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Improvement of parameter identification method for the photovoltaic cell

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ABSTRACT

The parameters of photovoltaic (PV) cell may change with the operation conditions. Thus it is important to identify these parameters according to the measured data. In this paper, a four-parameter model was used to describe the PV cell. A method of nonlinear least squares based on stepwise linear search was proposed to identify the parameters of the model. The feasibility of the method was proved by the comparison between the identification curve and the measured data. The results have shown that this method has the advantages of high accuracy and simple realization. Moreover, the three coefficients (α, β and γ) in the model were optimized further. The parameter identification and coefficient optimization (PI-CO) iterative method was proposed through the combination of parameter identification and coefficient optimization. In the iterative process, the values of the parameters and coefficients converged to the optimal points quickly, and the objective function value also decreased gradually, which showed that PI-CO iterative method can further improve the simulation accuracy.

1. Introduction

Solar energy always attracts scientists and technician's attention, since it is the most promising renewable energy source, especially in the domain of power generation. The PV array which is consisted by PV cells is an important part of the PV power generation system [1,2]. The accurate description of the electrical characteristics of the PV cell is vital to optimize the electrical behavior of the PV source. Up to now, many models have been used to describe the current-voltage (I–V) characteristic of the PV cell have been proposed [3–6]. These models contain some parameters which are related to the intrinsic characteristics of the PV cell. Through the accurate identification of these parameters, the simulation accuracy of the model can be improved. It is benefit to the research of the PV system characteristics. Also, the variation of the parameters can be used to further research the cause of the PV module failure [7,8]. Therefore, it is significant to identify the internal parameters of PV cells.

The methods for the parameter estimation of the PV model can be classified into three categories, the analytical, the numerical and the bio-inspired optimization methods. The analytical technique is based on the key points at the I–V curves [9–12]. It is easy to implement, but the error can be large and hardly be improved if the value of the key points are wrong. The numerical technique adopts iterative method usually [13–15]. It fit theoretical I–V curves to the experimental data. The

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results are often more accurate since all measured data can be used in the fitting process. The performance of this method depends on the type of fitting algorithms, the selected function as well as the initial values of the parameters. Sometimes, it has long running time and slow convergence speed if the number of measured data is large. The bio-inspired method is also called intelligent algorithm, including genetic algorithm, particle swarm optimization, bacterial foraging algorithm and Artificial Bee Colony etc [16–21]. They search for the optimal values of parameters based on biological foraging. Compared to the front two methods, the bio-inspired method has obvious advantages in terms of accuracy and reliability. However, the problems that most bio-inspired methods have still can not be solved completely, such as long optimization time, easy to fall into premature and complicated to be implemented. Moreover, the optimal results are related to the setting of internal search parameters closely.

Upon these problems, this paper established a four-parameter model for the PV cell, and further proposed a parameter identification method based on step by step linear search. Because the coefficients in the model are related to the material of the PV module, the values of them can affect the accuracy of the parameters directly. Thus a method of PI-CO iteration was formed. The results showed that this method converges fast and could improve the accuracy of simulation further.

2. Model of PV array

The PV array in the PV power generation system is composed of a series of PV cells. Therefore, the research on the mathematical model of PV cell is the foundation for the simulation of the PV array.

2.1. Model of PV cell

The single diode equivalent circuit presented in Fig. 1 can be applied to describe the working mechanism of the PV cell [22]. Ignoring the capacitance of PN junction, it contains series resistance R_s and bleeder resistance R_{sh}. R_L is the external load. U_L and I_L are output voltage and current of the PV cell respectively.

The relation between I_L and U_L can be shown as,

$$I_L = I_{sc} - I_0 \left\{ \exp\left[\frac{q(U_L + I_L R_s)}{AKT} - 1\right]\right\} - \frac{(U_L + I_L R_s)}{R_{sh}} \tag{1}$$

Where I_{sc} and I_0 represent photocurrent and the saturation current of the PV cell respectively. q is the electronic charge. A is a constant factor and its value is 1.3 generally. K is Boltzmann constant. T denotes the absolute temperature of the PV cell.

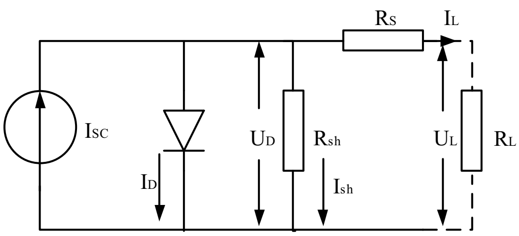

Fig. 1. Single diode equivalent circuit of the PV cell.

2.2. Four-parameter model of the PV cell

Formula (1) is a transcendental equation which is difficult to get the solution. Under the condition that the precision can be ensured, it needs to be simplified and transformed. Thus a four-parameter model is proposed.

Manufacturers provide five characteristic values of the PV cell at the standard test condition usually. These characteristic values include the short-circuit current I_{sc}, open circuit voltage U_{oc}, maximum output power P_m, voltage U_m and current I_m. In general operating condition, we need to deduce the value of them from the given standard one. Let I_{sc}, U_{oc}, U_m and I_m be the values of general operating condition, I_{sc0}, U_{oc0}, U_{m0} and I_{m0} denote the standard one. The output of PV cell is related with irradiance and temperature mainly. Suppose S_{nom} and T_{nom} to be standard irradiance and temperature,

The temperature difference ΔT between general condition and standard one and the relative irradiance difference ΔS can be respectively expressed as,

$$\Delta T = T - T_{nom} \tag{2}$$

$$\Delta S = \frac{S}{S_{nom}} - 1 \tag{3}$$