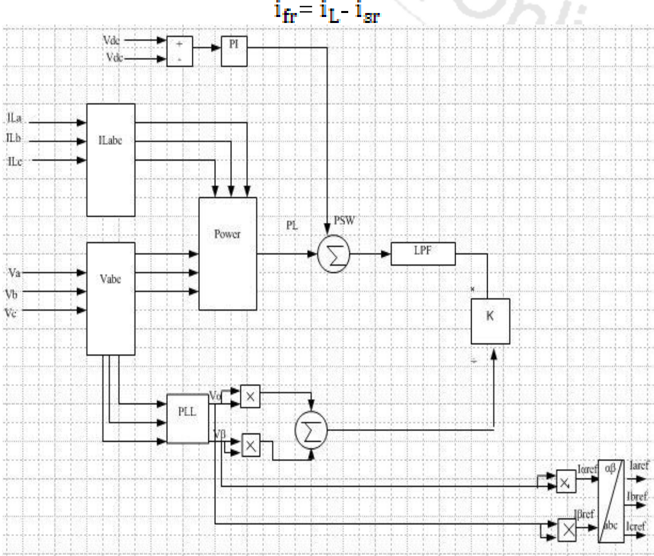

Figure 9: block diagram of the reference current generation by using PHC method

4.2.1 Simulation results of PHC method

The voltage and current wave forms of phase 'a' and their associated THD is calculated at two different period cases are illustrated in the below figures.

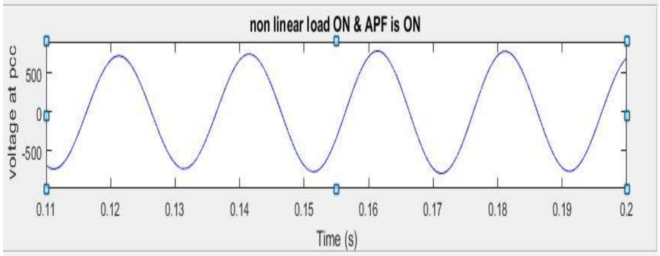

Figure 10: Voltage at PCC when Non Linear Load and APF ON

PV Output Current

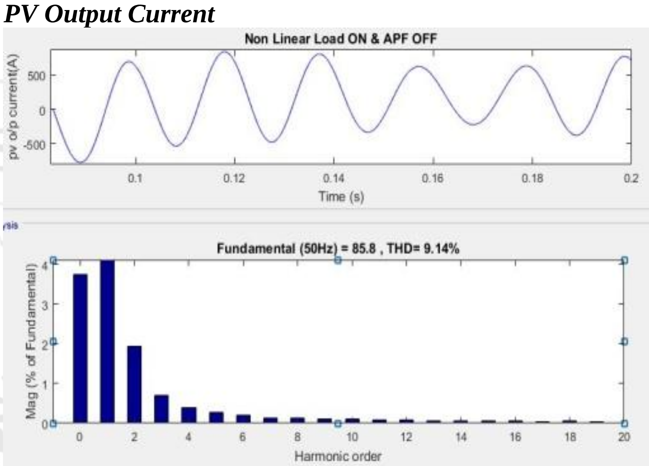

Figure 11: with Non Linear load before using APF

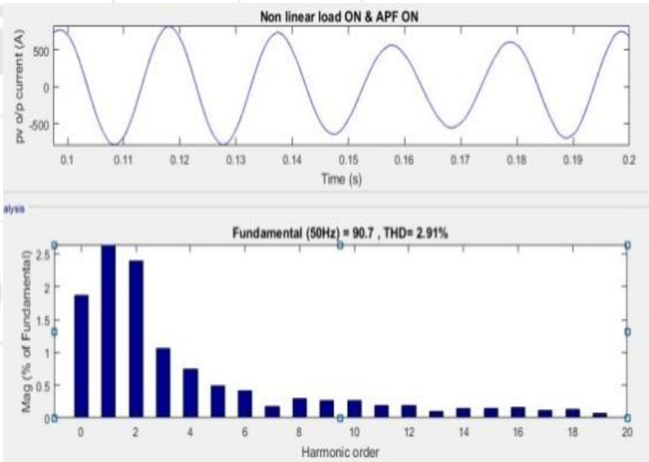

Figure 12: with Non Linear load after using APF

Grid current

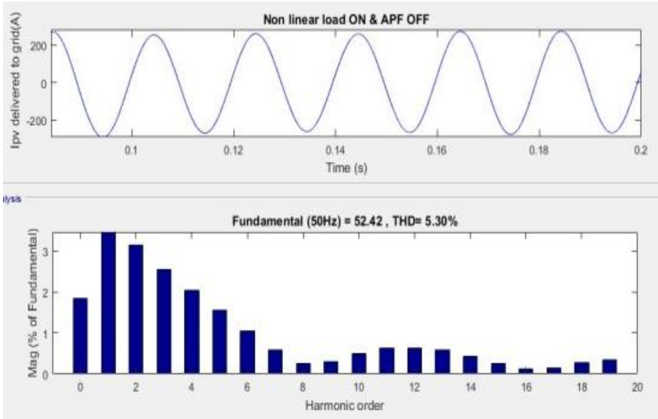

Figure 13: with Non Linear load before using APF

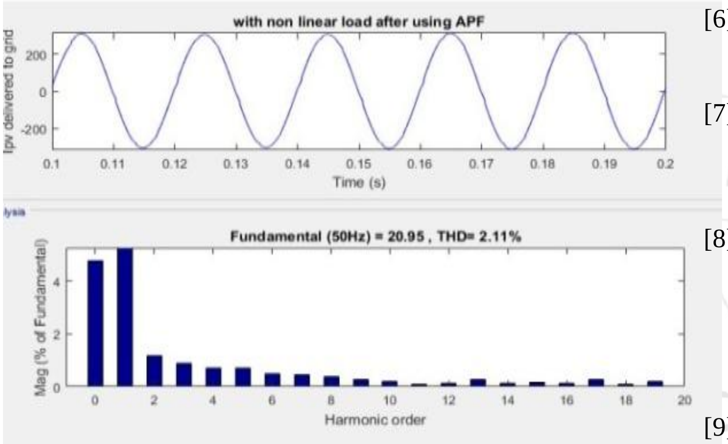

Figure 14: with Non Linear load after using APF

5. Conclusion

In this paper, the overall performance of the proposed PV renewable electricity source tied to limitless bus Grid with shunt APF and non-linear load for power quality improvement was verified and observed through simulation matlab studies In the P Q method THD of the system without SAPF is 10.23 % and it is improved to 4.40% with SAPF at PV bus and at grid bus it is improved from 10.44% to 3.45%. In the PHC method THD of the system without SAPF is 9.14% and it is improved to 2.91% with SAPF at PV bus and at grid bus it is improved from 5.30% to 2.11%. Perfect harmonic cancellation strategy is the most sensitive to distortion and imbalance in the voltages at the PCC. The response of SAPF to compensate the load is found effective and fast.

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