A survey on various MPPT methods for Solar Photo Voltaic

Pavan Pathak, Dr. Amita Mahor

***Abstract*— Maximum power point trackers (MPPTs) play an important role in the photovoltaic (PV) power system to maximize the overall efficiency of the system for available operating conditions. Hence lots of researchers have dev loped different Maximum Power Point tracking algorithms and shown superior results. In this paper authors have studied the various aspects of maximum power point tracked solar photo voltaic system using Hill climbing, Incremental conductance. Look up method and Particle Swarm Optimization (PSO) based method. The exhaustive review clearly shows that modified hill climbing methods give superior results in comparison to conventional hill climbing method.**

***Index Terms*—** PV, Hill Climbing, MPPT, PSO.

INTRODUCTION

Maximum Power Point Tracking of a photovoltaic array is an essential part of a Photo Voltaic system. Renewable sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Also, solar energy is the most readily available source of energy and it is free. The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions.
Solar energy has offered promising results in the quest of finding the solution to the problem. A great deal of research has been done to improve the efficiency of the Photo Voltaic modules. A number of methods of how to track the maximum power point of a Photo Voltaic module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for. The Maximum Power Point Tracking is used for extracting the maximum power from the solar PV module and transferring that power to the load. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

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MAXIMUM POWER POINT TRACKING METHODS

Maximum Power Point Tracking algorithms are necessary in Photo Voltaic applications because the Maximum Power Point of a solar panel varies with the irradiation and temperature. Use of Maximum Power Point Tracking algorithms is required in order to obtain the maximum power from a Solar Photo Voltaic Array. Over the last decades many methods have been developed and published to find the Maximum Power Point. These methods differ in many factors such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and or temperature change, hardware needed for the implementation or popularity, among others.
Among various methods, the Perturb & Observe methods are the most common. These techniques have the advantage of an easy implementation, although they also have drawbacks. Other methods are based on different principles like fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc. Almost these methods yield a local maximum and some, like the fractional open circuit voltage or short circuit current, give an approximated MPP, not the exact one. In normal conditions the V-P curve has only one maximum, so it is not a problem. However, if the PV array is partially shaded, there are multiple maxima in these curves.

a) Hill-Climbing technique

P&O algorithms are based on the “hill-climbing” principle, which consists of moving the operation point of the PV array in the direction in which power increases. Hill-climbing techniques are the most popular MPPT methods due to their ease of implementation and good performance when the irradiation is constant. The advantages of both methods are the simplicity and low computational power they need. The shortcomings are also well-known: oscillations around the MPP and they can get lost and track the MPP in the wrong direction during rapidly changing atmospheric conditions. In Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of the DC link between the PV array and the power converter

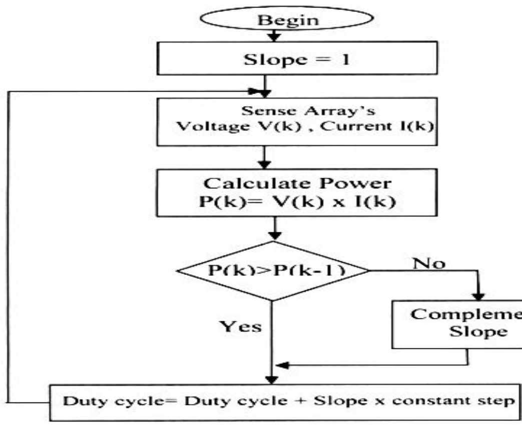

Fig 1: Flow chart of Hill Climbing Method

b) Incremental Conductance Algorithm

The disadvantage of the Perturb & Observe algorithm when tracking the peak power under fast varying atmospheric condition is overcome by the Incremental Conductance algorithm. The Incremental Conductance (IncCond) method is based on the fact that the slope dP/dv of the PV panel power-voltage curve is positive on the left side of the MPP, zero at the MPP and negative on the right side of the MPP as shown in Fig.2.

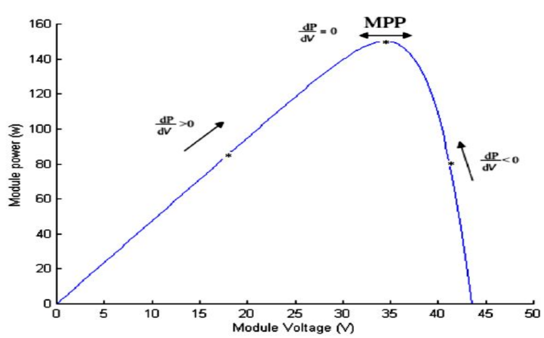

Fig.2: Plot of power vs. voltage for PV module

c) Voltage Control MPPT Method

It is considered that a maximum power point of a particular solar PV module lies near about 0.75 times the open circuit voltage of the module. So by measuring the open circuit voltage a reference voltage can be generated and feed forward voltage control method can be implemented to bring the solar pv module voltage to the point of maximum power. One major problem of this method is the open circuit voltage of the module varies with the temperature. So as the temperature is increased the module open circuit voltage changes and we have to determine the open circuit voltage of the module very often. Hence the load must be cut off from the module to measure open circuit voltage. Because of which the power during that instant will not be utilize.

d) Current Control MPPT Method

The maximum power of the module exists at the point which is at about 0.9 times the short circuit current of the module. In order to measure this point the module or array is kept short-circuited. And then by using the current control technique the module current is adjusted to the value which is approx 0.9 times the short circuit current. The problem with this method is that a high power resistor is needed which can stain the short-circuit current. The module has to be short circuited to determine the short circuit current as it goes on varying with the changes in insolation level.

e) Parasitic Capacitance Method

The parasitic capacitance method is a refinement of the incremental conductance method that takes into account the parasitic capacitances of the solar cells in the PV array. Parasitic capacitance uses the switching ripple of the MPPT to perturb the array. To account for the parasitic capacitance, the average ripple in the array power and voltage, generated by the switching frequency, are measured using a series of filters and multipliers and then used to calculate the array conductance. The incremental conductance algorithm is then used to determine the direction to move the operating point of the MPPT. One disadvantage of this algorithm is that the parasitic capacitance in each module is very small, and will only come into play in large PV arrays where several module strings are connected in parallel. Also, the DC-DC converter has a sizable input capacitor used filter out small ripple in the array power. This capacitor may mask the overall effects of the parasitic capacitance of the PV array.

f) Look Up Method

Photovoltaic voltage and current posses a non linear relationship and continuous identification of the optimal operating power point is needed. PV array is able to deliver maximum available power that is also necessary to maximize the photovoltaic energy utilization if the operating points are in the vicinity of MPP. So considerably for this most important point a search function is used. This search function continuously reads in the values of photovoltaic voltage and current and then compares it with the values stored in the memory. It then outputs the optimum power point values for the specific irradiance and temperature condition. Further it makes the system more immune to spikes and fast temporary instabilities. As the initial simulation result validates it's much smoother response then basic Hill Climbing method explained above.

RELATED WORK

A maximum power point tracking algorithm is absolutely necessary to increase the efficiency of the solar panel. It has been found that only 30-40% of energy incident is converted into Electrical energy so it is very important to track Maximum power points. Over the last one decade many researchers have worked on MPPT, still it is an open research area. Work done by some of the researchers is listed below.

Kashif Ishaque et al.[1] have proposed an improved maximum power point tracking approach for the photovoltaic system using a modified particle swarm optimization algorithm. Advantage of the method is the reduction of the steady state oscillation once the maximum power point is located. Also, the proposed method has the ability to track the MPP for the extreme environmental conditions. The algorithm is simple and can be computed very fast. MATLAB simulations are carried out under very challenging conditions, namely step changes in irradiance, step changes in load, and partial shading of the PV array to evaluate the performance of the proposed method. Its performance is compared with the conventional Hill Climbing method. Experimental results show the superiority of their method over the HC in terms of tracking speed and steady-state oscillations. In their work, a PSO with the capability of direct duty cycle is used to track the MPP of a PV system. It is shown that the proposed MPPT controller exhibits an adaptive form of the HC method. The results indicate that the proposed controller outperforms the HC and gives a number of advantages like faster tracking speed and zero oscillations at the MPP. It could locate the MPP for any environmental variations including partial shading condition and large fluctuations of insolation and algorithm can be easily developed using a low-cost microcontrollers.

Miyatake, M et al. [2] presented multiple photovoltaic modules form of power distribution used in solar PV systems. Normally in such systems individual maximum power point tracking schemes for each of the PV modules increases the cost. Proposed algorithm solved this difficulty of multiple maxima because of partial shading by introducing a particle swarm optimization technique. The proposed algorithm uses only one pair of sensors to control multiple PV arrays, thereby resulting in lower cost, higher overall efficiency, and simplicity with respect to its implementation. Experimental results validate of the proposed algorithm. Further, a detailed performance comparison with conventional fixed voltage, hill climbing, and Fibonacci search MPPT schemes are presented in their work.

Kuei-Hsiang Chao et. al.[3] investigated the output characteristics of photovoltaic module arrays with partial module shading. They have presented a maximum power point tracking method that can efficiently track the global optimum of multiple peak curves. Proposed method was based on particle swarm optimization. The concept of linear decreases in weighting was added to improve the tracking performance of the maximum power point tracker. Simulation results verified that proposed method can successfully track maximum power points in the output characteristic curves of photovoltaic modules with multiple peak values. Experimental results also show that the performance of the modified PSO-based MPPT method is superior as compare to conventional PSO methods. The primary feature of proposed method is the linear decreases used to adjust weighting, in contrast to the fixed weights adopted by conventional PSO.

Malathy S. and Ramaprabha R.[4] proposed lookup table based model for solar photovoltaic module. Insolation level and temperature greatly influenced the performance of a solar PV module. The experimental data including voltage and current of the PV module are obtained for various insolation conditions. These data are then used to develop a lookup table to mimic the behavior of the actual PV module. To ensure that the maximum power is transferred from the PV module to the load, maximum power point tracking (MPPT) algorithm is usually employed. A LUT based MPPT method is presented to track the optimal operating point whenever the insolation changes. The V-I and V-P characteristics obtained from the look up table based Simulink model and the conventional model are compared. Experimental data validates the V-P and V-I characteristics obtained by this method. Proposed method responded quicker to the environmental changes than the conventional model due to less computational complexities. Also the time taken for simulation is lesser than the conventional model especially when interfaced with the power conditioning systems. This work can be extended to study the impact of partial shading conditions in different types of configurations.

Moacyr A. G. de Brito, et. al.[5] presented a comparisons among the most usual MPPT with respect to the amount of energy extracted from the photovoltaic panel, PV voltage ripple, dynamic response and use of sensors. In presented work models are first implemented via Mat Simulink, and after a digitally controlled boost DC-DC converter was implemented and connected to an Agilent Solar Array simulator in order to verify the simulation results. Beta was presented as an excellent solution regarding the best tracking factor, reduced and smaller ripple voltage in

steady state, good transient performance and simplicity of implementation, resulting in the best overall performance among the techniques. Also Ripple Correlation, modified IC and P&O, also deserve mention as an alternative for good PV performance.
Trishan et.al.[6] discussed many different techniques for maximum power point tracking of photovoltaic arrays. The techniques are taken from the literature dating back to the earliest methods. Various methods have been introduced in the literature, with many variations on implementation. Presented review can serve as a convenient reference for future work in PV power generation. This manuscript steps through a wide variety of methods with a brief discussion and categorization of each. The review concludes with a discussion on the different methods based on their implementation, the sensors required their ability to detect multiple local maxima, their costs, and applications they suit. Author presented a comparative table that summarizes the major characteristics of the methods is also provided which can be useful guide in choosing the right MPPT method for specific PV systems.

Mohamed Azab [7] proposed a new maximum power point tracking algorithm for photo voltaic arrays. This algorithm detects the maximum power point of the Photo Voltaic. The computed maximum power is used as a reference value of the control system. ON or OFF power controller with hysteresis band is used to control the operation of a Buck chopper such that the Photo Voltaic module always operates at its maximum power computed from the MPPT algorithm. The proposed MPPT has several advantages like simplicity, high convergence speed. The proposed MPPT method requires only measurements of PV voltage and current with the need to any environmental measurements. The method is considered as a modified P&O method. The proposed method attempts to track and compute the maximum power and controls directly the extracted power from the PV to that computed value, while all the other methods attempt to reach the maximum point by the knowledge of the voltage or the current corresponding to that optimum point. The proposed method offers different advantages like good tracking efficiency, relatively high convergence speed and well control for the extracted power thanks to the direct power control unit based on the ON or OFF hysteresis controller.
Amine Daoud et.al.[8] proposed new techniques of maximum power point (MPP) tracking for solar water pumping system. The latter system consists of a PV array, a DC/DC buck converter and a universal motor coupled to a centrifugal pump. Experimental results are presented and a comparison with conventional algorithm which requires both voltage and current sensors is provided. This paper presented a MPP Traker for solar PV water pumping system using single sensor techniques. Solar energy is captured by a PV array and delivered into a motor-pump through a DC/DC buck converter which performs the function of tracking the MPP. The system is controlled by a RISC microcontroller based on an analog tachometer or a pressure sensor to draw the maximum available power that the PV array can generate under all operating conditions. It has shown that the speed control based MPP tracking method offers better performance than the conventional or the pressure control method.
Tarak Salmi et.al.[9] presented a SIMULINK model of a photovoltaic cell. This model is based on mathematical equations and is described through an equivalent circuit including a photocurrent source, a diode, a series resistor and a shunt resistor. The presented model allows the prediction of PV cell behaviour under different physical and environmental parameters. It can also be used to extract the physical parameters for a given solar PV cell as a function of temperature and solar radiation. In order to validate the developed model, an experimental test bench was built and the obtained results exhibited a good agreement with the simulation ones. A SIMULINK model for the solar PV cell, modules and array was presented in this paper. The module model was simulated and validated experimentally using the high efficient PVL-124 solar laminate panel. We can benefit from this model as a photovoltaic generator in the framework of the Sim-Power-System SIMULINK toolbox in the field of solar PV power conversion systems.

CONCLUSION

Mostly researchers did their research work on P & O algorithm to achieve maximum power point tracking using MATLAB/SIMULINK environment. Using different MPPT techniques modeling and the simulation of PV system in Matlab/Simulink environment has been done. With the help of this survey the design and modeling of PV system and MPPT using LOOK UP method and PSO based method is achieved.
The most popular MPPT algorithms according to available literature are Hill Climbing, In Cond and Fuzzy Logic. However lookup table and PSO approach also makes sense because they are the simplest algorithms capable of finding the real MPP. Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, Hill Climbing takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP. However this problem gets avoided in Lookup table method as the algorithm refers the index and reaches to the best samples of voltage and current to calculate MPP. It is seen that the efficiency of the

system also depends upon the converter. Typically it is maximum for a buck topology, then for buck-boost topology and minimum for a boost topology. It is very simple to implement and has high efficiency both under stationary and time varying atmospheric conditions. The PSO and lookup table approach is designed according to the references and its output is tested and compared to the hill-climbing MPPT method.

The main focus of this study is to review and summarize the use of PSO and its application to MPPT of solar PV system problems reported in literature along with other non-conventional and conventional methods. It has been also observed that application of PSO in various real world problems outperforms other state of the art of non-conventional or conventional mathematical algorithm.PSO has been accepted widely for obtaining the global optimal solution because of its simplicity and low constraints on objective function. Although PSO approach is capable of providing good quality results at faster rate, but when compared with other evolutionary optimization methods, their ability to fine tune the optimum solution is comparatively weak, mainly due to the lack of diversity at the end of search. Hybridization of PSO with conventional mathematical approaches is the major areas which need further research to increase the global optimal ability of PSO.

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