

# Modelling & Simulation of PV System using Different MPPT Techniques

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**Abstract:** In this paper a new maximum power point tracking algorithm for photovoltaic arrays is proposed. The algorithm detects the maximum power point of the PV. The computed maximum power is used as a reference value (set point) of the control system. ON/OFF power controller with hysteresis band is used to control the operation of a Buck chopper such that the PV module always operates at its maximum power computed from the MPPT algorithm. The major difference between the proposed algorithm and other techniques is that the proposed algorithm is used to control directly the power drawn from the PV. The proposed MPPT has several advantages: simplicity, high convergence speed, and independent on PV array characteristics. The algorithm is tested under various operating conditions. The obtained results have proven that the MPP is tracked even under sudden change of irradiation level.

**Keywords:** Photovoltaic, maximum power point tracking (MPPT), Buck chopper

## 1. Introduction

Renewable sources of energy acquire growing importance due to massive consumption and exhaustion of fossil fuel. Among several renewable energy sources, Photovoltaic arrays are used in many applications such as water pumping, battery charging, hybrid vehicles, and grid connected PV systems. As known from a (Power-Voltage) curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. The optimum operating point changes with the solar irradiation, and cell temperature. Therefore, on line tracking of the maximum power point of a PV array is an essential part of any successful PV system. A variety of maximum power point tracking (MPPT) methods is developed. The methods vary in implementation complexity, sensed parameters, required number of sensors, convergence speed, and cost [1]. This paper presents a simple MPPT scheme that does not require special measurements of open circuit voltage or short circuit current.

The proposed algorithm is divided into two major parts: maximum power computation, and direct power control of the power drawn from the PV. The maximum power is computed online using a modified perturb and observe algorithm. The computed maximum power is compared with instantaneous actual PV power, the error between reference (maximum) power and actual power activates ON/OFF controller with a hysteresis band to drive the buck chopper. Therefore, the instantaneous power extracted from the PV is maintained between the tolerance bands.

## 2. PV Equivalent Circuit

A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. The generated current varies linearly with the solar irradiance. The standard equivalent circuit of the PV cell is shown in Fig. 1.

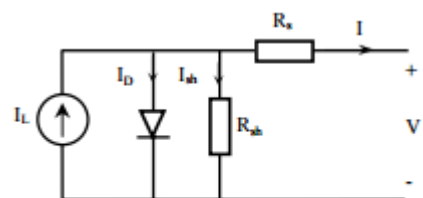


Fig. 1 Equivalent circuit of PV solar cell

The basic equation that describes the (I-V) characteristics of the PV model is given by the following equation:

Where

$I$  is the cell current (A).

$I_L$  is the light generated current (A).

$I_0$  is the diode saturation current.

$q$  is the charge of electron =  $1.6 \times 10^{-19}$  (coul).

$K$  is the Boltzman constant (j/K).

$T$  is the cell temperature (K).

$R_s, R_{sh}$  are cell series & shunt resistance (ohms)

$V$  is the cell output voltage (V).

## 3. Commonly Used MPPT Techniques

The problem considered by MPPT methods is to automatically find the voltage  $V_{MPP}$  or current  $I_{MPP}$  at which a PV array delivers maximum power under a given temperature and irradiance. In this section, commonly used MPPT methods are introduced in an arbitrary order.

### 1. Fractional Open-Circuit Voltage

The method is based on the observation that, the ratio between array voltage at maximum power  $V_{MPP}$  to its open circuit voltage  $V_{oc}$  is nearly constant.

$$V_{MPP} \approx k_1 V_{oc}$$

This factor  $k_1$  has been reported to be between 0.71 and 0.78. Once the constant  $k_1$  is known,  $V_{MPP}$  is computed by measuring  $V_{oc}$  periodically. Although the implementation of this method is simple and cheap, its tracking efficiency is relatively low due to the utilization of inaccurate values of the constant  $k_1$  in the computation of  $V_{MPP}$ .

## 2. Fractional Short-Circuit Current

The method results from the fact that, the current at maximum power point IMPP is approximately linearly related to the short circuit current ISC of the PV array  $IMPP \approx k_2 ISC$  (3) Like in the fractional voltage method,  $k_2$  is not constant. It is found to be between 0.78 and 0.92. The accuracy of the method and tracking efficiency depends on the accuracy of  $K_2$  and periodic measurement of short circuit current.

## 3. Perturb and Observe

In P&O method, the MPPT algorithm is based on the calculation of the PV output power and the power change by sampling both the PV current and voltage. The tracker operates by periodically incrementing or decrementing the solar array voltage. If a given perturbation leads to an increase (decrease) in the output power of the PV, then the subsequent perturbation is generated in the same (opposite) direction. So, the duty cycle of the dc chopper is changed and the process is repeated until the maximum power point has been reached. Actually, the system oscillates about the MPP. Reducing the perturbation step size can minimize the oscillation. However, small step size slows down the MPPT. To solve this problem, a variable perturbation size that gets smaller towards the MPP. However, the P&O method can fail under rapidly changing atmospheric conditions. Several research activities have been carried out to improve the traditional Hill-climbing and P&O methods. Reference [4] proposes a three-point weight comparison P&O method that compares the actual power point to the two preceding points before a decision is made about the perturbation sign. Reference [5] proposes a two stage algorithm that offers faster tracking in the first stage and finer tracking in the second stage.

## 4. Incremental Conductance

The method is based on the principle that the slope of the PV array power curve is zero at the maximum power point.

$(dP/dV) = 0$ . Since  $(P = VI)$ , it yields:

$$\Delta I/\Delta V = -I/V, \text{ at MPP}$$

$$\Delta I/\Delta V > -I/V, \text{ left of MPP}$$

$$\Delta I/\Delta V < -I/V, \text{ right of MPP}$$

The MPP can be tracked by comparing the instantaneous conductance  $(I/V)$  to the incremental conductance  $(\Delta I/\Delta V)$ . The algorithm increments or decrement the array reference voltage until the condition of equation (4.a) is satisfied. Once the Maximum power is reached, the operation of the PV array is maintained at this point. This method requires high sampling rates and fast calculations of the power slope.

## 4. Proposed MPPT Method

Most MPPT techniques attempt to find (search) the PV voltage that results in the maximum power point VMPP, or to find the PV current IMPP corresponding to the maximum power point. The proposed algorithm tracks neither the VMPP nor the IMPP. However, it tracks directly the maximum possible power PMAX that can be extracted from the PV. The flowchart of the proposed MPPT method is shown in Fig. 2.

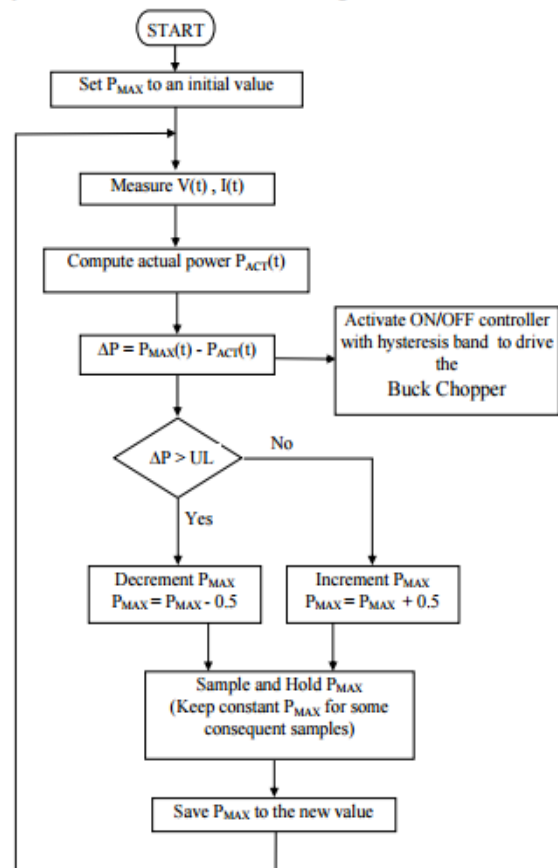


Fig. 2 Flowchart of the proposed MPPT algorithm

Increase gradually the computed value of PMAX and controls the power extracted from the PV to this value. If the actual power is well controlled within the tolerance band of the hysteresis controller, the partial tracking is succeeded and PMAX can be increased to greater value. But, if the power controller fails to track the PMAX, this means that the computed.

PMAX is greater than the maximum possible power of the PV. Therefore, a reduction (decreasing) in the computed PMAX must be done until the error between PMAX and PACT is limited between upper and lower limit. Actually, the algorithm starts by setting the computed maximum power PMAX to an initial value (zero or any other value). Actual PV voltage and current are measured. Then, the instantaneous value of PV power PACT is computed. The error between PMAX and PACT is input to ON/OFF controller with hysteresis band. The output of the controller is used to drive the power transistor of the Buck Chopper such that the PACT tracks PMAX. Till now, the real maximum power is not tracked. To track the maximum power, the error between PMAX and PACT is checked. If the error is lower than a certain upper limit (0.5 Watt), this means that the Power drawn from the PV is within allowable value, so we can increment PMAX by a certain step size. This new value of PMAX is stored and used to control the actual power of the PV to track this new value. Then the algorithm is repeated again. When the error between PMAX and PACT exceed the upper limit it means that the PV is no longer able to deliver this value of PMAX. Therefore, we

have to decrement of P<sub>MAX</sub> by a certain step size (0.5 Watt).

## 5. System Modeling

The block diagram of the PV system under investigation is shown in Fig. 3. The PV power system is modeled using Power System Block set under Matlab. The MPPT algorithm is modeled using Simulink blocks. The simulation parameters are summarized in Table I.

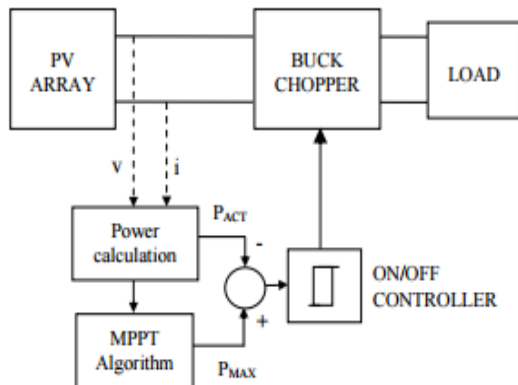


Fig. 3 Block diagram of the PV system under investigation

TABLE I  
SIMULATION PARAMETERS

Sampling rate	20 kHz
$C_{LOAD}$	200 $\mu$ F
$R_{LOAD}$	1-100 $\Omega$
Buck Chopper	MOSFET

## 6. Simulation Results

In Fig.4.a, the computed maximum power P<sub>MAX</sub> and the actual extracted PV power P<sub>ACT</sub> are plotted together. The PV current was 3A which is corresponding to irradiance of 1 kW/m<sup>2</sup>. As explained before, the P<sub>MAX</sub> is started from initial value (0) and is increased gradually. According to the results, computed P<sub>MAX</sub> is 51.5 W, while the theoretical value was 54 W. So the tracking efficiency is 95 %. At the same time the direct power control algorithm keeps the actual power at 51.5 bounded between an upper and lower limit of + 0.1 W. The details of the tracking performance are presented in Fig.4.b.

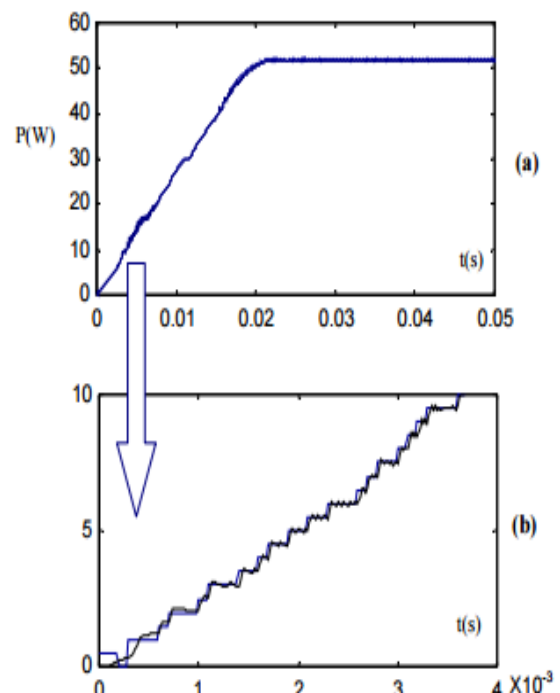
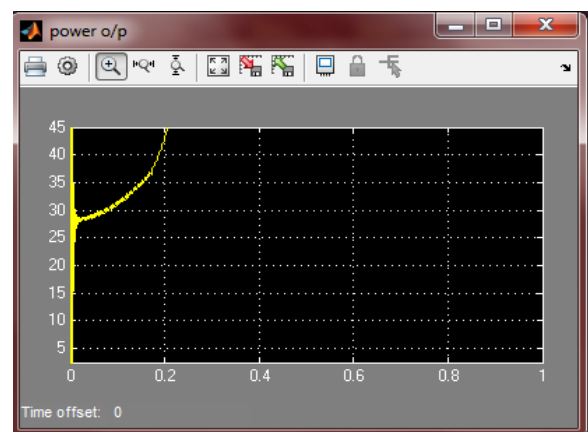
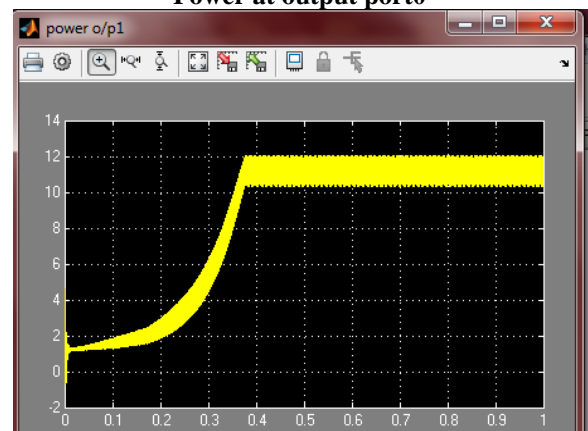


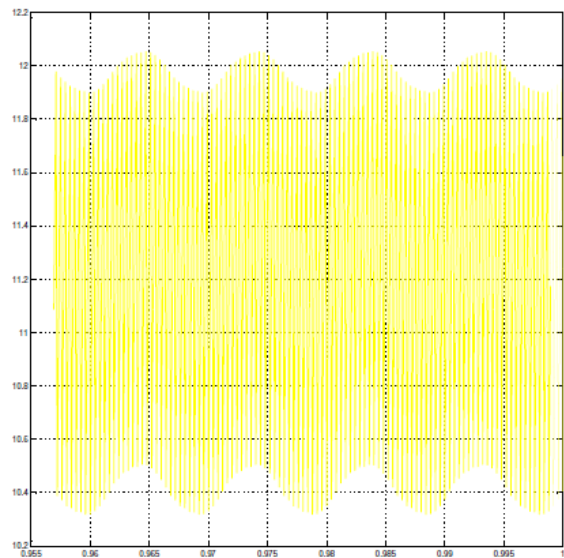
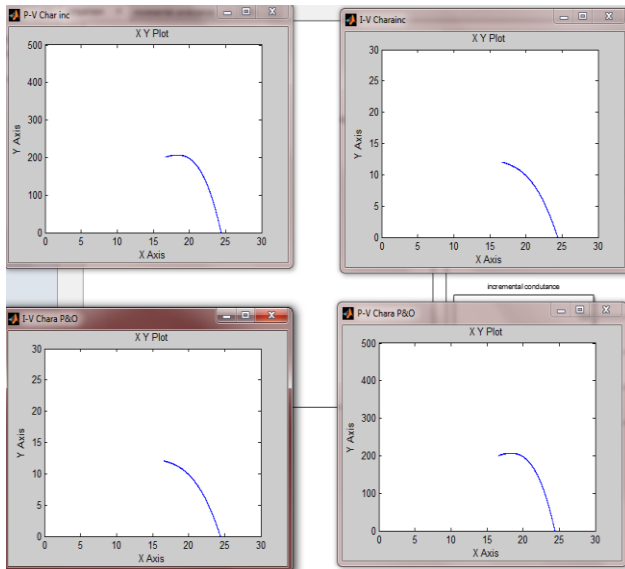
Fig. 4 Tracked maximum power and Extracted PV power  
 a) Overall response.  
 b) Performance during the 1<sup>st</sup> Four ms.



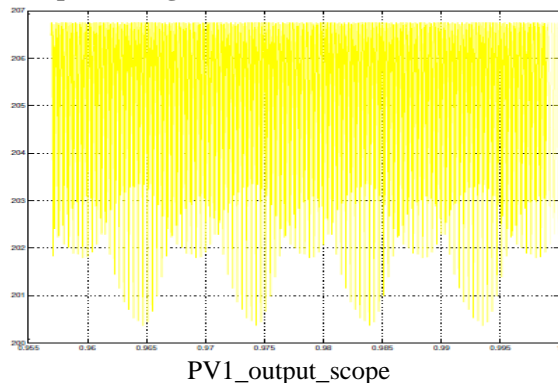
Power at output port0



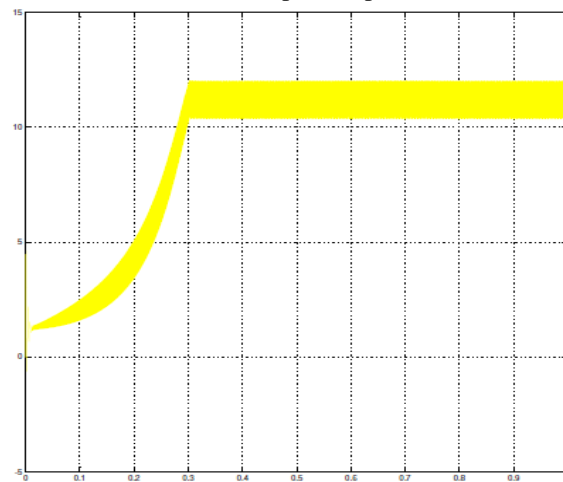
Power at output port1



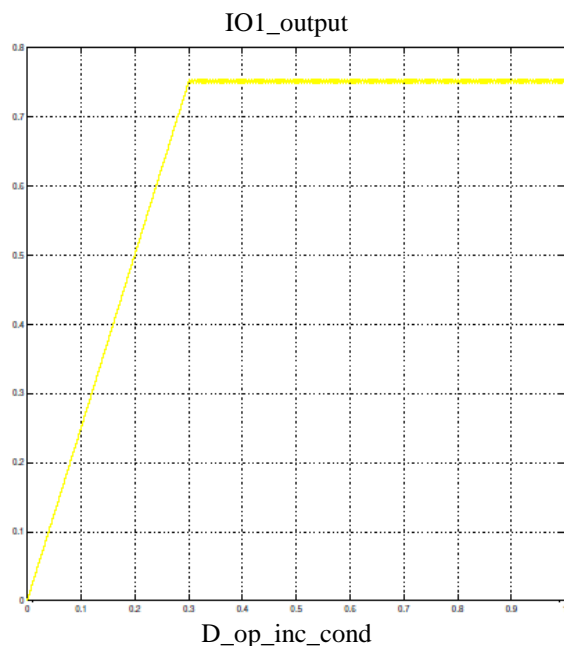
**Comparison figures of I-V and P-V characteristics**



**PV1\_output\_scope**



**Power\_op1\_inc\_cond**



**D\_op\_inc\_cond**

## 7. Conclusion

The paper proposes a simple MPPT method that requires only measurements of PV voltage and current with the need to any environmental measurements (temperature, irradiance). The method is considered as a modified perturb and observe method. However, the principle difference between the proposed method and any other tracking method, is that the proposed method attempts to track and compute the maximum power and controls directly the extracted power from the PV to that computed value. While, any other method attempts to reach the maximum point by the knowledge of the voltage or the current corresponding to that optimum point. The proposed method offers different advantages which are: good tracking efficiency, relatively high convergence speed and well control for the extracted power thanks to the direct power control unit based on the ON/OFF hysteresis controller.

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