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# Simulation of Shunt Active Power Filter for Compensating Current Harmonics for Single Phase System

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***Abstract*— Among the various power quality problem, current harmonics are most commonly seen on the power system. This is mainly due to increased application of non-linear loads by the end users. In this paper, an analysis and simulation of a PV interactive shunt power active filter (SPAF) is done for single phase system. The shunt active power filter is used to eliminate harmonics generated by the nonlinear load. During the day-time with intensive sunlight, the PV interactive Shunt Active Filter system brings all its functions into operation. At night and during no sunlight periods, the power required by the loads is received from the distribution system while the inverter system only provides reactive power and filter harmonic currents. For the Shunt Active Filter reference current computation, the instantaneous real and reactive current ($I_p$-$I_q$) method is used. For gating signal generation we apply the hysteresis current control technique. The Simulation results (using MATLAB/SIMULINK) are presented and discussed. The proposed solution has achieved a low THD (Total Harmonic Distortion), demonstrating the effectiveness of the presented method.**

***Index Terms*— Shunt active power filter, pv cell, current harmonics, non linear load.**

## I. INTRODUCTION

Harmonic currents are present in modern electrical distribution system caused from non-linear loads such as adjustable speed drives, electronic blast lightning, power supply of computer, fax machine and more of telecom equipment used in modern offices. The wide spread and growing demand of these loads greatly increased and the flow of harmonic currents on facilitated distribution system and has created a number of problems. These problems included over heated transformers, motors, conductors and neutral wire; nuisance breaker trips; voltage distortion, which can causes sensitive electronic equipment to malfunction or fail.
The need to generate pollution-free energy has starts considerable effort toward renewable energy (RE) system.RE sources such as wind, sunlight, and biomass offer the promise of clean and abundant energy. Among the RE sources, solar energy, is an attractive one. This useful energy is supplied in the form of DC power from photovoltaic (PV) arrays bathed in sunlight and converted into more convenient AC power

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through an inverter system. The photovoltaic arrays interactive shunt active power filter system can supply real power from the photovoltaic arrays to loads, and support reactive and harmonic power simultaneously to use its almost installation capacity. This paper presents an analysis and simulation of a PV interactive Shunt Active Power Filter topology that achieves simultaneously harmonic current damping and reactive power compensation [2]. Also, the inverter is always used to act as an active power filter to compensate the nonlinear load harmonics and reactive power[4]. In the day-time with intensive sunlight, the PV interactive shunt active power filter system brings all its functions into operation. At night and during no sunlight periods, the power required by the load is received from the distribution system while the inverter system only provides reactive power compensation and filter harmonic currents.
The shunt active power filter (SAPF) is a device that is connected in parallel to the power system. The performance of a shunt active power filter depends on many factors. .Block Diagram of PV Interactive shunt active filter shown in Figure 1.Among them, the reference generation is the most important.

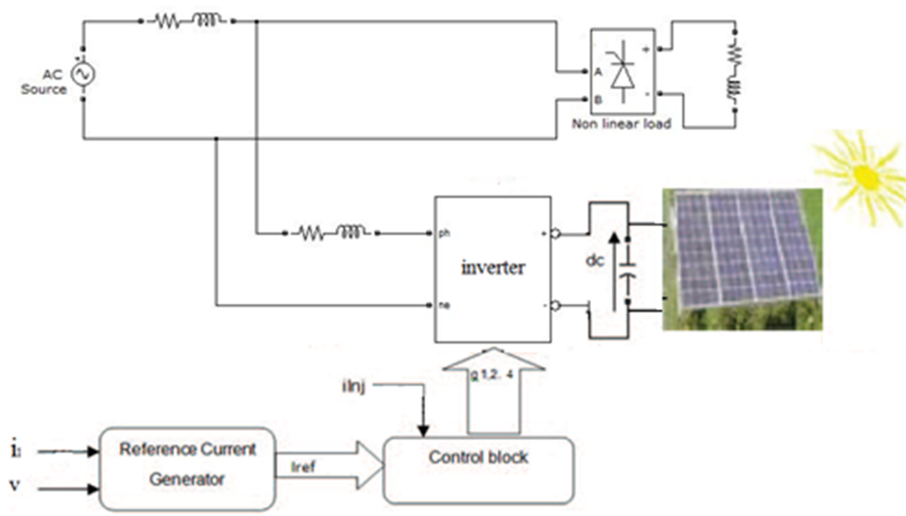


Figure 1. Block Diagram of PV Interactive shunt active filter

The method to generate the reference template is responsible for the reference of currents that must be followed by an inverter current to produce the desired compensation currents that will mitigate harmonic currents generated by non-linear loads[4]. Harmonic detection method will calculate the reference compensating currents. In this paper the instantaneous real and reactive current method ($I_p$-$I_q$) algorithm is used to generated the reference compensating current[3].From this reference compensating current the actual compensating current are generated with the help of hysteresis current controlled voltage source inverter.Hysteresis current controlled inverter will inject the compensating current into the power system. These compensating currents, will cancel the harmonics generated by nonlinear load.

## II. PV MODEL

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. To find the model of the photovoltaic generator, we must start by identifying the electrical equivalent circuit to that source. Many mathematical models have been developed to represent their highly nonlinear characteristics resulting from that of semiconductor junctions that are the major constituents of PV modules. There are several models of photovoltaic generators which have a certain number of parameters involved in the calculation of voltage and current output. In this study, we will present the model of single diodes (Figure 2) taking into account the internal shunt and series resistances of the PV cell

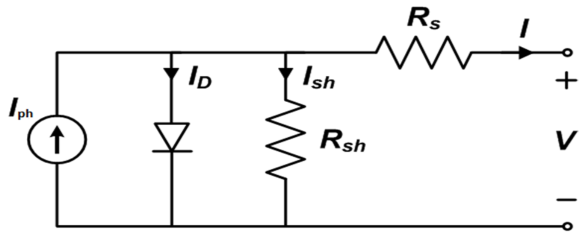


Figure 2. Model of a photovoltaic cell

The current source $I_{ph}$ represents the cell photocurrent. $R_{sh}$ and $R_s$ are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of $R_{sh}$ is very large and that of $R_s$ is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel can be modeled mathematically as given in equations (1) - (4)

Module photo-current :

$$I_{ph} = [\, I_{SCr}+K_i(T-298)]*\lambda/1000 \qquad (1)$$

Module reverse saturation current :

$$I_{rs}= I_{SCr} / [\exp(Qv_{OC}/ N_S kAT) – 1] \qquad (2)$$

The module saturation current $I_0$ varies with the cell temperature, which is given by

$$I_O = I_{rs}\,[T/T_r]^3 \exp\left[\frac{q*E_{go}}{Bk}\left\{\frac{1}{T_r}-\frac{1}{T}\right\}\right] \qquad (3)$$

The current output of PV module is

$$I_{PV}= N_P*I_{Ph}-N_P*I_0\left[\exp\left\{\frac{q*(V_{PV}+I_{PV}\ R_S)}{N_S\ AkT}\right\}-1\right] \qquad (4)$$

Where $V_{pv}$ and $I_{pv}$ represent the output voltage and current of the PV, $I_{ph}$ is the photocurrent; $I_O$ are diode saturation current; q is coulomb constant (1.602 e-19C); Tr is the reference temperature is 298 K;K is Boltzman's constant (1.381e-23 J/K); T is cell temperature (K); $N_S$ are P-N junction ideality factor; $R_{sh}$ and $R_s$ are the intrinsic shunt and series resistance of the cell respectively; Ns is the number of cells connected in series is 36 ;Np is the number of cells connected in parallel is 1.

## III. Detection Method Based On Instantaneous Reactive Power Theory

The instantaneous reactive power theory is used to detect the harmonics here. The source voltage V(t)=Vsinωt, where V is the peak value of voltage[1]. The load distortion current consisting by fundamental and harmonic components is expressed by Fourier series as

$$i_s = i_\alpha = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \varphi_n) \qquad (5)$$

The distortion current is delayed by π/2 to get the other current component $i_\beta$.

$$i_\beta = \sum_{n=1}^{\infty} I_n \sin[n(\omega t - \pi/2) + \varphi_n] \qquad (6)$$

$i_\alpha$ and $i_\beta$ are divided into three components, viz.,active, reactive and harmonic current as follows:

$$i_\alpha = I_1 \cos\varphi_1 \sin\omega t + I_1 \cos\omega t \sin\varphi_1 + \sum_{n=2}^{\infty} I_n \sin(n\omega t + \varphi_n)$$
$$= i_{\alpha p}(t)+i_{\alpha q}(t)+i_{\alpha h}(t) \qquad (7)$$

$$i_\beta = I_1\cos\varphi_1\sin(\omega t-\frac{\pi}{2})+I_1\cos(\omega t-\frac{\pi}{2})\sin\varphi_1+\sum_{n=2}^{\infty} I_n\sin(n(\omega t-\frac{\pi}{2})+\varphi_n)$$

$$= i_{\beta p}(t)+i_{\beta q}(t)+i_{\beta h}(t) \quad (8)$$

Where the fundamental active and reactive current is

$i_p(t)=I_p \sin\omega$ t, $i_q(t)=I_q\cos\omega$ t

Where $I_P$ and $I_q$ are their peak values

$I_p=I_1\cos\omega_1$, $I_q=I_1\sin\omega_1$

According to instantaneous reactive power theory we can make the following calculations

$$i_p = i_\alpha \sin\omega t - i_\beta \cos\omega t = (I_P + harmonics)$$

$$i_q = -i_\alpha \cos\omega t - i_\beta \sin\omega t = -(I_q + harmonics)$$

The harmonics are filtered by low pass filter (LPF)

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \sin\omega t & -\cos\omega t \\ -\cos\omega t & -\sin\omega t \end{bmatrix} \begin{bmatrix} i_p \\ -i_q \end{bmatrix}$$

$$i_\alpha = i_f = I_1\cos\varphi_1\sin\omega t + I_1\cos\omega t\sin\varphi_1 \quad (9)$$

The fundamental component is subtracted from actual current to get harmonic current. The result of the original distortion current $i_{s(t)}$ subtracting the fundamental current $i_{f(t)}$ is the sum of harmonics $i_{h(t)}$. The calculation process shown in Figure 3.

$$i_{h(t)} = i_{s(t)} - i_{f(t)} \quad (10)$$

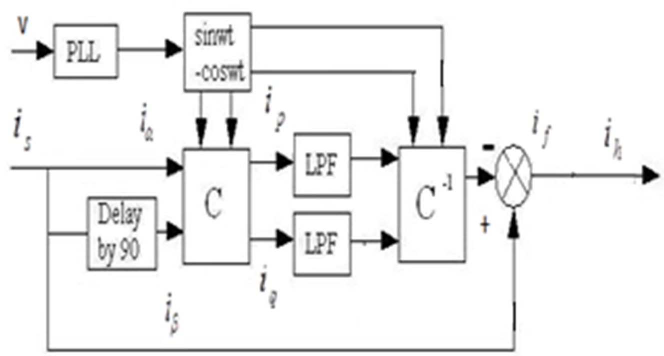


Figure 3. Calculation process the harmonic component

III. HYSTERESIS CURRENT CONTROLLER

Hysteresis current control method of generating the switching signal for the inverter switches in order to control the inverter output current [5]. It is adopted in shunt active filter due to best among other current control methods, easy implementation and quick current controllability [4]. It is basically a fed back current control method, where the actual current continuously tracks the reference current in the hysteresis band(Figure 4).The actual current within this hysteresis band. The reference and actual current is compared with respect to hysteresis band which decides switching pulse of voltage source inverter.

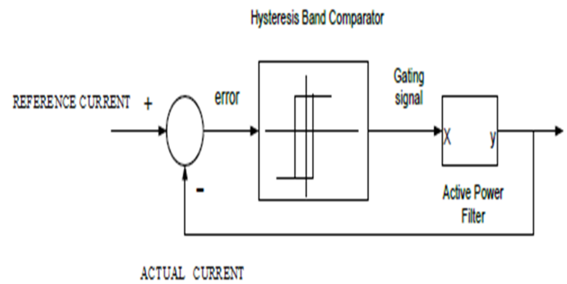


Figure 4. Hysteresis Current Controllers

As the current crosses a set hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on. As the current exceeds the lower band limit, the upper switch is turned on and the lower switch is turned off(Figure 5). The switching frequency depends on how fast the current changes from upper limit to lower limit and vie versa. This, in turn depends on voltage $v_d$ and load inductance.

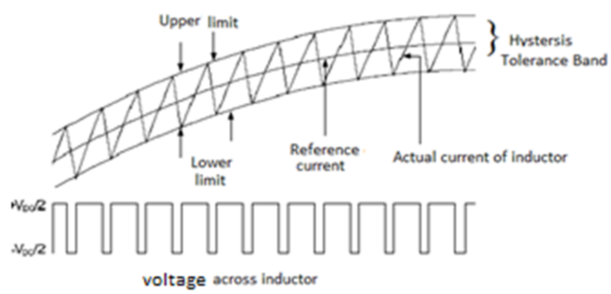


Figure 5.Hysteresis Band and Generation of Pulses

IV. SIMULATION RESULTS

The proposed model for a PV interactive shunt active power filter using harmonic detection method with hysteresis current controller has been successfully modelled and tested using MATLAB/SIMULINK toolbox it is shown in Figure 6.

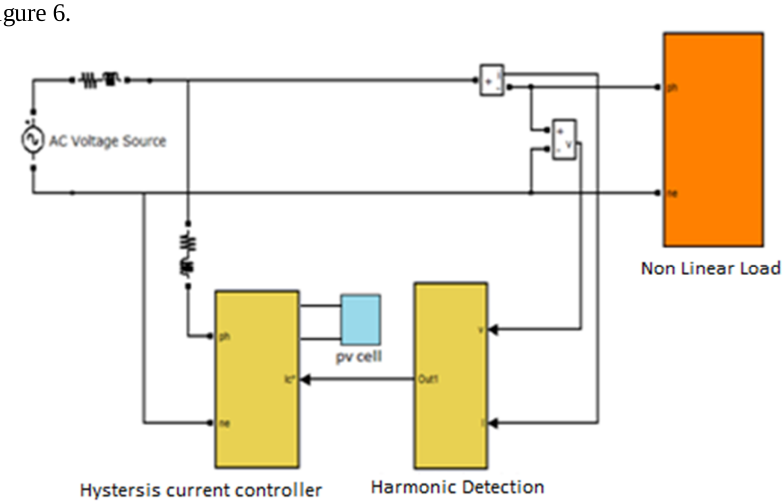


Figure 6.MATLAB/SIMULINK model of PV interactive SAPF

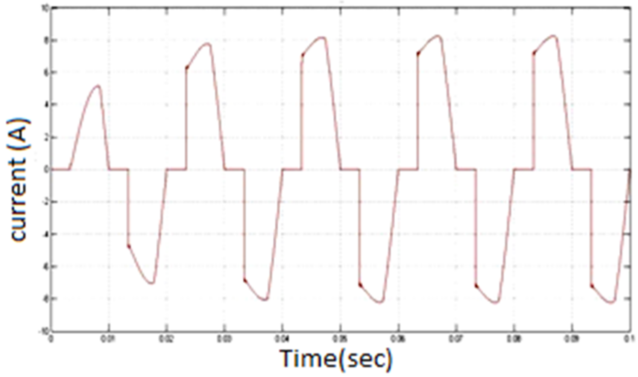


Figure7. Distorted current at source without compensation

Figure7 shows the distorted load currents of nonlinear load.

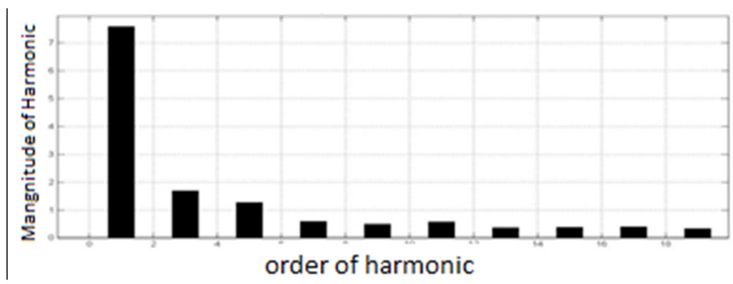


Figure 8. FFT analysis

Figure 8 shows FFT analysis for figure 7wave from. Harmonic currents are injected into power system by nonlinear load. Because of harmonics source current will be distorted. For distorted current THD is 33%.

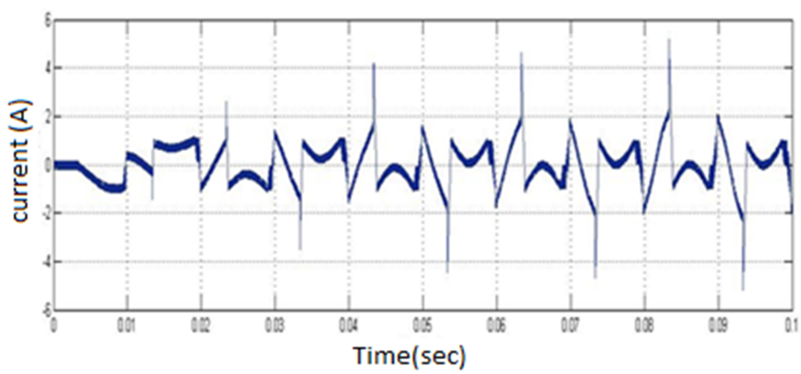


Figure 9.Compensating currents injected by the active power filter

Figure 9 shows the compensating currents injected by the active power filter at the point of common coupling.

Figure 10 shows the supply or source currents after compensation by active power filter.

Figure 11 shows FFT analysis for figure 10 wave from. Compensating currents are injected into power system by SAPF. AS a result THD is reduced 33% to 2.4%.reactive power will decreased and power factor will improve .

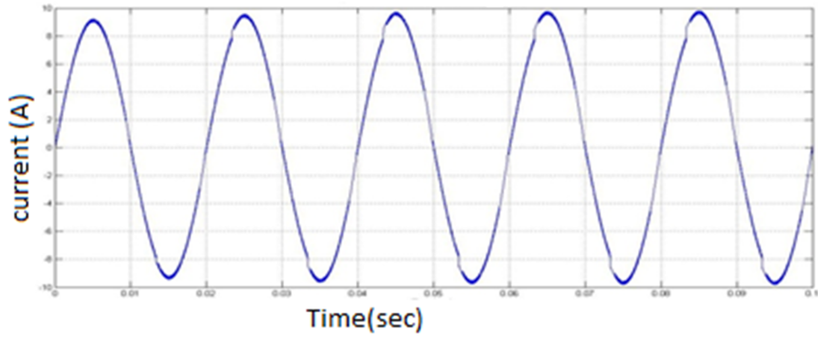


Figure 10.Current at source after compensation

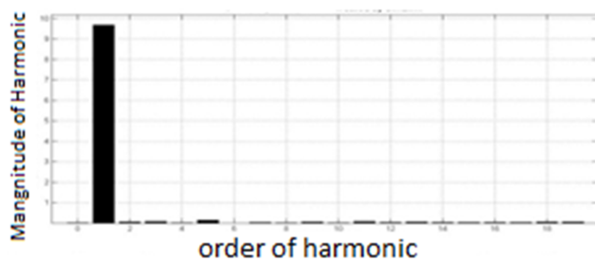


Figure11.FFT analyses for above distorted current

## V. CONCLUSION

In this paper, a PV interactive shunt active power filter is used for harmonic injection into the power supply. The harmonics generated due to nonlinear load are compensated by injected harmonics. A current control strategy is presented for SAPF in single phase circuit. The proposed method is capable of reducing the harmonics in the limits of IEEE 519-1992. After compensation of current harmonics, the source current is sinusoidal waveform, having THD 2.4%. The above system can be applied for single phase systems where there is a severity of current harmonics due to non-linear load.

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