# Single Phase Photovoltaic System with Maximum Power Point Tracking

**S.Sivakumar, V.Vanitha, S.R.Mohanrajan**

***Abstract***: ***Due to the increase in demand of electric energy, people are shifting towards renewable energy resources. Among the various renewable sources, solar power is growing at a faster rate due to its abundant availability. Solar panel characteristics show that the output power from the panel peaks only at one operating point. For extracting maximum power from the panel, tracking of the operating point has to be done continuously by a control algorithm. In this work, a solar system connected to the grid is considered, where there is a necessity of synchronizing the solar inverter with the grid apart from MPPT. Hysteresis current control is implemented in the inverter for synchronization and for tracking the maximum power, perturb and observe algorithm is applied. Grid connected PV systems are used in main cities by domestic and industrial consumers, where the excess power can be sold to the utility. Simulation of the grid connected PV system is done in Simulink and the results are presented.***

***Index Terms***: ***Hysteresis controller, Irradiance, MPPT, Solar PV panel***

## I. INTRODUCTION

At this present world, the utilization of electrical energy is at an increasing rate and it is proving to be highly essential for a developing nation. Harmful effects for the environment such as greenhouse effect, global warming and acid rain are making the researchers to come out of the dependence on fossil fuels and other non-renewable energy resources. Sun is one of the major renewable resources available to produce electricity. In a Solar based power generating system, the output power from panel peaks only at one operating point. This operating voltage varies with atmospheric conditions such as insolation, temperature etc. Hence the changing maximum power point(MPP) needs to be continuously tracked for optimum operation of solar panel. The PV panel has to be made to work at peak power point and lots of algorithms have been proposed for this MPP tracking (MPPT)[6]. Transfer of power from solar panel to grid is done by altering the angle between grid voltage and inverter voltage[7]. Perturb and Observe method is one such algorithm which is highly used everywhere. In this paper, MPPT is implemented in hysteresis controlled[3] DC-AC converter by varying its reference current, which is simple and efficient.

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## II. SYSTEM UNDER STUDY

A typical solar PV system[1] is shown in Fig 1, in which a number of solar cells are connected in different combinations to produce 2kW power. There are two types of topologies followed for a PV system which are connected to grid, two stage topology and single stage topology.

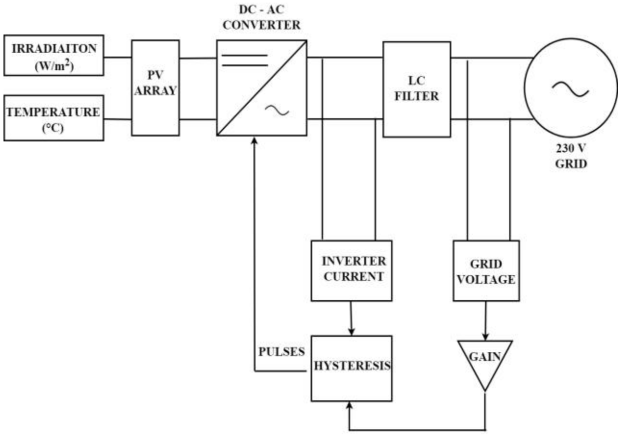


Fig 1: Grid connected solar PV system

Table 1: System specifications of PV module, grid and inverter

| | |
|---|---|
| Peak power | 305 W |
| Open circuit voltage | 64.2 V |
| Short circuit current | 5.96 A |
| Voltage at peak power point | 54.7 V |
| Current at peak power point | 5.58 A |
| Parallel strings | 1 |
| Series connected modules per string | 7 |
| LC filter | L = 60 mH; C = 100 nF |
| Grid voltage | 230 V |
| Grid frequency | 50 Hz |
| DC voltage | 350 V |
| DC link capacitor | 1.9 μF |

Two stage topology has its own drawbacks such as higher power losses, lower efficiency and high cost. So, a single stage grid connected PV system is implemented here, which will overcome the above mentioned drawbacks. The solar output is fed to the grid through through a LC filter and a single phase inverter [4], in which MPPT is implemented. Table 1 shows the specifications of solar panel and grid

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## III. METHODOLOGY

In perturb and observe based approach[5], voltage and current are sensed and power is calculated at various instants of time for different panel voltages and compared with the previous values. If the power increases for increase in panel voltage, then the voltage is increased in steps and the new power is calculated at each step. After some time, the power will reach its peak value. Now if the voltage is increased, then power will decrease, which shows that peak power is approached by the algorithm and the panel voltage os reduced in next step.. If these steps are repeated, the system will reach a stage in which the output power from the module will oscillating nearer to its peak value. This power variation can be decreased by incrementing or decrementing the panel voltage with a small value. The peak power point is achieved by giving a suitable reference current in such a way that the inverter draws the current at maximum power point from the PV panel. The grid voltage is stepped down, multiplied by a required gain value and given as a reference current for the hysteresis block. The gain value is given to increase the amplitude of the reference current so that the panel delivers the maximum power. A equation is derived relating the irradiance and gain for maximum power point tracking, which is given by Eqn. (1)

$$\text{Gain} = (\mathbf{5.798\times10^{-5}})\, G^2 - 0.05787G+26.21 \qquad (1)$$

Where G is the solar irradiance in W/sq.m. Fig. 2 shows the flow chart for the MPPT algorithm, which will automatically make the panel to work at Vmpp and deliver maximum power. Whole system can be implemented in MATLAB Simulink [2].

## IV. SIMULATION RESULTS

Before proceeding with the implementation of grid connected PV system, as a first step hysteresis based current control mechanism is implemented in Simulink. Fig 3(a) shows a sinusoidal reference current of amplitude 10 which is given as a reference signal and it is found that the inverter also follows the same reference current. The corresponding gating pulses generated from the hysteresis block are given in Fig. 3(b).

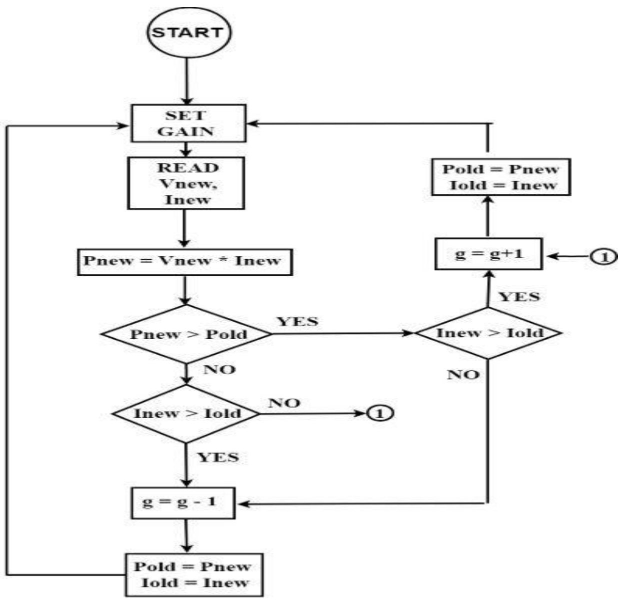
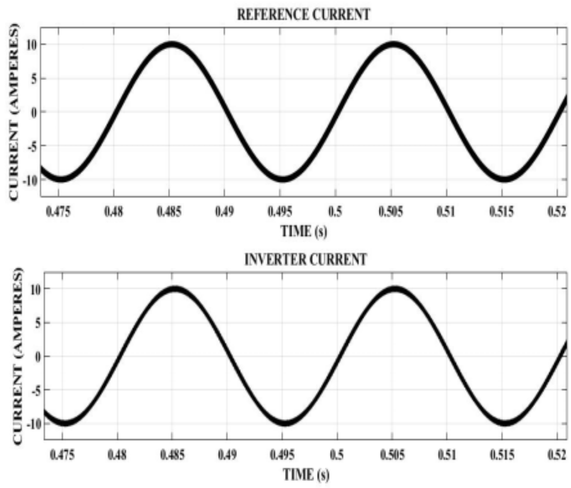
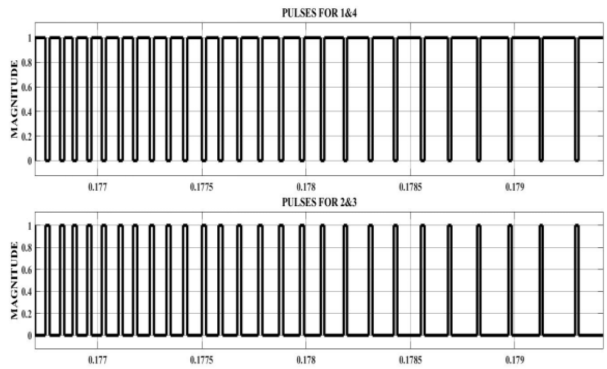



**Fig. 2: Flow chart of MPPT algorithm**




(a)




(b)

Fig. 3(a) Reference current and inverter output current
(b) Pulses generated from the hysteresis current controller

Simulink diagram of a photovoltaic system injecting power to a single phase grid is shown in Fig.4. Simulation is run for different solar irradiations and the readings are given in Table 2. Results show that, at each irradiance, for a particular gain value, peak power is injected into the grid. Maximum power point voltage and current of the PV array is shown in Fig.5 for the irradiance of 1000W/sq.m. Fig. 6 depicts the waveforms of grid power, panel power and tracking of reference current by inverter for the gain of 26.32.

Now the simulation is changed from one value to another and the dynamic performance of the system is observed. Fig 7, Fig 8, Fig 9 and Fig. 10 show the output graphs for the MPPT implemented using P&O algorithm for different irradiations. Results show that MPPT is achieved with the proposed algorithm for all irradiations.

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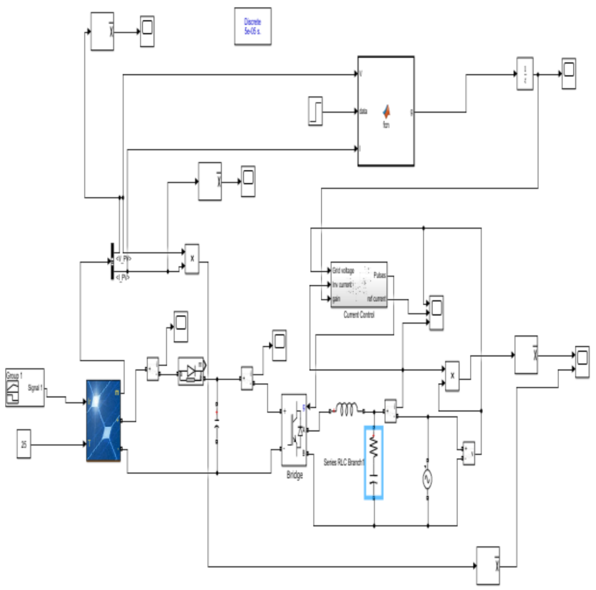
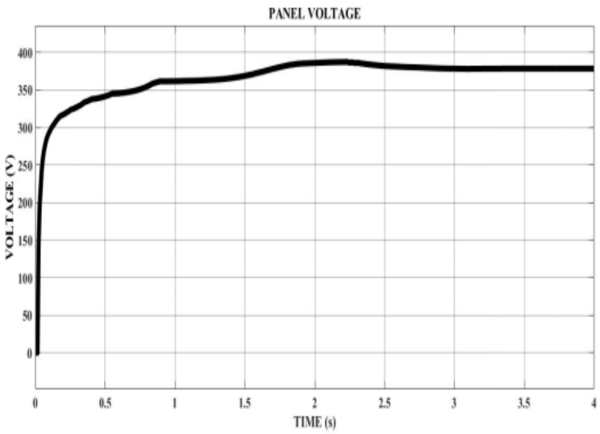


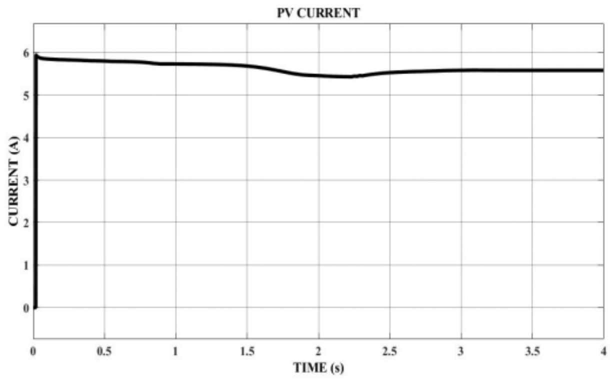
**Fig 4 Simulink model of a solar array feeding power to a singole phase grid with mppt.**

Table 2: Current, Voltage and Power from PV array during maximum power point extraction

| **Irradiance ($W/m^2$)** | **Gain for reference current** | **$V_{mp}$ (V)** | **$I_{mp}$ (A)** | **PV panel power (W)** |
|---|---|---|---|---|
| 1000 | 26.32 | 391 | 5.418 | 2108 |
| 900 | 21.09 | 413 | 4.006 | 1704 |
| 800 | 17.02 | 421.5 | 2.961 | 1375 |
| 700 | 14.1 | 418 | 2.72 | 1150 |
| 600 | 12.36 | 416.5 | 2.37 | 988 |
| 500 | 11.7 | 405 | 2.31 | 900 |
| 400 | 12.34 | 390 | 2.15 | 840 |
| 300 | 14.07 | 300 | 1.9 | 540 |
| 200 | 16.96 | 172 | 1.25 | 210 |
| 100 | 20.9 | 169 | 0.65 | 110 |

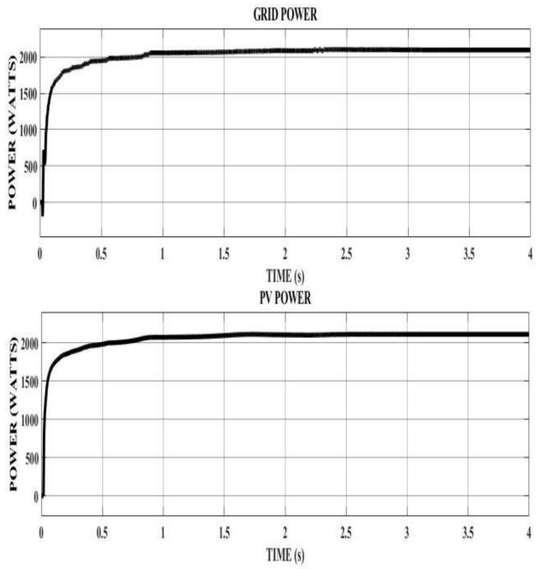



(a)

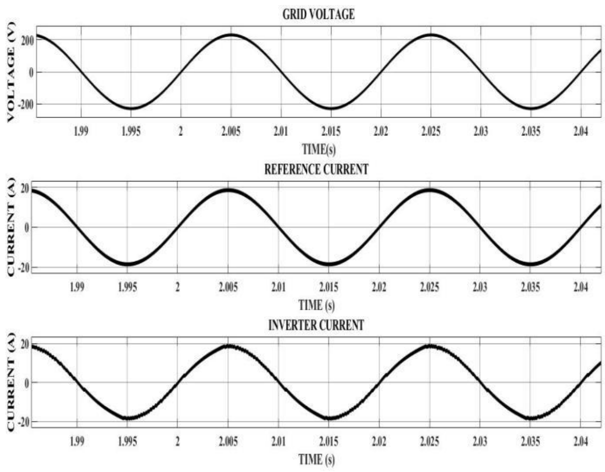



(b)

**Fig. 5 (a) Panel voltage (b) panel current for irradiation of 1000W/sq.m**



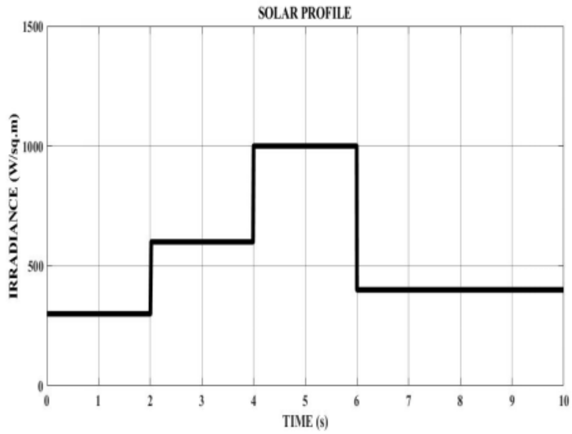

(a)



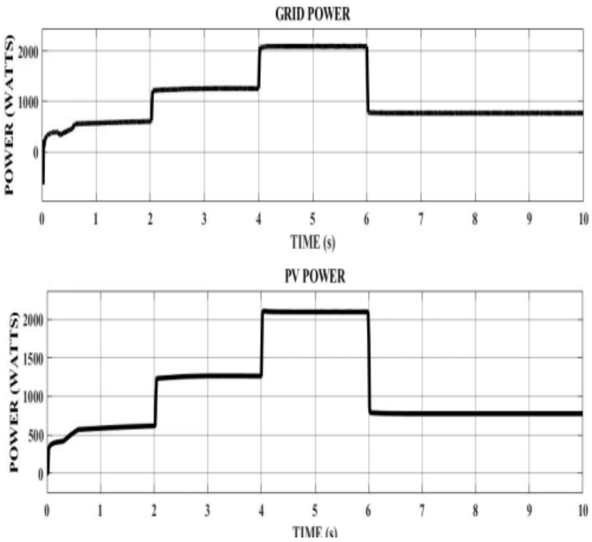

(b)

**Fig. 6 (a) Power balance of the system at an irradiation of 1000W/sq.m**

(b) Grid voltage, reference current and inverter current for irradiation of 1000W/sq.m




(a)




( b)

**Fig 7: (a) Solar irradiation (b) Power fed to grid and power generated from solar panel**

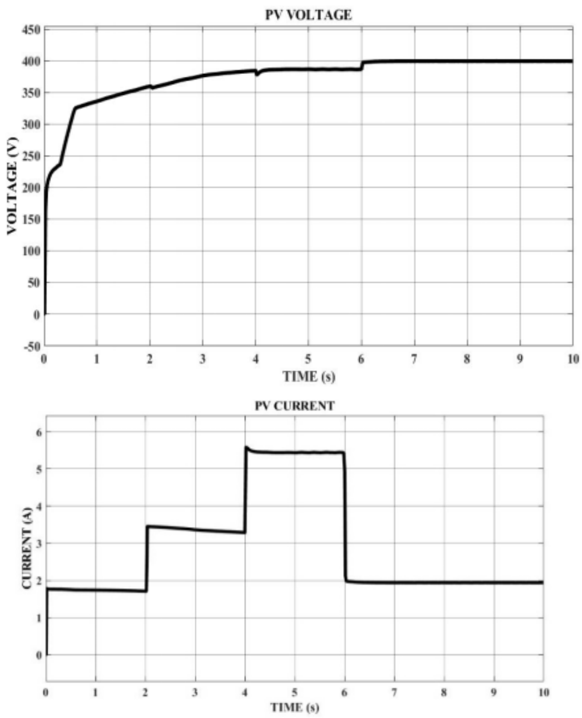



**Fig 8: PV panel voltage and current corresponding to MPPT**

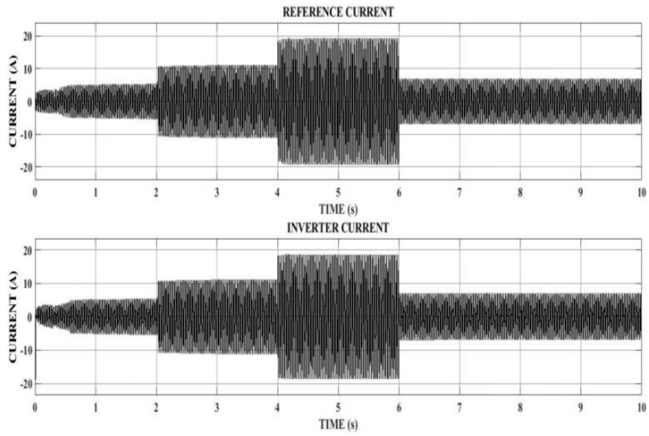



**Fig 9: Reference current and inverter current**

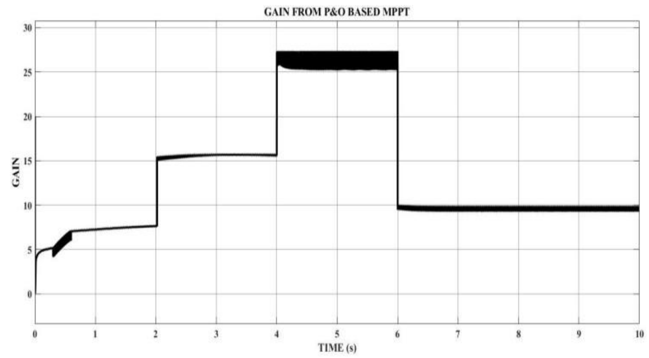



**Fig 10: Gain output from P&O based MPPT algorithm**

## V.CONCLUSION

In this work, an algorithm is depicted in order to inject maximum power to a single phase grid from a PV module. There are several algorithms proposed to extract peak power from the solar panel. In this paper, perturb and observe method is used for extracting the peak power. The grid is synchronized with the single phase full bridge inverter with the help of hysteresis current control strategy. The gain value given for the reference current in hysteresis controller is varied to track the maximum power point. Results show that the reference current is tracked efficiently for different irradiations by the proposed control algorithm. This work can further be implemented in hardware using STM microcontroller. Furthermore this control algorithm can also be extended to three phase grid connected inverters and compared with sinusoidal and space vector based pulse width modulation methods.

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