Two Mode Maximum Power Point Tracking for Photovoltaic System

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Abstract: This paper presents the two modes for maximum power point tracking of the photovoltaic system. The method combines the merits of the two methods consisting of the open circuit method and the three point weight comparison method. The maximum point found by this method is exactly than by the open circuit method. By the simulation results, the actual maximum point can be found that is better than the Perturb and Observe (P&O) method or the three point weight method only one method, especially, in the case of non regular pattern of Power-Voltage (P-V) curve.

Keywords: Solar cells, Photovoltaic, Maximum power point tracking, Two mode MPPT

1. INTRODUCTION

Nowadays, solar electricity, by photovoltaic, is the leading one of the promising alternative energy [1]. Photovoltaic systems are wide range in applications, such as for appliances, for domestics house hold used, both stand alone and grid connected systems, for telecommunication, etc. The numbers of installed systems are rapidly increasing, but the cost of PV modules and system components are decreasing by the way of market. The PV systems performances improvement can be done by various ways, i.e. to improve PV module efficiency, to improve components efficiency, and selection of optimum operating load conditions, called MPPT.

In generally, MPPT algorithms can be divided into 4 methods consisting of the open circuit method, the Perturb and Observe (P&O) method, the three point weight method and the incremental conductance (IncCond).

This paper proposes the new combination method between the open circuit method and the three point weight method that included the merits of each method.

2. CHARACTERISTIC OF PHOTOVOLTAIC

An equivalent circuit of PV cell shown in Figure 1 is used together with the following set of circuit equations to express a typical current voltage (I-V) characteristic of PV modules and arrays.

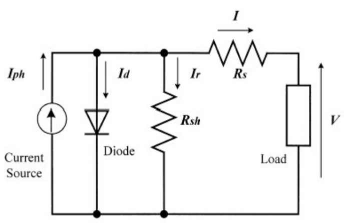


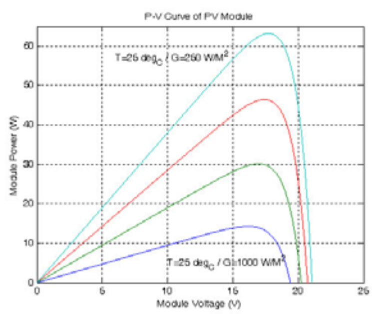
Fig. 1 Equivalent circuit for PV modules and PV arrays.

$$I = I_{ph} - I_d - I_r \qquad (1)$$

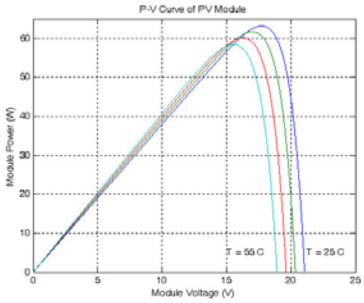
$$I = I_{ph} - I_0\left(e^{\frac{q(V+R_s I)}{nkT}} - 1\right) - \frac{(V+R_s I)}{R_{sh}} \qquad (2)$$

where
I_{Ph} = Photocurrent A/m^2
V = Terminal voltage of the cell
I_d = Diode current A/m^2
I_0 = Saturation current A/m^2($\cong 10^{-8}$)
n = Ideality factor $\cong$ 2
q = Electron charge
k = Boltzmann's constant
T = Junction temperature K
R_s = Series resistance
R_{sh} = Shunt resistance

Figure 2a shows the simulated characteristic curves for the PV array at different insolations. Figure 2b shows power voltage (P-V) curve at different temperatures. From these curves, it is observed that the output characteristics of the PV array are nonlinear and vitally affected by solar radiation, temperature, and load conditions. Each curve has a maximum power point (MPP), which is the optimal operating point for the efficient use of the PV arrays.



(a)



(b)

Fig.2 P-V curve at different insolations and temperatures.

3. MAXIMUM POWER POINT TRACKING

Certain loads have operating voltages that can be quite erratic and would do a poor job of tracking a PV array's MPP. A PV array can sometimes be placed in a location that will expose it to very wide temperature fluctuations; as a result, the photovoltaic MPP will vary greatly, and significant power losses will be suffered when the direct-connection or fixed-voltage techniques are used.

A MPP tracker is placed between a PV array and its load, and is based on a design that samples the PV output and changes the apparent impedance of the load until the PV power is maximized. PV output power can be sampled either by multiplying the PV voltage and current readings together or in a special way by measuring just the voltage or current. The heart of MPPT techniques is the software algorithm that hunts for the maximum power operating point (MPOP) relying on measured array parameters (voltage, current and power).

A frequently used class of MPPT algorithms operates by continuously changing the operating point of the PV array and detecting the corresponding change in the array output power; therefore they are known such as 'perturb and observe (P&O)' algorithm, 'three-point weight comparison', 'incremental and conductance (IncCond)' algorithm, and open circuit method. The two mode MPPT presented in this paper is a software development of a both algorithms are Three point weight comparison and Open circuit method. In the paper, models and simulations of our PV array and maximum power tracking algorithms are presented achieved simulation.

3.1 Perturb and Observe Algorithm

P&O algorithms are widely used in maximum power tracking because of their simple structure and the few measured parameters which are required. They operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing, the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed [3]. This means the array terminal voltage is perturbed every MPPT cycle; therefore when the MPOP is reached, the P&O algorithm will oscillate around it resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions.

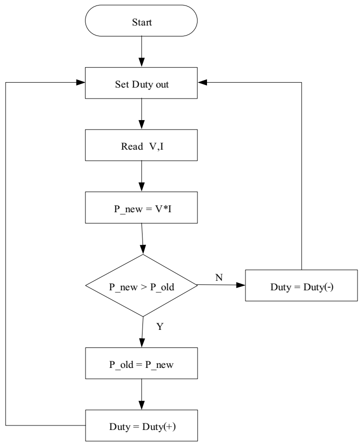


Fig. 3 Flow chart of the P&O algorithm.

3.2 Three-Point Weight Comparison Method

The P&O algorithm compares only two points, which are the current operation point and the subsequent perturbation point, to observe their changes in power and thus decide whether increase or decrease the solar array voltage [4].

The algorithm of the three-point weight comparison is run periodically by perturbing the solar array terminal voltage and comparing the PV output power on three points of the V-P curve. The three points are the current operation point (A), a point, B, perturbed from point A, and a point, C, with doubly perturbed in the opposite direction from point B. Figure 2 depicts nine possible cases.

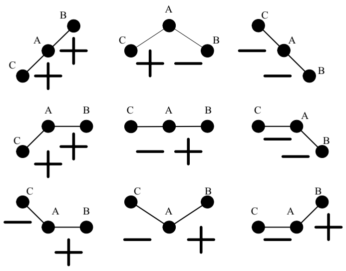


Fig.4 Possible states of the three perturbation points.

For the point A and B, if the power of point B is greater than or equal to that of point A, the status is assigned a positive weighting. In the other hand, the status is assigned a negative weighting. And, for the point A and C, when the power of point C is smaller than that of point A, the status is assigned a positive weighting. In the other hand, the status is assigned a negative weighting.

Of the three measured points, if two are positively weighted, the duty cycle of the converter should be increased. On the contrary, when two are negatively weighted, the duty cycle of the converter should be decreased. In the other cases with one positive and one negative weighting, the MPP is reached or the solar radiation has changed rapidly and the duty cycle is not to be changed. Figure 3 presents a flow chart of the three-point weight comparison algorithm.

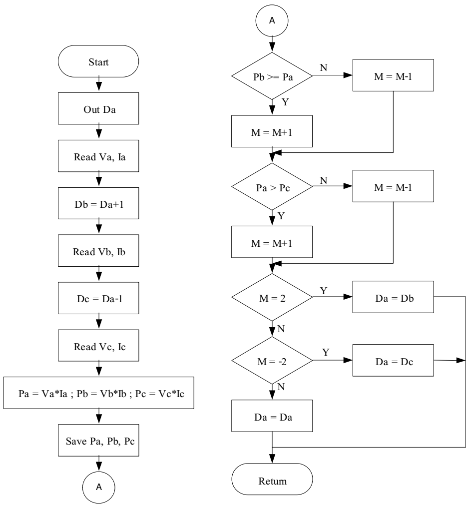


Fig. 5 Flow chart of the three-point weight comparison.

3.3 Incremental Conductance (IncCond)

The incremental conductance algorithm is derived by differentiating the PV array power with respect to voltage and setting the result equal to zero. This is shown in Equation (3).

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I + V\frac{dI}{dV} = 0 \ \text{at the MPP} \qquad (3)$$

Rearranging Equation (1) gives

$$-\frac{I}{V} = \frac{dI}{dV} \qquad (4)$$

Note that the lest-hand side of Equation (4) represents the opposite of the PV array's instantaneous conductance, while the right-hand side represents its incremental conductance [5]. Thus, at the MPP, these two quantities must be equal in magnitude, but opposite in sign. If the operating point is off of the MPP, a set of inequalities can be derived from Equation (4) that indicates whether the operating voltage is above or below the MPP voltage. These relationships are summarized in Equations (5a, 5 and 5). Figure 6 shows a flowchart for the incremental conductance algorithm.

$$\frac{dI}{dV} = -\frac{I}{V}; \ \left(\frac{dP}{dV} = 0\right) \qquad (5a)$$

$$\frac{dI}{dV} > -\frac{I}{V}; \ \left(\frac{dP}{dV} > 0\right) \qquad (5b)$$

$$\frac{dI}{dV} < -\frac{I}{V}; \ \left(\frac{dP}{dV} < 0\right) \qquad (5c)$$

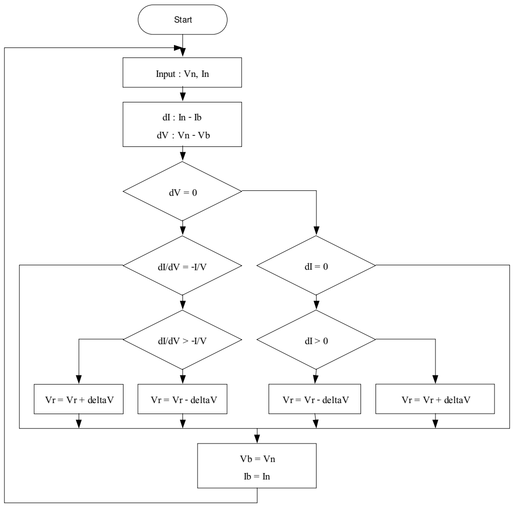


Fig. 6 Flow chart of the Incremental Conductance algorithm.

The incremental conductance method developed to improve these problems of P&O method tracks MPP of PV-module by comparing incremental conductance with instantaneous one [5]. As a result, under rapidly changing atmospheric conditions, this method tracks MPP very well, but the response speed of finding MPP is declined because the calculation time of DSP is increased by relatively complicated control algorithm.

3.4 Open Circuit Method

The open circuit method depends on the fact that voltage on MPP at any condition is between 65% and 80% of open circuit voltage (V_{oc}) at that condition [6]. This method is extremely simple, it is difficult to choose the optimal value of the constant that will be mutiplied with V_{oc}. Figure 7 shows flow chart of the open circuit method.

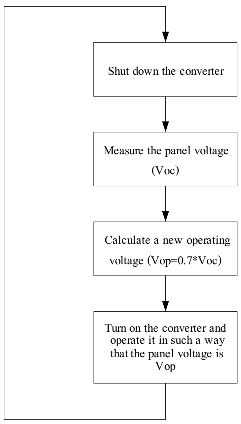


Fig. 7 Flow chart of the open circuit method.

Time response of system is appointed by together with capacitance and resistance at the PV module terminal. Capacitance is high, time is used, in measured V_{oc} is high too. For that reason, if we would like to quickly measured V_{oc}, the capacitance must be possible minimum value. Also, this method is suitableness with fixed loading from PV array such as centrifugal pump that is drived by DC motor.

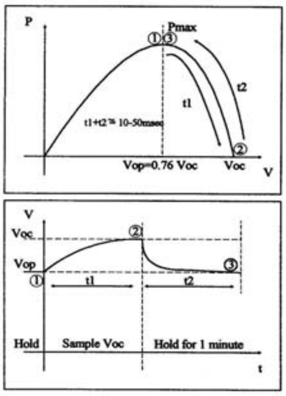


Fig. 8 Locus of the terminal voltage at open circuit of a PV module

3.5 Two Mode Maximum Power Point Tracking

The two mode algorithm MPPT is proposed in this paper, applied from together with three-point weight comparison method and open circuit method. Due to reduce oscillation around MPP and to be able to track with PV power system which have a P-V curve is non-uniform. A non-uniform P-V curve arise from PV cell that is non-identical, cause by manufacturing differences or degradation (cracked) or partial shading (shadows, leaf, bird droppings, discolouring, encapsulant, etc). The non-uniform P-V curve is shown, in Figure 9.

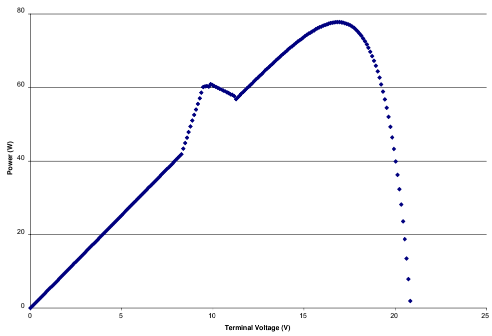


Fig. 9 The non-uniform P-V curve.

The Two mode MPPT algorithm starts at isolation between PV array and converter. The system controller measured the open circuit at terminal voltage and calculated a started operating voltage. Then flow into mode 2 is the three-point weight comparison algorithm. If condition is real, controller return to open circuit again. If condition is unreal, controller loop in mode 2 until condition as real. Figure 10 shows Two mode MPPT algorithm.

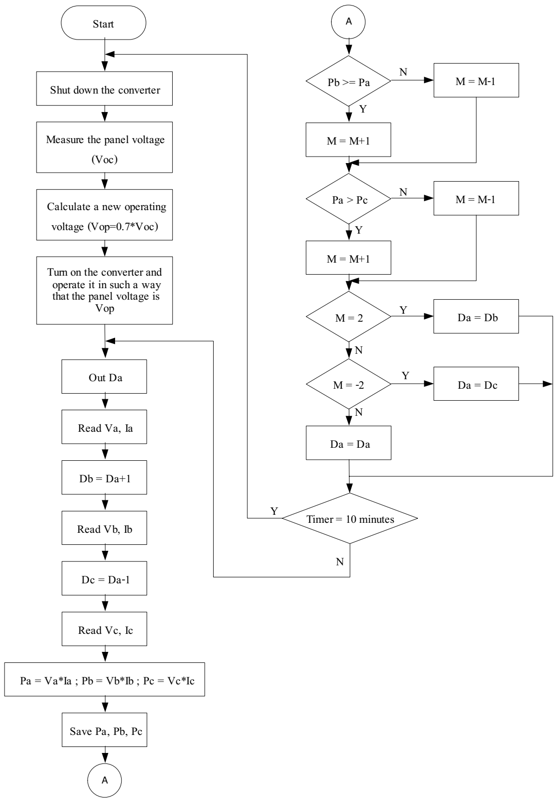


Fig. 10 Flow chart of the Two mode MPPT algorithm.

4. SIMULATION

4.1 System configuration

The system is simulated, consisting of a PV module, DC-DC converter, MPPT controller and gate drive, and dc load.

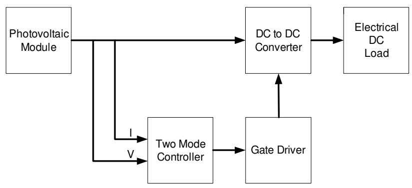


Fig. 11 System configuration.

DC-DC converter, which is Boost converter, is used to deliver the power from photovoltaic module to load.

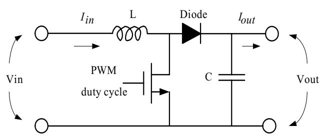


Fig. 11 Boost converter to control the operating voltage.

The basic circuit for a step-up converter has equation as follows

$$V_{out} = \left(\frac{1}{1-D}\right)V_{in} \quad (6)$$

where V_{in} is PV module or array voltage, V_{out} is optimum voltage and D is duty ratio.

4.2 Simulation Results

The simulation uses the data from a PV module test results, P-V curve, at the conditions of 1000 W/m^2 and module temperature at 25°C as shown in Fig. 12 as below
I

open circuit voltage (Voc)	=	20.8	V
short circuit current (Isc)	=	5	A
voltage at MPP (Vmp)	=	17.5	V
current at MPP (Imp)	=	4.4	A
power at maximum	=	77	W

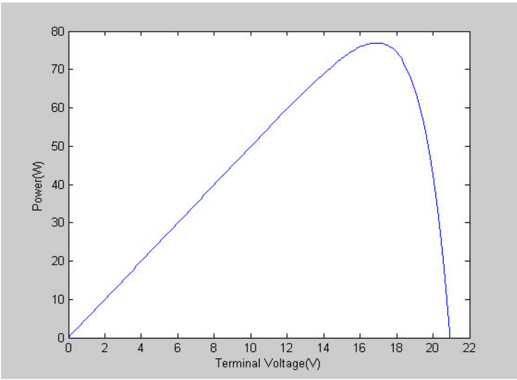
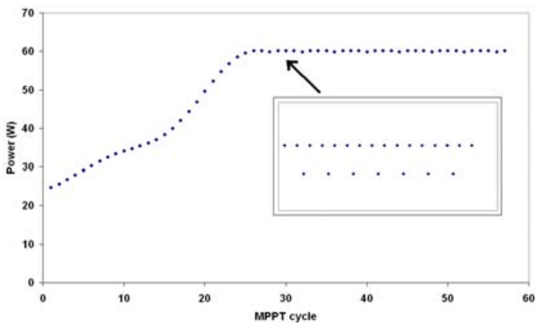
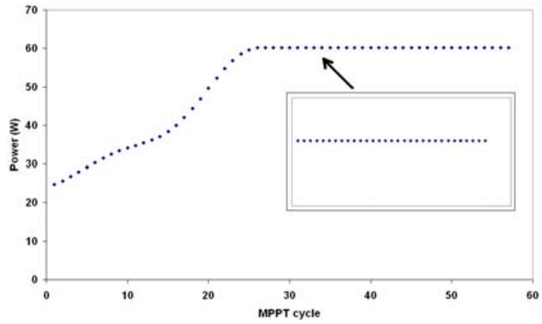


Fig. 12 The data of P-V curve for simulation

From Fig. 9, the simulation result that used only the P&O algorithm is shown in Fig. 13a. It is assumed to set the initial at 23 W, and then climbing to 60 W, but it can not go to 77 W that is the actual maximum power point at above condition. We observe the oscillation around the power at 60 W.



(a)



(b)

Fig. 13 Output power versus MPPT cycle.

From Fig. 9, the simulation result that used only the three point weight comparison algorithm is shown in Fig. 13b. It is assumed to set the initial at 23 W, and then climbing to 60 W, but it can not go to 77 W that is the actual maximum power point at above condition. We observe that the oscillation is not occurred.

Figure 14 is shown the result obtained by using the two modes MPPT algorithm at conditions as non-uniform P-V curve. In this figure, we observe that the MPPT controller can be tracked from initial value to the actual maximum point with no oscillations. It is found that the performance of a PV system can be improve when we use the two modes algorithm.

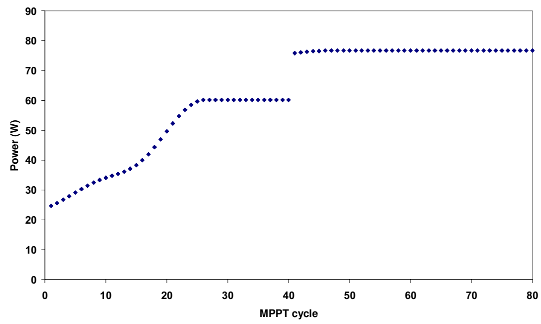


Fig. 14 Result obtained by using Two mode MPPT.

5. CONCLUSION

This method proposed in this paper is combined the two methods of MPPT algorithms, the open circuit method and the three point weight method. This algorithm uses the open circuit algorithm to set the initial operating point for finding the maximum power point at any conditions by three point weight algorithm. Then, it re-checks the maximum point back and forth, between the two algorithms. By this proposed algorithm, it can be solved the trouble of local maximum point that is not the global maximum for the case of non regular pattern of Power-Voltage (P-V) curve. The actual maximum power point can not be found by only one algorithm. The simulation results are shown the comparison of the only P&O method, the only three point weight and this algorithm. It confirms that the only one algorithm can not reach the exact maximum power point, especially, for this case.

ACKNOWLEDGEMENTS

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