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# Simulation of Advanced Perturb and Observe MPPT for a Standalone PV System

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**ABSTRACT**: Solar energy is one of the abundant renewable sources of energy which is widely available throughout the globe. Solar electricity or photovoltaic (PV) technology converts sunlight directly into electricity. This paper describes how to extract the Maximum power from the PV panel by making them to operate at the most efficient voltage. Improving the maximum power point with new control algorithms is less expensive and can be implemented very easily. Boost converter is used as an interface between PV panel and load. In this paper Advanced Perturb and Observe control algorithm is used to track the Maximum power point and hence generate PWM signals for MOSFET. Matlab software is used to simulate PV panel, Boost converter and Maximum power point tracking algorithm.

**KEYWORDS**: Maximum Power Point Tracking (MPPT), Pulse Width Modulation (PWM), Photo-Voltaic (PV), Incremental Conductance.

## I. INTRODUCTION

We use non-renewable energy sources like coal, oil, water and natural gas for meeting our energy demand, but we have a limited supply of the above fuels on the Earth. We use them much more rapidly than they are being created. Eventually, they get depleted in early years. Renewable energy sources are continually replenished by nature. Among all the renewable sources of energy, solar energy is one of the most clean and widely available sources, which is available throughout the globe. Solar electricity or photovoltaic (PV) technology converts sunlight directly into electricity. Solar electricity has been a prime source of power. Photovoltaic (PV) power generation has an important role to play due to the fact that it is a clean energy source. PV modules are made of silicon cells. These modules are connected in series and parallel to obtain higher power output forming PV array.

Authors have implemented many algorithms in which P&O MPPT method was easier and simpler to implement. It was observed that the system is able to track the maximum power point in spite of steady state oscillations in tracking power. The system is not able to track the MPP quickly during rapidly changing environmental conditions. It was observed that P&O gives number of oscillations [1]. Also it was noticed that the PV system when directly connected to the load operates at load voltage due to which the energy from the PV panel is not completely utilized. In addition to this different MPPT algorithms were proposed to overcome and to extract maximum power. In order to utilize energy from PV panel completely and to track MPP, Advanced P&O algorithm is selected which is efficient compared to P&O.

The major principle of MPPT ([1]-[2], [7]) is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). Improving the maximum power point tracking with new control algorithms is easier, less expensive and can be implemented very easily in the existing plant that has been incorporating other algorithms for maximum power point tracking. This paper explains about implementation of Advanced P&O control algorithm for a PV system so as to extract maximum power and also to charge a battery of 24V, 7.2Ah Lead-Acid rechargeable battery. In this paper, Boost converter is used as an interface between panel and load. The input to the converter is fed from the output of the PV panel and is controlled to regulate the operating point of the array.

## II. OVERVIEW

The overall system consists of PV panel, Boost converter, MPPT control block and a 24V, 7.2Ah Battery that acts as a load. This can be shown as in Fig. 1.

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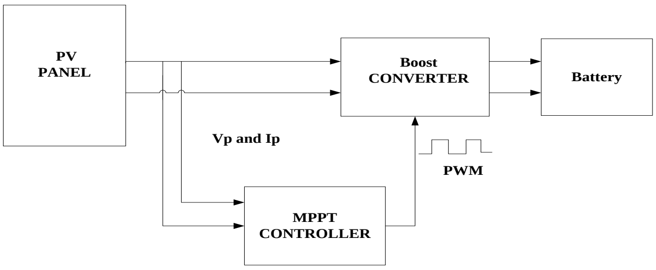


Fig. 1 Block Diagram

*A. PV Panel*

A solar panel is a set of photovoltaic modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Number of PV modules can be connected in series or parallel to increase the current and voltage rating of PV panel.

*B. Boost Converter*

When the Switch 'S' is closed, Vs $=V_L$ and diode is reverse biased. When the Switch is open, the voltage across the output will be the sum of input voltage ($V_s$) and inductor voltage ($V_L$). Hence the output voltage is always greater or equal to input voltage [6]. Fig. 2 shows the circuit diagram of Boost converter.

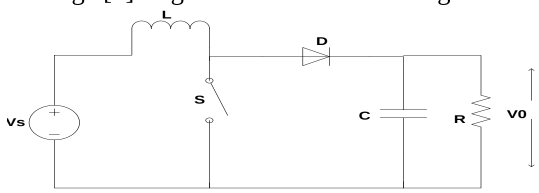


Fig. 2 Boost Converter

The output voltage is given by equation (1).

$$\frac{Vo}{Vs} = \frac{1}{(1-K)} \quad \text{(1)}$$

Here K is the duty cycle. The output voltage can be regulated by controlling the duty cycle.

*C. MPPT Controller*

MPPT controller is used to produce PWM signals to drive the gate of MOSFET. P&O control algorithm is applied generate PWM signals. As seen from Power versus Voltage curve in Fig. 3, the slope is zero at its MPP, positive to the left of MPP and negative to the right of MPP.

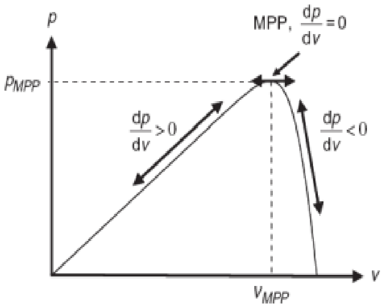


Fig. 3 Power versus Voltage Curve

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The flowchart of Advanced Perturb and Observe [4] is shown in Fig. 4. In conventional Perturb and Observe method, panel voltage and current are tracked continuously and the operating point is checked. If the operating point is at the left side of MPP, then duty cycle is increased and decreased if the operating point is at the right side of MPP. In this method, the number of stages of P&O are increased from (k-l) to (k-1), (k-2), (k-3) and (k-4). By performing this, the tracking speed of the MPPT controller is increased. Consequently the performance of the Advanced P&O algorithm is improved in terms of stability of Maximum Power Point (MPP) and hence the higher efficiency of PV panel. The oscillations of by using this algorithm are also less since the number of perturbations has been increased.

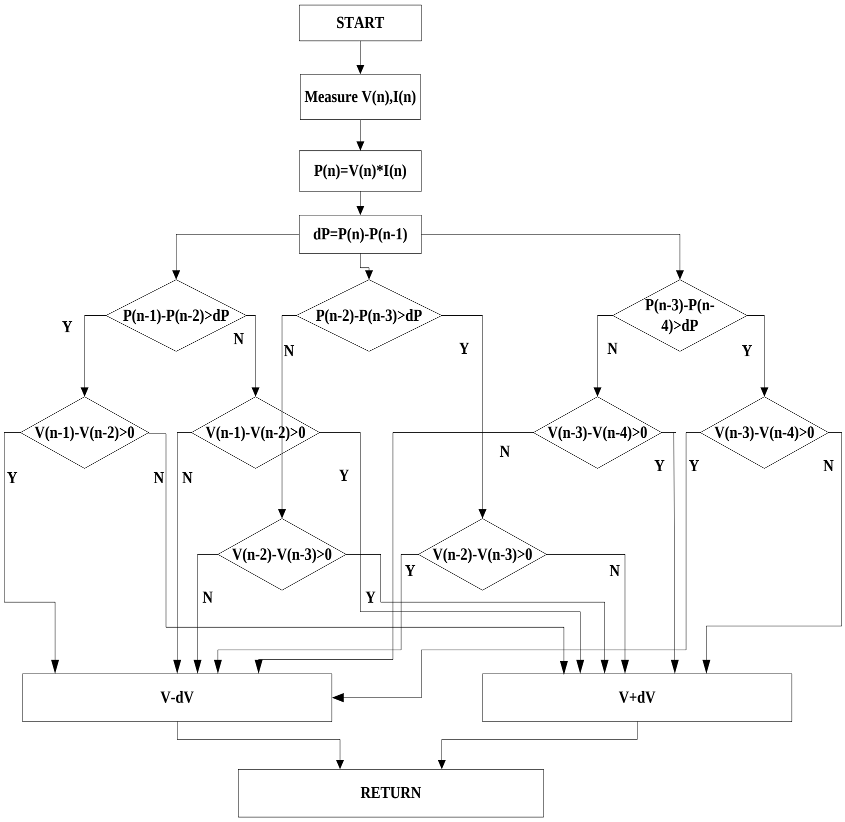


Fig. 4 Advanced Perturb and Observe Flowchart

## III. SIMULATION

A 20W PV module is chosen to charge a battery of 24V, 7.2Ah battery that acts as a load. Specification of 20W panel is given in TABLE I.

TABLE I
20W PANEL SPECIFICATIONS

| Parameters | Value |
|---|---|
| Maximum Power ($P_m$) | 20W |
| Maximum Voltage ($V_m$) | 17.64V |
| Maximum Current ($I_m$) | 1.18A |
| Open Circuit Voltage ($V_{oc}$) | 21.64V |
| Short Circuit Current ($I_{sc}$) | 1.23A |

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**Vol. 4, Issue 12, December 2015**

Power output from the PV panel changes with the change in radiation, temperature and orientation of the panel. Fig. 5 and Fig. 6 shows the typical P-V and I-V curves at different radiation levels.

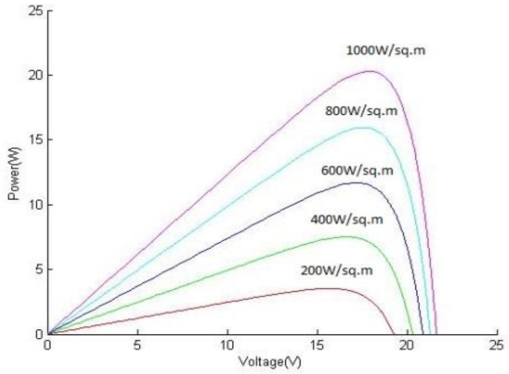


Fig. 5 Power versus Voltage curves at different radiation levels

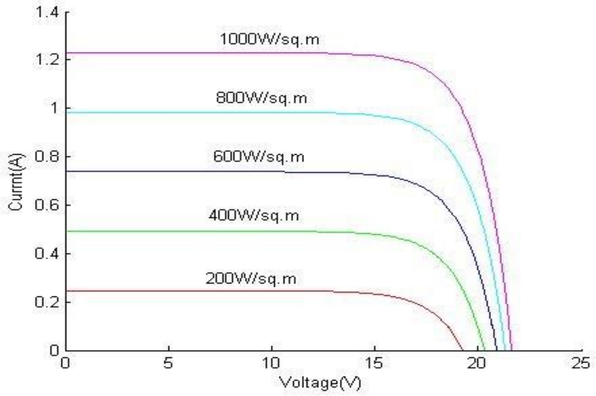


Fig. 6 Current versus Voltage curves at different radiation levels

There exists only one maximum power at each radiation level. It is desired to operate the panel at its peak power. When the panel is directly connected to the load, it operates at load voltage than the voltage at its peak power point. Hence this work makes use of Boost converter as an interface between panel and load. By changing the duty cycle, the impedance of the load as seen by the source can be varied and matched so that maximum power is transferred to the load.

*A. PV Panel Modeling*

Single solar cell can be represented by an equivalent circuit [3] as shown in Fig. 7.

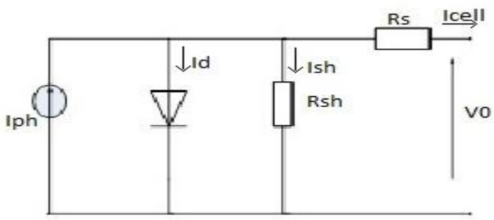


Fig. 7 Solar cell

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The symbols in Fig. 7 are defined as follows.
$I_{ph}$: photocurrent
$I_d$: current at parallel diode
$I_{sh}$: shunt current
$I_{cell}$ ($I_c$): output current
$V_0$: output voltage
$R_{sh}$: Parallel Resistance
$R_s$: Series Resistance
The equations as in [2] are used to model the PV panel.

$$I_c = I_{ph} - I_0 \left[\exp\left(\frac{q(V+R_sI)}{AKT}\right) - 1\right] - \left(\frac{V+R_sI}{R_{sh}}\right) \quad (4)$$

The term $(V+R_sI)/R_{sh}$ can be ignored, because it is far less than $I_{sh}$. Equation (1) can be written as

$$I = I_{sc}\left(1 - C_1\left(\exp\left(\frac{V}{C_2V_{oc}}\right) - 1\right)\right) \quad (5)$$

Where I: output current of PV panel
$C_1$, $C_2$: undetermined coefficients
Under maximum power output condition, equation (5) can be written as

$$I_m = I_{sc}\left(1 - C_1\left(\exp\left(\frac{V_m}{C_2V_{oc}}\right) - 1\right)\right) \quad (6)$$

Where

$$C_1 = \left(1 - \frac{I_m}{I_{sc}}\right)\exp\left(\frac{-V_m}{C_2V_{oc}}\right) \quad (7)$$

$$C_2 = \left(\left(\frac{V_m}{V_{oc}}\right) - 1\right) / \ln\left(1 - \left(\frac{I_m}{I_{sc}}\right)\right) \quad (8)$$

Considering the changes of temperature and radiation [2], the output current is given by equations below.

$$\Delta T = T - T_{ref} \quad (9)$$

$$\Delta I = \alpha \frac{S}{S_{ref}} \Delta T + \left(\frac{S}{S_{ref}} - 1\right) I_{sc} \quad (10)$$

$$I^1 = I + \Delta I \quad (11)$$

Where
T, $T_{ref}$: Current temperature and reference temperature.
S, $S_{ref}$: Solar insolation and Current solar insolation.
α, β:Temperature coefficients of current and voltage.
The equations mentioned are used to model the PV panel. The Simulink model of the Solar panel is as shown in Fig. 8.

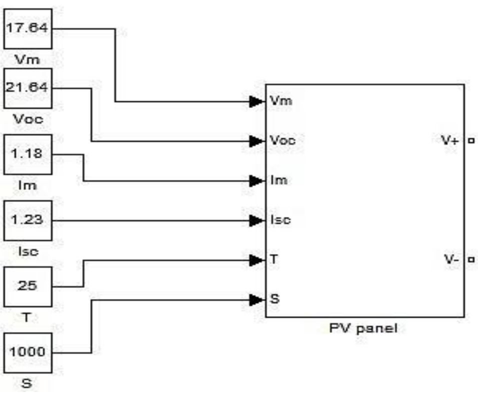


Fig.8 Simulink Model of PV panel

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*B. Boost Converter Modeling*

The Simulink model of Boost converter is as shown in Fig. 9 with following specifications. From the Simulink model of the Boost converter we can see that the gate voltage of the MOSFET is provided by comparing the ramp or triangular waveform with a reference value to generate the duty cycle for gate of MOSFET.

TABLE II
SPECIFICATIONS OF BOOST CONVERTER

| **Parameter** | **Value** |
|---|---|
| Inductor | 650µH |
| Filter Capacitor | 100µF |
| Frequency of Switching | 25KHz |

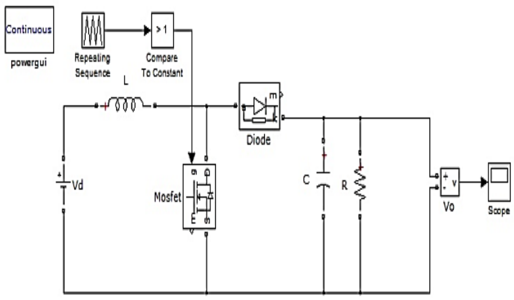


Fig. 9 Boost Converter

*C. Modeling entire System*

Fig. 10 shows the Simulink model of the entire system. The system consists of PV panel, Boost converter, MPPT block and Battery as load.

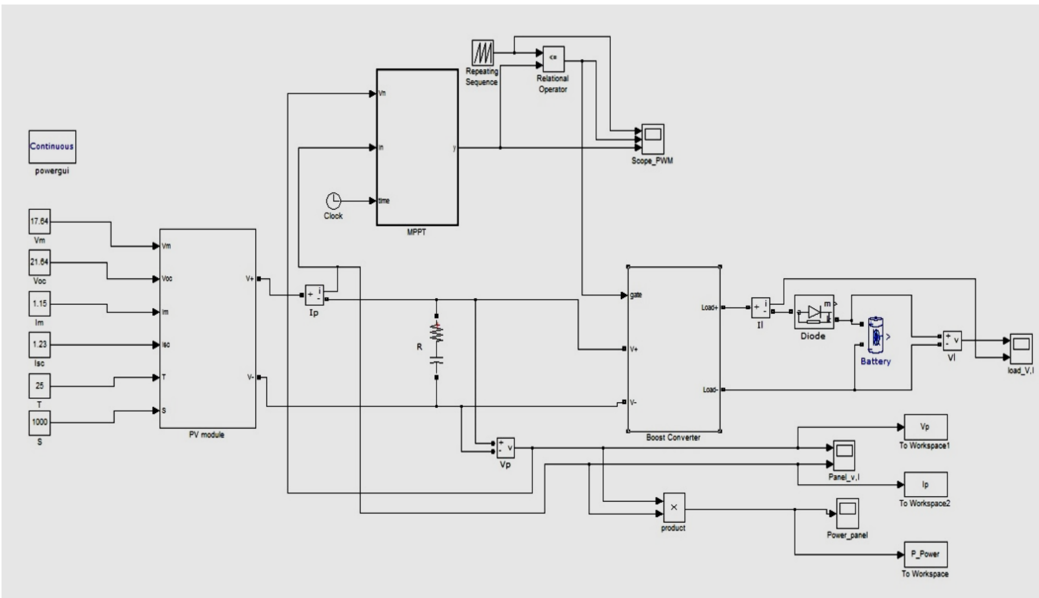


Fig. 10 Simulink model of the entire system

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## IV. RESULTS

Fig. 11 shows the tracked power when Advanced P&O is applied. As seen from the figure, we can see that unlike from the Power versus voltage curve, where the power maximum only at one point. By applying this algorithm the power is almost maintained constant once it reaches the maximum.

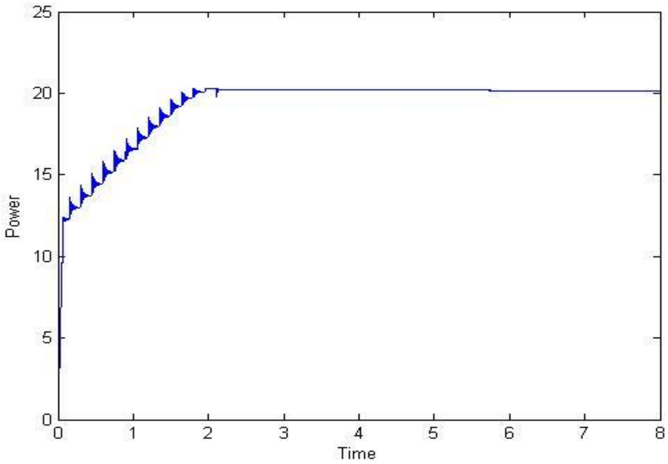


Fig. 11 Panel Power when MPPT applied

Fig. 12 shows the voltage tracked and it can be seen that the maximum power of 20W is tracked at the voltage of 17.9V and almost remains constant. Thus the operating point of 17.9V is fixed and maximum power is tracked by the algorithm.

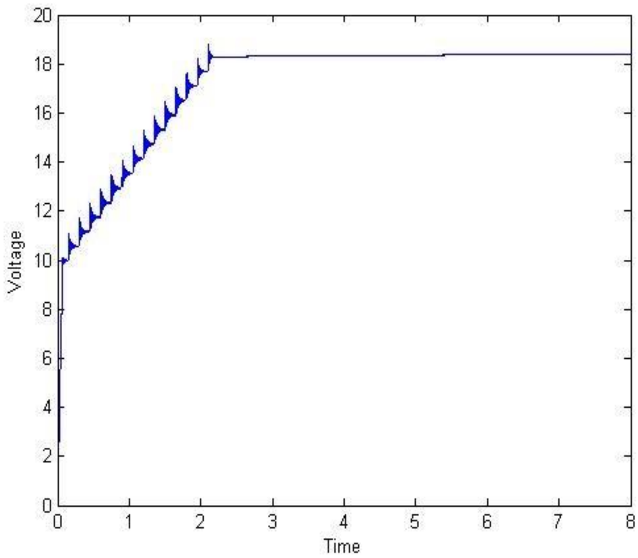


Fig. 12 Panel Voltage at MPP

Fig. 13 shows the current at the maximum power. The maximum current obtained is around 1.1A and almost remains constant. The oscillations initially in power, voltage and current are due to perturbing the duty cycle in tracking the maximum power.

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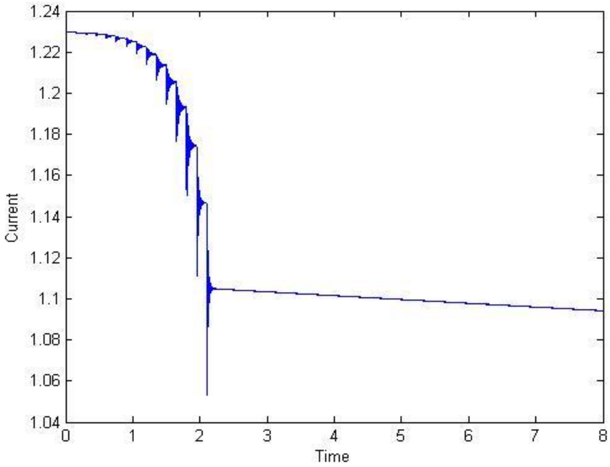


Fig. 13 Panel current at MPP

By observing the simulation results, tracking speed of Advanced perturb and observe is much better compared to perturb and observe. Also the number of oscillations has reduced by using advanced P&O algorithm compared to P&O. Furthermore P&O does not track the maximum power under rapidly changing atmospheric conditions. Advanced P&O algorithm track the maximum power of 20W and can be easily implemented on controllers. With the simulation results obtained, the system can be implemented on hardware.

## V. CONCLUSION

It can be concluded that the proposed Advanced P&O method is very easy to simulate and implement on a controller or processor. It can be seen that maximum power is tracked through this algorithm. But there is a compromise on tracking speed when the radiation level changes suddenly. Furthermore there are slight oscillations at its MPP but lesser than conventional P&O.

The effiency of the power tracking can be improved by carefully selecting the converter and different control algorithms so that the oscillations are suppressed completely resulting in a very low power loss. Furthermore the dual axis axial tracking incorporated with MPPT will improve the efficiency of power generation to a greater extent.

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