Solar Energy 144 (2017) 175–184

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

A MPPT strategy with variable weather parameters through analyzing the effect of the DC/DC converter to the MPP of PV system

Shaowu Li [a,b,*], Honghua Liao [a], Hailing Yuan [a], Qing Ai [a], Kunyi Chen [a]

[a] School of Information Engineering, Hubei University for Nationalities, Enshi, China
[b] Science and Technology College of Hubei University for Nationalities, Enshi, China

ARTICLE INFO

Article history:
Received 5 July 2016
Received in revised form 12 December 2016
Accepted 3 January 2017

Keywords:
PV system
MPPT
VWP
MPP
DC/DC converter

ABSTRACT

In order to achieve the maximum power point (MPP) of photovoltaic (PV) system as quickly as possible and improve the MPPT adaptability to the varying weather conditions, in this paper, a maximum power point tracking (MPPT) control strategy with variable weather parameters (VWP) is proposed. In this strategy, the MPP difference between PV system with and without DC/DC converter is analyzed and used as the theoretical basis of acquiring the MPP control signal. Meanwhile, the direct relationship between control signal and VWP is found out by the curve-fitting technique, which is the key work to implement this proposed strategy. Finally, some simulation experiments show that the proposed control strategy is feasible and available to track the MPP successfully, and has better MPPT performance than conventional perturbation and observation (P&O) method under different weather conditions and than fuzzy control method under fast changing weather conditions.

1. Introduction

Now almost all PV systems use the MPPT technique to avoid the produced power losses. These methods or strategies for MPPT control are mainly include the constant voltage tracking (Mohanty et al., 2014), the P&O method (Liu et al., 2014; Ahmed and Salam, 2015; Jiang et al., 2014; Ishaque et al., 2014), the incremental conductance (IncCond) method (Ishaque et al., 2014; Sivakumar et al., 2015; Elgendy et al., 2013), the genetic algorithm (Shaiek et al., 2013; Deshkar et al., 2015), the fuzzy logic control method (Mellit and Kalogirou, 2014; Guenounou et al., 2014), the neural network method (Salam et al., 2013), the sliding mode control method (Zhang et al., 2015; Hong and Chen, 2014), the predictive control technique (Tsang and Chan, 2013), and so on. In them, the P&O method, which is regarded as the representation of classical MPPT methods, and the fuzzy control method, which is regarded as the representation of intelligent MPPT methods, have been widely used in practical application. The advantages of P&O method mainly include its low-cost hardware, easy implementation and 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 MPP. The fuzzy control method mainly has the good performance under fast changing weather conditions while carrying its high-cost processor and its difficult acquisition of empirical data. In this paper, the P&O method and the fuzzy control technique are all selected as the compared object in order to study the output performance of proposed MPPT strategy.

With respect to the issue how the MPP of PV system is influenced by the DC/DC converter, hitherto, no work has been done. In this paper, the configuration and mathematical models of PV system with and without DC/DC converter are studied deeply. Through comparing the difference of output parameters of two PV systems at the MPP, the bridge in connecting control signal and the PV panel parameters (V_m and I_m) is built to propose the new MPPT strategy, which is one of the main aims and innovations in this work.

In existing MPPT methods, there are some MPPT methods taking the changing weather conditions in account directly. A MPPT control method while searching for optimal parameters corresponding to weather conditions at that time has been proposed by Nobuyoshi Mutoh, etc. (Mutoh et al., 2006). A novel and fast MPPT method, through using parameter estimation to calculate the solar irradiance and temperature directly, has been proposed

Abbreviations: **PV**, photovoltaic; **MPP**, maximum power point; **MPPT**, maximum power point tracking; **VWP**, variable weather parameters; *S*, solar irradiance; *T*, PV panel temperature; R_L, load resistance or equivalent load resistance.

* Corresponding author at: School of Information Engineering, Hubei University for Nationalities, Enshi, China.

E-mail address: xidu_surfer@163.com (S. Li).

http://dx.doi.org/10.1016/j.solener.2017.01.002
0038-092X/

by Jen-Hao Teng, etc. (Teng et al., 2016). Meanwhile, in order to improve the MPPT speed as well as possible, some VWP methods have been proposed in Li (2015), Li et al. (2013, 2015). Their main advantages are the fast MPPT speed and strong adaptability for varying weather conditions and the key technique is to find out the relationship between control signal and VWP. In this paper, the VWP technique will be studied continuously and considered specially from the effect of the DC/DC converter on the MPP, which is also one of the main aims and innovations in this work.

There are also some MPPT methods using the PV panel parameters V_m and I_m. In paper (Pan et al., 1999), a linear current control is proposed on the basis of the linear relationship between I_m and the level of irradiance. In paper (Takashima et al., 2000), a feedback MPPT control method is proposed by computing from equations involving temperature and irradiance. However, these methods are used difficultly because of the variability and measurement of parameters V_m and I_m. In this paper, the direct relationship V_m or I_m and weather parameters (irradiance S and temperature T) is used successfully, which finds a direction to study new MPPT methods by using the PV panel parameters V_m and I_m.

When it is comes to the MPPT control unit, the basic buck and boost DC/DC converters are usually used in most PV systems because of their simple structure and low cost (Li et al., 2015). Therefore, in this paper, PV system with boost DC/DC converter is selected to study new MPPT control strategy with VWP, and the conclusion on PV system with buck or buck/boost DC/DC converter can be analogy.

This paper is divided into the following sections: the configuration and mathematical models of PV system are studied, and the effect of the DC/DC converter on the MPP is analyzed in Section 2. The MPP difference between PV system with and without DC/DC converter is used to propose the new MPPT control strategy in Section 3. The implementation of proposed MPPT strategy is finished by finding out the relationship between MPP control signal and VWP in Section 4. The feasibility and availability of proposed MPPT strategy are verified, and the MPPT performance are analyzed and compared with P&O method and fuzzy method in Section 5. Some discussions are had in Section 6. Finally, some conclusions are drawn in Section 7.

2. Theoretical basis of proposed MPPT strategy

2.1. Configuration and mathematical models of PV system

The configuration of PV systems with DC/DC converter and without DC/DC converter can be shown in Figs. 1 and 2, respectively. 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; R_i represents the input resistance on the right of PV panel and R_L represent the load resistance or equivalent load resistance.

On the one hand, with respect to PV panel, its mathematical model in practical application can be simplified as Eq. (1) (Moura, 2009, Mutoh et al., 2006), and it has been used widely and is usually called as "Four-Parameter Model" whose basis is the one-diode model (Mutoh et al., 2006).

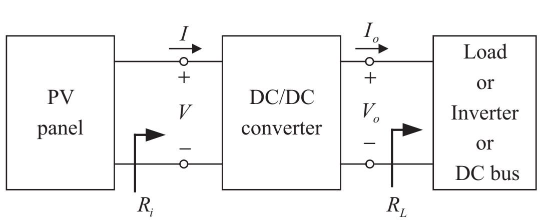

Fig. 1. Configuration of PV system with DC/DC converter.

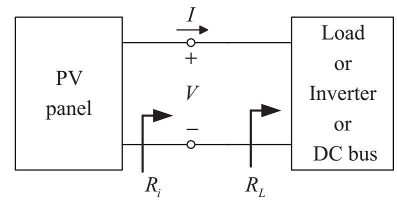

Fig. 2. Configuration of PV system without DC/DC converter.

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

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 testing conditions (1000 W/m^2 and 25 °C), respectively. All data above are usually given by the PV array manufacturer.

On the other hand, according to Figs. 1 and 2, the input resistance R_i can be expressed as

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

In Fig. 1, the mathematical models of PV system can be described by the different equations corresponding to the different DC/DC converters. For example, according to paper (Enrique et al., 2007), R_i in Eq. (2) can be represented by Eqs. (3)–(5) when the DC/DC converters are the buck circuit, boost circuit and buck/boost circuit, respectively. Where D represents the duty cycle of PWM control signal of buck, boost or buck/boost DC/DC converter.

$$R_i = \frac{R_L}{D^2} \tag{3}$$

$$R_i = (1 - D)^2 R_L \tag{4}$$

$$R_i = \frac{(1 - D)^2}{D^2} R_L \tag{5}$$

Here, to make the theoretical analysis simple, PV system with boost DC/DC converter will be selected as the studied object. When the buck circuit or buck/boost circuit is selected as the DC/DC converter of PV system, the analogical conclusion can be drawn.

In Fig. 2, R_i in Eq. (2) can be represented by Eq. (6).

$$R_i = R_L \tag{6}$$

According to Eq. (4), it is known that R_i can be changed by the changing D or R_L, which is the MPPT principle of using boost DC/DC converter. Likewise, according to Eq. (6), R_i can also be changed by the changing R_L. However, in practical application, R_L need commonly keep constant, therefore, normally, PV system shown in Fig. 2 cannot operate at the MPP. In this paper, when the effect of the DC/DC converter to the MPP is analyzed, assume that the available R_L is selected to make PV system shown in Fig. 2 operating at the MPP, and that PV systems shown in Figs. 1 and 2 are all operating under the same irradiance and temperature conditions.

2.2. Analysis on the effect of the DC/DC converter to the MPP

In order to analyze the effect of the DC/DC converter to the MPP, firstly, the mathematical models of PV systems with and without DC/DC converter operating at the MPP should be studied, respectively.

On the one hand, when PV system shown in Fig. 1 with boost DC/DC converter is operating at the MPP, Fig. 1 can be replaced by Fig. 3. Where R_{iMPP} represents the input resistance at the MPP;