Algorithms for Tracking of Maximum Power Point in Solar Energy System

Charu Pathak
Department of Electronics & Communication
Manav Rachna University, Faridabad
E-mail: charuup123@gmail.com

Shivani Aggarwal
Department of Electronics & Communication
Manav Rachna University, Faridabad
E-mail: shivaniaggarwal42@gmail.com

Abstract: Renewable energy generation has experienced consistent growth in the last two decades, motivated by the concerns of climate change and high oil prices, and supported by renewable energy legislation and incentives, with a close to $150 billion investment in 2007[1].Photovoltaic (PV) offers an environment friendly source of electricity of which fuel is sunshine. The maximum power point tracking (MPPT) algorithm is very commonly used because of its fast dynamic response and well regulated PV output voltage under widely varying atmospheric conditions.

PV array has non-linear I-V characteristic and output power depends on environmental conditions such as solar irradiation and temperature. There is a point on I-V, P-V characteristic curve of PV array called as Maximum Power Point (MPP), where the PV system produces its maximum output power. Location of MPP changes with change in environmental condition. The purpose of MPPT is to adjust the solar operating voltage close to MPP under changing environmental conditions. In order to continuously gather the maximum power from the PV array, they should operate at their MPPT despite of the inhomogeneous change in environmental conditions. The two most commonly algorithms for PV applications as they are easy to implement are Perturb and Observe (P & O) Incremental Conductance (Inc. Con.).

Keywords: *Maximum power point tracking, solar power*

I. INTRODUCTION

According to large use of the fossil fuel, the reserve of petroleum substantially and rapidly reduced and it will be depleted in a few decades. The extracting of solar energy using PV modules comes with its own problems, arise from the efficiency and output power of the PV modules. A great deal of research has been accomplished to improve the efficiency of the photovoltaic system. Solar power has two largest advantages over fossil fuels which have been used. The first is the fact that it is renewable and it is never going to run out. The second main advantage is its effect on the environment. Solar energy is completely non polluting.

A. Current status of photovoltaic technology

Photovoltaic solar electricity, together with solar thermal, has the highest potential of all the renewable energies, since solar energy is a practically unlimited resource, available everywhere [2]. Humanity have recognised the power in the sun's rays as early as the 3rd century B.C., when magnifying glasses were used to light torches [3]. The photovoltaic eûect was discovered by the French scientist Edmond Becquerel in 1839, but it was only explained in 1905 by a publication of Albert Einstein for which he won his Nobel-prize in 1921 [3]. The modern era of photovoltaics can be dated from 1954, when scientists at Bell Labs developed the ûrst silicone PV cell [4,3]. From the end of the 1950s, solar cells for space applications have been produced. Terrestrial applications of photovoltaics started to spread at the beginning of the 1970s.

Today a large variety of photovoltaic generators from mW- range for scientiûc calculators, through several kW residential applications, to tens of MW- scale photovoltaic power plants, are in operation all over the world. The vast majority, close to 90%, of photovoltaic modules are currently produced using waferbased crystalline silicone [4,5], but there are other emerging technologies which are gaining importance in the PV market. In recent years thin-ûlm modules have earned share in the PV market, taking advantage of the photovoltaic-grade silicone shortage and consequently the higher prices in the PV market [6]. Concentrator PV technology tries to decrease the amount of semiconductor necessary, by using small-area high-eûciency cells and inexpensive polymer lenses to focus the light on the cell. This technology generally needs a sun-tracking system [6] and it is more suitable for medium to large PV systems [7] in areas with a high percentage of direct radiation [8]. Photovoltaic energy has the potential to play an important role in the transition towards a sustainable energy supply system in the 21st century, to cover a signiûcant share of the electricity needs of Europe [4], and is expected to be one of the key energy technologies of this century [2].

B. Mathematical Equations

It is not merely the size of the PV array but also its pattern (i.e., the number of modules in series and parallel) that considerably affect its power output and the performance of the system. Therefore, a maximum power point tracking (MPPT) control to take out maximum power from the PV arrays at actual time becomes essential in PV generation system. In recent years, a large number of techniques have been proposed for tracking the maximum power point (MPP). Perturbation and observation (P&O) and hill climbing, incremental conductance, ripple correlation, etc. methods are extensively applied in the MPPT controllers due to their simplicity and easy implementation. Numerous MPPT algorithms have been projected from time-to-time. MPPT of a photovoltaic array is usually a necessary part of a PV system. The method vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware, popularity, and in other respects. It is also a clean source of energy.

MPPT system is a power conversion system with a suitable control algorithm that allows extracting the maximum power from a PV panel independently of the operating conditions (temperature, solar irradiation and shading). The maximization of the delivered power can be achieved by regulating the current drawn from the panels or the voltage across it to yield operation at or close to the Maximum Power Point(MPP).

A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. A non isolated DC-DC converter offers the purpose of conversion maximum power to the load. A DC-DC converter acts as an interface of load as it appear by the source is varied and matched at the peak power point with the source so as to conversion the maximum power[8-9].

The Fig. 1 show the equivalent circuit of solar cell and I-V characteristics of the solar cell circuit can be set by the following equations. The current through diode is given by:

$$Id = Io \left[\exp\left(q\left(\frac{V+I.Rs)}{KT}\right)\right) - 1\right] \quad ..(1)$$

While the solar cell output current:

$$I = Il - Id - Ish \quad ..(2)$$

$$I = Il - Io \left[\exp\left(\frac{V + I.\ Rs}{KT}\right) - 1\right]\left[\frac{V + I.\ Rs}{Rsh}\right] \quad ..(3)$$

where,

I	:	Solar cell current (A)
Il	:	Light generated current (A)
Io	:	Diode saturation current (A)
q	:	Electron charge (1.6×10-19 C)
K	:	Boltzman constant (1.38×10-23 J/K)
T	:	Cell temperature in Kelvin (K)
V	:	solar cell output voltage (V)
Rs	:	Solar cell series resistance (Ù)
Rsh	:	Solar cell shunt resistance (Ù)

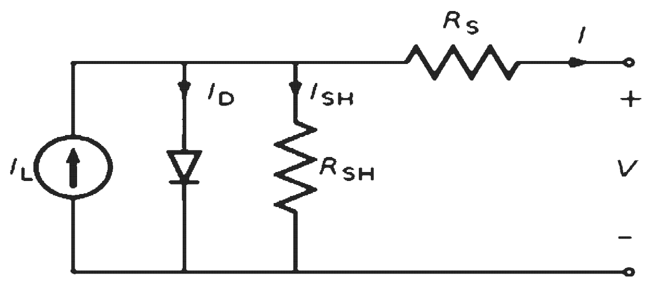

Fig. 1. The equivalent circuit of solar cell

II. DESCRIPTION OF MPPT ALGORITHMS

The MPPT method consider is to automatically find the current IMPP or voltage VMPP at which a PV array should work to extract the maximum output power PMPP under a given temperature and irradiance. Most of MPPT methods respond to variations in both irradiance and temperature, but some are precisely more useful if temperature is approximately constant. Most MPPT methods would automatically respond to various in the array due to aging, though some are open-loop and would require periodic fine tuning. Module will typically be connected to a power converter that can vary the current coming from the PV array to the load [10,11].

A. MPPT Control Algorithm

The weather and load changes cause the operation of a PV system to vary almost all the times. A dynamic tracking technique is important to ensure maximum power is obtained from the photovoltaic arrays. The following algorithms are the most fundamental MPPT algorithms, and they can be developed using micro controllers.

The MPPT algorithm operates based on the truth that the derivative of the output power (P) with respect to the panel voltage (V) is equal to zero at the maximum power point. In the literature, various MPP algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP.

B. Perturb And Observe Algorithm

A frequently used class of MPPT algorithms operate by continuously changing the operating point of the PV panels and detecting corresponding variation in the output power in order to determine the next variation that leads to the MPP; therefore they are known as 'Perturbation and Observation' algorithms.

P&O is the simplest method. In this algorithm only one sensor used, to sense either the PV array voltage or current. In P&O algorithm, the perturbation variable can be the references values for the PV panel terminal voltage, PV panel output current, or the duty cycle of the MPPT converter. If the output voltage of the PV panels is perturbed and dp/dv>0, it is known that the operating point is left side of the MPP. The P&O algorithms would then increase the PV panel references voltage to move the operating point towards MPP. If dp/dv<0 , then it is known that the operating point is on the right side of the MPP. The P&O algorithm would then decreases the PV panel references voltage. If the perturbation variable is current, then the perturbation in the PV output power is accomplished by periodically changing (either increasing or decreasing) the references current by a small value.

Fig 2.2 illustrates the flow chart for implementing P&O MPPT algorithm. Here the PV output current is used as a control variable. First of all, the terminal

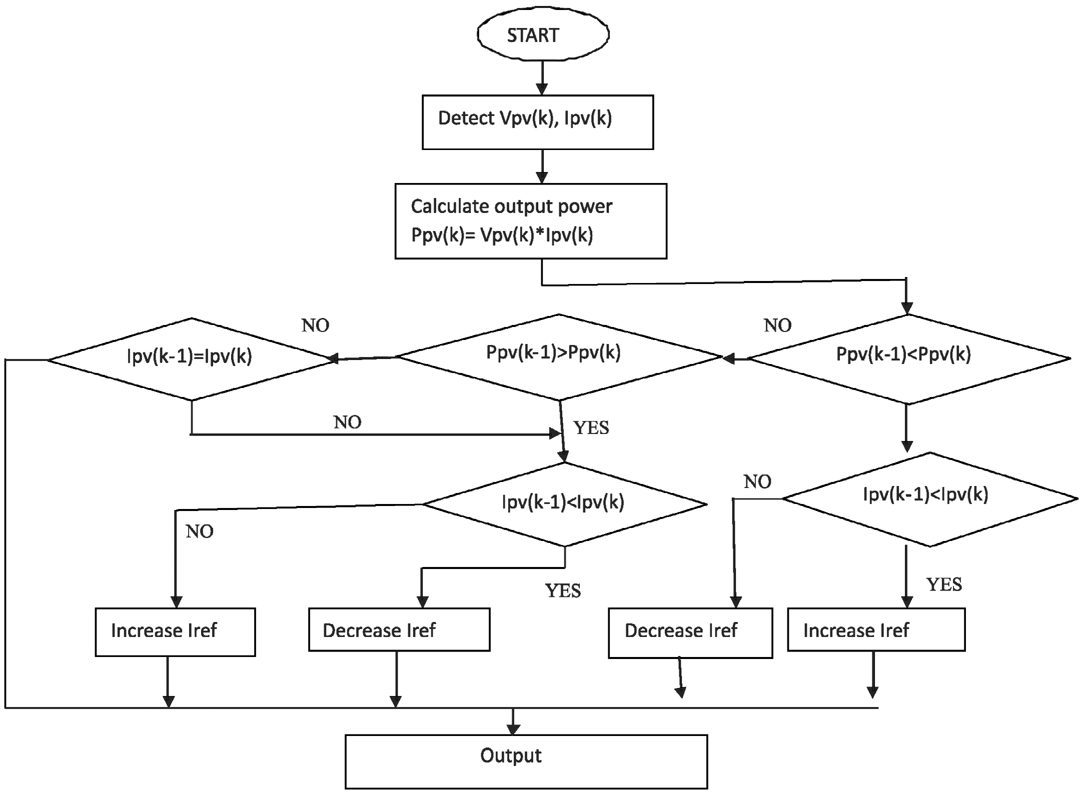

Fig. 2. Flow chart of perturb and observe

voltage, Vpv and current Ipv of panels are sensed. The output power of PV panels, Ppv can be obtained from the product of Vpv and Ipv.

C. Incremental Conductance

It has been shown above that P&O MPPT algorithm have some drawbacks. These would in principle be overcome by the Incremental Conductance with the instantaneous static conductance.

The basic idea of the Inc Cond algorithms [12] is that, at the MPP, the derivative of the power with respect to the voltage or current becomes zero because the MPP is the maximum point of the power curve. The output characteristics of p*v are analyzed. In the left side of the MPP the power increases with the voltage, i.e. $dp / dv >$ and it decreases with voltage in the right side of the MPP, i.e. $dp / dv < 0$.

$$dp / dv = 0 \quad \text{At the MPP} \qquad \dots (4)$$

$$dp / dv > 0 \quad \text{To the left of the MPP} \qquad \dots (5)$$

$$dp / dv < 0 \quad \text{To the right of the MPP} \qquad \dots (6)$$

These relations can be written in terms of the panel's current and voltage

Using

$$dp/dv = d\,(iv)/dv = I + V\,di/dv \qquad \dots (7)$$

$$\frac{1}{V}\,dp/dv = \frac{1}{V} + di/dv \qquad \dots (8)$$

Hence, the PV panel terminal voltage can be adjusted relative to the MPP voltage by measuring the incremental and instantaneous panel's conductance and making use of above equation.

III. CONCLUSION

In this paper a theoretical analysis allowing the optimal choice of the two main parameters characterizing the P&O algorithm has been carried out. The idea underlying the proposed optimization approach lies in the customization of the P&O MPPT parameters to the dynamic behavior of the whole system composed by the speciûc converter and PV array adopted.The PV Array mathematically modelled and the programmes implemented in the MPPT for PV application using P&O technique achieve the maximum power point. It has been shown that for the particular irradiance levels and for variation in the temperature, the maximum power is achieved. This technique is a simple and setup results in a highly efficient system. Incremental conductance performed as well as P&O, but in general its higher implementation cost would not be justified by any improvement in performance.

REFERENCES

[1] UNEP, "Global Trends in Sustainable Energy Investment 2008," United Nations Environment Programme, Tech. Rep., 2008, executive summary.

[2] EPIA, "EPIA roadmap," EPIA, Report, June 2004. [Online]. Available: http: //www.epia.org/04events/docs/EPIAroadmap.PDF

[3] U. DOE. The History of Solar. U.S. Department of Energy - Energy Eûciency and Renewable Energy. [Online]. Available: www1.eere.energy.gov/solar/pdfs/solar timeline. Pdf.

[4] PV-TRAC, "A Vision for Photovoltaic Technology," European Comission - Photovoltaic Technology Research Advisory Council, Tech. Rep., 2005.

[5] V. Benda, "Solar cell and module fabrication technology," November 2008, course presented at the Institute of Energy Technology.

[6] U. DOE, "Solar energy technologies program. multi-year program plan 2007-2011," U.S. Department of Energy, Tech. Rep., 2007.

[7] D. Pachon, I. Anton, and G. Sala, "Rating and modelling of concentrator systems," in Photovoltaic Specialists Conference, 2002. Conference Record of the Twenty-Ninth IEEE, 2002, pp. 1600–1603.

[8] M.E.Ahmad and S.Mekhilef, "Design and Implementation of a Multi Level Three-Phase Inverter with Less Switches and Low Output Voltage Distortion," Journal of Power Electronics, vol. 9, pp. 594604, 2009.

[9] H.N.Zainudin and S. Mekhilef, "Comparison Study of Maximum Power Point Tracker Techniques for PV Systems" Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010.

[10] R.Faranda and S. Leva, "Energy Comparison of MPPT techniques for PV Systems," WSEAS Transaction on Power Systems, vol. 3, pp. 446-455.

[11] M.Azab, "A New Maximum Power Point Tracking for Photovoltaic Systems," WASET, vol. 34, 2008, pp. 571-574.

[12] Y.C.KUO, T.J.Liang and J.F,Chen, "Novel Maximum Power Point Tracking Controller for Photovoltaic Energy Conversion System", IEEE Transaction on Industrial Electronics, Vol.48,No.3, JUNE 2001,pp594-601.

❒