Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 2,Issue 11, November -2015

A Study on Maximum Power Point Tracking Algorithms for Photovoltaic Systems

Pushpak Patel[1], Nayan Patel[2]

[1]*Assistant Professor, LDRP-ITR, Gandhinagar*
[2]*M. E. scholar, LDRP-ITR, Gandhinagar*

Abstracts : *The purpose of this paper is to study different maximum power point tracking (MPPT) algorithms in a photovoltaic system. The power delivered by a PV system of one or more photovoltaic cells is dependent on the irradiance, temperature, and the current drawn from the cells. The maximum power point tracking (MPPT) is a process which tracks one maximum power point from array input, varying the ratio between the voltage and current delivered to get the most power it can. A number of algorithms have been developed for extracting maximum power. Such applications as putting power on the grid, charging batteries, or powering an electric motor benefit from MPPT.*

I. INTRODUCTION

Recently, countries around the world pay attention to seeking a variety of renewable and clean alternative energy. Solar energy has attracted all the countries for the advantages such as clean, carbon-free and inexhaustible. It is suggested that solar power generation has a very broad prospect of development. Stand-alone photovoltaic (PV) system is one of the most important applications in solar power generation, and has high practical value in the areas which is uncovered by power grid, such as remote area, desert and border outpost. However, the power of PV cell is greatly influenced by light intensity and temperature.

In this world 80 % of the green houses gases are released due to the usage of fossil fuel based. The world primary energy demand will have increased almost 60% between 2002 and 2030, averaging 1.7% increase annually, increasing still further the Green House Gases. Oil reserves would have been exhausted by 2040, natural gas by 2060, and coal by 2300. This cause issues of high per KW installation cost but low efficiency in PV generators. Currently, more research works has been focussed on how to extract more power effectively from the PV cells. There are two ways such as solar tracking system and Maximum Power Point Tracking (MPPT). In the literature survey show that there will be an increasing percentage of 30-40 % of energy will be extracted compared to the PV system without solar tracking system. The Maximum Power Point Tracking (MPPT) is usually used as online control strategy to track the maximum output power operating point of the Photovoltaic generation (PVG) for different operating condition of insolation and temperature of the PVG. It clearly shows that when we use MPPT with the PV system, the power extraction efficiency is increase to 97%. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm.

An overview of Maximum Power Point Tracking

In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. MPPT algorithms are necessary because PV arrays have a non linear voltage-current characteristic with a unique point where the power produced is maximum. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore, irradiation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained. The overall block diagram of PV panel with Dc-Dc converter and MPPT is shown in this figure 1:

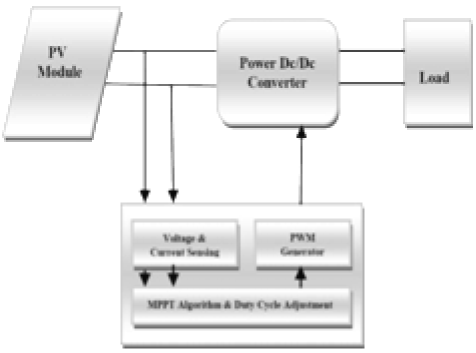

Figure 1

DC-DC converters are used for extracting the maximum power of the solar cell or module. Converter uses the fact that by varying the duty ratio D, Rin i.e. input impedance of converter can be changed. Rin is equal to Rpv i.e. impedance of the solar PV module. Also by using principle of "IMPEDANCE MATCHING" when Rin becomes equal to RL i.e. Load resistance, maximum power will be transferred from panel.

MPPT mechanism makes use of an algorithm. Many techniques have been developed for the maximum power point techniques. These techniques use the principle of impedance matching between load and PV-module. The impedance matching is done with the help of DC to DC-Converter.

The power from solar module is calculated by measuring the voltage and current. This sensed voltage and current is given to MPPT algorithm which adjusts the duty cycle of switch, resulting in the adjustment of the reflected load impedance according to power output of the PV module. Input resistance of the converter reflected across the array is equal to PV array resistance. Hence by varying the duty ratio of the converter impedance matching can be done.

$$Rin = Rpv = Vpv/Ipv$$

Here,
Rin = Resistance of the Converter reflected Across the PV array.
Rpv = Resistance of the PV array
Vpv, Ipv = PV array output voltage and current.

Different techniques of MPPT

A lot of MPPT algorithms have been developed by researchers and industry delegates all over the world. There are many methods used for maximum power point tracking a few are listed below:

- Constant voltage method
- Perturb and Observe
- Incremental Conductance method
- Fractional short circuit current
- Fractional open circuit voltage
- Fuzzy logic method
- Maximum Voltage and current method
- DC link capacitor droop control method
- Current sweep method
- Ripple correlation control method
- Neural network and so on.

- *Constant voltage method*

The constant voltage method is the simplest method. This method simply uses single voltage to represent the VMP. In some cases this value is programmed by an external resistor connected to a current source pin of the control IC. In this case, this resistor can be part of a network that includes a NTC thermistor so the value can be temperature compensated. Reference 1 gives this method an overall rating of about 80%. This means that for the various different irradiance variations, the method will collect about 80% of the available maximum power. The actual performance will be determined by the average level of irradiance. In the cases of low levels of irradiance the results can be better.

- *Perturb and Observe*

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP.

If the operating voltage of the PV array is perturbed in a given direction and $dP/dV > 0$, it is known that the perturbation moved the array's operating point toward the MPP.

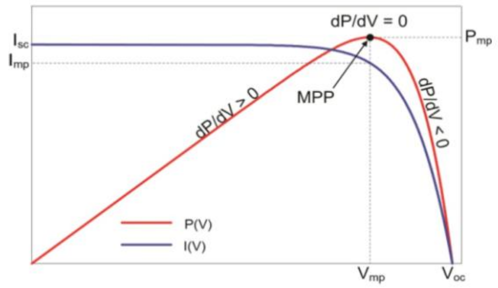

Figure 2

The P&O algorithm would then continue to perturb the PV array voltage in the same direction. If dP/dV < 0, then the change in operating point moved the PV array away from the MPP, and the P&O algorithm reverses the direction of the perturbation. The flowchart for the P&O algorithm is shown in Figure 3:

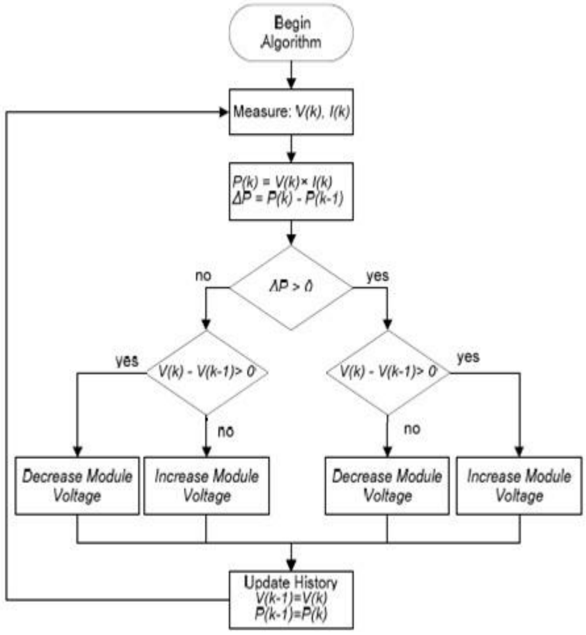

Figure 3

- The main advantage of the P&O method is that it is easy to implement, it has low computational demand, and it is very generic, i.e. applicable for most systems, as it does not require any information about the PV array, but only the measured voltage and current.
- The main problem of the P&O is the oscillations around the MPP in steady state conditions and poor tracking (possibly in the wrong direction, away from MPP) under rapidly-changing irradiations.

➢ *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.

$$dP/dV = d(VI)/d(V) = I + V*dI/dV$$

$I/V > dI/dV$	for $dP/dV > 0$	*Left of MPP*
$I/V < dI/dV$	for $dP/dV < 0$	*Right of MPP*
$I/V = -dI/dV$	for $dP/dV = 0$	*At the MPP*

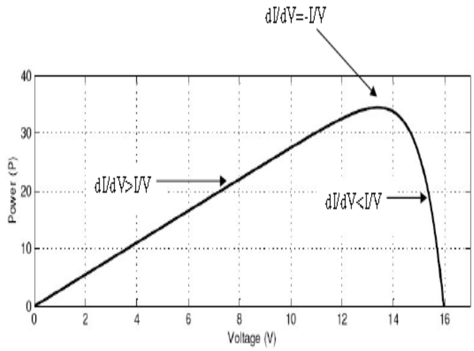

Figure 4

If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/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 flowchart for the IC method algorithm is shown in Figure 5:

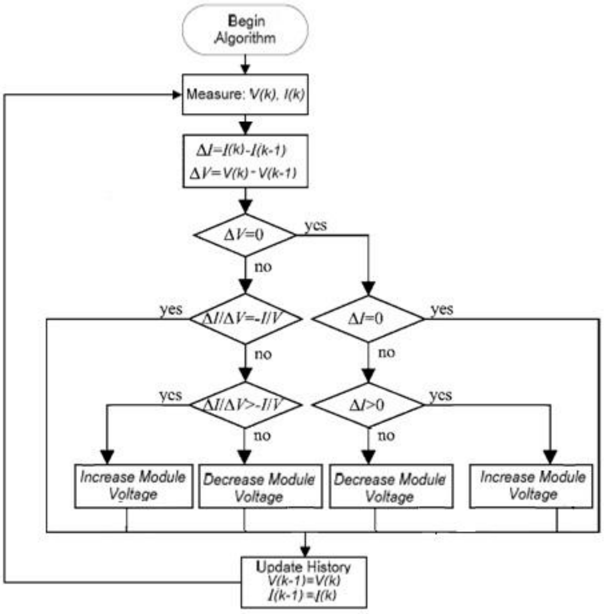

Figure 5

➢ *Fractional open circuit voltage*

The near linear relationship between VMPP and VOC of the PV array, under varying irradiance and temperature levels, has given rise to the fractional VOC method.

$V\text{MPP} = k1*Voc$

Where, k1 is a constant of proportionality. Since k1 is dependent on the characteristics of the PV array being used, it usually has to be computed beforehand by empirically determining VMPP and VOC for the specific PV array at different irradiance and temperature levels. The factor k1 has been reported to be between 0.71 and 0.78. Once k1 is known, VMPP can be computed with VOC measured periodically by momentarily shutting down the power converter. However, this incurs some disadvantages, including temporary loss of power.

➢ *Fractional short circuit current*

Fractional ISC results from the fact that, under varying atmospheric conditions, IMPP is approximately linearly related to the ISC of the PV array.

$I\text{MPP} = k2*Isc$

Where, k2 is a proportionality constant. Just like in the fractional VOC technique, k2 has to be determined according to the PV array in use. The constant k2 is generally found to be between 0.78 and 0.92. Measuring ISC during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that ISC can be measured using a current sensor.

- *Fuzzy logic control method*

Microcontrollers have made using fuzzy logic control popular for MPPT over the last decade. As mentioned in, fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. Fuzzy logic control generally consists of three stages: fuzzification, rule base table lookup, and defuzzification. During fuzzification, numerical input variables are converted into linguistic variables based on a membership function. The inputs to a MPPT fuzzy logic controller are usually an error E and a change in error ΔE. The user has the flexibility of choosing how to compute E and ΔE. Since dP/dV vanishes at the MPP

$$E(n) = \frac{P(n) - P(n-1)}{V(n) - V(n-1)}$$
$$\Delta E(n) = E(n) - E(n-1)$$

Once E and ΔE are calculated and converted to the linguistic variables, the fuzzy logic controller output, which is typically a change in duty ratio ΔD of the power converter. The linguistic variables assigned to ΔD for the different combinations of E and ΔE are based on the power converter being used and also on the knowledge of the user. The flowchart for the IC method algorithm is shown in Figure 6:

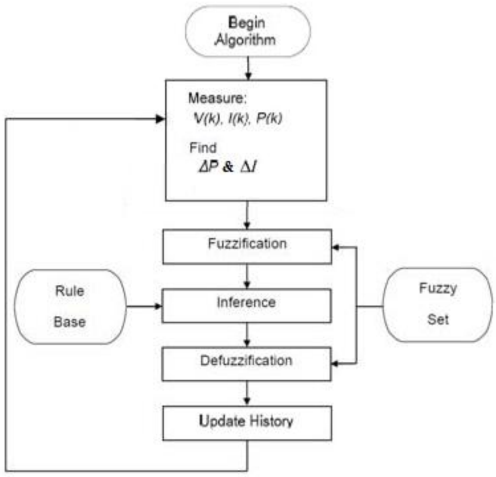

Figure 6

In the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to a numerical variable still using a membership function. This provides an analog signal that will control the power converter to the MPP. MPPT fuzzy logic controllers have been shown to perform well under varying atmospheric conditions. However, their effectiveness depends a lot on the knowledge of the user or control engineer in choosing the right error computation and coming up with the rule base table (Table 1).

The five linguistic variables used are: NB (Negative Big), NS (Negative Small), ZE (Zero Approximately), PS (Positive Small), PB (Positive Big). The fuzzy inference is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the duty cycle:

$$d\alpha = \frac{\sum_{j=1}^{n} d(\alpha_j) - d\alpha_j}{\sum_{j=1}^{n} \mu(d\alpha_j)}$$

ΔE / E	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

Table 1

These two variables and the control action α for the tracking of the maximum power point are illustrated in figure 7.

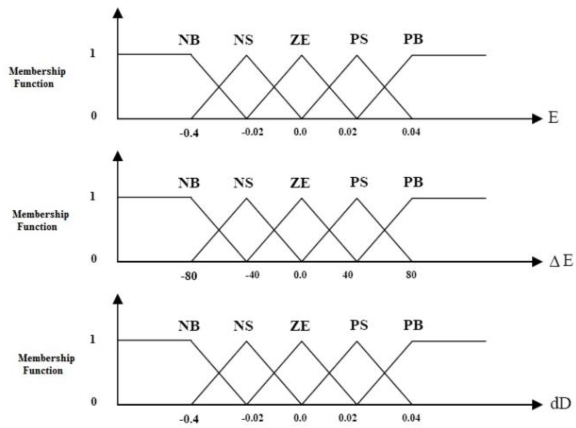

Figure 7

➢ *Neural Network*

Along with fuzzy logic controllers came another technique of implementing MPPT neural networks, which are also well adapted for microcontrollers. Neural networks commonly have three layers: input, hidden, and output layers as shown in figure. The numbers of nodes in each layer varies and are user-dependent. The input variables can be PV array parameters like *VOC* and *ISC*, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP.

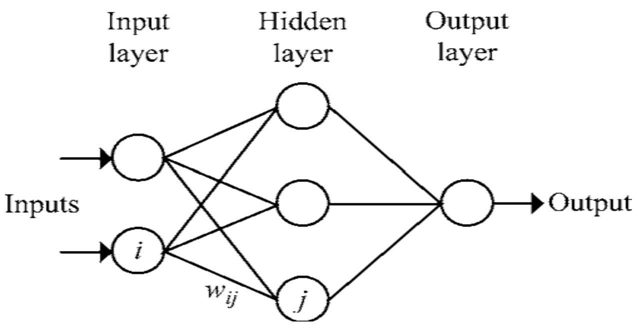

Figure 8

How close the operating point gets to the MPP depends on the algorithms used by the hidden layer and how well the neural network has been trained. The links between the nodes are all weighted. The link between nodes *i* and *j* is labelled as having a weight of *wij in* figure. To accurately identify the MPP, the *wij's* have to be carefully determined through a training process, whereby the PV array is tested over months or years and the patterns between the input(s) and output(s) of the neural network are recorded. Since most PV arrays have different characteristics, a neural network has to be specifically trained for the PV array with which it will be used. The characteristics of a PV array also change with time, implying that the neural network has to be periodically trained to guarantee accurate MPPT.

➢ *Ripple correlation control*

When a PV array is connected to a power converter, the switching action of the power converter imposes voltage and current ripple on the PV array. As a consequence, the PV array power is also subject to ripple. Ripple correlation control (RCC) makes use of ripple to perform MPPT. RCC correlates the time derivative of the time-varying PV array power $p^{\cdot}$ with the time derivative of the time-varying PV array current $^{\cdot}i$ or voltage $v^{\cdot}$ to drive the power gradient to zero, thus reaching the MPP.

Referring to PV curve, if v or i is increasing ($v^{\cdot} > 0$ or $i^{\cdot} > 0$) and p is increasing ($^{\cdot}p > 0$), then the operating point is below the MPP ($V < VMPP$ or $I < IMPP$). On the other hand, if v or i is increasing and p is decreasing ($p^{\cdot} < 0$), then the operating point is above the MPP ($V > VMPP$ or $I > IMPP$). Combining these observations, we see that $^{\cdot}\ p\ ^{\cdot}\ v$ or $^{\cdot}\ p^{\cdot}i$ are positive to the left of the MPP, negative to right of the MPP, and zero at the MPP. When the power converter is a boost converter as in increasing the duty ratio increases the inductor current, which is the same as the PV array current, but decreases the PV array voltage. Therefore, the duty ratio control input is

$$d(t) = -k_3 \int \dot{p}\dot{v}\, dt$$

$$d(t) = k_3 \int \dot{p}\dot{i}\, dt$$

Where, $k3$ is a positive constant. Controlling the duty ratio in this fashion assures that the MPP will be continuously tracked, making RCC a true MPP tracker.

II. CONCLUSION

The purpose of this paper is to study and compare advantages, shortcomings and execution efficiency for different type MPPT methods, including perturbation & observation, incremental conductance and fuzzy logic control method etc. P&O algorithm is advance of hill climbing algorithm has a well regulated PV output voltage. P&O algorithm possesses faster dynamic response than hill climbing algorithm. Besides, the tracking elapsed time of the incremental conductance method is longer than the other two methods owing to its complicated judgment procedure in every perturbing period. The incremental conductance method has advantages of exact perturbing and tracking direction and steady maximum power operating voltage. However, the other two methods have the possibility of misjudgement for determining the perturbing and tracking direction. Therefore, the incremental conductance method is more competitive than the other two methods in the PV system which uses hardware technology to implement the MPPT algorithms. Fuzzy logic control method has advantages of faster and smart dynamic response than P&O and incremental conductance method. The different results with different robustness test confirms the proper fonctionnement of fuzzy controller with good performance in the atmospheric variations of illumination and temperature thereby reducing power losses, with better dynamics than conventional numerical methods. The following fuzzy controller with satisfaction at the sharp variations of temperature and illumination and a fast response time and less than that of conventional algorithms (P & O and INC). This eliminates the fluctuations in the power, voltage and duty ratio in steady state. The controllers by fuzzy logic can provide an order more effective than the traditional controllers for the nonlinear systems, because there is more flexibility. A fast and steady fuzzy logic MPPT controller was obtained. It makes it possible indeed to find the point of maximum power in a shorter time runs. There is also other method like Maximum Voltage and current method, DC link capacitor droop control method, nueral networks method and Current sweep method, have their own advantages and disadvantages.

REFERENCES

[1] Resource and Energy Economics - C Withagen - 1994 – Elsevier
[2] Energy comparison of MPPT techniques for PV Systems, Roberto Faranda, Sonia Leva
[3] Semana Científica - L Pedroni - 2004 - Google Books
[4] "Development Of a Micro-controller Based, Photovoltaic Maximum Power Point Tracking Control System", Eftichios Kourtoulis, Kostas Kalaitzakis, IEEE Transactions on Power Elctronics, VOL. 16, No. 1, January 2001.
[5] "A Modified Adaptive Hill Climbing MPPT Method for Photovoltaic Power Systems", Weidong Xiao, William G. Dunford, 35th Annual IEEE Power Electronics Specialisrs Conference, pp. 1957-1963, June 2004.
[6] "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques", Trishan Esram, Patrick L. Chapman, IEEE Transaction on Energy Conservation, VOL. 22, NO. 2, June 2007.
[7] "A Study on Maximum Power Point Tracking Algorithms for Photovoltaic Systems", Ting-Chung Yu, Yu-Cheng Lin, December 2010.
[8] "Comprehensive Approach to Modelling and Simulation of Photovoltaic Arrays" Marcelo Gradella Villalva, Jonas Rafael Gazoli, and Ruppert Filho IEEE Transaction on Power Electronics,VOL.,24, NO. 5, MAY 2009
[9] "Maximum power point tracking using adaptive fuzzy logic control for grid-connected photovoltaic system", N. Patcharaprakitia, in IEEE Power Eng. SocietyWinter Meeting,2002, pp. 372-377.

[10] "Design, Simulation and Implementation of A Fuzzy-Based MPP Tracker under Variable Insolation and Temperature Conditions", M. A. S. Masoum, M. Sarvi, Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 29, No. B1, Shiraz University 2005.

[11] "Fuzzy Logic Control for the tracking of maximum power point of a PV system", F.Bouchafaa, I.Hamzaoui, A.Hadjammar, Laboratory of Instrumentation,University of Sciences and Technology Houari Boumediene, Algeria.

