Parallel active filter for harmonics reduction in a solar conversion chain connected to the electrical network with nonlinear loads

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Industrial and domestic devices use increasingly electronic circuits having a non-linear behavior. They generate in the distribution networks non-sinusoidal currents causing harmful effects. This work focuses on using a parallel active filter for rejection of harmonic disturbances. The feed source is not an autonomous voltage source but a capacitance which is charged through a rectifier formed by diodes connected in anti-parallel with the terminals of the transistors. In order to maintain this tension constant, ensure good quality and availability of generated electricity an optimal solution is preferred using photovoltaic solar energy with DC-DC boost converter and a global research method of perturbation and observation (P&O).

The entire network is modeled using Matlab-Simlulink based on an electrical study. A non-linear load is associated with a photovoltaic generator (GPV) and a shunt active filter is implemented which has two main functions: identifying harmonic currents and controlling the inverter to inject the compensating currents. Conventional techniques (Fast Fourier Transform (FFT)) and instantaneous powers method ('p-q' Theory) are used to calculate and identify the harmonic current.

For the injection of the currents in the electric network a PI controller is employed to adjust the DC current. A command with hysteresis control compared to a natural PWM control (Pulsation Width Modulation) used to re-inject harmonics currents. Finally a simulation with Matlab/Simulink environment demonstrated the effectiveness and the robustness of these strategies.

Keywords

Photovoltaic generator, nonlinear load, Harmonics, parallel active filter, (FFT), instantaneous powers method, PWM control, Hysteresis, PI regulator.

1. Introduction

Solar is the most important source of renewable energy in Morocco. [10] With over 3000 h / year of sunshine, or 2,600 kWh / m² / year, Morocco has a considerable solar field. This source of energy constitutes a particularly important potential, especially in the regions badly served with low electricity production capacity. Photovoltaic solar is a way to produce electricity using the sun's radiation. This energy is part of renewable energies, ie energies based on natural sources (wind, sun, but also current of water for example), which do not produce CO2 or radioactive waste during the electricity production. Photovoltaic electricity can be used for immediate use at the place of production (an urban lamppost, a house, a business or an agricultural building) or it can be injected into the country's electricity distribution network Against remuneration of the producer. This is possible for an individual, a company or a community. On-site use or local use is particularly useful in isolated areas (islands, high mountains) or in regions where the electricity grid is insufficient in relation to demand.

In this work our research involves the problems of integration of the photovoltaic solar energy in the electric network; especially we treat the problem of harmonics.

Today, harmonic pollution is one of the major preoccupations of specialists in the field of electrical energy, at the beginning of their appearance, the harmonics were caused by the saturation of the magnetic circuits, now it is rather the charges Nonlinear based on power electronics which are the principal source of disrupting and this is the case of our solar conversion chain that contains chopper and inverter as well as a non linear load that characterising the consumer side formed by a diode rectifier bridge feeding a serial resistive load with an inductor. This static converters are So-called deforming loads caused by the fluctuating and unpredictable character of the harmonic production which complicates the management of the network, absorb non-sinusoidal currents and consequently generates harmonics whose circulation in the network brings: Protections adjustment problems , Problems of energy quality and voltage control as well as unjustified disconnections of photovoltaic panels. To deal with these problems and to reduce the effects of harmonic currents and reactive power absorbed by non-linear loads the active filter Parallel is a seductive alternative.

Active parallel power filtering (FAP) is a modern and adequate solution making it possible to remedy disturbances of current. This compensator can be used to compensate for harmonic currents, unbalanced currents and fundamentally reactive. It is fits between the network and the non-linear load. The performance of a parallel active filter depends to a large extent on the type of control, the sizing of the coupling elements to the network and the storage system (generally capacitive), the dynamics of the extraction and current control algorithms. Its principle is to inject into the network a harmonic current of the same amplitude and of opposite phase as that generated by the load and a reactive component of the current similar to that absorbed by the electronic component of the nonlinear load in order to maintain the Sinusoidal line current and compensate for the reactive power absorbed. Our work is focused on the FAP (Parallel Active Filter) combined with a photovoltaic generator which has two main functions: an identification function of harmonic currents and inverter control function to inject compensation currents.

The PAF control step must consider the inverter associated with an output filter to restore accurately the compensating currents in order to have a stable power grid. This article is organized as follows: The first part is the introduction, the second part presents the mathematical model of the photovoltaic system, the third part is devoted to parallel active filter, his control strategy, regulation and dimensioning, the fourth part is reserved to the discussion of simulation results obtained using MATLAB/SIMULINK, The fifth part is conclusion and perspectives.

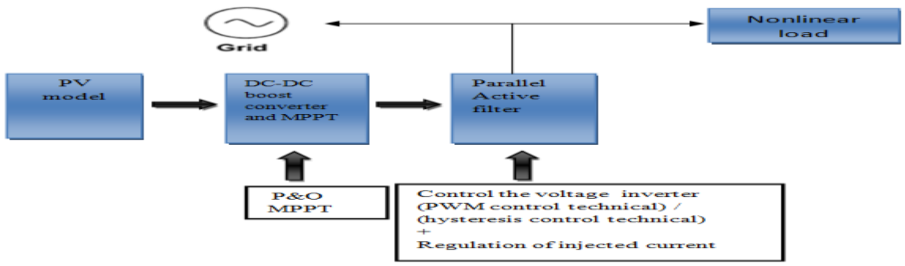

Figure 1. Diagram of photovoltaic system

The figure describes a photovoltaic generator connected to the grid with a parallel active filter. The proposed system consist of a field of solar panels, a MPPT global search method type (P&O), a step-up (boost DC-DC), an inverter act to convert the direct current generated by the photovoltaic in alternating current compatible with the network ,a hysteresis control technique compared to a PWM control technique ,a non linear load diode rectifier.

2. Modeling of PV systems connected to the power grid

The PV cell, also called solar cell, is the basic element of the photovoltaic conversion. This is a semiconductor device that converts electrical energy into light energy from the sun. PV arrays are then made to increase the voltage (Groupement in series) or increase the current (Groupement in parallel).

2.1 photovoltaic cell

The equivalent circuit consists of a diode (D) characterizing the junction, a current source (Isc) characterizing the photo-current, a series resistor (Rs) representing the losses by Joule effect, and resistance shunts (Rp) characterizing a leakage current between the upper grid and the rear contact which is generally much higher than (Rs). [5]

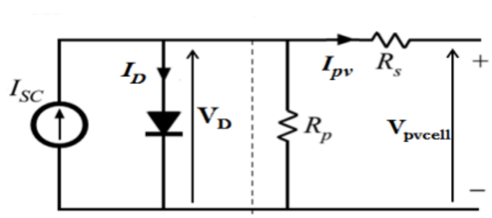

Figure 2.model of a photovoltaic cell

The mathematical model of the circuit of the figure is given by the following equations:

Kirchhoff's laws : [5]

$$I_{SC} - I_D - \frac{V_D}{R_P} - I_{PV} = 0 \quad (1)$$

$$I_{SC} = G.E \quad (2)$$

$$V_{PVcell} = V_D - R_S . I_{PV} \quad (3)$$

$$I_{PV} = N_S . V_{PVcell} \quad (4)$$

Characteristic of the diode:

$$I_D = I_0(e^{V_D - V_T} \_1) \quad (5)$$

$$V_T = \frac{a.k.T}{q} \quad (6)$$

Electric power:

$$P_{pv} = V_{pv} \cdot I_{pv} \quad (7)$$

I_{sc}: Current picture or current generated by the illumination.

N_s : Number of cells in series.

I_0 : The diode saturation current (A).

V_T: Thermal voltage of the cell (V).

a: The junction ideality factor.

k: Boltzmann's constant (1.3806503e-23 J / K).

q: charge of the electron (q = 1.6.10 -19 C).

2.2 Modeling of DC-DC Boost Converter

A boost converter is a switching power supply that converts a DC voltage into another DC voltage of higher value. [4] [6]

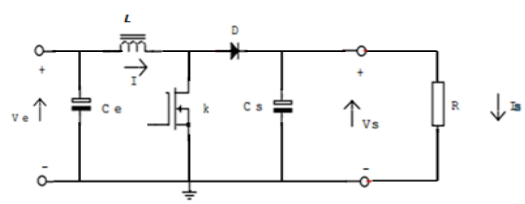

Figure 3 .DC-DC Boost converter

The power voltage source of the circuit is V_e, the output load is a resistor R and delivers a current I_s.
Switch K, symbolized here as a power MOSFET is rendered conductive periodically with a cyclic α relative to the frequency F = 1 /T. The output voltage V_S is giving using (8): [6]

$$\frac{V_S}{V_E} = \frac{1}{1-\propto} \quad (8)$$

Where, $\propto$ is the duty cycle of the converter. The inductor value is chosen such that the current through the inductor is continuous. The current ripple (ΔI) is chosen to be 5% of the output current I_o and the voltage ripple (ΔV) is to be 3% of the output voltage V_o. The inductor L and capacitor C values are chosen using: [6]

$$L = \frac{1}{8} \frac{V_{in}\propto}{\Delta I \, f_s} \quad (9)$$

$$C = \frac{I_o\propto}{f_s \Delta V} \quad (10)$$

Where f_s is the switching of the boost converter. The parameters used in the photovoltaic module and the DC-DC boost converter are shown in the following Table. In our model the input of the boost converter is 60V when we applied PWM is stepped up to 285V, and when we applied hysteresis control is stepped up to 500V.

Table 1: parameters used in the panel model and the boost converter

Parameter	value
Output voltage of the pv Module	60V
Switching Frequency of the Boost Converter	20khz
inductor L in the boost converter circuit	0.01H
Capacitor C value in the boost converter circuit	2.10-3F

3. Harmonic Parallel Active Filter

In this part, parallel active filter is the subject of our discussion, this is why we will talk about their structure, characteristics and modeling, before that we will present our model based on a nonlinear load (NL) represented by a thyristor rectifier bridge / diodes debiting on a load RL feed by a three-phase network, supposedly balanced like it is shows in the figure 4. [9] [1]

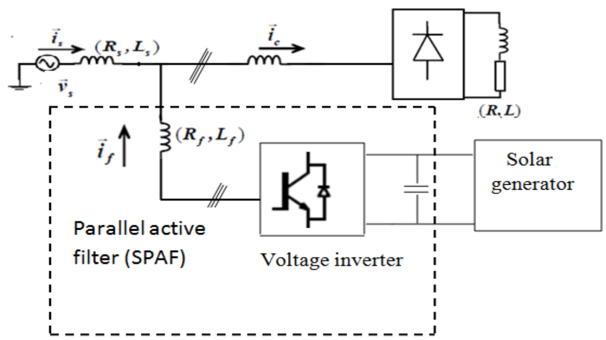

Figure 4. General structure of parallel active filter

3.1 Nonlinear load, energy study for compensation

The feed network is modeled by three perfect sinusoidal voltage sources in series with an inductance L_s and a resistance Rs. An additional inductor L_c is connected to the input of the bridge rectifier to limit the gradient $\frac{di}{dt}$ at initiation of thyristor / diode Like is shown in Figure 5. [7]

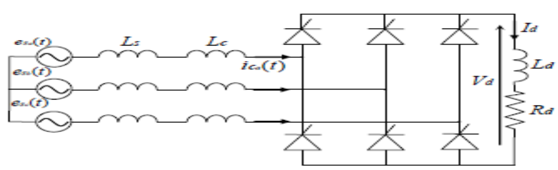

Figure 5. Diagram of a thyristor three-phase rectifier

The current flowing in the load can therefore decompose into: a fundamental component i_{ch-1} and a harmonic component as shown: [7]

$$i_{ch-h} = i_{ch-1} + i_c \quad (11)$$

For the fundamental component:

$$i_{ch-1}(t) = I_1.\sqrt{2}\sin(\mathrm{wt}+\varphi_1) \quad (12)$$

For a harmonic component:

$$i_c(\mathrm{t}) = \sum_{h=1}^{\infty} \sqrt{2}\,.I_h.\sin(\mathrm{wt}+\varphi_1) \quad (13)$$

Compensation of harmonic currents:

$$\mathrm{Pf} = \frac{\mathrm{P}}{\mathrm{S}} = \frac{\mathrm{KW}}{\mathrm{KVA}} \neq \cos\varphi \quad (14)$$

$$\mathrm{S} = \sqrt{P^2 + Q^2 + H^2} \quad (15)$$

$$\text{KVA}=\sqrt{KW^2 + KVAR^2 + KVAR_H{}^2} \qquad (16)$$

The apparent power of the filter, compensating the harmonic current:

$$S_f = \sqrt{D^2{}_c} = 3.V_s.\,I_{ch} \qquad (17)$$

3.2 Modelisation of parallel active filter

Parallel active filter used in our model is a voltage inverter that is controlled by the current, this is a PWM voltage inverter, treated the eliminating of harmonic current created by the bridge rectifier. Their principle consists in generating harmonics in phase opposite to those existing on the network.
It possess a floating called source (capacitor) that plays the role of à DC voltage source. The voltage inverter Connected to the network disturbed by an inductive filter.

3.2.1 Structure of a parallel active filter

The general structure of the parallel active filter is presented in two parts: the power part and the control systems part. [2]

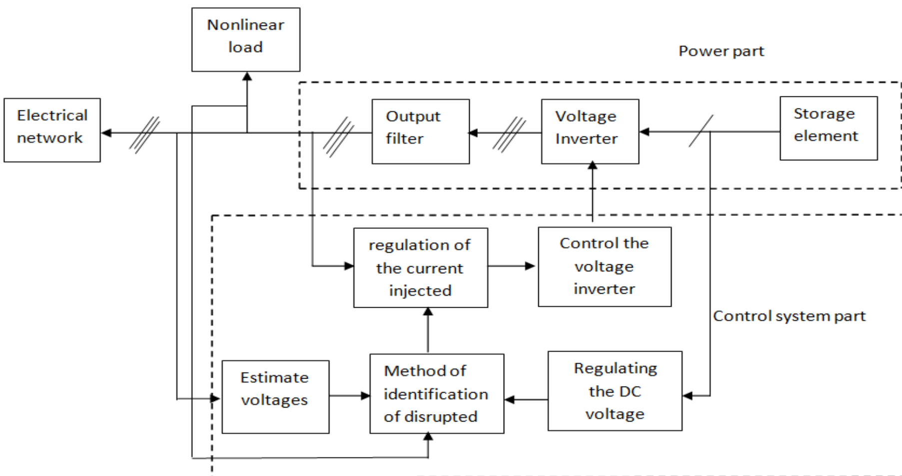

Figure 6.General structure of the parallel active filter

3.2.1.1 *DC-AC Voltage inverter*

A three-phase voltage inverter consists of three arms switches reversible in current, commanded in the opening and the closing by a transistor (IGBT or GTO) and a diode antiparallel. The energy storage the DC side is done via a voltage capacitor. [3]

<u>Supplied voltage by the inverter:</u> [3]

The opening and closing of the switches of the inverter depending on the state of control signals:

$$S_1 = \begin{cases} 1 & T_1 \text{ closed and } T_4 \text{ open} \\ 0 & T_1 \text{ open and } T_4 \text{ closed} \end{cases}$$

$$S_2 = \begin{cases} 1 & T_2 \text{ closed and } T_5 \text{ open} \\ 0 & T_2 \text{ open and } T_5 \text{ closed} \end{cases}$$

$$S_3 = \begin{cases} 1 & T_3 \text{ closed and } T_6 \text{ open} \\ 0 & T_3 \text{ open and } T_6 \text{ closed} \end{cases}$$

Eight possible cases output voltage of the active filter V_f as shown in table: [3]

Number of cases	S_1	S_2	S_3	Vf_3	Vf_2	Vf_1
0	0	0	0	0	0	0
1	0	0	1	-Vdc/3	-Vdc/3	2Vdc/3
2	0	1	0	-Vdc/3	2Vdc/3	-Vdc/3
3	0	1	1	-2Vdc/3	Vdc/3	Vdc/3
4	1	0	0	2Vdc/3	-Vdc/3	-Vdc/3
5	1	0	1	Vdc/3	-2Vdc/3	Vdc/3
6	1	1	0	Vdc/3	Vdc/3	-2Vdc/3
7	1	1	1	0	0	0

Table 2. Tensions generated by the inverter

<u>Vector representation:</u>

In the two-phase plane ($\propto, \beta$), considering the vector $\vec{V}_f$ corresponding to the voltages of the inverter, the eight possible cases of the vector are given in Figure 7. [3]

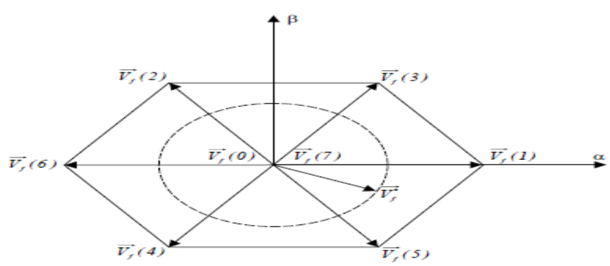

Figure 7. Vector representation of the tensions generated by the inverter

3.2.1.2 Identification of harmonic currents

This strategy of identification is based on the detection of disturbing currents in the time domain. For our study we chose the identification from the detection the current of the pollutant load, and then we are worked with the real and imaginary powers method. [9]

<u>The instantaneous power method:</u> [9]

This method has the advantage of identification of the disturbances with precision, speedy and an ease of implementation, it exploits the transformation of the system parameters in three phases into two phases, this transformation is called Concordia direct transformation.

We write:

$\hat{V}_a$, $\hat{V}_b$, $\hat{V}_c$ the estimated tensions and i_a ,i_b, i_c the currents absorbed by pollutant load.

The Concordia direct transformation allows writing these components in the stationary reference as follows: [9]

$$\begin{bmatrix}\hat{V}_\alpha\\ \hat{V}_\beta\\ \hat{V}_0\end{bmatrix}=\sqrt{\frac{2}{3}}\begin{bmatrix}1 & \frac{-1}{2} & \frac{-1}{2}\\ 0 & \sqrt{\frac{3}{2}} & \sqrt{\frac{3}{2}}\\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}\end{bmatrix}\begin{bmatrix}\hat{V}_a\\ \hat{V}_b\\ \hat{V}_c\end{bmatrix} \quad (18) \qquad \begin{bmatrix}i_\alpha\\ i_\beta\\ i_0\end{bmatrix}=\sqrt{\frac{2}{3}}\begin{bmatrix}1 & \frac{-1}{2} & \frac{-1}{2}\\ 0 & \sqrt{\frac{3}{2}} & \sqrt{\frac{3}{2}}\\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}\end{bmatrix}\begin{bmatrix}i_a\\ i_b\\ i_c\end{bmatrix} \quad (19)$$

The components with the index (0) represent homopolar sequences of the three-phase system of current and voltage. The instantaneous active power, denoted p (t): [9]

$$\begin{cases} P\,(t) = \hat{V}_a i_{la} + \hat{V}_b i_{lb} + \hat{V}_c i_{lc} = p\,(t) + p_0(t) \\ P\,(t) = \hat{V}_\alpha i_{l\alpha} + \hat{V}_\beta i_{l\beta} \\ p_0(t) = V_0 I_0 \end{cases} \tag{20}$$

With:
$p_0(t)$ Represent power homopolar instantaneous.
Similarly, the instantaneous imaginary power can be written as follows: [9]

$$q\,(t) = -\frac{1}{\sqrt{3}}\left[(\hat{V}_a - \hat{V}_b)\, i_{lc} + (\hat{V}_b - \hat{V}_c)\, i_{la} + (\hat{V}_a - \hat{V}_b)\, i_{lb}\right] = \hat{V}_\alpha i_{l\beta} - \hat{V}_\beta i_{l\alpha} \tag{21}$$

Calculation of harmonic currents: [9]

From the relations (20) and (21) we can establish the following matrix relationship:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} \hat{V}_\alpha & \hat{V}_\beta \\ -\hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \tag{22}$$

By reversing the relationship (22) we can re-calculate the current in the stationary reference as shown the following equation:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{\hat{V}_\alpha{}^2 + \hat{V}_\beta{}^2} \begin{bmatrix} \hat{V}_\alpha & -\hat{V}_\beta \\ \hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} P_1 \\ q_1 \end{bmatrix} \tag{23}$$

With

$$\begin{bmatrix} P_1 \\ q_1 \end{bmatrix} = \begin{cases} \overline{P} + \tilde{p} \\ \overline{q} + \tilde{q} \end{cases} \tag{24}$$

$\overline{P}$ and $\overline{q}$: continuous power related to the fundamental components active and reactive respectively of the current and the voltage. From the equations (23) and (24) we can write:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \hat{V}_\alpha & -\hat{V}_\beta \\ \hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} \overline{P} \\ 0 \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} \hat{V}_\alpha & -\hat{V}_\beta \\ \hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} 0 \\ \overline{q} \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} \hat{V}_\alpha & -\hat{V}_\beta \\ \hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad [9] \tag{25}$$

With

$\Delta = \hat{V}_\alpha{}^2 + \hat{V}_\beta{}^2$ supposed constant in the hypothesis of a balanced sinusoidal voltage of the electrical network. The three-phase interference currents that represent the identified current, said reference currents of the filter I_f*, are calculated from the inverse transformation Concordia defined by:

$$\begin{bmatrix} I_{fa}* \\ I_{fb}* \\ I_{fc}* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \tilde{i}_{l\alpha} \\ \tilde{i}_{l\beta} \end{bmatrix} \quad [9] \tag{26}$$

The Figure (8) represents the block diagram of the method of instantaneous power in the case of compensation the harmonic currents without reactive energy compensation. After having identified the pulsations of instantaneous power, a low pass filter with a substractor is used to isolate the active and reactive powers.

In our study, we have chosen a low-pass filter of the second order to simplify the digital implementation approach of the filter.

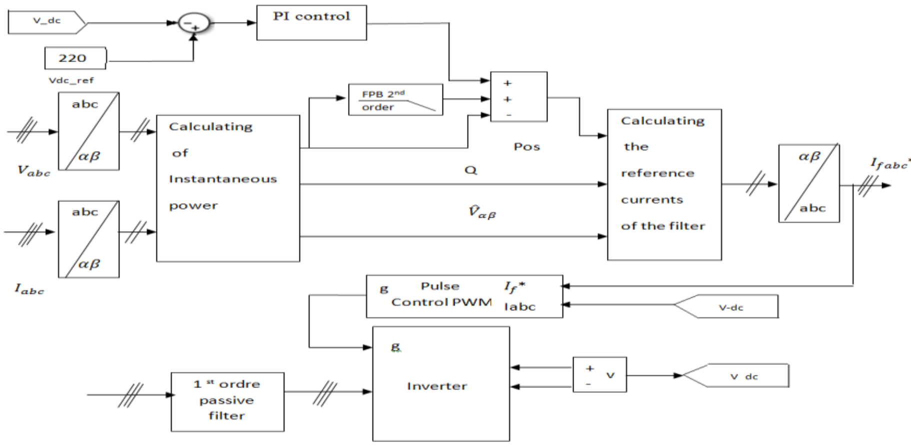

Figure 8. Block diagram of the method of instantaneous power

4. RESULTS AND DISCUSSION

We fixed the temperature and illumination under standard conditions (STC): (G_a=1000w/m^2. T_a=25°C) and we simulate the overall system with two type The hysteresis control and the pulse width modulation (PWM) control so as to operate the system as an energy source (power injection to the power grid) and an active shunt filter (harmonic compensation and reactive power)

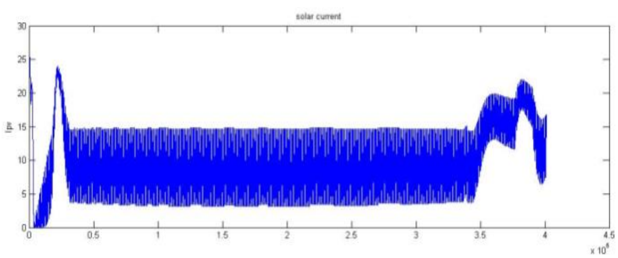

Figure 9. Ipv solar current

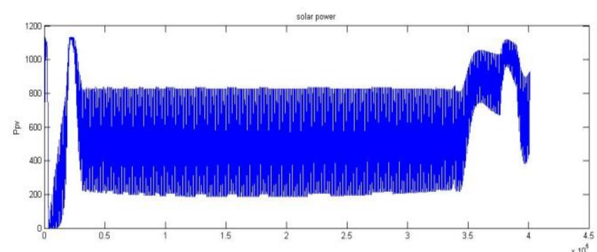

Figure 10. Vpv solar voltage

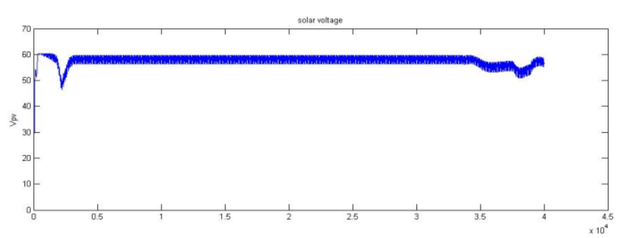

Figure 11. Ppv solar power

The figures 9, 10, 11 represent the allures of the current, voltage and power of the GVP, with a duty cycle always greater than 0.5.

Case 1: with an applied PWM control to the inverter (Parallel active filter).

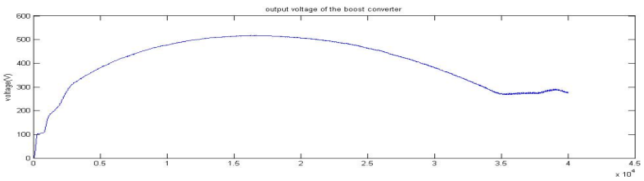

Figure 12.output voltage of boost converter

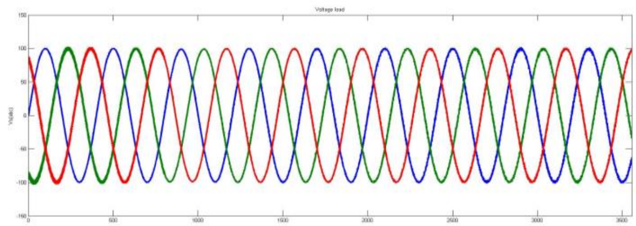

Figure 13. Voltage load

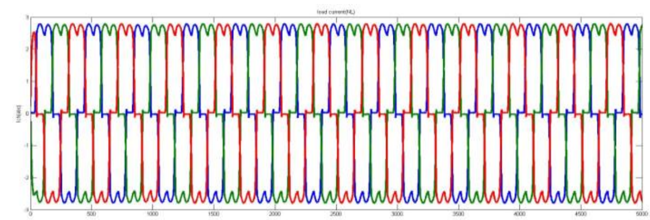

Figure 14. Load current

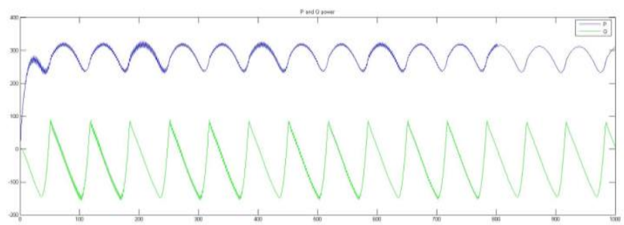

Figure 15. Active and reactive power

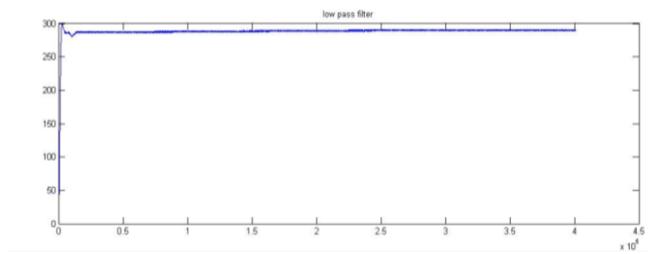

Figure 16. 2nd order low pass filter

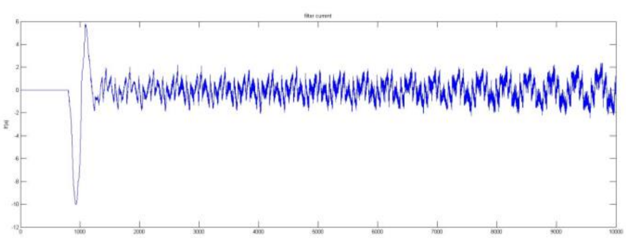

Figure 17.filter current

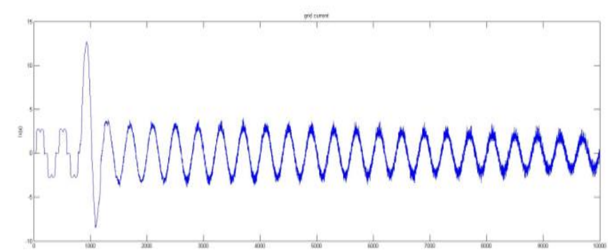

Figure 18.grid current

The figure 14 shows the waveform of the current consumed by the non-linear load before introducing the parallel active filter, the figures . 15, 16, 17, 18 represents the three-phase source waveforms (current Is) as well as the active and reactive powers of the three-phase source after being injected into the grid after the introduction of the photovoltaic compensation system using PWM control technique.

Case 2: with an applied hysteresis control to the inverter (Parallel active filter).

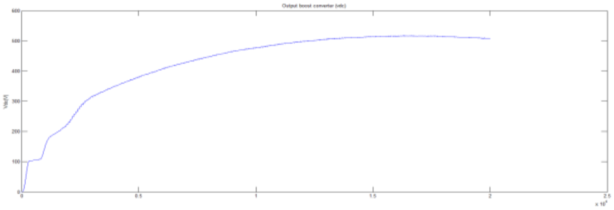

Figure 19. Output voltage of boost converter

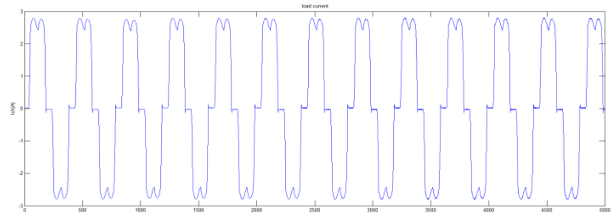

Figure 20.load current

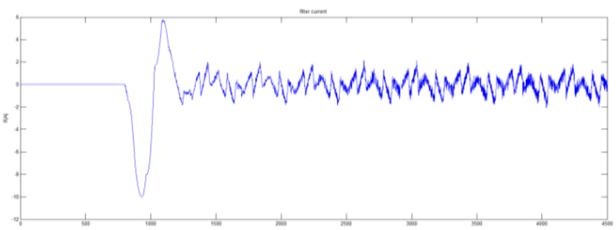

Figure 21.filter current

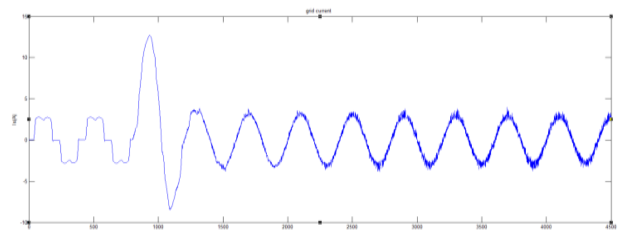

Fig 21. Grid current

The figure 20 shows the waveform of the current consumed by the non-linear load before introducing the parallel active filter, the figures . 21, 22 represents the three-phase source waveforms injected filter current as well as powers of the three-phase source current injected into the grid after the introduction of the photovoltaic compensation system using hysteresis control technique.

5. Conclusion

In this article we demonstrated the feasibility of harmonic compensation system using photovoltaic generator, boost converter, parallel active filter which feeds a nonlinear load. The proposed compensation system acts as a compensator of the reactants in the case of low light, and acts as a shunt active filter with an injection of a real power into the electricity network produced by the photovoltaic conversion chain in the case of a high illumination. The next work will be devoted to the use of artificial neural networks for detection of harmonics, because they present a better pursuit of the harmonic content varies in the time.

References

[1] Abdelmadjid Chaoui, Jean-Paul Gaubert, Fateh Krim, « Power quality improvement using DPC controlled three phase shunt active filter », Electric Power Systems Research, vol. 80, num. 6, pp. 657-666, June 2010.

[2] M.A.CHAOUI "Three-phase active filtering for nonlinear loads « filtrage actif triphasé pour charges non linéaire »" Automatic Laboratory and Industrial (LAII) Poitiers and Power Electronics Laboratory and Industrial Control (LEPCI) Setif. 05-10-2010.

[3] Alaa Eddin Alali Contribution to the Study of countervailing Assets of Electrical Low Voltage Network (Automation of electric power systems) Doctor of University Louis Pasteur - Strasbourg I.

[4] *P.* Umang Shantilal1 A. D. Joshi2 "Simulation of Boost Converter Topology for PV System with Perturb and Observe MPPT Algorithm" IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 01, 2015 | ISSN (online): 2321-0613.

[5] S. Abada, “Study and optimization of a photovoltaic generator for the recharging of a battery with a Sepic convertere “ Etude et optimisation d’un génerateur photovoltaïque pour la recharge d’une batterie avec un convertisseur Sepic” ”Master of Electrical Engineering, Faculty of Graduate Studies Université Laval, QUEBEC 2011

[6] APPLICATION NOTE p09AB06 Sizing a booster chopper "Dimensionnement d’un hacheur survolteur " Year 2009-2010.

[7] S. Abdeslem "Active filtering and monitoring powers: application to photovoltaic systems interconnected to the network « Filtrage actif et contrôle de puissances : application aux systèmes photovoltaïques interconnectés au réseau »" Ferhat Abbas University - Magister thesis of the Faculty of Technology Setifufas (ALGERIA), 2012.

[8] Z. Ayache, A. Bendaoud, H. Slimani, B. Benazza .H. Miloudi, Bentaallah A. " MPPT Command and Control of Photovoltaic per Fuzzy Logic System « Commande MPPT et Contrôle d’un Système Photovoltaïque per la Logique Floue »" IRECOM Laboratory, University Djilali Sidi Bel Abbes Liabes 22000, Algeri.

[9] Z .MAID " parallel Active filtering of harmonic current generated by a three-phase bridge rectifier uncontrolled « Filtrage actif parallèle des harmoniques du courant générés par un pont redresseur triphasé non commandé » " degree of Magister, 2006.

[10] http://www.fellah-trade.com/fr/developpement-durable/energies-renouvelables-maroc

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