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METHODS OF PHOTOVOLTAIC POWER CONTROL MODE

This paper gives an overview and classification of modern methods maximum power point tracking for the solar photovoltaic systems. Considered methods are briefly described. Advantages and disadvantages of each method are described and compared. The conclusion is formulated that using of a combination of different methods is promising, including short-circuit current method with of one of the direct methods in conjunction with the serial PWM (pulse width modulation) output control of solar photovoltaic systems. This statement authors intend to confirm through further experimental research.

Keywords: *photovoltaic systems, мaximum power point tracking.*

Introduction

The output of a photovoltaic system depends very much upon the weather conditions, i.e. solar irradiation, temperature and shading effects due to clouds. These parameters in PV (Photovoltaic Power) system never remain constant, instead kept on changing at each instant. Also, most solar cells in the market can achieve a maximum of 15-20% energy conversion. But after a lot human effort and research, under these circumstances, it is very important to for power electronic converter to have such a control that can ensure to have a maximum possible output power from PV array with changing weather conditions. MPPT (Maximum Power Point Tracking) function is to regulate the DC (Direct Current) output voltage or current in such a way that the maximum possible power can be obtained, with respect to any changes in weather conditions. The maximum power point (MPP) is the point at which system has the highest possible efficiency. In one weather condition, there can only be one operating point in the system that can give the optimal maximum efficiency. Therefore, to track this point in the system is very important in order to increase the system efficiency. Particularly, the system having any kind of converter needs MPPT in order to make sure that it deliver maximum power to the other side. PV array characteristics are nonlinear and greatly depend upon weather condition. Due to this weather dependence there is one single operation point in each characteristic that will give us the maximum point out of the array. Particularly with grid connected PV system, it is very important for a converter to track the maximum power point with every change in the solar irradiation and temperature. Therefore MPPT control in a PV system became very essential for an efficient system.

At the appropriate operating point of a solar cell, assuming a given cell efficiency, the maximum output power depends on the radiation intensity, ambient temperature and load impedance. There is a single operating point enabling the attainment of maximum power, tracking of which through variations in radiation intensity and temperature is essential in order to ensure the efficient operation of the solar cell array Fig. 1. The fundamental problem addressed by MPPT is to automatically determine the PV output voltage or output current for which the PV array produces maximum output power under a given temperature Fig. 2 b and Fig. 2 a irradiance. Attainment of maximum power involves load-line adjustment under variations in irradiation level and temperature. The maximum power point tracking, MPPT not only enables an increase in the power delivered from the PV module to the load, but also enhances the operating lifetime of the PV system [1-3]. A variety of MPPT methods have been developed and implemented [4, 5].

Maximum Power Point Tracking

We discuss the concept of Maximum power point tracking (MPPT). This concept is very unique to the field of PV Systems, and hence brings a very special application of power electronics to the field of photovoltaics. The concepts discussed in this section are equally valid for cells, modules, and arrays, although MPPT usually is employed at PV module/array level. The behavior of an illuminated solar cell can be characterized by an I-V curve Fig. 1. Interconnecting several solar cells in series or in parallel merely increases the overall voltage and/or current, but does not change the shape of the I-V curve Fig. 1. Therefore, for understanding the concept of MPPT, it is sufficient to consider the I-V curve of a solar cell. The P-V curve is dependent on the module irradiance Fig. 2 a and temperature Fig. 2 b. For example, a decreasing irradiance leads to an increased power and slightly increased voltage, as illustrated in Fig. 2 a and the Fig. 2 b. Shows that an increasing temperature has a detrimental effect on the voltage. Now we take a look at the concept of the operating point, which is the defined as the particular voltage and current, at that the PV module operates at any given point in time. For a given irradiance and temperature, the operating point corresponds to a unique (I,V) pair which lies on to the I-V curve.

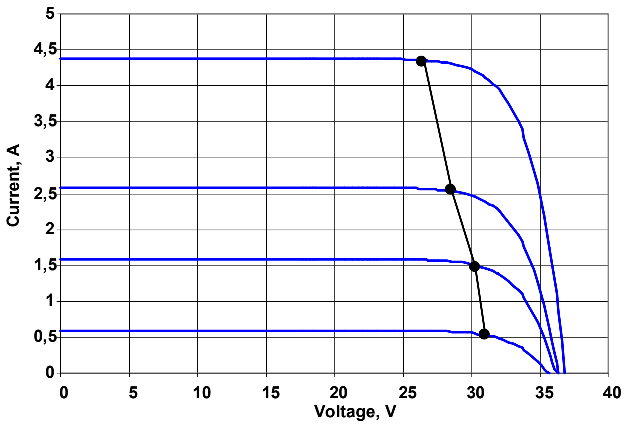
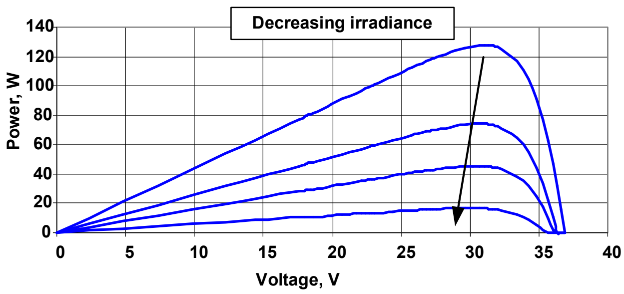
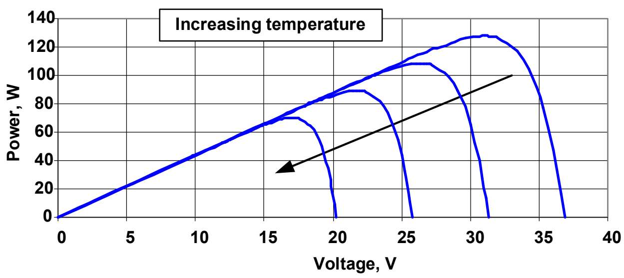


Fig. 1. The I–V characteristics of solar cell under varying sunlight



a



b

Fig. 2. Impact of factors on power-voltage characteristics of PV array:
a - irradiation; b - temperature

The power output P = I·V. The power - voltage (P-V) curve, shown in Fig. 2 a and Fig. 2 b. For generating the highest power output at a given irradiance Fig. 2 a and temperature Fig. 2 b.

The operating point should such correspond to the maximum of the (P-V) curve, which is called the maximum power point (MPP) shown in Fig. 3.

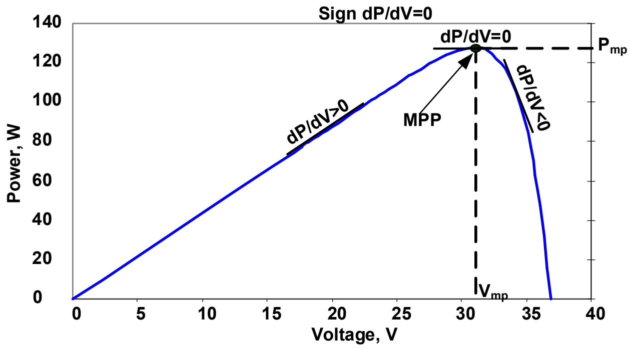


Fig. 3. The maximum power point (MPP) of the P-V curve

If a PV module (or array) is directly connected to an electrical load, the operating point is dictated by that load. For getting the maximal power out of the module, it thus is imperative to force the module to operate at the maximum power point. The simplest way of forcing the module to operate at the MPP, is either to force the voltage of the PV module being that at the MPP (called V_{mp}) or to regulate the current to be that of the MPP (called I_{mp}).

However, the MPP is dependent on the ambient conditions. If the irradiance or temperature change, the IV and the P-V characterisics will change as well and hence the position of the MPP will shift.

MPPT Methods

A major disadvantage of the PV systems is the relatively high cost required for generation of energy as compared to that produced by conventional power generation systems. Therefore, maximizing the efficiency of power delivered to the output by tracking the maximum power point is critical for optimal operation of the PV systems. These methods have been classified into two broad categories: indirect methods, direct methods.

Indirect Methods

In indirect methods usually the physical values of the PV panel are used to generate the control signals.These methods that only are used for PV systems are open circuit voltage method (OCV), short circuit current method (SCC).

Open Circuit Voltage (OCV) Method. This method is one of the simplest indirect methods [7–11], which uses the approximately linear relationship between the open circuit voltage (V_{oc}) and the maximum power point voltage (V_{mp}) under different environmental conditions as described by the follow in the equation:

$$V_{mp} = K_V \cdot V_{oc}, \quad (1)$$

where K_V is a constant, which depends on the solar cell characteristics.

This constant is empirically derived based on measurement of the V_{oc} and V_{mp} under different environmental conditions. It is difficult to choose an optimal value for the constant K, however values for this parameter ranging 0,73...0,80 have been reported imply crystalline PV modules [7–10]. From Eq. (1) V_{mp} is determined following each measurement of the V_{OC}. In each successive stage as MPP is tracked, this value of V_{mp} which is chosen as the set point is assumed to remain relatively constant over a wide range of temperature and irradiance values. In Spite of the relative ease of implementation and low costs, this method suffers from two major disadvantages. First, the MPP may not be tracked accurately.Second, measurement of V_{oc} requires periodic shedding of the load, which may interfere with circuit operation and will cause more power losses. To prevent this loss of power, pilot cell shaves been used to obtain V_{oc} [11–13]. These pilot cells must with load interruption, a more straight forward, but be carefully chosen so that the characteristics of the PV array are represented realistically.

Short Circuit Current (SCC) Method. This method represents another Indirect approach [14–18] which is relatively similar to the OCV method.There is also an approximately linear relationship between the short circuit current (I_{sc}) of the solar panel and the MPP current (I_{mp}), which can be described by the following equation:

$$I_{mp} = K_I \cdot I_{sc}, \quad (2)$$

where K_I is a constant in range 0,8...0,9.

Similar to the OCV method, the load should be she din order to determine the ISC. While the SCC method is more accurate and efficient than the OCV method [17], due to practical issues associated with measuring the ISC, its simple mutation costs are higher. In [18], a boost converter is used, where the switch in the converter itself can be used to apply a short circuit to the PV array. An improvement similar to that proposed above for the OCV method can be applied to the SCC method. In particular, power losses associated with load interruption can be avoided if the measurement of the temperature and irradiance is employed to estimate the SCC based on the governing model equations.

Direct Methods

In Direct methods usually the instantaneous values of the PV output voltage or current are used to generate the control signals. The direct methods Perturbation and observation method (P&O), and as well as the incremental conductance method (IncCond).

Perturbation And Observation (P&O) Method. P&O method is one of the most widely used MPPT methods because of its simplicity and ease to implement. It works by creating a perturbation in terminal DC voltage of the PV array and observes its consequences on the output power of the PV array. It continues to make perturbation in the same direction, otherwise it is reversed. In case of power increase with incremental perturbation, the operating point would be on the left hand side of the maximum power point. If incremental perturbation causes power to decrease, it indicates that MPP has crossed and operating point is some where on the right hand side of MPP. In this case, it reverses its perturbation and start power point. Once the MPP is achieved, the operating point would be at maximum power point as shown in Fig. 4. Making detrimental perturbation in the voltage of PV array in order to track the maximum.

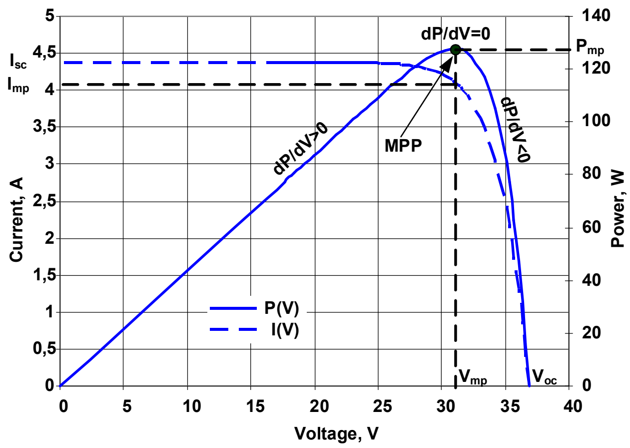


Fig. 4. Perturb and Observe (P & O)

It has three conditions:

$$\begin{aligned} &dP/dV > 0 \text{ (Left hand side of MPP);} \\ &dP/dV < 0 \text{ (Right hand side of MPP);} \quad (3) \\ &dP/dV = 0 \text{ (At MPP).} \end{aligned}$$

It can also be seen from Fig. 4. That voltage corresponding to MPP called Vmp and current I called I_{mp}. These values at STC are available in the data sheet of every PV module.

Incremental Conductance (IncCond) Method. In order to avoid the drawbacks caused by P&O method, Incremental Conductance (IncCond) MPPT techniques is developed. This method provides better results in tracking the MPP without having many oscillations around maximum power point. This method based on the fact that the slope of the power curve is zero at MPP. Calculating the slope of the power curve as shown in Eq. 3. Can be note of the Fig. 5. Three regions:

$$dI/dV > -I/V \text{ (Left of MPP)};$$
$$dI/dV < -I/V \text{ (Right of MPP)}; \qquad (4)$$
$$dI/dV = -I/V \text{ (At MPP)}.$$

From Fig. 5 it is clear that if dI/dV > -I/V holds, operating point is at the left of the MPP and voltage needs to be increased to track towards MPP. Similarly, if I/dev< -I/V holds, then voltage should be decreased in order to find MPP. But if dI/dV= -I/V holds, there is no need to change the terminal DC voltage as in this case it is already at MPP. The decision to select a given MPPT.

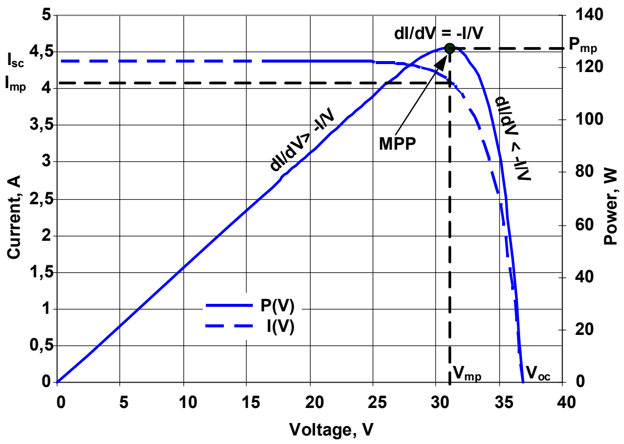


Fig. 5. Incremental Conductance (IncCond)

Conclusion

Several MPPT methods have been scanned and their advantages and disadvantages were compared based on simulations. These methods have been classified into two categories: indirect, direct methods. This classification is based on the approach used for generation of the control signal as well as the PV system behavior around the steady state conditions. The results indicate that the implementation considerations influence both the efficiency and the dynamic response of the system. In particular, methods with low cost, low hardware requirements and easy implementation exhibit relatively poor dynamic response as well as efficiency. Finally, at able is provided which can serve as a guide for selection of the appropriate MPPT method for specific PV system applications.

Also it seems promising to use the SCC method in combination with the control of the pulse-width modulation (PWM) controller, possibly in conjunction with one of the direct methods for periodically verification of K_I. This assumption requires added investigation.

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МЕТОДЫ УПРАВЛЕНИЯ РАБОЧЕЙ ТОЧКОЙ ФОТОЭЛЕКТРИЧЕСКИХ ЭНЕРГОУСТАНОВОК

Али. М. Джасим, Ю. А. Шепетов

В данной статье выполнен обзор и классификация современных методов удержания рабочей точки солнечных фотоэлектрических энергоустановок (СФЭУ) в области максимальной выходной мощности. Приведено краткое описание методов. Описаны достоинства и недостатки методов, выполнено их сравнение. Сделан вывод о перспективности использования комбинации различных методов, в т.ч. метода тока короткого замыкания и одного из прямых методов в сочетании с ШИМ (широтно-импульсная модуляция) регулятором выходной мощности СФЭУ. Это утверждение авторы намереваются подтвердить дальнейшим экспериментальным исследованием.

Ключевые слова: фотоэлектрические системы, отслеживание точки максимальной мощности.

МЕТОДИ УПРАВЛІННЯ РОБОЧОЇ ТОЧКИ ФОТОЕЛЕКТРИЧНИХ ЕНЕРГОУСТАНОВОК

Алі. М. Джасім, Ю. О. Шепетов

У даній статті виконано огляд і класифікацію сучасних методів утримання робочої точки сонячних фотоелектричних енергоустановок (СФЕУ) в області максимальної вихідної потужності. Наведено короткий опис методів. Описано переваги і недоліки методів та виконано їх порівняння. Зроблено висновок про перспективність використання комбінації різних методів, в т.ч. методу струму короткого замикання та одного з прямих методів у поєднанні з ШІМ (широтно-імпульсна модуляція) регулятором вихідної потужності СФЕУ. Це твердження автори мають намір підтвердити подальшим експериментальним дослідженням.

Ключові слова: фотоелектричні системи, відстеження точки максимальної потужності.

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