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# Control of Grid Interfacing Photovoltaic Generation System

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**Abstract**

*Renewable energy is harvested from the natural resources like sunlight, wind, tides, geothermal heat etc. These renewable energy resources can be considered to be limitless unlike the highly exhaustible conventional fossil fuels. Solar energy is one of the most important forms of renewable energy. Photovoltaic (PV) converts solar energy into electricity. This paper presents simulation of the grid-connected PV generation system under MATLAB/Simulink. The control system used is P&O algorithm based on maximum power point tracking (MPPT). It helps PV array to generate the maximum power under various operating conditions. The system is then connected to the AC utility grid by DC/AC inverter. The inverter is controlled by voltage controller and current controller. Voltage controller makes the DC link voltage constant. Current controller controls power flow for achieving the unity power factor at point of connection.*

**Keywords-** *PV system, MPPT, DC/AC inverter, Current controller*

## 1. Introduction

Solar energy generation presents several benefits for use as a distributed energy resource. Nowadays, renewable energy sources such as photovoltaic (PV) panels and wind-generators are used on wider basis because renewable energy sources have become a major necessity of today's era. PV systems are used to convert solar radiation into electricity[1][2]. MPPT controllers can extract the maximum possible power from the PV module using MPPT controllers. There are a variety of MPPT methods which can extract maximum power from PV array such as Incremental Conductance algorithm, Perturb and observe method[3]. This paper presents the modeling and control of a grid connected PV generation system[4][5]. The three phase full bridge DC-AC inverter provides suitable three-phase voltage with the right frequency and phase angle for interconnection to the grid. Central Inverter is satisfactorily controlled by voltage and current controller and interfaced with the utility grid. The voltage controller maintained the dc-link voltage constant and current controller maintained unity power factor.

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## 2. Grid-Connected PV Generation System

PV cell is the most basic generation part in PV system. Single-diode model of PV cell consists of a photocurrent source, a nonlinear diode, series resistance and shunt resistance. PV cells are arranged together in series and parallel to form arrays. Characteristic equation for PV cell is as given in (1). The equivalent circuit of PV array can be described as illustrated in Fig. 1.

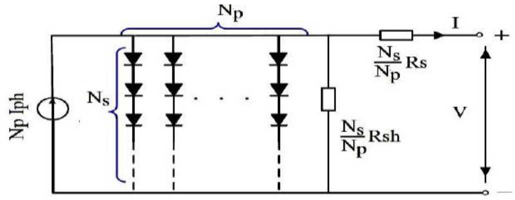



**Fig. 1:** Single-diode mathematic model of a PV cell

$$I = Np \times Iph - Np \times Is \times \left[\exp\left(\frac{q}{A \times K \times T}\left(\frac{V}{Ns} + \right.\right.\right.$$

I×RsNp−1−NpRsh(VNs+Is×RsNp)
(1)

Where $N_s$ and $N_p$ are respectively cell numbers of the series and parallel cells

### 2.1 Maximum power point tracking

The principle of P&O MPPT strategy is to periodically vary next step direction by a fixed factor $\mp \Delta P_{PV} / \Delta V_{PV}$, which is considered as the perturbation cycle. Regardless of where the tracking point firstly starts, the final goal is to arrive at the steady state operation region around the maximum power point. By comparing the current PV array output power with that of the previous perturbation cycle, the decision of the subsequent perturbation direction can be made. If the PV array output power increases, the subsequent voltage perturbation should continuously increase in the same direction, otherwise the voltage perturbation direction should be reversed in the next perturbation cycle. In this case, the operating point of the system gradually moves towards the maximum power point and finally oscillates around it in steady state region.

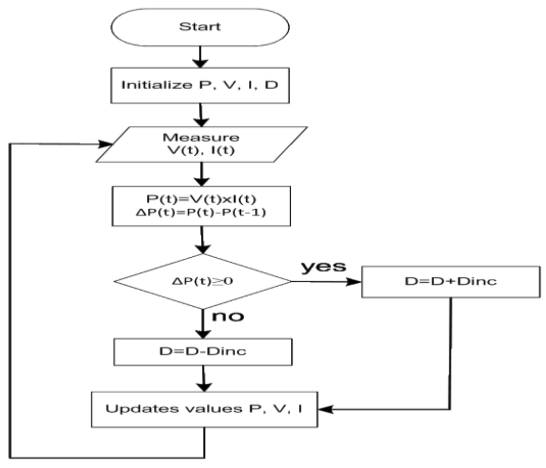



**Fig. 2** Flowchart of P&O MPPT strategy

### 2.2 Grid-Connected Inverter

In grid connected VSI (Voltage Source Inverter), a three-phase bridge circuit consisting of IGBTs, operates according to the control signal generated by control algorithm. Each IGBT works as a controllable switch to be turned on or off and thus controls the magnitude and the phase angle of the output waveform. The regulated output voltage or current curve according to grid-side's requirements will be generated by the grid-connected VSI. The three phase grid connected VSI provides suitable three-phase voltage with the right frequency and phase angle for interconnection to the grid. The control of the power flow to the grid is based on active and reactive power control

### 2.3 Control strategy for the two stage PV system

A voltage controller is required to maintain the DC link voltage constant. The boost DC/DC converter is driven by the duty cycle from the MPPT. Then, the voltage from the boost is compared to the reference voltage Vref.

For the current control, the three-phase current in abc reference frame is decoupled in dq reference frame. The current iq* reference is set to zero to obtain unity power factor. The current id* reference is the current from the voltage controller. The difference of current Δid and Δiq are the input for the current controller. The outputs from the current controller are the voltage reference for the PWM generator. The input command for the PWM generator are vd*, vq* and the phase angle θ. The three-phase inverter uses PWM modulation techniques.

## 3 Simulation Results and Discussion

To evaluate the performance of the system with implemented control scheme, simulation by MATLAB software has been carried out. In this section, the overall simulation model of the grid connected photovoltaic system is presented and the simulation results are examined.

### 3.1 Matlab Simulink model

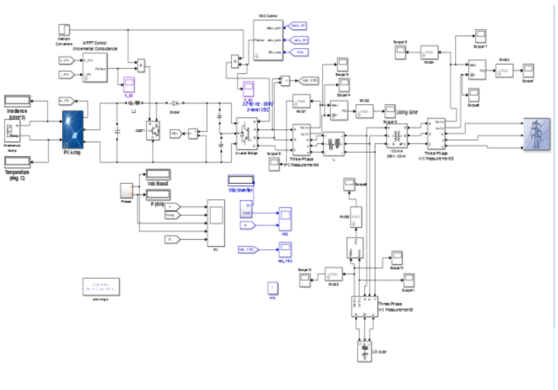


**Fig. 3:** Matlab Simulink model of the grid-connected PV generation system

### 3.2 PV Matlab model simulation results

The irradiance level and temperature are set at 1000w/m$^2$ and 25 degree Celsius respectively as shown in figure 4. Under this condition the value of PV maximum power, voltage and current is shown in figure 5.

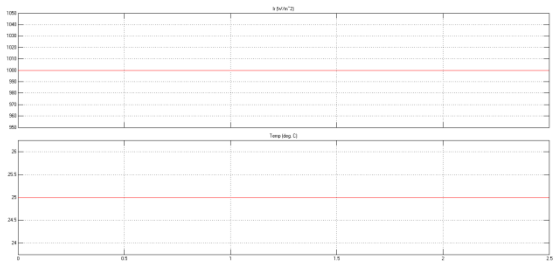
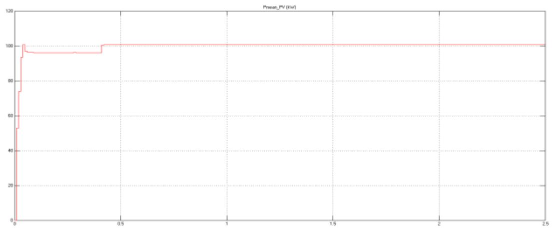
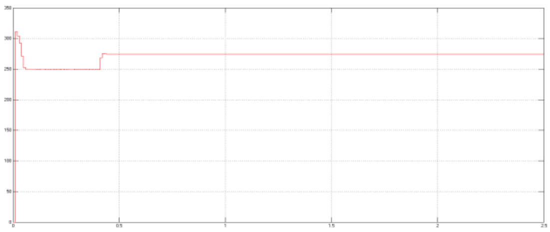


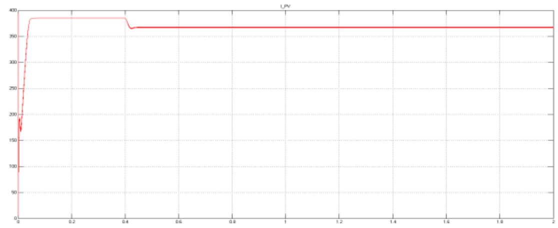
**Fig.4:** Photovoltaic irradiance level set at 1000w/m$^2$ and temperature at 25 degree Celsius



**(a)**Photovoltaic power



**(b)**Photovoltaic voltage



**(c)Photovoltaic current**

**Figure.5:** Photovoltaic output Power, Voltage and current for irradiation level of 1000w/m$^2$ and temperature 25 degree Celsius

The duty cycle value for boost converter generated by MPPT for PV system is 0.5 as shown in figure 6.

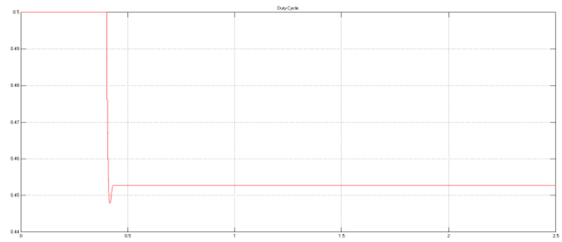


**Fig.6:** Duty cycle for boost converter

The boost DC/DC converter is driven by the duty cycle from the MPPT. Boost converter step up the PV voltage. Figure 7 shows constant DC output voltage of boost converter.

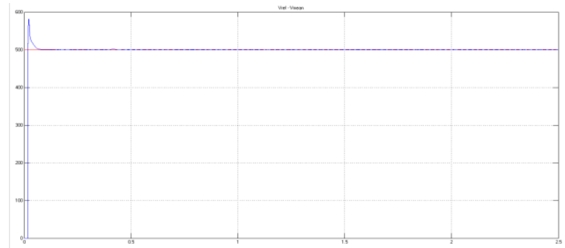


**Figure.7:** Constant DC output voltage of boost converter

The VSC controller which generates signal command for inverter works at modulation index of 0.85 as shown in figure 8

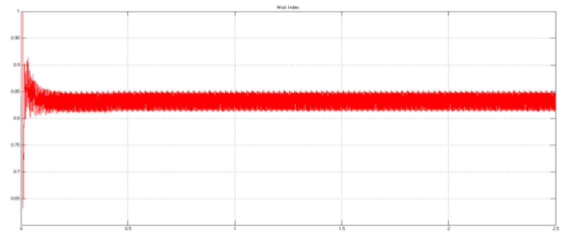
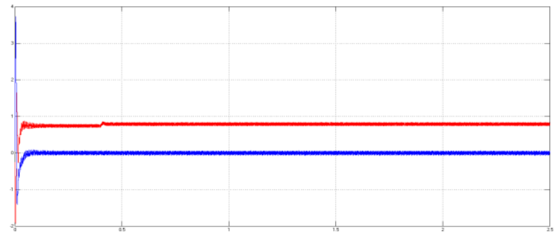
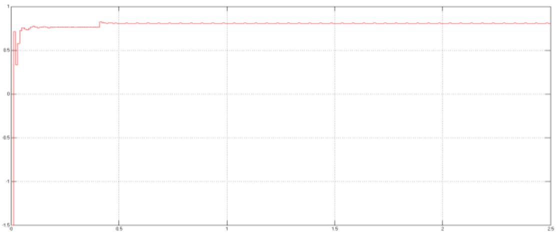


**Fig.8:** Modulation index of VSC controller

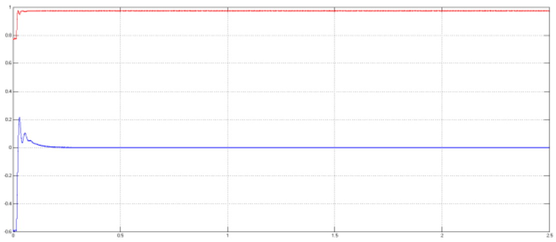
In order to control the current delivered by photovoltaic array, it is essential to transform the three-phase ac signals into d-q reference frame. By changing the reference frame the three-phase symmetric grid voltage and grid current become DC variables as shown in figure 9.



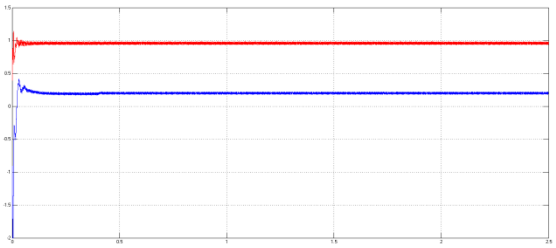
**(a)** Id and Iq measured on grid side



**(b)** Id reference generated by voltage controller



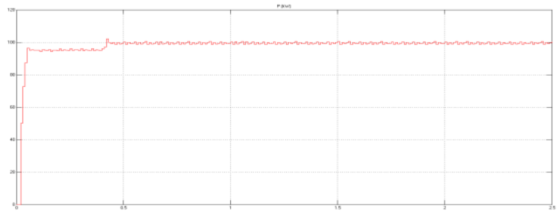
**(c)**Vd and Vq measured on grid side



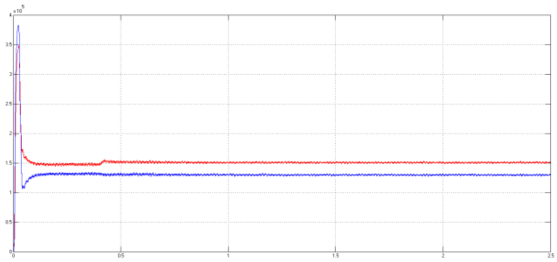
**(d)**Vd and Vq generated by current controller

**Figure.9:** Overall simulation results in d-q frame

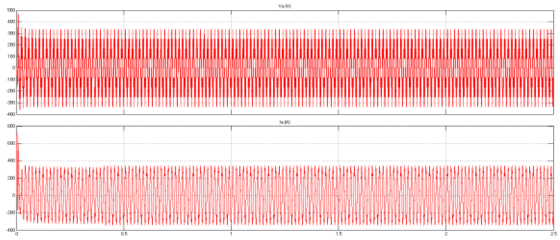
Load consumes power according to its requirement and remaining power left after losses is transferred to grid. The results in figure 10, 11 and 12 show the power, voltage and current waveforms at inverter side, load side and grid side.



**(a)** Output power of three phase inverter

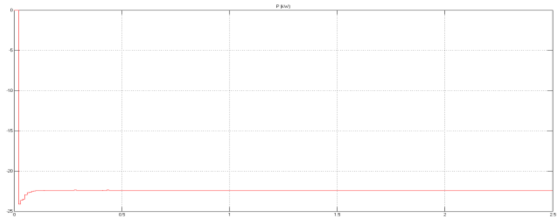


**(b)** Active and Reactive output power of three phase inverter

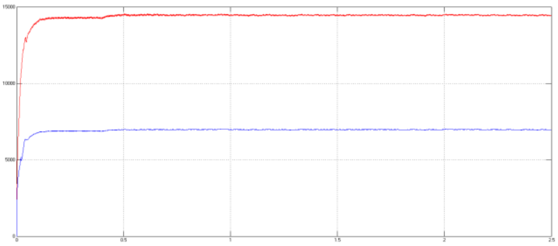


**(b)** Output voltage and current of three phase inverter

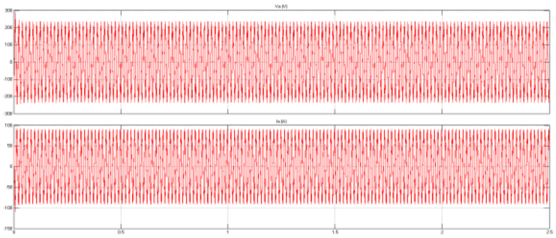
**Figure.10:** Overall simulation results at inverter side



**(a) Power at load side**

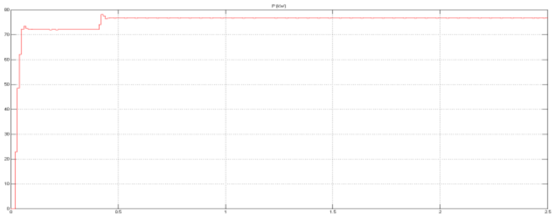


**(b)** Active and Reactive power at load side

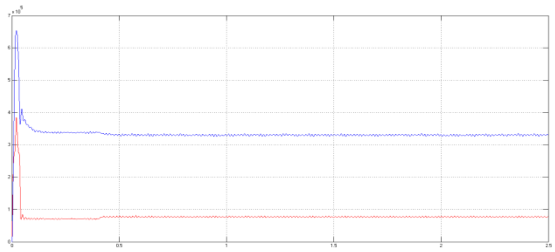


**(b)** Voltage and Current at load side

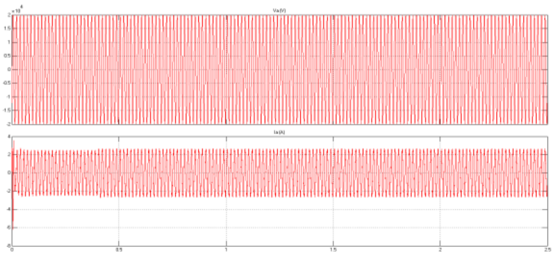
**Figure.11:** Overall simulation results at load side



**(a)**Power at grid side



**(b)** Active and Reactive power at grid side



**(b)**Voltage and Current at grid side

**Figure.12:** Overall simulation results at grid side

## 4. CONCLUSION

In this paper PV array, Maximum Power Point Controller, Inverter, Current and voltage Controller has been designed and simulated with Simulink MATLAB. The simulations showed that Perturb and observe algorithm can track the maximum power point of the PV as it always runs at maximum power at any operating condition. The three phase full bridge DC-AC inverter provides suitable three-phase voltage with the right frequency and phase angle for interconnection to the grid. Central Inverter is satisfactorily controlled by voltage and current controller and interfaced with the utility grid. The voltage controller maintained the dc-link voltage constant and current controller maintained unity power factor at point of connection. System provides good results and show that the control system is efficient.

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