Comparison of Maximum Power Point Tracking (MPPT) Techniques

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Abstract---Solar energy has maximum efficiency to convert energy into electrical among all the renewable sources, by using solar cell. But initial cost of solar cell is very high. Also in rapid changing environmental condition also partially shaded condition by somehow, the efficiency of conversion into electricity is decreases. So, the overall cost of solar energy will be increased and not economical. So, it is desired to extract maximum energy from solar cell by the way the maximum power point tracking techniques. There are two most popular methods, which are Perturb & Observe (P&O) and Incremental Conductance (IC). The comparative study of these two techniques is described in this paper by theoretically and MATLAB simulation based.

Keywords: Photovoltaic cell, PV array, MPPT, Perturb & Observe (P&O) and Incremental Conductance (IC).

I. INTRODUCTION

Nowadays renewable energy sources importance are increase because fossil fuels are limited and their consumption and exhaustion are increased day by day. And solar energy is most popular among them. Because it is readily available, free and pollution free. But initial cost of solar cell is high and also conversion efficiency is also low. In other side increasing the oil price, it will make solar energy popular in future. By the use of maximum power point tracking (MPPT) algorithm, extraction of power will be increased. There are two most popular algorithm for maximum power tracking, which are Perturb & Observe (P&O) and Incremental Conductance (IC) [1].

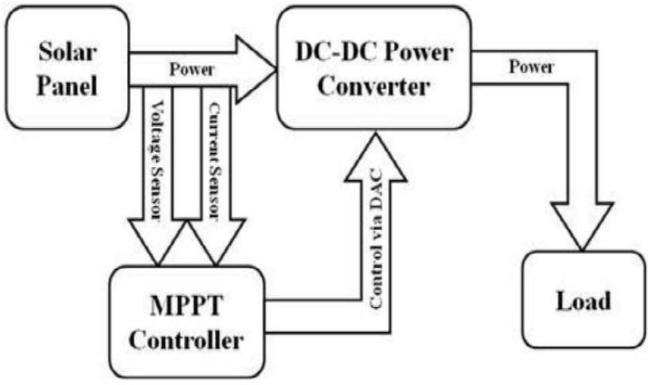

Fig. 1: Basic block diagram of MPPT.

A MPPT is used to extract maximum power from the solar PV module. And this power transfer to the load. Fig. 1 shows the basic block diagram of MPPT. A DC-DC converter (step up/step down) is used to transfer maximum power from solar PV module to load. A DC-DC converter acts as interface between the load and solar PV module. By changing the duty cycle the load impedance as seen by the source is varied and matched at the peak point of the peak power with the source so as to transfer the maximum power [2].

II. EQUIVALENT CIRCUIT OF SOLAR CELL

Fig. 2 shows the simple circuit of solar cell as current source in parallel with diode. Its output is depends on the falling of light on the cell. The diode determines the I-V characteristic of the cell.

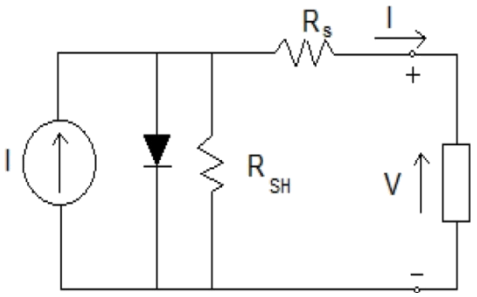

Fig. 2: Equivalent circuit of Solar Cell.

The equation of I-V characteristics are

$I=I_{sc} – I_d$

$I_d= I_o (eqVd/kT - 1)$

Where Io is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant (1.38 * 10-23 m2Kg/s2K) and T is the junction temperature in Kelvin (K)

From above equation

$I = I_{sc} – I_o (eqVd/kT - 1)$

Using suitable approximations,

$I = I_{sc} – I_o (eq((V+IRs)/nkT) - 1)$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor [3].

III. SOLAR CHARACTERISTICS

The I-V characteristics of a typical solar cell are as shown in the Fig. 3.

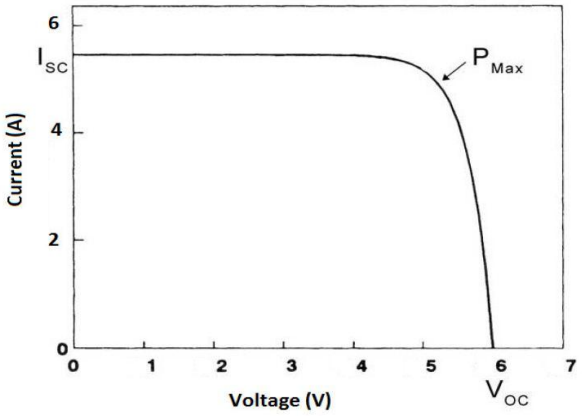

Fig. 3: I-V characteristic of solar cell.

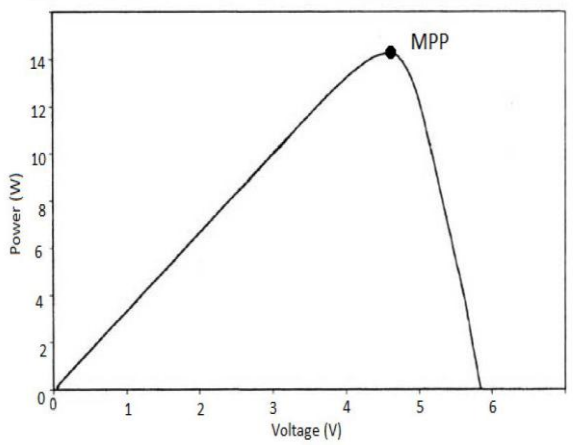

Fig. 4: P-V characteristic of solar cell.

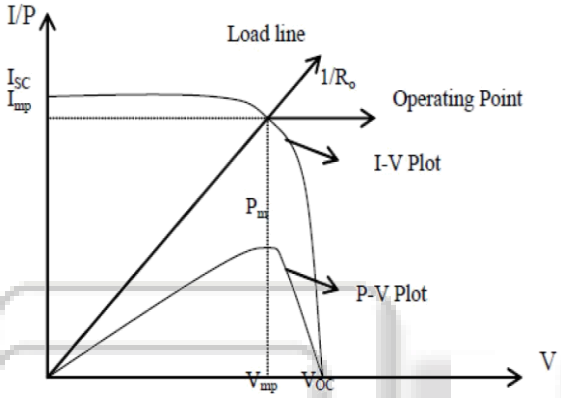

Fig. 5: Maximum power point.

In Fig. 5 the point at which Imp and Vmp meet is the maximum power point. This is the point at which maximum power is available from the PV cell. If the „load line" crosses this point precisely, then the maximum power can be transferred to this load. A boost converter is used on the load side and a solar panel is used to power this converter [1].

IV. MPPT TECHNIQUES

There are many techniques used for MPPT, few are listed below:

- Perturb & Observe
- Incremental Conductance
- Constant Voltage and Current
- Parasitic Capacitance

A. Perturb & Observe

Fig. 6 shows the algorithm of Perturb & Observe method. In this method small perturbation accrued. So, the power of solar module changes due to perturbation. If the power increases due to perturbation the perturbation continue in this direction. If the peak power is reached then it decreases and the perturbation reverses. At steady state algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module [3].

A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple. Fig. 7 shows the P-V characteristic for Perturb & Observe method [2].

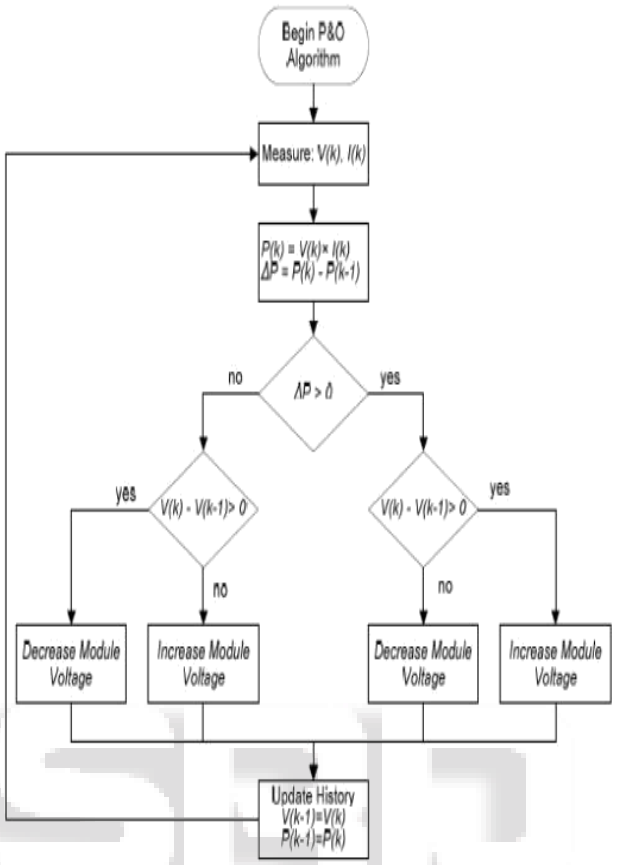

Fig. 6: Perturb & Observe algorithm.

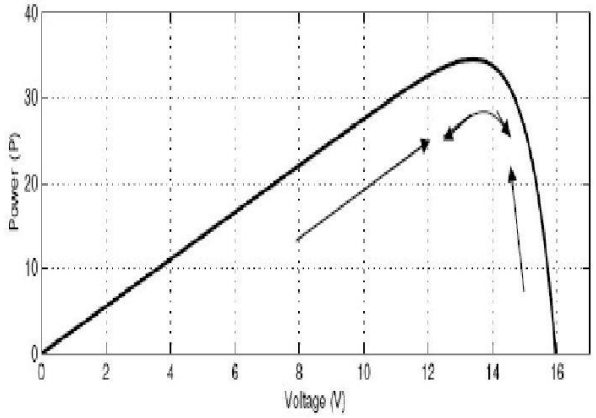

Fig. 7: P-V Characteristic for Perturb & Observe method.

B. Incremental Conductance

The disadvantage of Perturb & Observe method under fast varying condition is overcome by IC method. In IC method once it determines MPP then stops perturbing. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/dV and –I/V [3].

- dI/dV = –I/V At MPP
- dI/dV > –I/V Left to MPP
- dI/dV < –I/V Right to MPP

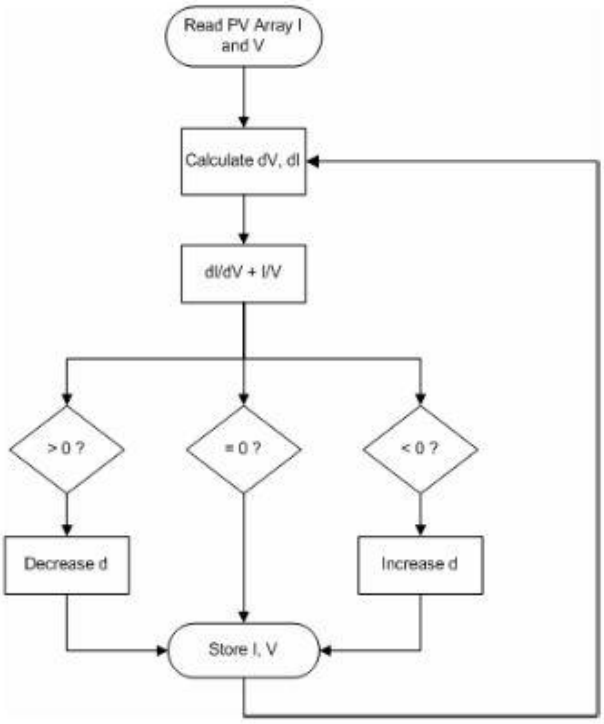

Fig. 8: Incremental Conductance Algorithm.

This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Fig. 8 shows the Incremental Conductance algorithm [4].

Incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to P&O. Fig. 9 shows the P-V characteristic for IC method [2].

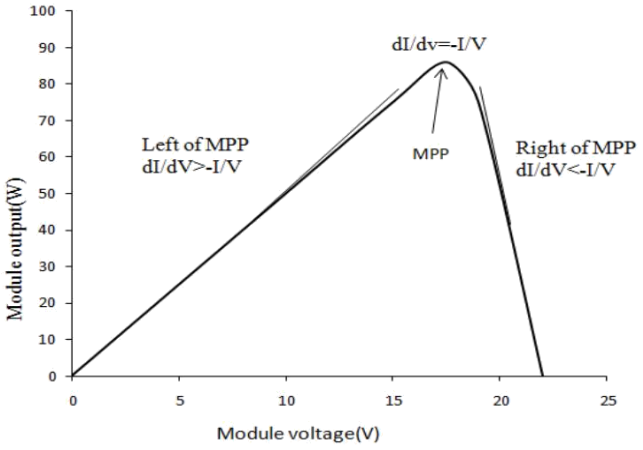

Fig. 9. P-V Characteristic for IC method.

C. *Comparison of P&O and IC method*

Parameters	P & O Method	IC Method
Efficiency	Medium	High
Complexity	less	More
Real time implementation	Easy to implement as few measured parameters	More complex So, Micro controller/DSP required
Cost	Relatively lower	Higher cost
Reliability	Not very accurate	Accurate
Rapid changing atmospheric conditions(varying radiation)	Unpredictable performance with oscillations around MPP, slower response	Good and automatically adjust module operating voltage with no oscillations

Table. 1: Comparison

V. SIMULATION RESULTS

Simulation is based on MSX 60, which is 60W PV module The specifications of MSX 60 at 250 C are [5]:

Open circuit voltage	21 (V)
Short circuit current	3.7 (A)
Voltage at maximum power	17 (V)
Current at maximum power	3.5 (A)
Maximum power	60 (W)

Table. 2: Specification Of Msx 60 At 25^0c

A. *Simulation Result of PV module*

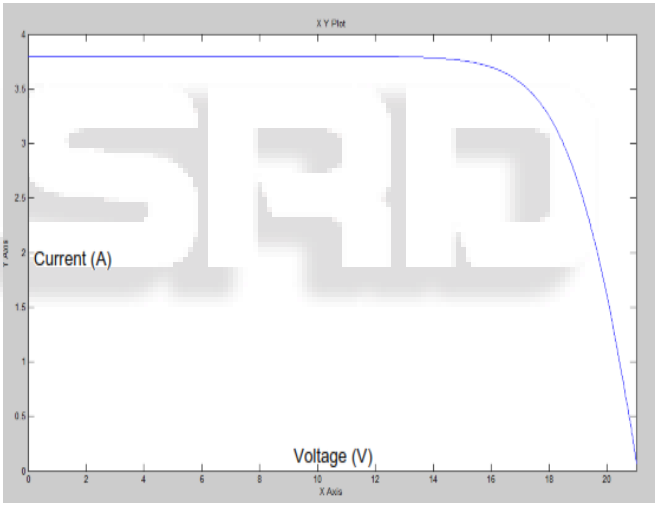

Fig. 10: I-V characteristic of PV model.

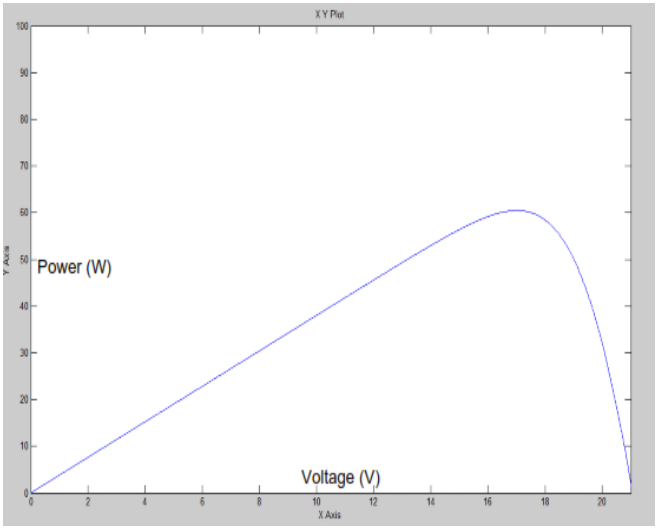

Fig. 11: P-V characteristic of solar cell.

Time (Second)	Irradiance (W/m2)
0 – 0.3	750
0.3 – 0.6	1000
0.6 – 0.9	750
0.9 – 1.2	500

Table. 3: Varying Irradiance For Simulation

B. Simulation Result of P&O under varying irradiance

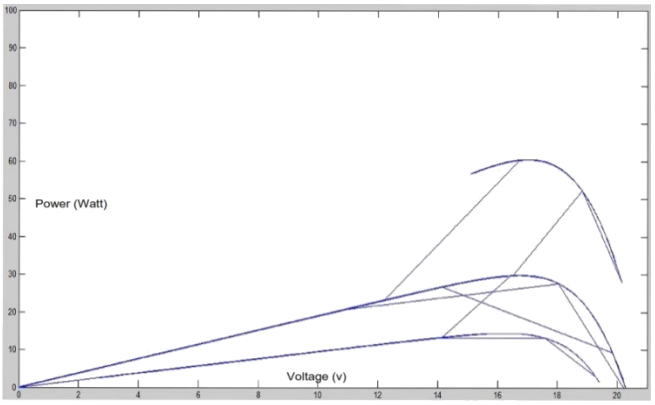

Fig. 12: P-V characteristic for P&O method.

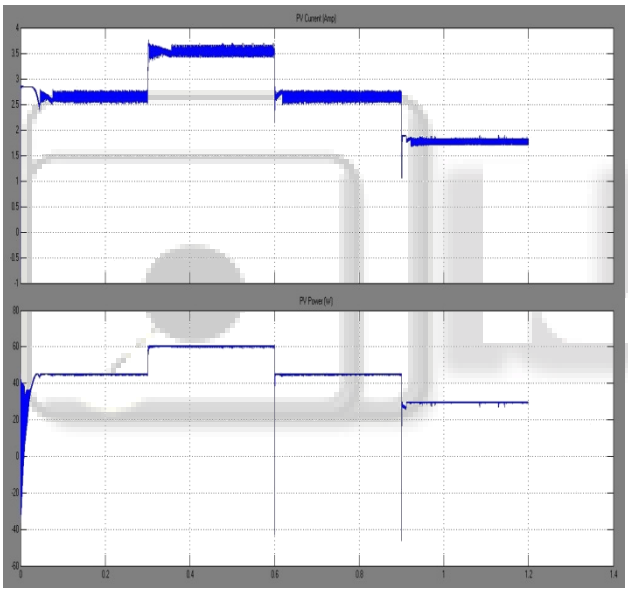

Fig. 13: Current and Power for P&O method.

C. Simulation Result of IC under varying irradiance

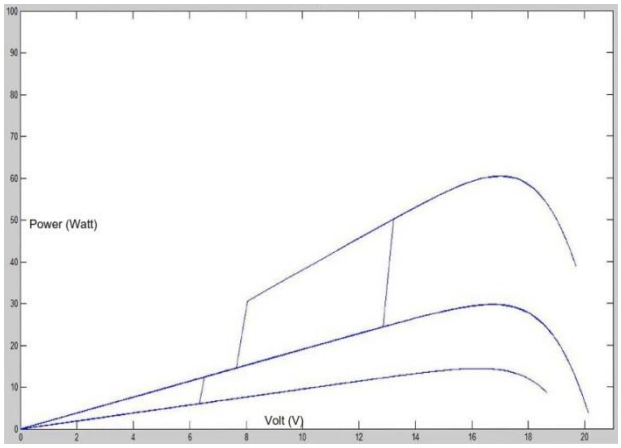

Fig. 14: P-V characteristic for IC method.

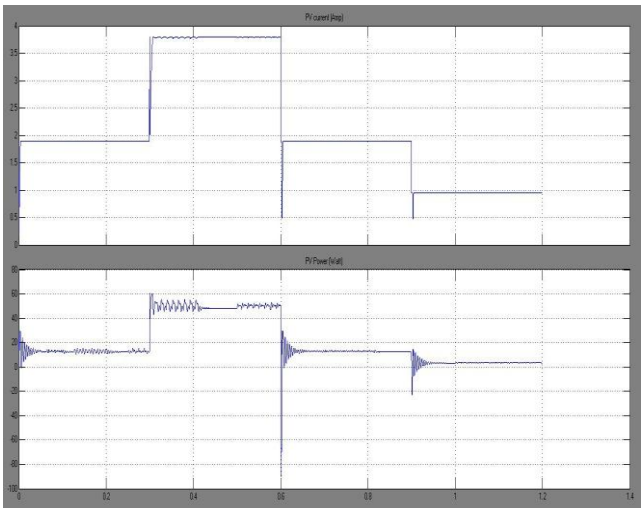

Fig. 15: Current and Power for IC method.

VI. CONCLUSION

By studying and comparing these two methods, IC method is better for rapid changing atmospheric condition than P&O. It responds fast too. Its efficiency is also higher. But real time implication is difficult and also the higher cost. P&O method is less efficient. But it is easy to implement in real time and also cost effective. If the changing in atmospheric condition is not fast and the solar panel is not sufficient large than the P&O method is better option.

By simulation under varying condition, from comparing P-V characteristic, IC method gives fast response than P&O method. But for general selection is based on accuracy and fast acting. It is better to accurate than fast because fast method tend to bounce around the MPP. So, accurate and fast method would be preferred but the cost of implementation needs to be considered.

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