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Artificial bee swarm optimization algorithm for parameters identification of solar cell models

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HIGHLIGHTS

- ▶ Artificial bee swarm optimization (ABSO) is proposed to identify the solar cell parameters.
- ▶ The performance of ABSO algorithm is quite promising.
- ▶ The results of ABSO outperform those of the other studied algorithms.
- ▶ ABSO is a helpful technique for solar cell parameters identification.

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ABSTRACT

An accurate mathematical model is an extremely helpful tool for simulation, evaluation, control, and optimization of solar cell systems. Due to the non-linearity of the solar cell models and the inability of traditional optimization methods to accurately identify the unknown parameters, recently, metaheuristic algorithms have attracted significant attention. Artificial bee swarm optimization (ABSO) is a recently invented algorithm inspired by the intelligent behaviors of honey bees such as collection and processing of nectar. In this paper, we propose an ABSO-based parameter identification technique based on the single and double diode models for a 57 mm diameter commercial (R.T.C. France) silicon solar cell. The results obtained by ABSO algorithm are quite promising and outperform those found by the other studied methods.

1. Introduction

Thanks to the growing price of fossil fuels and air pollution, the tendency to use renewable energy sources has noticeably increased over the past years. Among renewable energy sources, solar cells are being used all over the world to produce electricity not only for the high demand of electrical power, but also for their promising features like easy installation, little maintenance, no pollution, and noise-free.

Solar cell accurate modeling has received significant attention in recent years [1–5]. Solar cell modeling primarily involves the formulation of the non-linear current vs. voltage (*I–V*) curve. Several models have been developed to represent the behavior of the system under different operating conditions. They vary from models with simple assumptions to advanced models accompanying with many physical variables. Nevertheless, two solar cell models are widely used in practice: the single and double diode models. The single diode model is much more common than its counterpart. This model contains five unknown parameters while the double diode model has seven unknown parameters. Accurate determination of the parameters plays an important role in solar cell simulation, performance evaluation, design, optimization, and control. Therefore, parameters identification with the help of a capable optimization technique is necessity.

Two main approaches have been used in the literature to solve the parameter identification problem: traditional [6–9] and metaheuristic [10–12] search approaches. In [6] a modified non-linear least error squares estimation approach based on Newton's method has been developed to obtain solar cell parameters. Dependency on the initial point used in the iterative method is a major deficiency of this approach. Besides, this type of optimization method is local in nature and may achieve a local optimum rather than a global one if multiple solutions exist. Similar analytical methods have been proposed in [7–9]. These traditional optimization techniques needing continuity, convexity and differentiability conditions for being applicable, involve heavy computations, are sensitive to the initial solution, and most often lead to local optima. Another reason for the inability of traditional methods to

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effectively solve the parameter identification problem is the non-linearity of the solar cell characteristic. As a result, in solar cell optimization problems, to increase the probability of obtaining the global solution at a reasonable time, metaheuristic search approaches have been proposed [13–16]. In the literature, solving the problem of solar cell parameter identification can be addressed by genetic algorithm (GA) [10], particle swarm optimization (PSO) [11], and simulated annealing (SA) [12]. Although these metaheuristic algorithms yield better results than traditional ones, they have their respective limits [17]. As the most popular metaheuristic algorithm, GA frequently finds promising regions of search space quickly, but it has some drawbacks: it has a trend to converge towards local optima rather than the global optimum, unless the objective function is defined well; suffers from the lack of good local search ability; and simpler optimization algorithms may find better solutions than GA at a same amount of computation time. In comparison with GA, the advantages of PSO are that it is easy to implement and there are few parameters to adjust. Nevertheless, this algorithm has some drawbacks: PSO performance depends strongly on its parameters; it might easily lose the diversity; and may be influenced by premature convergence, especially when the best solution is a local one. SA is another metaheuristic trying to simulate the process of annealing in metallurgy. Due to the fact that SA is a solo-searcher, its performance is sensitive to the starting point of the search. Furthermore, there is no rigorous theoretical foundation for determining SA parameters, particularly the parameters of the cooling schedule. The selection of these parameters is extremely difficult and the designer needs to trial in order to obtain values that can provide a proper optimization in a reasonable amount of computational time.

The non-linearity of the solar cell characteristics expects a high-performance optimization technique. The success of an optimization algorithm depends strongly on the ability of providing a good balance between exploration and exploitation. Exploration refers to generation of new solutions in as yet unseen regions of the search space and exploitation means the concentration of the algorithm's search at the vicinity of current good solutions. The inability of the algorithm to make a good balance between exploration and exploitation leads to premature convergence, getting trapped in a local optima, and stagnation. Motivated by the swarm behavior of honey bees, bee algorithms (BAs) are recently invented metaheuristic optimization techniques. BAs employ different kinds of bees with different updating patterns to probe the search space. Using distinct updating patterns increases the flexibility of the algorithm to establish good balance between exploration and exploitation. Hence, BAs are promising algorithms that have more chance than the other algorithms to find the optimal parameters of solar cells which are closer to the real ones. The effectiveness of BAs has led to their application to optimization problems in different areas [18–21]. Different approaches have been developed for simulating the intelligent behavior of honey bees [20–23]. Here, artificial bee swarm optimization algorithm, ABSO, proposed by the authors [20] is used to solve the parameter identification problem. In ABSO, two kinds of bees are employed: onlooker and scout bees. Scout bees are those bees that try to provide exploration while the most focus of onlooker bees is to provide exploitation.

In this paper, ABSO is applied to identify the optimal parameters of a 57 mm diameter commercial (R.T.C. France) silicon solar cell [6]. In order to evaluate the ABSO performance, the obtained results are compared with those of genetic algorithm (GA), chaos particle swarm optimization (CPSO), simulated annealing (SA), pattern search (PS), and harmony search (HS) algorithm.

The rest of this paper is arranged as follows: Section 2 provides a description of the solar cell models; In Section 3, ABSO algorithm is explained in detail; Simulation results and discussions are reported in Section 4, and finally, conclusion is stated is Section 5.

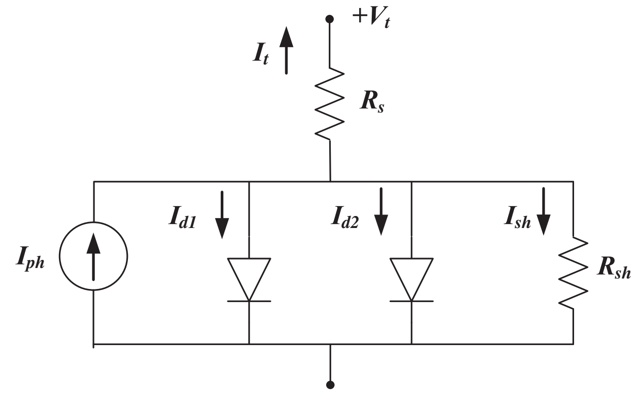

Fig. 1. The double diode model of solar cell.

2. Problem formulation

2.1. Solar cell models

Several models have been developed to describe the *I–V* characteristic of solar cells, but only two models are used in practice. These models will be briefly discussed in the following subsections.

2.1.1. Double diode model

For modeling an ideal solar cell under illumination, a light-generated current source is shunted with a rectifying diode. Nevertheless, in practice to consider the space charge recombination current the current source is also shunted with another diode and a shunt leakage resistor to take into account the partial short circuit current path near the cell's edges related to the semiconductor impurities and non-idealities. In addition, due to the solar cell metal contacts and the semiconductor material bulk resistance, a series resistor is connected with the cell shunt elements [24]. The equivalent circuit of the double diode model is as Fig. 1.

The terminal current, I_t, can be written as follows:

$$I_t = I_{ph} - I_{d1} - I_{d2} - I_{sh} \quad (1)$$

where I_{ph} is the photo-generated current, I_{d1} denotes the first diode current, I_{d2} is the second diode current, and I_{sh} denotes the shunt resistor current.

Considering Shockley equation for the diodes currents and substituting the current of the shunt resistor, Eq. (1) is rewritten as the following form:

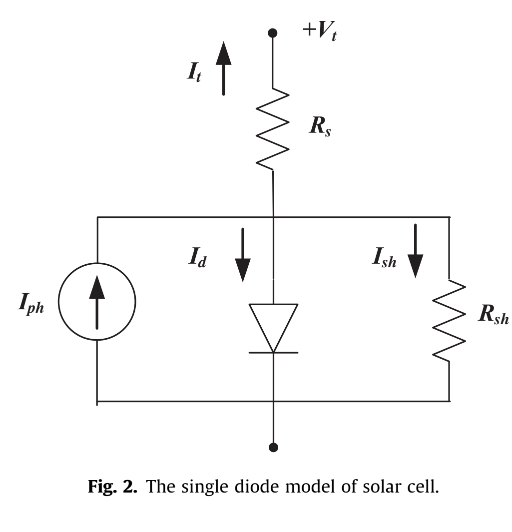

Fig. 2. The single diode model of solar cell.