IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 3, May 2014.
www.ijiset.com
ISSN 2348 - 7968

A Comprehensive Review of Maximum Power Point Tracking (MPPT) System

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***Abstract*- Maximum power point tracking (MPPT) for optimizing the output in solar photovoltaic (PV) system is an integral to maximize power output under variable isolations (input solar radiations). Methods used for achieving MPPT have evolved over the time and used functionally under various climatic conditions. Some of the constraints like accuracy, ease of implementation, cost and tracking time adjoin to advantages and disadvantages of the particular methodology. This paper presents an assessment among the common methods along with the comparison. The review aims at providing help in further research, in the direction of maximum power point tracking of solar PV.**

1. INTRODUCTION

The growing energy demand coupled with the possibility of reduced supply of conventional fuels, evidenced by petroleum crisis 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.

The overall socio economic growth results in escalating energy demand as conventional sources of energy is not sufficient to fulfill present energy need. 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 [1].

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. Among wide variety of renewable energy projects in progress, 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. The efficiency enhancement is a big issue in reducing cost of PV system since maintenance requirement is very low in PV systems the only real cost savings to be made is in reducing capital cost of installation[2].

Fig.1 shows the IV characteristic and power versus voltage curve of a solar PV system; from the fig.1 it is clear the only one point is there at which solar PV gives maximum power. For extracting the maximum power from the cell the operating voltage or current should be corresponding to the maximum power point (P_{max}) i.e. V_m and I_m respectively under a given temperature and solar radiation[3],[4].

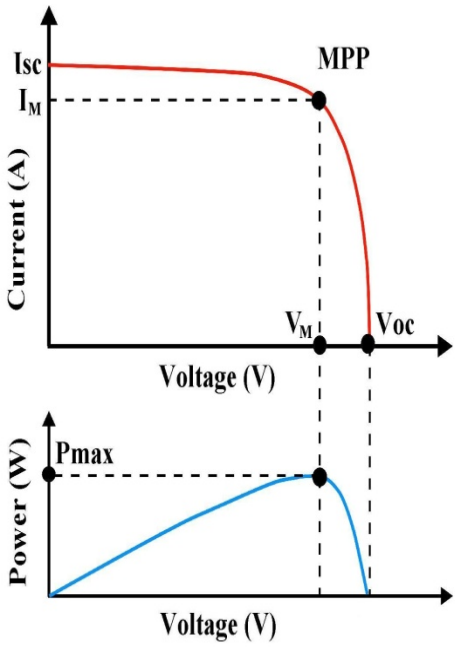

Fig1. Solar PV characteristic [1],[5].

Since solar radiation, falling on the solar PV module varies with time operating point or maximum power point (MPP) also changes. The phenomenon of tracking the maximum power point is same as impedance matching by tap changing transformer in case of AC. Here DC to DC converter can be used for this purpose where resistance can be matched by changing duty ratio.

Fig. Maximum power point for different time [1],[5].

In Fig2 three operating time consider, as an example i.e. mid-day, 2 pm and 4 pm. With change in time solar radiation also changes. Solar PV in this example with a load resistive type gives three characteristic with different time also the maximum power points would be change. Maximum power point tracking is all about solar PV module to run at the maximum power point. The electronic circuitry used to track the maximum power point is known as maximum power point tracker. There are methods are there to track the maximum power point. In this paper some commonly used methods are discussed [5][6][7][8].

2. EXISTING MPPT SYSTEM

Many system of finding MPP have been reported in literature. Few among them are discussed here.

2.1 Constant voltage [9][1]

Constant voltage method is based on observation that is maximum power point occurs between 72-78% of the open circuit voltage Voc for the standard atmospheric condition. The solar PV module is always operated at this constant voltage. The duty ratio of the DC-to-DC convertor ensures that the PV voltage is equal to:

Where K = 0.72 to 0.78

2.2 Constant current

Constant current method based on the same phenomenon of the constant voltage method. The maximum power point arrives between 78-92% of the short circuit current I_{sc} [10].

$$I_M = K \times I_{sc} \quad (2)$$

Where K = 0.78 to 0.92

2.3 Perturb and observe (P&O) or Hill climbing

Perturb and observe (P&O) method is basically iterative approach in this method the operating point of solar PV oscillates around the maximum power point. In figure 1 the power versus voltage curve of solar PV shows that, change in power with respect to voltage (dP/dV) is positive, negative and zero for region before maximum power point, after maximum power point and at maximum power point respectively.

This method is applied by perturbing the duty cycle at regular interval. And oscillate around the point dP/dV=0 i.e. MPP [10]

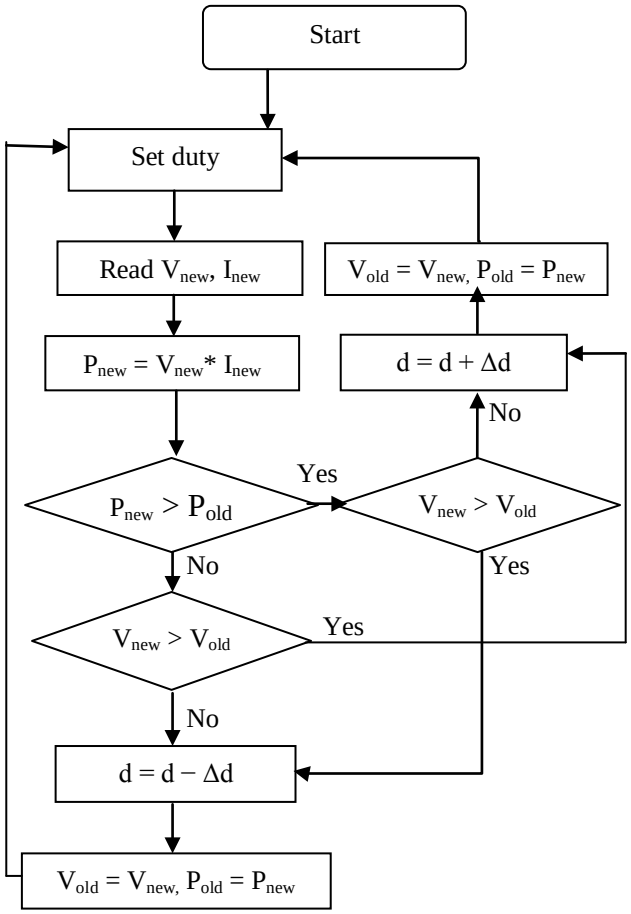

Fig 3. Flowchart of P and O method [1]

TABLE I
METHODOLOGY OF P&O METHOD [10]

Perturbation	Change in power	Next perturbation
Positive	Positive	Positive (increment in duty cycle 'd')
Positive	Negative	Negative (decrease in duty cycle 'd')
Negative	Positive	Negative (decrease in duty cycle 'd')
Negative	Negative	Positive (increment in duty cycle 'd')

2.4 Incremental conductance (IC)

Power

$$P = V \times I \quad (3)$$

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \quad (4)$$

At true MPPT

$$\frac{dP}{dV} = 0 \quad (5)$$

$$I + V\frac{dI}{dV} = 0 \quad (6)$$

ISSN 2348 - 7968

$$\frac{dI}{dV} = -\frac{I}{V}$$

Where dI/dV : Incremental conductance
I/V : Instantaneous conductance

Before MPP

$$\frac{dP}{dV} > 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} > 0 \qquad (7)$$

After MPP

$$\frac{dP}{dV} < 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} < 0 \qquad (8)$$

At MPP

$$\frac{dP}{dV} = 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} = 0 \qquad (9)$$

In this method MPP can be found by comparing instantaneous conductance to the incremental conductance by changing the duty ratio (d) [12][13]

2.5 System oscillation

This method is based on the principle of maximum power transfer and based on comparing the ac component (due to the variation of the duty cycle) and the average value of the input voltage of the Power Conversion Stage to determine the duty cycle. At MPP the ratio of oscillation amplitude and average voltage is constant [14][15].

2.5.1 Advantages and disadvantages of the method

A) Easy to implement
B) Only voltage needs to be measure

2.6 Ripple correlation control (RCC)

This method takes advantage of the signal ripple, which is automatically present in power converters. The ripple is analyzed as a perturbation that can realize gradient ascent optimization [14],[15].

2.7 Temperature method

In this method, temperature of solar PV measured. Variation in MPP with respect to the temperature is obtained in similar way of constant voltage method. [14][15]

2.8 Beta method

In this method a constant called beta (β) is given, the value of β is given by the formula

$$\beta = ln\frac{Ipv}{Vpv} - \left(\frac{q}{k \times T \times \eta}\right) \times Vpv \qquad (10)$$

Where 'k' is Boltzmann's constant, 'η' is diode quality factor, 'T' is ambient temperature in Kelvin and 'q' is electric charge.

It is clear from above equation β is independent from the solar radiation but depends on the temperature. In this method the solar PV operates near to this value β[14][15].

2.9 Some methods are also available which uses the optimization system such as *fuzzy logic control, Neural Network, Particle Swarm Optimization (PSO*) which gives excellent results.[16][17][18]

SUMMARY TABLE 1.

S.No.	MPPT Method	Merits	Demerits
1	Constant voltage method	Simple, Easy to implement, fast	Not highly accurate, V_{oc} needs to measured at regular interval, Only used where temperature varies very little.
2	Constant current method	Simple , Easy to implement, fast	Less accurate, I_{sc} needs to be measured at regular interval.
3	P&O method	Easy to implement, Iterative approach, Solar characteristic not required to be known earlier	Less accurate operating point oscillate around MPP, Not suitable for fast changing condition, Oscillation can be minimized by reducing perturbation step size, which slow down MPPT.
4	RCC method	Easy to implement, simple circuitry	Voltage and current both required to be measured.
5	Temperature method	Easy to implement, simple circuitry	Voltage and Temperature both required to be measured
6	Beta method	Tracking speed is high	Applicable for changing solar radiation but temperature should be constant.

3. CONCLUSION

Various system to obtain Maximum Power Point in solar PV have been discussed in this paper. Majority of the times some constraints are associated with MPPT system like cost, ease of implement, tracking time, accuracy etc. Among these only one or two of them are

more imperative for different application of solar 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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