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Survey on MPPT Techniques in Photovoltaic Solar Energy Systems

Gurpinder Singh [1], Amanpreet Kaur [2]

M.Tech Student, Department of EE, BBSBEC, Fatehgarh Sahib, Punjab, India [1]

Asst. Professor, Department of EE, BBSBEC, Fatehgarh Sahib, Punjab, India [2]

ABSTRACT-_Tracking of the maximum power point of a photovoltaic array is usually an essential part of PV systems. In general, PV generation systems have two major problems; the conversion efficiency of electric power generation is low, and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell I-V characteristic is nonlinear and varies with irradiation and temperature. There is a unique point on the I-V or P-V curve of the solar array called MPP, at which the entire PV system operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models, or by search algorithms. Therefore MPPT techniques are needed to maintain the PV array's operating point at its MPP. In this paper, some of the most popular techniques are surveyed which are used in their work by most of the authors.

KEYWORDS: MPPT, Photovoltaic cells, Renewable energy

I. INTRODUCTION

In the current century, the world is increasingly experiencing a great need for additional energy resources so as to reduce dependency on conventional sources, and photovoltaic (PV) energy could be an answer to that need. PV cells are being used in space and terrestrial applications where they are economically competitive with alternative sources. Generally, PV systems can be divided into three categories: stand-alone, grid-connection and hybrid systems. For places that are far from a conventional power generation system, stand-alone PV power supply systems have been considered a good alternative. These systems can be seen as a well-established and reliable economic source of electricity in rural remote areas, especially where the grid power supply is not fully extended.

Currently, although the cost of the solar energy is still higher than that of energy from fossil fuels, the trend of oil shortage is one factor that increases the cost of fossil fuels and can eventually enable the cost of solar energy to be lower than that of energy from fossil fuels. In addition, the advances in the maximum-power-point-tracking (MPPT) algorithm used in solar photovoltaic systems and the resulting efficiency improvement of the inverter enable the cost of solar energy systems to be further reduced. Therefore, in the future, the cost between solar energy and fossil fuel energy may become closer to each other. However, due to the characteristics of the solar cell, the maximum power of the solar cell cannot be provided without the use of a MPPT controller. By using a MPPT converter, the input impedance of the converter can match the output impedance of the solar cell to achieve the maximum power output of the solar cell. Because of its clean and stable output power, solar photovoltaic systems using a MPPT converter will find a place in the field of the green energy application. The programmable advantage of the digital chip accelerates the research of the MPPT algorithm. Different algorithms have different tracking performances. Thus, determining how to obtain improved tracking performance using a simple algorithm is an important topic. By reducing the specification requirement of the digital chip used in MPPT, the use of a simple algorithm can reduce the cost of a PV system. Therefore, a MPPT method using a simple algorithm that provides good tracking performance is desired[1].

II. HIGHLY PREFERRED METHODS FOR MPPT IN PV SYSTEM

The characteristic curve of the solar cell exhibits a maximum power point. By feeding back the voltage and current values of the solar module to determine the maximum power point position and to provide the adequate duty cycle to the converter, the maximum power point can be obtained. The typical tracking method the “perturb and observe” (P&O) method[2].The P&O method is widely used because of its easy implementation. However, the P&O algorithm continues to operate, even at the maximum power point; as a result, the output power may be unstable, thereby decreasing the efficiency of power generation. Furthermore, P&O method also has the possibility of errors in determining the maximum power point. This error causes the tracking speed of the P&O method to decrease. The hill-climbing[3] and incremental conductance (INC) [4] methods use the characteristics of the power and voltage of the solar cell to determine the maximum power point. The maximum power point occurs when the slope of the power–voltage curve of the solar cell becomes zero. However, perturbations in the zero slope state can still occur. Although some other tracking algorithms, such as fuzzylogic[5], neural-network [6] and swarm chasing [7], exhibit precise tracking capability, these algorithms are very complicated. In addition to the above methods, the fractional open circuit voltage and short current methods have also been proposed. The position at the eighty percent of the open circuit voltage is taken as the maximum power point. However, these methods must detect the open circuit voltage and short current periodically, and the aforementioned maximum-power point position is not the exact maximum power point. The above methods are classified according to the judgment algorithm. In addition, research studies on the variable step-size methods have also been proposed [8].In the conventional method, a fixed step size is applied to track the maximum power point. The use of a fixed step size will cause some problems because the step size cannot be changed in the neighborhood of the MPP. Although the MPP can be achieved, the system cannot produce stable output power if too large a step size is used, resulting in a reduction in the power produced by the overall system. To achieve a stable output power in the neighborhood of the MPP, the step size can be designed to be small, but at the cost of a slow dynamic response. To solve the above dilemma, the variable step-size method was proposed. With the variable step-size concept, fast dynamic response and stable output power can be obtained simultaneously. The variable step-size method has evolved from the Hill-climbing method. The step size of the Hill-climbing algorithm can be varied to achieve good tracking performance. Although the conventional variable step method exhibits good tracking performance, it also has the following problems. To solve the convergence problem, a constant value is often needed to be multiplied in the tracking algorithm. To keep the fast dynamic response and maintain a stable output power, the choice of this constant value is very important. A poor choice of the constant value causes the system to oscillate, thereby reducing the power generation. Another problem regarding the use of this constant value involves significant changes in the irradiation, which cause the power–voltage curve of the solar cell to vary significantly; because this constant value cannot be adjusted with the variation in weather, the dynamic response of the solar system will be slow when the irradiation exhibits a large variation.

III. A BRIEF SURVEY OF OPERATION OF DIFFERENT MPPT TECHNIQUES

A. Feedback voltage (current) method

If there is no battery present in the system, in order to tie the bus voltage at a nearly constant level, a simple control can be applied [9]. Thus, the feedback of the PV voltage (current) and the comparison with a constant voltage (current) can be used to continuously adjust the duty cycle (D) of a DC/ DC converter, to operate the PV panel at a predefined operating point, close to the MPP, Fig. 8. The disadvantages of this configuration are the same as for the method of direct connection (PV generator+load profile). That is, the system is not able to adapt to changeable environmental conditions, such as irradiance and temperature. However, if batteries are present in the system, a common technique is to compare with a reference constant voltage, where it is assumed that it corresponds to the VMPP, under environmentally specific conditions. The resultant signal differentiation (error signal) is used to control the DC/DC converter. Although the implementation of this variant is not relatively simple, it fails as well to fulfill the proposed objective because it does not take into account the effects of irradiation and temperature variations. The advantages of this method are the same as the previous methods: it is a simple and economical method and uses only one feedback-loop control. Nevertheless, as has been mentioned before, it presents the following disadvantages: it cannot be applied in a generalized fashion in systems which do not consider the effect of variations of the irradiation and temperature of the PV panels. It cannot be applied to the systems with batteries.

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B. Perturbation and observe (''P&O'') method

The ''P&O'' method is that which is most commonly used in practice by the majority of authors among others. It is an iterative method of obtaining MPP. It measures the PV array characteristics, and then perturbs the operating point of PV generator to encounter the change direction[10].

In the fig.2, the flowchart for Conventional Perturbation and Observe algorithm has been shown for the measurement of power. This flowchart involves the following steps:

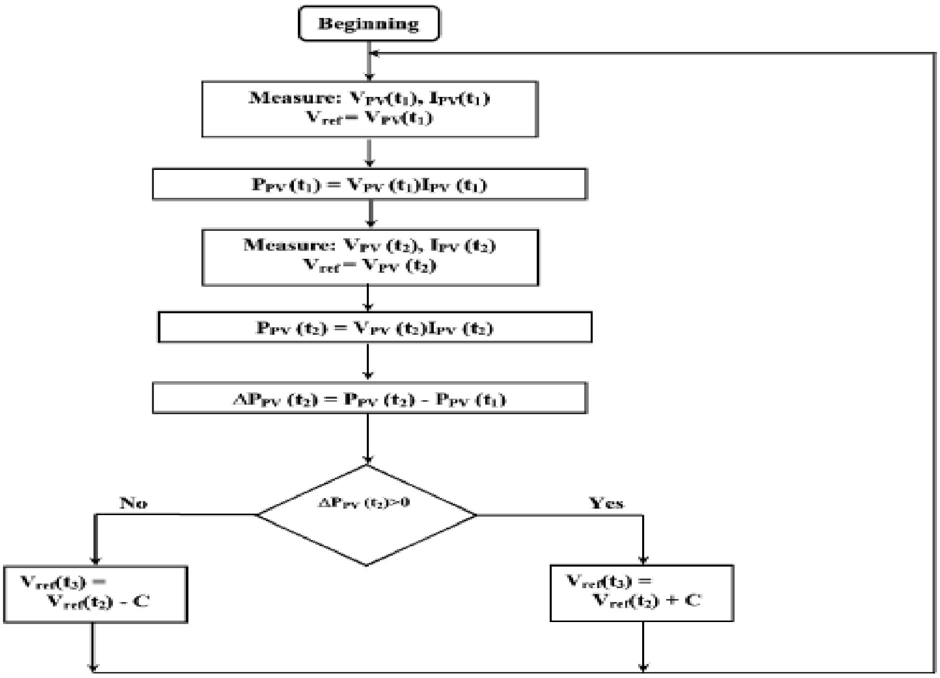

Fig. 1 Conventional Perturbation and Observe algorithm flowchart, C is the step of the perturbation [10]

The maximum point is reached when $\dfrac{dp}{dv}=0$. There are many varieties, from simple to complex. An example algorithm flowchart of the most basic form is shown in Fig. 9. Doing this, the operating voltage of the PV generator is perturbed, by a small increment Δp, and the resulting change, Δv, in power, is measured. If Δp is positive, the perturbation of the operating voltage should be in the same direction of the increment. However, if it is negative, the system operating point obtained moves away from the MPPT and the operating voltage should be in the opposite direction of the increment.

C. Conductance incremental method

An alternative to the ''P&O'' method was proposed by Hussein et al. [11], developing the ''C.I.'' method.It is based on Eq. (1). That is, differentiating the PV power with respect to voltage and setting the result to zero,

$$-\frac{I_{fv}}{V_{fv}}=\frac{dI_{fv}}{dV_{fv}} \quad \text{....(1)}$$

The left-hand side of Eq. (1) represents the opposite of the instantaneous conductance, $G=\dfrac{I_{fv}}{V_{fv}}$ whereas the right hand side of the Eq. (1) represents its incremental conductance.

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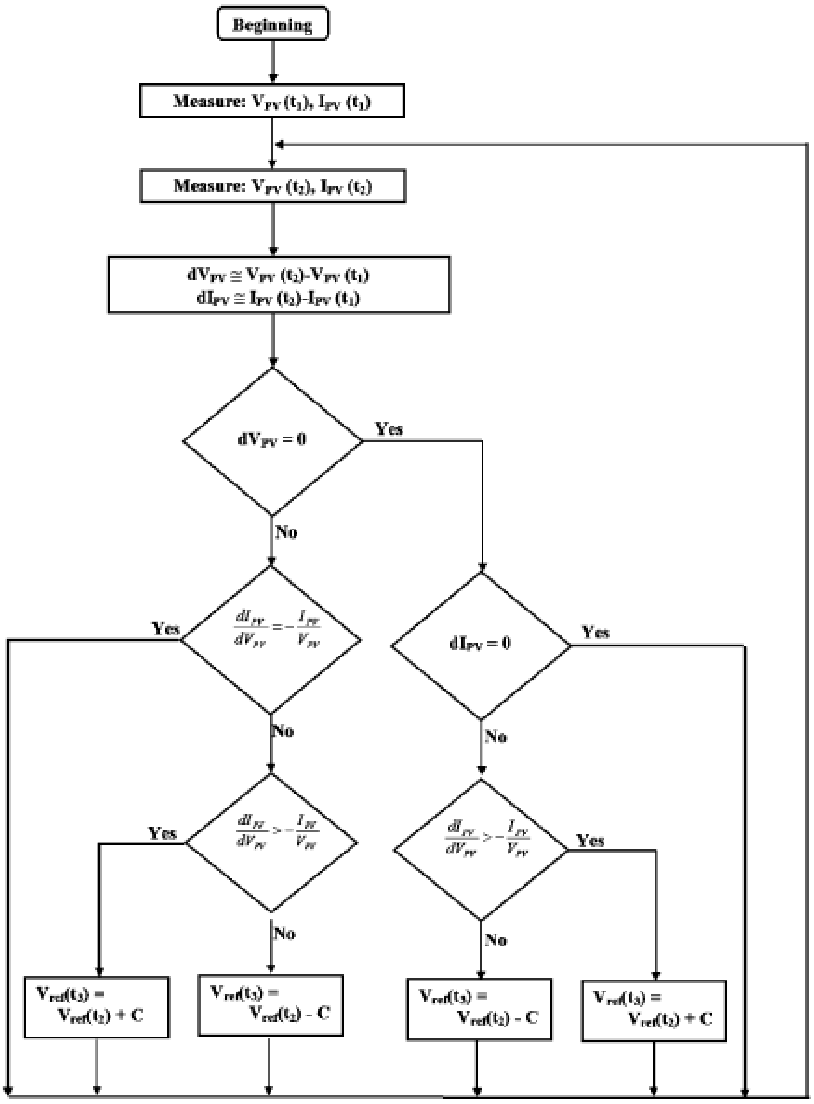

Fig. 2 Incremental conductance algorithm flowchart[10]

The main advantage of this algorithm is that it offers a good yield method under rapidly changing atmospheric conditions. Also, it achieves lower oscillation around the MPP than the P&O method, even though, when the P&O method is optimized, the MPPT efficiencies of the incremental conductance and P&O MPPT algorithms are, essentially, the same.

D. Forced oscillations methods

By introducing a small voltage, 100 Hz, that is added to the voltage of operation voltage of the PV generator [13]. In this given figure below i.e fig.3, ripple power is shown whose phase and amplitude are dependent on the relative location of the operation point to the MPP. If this modulation occurs in zone ‘‘Yes’’in the fig.3, the left side of the MPP, the ripple voltage of the power will be perfectly in phase. However, if the modulation occurs in a point of operation of zone ‘‘No’’ in the fig.3, to the right side of the MPP, the curling of the power output will be 180^0 out of phase with respect to the voltage. In case that the operation point is exactly the MPP, the curling of power output will have twice the frequency of the curling of the voltage, with very small amplitude.

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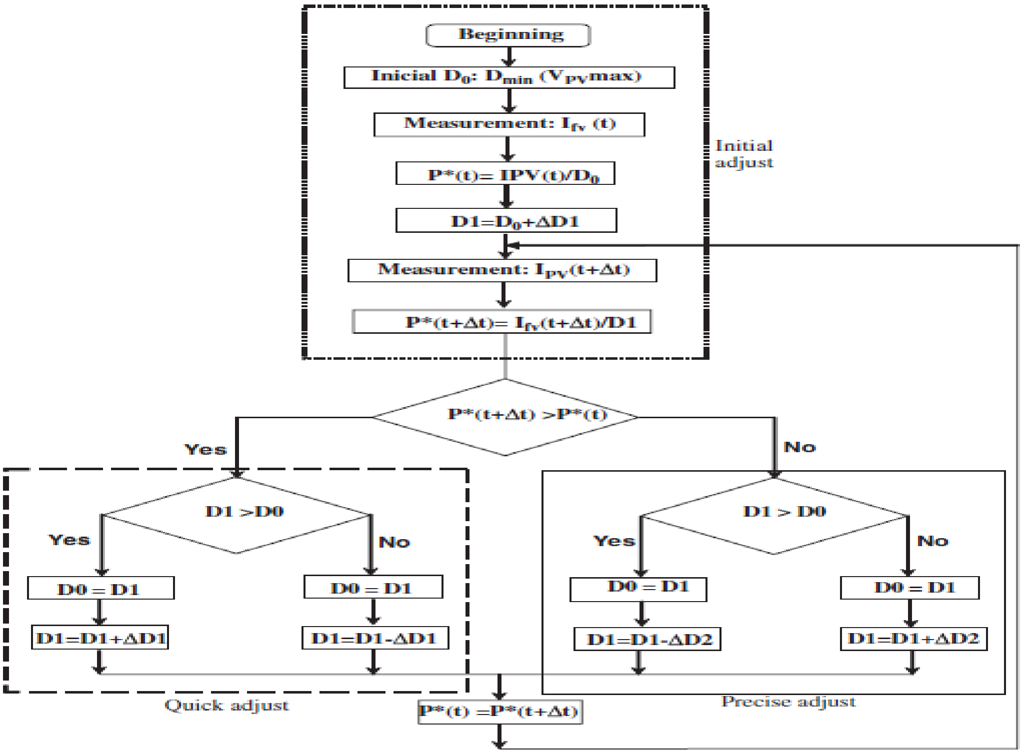

Fig. 3 Flowchart for the Algorithm of Measurement of the Photovoltaic Current, IPV [12]

The advantage of this method is that analysis of the amplitude and the phase provides information on the location of the MPP. In addition, the exit signal converges slowly towards zero, when the point of operation approaches the MPP. This allows the operating voltage to be adjusted slowly to the MPP voltage. With it, there will be no continuous oscillation around the MPP caused by a fixed width of passage of converter MPPT. The only oscillation that happens with this method, is 100Hz of modulation of the voltage operation.

IV. CONCLUSION

In this paper as demonstrated above , there are many ways of distinguishing and grouping the methods for tracking the MPP to the PV generator. This paper provides a study on the most MPPT techniques used in the PV systems, i.e. the perturbation and observation(P&O) method, the incremental conductance (IncCond) method , Feedback voltage (current) method and Forced oscillations methods based MPPT method. In future work, a hybrid PSOGSA algorithm based MPPT tracker will be proposed.

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