Power active filter system implimentation for photovoltaic generation system (PVGS) used in standing alone zones

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Abstract—**This paper presents an autonomous power generation system implementation destined for the isolated zones consisting of photovoltaic generators and a regulation electronic power converter, since the most of the grids contain a power converter system based on power electronics components which generate harmonic currents and consume reactive power, this phenomena generate some perturbations going from dysfunction to the destruction of the sensitive connected equipment, in this paper we aim to propose a solution to solve this problem using an active filter based on recent methods in the identification of the perturbation this system was installed to the previous generation system to increase the performances of the power generation in the isolated zones.**

Keywords-component; Photovoltaic generators, electronic power converter, harmonic current, active filter based.

I. Introduction

Solar power generation system penetration is continuously increasing in many power systems around the world in an effort to increase renewable energy penetration in the energy mix with cost-effective solutions [1] in recent years the increasing concerns about the limited fossil fuel resources led to the awareness that the amount of energy import should be decreased so as to become less dependent of oil exporting countries. Further, the impact of fossil fuel on the environment, especially the global warming and the harmful effects of carbon emissions have created a new demand for clean and sustainable energy sources [2]. The need push us to turn the view to renewable energy such as the Wind, sea, solar, biomass, geothermal powers are sustainable energy sources. The isolated cites is the most need to these renewable energies looking to the high cost, starting from the grids the transformers and the required equipment. The development in the technology of the solar cells generators came with the needs for an effective solution to cover the needs of the electrical power energy. The most of the electrical equipment contain the power converter system based on power electronics components or nonlinear loads such as diode/thyristor rectifiers, cycloconverters, and arc furnaces are being used widely in industrial, commercial and consumer environment [3]. used even for the regulation or for the command of these equipment .These power electronic devices usually draw non-sinusoidal currents from the utility grid, looking to their consumption to the reactive power which cause the perturbation of the sensitive equipment, different solutions was proposed between traditional and modern based on both passive and active filters. In this paper we aim to propose a solution based on an active filter driven by different harmonic detection algorithms implemented to a solar photovoltaic generation system.

II. SYSTEM MODELING AND CONTROL

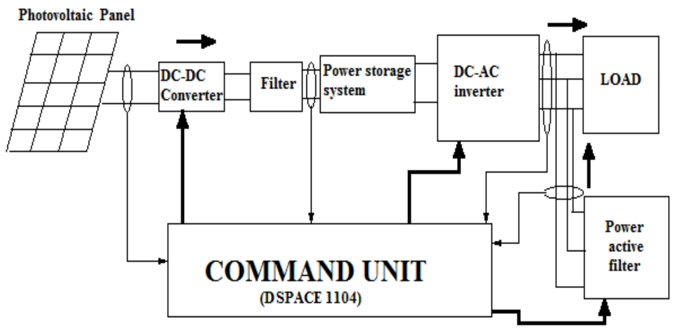


Figure 1. System structure contains PVGS and PAF systems

The figure shows the standard diagram of the system under consideration. Energy is extracted by the PV(photovoltaic) modules, stepped up by an MPPT command system containing an MPPT (Maximum Power Point Trucking)command algorithm which command the boost converter to extract the maximum power possible this from the DC side. From the AC side, the system start by a three phases PMW inverter feeding the distorted grid using the three phases rectifier system based on diodes since this last is one of the most responsible equipment in the generation of the harmonics looking to its structure. The regulator current of the active filter was injected into the AC grid through an inverter model based on IGBTs power electronics elements.

A. *Modelization and control of the photovoltaic generation system (PVGS)*

The model of the PV is defined by an ideal current source associated to a diode [D] and two resistances respectively

[Rs],[Rsh]. The diode demonstrate the semi conduction behavior of the panel on the obscurity, the [Rs] demonstrate the losses on the panel core, [Rsh] demonstrate the parasites current going through the solar cell.

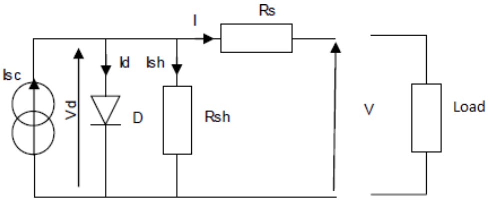


Figure 2. Electrical model of the PV panel.

We suggest that $Rsh \longrightarrow \infty$

Which means $Ish \longrightarrow 0$

$$Isc = Id + I \qquad (1)$$

$$\begin{cases} Id = Is.[e^{(q.\frac{Vd}{n.K.T})} - 1] \\ Vd = V + Rs.I \end{cases} \qquad (2)$$

Since

n: diode's idealization factor.

q: electron's charge = $1{,}602.10^{-19}$

K: Boltzmann constant $=1.38.10^{-23}$

T: cell temperature in degree Kelvin

Is: saturation current

The calculation of the parameters Rs is necessary

From the above diagram

$$Isc = Is.[e^{(q.\frac{Vd}{n.K.T})} - 1] + I \qquad (3)$$

The time that we reach the MPP (Maximum Power Point) on the diagram we get the V=Vmp and I=Imp on this case

$$Isc = Id + Imp \qquad (4)$$

$$Isc = Is.[e^{(q.\frac{Vmp+Rs.Imp}{n.K.T})} - Imp] \qquad (5)$$

With n=ncell

$$Rs = ncell.\left(\frac{KT}{q}\right).\ln\left(\frac{Isc-Imp}{Is}\right)/\left(\frac{Imp-Vmp}{Imp}\right) \qquad (6)$$

B. MPPT topology for the proposed converter structure

The proposed boost converter is used to be connected to the DC side of an inverter which should be stable enough for the inverter feeding and without any fluctuations. In the paper is proposed a DC-DC converter. There are many topologies of DC-DC converters [4][5][6]. The proposed boost converter was used because the MPPT algorithms implementation and control are relatively simple. The converter output voltage can be higher than an input voltage. Value of the output voltage depends on a duty factor.

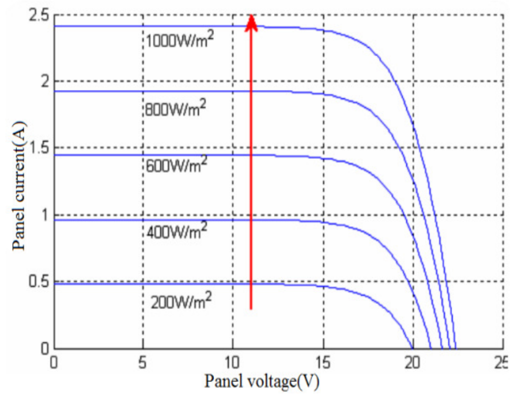
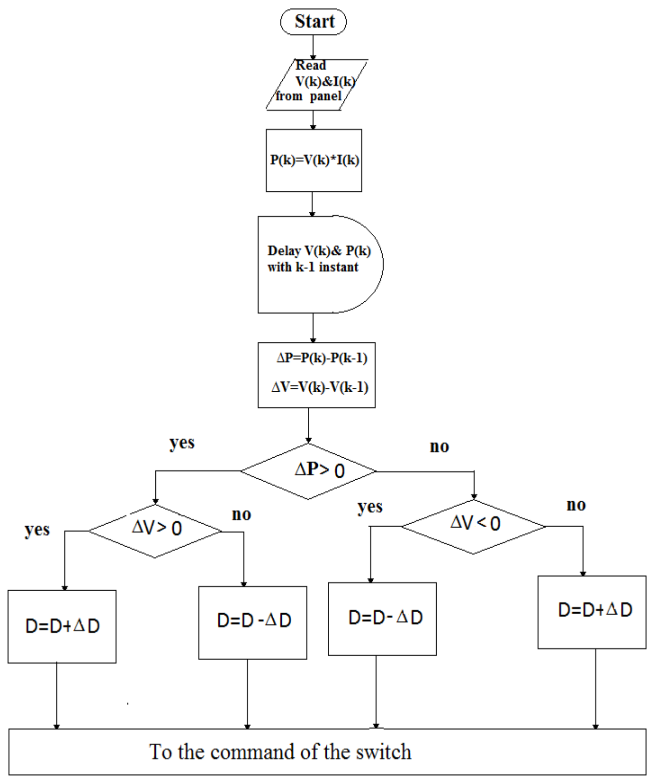


Figure 3. Panel characteristics



D= duty cycle
ΔD=the variation in the duty cycle

Figure 4. P&O algorithm topology for the MPPT process

III. HARMONICS PROBLEMS , DETECTION AND IDENTIFICATION

The concept of the harmonics was introduced since a long time by Joseph Fourier who gave the demonstration that a non-sinusoidal signal could be represented by the summer of series signals with a sinusoidal form under discrete frequencies.

$$i(t) = I_0 + \sum_{h=1}^{\infty} I_h.\cos(w_h t + \theta_h) \quad (7)$$

Where I_0 is the continuous component of Fourier series called the fundamental, I_h the rest of the series are the harmonics under the rang h

A. Active filter structure and compesition

The following figure give the principal process of the active filter starting from identification of the harmonics using an algorithm of detection then to regenerate their image using a power electronic inverter based on IGBT electronics components that inject that image of the harmonics currents in the main grid through an passive filter used to keep the propagation of fluctuation generated from the commutation of the switcher in order to avoid the grid from the different perturbations caused by the harmonics

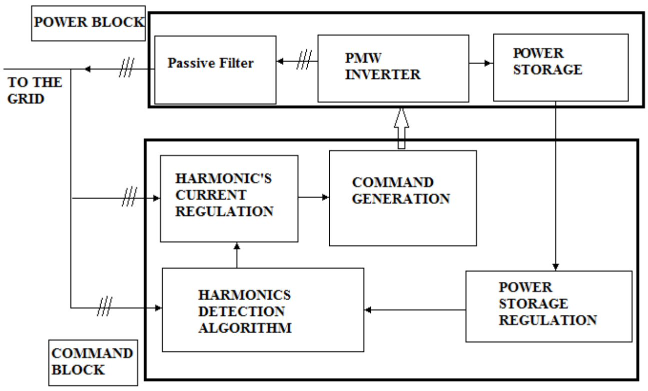


Figure 5. Active filter structure block diagram

B. Harmonics detection algorythm

different methods were proposed and in different applications in order to identify the harmonics currents available in the power grid starting from the NOTCH FILTER [3][7][8][9][10], the PQ theory [11] based on the both low-pass and high-pass filter, the MVF (Multi-variable FILTER) so and so, looking to its high performances and speed in the detection we proposed to integrate the MVF detection method in the PQ theory method to increase the fast response and the detection capacity of the filter.

The MVF extraction method allow to obtain an elimination with more or less satisfaction results of the continuous component, its main idea is based on the extraction of the fundamental component of the signals directly from the (α,β) axis, the expressions linking the $\hat{x}_{\alpha\beta}$ in the output of the MVF their component $x_{\alpha\beta}$ in the input are as follow

Figure 6. MVF main diagram

$$\hat{x}_\alpha = \left(\frac{K}{s}[x_\alpha(s) - \hat{x}_\alpha(s)] - \frac{w_c}{s}.\hat{x}_\beta(s)\right)$$
$$\hat{x}_\beta = \left(\frac{K}{s}[x_\beta(s) - \hat{x}_\beta(s)] - \frac{w_c}{s}.\hat{x}_\alpha(s)\right) \quad (8)$$

With

$x_{\alpha\beta}$: Electrical signals in the input according to the α,β axis.

$\hat{x}_{\alpha\beta}$: Fundamentals components of $x_{\alpha\beta}$.

k : Constant to fixe (between 20 and 100).

w_c :$2\pi f$ Fundamental Pulsation of the grid.

The components of the harmonics current according to α-β axis which are $\tilde{\imath}_\alpha$, $\tilde{\imath}_\beta$ are obtained by the subtraction the input of the MVF block from its output.

$$\begin{cases} i_\alpha = \hat{\imath}_\alpha + \tilde{\imath}_\alpha \\ i_\beta = \hat{\imath}_\beta + \tilde{\imath}_\beta \end{cases} \quad (9)$$

$$\begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} = \begin{bmatrix} \hat{V}\alpha & \hat{V}\beta \\ -\hat{V}\beta & \hat{V}\alpha \end{bmatrix} \begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} \quad (10)$$

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \frac{1}{\hat{V}_\alpha^2 + \hat{V}_\beta^2} \begin{bmatrix} \hat{V}\alpha & -\hat{V}\beta \\ \hat{V}\beta & \hat{V}\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (11)$$

i_α^* and i_β^* are the references of the harmonics currents according to the α-β axis that should regenerate and inject in the grid.

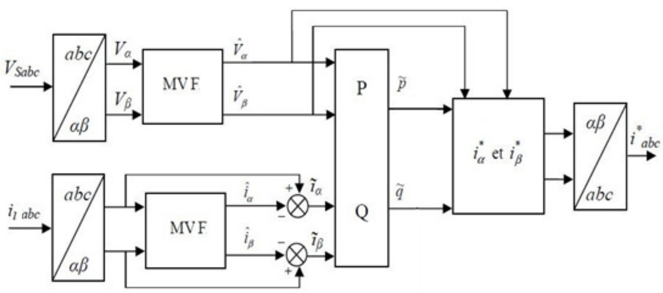


Figure 7. MVF detection method block diagram

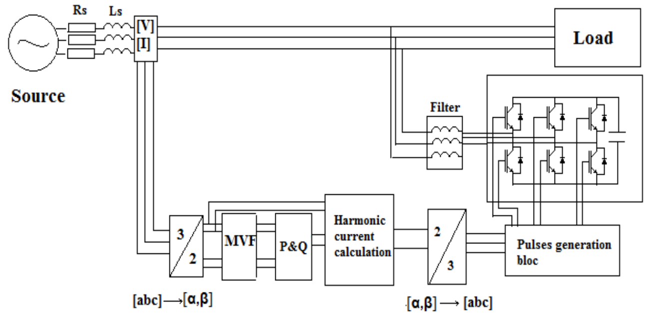


Figure 8. Active filter structure using MVF with PQ theory for harmonics detection

IV. SIMULATION, IMPLIMENTATION AND RESULTS

The whole system composed from the photovoltaic and the MPPT command system from a part, and the power inverter with the power active filter from another part was simulated in Matlab/Simulink on both high and low power since before the system was implemented on a DSPACE card hardware. There has been verified the system behavior. The simulation results were used in the converter design. There was simulated the controller too. Controller constants and parameters were based on the simulations. The simulation results were improved with the experimental ones.

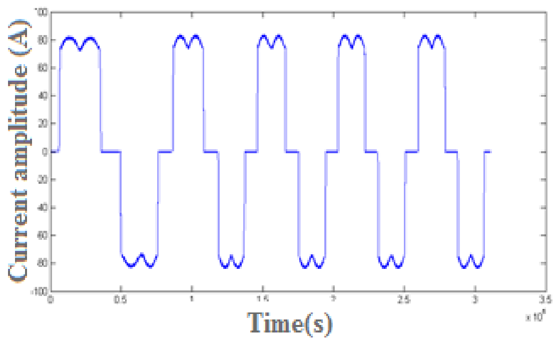


Figure 9. Load line current distorted

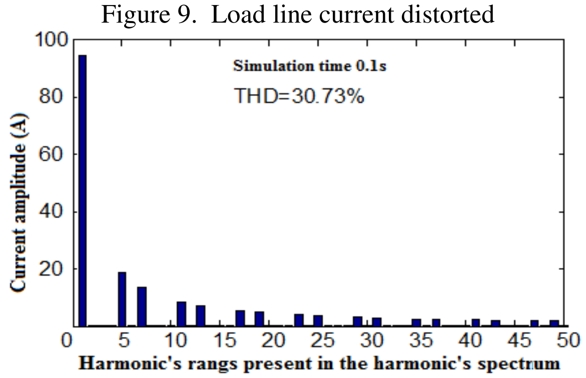


Figure 10. Load current frequency spectrum

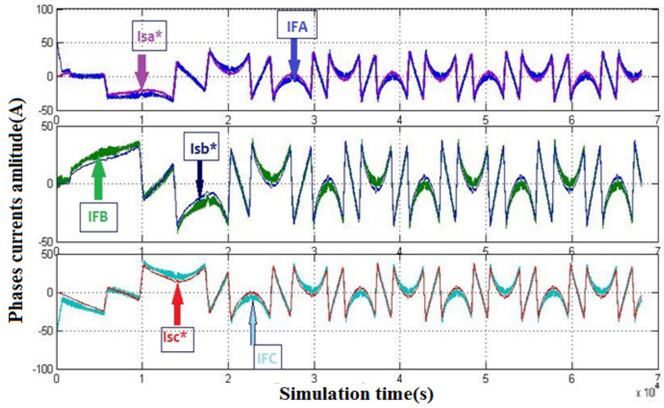


Figure 11. Three phases harmonics extraction

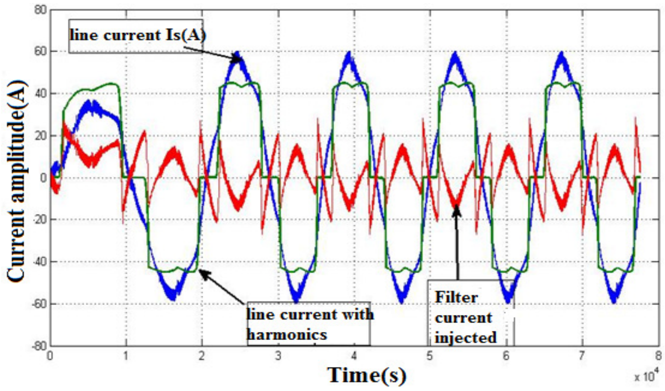


Figure12. Line current after the inject of the filter's currents

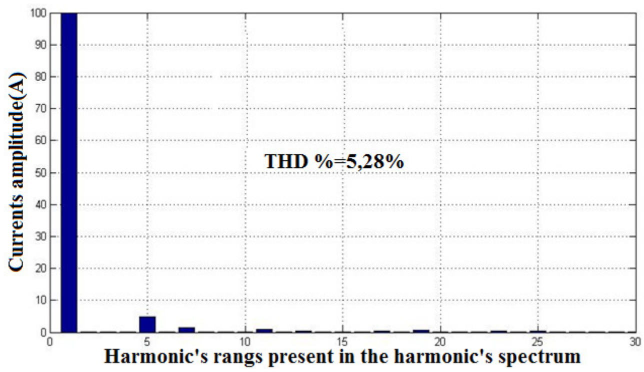


Figure 13. Current frequency spectrum after compensation

In order to create compatibility between our system in the simulation part and the experimental one, since we work under a low power rang, we rebuilt the simulated model using the same parameters of real model where we got the following results

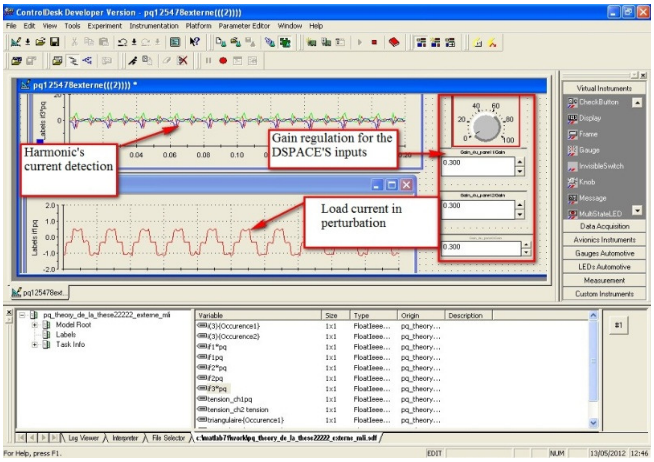


Figure 14. Control desk for command system using DSPACE platform

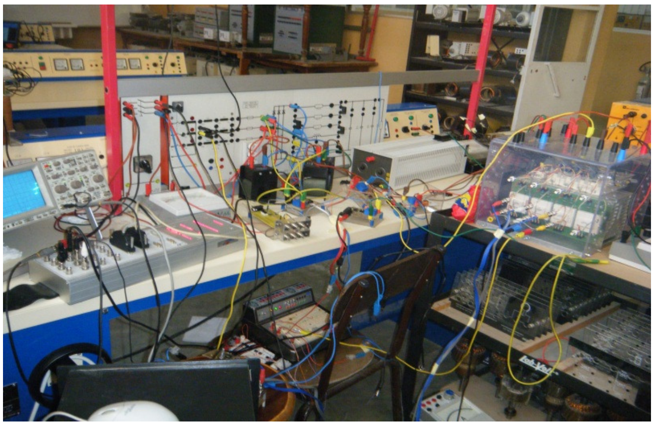


Figure 15. Experimental model used in the extraction of harmonics

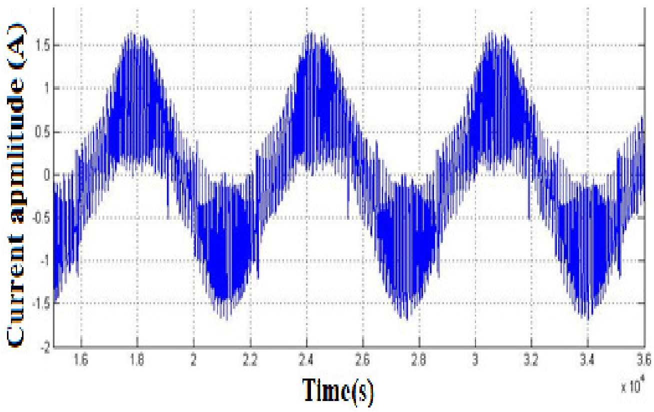


Figure 16. Simulation waveform for the load current after compensation

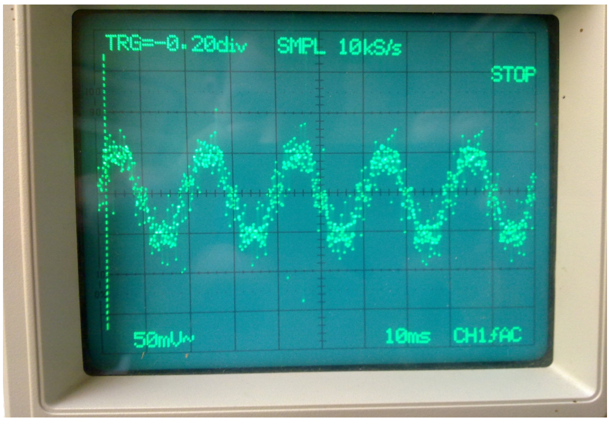


Figure 17. Real waveform for the load current after compensation

CONCLUSION

The performance of a shunt active power filter was proposed simulated analyzed in the hope to open a new gate in the integration of a such devices in the renewable energy domain. The compensation performance of power active filter was studied for different active power filter parameters change. Above all, an conclusion can be obtained that the harmonic attenuation rate is insensitive to the variation of detection method and the device parameters when the active power filter with an enough feedback gain is combined. The feasibility and validity of proposed scheme is verified by Simulation using Matlab and an active power filter prototype.

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