



Three Phase Grid Connected PV System for Mitigation of Voltage and Current Harmonics Compensation Using SRF Method

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ABSTRACT: Power quality is an all-encompassing concept for a multitude of individual types of power system disturbances. The presence of harmonics in power supply network poses a severe power quality problem that results in greater power losses in the distribution system, interference problems in communication systems and, sometimes, in operation failures of electronic equipment. This paper presents a three -phase active power filter for harmonic compensation which consists of a series active power filter and a shunt active filter. The active filter connected in series to a source acts as a harmonic isolator between the sources and loads whereas the shunt active filter is connected in parallel with a load and suppresses the harmonic current produced by the load and reduce the total harmonic distortion (THD). The voltage source inverter (VSI) is the core of an active power filter. The hysteresis current control is a method of controlling the VSI. Hysteresis control can be either of fixed band type or adaptive band type. In this paper, Synchronous Reference Frame (SRF) theory is implemented for the generation of reference current signals for the controller. Mat lab /Simulink and are used for simulation. From the simulation results it is confirmed that the filter topology is capable of compensating the load current and voltage harmonic distortion within the stipulated limits laid down by the IEEE 519 standard.

KEYWORDS: Shunt active power filter, series active power filter, pv system ,voltage harmonics, current harmonics, nonlinear load.

I.INTRODUCTION

Power-electronics circuits are widely used in industrial equipment, such as frequency changers, motor-drive systems (AC voltage controller, chopper), etc. Such equipment presents nonlinear impedance to the utility, generating large harmonic currents and voltages with well-known conflicting effects, such as low power factor, low efficiency and destruction of other equipment. Also, some precision instruments and communication equipment will be interfered with the EMI. The effects of current harmonic distortion are poor utilization of distribution wiring and plant, increased power loss, high current flow in the neutral line and dangerous cable overheating. Voltage harmonic interrupts the proper operation of digital electronics mainly communications and process control, which needs sinusoidal supply voltage. Harmonic problem may result in mal-operation of protection equipment. To minimize the power quality problems by solely active Filters, different from the passive filter, have the capability of dynamically adjusting to the conditions of the system in terms of harmonics and reactive power compensation.

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 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 technology has many excellent

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features and it causes little environmental burden, it is of a modular type technology that can be easily expanded, and it is applicable almost everywhere. This paper presents an analysis and simulation of a PV interactive Active Power Filter topology that achieves simultaneously harmonic current damping and reactive power compensation. Also, the inverter is always used to act as an active power filter to compensate the nonlinear load harmonics and reactive power. In the day-time with intensive sunlight, the PV interactive 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 and voltage

The effectiveness of Active Power Filter depends on the requirements, inverter type and topology. On the basis of topology Active Power Filter can be classified as series connected Active Power Filter and Shunt connected Active Power Filter. Series connected Active Power Filter can be connect before the load in series with the mains using a matching transformer to eliminate the voltage harmonics and to balance and regulate the terminal voltage of the load. Also it can be used to regulate the negative sequence voltage at the load. So the series Active Power Filter works as a controllable voltage source. The drawbacks of this series connected Active Power Filter is, it only compensates the voltage harmonics and another problem is for the short circuit in the load end. This short circuit current passes through the series transformer winding, which may overload the series transformer. A shunt active power filter (SAPF) is a device that is connected in parallel to a group of loads. it cancels the reactive and harmonic currents drawn by the load so as to make the supply current sinusoidal.

II. SYSTEM CONFIGURATION

The proposed topology consists of a series and shunt active power filter and pv system. The active filter connected in series to a source acts as a harmonic isolator between the source and load whereas the shunt active filter is connected in parallel with a load and suppresses the harmonic currents produced by the load as shown in Figure 1.

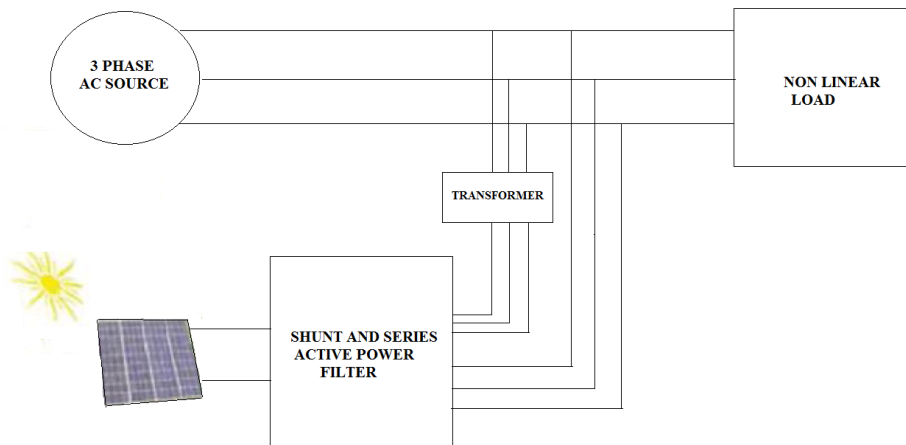


Fig .1 proposed topology consists of series and shunt active power filter and pv system

The series active filter compensates the harmonic voltage by synchronous reference frame (SRF) -based controllers. The shunt active filter compensates the harmonic currents by using synchronous reference frame (SRF) -based controllers. The three-Phase PLL used for generation of the unit vector coordinates ($\sin \theta$ and $\cos \theta$) used in the SRF-based algorithms. The SRF-based controller was used to generate the sinusoidal compensating current and voltage references applied to a three-phase line-interactive pv System.

III.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

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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 (Fig.2) taking into account the internal shunt and series resistances of the PV cell.

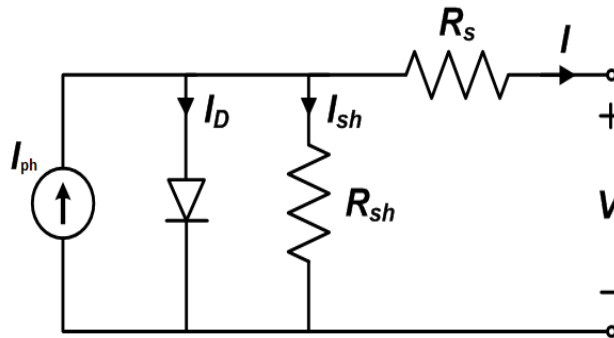


Fig.2 Model of a photovoltaic cell

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 modelled mathematically as given in equations (1)- (4)

Module photo-current:

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

Module reverse saturation current :

$$I_{rs} = I_{SCr} / [\exp(Qv_{OC} / N_s k A T) - 1] \quad (2)$$

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

$$I_0 = I_{rs} [T/T_r]^3 \exp \left[\frac{q * E_{go}}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right] \quad (3)$$

The current output of PV module is

$$I_{PV} = N_p * I_{ph} - N_p * I_0 \left[\exp \left\{ \frac{q * (V_{PV} + I_{PV} R_s)}{N_s A k T} \right\} - 1 \right] \quad (4)$$

Where V_{pv} and I_{pv} represent the output voltage and current of the PV, I_{ph} is the photocurrent; I_0 are diode saturation current; q is coulomb constant ($1.602 \times 10^{-19}C$); T_r is the reference temperature is 298 K; k is Boltzman's constant



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(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; N_s is the number of cells connected in series is 36 ; N_p is the number of cells connected in parallel is 1.

IV. CURRENT AND VOLTAGE HARMONIC DETECTION

In this paper synchronous reference frame (SRF) method is used to generate the reference voltage and current required to compensate the voltage and current harmonics. The three voltage and/or current signals in a-b-c coordinates are transformed to the orthogonal α - β stationary frame using (1) and then to synchronous rotating frame (d-q) using (2). Based on the control needs the required components are extracted/ separated in d-q frame. To generate the reference signals and thus, to transform them back to original frame, the inverse transformation from d-q to α - β frame, and then to a-b-c frames carried out utilizing (3) and (4), respectively

i. Clark's Transformation

It transforms sensed source voltage /current signal from a-b-c stationary to α - β stationary coordinate system by following equation (5)

$$\begin{bmatrix} x_{ca} \\ x_{cb} \\ x_{cc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} x_{\alpha} \\ x_{\beta} \\ x_o \end{bmatrix} \quad (5)$$

ii. Park's Transformation

Now this signal α - β is converted in d-q frame by using equation (6)

$$\begin{bmatrix} x_{\alpha} \\ x_{\beta} \end{bmatrix} = \begin{bmatrix} \cos \omega t & \sin \omega t \\ -\sin \omega t & \cos \omega t \end{bmatrix} \begin{bmatrix} x_d \\ x_q \end{bmatrix} \quad (6)$$

iii. Reverse Park's Transformation (α - β to d-q)

$$\begin{bmatrix} x_d \\ x_q \end{bmatrix} = \begin{bmatrix} \cos \omega t & \sin \omega t \\ -\sin \omega t & \cos \omega t \end{bmatrix} \begin{bmatrix} x_{\alpha} \\ x_{\beta} \end{bmatrix} \quad (7)$$

iv. Reverse Clark's Transformation (d-q to a-b-c)

$$\begin{bmatrix} x_{\alpha} \\ x_{\beta} \\ x_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad (8)$$

Where x represents the variable under consideration, and can be voltage or current.

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A. Current SRF controller

In this method the measured load currents are transformed into the rotating reference frame (d-q frame) that is synchronously rotating at the line current frequency using (5) and (6). The line frequency components of the load currents become DC quantities and the harmonic components are frequency shifted by ωt in the d-q reference frame. A high pass filter in the d-q frame, with a cut-off at the line frequency can be used to extract the DC components. Currents to transform them back to original frame, the inverse transformation from d-q to α - β frame, and then to a-b-c frame is carried out utilizing (7) and (8). Reference compensating currents ($i_{ca}^*, i_{cb}^*, i_{cc}^*$) generated using current SRF controller which shown in fig 3

B. Voltage SRF controller

In this method the measured voltages are transformed into the rotating reference frame (d-q frame) that is synchronously rotating at the line voltage frequency using (5) and (6). The line frequency components of the voltages become DC quantities and the harmonic components are frequency shifted by ωt in the d-q reference frame. A high pass filter in the d-q frame, with a cut off at the line frequency can be used to extract the DC components. Voltages to transform them back to original frame, the inverse transformation from d-q to α - β frame, and then to a-b-c frame is carried out utilizing (7) and (8). Reference compensating voltages ($v_{ca}^*, v_{cb}^*, v_{cc}^*$) generated using voltage SRF controller which shown in fig 3

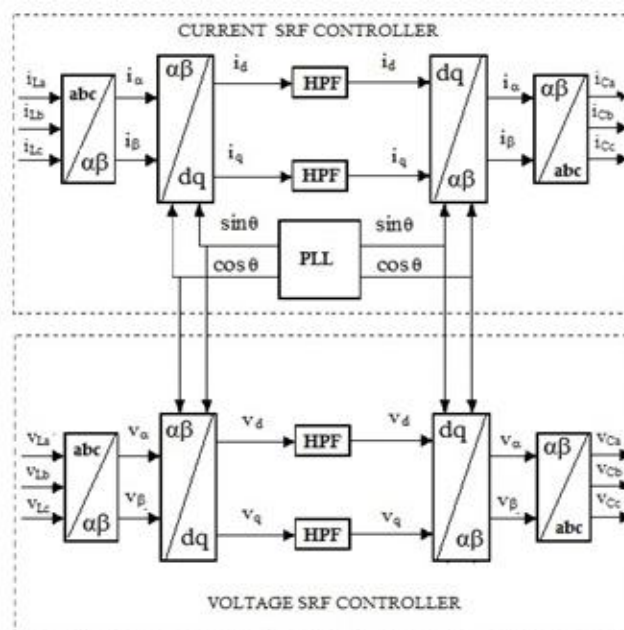


Fig.3 current SRF controller and voltage SRF controller

V. HYSTERESIS CONTROLLER

Hysteresis control method of generating the switching signal for the inverter switches in order to control the inverter output voltage or current [5]. It is adopted in 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. The actual current with in this hysteresis band. The reference and actual current or voltage is compared with respect to hysteresis band which decides switching pulse of voltage source inverter. 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 (Fig 5). As the current exceeds the lower band limit, the upper switch is turned on and the lower switch is turned off. The switching frequency depends on how fast the current changes from upper limit to lower limit and vice versa. This, in turn depends on voltage v_d and load inductance.

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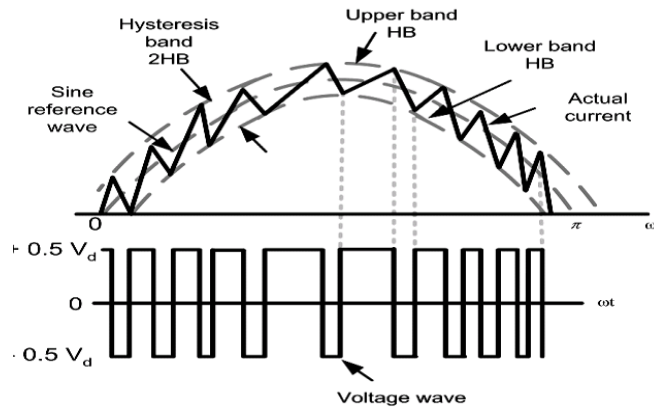


Fig.4 Hysteresis Band and Generation of Pulses

VI. SIMULATION RESULTS

The proposed model for a shunt series active power filter using harmonic detection method with hysteresis current controller has been successfully modelled and tested using MATLAB/SIMULINK toolbox.

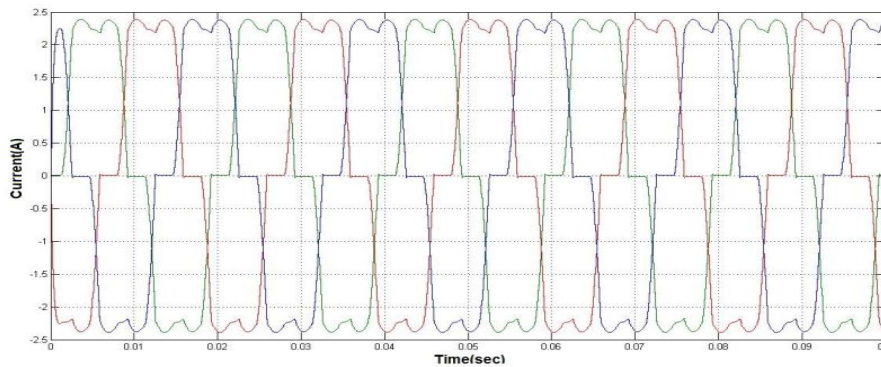


Fig.5 Distorted current at source without compensation

Fig .5 shows current wave form at the source .where shunt and series active power filter is absent in the system .

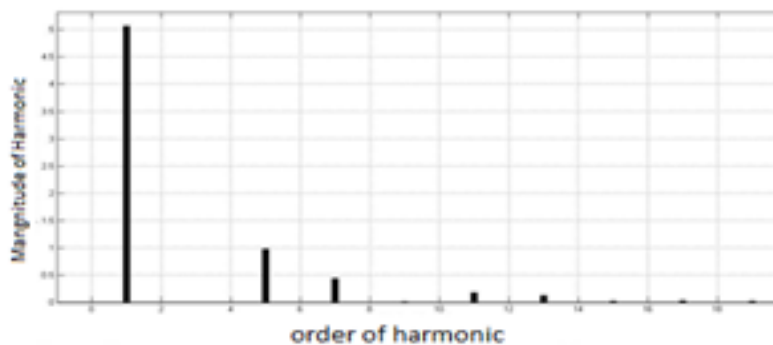


Fig. 6 FFT analysis for above distorted current wave forms

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Figure 7. Shows FFT analysis for figure 5 wave from. Harmonic currents are injected into power system by nonlinear load. Because of harmonics source current will be distorted. For distorted current THD is 22.06%.

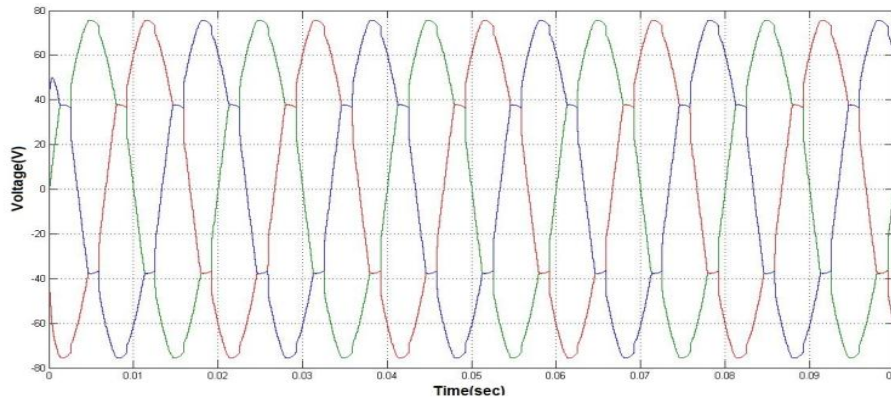


Fig. 7 Distorted voltages at source without compensation

Fig. 7 shows voltage wave form at the source .where shunt and series active power filter is absent in the system .

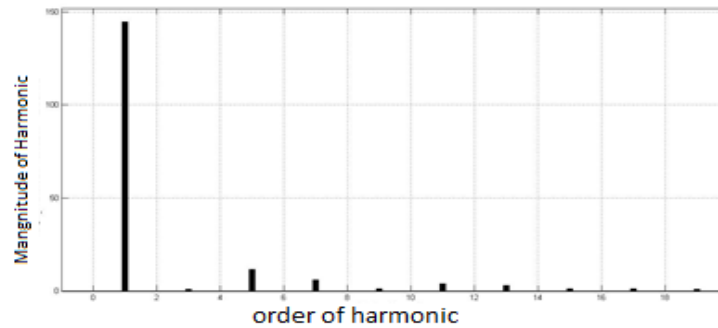


Fig. 8 FFT analysis for above distorted voltages wave form

Figure 8 shows FFT analysis for figure 7 wave from. Harmonic voltages are injected into power system by Nonlinear load. Because of harmonics source voltages will be distorted. For distorted current THD is 11.03%.

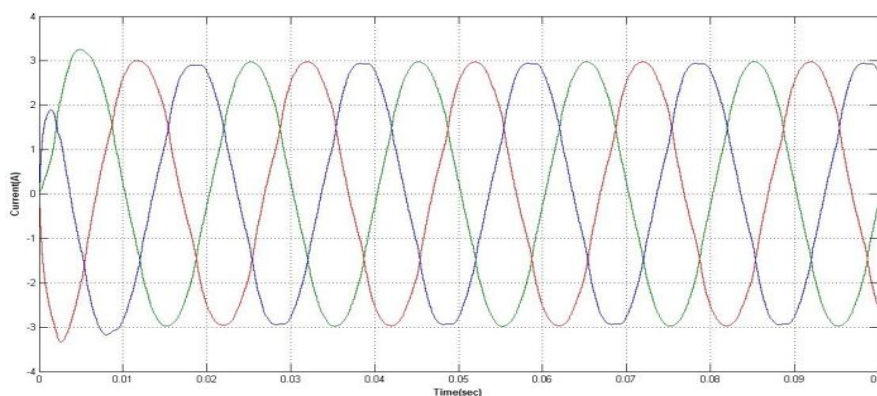


Figure 9. Current at source after compensation

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Fig .9 shows current wave form at the source .where shunt and series active power filter is present in the system .

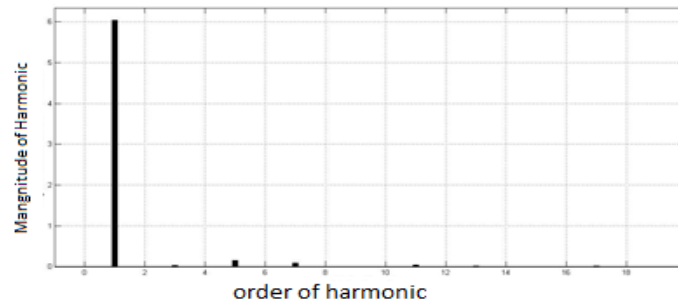


Figure 10. FFT analysis for above currents wave form

Figure 10 shows FFT analysis for figure 9 wave from .Compensating currents are injected into power system by SAPF. AS a result THD is reduced 22.06% to 2.03%, reactive power will decreased and power factor will improve.

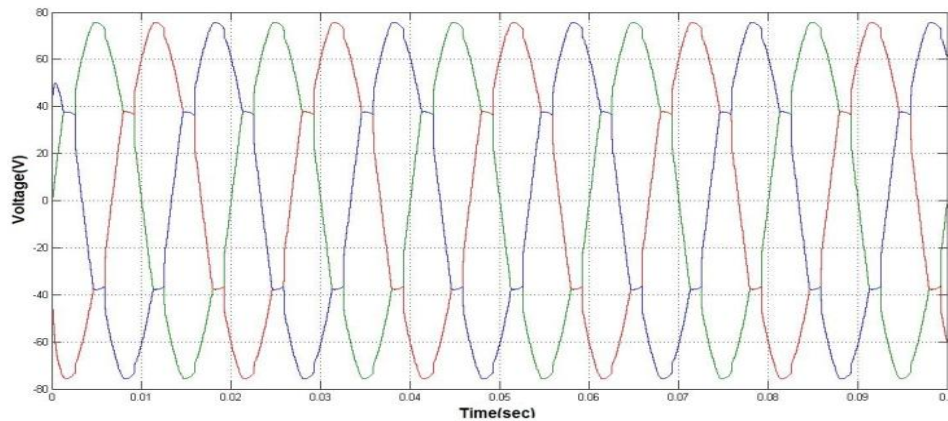


Fig. 11 voltages at source after compensation

Fig .11 shows voltage wave form at the source .where shunt and series active power filter is present in the system .

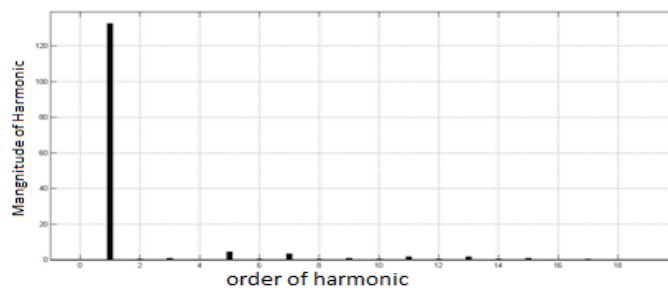


Fig. 12 FFT analysis for above voltages wave form

Figure 12 shows FFT analysis for figure 11 wave from .Compensating voltages are injected into power system by series APF. AS a result THD is reduced 11.03% to 3.97%.



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V. CONCLUSION

This paper presents some insight about the pv system interactive active power flow in an electrical system with a three Phase Series and shunt Active power filter. The presented three -Phase Series and shunt Active power filter makes use of two back-to-back converters with different purposes and distinct coupling with the electrical power system. One is shunt connected to the electrical grid through a transformer, and the other is series connected without a transformer to the electrical grid. The Shunt Converter performs the regulation of the DC link shared by both converters, by consuming or injecting sinusoidal current. The Series Converter compensates Power Quality issues related with the voltage waveform. The analysis of the active power flow through an electrical system is performed mathematically, and Simulation results were obtained to verify those active power flow issues in a harmonic free electrical System.

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