Abstract

This thesis presents a new approach for converting the implicit current-voltage (I-V) expression of a photovoltaic (PV) module into an explicit expression of current as a function of voltage. The maximum power point (MPP) of a double diode model (DDM) PV module is estimated directly from the explicit I-V expression of a module under different environmental conditions (DECs). The extension of use of explicit I-V expression to estimate the MPP of a DDM PV module under different shading conditions is also carried out. Since the explicit I-V expression is used for the estimation of the MPP of a DDM PV module under both uniform and non-uniform irradiance conditions, the proposed method is simple, accurate, and efficient. A comparison of the MPP of a DDM PV module, as extracted using the proposed method, with that obtained from different existing methods under various irradiance conditions, is presented. The MPP of the DDM PV array at non-STC (Standard Test Condition), as determined by the proposed method, is verified through experimental measurements and MATLAB simulations. The results show that the estimation of the MPP of a DDM PV module using the proposed method is more accurate and computationally efficient. The explicit I-V expression of a module, used for estimating the MPP, will be useful to PV professionals.

This thesis also presents a novel generalized model of the series-parallel (S-P) connected PV array, along with its circuit equation, and an algorithm for estimating its global maximum power point (GMPP) under partial shading conditions (PSCs). A set theory-based approach is proposed to develop equations in terms of the voltage and current of strings and arrays in the generalized model of the S-P PV configuration under PSCs. Furthermore, a mathematical expression for the iteration voltage is derived based on a generally observed property of local maximum power point (LMPP). The proposed GMPP estimation algorithm converges quickly by simultaneously eliminating non-potential sections and subsections of the power-voltage (P-V) curve of an array. Robustness of the proposed method for GMPP estimation is tested by considering 2,000 random shading patterns generated by MATLAB for two different PV arrays. Comparisons with other existing methods in terms of GMPP estimation accuracy and computational time demonstrate the competitiveness of the proposed method. Experimental validation of the proposed method was conducted using a box with halogen lights to measure the I-V characteristics of a PV array. Both simulation and experimental results demonstrate the superiority of the proposed GMPP estimation method for PV arrays under PSCs, making it valuable for PV professionals.

A novel approach is proposed for estimating the operating point of a photovoltaic (PV) source directly connected to single or multiple loads. This proposed algorithm divides the PV with load system into two components: PV without series resistance, and series resistance with load. The estimation of the operating point for the PV and load combination, using the proposed technique, is carried out by matching the I-V characteristics between the PV without series resistance and the series resistance with load, employing a novel method. As this proposed method is free from derivatives and does not require any prediction of the initial value, the estimation technique is notably simple in terms of computational complexity and applicability. The estimated results obtained from this technique closely match the actual results. Furthermore, the outcomes of this technique surpass those of other methods in terms of computational time. This proposed estimation technique will be beneficial for the design, operation, and maintenance of standalone PV systems, as well as for the energy management of various types of storage systems, such as thermal, mechanical, and chemical, connected to the PV source.

Finally, this thesis introduces a novel algorithm to estimate the parameters of a DDM PV module. Moreover, the bisection method is employed to identify the discrepancy between the MPP voltage obtained and the MPP voltage specified in the datasheet. This iterative process aids in determining the independent parameters, and subsequently, the other dependent parameters.