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A comparative study of the maximum power point tracking methods for PV systems

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ABSTRACT

Maximum power point tracking (MPPT) algorithms play an important role in the optimization of the power and efficiency of a photovoltaic (PV) generation system. According to the contradiction of the classical Perturb and Observe (P&Oa) method between the corresponding speed and the tracking accuracy on steady-state, an improved P&O (P&Ob) method has been put forward in this paper by using the Atken interpolation algorithm. To validate the correctness and performance of the proposed method, simulation and experimental study have been implemented. Simulation models of classical P&Oa method and improved P&Ob method have been established by MATLAB/Simulink to analyze each technique under varying solar irradiation and temperature. The experimental results show that the tracking efficiency of P&Ob method is an average of 93% compared to 72% for P&Oa method, this conclusion basically agree with the simulation study. Finally, we proposed the applicable conditions and scope of these MPPT methods in the practical application.

1. Introduction

Solar energy is clean, inexhaustible and free as one of the most important renewable energy. The application of photovoltaic (PV) system becomes more and more widely, the main application of PV systems are in either stand-alone or grid-connected configurations. Solar PV generation is an important form of solar energy utilization, it is one of the most promising power generation technologies due to restrictions from raw materials and application environment. There are two major technical difficulties of PV generation systems in the application. Firstly, the conversion efficiency of electric power generation is low. Generally, laboratory cell efficiency is approximately 18–20% and the commercial cell efficiency is about 13–18%; Secondly, the output power of PV cells is influenced by the radiance and ambient temperature. In order to overcome these problems, we should track the maximum power point of the PV cells' output power, thus improving the efficiency of the PV power generation system, reducing the cost of power generation [1,2].

In recent years, many MPPT techniques have been proposed by scholars; such as Constant Voltage (CV) method, Perturb and Observe (P&O) method, Incremental Conductance (IC) method, Fuzzy Logic method, and Artificial Neural Network method. The P&O method has been widely used for its simple control algorithm and less measured parameters. Even though the P&O method with an easy control algorithm, it has a great oscillation around MPP which will lead to a certain amount of power loss [3]. Some improved IC methods are also proposed by researchers [4,5], which can eliminate the oscillations around the MPP, however, these methods need high precision sensor to measure the voltage or current, so the cost of hardware is higher. In Fu-Sheng et al. [6], a new method based on parabolic estimation MPPT algorithm to obtain the maximum power point is proposed. This method can operate well both in the fast changing and the stable atmospheric conditions, but the tracking speed of this method is limited [6].

In this paper, an improved P&O method based on CV method and Atken interpolation technique is proposed in order to enhance the tracking efficiency. When the solar irradiance changes under sudden increase or decrease, the CV method is used to adjust the working point of PV cell near the MPP. On the basis, Atken interpolation technique is used for further improve the tracking efficiency of PV cell. This method avoids the drawbacks of classical P&O method and can largely improve the tracking efficiency of PV system.

2. PV panel model

A PV cell is composed by a *P–N* semiconductor junction, it is possible to directly convert light to electricity. And a PV array is

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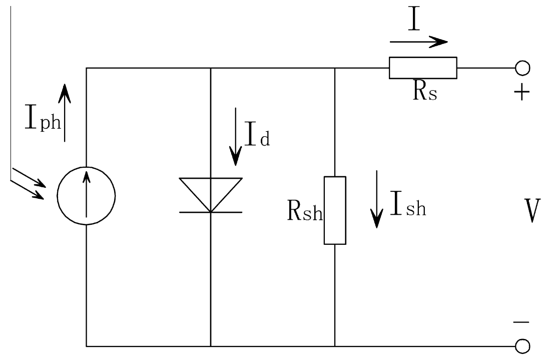

Fig. 1. Equivalent circuit of PV cell.

composed of many PV cells. The PV cell equivalent circuit is shown in Fig. 1. The model includes a photovoltaic current generator in parallel with a diode and a serial resistor, R_s for the interface metal semiconductor and the intrinsic silicon resistances and with a shunt resistor, R_{sh} for the surface roughness along the cell periphery [7]. From Fig. 1, the mathematical expression of current I for PV cell is given by:

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

$$I = I_{ph} - I_0\{\exp[q(V + IR_s)/AKT] - 1\} - (V + IR_s)/R_{sh} \tag{2}$$

where I_{ph} is the internal photocurrent of photovoltaic cells and I_0 is the total diffusion current through the P–N junction, A is an ideality factor of the P–N junction, K is the Boltzmann constant equal to 1.38×10^{-23}J/K. T is the temperature of P–N junction in K, q is the electron charge (1.60218×10^{-23}C).

Solar cell is a nonlinear system, in Eq. (2) the ideality factor of the P–N junction A, the total diffusion current through the P–N junction I_0 the series resistance R_s and the parallel resistance R_{sh} are important factors that affect the power characteristics of PV cells. Therefore, it is crucial to determine the value of these factors.

Table 1
Electrical characteristics of PV panel.

Symbol	Meaning	Value
P_{max}	Maximum power	230 W
V_m	Voltage at P_{max}	29.5 V
I_m	Current at P_{max}	7.8 A
V_{oc}	Open-circuit voltage	36.8 V
I_{sc}	Short-circuit current	8.45 A

For crystalline silicon PV modules, the value of ideality factor is between 1 and 1.3 [8]. When the value of A between 1 and 1.3, the maximum power point in different I-V curves almost coincides, that is, the value of A almost has no effect on the maximum power point. Thus, in this paper, the value of A will take that $A = 1$.

The value of R_{sh} impact little on the output characteristics of PV cells, while R_s has a big influence on the output characteristics of PV cells. Therefore, the value of R_{sh} can be neglected. Eq. (2) can be simplified as:

$$I = I_{ph} - I_0\{\exp[q(V + IR_s)/AKT] - 1\}, \tag{3}$$

In open circuit conditions, $I = 0$, we can obtain the equations as follows:

$$V_{oc} = (AKT/q)\ln[(I_{ph}/I_0) + 1] \approx (AKT/q)\ln(I_{ph}/I_0), \tag{4}$$

The I_0 value is obtained by Eq. (4):

$$I_0 = I_{ph}\exp(-qV/AKT), \tag{5}$$

The reverse saturation current of the diode is very low in the order 10^{-5} to 10^{-6} A, therefore the current photocurrent is equal to the short circuit Ref. [9].

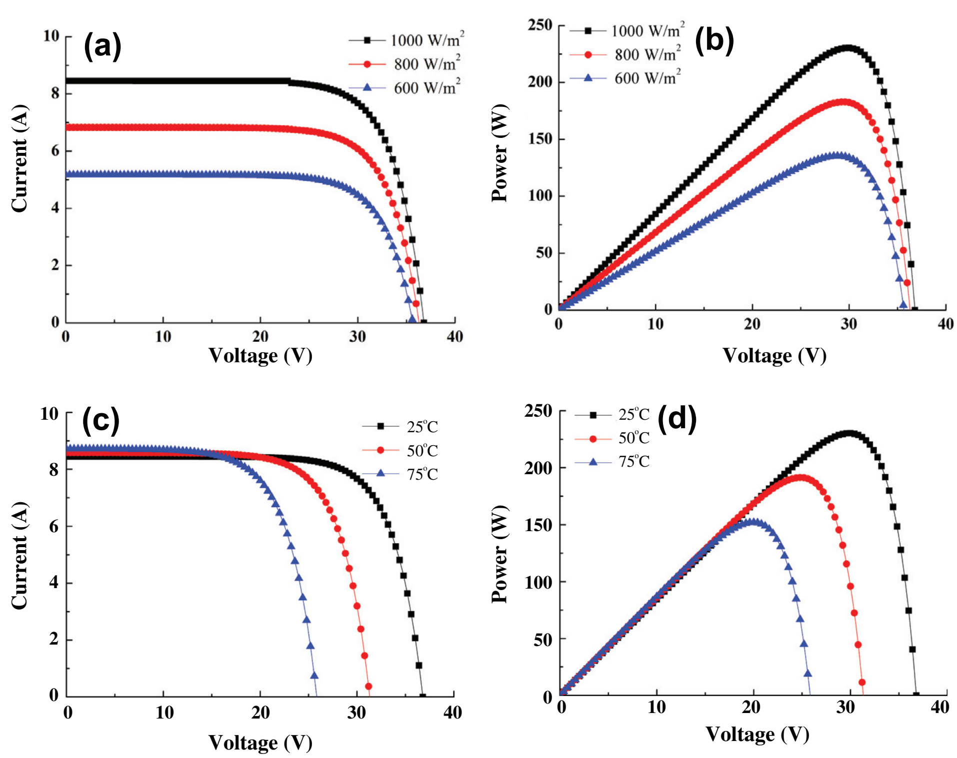

Fig. 2. The I–V, P–V curves of PV panel: (a) T = 25 °C, the I–V curves under different irradiance, (b) T = 25 °C, the P–V curves under different irradiance, (c) S = 1000 W/m^2, the I–V curves under different temperature, and (d) S = 1000 W/m^2, the P–V curves under different temperature.