

ANALYSIS AND COMPARISON OF MAXIMUM POWER POINT TRACKING ALGORITHMS FOR PV SYSTEMS

BRAHMAN SINGH BHALAVI

Assistant Professor, SEES, DAVV, INDORE, INDIA

ABSTRACT

The maximum power point Tracker (MPPTs), for the solar panels plays an important role because it provides the maximum output from the PV system, for a given set of conditions of their electric power systems, and therefore maximizes the efficiency of the panel, which thereby helps in minimizing the total system cost. Presently a number of MPPT algorithms are available for maintain operation at the maximum power point, however, every algorithm has their own advantages and limitations which causes the different behavior when used in commercial solar power MPPTs. This paper is intended to publish effective comparison amongst the different algorithms and represent an optimized solution on the basis of requirement specific criteria. The results from this work can be utilized to find the best MPPT system depending upon specific requirements and resources availability.

Keywords: Maximum Power Point Tracking (MPPT), Solar Panel, Photovoltaic Systems (PV).

1. INTRODUCTION

Under uniform illumination, PV array has a constant current voltage (IV) characteristic on which there is a unique point on the IV curve known as the maximum power point (MPP). The array can be operated in the highest efficiency to produce a maximum output power. When the PV array is connected to the load (the so-called "directly coupled" systems) it may direct the PV panel to different operation points. In general, depending on the operating point it is difficult to achieve the MPP. To overcome this problem, MPPT converter are used to track maximum power point, and maintain the operating point of the PV array at the MPP.

If properly controlled by the algorithm, MPPT can locate and track the MPP in PV array. However, the location of the MPP in the $I - V$ plane is not known in advance, hence it should be located, or by means of model calculations or through a search algorithm. Furthermore the situation is again complicated by the fact that MPP depends nonlinearly on the light and temperature, as shown in figure 1(a) under increasing radiation at a constant temperature, and Figure 1 (b) shows the $I - V$ curves under the same values of the light, but at a higher temperature. This paper presents a variety of ways for discussion of each algorithm. In this paper minor modifications of different existing methods are avoided and discussed under main method.

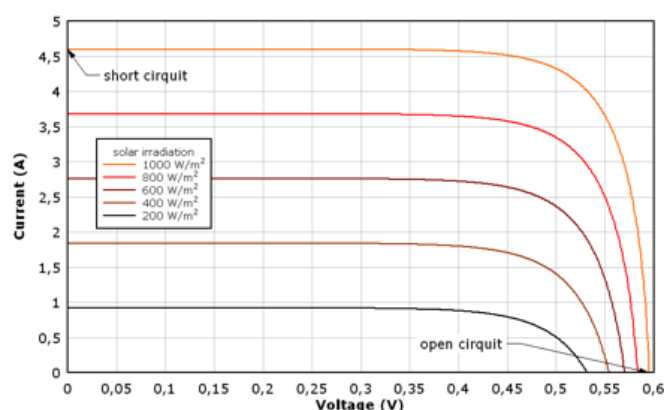


Figure 1(a): Solar cell I-V characteristics for different irradiation values.

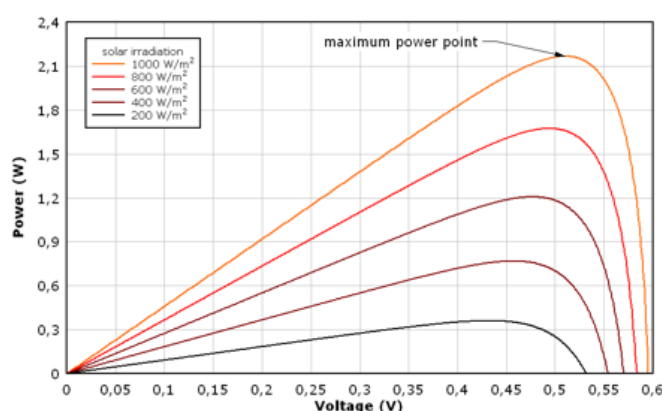


Figure 1(b): Solar cell power characteristics for different irradiation values.

Manuscript concludes with a discussion on different ways depending on their implementation, the necessary sensors, their ability to detect many local Maxima, their costs, and they suit applications. A summary of the key features of different methods are also provided.

2. MPPT ALGORITHMS

As explained earlier, the MPPT algorithm is required in order to get the most power from solar panels. The MPPT algorithms are used to track the MPP of a solar panel which largely depends on the radiation and temperature. Over the last decade, many methods are developed and published to find the MPP with reliability. These methods differ in many aspects, such as the necessary sensors, complexity, cost, range, rate of convergence, effectiveness of tracking under the dynamic radiation and temperature variations. Presently P&O (Perturb and Observe) and In-Cond (Incremental Conductance) algorithms are the most commonly used for MPPT. These methods have the advantage of a simple implementation, but they also have disadvantages, as will be shown later. Other methods based on different principles fuzzy logic control, neural networks, open circuit voltage and the fraction of short circuit current, the current sweep, etc. most of these methods give a local maximum, and some, such as fractional open circuit or short circuit current, give approximate and multiple MPP's which is helpful specifically for partially shaded PV ARRAY's, where several MPP's can exist. In the next section, some of the most popular MPPT techniques are discussed.

2.1 HILL-CLIMBING TECHNIQUE

P & O and In-Cond algorithms are based on the principle of the "Hill climb", which consists of moving the operation of PV in the direction in which the power increases. Hill climbing techniques are the most popular methods of MPPT, thanks to their ease of implementation and good performance, for constant irradiation. The advantages of both methods are simplicity and low computational complexity. Also they have well known disadvantages such as vibrations around MPP and completely fails to track the MPP during a rapidly changing operational conditions.

2.2 PERTURB AND OBSERVE (P&O)

The P&O algorithm is also known as "hill-climbing", hence both names refer to the same algorithm concept the only difference is how it is implemented. The Hill-climbing method involves a perturbation on the duty cycle of the DC to DC converter and P&O a perturbation in the operating voltage of the DC connection between the PV array and the DC to DC converter. In the case of the Hill-climbing, perturbation in the duty cycle of the power converter is performed to change the voltage of the DC link between the PV array and the DC to DC converter, hence both refers to the same concept.

Finally the technique utilizes previous growth disturbances to decide what should be the next disturbance depending upon the change in power. If there is an increase in power, procedure must be followed in same direction otherwise it must be moved in the opposite direction and this process is repeated until it reaches the MPP. However in practice it never stabilized on a MPP instead it fluctuates around MPP.

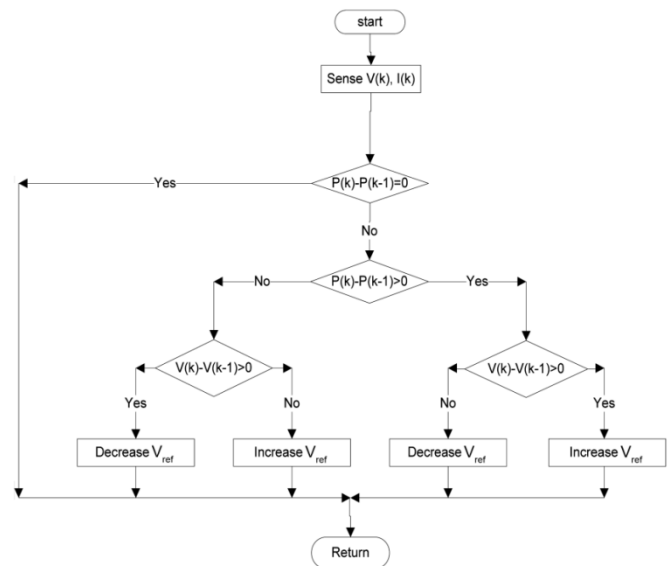


Figure 2: Perturb and Observe (P&O) Algorithm Flow Chart

2.3 INCREMENTAL CONDUCTANCE

Incremental conductance algorithm utilizes the characteristic curve between power and voltage (current) of PV panel which shows the zero slope at MPP and positive or negative on to the other respective sides.

$$\Delta V / \Delta P = 0 \quad (\Delta I / \Delta P = 0) \text{ at the MPP}$$

$$\Delta V / \Delta P > 0 \quad (\Delta I / \Delta P < 0) \text{ on the left}$$

$$\Delta V / \Delta P < 0 \quad (\Delta I / \Delta P > 0) \text{ on the right}$$

Comparing the change in increment of voltage against output (current) between two consecutive measurements of the PV panel the required voltage change for MPP can be determined.

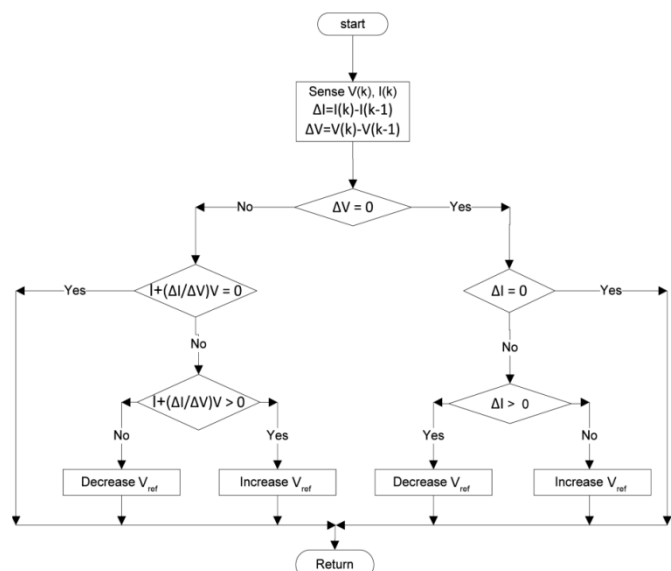


Figure 3: Incremental Conductance Algorithm Flow Chart

In both P&O and In-Cond schemes the time to achieve MPP depends on the size of the MPP increment the reference voltage. Besides providing quicker convergence these algorithms has to main limitations. The first and most important of them, that they can easily lose track of the MPP if the radiation changes quickly, although in case

ofstep changes they track MPP very well, because of the instantaneous change which does not require continuous changing of the curve. However, when environmental conditions modifies the curve, on which the algorithms are based on; then changes in voltage and current do not only because of the perturbation of voltage. As a result, it is not possible for algorithms to determine whether changes in the PV panel power is due to voltage perturbation or due to a change in exposure.

Another obstacle is both voltage and current fluctuates around MPP in the steady state. This is due to the fact that control is discrete and voltage and current do not constantly remains at MPP, but oscillates around it. The magnitude of the oscillations depends on the rate of change of the reference voltage. The bigger it is, the higher the amplitude fluctuations. However the frequency of oscillation is inversely proportional to the step size of the increment of voltage. The traditional solution is a tradeoff between oscillations and tracking time as if the increment is small so that the oscillations decrease, then the MPP is reached slowly and vice versa, so a compromise solution has to be found. Thus, the last three MPPT methods are based on the same principles, P&O and In-Cond algorithms, so they have the same advantages and disadvantages. All Climbing Hill MPPT methods of Photovoltaic array depend on V-P or P features that depends on the temperature and radiation, so these methods MPPT can be confused when radiation or temperature changes. Finally, other methods of Hill climb MPPT does not offer any improvement in the original algorithms P & O and In-Cond.

2.4 FUZZY LOGIC CONTROL

The use of fuzzy logic control has gaining popularity over the traditional control systems because it can deal with complex systems without an accurate mathematical model and can also handle the nonlinearity. Recent growth in digital electronics such as microprocessors and microcontrollers also helped in popularizing fuzzy the control logic.

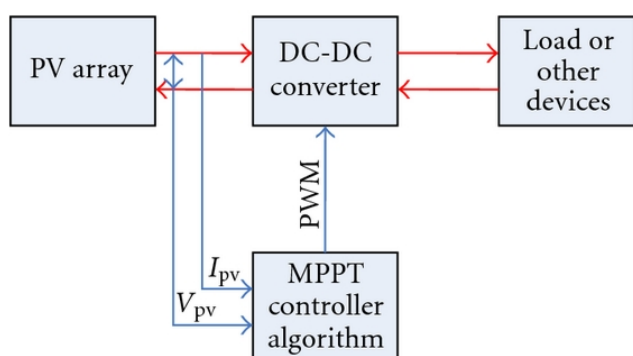


Figure 3: Fuzzy Logic Controlled MPPT Block Diagram

In Basic structure the Fuzzy logic controller can be divided into three phases: fuzzy-fication, inference systems and de-fuzzy-fication.

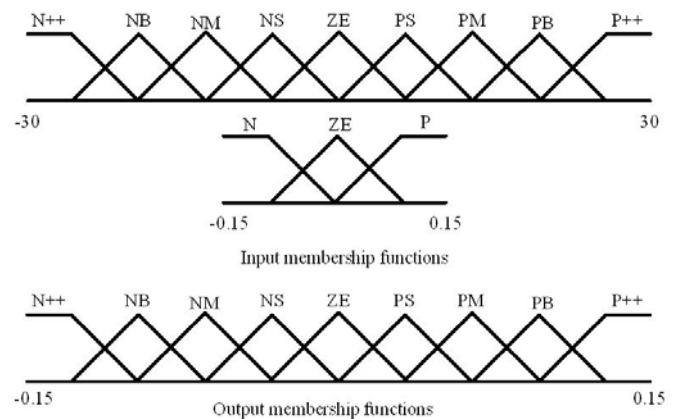


Figure 4: fuzzy-fication and de-fuzzy-fication membership functions.

Fuzzy-fication process extracts linguistic variables based on degree of membership for certain sets from input numeric values. Membership functions, are used to associate a class membership or relation for each the linguistic notion. The number of membership functions required is depends on the accuracy of the controller.

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Figure 5: fuzzy inference system rule base.

The inference systems is simple a lookup table of rules which used to estimate the output from each linguistic variables combinations (AND or OR). Finally the output of inference systems for all derived linguistic variables combinations of numeric inputs are combined using de-fuzzy-fication to produce required control output.

2.5 NEURAL NETWORKS

Neural networks came along with Fuzzy Logic and both are the part of Soft Computing techniques. However the neural network is completely different from fuzzy logic. The neural network or more accurately artificial neural network is a mathematical model of bio-neurons designed to gain the information from given set of training data samples. The tracking accuracy of such systems depend upon number of neurons and layers of neurons and quality of training data set.

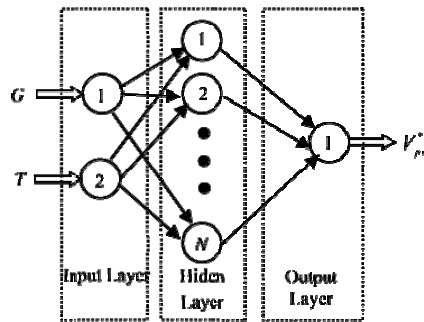


Figure 6: Simple 3-Layer Neural Network Structure.

The main complexity in this system is the training data needed for the process has to be specifically acquired for every PV array and for every operating conditions which is difficult because the characteristics of a panel may also change with time, so the neural network required periodical re-training.

3. MAXIMUM POWER POINT TRACKING SUMMARY AND CONCLUSION

The vast majority of the MPPT algorithms created over the previous years have been reviewed in the previous sections. Some of them are extremely comparable and use the same fundamental concept however applied or implemented in distinctive ways.

This study shows an examination of the maximum power point tracking efficiencies of a few MPPT control algorithms that are examined in previous sections and the extent of the study was restricted to those algorithms. The results propose that, on the premise of maximum power point tracking effectiveness, the perturb-and-observe strategy, is the most generally utilized algorithm as a part of business converters, can possibly be most competitive with all other strategies considering that it is legitimately streamlined for the given equipment. Incremental conductance performs similar to P&O, yet because its higher execution cost would not be advocated even if it provide a bit better performance. The Fuzzy logic controller based method could provide much better results but requires microcontrollers, finally the neural network based technique could be used to achieve best performance instantaneously however for that it requires complete characteristics information of the panel which is not practically feasible also the change in characteristics due to panel aging can also affect its performance.

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