A New Maximum Power Point Tracking for Photovoltaic Systems

Mohamed Azab

***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.

I. 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 are 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.

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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.

II. 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.

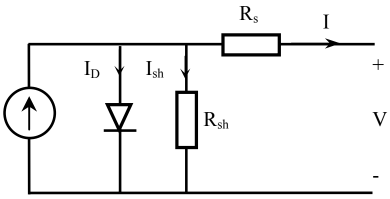

Fig. 1 Equivalent circuit of PV solar cell

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

$$I = I_L - I_o\left(e^{\frac{q(V + IR_s)}{kT}} - 1\right) - \frac{V + IR_s}{R_{sh}} \quad (1)$$

Where:

I is the cell current (A).
I_L is the light generated current (A).
I_o is the diode saturation current.
q is the charge of electron $= 1.6x10^{-19}$ (coul).
K is the Boltzman constant (j/K).
T is the cell temperature (K).
R_s, R_{sh} are cell series and shunt resistance (ohms).
V is the cell output voltage (V).

III. 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.

A. 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.

$$V_{MPP} \approx k_1 V_{OC} \quad (2)$$

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 $V_{MMP.}$

B. Fractional Short-Circuit Current

The method results from the fact that, the current at maximum power point I_{MPP} is approximately linearly related to the short circuit current I_{SC} of the PV array.

$$I_{MPP} \approx k_2 I_{SC} \quad (3)$$

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.

C. 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. To prevent divergence from MPP, modified adaptive algorithm is proposed in [6].

D. 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:

$$\Delta I/\Delta V = -I/V \text{ , at MPP} \quad (4.a)$$

$$\Delta I/\Delta V > -I/V \text{ , left of MPP} \quad (4.b)$$

$$\Delta I/\Delta V < -I/V \text{ , right of MPP} \quad (4.c)$$

The MPP can be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ΔV). 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.

IV. PROPOSED MPPT METHOD

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

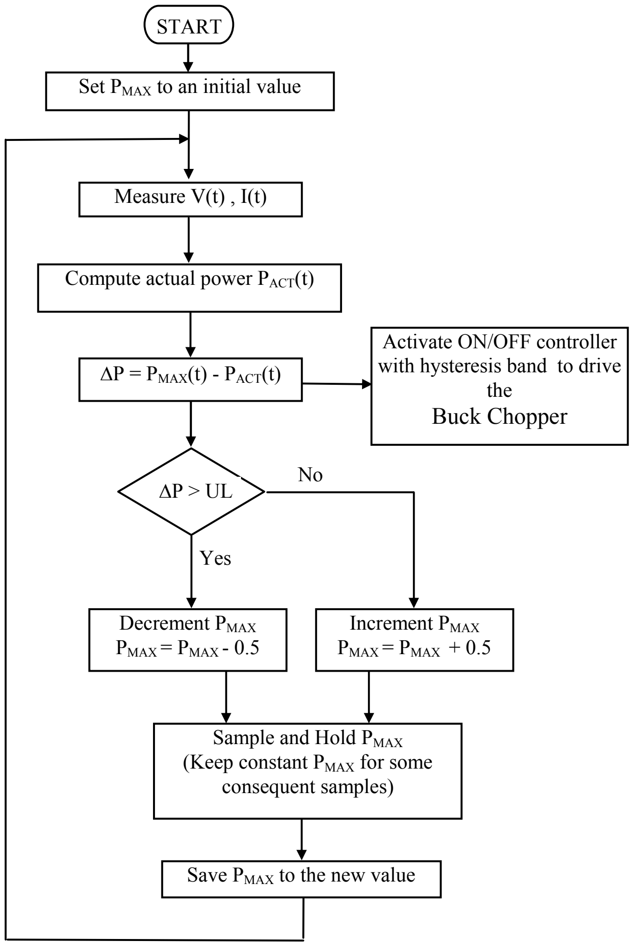

Fig. 2 Flowchart of the proposed MPPT algorithm

increase gradually the computed value of P_{MAX} 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 P_{MAX} can be increased to greater value. But, if the power controller fails to track the P_{MAX}, this means that the computed

P_{MAX} is greater than the maximum possible power of the PV. Therefore, a reduction (decreasing) in the computed P_{MAX} must be done until the error between P_{MAX} and P_{ACT} is limited between upper and lower limit.

Actually, the algorithm starts by setting the computed maximum power P_{MAX} to an initial value (zero or any other value). Actual PV voltage and current are measured. Then, the instantaneous value of PV power P_{ACT} is computed. The error between P_{MAX} and P_{ACT} 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 P_{ACT} tracks P_{MAX}. Till now, the real maximum power is not tracked. To track the maximum power, the error between P_{MAX} and P_{ACT} 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 P_{MAX} by a certain step size. This new value of P_{MAX} 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 P_{MAX} and P_{ACT} exceed the upper limit it means that the PV is no longer able to deliver this value of P_{MAX} . Therefore, we have to decrement of P_{MAX} by a certain step size (0.5 Watt).

V. 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 Blockset under Matlab. The MPPT algorithm is modeled using simulink blocks. The simulation parameters are summarized in Table I.

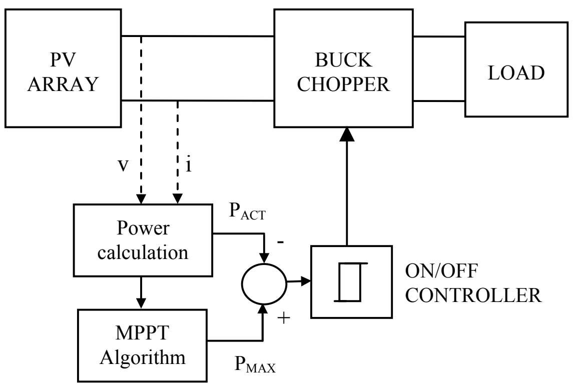

Fig. 3 Block diagram of the PV system under investigation

TABLE I
Simulation Parameters

Sampling rate	20 kHz
C_{LOAD} R_{LOAD}	200µF 1-100 Ω
Buck Chopper	MOSFET

TABLE II
Key Specification of BP Solar Panel

Maximum Power	P_{max}	50 W
Voltage @ max. power	V_{max}	17.3 V
Current @ max. power	I_{max}	2.89 A
Short circuit current	I_{SC}	3.17 A
Open circuit voltage	V_{OC}	21.8 V

VI. Simulation Results

In Fig.4.a, the computed maximum power P_{MAX} and the actual extracted PV power P_{ACT} are plotted together. The PV current was 3 A which is corresponding to irradiance of 1 kW/m^2 .As explained before, the P_{MAX} is started from initial value (0) and is increased gradually. According to the results, computed P_{MAX} 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 $\pm$ 0.1 W. The details of the tracking performance is presented in Fig.4.b, while the steady state performance of the tracker is shown in Fig. 4.c.

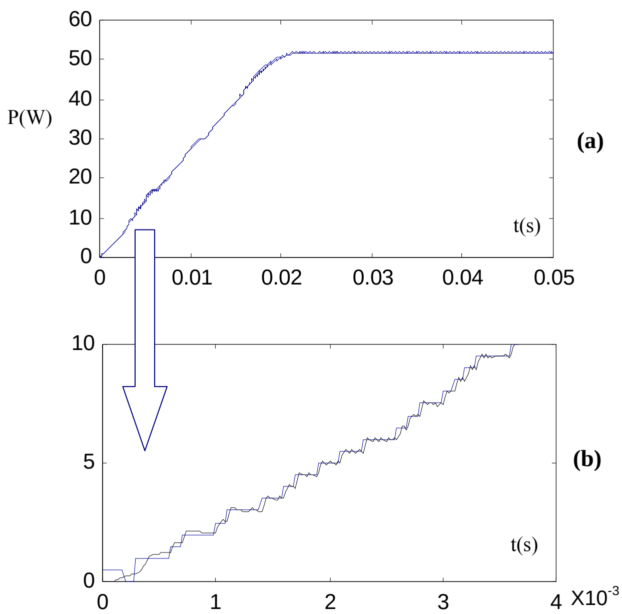

Fig. 4 Tracked maximum power and Extracted PV power
a) Overall response.
b) Performance during the 1st Four ms.

Fig. 4.c illustrates the steady state performance of the MPPT at the same operating conditions. It is clear that the PMAX oscillates between 51.5 W and 52 W. The actual extracted PV power is 51.5 $\pm$ 0.1 W.

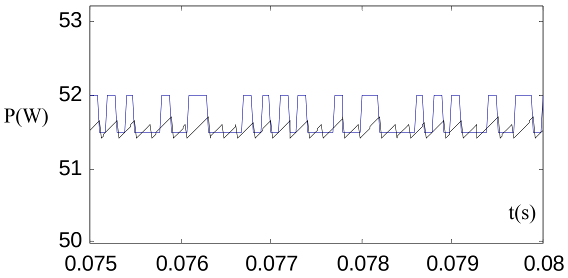

Fig. 4.c Tracked maximum power and Extracted PV power (Steady state Performance)

Moreover, to evaluate the performance the proposed MPPT, the PV is exposed to different levels of irradiance that is changed randomly and rapidly (although normal solar irradiance does not abruptly, but this would happen in partially shaded PV systems. According to the obtained results presented in Fig. 5, the MPPT algorithm tracks the new values of maximum power. In each case, the power extracted from the PV is well controlled. The results prove that the convergence speed is relatively high.

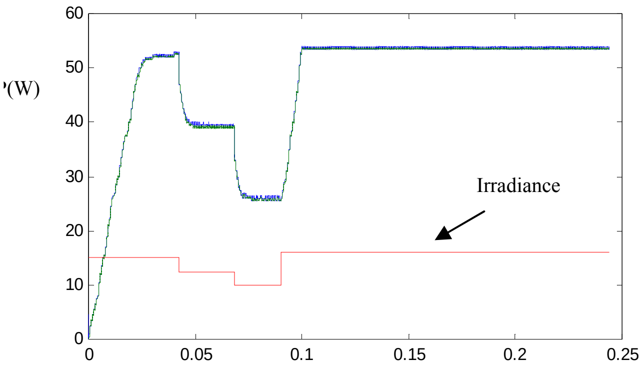

Fig. 5 Tracked maximum power and Extracted PV power under varying solar irradiance

To evaluate the performance of the proposed method, a comparison between theoretical values of PV maximum power and that computed from the algorithm is carried out for different values of solar irradiance and the results are plotted in Fig. 6. Moreover, the corresponding tracking efficiencies of the proposed MPPT under different irradiance levels are computed and presented in Fig. 7. According to the obtained results, the tracking efficiency is not less than 95 %. Therefore, the proposed method guarantees good tracking efficiency under different operating conditions.

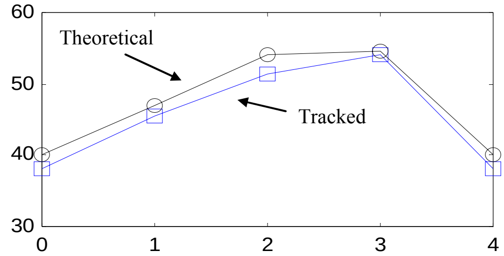

Fig. 6 Theoretical and tracked values of PV maximum power under different irradiance

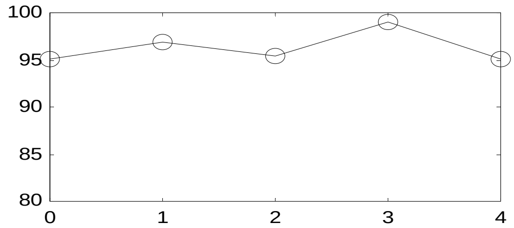

Fig. 7 Calculated values of tracking efficiencies

VII. 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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