

Mathematical Model for Computing Maximum Power Output of a PV Solar Module and Experimental Validation

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Abstract

The conversion of solar radiation into electricity has been extensively studied by many authors. In particular, photovoltaic (PV) cells allow the energy transported by electromagnetic waves (i.e., photons) to be directly converted into electricity. Predicting the performance of PV panels is essential for design engineers. From the characteristic I–V curve of a given PV cell, three key physical quantities are defined: the short-circuit current, the open-circuit voltage, and the values of current and voltage that permit the maximum power to be obtained. These variables correspond to well-defined points in the I–V plane. The determination of these points is essential for the development of appropriate PV cell models. The nonlinear and implicit relationships that exist between them, however, necessitate using iterative numerical calculations. Furthermore, most of these parameters depend on both the cell temperature and the solar irradiance; therefore, the knowledge of their behavior is crucial to correctly predict the performance of PV cells and arrays. In terrestrial applications, solar cells are generally exposed to temperatures varying from 10 °C

to 50 °C. The performance of a solar cell is influenced by temperature as its performance parameters, namely, open-circuit voltage (V_{oc}), short-circuit current (I_{sc}), curve factor (CF), and efficiency, are temperature dependent.

Many mathematical models have been developed to estimate PV efficiency, power, short-circuit current, and open-circuit voltage. An excellent review of different correlations is used to determine these quantities as a function of irradiance and cell temperature [8]. An explicit model was developed in [1] to determine currents and voltages for PV points by using manufacturers' data, where the electrical current changes linearly with irradiance and temperature, while voltages are expressed by temperature coefficients and a correlation term for the irradiance. An analytical model based on manufacturers' data was presented in [6]. The authors have explicitly expressed the PV current and power as a function of voltage by using a shading linear factor expressed for open-circuit voltage losses for irradiances from 1,000 W/m² to 200 W/m²; I–V and P–V curves can thus be produced without calculating explicit expressions of current and voltage at key operational points. It must be pointed out that most of the aforementioned works deal with models that are essentially based on linear temperature and irradiance relationships that require parameters which are not available from manufacturers' datasheets. In the current study,