

A Review of Maximum Power Point Tracking: Design and Implementation

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Abstract: Photovoltaic Energy is the most important Energy Resource since it is clean pollution free and inexhaustible. In recent years a large number of techniques have been proposed for tracking the Maximum Power Point. PV array has non-linear I-V characteristic and output power depends on environmental conditions such as solar irradiation and temperature. There is a point on I-V, P-V characteristic curve of PV array called as Maximum Power Point (MPP), where the PV system produces its maximum output power. Location of MPP changes with change in environmental condition. The purpose of MPPT is to adjust the solar operating voltage close to MPP under changing environmental conditions. In order to continuously gather the maximum power from the PV array, they have to operate at their MPPT despite of the inhomogeneous change in environmental conditions. The two most commonly algorithms for PV applications as they are easy to Implement are Beta method Incremental Conductance (Inc. Con.).Beta algorithm is a type of MPPT algorithm. It is having fast tracking ability. The algorithm has been verified on a photovoltaic system, A review of various MPPT algorithms is proposed with more focus on above two algorithms.

Keywords: Photovoltaic cell, Maximum Power Point Tracking (MPPT), Algorithms.

1. INTRODUCTION

The growing energy demand coupled with the possibility of reduced supply of conventional fuels, along with growing concerns about environmental conservation has driven research and development of alternative energy sources that are cleaner, renewable, and produce little environmental impact. Among the alternative sources, the electrical energy from solar energy is currently regarded as a natural energy source that is more useful since it is free, abundant, clean, and distributed over the earth and participates as a primary factor of all other processes of energy production on earth. One of the greatest concerns is due to the skyrocketing growth of fossil fuels prices. Another factor is the carbon emission due to conventional energy sources lead to global warming. Renewable energy sources like solar and wind energy are best options available of to achieve all the above objectives .Solar energy is an abundant source, which is free of cost and available to all. Two methods are there to extract the solar energy 1) Solar thermal plants 2) Solar cells i.e. photovoltaic cells. photovoltaic cell (Solar PV) is one of the most promising future energy technologies options. The direct conversion of solar radiation to electricity by PV cells has a number of significant advantages as an electricity generator but some significant challenges to be overcome to make use of Solar energy like energy cost, energy fluctuation, location dependence, huge investment requirements.[1]

The equivalent circuit of a PV cell is shown in Figure..1 An ideal solar cell is modeled by a current source and a diode in parallel with it. However no solar cell is ideal there by series resistance which has a very small value. Rsh is the equivalent shunt resistance whose value is very high.[2]

Applying Kirchoff's current law to the junction where I_{ph}, diode, Rsh and R_s meet, we get,

$$I_{ph} = I_d + I_{Rp} + I$$

$$I = I_{ph} - (I_d + I_{Rp})$$

We get the following equation for the PV cell current

$$I = I_{ph} - (I_0 [e^{(V+IR_s)/VT} - 1] + V + IR_s/R_p)$$

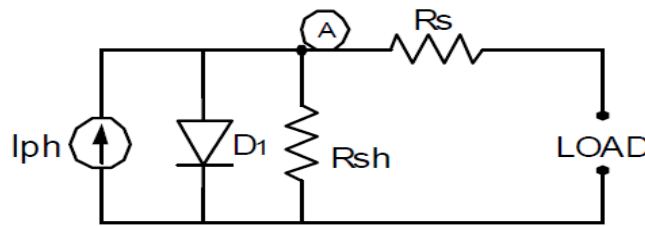


Figure.1.PV CELL EQUIVALENT CIRCUIT

2. MAXIMUM POWER POINT TRACKING ALGORITHMS

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Among all the algorithms Beta Method and Inc Con algorithms are most common as they have the advantage of an easy implementation. As MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Over the past decades many methods to find the MPP have been developed .when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others.there are many MPPT techniques whicr are used to extract the maximum power from solar PV system.[3]

1. Curve Fitting Method
2. Open Circuit Voltage Method
3. Short Circuit Method
4. Perturb & Observe Method
5. Incremental Conductance Method
6. Beta Method

Curve Fitting Method:

The curve-fitting method is an offline method where PV module characteristics, all Data and manufacturing details are required, mathematical model and equations Describing the output characteristics is pre-decided. PV module characteristic is given by eq. (1), where a, b, c and d are coefficients determined by sampling values of PV voltage VPV, PV current IPV and output power PPV Once these Coefficients are calculated, the voltage at which power becomes maximum is obtained by eq. (2).

$$PPV = a VPV^3 + b VPV^2 + c VPV + d \quad (1)$$

At maximum power point, $dPPV/dVPV = 0$

$$VMPP = -b \pm \sqrt{b^2 - 3ac} / 3a \quad (2)$$

The advantage of this method is its simplicity. Disadvantage is that it requires large memory as number of calculation is more speed is less[4]

Open Circuit Voltage Method:

The open circuit voltage algorithm is the simplest MPPT control method .this technique is also known as constant voltage method .Voc is the open circuit voltage of the PV panel .Voc depends on the property of the solar cells.A commonly used Vmpp/Voc value is 76% .this relationship can be described by equation 3.

$$V_{mpp} = k_1 * V_{oc} \quad (3)$$

Here the factor K_1 is always less than unity. It looks very simple but determining best value of K is very difficult and K_1 varies from 0.71 to 0.8. The common value used is 0.76. Hence this algorithm is also called as 76% algorithm. The operating point of the PV array is kept near the MPP by regulating the array voltage and matching it to a fixed reference voltage. The reference voltage value is set equal to the V_{mpp} of the characteristic PV module or to another calculation. [5]

Short Circuit Method:

This method is similar to Open-Circuit Voltage method, in this current in MPP (I_{MPP}) is linearly proportional to Short-Circuit current (ISC) given by eq. (5). The value of K_2 is considered to be around 0.85.

$$I_{mpp} = K_2 \cdot I_{sc} \quad (4)$$

The way of determining K_2 is more complicated than any of fixed value. The advantages and disadvantages are similar to that of Open-Circuit Voltage method. [4]

Perturb And Observe Method:

In this algorithm a slight perturbation is introduced into the system. This perturbation causes the power of the solar module to change. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation also it fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple. [6]

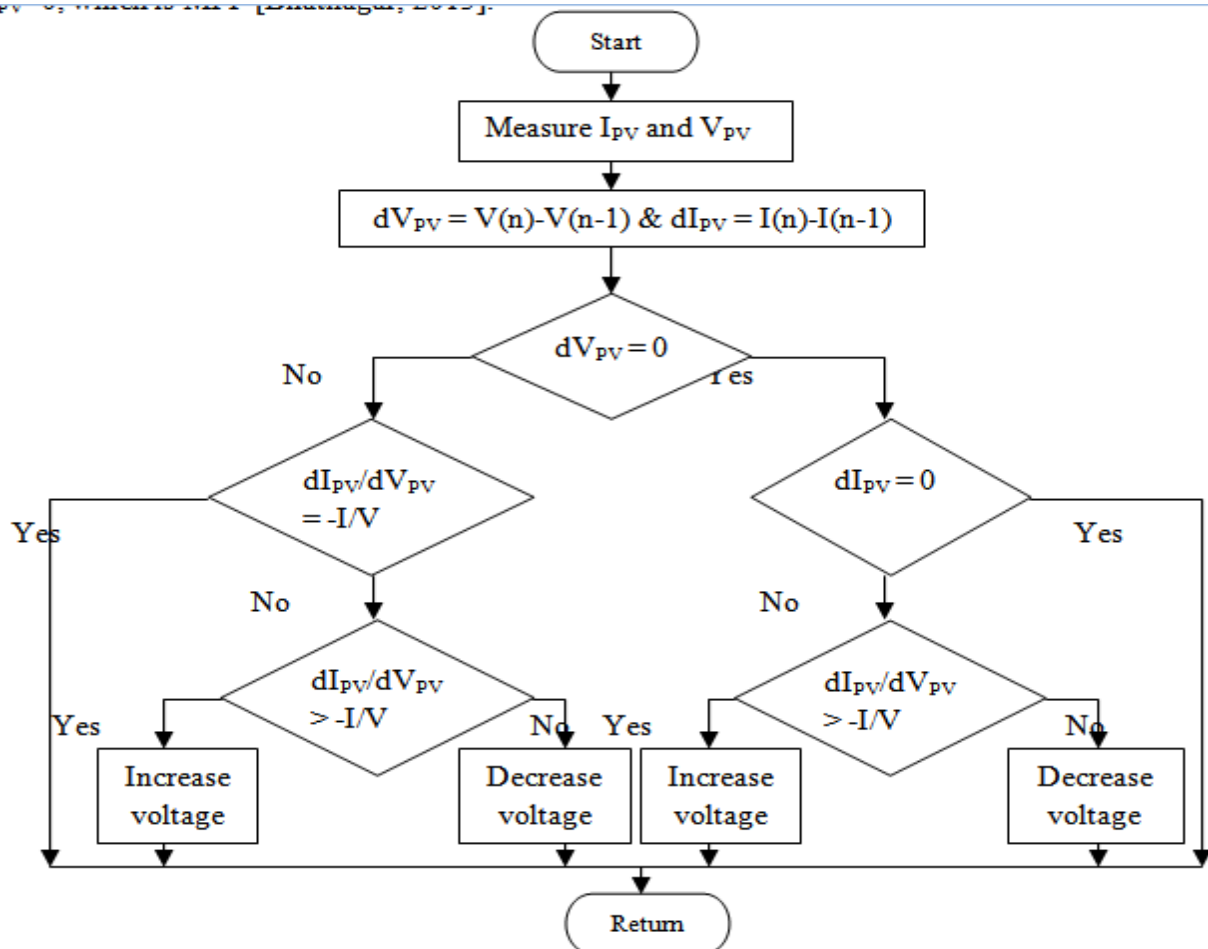


Figure 2. Flow Chart of Perturb & Observe Algorithm

If $dP/dV > 0$ then operating point is moving towards MPP and if $dP/dV < 0$ then operating point is moving away from MPP. The advantages of this algorithm, as stated before, are simplicity and ease of implementation. However, P&O has limitations that reduce its MPPT efficiency. One such limitation is that as the amount of sunlight decreases another limitation of P&O is that it oscillates around the MPP, as this method becomes unstable with rapid change in atmospheric conditions such as irradiance and temperature. [4]

Incremental Conductance Method:

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. 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 $-I/V$. 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. Also, 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. The Incremental Conductance method is based on the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by[7]

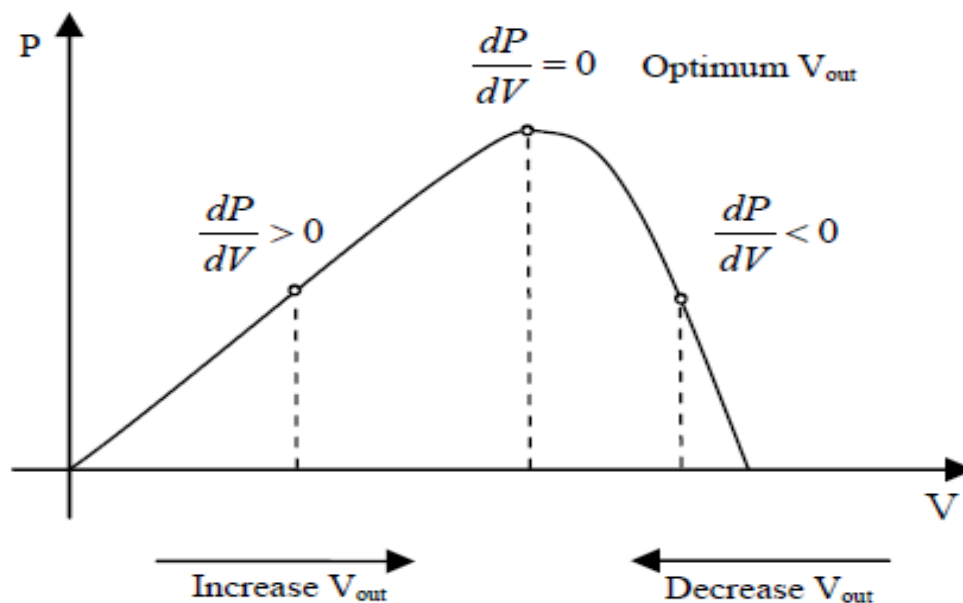


Figure:3 -Incremental Conductance power slope

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V \frac{dI}{dV} \approx I + V \frac{\Delta I}{\Delta V} \dots \dots \dots (5)$$

Eqn. (5) can be written as

$$\begin{cases} \Delta I/\Delta V = -I/V, & \text{at MPP} \\ \Delta I/\Delta V > -I/V, & \text{left of MPP} \\ \Delta I/\Delta V < -I/V, & \text{right of MPP.} \end{cases}$$

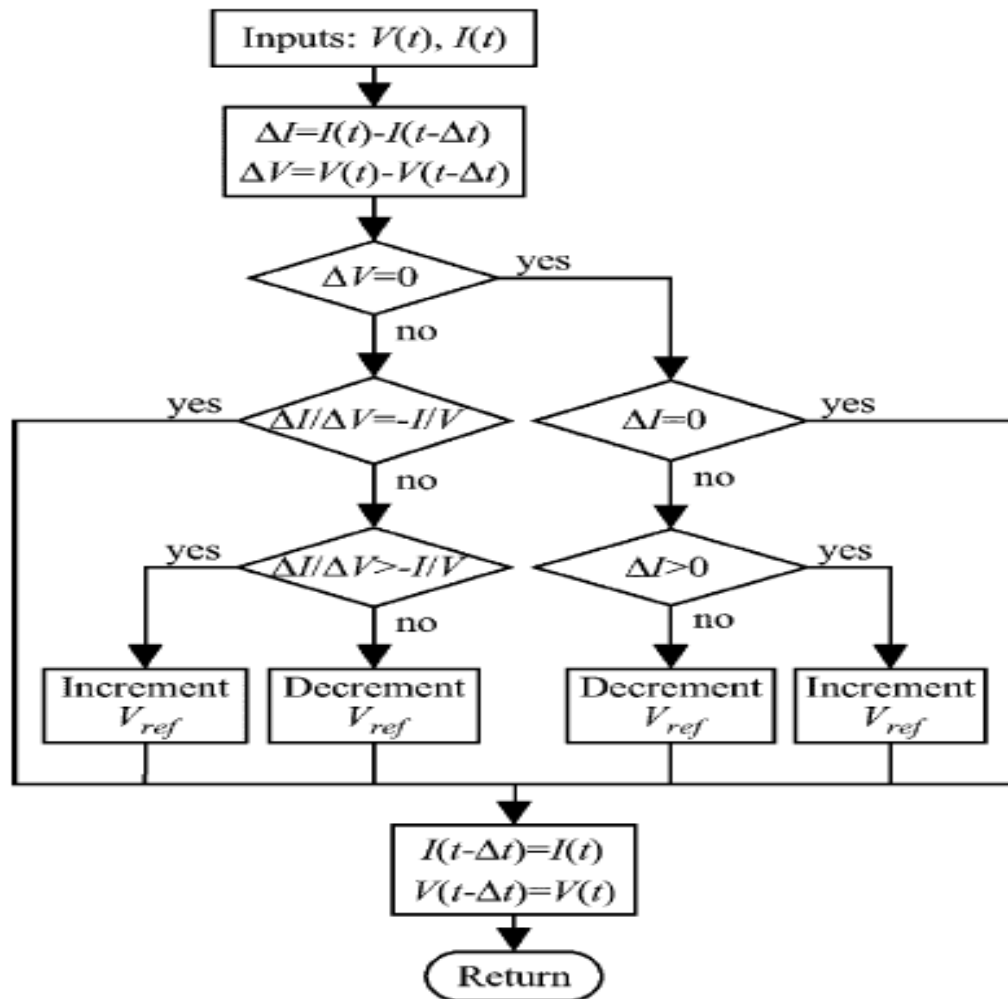


Figure.4. Flowchart of the IC Algorithm

Beta Method:

In Incremental Conductance Method duty cycle is fixed, due to that efficiency is reduced. In order to overcome drawbacks of INC method, beta method is used. Duty cycle is calculated based on the intensity of sunlight. MPP Beta is a variable used to find the intermediate value between current and voltage. Beta is calculated by using the following equation.

$$\ln(I_{pv}/V_{pv}) - C \cdot V_{pv} = \ln(I_0 \cdot C) = \beta \quad (6)$$

Where I_{pv} denotes panel output current, V_{pv} denotes panel output voltage. C denotes conductance, is calculated by using $C = q / (\eta K T N_s)$

$$(7)$$

Where q denotes the electron charge (charge carried out by single electron or photon $1.602176565 \times 10^{-19}$ coulombs), η denotes the quality factor of the junction panel, K denotes the Boltzmann constant ($1.380648813 \times 10^{-23}$ J/K), T represent the temperature, and N_s represent number of cells in series. It may be noted that β is independent of insolation but depends on temperature [8] The initial step of the algorithm is to reading the output voltage (V_{pv}) and current (I_{pv}) measured from Photovoltaic panel. After getting the value V_{pv} and I_{pv} the β value is calculated. Check β value is in steady state or not. If β is in the steady state, then β is checked whether it is within range of steady state or not. if β in that range then it is switched to Hill climbing or other methods. After that same process repeated again from the initial state. If the β is not in steady state, it starts processing from initial steps. If the β is not in the steady state range and then error value is calculated. β_g , the value of β corresponding to the most probable array temperature is used as the guiding value.

The steady state value is calculated by a fixed temperature, the difference in the magnitude value of β at maximum power point lies smaller, from that β Min and β Max ranges are fixed. Smaller changes irradiation level made changes in wide range. β Max is taken from maximum irradiation in maximum temperature. β Min is taken in minimum irradiation and in minimum temperature. Both values β Min and β Max calculated at maximum power point. Error values are calculated from the difference between β_g and β_a . From that new duty is calculated, by summing the old duty cycle with the product of error and Boltzmann constant.

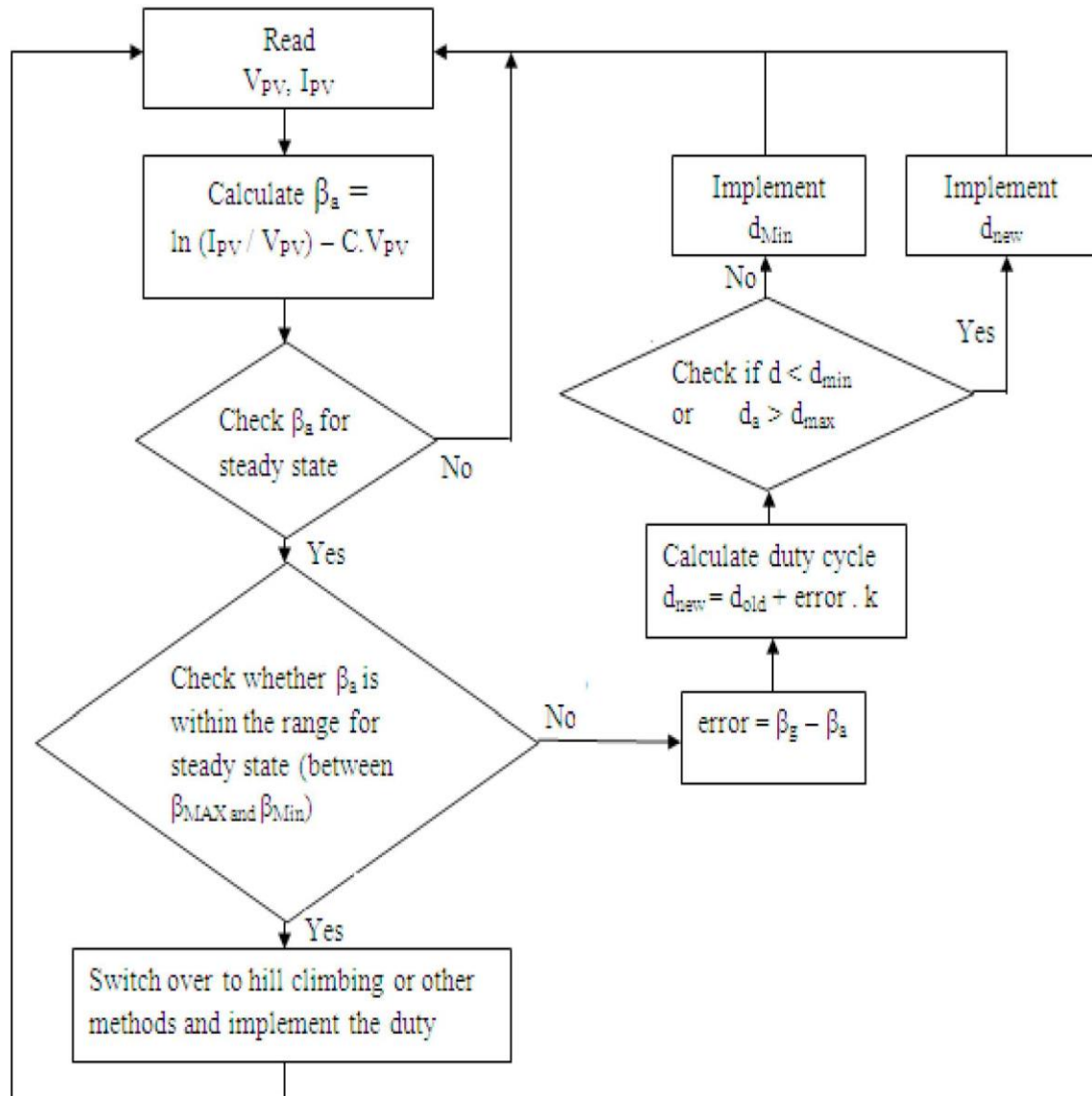


Figure.5. Flowchart of the Beta Algorithm

3. CONCLUSION

In this paper, the various MPPT algorithms has been reviewed. As has been demonstrated, there are many ways of distinguishing and grouping the methods for tracking the MPP to the PV generator. Finally, it has been shown that other methods also exist by which MPP of PV module can be tracked. PV.The MPPT technique for a specific application is decided by these imperative constraints. For example, P&O and IC are widely used where low cost is imperative factor. This assessment of MPPT system helps in choosing particular MPPT technique for specific application and also for further research in the area of MPPT.

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