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A maximum power point tracking method with variable weather parameters based on input resistance for photovoltaic system

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ABSTRACT

In order to greatly improve the maximum power point tracking (MPPT) speed and adaptability to the varying weather conditions for photovoltaic (PV) system, in this paper, a MPPT method with variable weather parameters (VWP) considered specially from input resistance standpoint is proposed. As well as other VWP methods, it can also track the maximum power point (MPP) as quickly as possible. In this method, the approximate relationship between control signal and PV cell parameters (V_m and I_m) is firstly built by studying the input resistance of PV system deeply, then the relationship between VWP and V_m, I_m is found by the curve fitting technique. Through these relationships, the bridge between control signal and VWP is built successfully, which is the key work to implement the direct MPPT control. Finally, some simulation experiments show that the proposed method is feasible and available to track the MPP successfully and has better MPPT rapidity, accuracy, stability and adaptability than conventional perturbation and observation (P&O) method and fuzzy control method.

1. Introduction

In order to avoid the produced power losses, now almost all PV systems use the DC/DC converters as MPPT control units. There are many existing MPPT methods such as the constant voltage tracking [1], the P&O method [2,3], the incremental conductance (IncCond) method [3–5], the genetic algorithm [6,7], the fuzzy logic control method [6–8], the neural network method [9,10], the sliding mode control method [11] and the predictive control technique [12–14]. In them, the P&O method is one of most widely used MPPT techniques. Its advantages mainly include the low-cost hardware, the easy implementation and the good performance without solar irradiance and temperature varying quickly with time. However, there are also some shortcomings including its slow tracking speed and oscillation around the MPP. In this paper, in order to study the output performance of proposed MPPT method, the P&O method is selected as the main compared object.

With respect to the issue how the changing weather influence on MPPT control of PV system, some works have been done in papers [15,16]. Remarkably, some VWP methods have been proposed in papers [16–18] to implement the real-time MPPT control for PV systems with different topology. In these methods, the key technique is to find out the relationship between control signal and VWP, and their main advantages are the fast MPPT speed and strong adaptability under varying weather conditions. In this paper, the VWP technique will be studied continuously and considered specially from input resistance of PV system standpoint, which is one of the main aims and innovations in this work.

In existing MPPT methods, except for paper [19], there is hardly a technique specially considered from input resistance of PV system standpoint because of its variability and difficult measurement. In paper [19], a real-time identification scheme using the Lambert W-Function is proposed to estimate the model of PV module and its desired resistance at the MPP. By contrast, in this paper, the input resistance of PV system is only used as a bridge in connecting control signal and cell parameters (V_m and I_m), which lays the foundation of the relationship between control signal and VWP. It is clear that the innovative and reasonable use of input resistance is the key work to study the principle of proposed MPPT method.

On the other hand, there are some MPPT method using the cell parameters V_m and I_m. In paper [20], a linear current control is proposed on the basis of the linear relationship between I_m and the level of irradiance. In paper [21], a feedback MPPT control method is proposed by computing from equations involving temperature and irradiance. In addition, the fractional open-circuit voltage method [22], the ripple correlation control (RCC) method [23] and so on also use V_m or I_m as the key parameter to implement the MPPT control of PV system. However, in all these methods,

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the direct relationship V_m or I_m and weather parameters (irradiance and temperature) is not still found out. Therefore, another purpose of this paper is to build this relationship.

This paper is divided into the following sections: the principle of proposed MPPT method is analyzed in Section 2. The relationship between control signal of PV system and VWP is found out, then the description and implementation of proposed MPPT method are given in Section 3. The feasibility and availability of proposed method are verified and the MPPT rapidity, accuracy, stability and adaptability are compared with P&O method and fuzzy method in Section 4. Some discussions are had in Section 5. Finally, some conclusions are drawn in Section 6.

2. Principle of proposed MPPT method

2.1. Model and input resistance of PV system

The configuration of common PV system can be shown in Fig. 1. Where V and I represent the output voltage and current of PV panel, respectively; V_o and I_o represent the output voltage and current of DC/DC converter, respectively. In Fig. 1, the DC/DC converter between PV panel and load or grid-connected inverter is usually an indispensable unit to implement the MPPT function.

In practical application, the simplified mathematical model of PV panel can be shown in Eq. (1) [24,15]. This model is usually called as "Four-Parameter Model" [15].

$$I = I_{sc}\left[1 - C_1\left(e^{\frac{V}{C_2 V_{oc}}} - 1\right)\right] \tag{1}$$

where $C_1 = (1 - I_m/I_{sc})\exp(-V_m/C_2V_{oc})$; $C_2 = (V_m/V_{oc} - 1)/\ln(1 - I_m/I_{sc})$; I_{sc}, V_{oc}, I_m and V_m represent the short circuit current, the open circuit voltage, the MPP current and voltage at standard conditions (1000 W/m^2 and 25 °C), respectively. All data above are given by the PV panel manufacturer.

When the DC/DC converter shown in Fig. 1 is the buck circuit, the structure of PV system can be shown in Fig. 2. Where R_i represents the input resistance on the right of PV panel. Here, assume that the buck DC/DC converter, which is operating in the continuous conduction operational model, is the ideal circuit and its output load or inverter can be regarded as a pure resistance R_L. According to Fig. 2, Eqs. (2)–(4) can be given by laws of circuit and conservation of energy.

$$R_i = \frac{V}{I} \tag{2}$$

$$P_o = VI = V_o I_o = \frac{V_o^2}{R_L} \tag{3}$$

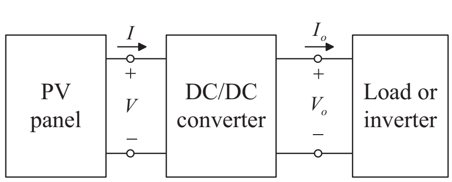

Fig. 1. Structure of common PV system.

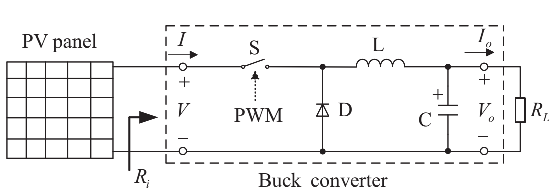

Fig. 2. Structure of PV system with buck DC/DC converter.

$$V_o = DV \tag{4}$$

where P_o and D represent the output power and duty cycle of PWM signal, respectively. According to Eqs. (2)–(4), the input resistance R_i can be expressed easily as Eq. (5) [25].

$$R_i = \frac{R_L}{D^2} \tag{5}$$

Moreover, according to Eqs. (1), (3) and (4), the mathematical model of PV system can be expressed as

$$P_o = \frac{R_L I_{sc}^2}{D^2}\left[1 - C_1\left(e^{\frac{\sqrt{P_o R_L}}{C_2 D V_{oc}}} - 1\right)\right]^2 \tag{6}$$

It is obvious that the model shown in Eq. (6) is the mathematical relationship between control signal D and P_o, which is one of the ideal mathematical models of PV system [17].

2.2. Acquisition of control signal based on input resistance at MPP

Firstly, in practical application, PV system usually operates at the MPP, now Eq. (5) can be replaced as

$$R_{i\text{MPP}} = \left.\frac{R_L}{D^2}\right|_{\text{MPP}} = \frac{R_L}{D_{\max}^2} \tag{7}$$

where $R_{i\text{MPP}}$ and $D_{\max}$ represent the input resistance and duty cycle of PWM signal, of PV system at the MPP, respectively.

Secondly, according to Fig. 2, the input resistance of PV system can also be expressed as

$$R_{i\text{MPP}} = \frac{V_{\text{MPP}}}{I_{\text{MPP}}} \tag{8}$$

where V_{MPP} and I_{MPP} represent the values of V and I corresponding to the MPP, respectively.

According to paper [17], Eq. (9) can be given.

$$V_{\text{MPP}} = C \tag{9}$$

where C is a variable parameter whose value can be calculated by Eq. (10).

$$C = C_2 V_{oc}\left[lambertw\left(e \times \frac{1 + C_1}{C_1}\right) - 1\right] \tag{10}$$

Now, Eq. (11) can be expressed as

$$R_{i\text{MPP}} = \frac{C}{I_{\text{MPP}}} \tag{11}$$

Thirdly, in order to study the input resistance at the MPP in depth, the cell parameters V_m and I_m can be taken into account. Here, a virtual input resistance R_{im} can be introduced and expressed as

$$R_{im} = \frac{V_m}{I_m} \tag{12}$$

According to Eqs. (11) and (12), it is obvious that the inequality $R_{im} \neq R_{i\text{MPP}}$ is usually satisfied because $V_m \neq C$ under a given weather condition. Here, assume that there is the relationship between $R_{i\text{MPP}}$ and R_{im} as shown in Eq. (13). Where R_{iE} represents the error between $R_{i\text{MPP}}$ and R_{im}.

$$R_{iE} = R_{i\text{MPP}} - R_{im} \tag{13}$$

Finally, according to Eqs. (7), (12), and (13), Eq. (14) can be given.

$$D_{\max} = \sqrt{\frac{I_m R_L}{V_m + V_{iE}}} \tag{14}$$

where $V_{iE} = I_m R_{iE}$. Eq. (14) shows the relationship between control signal $D_{\max}$ and cell parameters (V_m and I_m), which is the key