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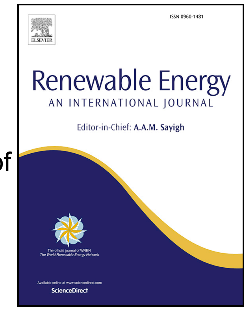

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Parameter estimation of solar cells using datasheet information with the application of an adaptive differential evolution algorithm

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Abstract: A solar cell or photovoltaic (PV) module is electrically represented by an appropriate circuit model with certain defined parameters. The parameters are required to be correctly computed from solar cell characteristic and/or a set of experimental data for simulation and control of the PV system. However, experimental data or accurate characteristic data (i.e. current-voltage or I-V curve) of a PV module may not be readily available. The manufacturer of a PV system usually provides relevant information on open circuit, short circuit and maximum power points. Therefore, an alternate approach is to estimate the PV system parameters by utilizing the I-V characteristic data at these three major points. The process involves formulation and solution of complex non-linear equations from an adopted solar cell model. This paper proposes an application of an advanced adaptive differential evolution algorithm on the problem of PV module parameter estimation using minimum available information from the manufacturer datasheet by implementing single-diode and double-diode models. Linear population size reduction technique of success history based adaptive differential evolution (L-SHADE) algorithm is implemented to minimize the error of current-voltage relationships at the above-mentioned three important points defining the I-V characteristic. The algorithm facilitates evolution of solutions that result in almost zero error ($< 10^{-12}$) at these three major points. All relevant parameters of the PV cell are optimized by the algorithm without an assumption or predetermination of any parameter. It is observed that a set of feasible solutions (parameters) is obtained for the PV module from multiple runs of the algorithm. The fact of attaining several probable solutions from datasheet information using few other metaheuristics is also discussed in this work.

Keywords: Photovoltaic module · Parameter estimation · Single-diode model · Double-diode model · Current-voltage characteristic · Adaptive differential evolution algorithm

1. Introduction

Depletion of fossil fuels, environmental regulation and carbon tax imposition in many countries force mankind to look for clean, replenishable sources of energy. Solar energy is a popular form of renewable energy as it is abundant and almost ubiquitous. The energy can be directly converted to electricity by photovoltaic (PV) system. The unit of a PV system is the PV cell. Normally, many PV cells are grouped together to form a PV module. The array of PV modules can directly feed small DC loads. However, converter is necessary for larger application of the electricity generated by the PV system. For effective utilization, the PV device is needed to be operated at maximum power point (MPP). Therefore, a designer must know the appropriate model of a PV cell for the detailed study, simulation and analysis.

A PV cell is a p-n junction diode, typically represented with an equivalent electrical circuit [1]. Depending on the accuracy sought, the designer can assume a model with one, two or even more diodes. Single-diode model has been the most popular model due to its simplicity coupled with an acceptable level of accuracy in representing the I-V characteristic. Double-diode model accounts for the loss in the depletion region caused by the recombination of carriers [2]. Though three-diode model has been studied in literature [3-4], the model has not been so popular as increment in accuracy with this model is not high enough considering the escalation in complexity due to addition of one more diode [5]. No matter whatever circuit model is adopted for the PV system, finding the optimum circuit parameters requires solution of transcendental equations relating I-V characteristic of the PV device. For a single-diode model, the parameters to be found are the diode ideality factor (a), the photocurrent (I_{PV}), the reverse saturation current of the diode (I_O), the series resistance (R_S) and the parallel resistance (R_P). Population based metaheuristic methods have been very effective in solving non-linear, multimodal optimization problems. In recent years, several evolutionary algorithms (EAs) have been applied in finding optimal parameters of a PV cell. Usually an error function between the sets of experimental and the simulated I-V data of the PV system is minimized by the EAs to provide optimal cell parameters. Variants of particle swarm optimization (PSO)

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