Photovoltaic Model Identification Using Particle Swarm Optimization With Inverse Barrier Constraint

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***Abstract*—The photovoltaic (PV) model is used in simulation studies to validate system design such as the maximum power point tracking algorithm and microgrid system. It is often difficult to simulate a PV module characteristic under different environmental conditions due to the limited information provided by the manufacturers. In this paper, a new approach using particle swarm optimization (PSO) with inverse barrier constraint is proposed to determine the unknown PV model parameters. The proposed method has been validated with three different PV technologies and the results show that the maximum mean modeling error at maximum power point is less than 0.02% for $P_{\rm mp}$ and 0.3% for $V_{\rm mp}$.**

***Index Terms*—Inverse-barrier method, maximum power point (MPP), particle swarm optimization (PSO), photovoltaic (PV) model.**

I. Introduction

THE USE of photovoltaic power as a source of energy has become increasingly important in recent years. Environmental effects such as irradiation and temperature affect the performance of the photovoltaic (PV) system [1]. Ideally, the PV module operates at the maximum power point (MPP). This has led to further research in real-time optimization algorithms such as the improved perturb and observe techniques, neutral network, fuzzy logic, etc [2]–[10]. As a result, it is important to have an accurate and comprehensive PV model that can provide the required results for system design and simulation study under different environmental conditions.

Table I shows the typical parameters under standard test conditions (STC), provided in the datasheet from the manufacturer. It is observed that only the short-circuit current $I_{\rm sc}$, the maximum power voltage $V_{\rm mp}$, the maximum power current $I_{\rm mp}$ and the open circuit voltage $V_{\rm oc}$ are provided. Thus, the data is insufficient to replicate the *I–V* characteristic curves under different temperatures and irradiances.

Over the past few years, due to its simplicty, many research works have been conducted using the single diode PV model. Fig. 1 shows the model and the main issue which is to determine the five unknown parameters namely the ideality factor

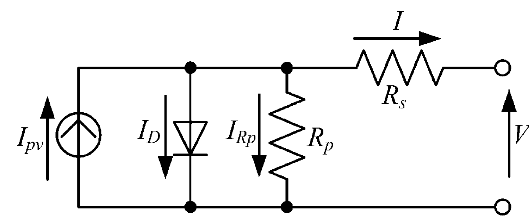

Fig. 1. Electrical model of a PV module.

a, photovoltaic current $I_{\rm pv}$, reverse saturation current I_o, series resistance R_s, and parallel resistance R_p. These parameters must be determined by using measurement, analytical calculation, or numerical iteration.

By removing both the resistances from the model in Fig. 1, the ideal model [11], [12] can be obtained. It has the advantage of simplicity at the expense of accuracy. In [13]–[17], the use of four parameter models with R_p taken as infinite is proposed. Although it simplifies the parameters identification, its accuracy is less competitive as compared to the five parameters model [18].

As a means to generate accurate MPP at different temperatures, the authors in [15] proposed a data-based approach by using the MPP at different temperatures obtained from the manufacturer. The diode ideality factor is adjusted to match the MPP by iteration. The main issue of this approach is the availability of MPP at different temperatures, which are not provided in the manufacturer datasheet.

In order to overcome the needs for obtaining parameters from the manufacturer, the authors in [19] presented a five parameters PV model using the nominal values from the datasheet. The parameter a is estimated by trial and error, whereas R_s and R_p are obtained by increasing the value of R_s. This is achieved by calculating R_p until the maximum power of the model matches the manufacturer's experimental data under STC. Once the parameters a, R_s, and R_p are obtained, they are fixed to recalculate the model with respect to the effects of irradiation and temperature. This method gives almost zero MPP error under STC condition. However, the accuracy degrades if there is a change of temperature [20].

With the aim of avoiding the need to estimate any unknown parameters for the PV model, the authors in [21] proposed the use of field test data together with particle swarm optimization (PSO) to search for a, R_s, and R_p. The field test requires the measurement of data such as the load and short circuit currents.

To overcome some of these shortcomings, this paper proposes a novel method to determine the unknown parameters (a, R_s, and R_p) of the single-diode model. This is achieved by developing a new PSO with an inverse barrier constraint while taking into

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