An overview of major MPPT techniques

M. NECDET YILDIZ[a*], EŞREF DENİZ[b]
[a]*Ege Higher Vocational School Aircraft Technology Program Activities, Ege University, Bornova, İzmir*
[b]*Solar Energy Institute/ Ege University, Bornova, İzmir*

Tracking of Maximum Power Point of a PV panel or PV panel array is of essential importance for yielding high energy outputs from solar energy power systems. MPPT (Maximum Power Point Tracking) is utilized by on grid inverters and charge regulators in order to make the system operate with maximum efficiency. The main mission of the MPPT is to adopt the operating point of a module or array usually modifying the output voltage in order to adapt the system to different irradiance conditions and also temperature variations. Within the scope of this study a wide range of MPPT techniques have been investigated. Among all methods investigated much focus has been on Hill Climbing and Perturb and Observe methods. This paper outlines different versions of both method and discusses the advantages and disadvantages of each technique. It overviews the main shortcomings of those two conventional methods.

(Received December 18, 2012; accepted April 11, 2013)

Keywords: MPPT, Hill Climbing, Perturb and Observe

1. Introduction

Tracking of Maximum Power Point of a PV panel or a PV panel array is of essential importance for yielding high energy outputs from solar energy power systems. MPPT (Maximum Power Point Tracking) is utilized by on grid inverters and charge regulators in order to make the system operate with maximum efficiency. The main mission of the MPPT is to adopt the operating point of a module or array usually modifying the output voltage to different irradiance conditions and also temperature variations.

Therefore in theory and practice a great number of MPPT methods have been developed. Among those methods, there are major differences in terms of complexity of the systems, sensors used, convergence speed, cost, efficiency and hardware.

Within the scope of this study a wide range of MPPT techniques have been investigated. First studies about MPPT techniques had started in the beginning of 70's. The number of papers per year has grown considerably of the last decades and remains strong. However, despite the growing number of MPPT techniques, methods that had been developed were different versions of a handful of MPPT techniques.

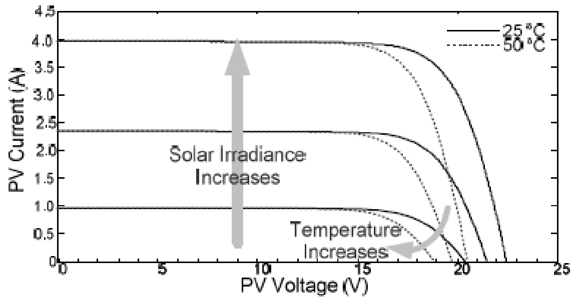
Among all methods investigated, much focus has been on Hill Climbing and Perturb and Observe methods. This paper outlines different versions of both method and discusses the advantages and disadvantages of each technique. It overviews the main shortcomings of those two conventional methods.

2. Major MPPT methods

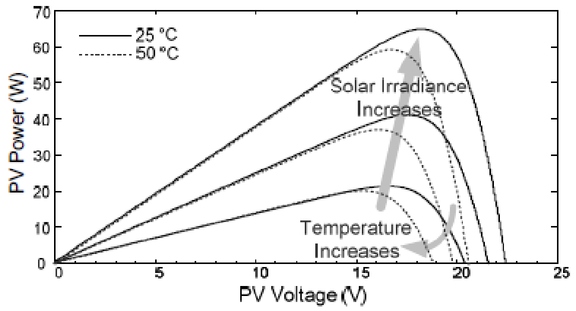
Hill Climbing [2-4] and Perturb and Observe [5-12] are the most investigated MPPT techniques in the literature. In the Hill Climbing method the duty cycle of the power converter is altered while in the Perturb and Observe Method perturbation is achieved by altering the operation voltage of the module array. The perturbation of the duty cycle of a module means the perturbation of the voltage of the module array. Therefore Hill Climbing and Perturb and Observe are different versions of the same method.

Perturb and Observe method is the most preferred method due its implementation simplicity and small number of parameters needed. In this method, the output voltage of the module array is perturbed periodically (increased and decreased) and, after each perturbation the output power of the module array is compared with power generated during preceding period. If the output power keeps increasing, the perturbation is continued in the same direction, otherwise the direction of the perturbation is reversed [5]. Despite its prevalence, this method has many drawbacks. Its slow response to changes in ambient temperature and solar irradiation, the lack of capturing the Maximum Power Point (MPP), oscillations around the MPP and reacting to sudden environmental changes in the reverse direction are the most important disadvantages.

In the Perturb and Observe Method, the amplitude of the change in the voltage of the module array in positive and negative direction is called as Perturb and Observe Step Size (POSS). POSS has a important effects on the accuracy of the MPPT method and the convergence time of Maximum Power Point.



(a) I-V characteristic



(b) P-V characteristic

Fig. 1. The effect of solar irradiance and temperature on PV I-V and P-V characteristics [6].

For any perturb and observe operation greater POSS means shorter convergence time for Maximum Power Point. However, greater POSS values causes high oscillations around MPPT point during steady state conditions when there are not sudden changes in solar irradiation and temperature. Smaller POSS values assure smaller oscillations around the Maximum Power Point especially during the steady state conditions and provide enhanced power conversion efficiency after reaching the Maximum Power Point. However, upon leaving the steady-state operating conditions, especially sudden changing environmental conditions is responded quiet slowly. Dynamic POSS eliminates the disadvantages describes above [6].

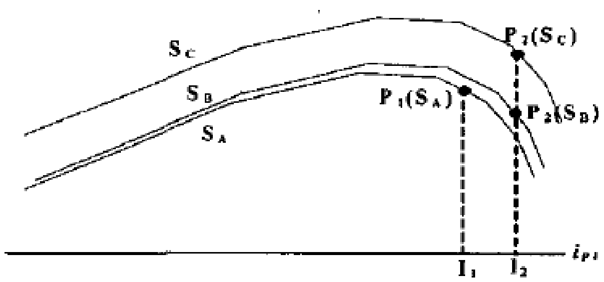


Fig. 2. The comparison between samplings for long and short perturbation cycles under rapidly changing atmospheric conditions [7].

In an research, in order to speed and efficiency of the method, for indicating the direction of the next perturbation step instantaneous values are utilized instead of averages. Thus, the amplitude of the oscillations around Maximum Power Point are reduced. Besides this, for the same purpose hill current method is applied and smaller POSS values are used. For deciding the direction of the next perturbation step more quickly, the number, the type (synchronous or asynchronous) and the ideal time of samples in each switching period are investigated. As a result, the response time of MPPT module and the amplitude of the oscillations around MPPT value are reduced and tracing of the sudden changes in solar radiation in reverse direction is prevented [7].

Fuzzy Logic Method copes with ever changing POSS with the non linear characteristics of the VPV x IPV plane [8]. When this method is implemented with a DSP controller, problems like high density of calculations and obligation of using relatively larger time steps arise. This situation limits the rate of update of reference current thus adversely affects the reaction speed of MPPT.

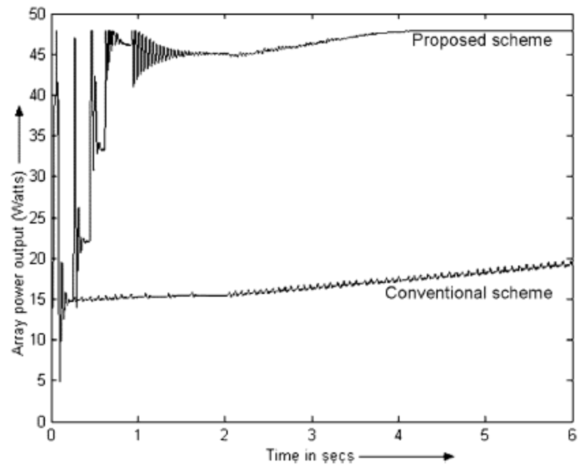


Fig. 3. Simulation plots for comparison of proposed MPPT technique with conventional hill climbing technique [9].

In another research aiming the optimization of the Perturb and Observe method, the initial approximation of the Maximum Power Point is achieved quickly by variable POSS [9]. Afterwards, for capturing the exact Maximum Power Point, conventional methods like Hill Climbing and Incremental Conductance are applied. In this way, throughout the range Maximum Power Point scanned, dependence on constant and small POSS value is eliminated, number of iterations is reduced and much faster Maximum Power Point is scanned much more quickly with respect to conventional methods. Instead of monitoring and screening the output power of a module array which has no one to one relationship with duty cycle, monolithic structure β intermediate value, which has one to one relationship with duty cycle is monitored and screened. While one of the conventional methods is being utilized, β value is calculated for determining whether the system is in a stable state or not. If it is determined that the system is in a steady state, the valued of the duty cycle is incremented by larger values.

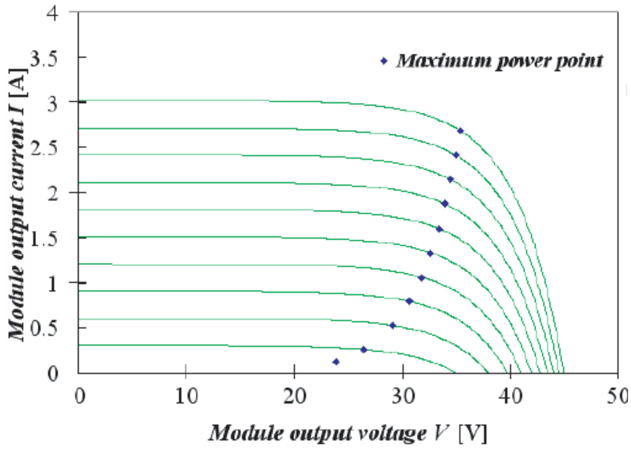


Fig. 4. I – V characteristics of the PV module: T T = 25 oC, FF = 0.7, from the top, radiation = 1.0 kW/m2 with PMAX = 94.0 W to the bottom, radiation 0.1 kW/m2 with PMAX = 6.86 W, every 0.1 kW/m2 of radiation [10].

A PV module and an integrated DC/AC inverter together are called AC modules. Each AC module has its own MPPT module and the output of the AC module is coupled directly to the AC busbar. In the AC module for an effective MPPT, the characteristics of the module is well – known by the producer, thus the domain of POSS can be presumably determined. In [10, 11], an MPPT method for the AC modules was developed. In this method VPV x IPV plane is divided by a particularly defined curve in to two areas; the one that contains the Maximum Power Point and the other. In the Maximum Power Point area Incremental Conductivity Method utilizing the smaller ΔVPV-ref values is applied while on the other area VPV-ref values are used.

One of the other drawbacks of the Conventional Hill Climbing and Perturb and Observe Methods is the difficulty in capturing the Maximum Power Point expeditiously on the areas of low solar irradiation. Within the steady ambient temperatures, the linear relationship between Short Circuit Current and Maximum Power Point is proved theoretically and experimentally. In the light of those findings, MPPT control rules reacting quickly to the sudden changes in solar irradiation were developed. Proposed MPPT method traces the output current on the curve giving the relationship between Maximum Power Point and Maximum Power Current. VPV x IPV plane is divided into two areas with this curve. The value of is calculated regarding to the algorithm of the related area. Considering the solar irradiation has linear characteristics under half of its maximum value, proportionality coefficient (voltage coefficient) is corrected for the values higher than the half of its maximum value [12].

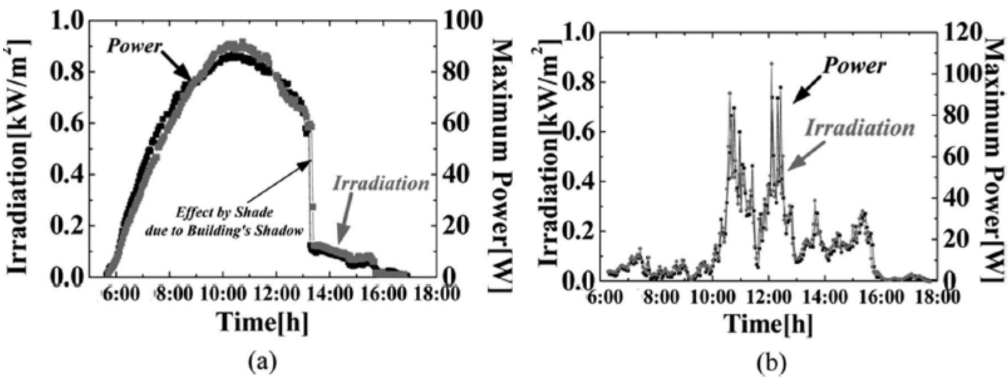


Fig. 5. I – V Acquired MP characteristics of the proposed MPPT control method when the weather changes. (a) When the weather is fine. (b) When the weather changes frequently [12].

Because of above – mentioned disadvantages of conventional MPPT methods which perform the control and perturbations on the DC side, a different method which performs control and perturbation functions on the AC side of the inverter were investigated. [13, 14]. With references to those publications the implementations of the preferred methods were realize. (Fig.6).

Fig. 6. Implementation of an MPPT Method which realizes the control and perturbations on the AC side.

The system was tested with a Solar Array Simulator (SAS). From the result read on the screen of the SAS (Fig.7), MPPT efficiency was calculated.

String Open Circuit Voltage (V_{oc}) = 409,20V
String Short Circuit Current (Isc) = 3,2A
Module Maximum Power Voltage (Vmp) = 326,7V
Module Maximum Power Current (Imp)=3,1A
Calculated Maximum Power (EQ_PMP=1033,2W
Calculated Maximum Power Point Voltage=338,42V
Calculated Maximum Power Point Current=3,053
Power Output of the String=1027,9
MPPT Efficiency=1027,9/1033,2=99,49%

Fig. 7. Screen of SAS.

3. Results

For all of the MPPT techniques in which processes are executed on the DC side, due to output of module arrays are perturbed, oscillations on the output power are generated. In all of those methods0, the number of perturbations is increased to capture the Maximum Power Point. This action increases the oscillations around the Maximum Power Point. In case the frequency of perturbation is chosen so high, excessive amount of ripples is generated which reduce the efficiency especially cloudy and windy weather conditions. Beside those, control and execution processes of MPPT on the DC side increase the stresses on the components.

Ripples on the DC side are transferred directly to AC side causing harmonic distortions and AC ripples. As the share of solar energy in the energy mix of grids, grid quality concerns that may be originated by those systems are increasing. Therefore new MPPT methods which do not contribute to the grid quality problems should be investigated. Those new methods should also find new ways to reduce the stress on the components of implementation circuits, thus providing less and smaller sized components.

References

[1] T. Esram, P. L. Chapman, IEEE Transactions on Energy Conversion **22**(2), 439 (2007).
[2] E. Koutroulis, K. Kalaitzakis, N. C. Voulgaris, IEEE Transactions on Power Electronics **16**(1), 46 (2001).
[3] O. Hashimoto, T. Shimizu, G. Kimura, Conf. Record 2000 IEEE Ind. Applicat. Conf., 2000, pp. 2255.
[4] W. Xiao, W. G. Dunford, Proc. 35th Annu. IEEE Power Electron. Spec. Conf., 2004, pp. 1957.
[5] K. H. Hussein, I. Muta, T. Hoshino, M. Osakada, IEEE Proc – Gener. Transm. Distrib., **142**, 59 (1995).
[6] C. W. Tan, T. C. Green, A. H. A. Carlos, 2nd International IEEE Conference on Power and Energy (PECon 08), Johor Baharu, Malaysia, 2008, pp. 237.
[7] X. Liu, L. A. C. Lopes, 35th Annual IEEE Power Electronics Specialists Conference, Aachen, Germany, 2004, pp. 2005.
[8] N. S. D'Souza, L. A. C. Lopes, X. J. Liu, Proc. 36th IEEE Power Electronics Specialists Conference, Recife, Brazil, 2005, pp. 172.
[9] S. Jain, V. Agarwal, IEEE Power Elec. Lett. **2**(1), 16 (2004).
[10] H. Koizumi, K. Kurokawa, Proc. 36th IEEE Power Electronics Specialists Conference, Recife, Brazil, 2005, pp. 2081.
[11] H. Koizumi, K. Kurokawa2006 IEEE International Symposium on Industrial Electronics, **2**, Montreal, Canada, 2006, pp. 1265.
[12] N. Mutoh, M. Ohno, T. Inoue, IEEE Trans. Ind. Electron. **53**(4), 1055 (2006).
[13] N. S. D'Souza, L. A. C. Lopes, X. J. Liu, Proc. 36th IEEE Power Electronics Specialists Conference, Recife, Brazil, 2005, pp. 172.
[14] A. K. Abdelsalam, A. M. Massoud, S. Ahme, P. N. Enjeti, IEEE Transactions on **26**(4), 1010 (2011).

*Corresponding author: necdet.yildiz@ege.edu.tr