POWER QUALITY IMPROVEMENT IN A SINGLE PHASE VOLTAGE CONTROLLED GRID CONNECTED TO PV SYSTEM

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***Abstract*—This project deals with a single phase Photo Voltaic system with grid connected voltage control. When Distributed Power Generation System (DPG) is connected to a low voltage grid then the frequency and voltage of a grid cannot be controlled by adjusting the active and reactive power independently and also it is cost effective. To overcome this DPGS are replaced by PV systems where the shunt controllers are used to compensate small voltage variations which can be controlled by reactive power injection. The shunt controllers can be used as static VAR generator for stabilizing and improving voltage profile of power systems and to compensate current harmonics, unbalanced load current and improving voltage quality in case of small voltage dips. There the present topology of PV system adopts a repetitive controller, able to compensate the selected harmonics. The power provided by the PV panels are controlled by a recent algorithm know as Maximum Power Point Tracking (MPPT) based on the incremental conductance method and it has been modified to change the phase displacement between the converter voltage and the grid voltage, maximizing the extraction of power from the PV panels and compensation of harmonic distortion at the Point Of Common Coupling (PCC).**

***Key Words — Maximum Power Point Tracking, photo voltaic, Distributed Power Generation System, Point of Common Coupling*.**

I.INTRODUCTION

Now a days there is a lot of demand for the generation of the power to meet the load demand. So, the renewable energy sources are the best choice of power generation, among this Photo Voltaic (PV) power plants have a noticeable growth. In future the low-voltage distribution networks connected to small Photo Voltaic (PV) power plants small is expected.

Transmission networks are less robust and has less reliability than distribution networks, due to decrease in radial configuration as the voltage level decreases. so, when the voltage is lower than 0.85 pu or higher than 1.1 pu,we recommend the disconnection of low-power systems because the grid voltage and grid frequency cannot be controlled by adjusting the reactive and active powers independently. When a low-voltage grid is connected to Distributed Power Generation System (DPGS), with the addition of ancillary services the design of DPGS system becomes convenient & economical which meets the requirement of need of limiting the cost and size. To overcome this problem we are proposing this scheme comprises of a shunt controller which acts as a voltage controlled converter in case of voltage dips & non linear loads also controlling and improving the voltage profile. Also to compensate current harmonics and unbalanced load current to improve the voltage profile for stabilizing the shunt controller are used as static VAR generator.

This project mainly has a Maximum Power Point Tracking (MPPT) algorithm on the basis of incremental conductance method the phase of the PV inverter voltage is controlled by taking the power oscillations on the PV side. The power produced by the PV panels is supplied by the PV inverter and also improves the voltage profile the selected harmonics are able to compensate by therepetitive controller.

II.SUPPORT OF VOLTAGE AND FREQUENCY

The power transfer between two lines connecting a DPGS converter to the grid can be studied using a short line model and complex phasors, as shown in Fig.

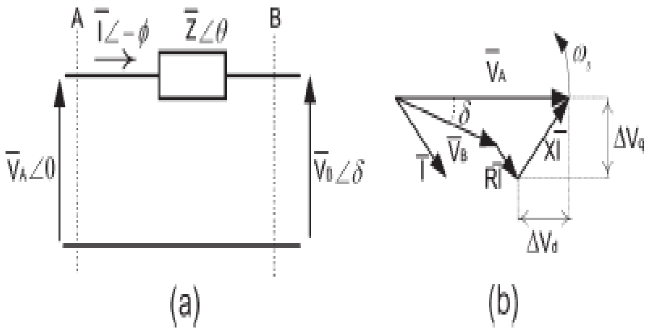


Fig.1. (a) Power flow through a line. (b) Phasor diagram.

When the DPGS is connected to the grid through a mainly inductive line $X \gg R$, R may be neglected. If the power angle δ is also small. the equation given by $\sin\delta \cong \delta$ and $\cos\delta \cong 1$,

also,

$$\delta \cong \frac{XP_A}{V_A V_B}$$

$$V_A - V_B \cong \frac{XQ_A}{V_A}$$

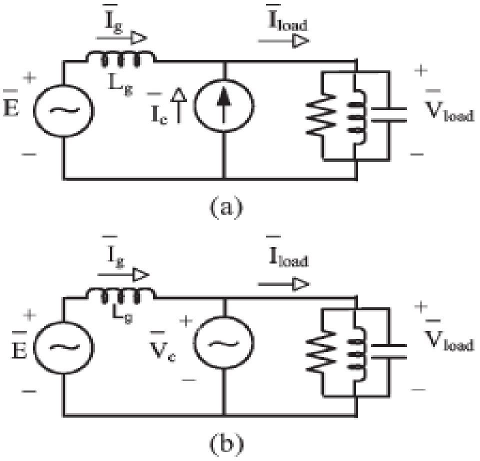
where V_A, P_A, and Q_A denote, respectively, the voltage, active power, and reactive power in section A, and V_B is the voltage in section B, as indicated in Fig.

For X >>R, a small power angle δ, and a small difference $V_A - V_B$, equations show that the power angle predominantly depends on the active power, whereas the voltage difference $V_A - V_B$ predominantly depends on the reactive power. That means, the angle δ can be controlled by regulating the active power, whereas the inverter voltage V_A is controlled through the reactive power. Therefore independently by adjusting the active and reactive powers, the amplitude of the grid voltage and frequency can be determined. These conclusions are the basis of the voltage drop control and the frequency through active and reactive powers, respectively. In this project, these relations are adopted to optimize the power extraction from PV panels (MPPT).

III.Mitigation Of Voltage Dip By Using Shunt Controllers

Small voltage variations are controlled by reactive power injection. This can be compensated by adopting shunt devices, the grid impedance and the power factor of the load are important at a point to control the fundamental voltage to increase the load voltage by current injection has to be very high because there will below grid impedance. so it is difficult to compensate the voltage dip by the injection of current & the shunt controller used are current or voltage controlled.

That is, the grid-feeding component is current controlled converter. In this based on the grid voltage variations the reactive output power is adjusted which supports the grid voltage. The other is voltage controlled converter know as grid-supporting component. Here the voltage is stabilized by reactive power injection which results as control action for controlling the output voltage.



(a)

(b)

Fig.2. Use of a shunt controller for compensation of voltage dips. (a) Simple power circuit of the current-controlled shunt controller. (b) Simplified power circuit of the voltage-controlled shunt controller.

However, also in this second case, the action of control result in the injection of the reactive power in order to stabilize the voltage. The shunt controller vector diagrams are designed to provide only reactive power are reported in Fig. When the grid voltage is 1 pu, the converter supplies the reactive power absorbed by the load, and the vector diagram of the voltage- or current -controlled converter is the same, then it is controlled by the compensating current $I_{C,}$ that is in the first case, and in the second one, it is controlled by the load voltage, as underlined in Fig (a) and (b).

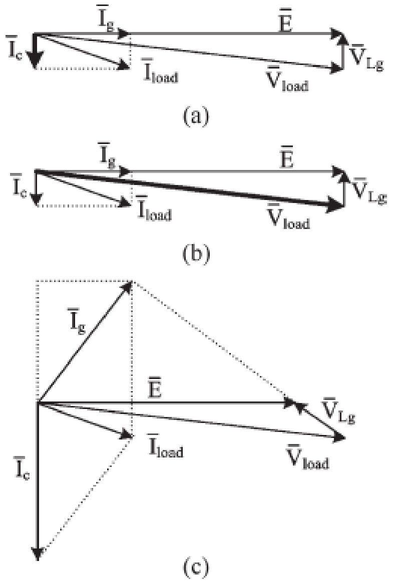


Fig.3. Vector diagram of the shunt controller providing only reactive power. (a) In normal conditions the Current-controlled converter. (b) In normal condition Voltage-controlled converter. (c) compensation of a voltage dip of 0.15 pu based Vector diagram.

When a voltage sag occurs, the converter provides reactive power in order to support the load voltage, and the grid current Ig has a dominant reactive component.

$$\overline{I}_g + \overline{I}_C = \overline{I}_{\text{load}}.$$

The grid current amplitude depends on the value of the grid impedance since

$$\overline{I}_g = \frac{\overline{V}_{L_g}}{j\omega L_g}$$

Where $\bar{V}_{Lg}$is the inductance voltage drop shown in Fig. (c). If the shunt controller supplies the load with all the requested reactive powers and active, in normal conditions, it provides compensating current Ic = $I_{load;}$ hence, the system operates as in island mode, and $I_g = 0$.

In case of a voltage dip, the converter has to provide the active power required by load, and the reactive power has to be injected by it which is needed to stabilize the load voltage, as shown in Fig. (b). The grid current in this case is reactive. It is seen that

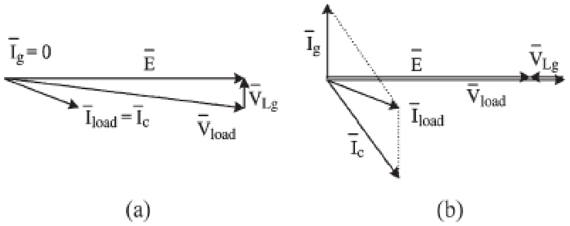


Fig.4. Vector diagram of the shunt controller providing both active and reactive powers. (a) Normal conditions. (b) Vector diagram for compensation. Value of 0.15 pu of a voltage dip.

$$\overline{V}_{\text{load}} = \overline{E} + \overline{V}_{L_g}.$$

Hence during a voltage sag the amount of reactive current needed to maintain the voltage at the desired value is inversely proportional to ωLg. This is a large inductance will help in mitigating of voltage sags, although in normal operation it is not desirable.

IV.PV SYSTEM WITH MULTIFUNCTIONAL SHUNT CONTROLLER

When the converter is connected in parallel with the grid, then it is more advantageous to compensate small voltage sags in case of low-power applications. This can be provided for local loads as an ancillary service by the system. In the presence of sun the reactive and active powers are supplied to proposed PV converter to operate it, then the PV converter operates as a harmonic and reactive power compensator when low irradiation is present. Since, it is difficult to improve the voltage quality with a shunt controller and it cannot provide simultaneous control of the output voltage and current to avoid this, a large capacity converter is used in order to compensate voltage sags. In the PV applications this topology is acceptable because for the peak power produced by the panels the PV shunt converter is rated. The PV converter operates as a shunt controller, in this proposed system, through an LC filter it is connected to the load and to the grid through an extra inductance Lg value 0.1in pu, as shown in Fig.

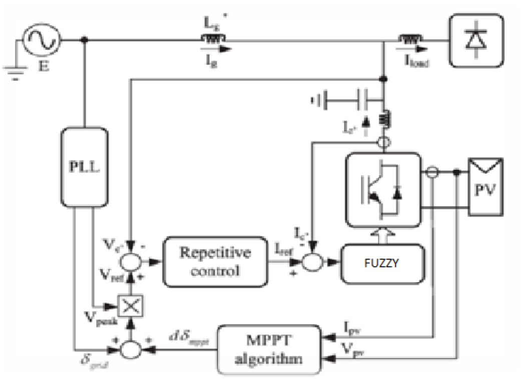


Fig.5. Grid-connected PV system with shunt controller functionality using fuzzy control.

The systems are connected to low-voltage distribution lines whose impedance is mainly resistive, in case of low-power applications. In the proposed topology, the grid can be considered mainly inductive as a consequence of Lg addition on the grid side. Due to the presences of the inductance Lg the voltage regulation is directly affected by the voltage drop during grid normal conditions in order to limit the voltage drop. It is not convenient to choose on an inductance Lg of high value, this is the main drawback of the proposed system.

A. Control of Converter

The displacement between the ac voltage and the grid voltage produced by the converter is modified by the MPPT algorithm in given atmospheric conditions in order to inject the maximum power available, thus indirectly current injection is controlled. The current amplitude depends on the difference between the grid voltage and the voltage on the ac capacitor Vc.

The injected active power (decided by the MPPT algorithm), is determined by the phase displacement between these two voltages and the voltage reactive power exchange with the grid is determined by the differences of voltage amplitude. The PV system will be forced to disconnect (as requested by standards). When the voltage dip higher than 15% this limits the injection of reactive power. The PV system rating limits the active power and leads to a limit on the maximum displacement angle dδmppt. Moreover, the inverter has its over current protections & inner fuzzy based current control loop. The amplitude Vpeak & phase δgrid of the grid voltage are detected by a phase-locked loop (PLL).Then, the MPPT algorithm provides the phase displacement dδmpp & the repetitive controller preprocess the voltage error between Vref and Vc, which is the periodic signal generator of the fundamental component and the selected harmonics. In this present case, the third and fifth are compensated.

The proposed repetitive controller is based on a finite impulse response (FIR) digital filter [20]. It is a “moving” or “running” filter, with a window equal to one fundamental period, defined as

$$F_{\mathrm{DFT}}(z) = \frac{2}{N}\sum_{i=0}^{N-1}\left(\sum_{h\in N_h}\cos\left[\frac{2\pi}{N}h(i+N_a)\right]\right)\cdot z^{-i}$$

Where N is the number of samples within one fundamental period, Nh is set of selected harmonic frequencies, and Na is number of leading steps to be determined to exactly track the reference. The repetitive controller ensures a precise tracking of the selected harmonics, and it provides the reference for the inner loop. In it, a fuzzy controller improves the stability and reduces the ripples of the system, offering a low-pass filter function.

In normal operation mode, the shunt-connected converter injects the surplus of active power in the utility grid, and at the same time, it is controlled in order to cancel the harmonics of the load voltage. At low irradiation, the PV inverter only acts as a shunt controller, eliminating the harmonics. Controlling the voltage Vc , the PV converter is improved with the function of voltage dip compensation. In the presence of a voltage dip, the grid current Ig is forced by the controller to have a sinusoidal waveform that is phase shifted by 90◦ with respect to the corresponding grid voltage.

B. MPPT Algorithm

The power supplied from a PV array mostly depends on the present atmospheric conditions (irradiation and temperature). So in order to collect the maximum available power, the operating point needs to continuously be tracked using an MPPT algorithm. To find the maximum power point for all conditions, based on the incremental conductance method an MPPT control method is operated. This can tell on which side of the PV characteristic the current operating point is present. The MPPT algorithm modifies the phase displacement between the grid voltage and the converter voltage, providing the voltage reference Vref . Furthermore, there is an extra feature added to this algorithm that monitors the maximum and minimum values of power oscillations on the PV side.

In case of single-phase systems, with twice the line frequency the instant power oscillates. This oscillation in power on the grid side leads to a 100-Hz ripple in voltage and power on the PV side. The ripple of the power on the PV side is minimized when the system operates in the area around the MPP. By this feature it is detected that in which part of the power–voltage characteristics of a system operates. In the proposed control scheme it happens that where information about the power oscillation can be used to find out how close the current operating point is to the, Maximum Power Point there by slowing down the increment of the reference, in order not to cross the Maximum Power Point.

A flowchart of the MPPT algorithm is shown in Fig., explaining how the angle of the reference voltage is modified in order to keep the operating point as close to Maximum Power Point as possible. The Maximum Power Point can be tracked by comparing the incremental conductance dIpv/dVpv to the instantaneous conductance Ipv_k/Vpv_k to, as shown in the flowchart. Considering the power–voltage characteristic of a PV array, it can be observed. That, operating in the area on the left side of the Maximum Power Point , dδmppt has to decrease.

This decrement is indicated in Fig. with side = −1. Moreover, operating in the area on the right side of the, Maximum Power Point dδmppt has to increase, and it is indicated with side =+1. The increment size determines how fast the Maximum Power Point is tracked. The measure of the power oscillations on the PV side is used to quantify the increment that is denoted with incr in Fig.

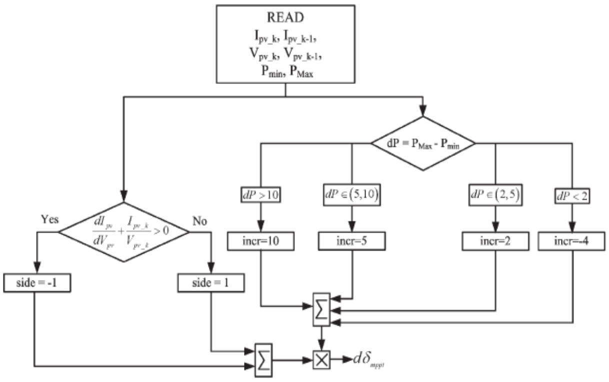


Fig.6. Flowchart of the modified MPPT algorithm.

V. FUZZY LOGIC CONTROL IMPLEMENTATION WITH PV SYSTEM

FLC are formed by simple rule based on “If x and y then z”. These rules are defined by taking help from person’s experience and knowledge about the system behavior. The performance of the system is improved by the correct combinations of these rules. Each of the rules defines one membership which is the function of FLC. More sensitivity is provided in the control mechanism of FLC by increasing the numbers of membership functions. In this study, the inputs of the fuzzy system are assigned by using 7 membership functions and the fuzzy system to be formed in 49 rules. Hence, the sensitivity in the control mechanism is increased.

The basic if-then rule is defined as “If (error is very small and error rate is very small) then output”. Thesignals error and error rate are described as linguistic variables in the FLC such as large negative (LN), medium negative (MN), small negative (SN), very small (VS), small positive (SP), medium positive (MP) and large positive (LP). These are shown in Fig.5. In the same way, the input values of the fuzzy controller are connected to the output values by the if-then rules. The relationship between the input and the output values can be achieved easily by using Takagi- Sugeno type inference method. The output values are characterized by memberships and named aslinguistic variables such as negative big (NB), negative medium (NM), negative small (NS), zero (Z), positive small (PS), positive medium (PM) and positive big(PB). The membership functions of output variables.

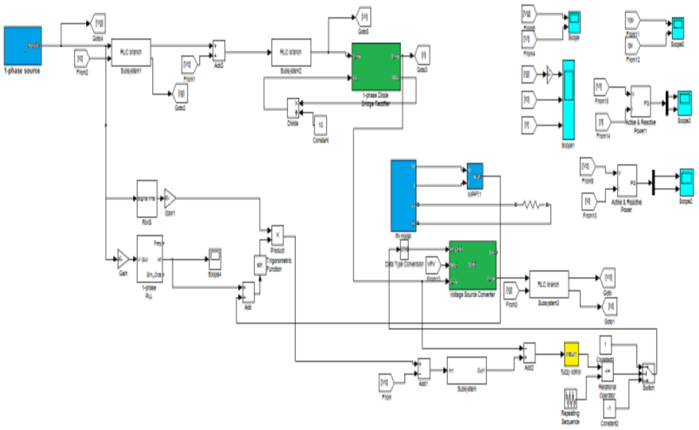


Fig.7.simulink model for the proposed scheme

VI. SIMULATION RESULTS

The PV system with power quality conditioner functionality has been tested in the simulation with the following system parameters: the LC filter made by 1.4-mH inductance, 2.2-μF capacitance, and 1-Ω damping resistance; an inductance Lg of 0.1 pu; and a 1-kW load.

The control has been validated in the presence of sudden changes of the PV power caused, for example, by irradiation variations. The reported tests show the behavior of the MPPT for a voltage sag. The results refer to the case of a controlled inverter in order to collect the maximum available power (i.e.,2 kW).

The controller parameters are kFIR = 0.3, N = 128 (sampling frequency = 6400 Hz), Na = 0, kp = 4.5, and ki = 48. The set of test aims to demonstrate the behavior of the system during a voltage sag and the interaction of the voltage control algorithm with the MPPT algorithm.

The simulation results, shown in Figs , are obtained in case of 0.15 pu of a voltage dip

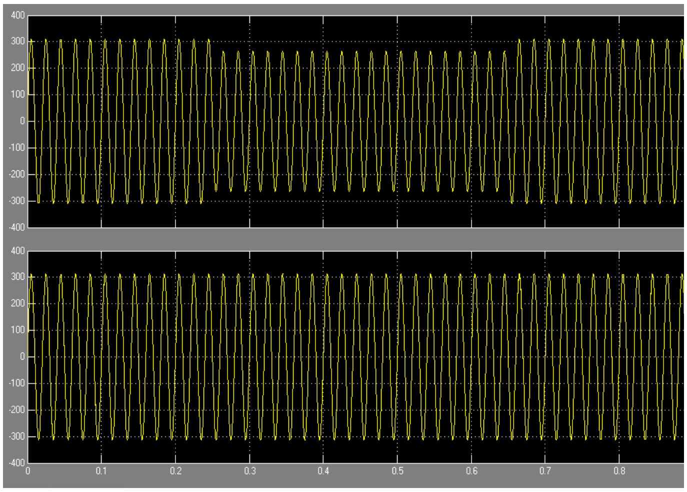


Fig.8. Performance of the voltage-controlled shunt converter with MPPT algorithm: grid voltage *E* and load voltage *V*load.

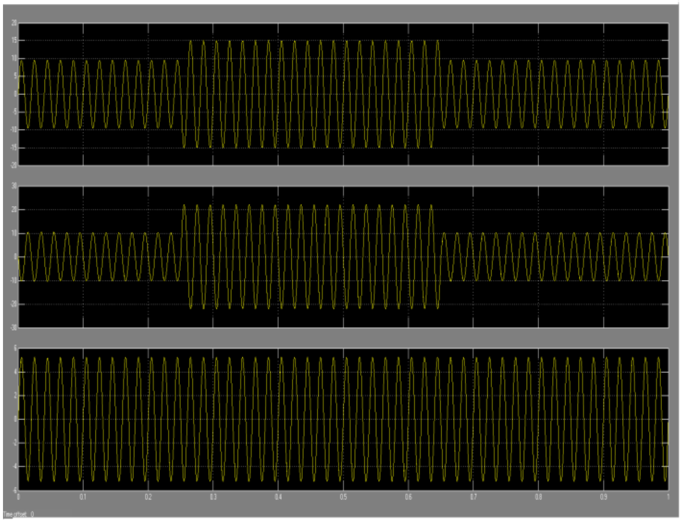


Fig.9. Performance of the voltage-controlled shunt converter with MPPT algorithm: grid current *Ig*, converter current *IC*, and load current *I*load.

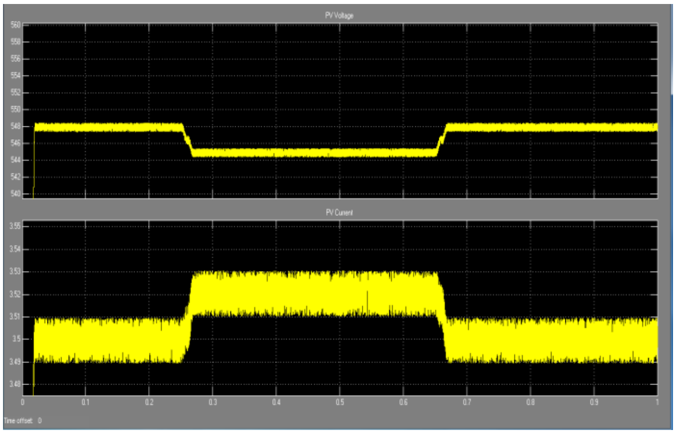


Fig.10. Performance of the the pv current and voltage at active and reactive power provided by the shunt-connected multifunctional converter.

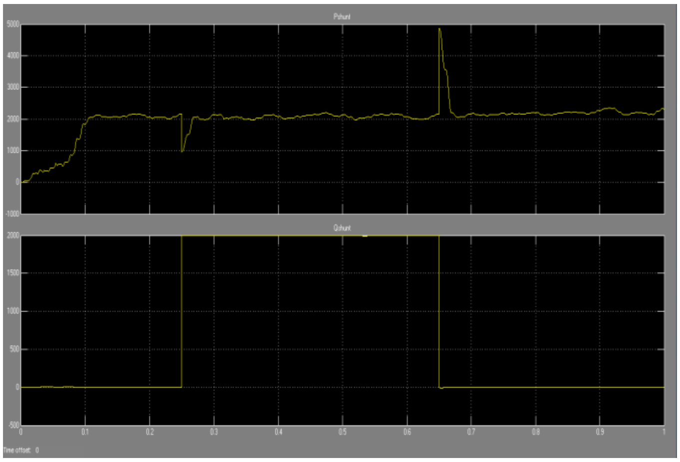


Fig.11. Active and reactive power provided by the shunt-connected multifunctional converter to compensate the voltage sag of 0.15 pu.

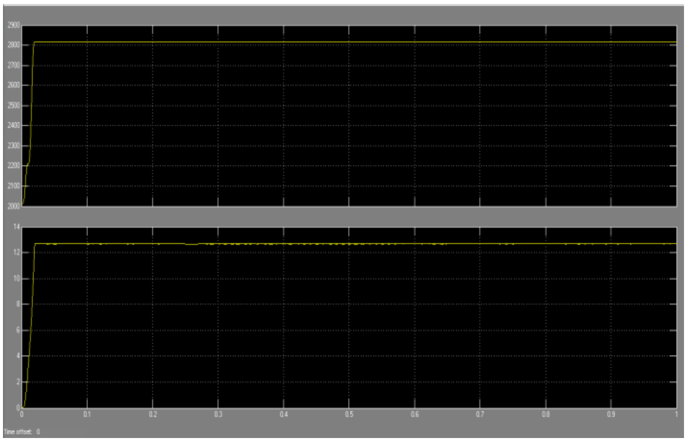


Fig.10. Active and reactive power provided by the pv system at the load.

During the sag, the inverter sustains the voltage for the local load (Fig.), injecting a mainly reactive current into the grid. The amplitude of the grid current Ig grows from 4.5 to 8.5 A, as shown in Fig, which corresponds to the reactive power injection represented in Fig.

The inductance Lg connected in series with the grid impedance limits the current flowing through the grid during the sag. When the voltage sag of 0.15 pu occurs, the converter current grows from 8 to 10.5 A. For this reason, the shunt controller is not a good choice to compensate for deeper dips. Fig. demonstrates the robustness of the presented MPPT algorithm to the voltage dip. In fact, in it are shown the voltage and current on the PV side during the sag. They are not significantly influenced by the dip.

V11. CONCLUSION

In this project, a single-phase PV system with shunt controller functionality has been presented. The PV converter is voltage controlled with a repetitive algorithm. An MPPT algorithm has specifically been designed for the proposed voltage-controlled converter. It is based on the incremental conductance method, and it has been modified to change the phase displacement between the grid voltage and the converter voltage maximizing the power extraction from the PV panels.

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