Solar Energy Materials & Solar Cells 118 (2013) 124–134

Contents lists available at ScienceDirect

Solar Energy Materials & Solar Cells

journal homepage: www.elsevier.com/locate/solmat

Review

Experimental analysis of the maximum power point's properties for four photovoltaic modules from different technologies: Monocrystalline and polycrystalline silicon, CIS and CdTe

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ARTICLE INFO

Article history:
Received 27 August 2012
Received in revised form
6 August 2013
Accepted 9 August 2013
Available online 4 September 2013

Keywords:
PV module
Maximum power point (MPP)
Monocrystalline silicon
Polycrystalline silicon
CdTe
CIS

ABSTRACT

This paper examines the maximum power point's (MPP) properties of PV modules from different technologies: monocrystalline silicon, polycrystalline silicon, CIS and CdTe. The work aims at finding the best way to identify and track the MPP position under changing working conditions. Special attention is paid to the existing correlation between the MPP coordinates and the corresponding working conditions (ambient temperature, global solar radiation) and *I–V* curves' parameters (short circuit current, open circuit voltage). This study, based on outdoor exposure data, reveals quite clearly that the often used correlations, on which some algorithms are based, are most of the time far from the technical reality and that the assumptions used are true and verified only for certain PV technologies and certain working conditions.

Contents

1. Introduction

A photovoltaic array is inherently a nonlinear device consisting of several PV modules connected in series/parallel combinations to provide the desired power to its load. The output electrical characteristics (*I–V*, *P–V*) of the PV modules/array are nonlinear and vary as functions of solar radiation intensity and ambient temperature. For a given atmospheric conditions, the *P–V* curve

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0927-0248/$ - see front matter
http://dx.doi.org/10.1016/j.solmat.2013.08.010

contains one point at which the generated PV power is at its maximum, this point is called maximum power point. In order to optimise the whole PV system, an electronic device is generally used to position the operating point at/or near the MPP and ensure that it is tracked, quickly and precisely, according to variation in the working conditions. This task is called maximum power point tracking (MPPT).

Over the years, several researchers were interested in the maximum power point tracking task. Various MPPT methods have been proposed and used to extract maximum power from PV arrays under varying atmospheric conditions [1–9]. There are several ways to classify MPPT algorithms [10,11]. However, in this article, they are grouped in two classes:

(A) The power feedback algorithms like the Perturbation and Observation method [12–14], the Incremental Conductance method [15,16] and the Hill Climbing method [17,18]. All these algorithms attempt to track the MPP by periodically perturbing the operating voltage and adjusting it according to the power variation observed during the past perturbation period which is used as the feedback variable.
(B) The computational algorithms that exploit: (1) mathematical models, (2) the PV module's electrical characteristics with the maximum power point's properties [19–25] or (3) Artificial Intelligence's concepts such as fuzzy logic and neural network methods [26–33]. The simplest MPPT algorithms belonging to this class include the voltage constant algorithm and the current constant algorithm which suppose that the voltage and current at the MPP are linearly proportional to the open circuit voltage and the short circuit current respectively. The proportional voltage constant K_V is generally about 0.76 while the proportional current constant K_i is often chosen to be 0.91. However, these two MPPT methods require periodical disconnection or short circuit of the PV modules to measure the open circuit voltage or the short circuit current leading to more power loss.

Nowadays, photovoltaic modules based on thin film technology are gaining importance in the photovoltaic market. Two new PV technologies have begun to be employed commercially alongside the more traditional Si based systems: cadmium telluride (CdTe) and copper indium diselenide (CIS) [34]. However, thin film technologies show significant initial performance degradation when deployed outdoors as the well known Staebler–Wronski effect for amorphous silicon PV modules [35]. The results of basic studies regarding the efficiency of CIS and CdTe modules and their variation have been reported by some researchers [36–40], while no interest has been shown to its impact on the MPPT task, especially when dealing with MPPT algorithms which belong to the second class.

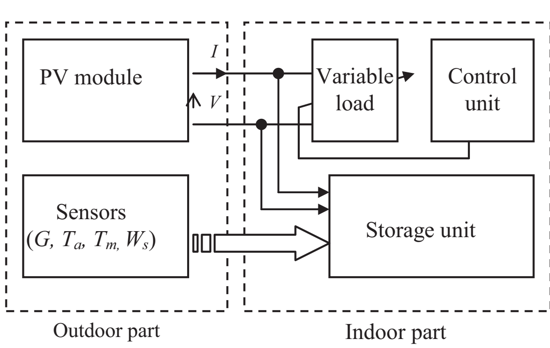

Fig. 1. Diagram of the experimental device.

The present study deals with the analysis of the maximum power point's properties for two silicon wafer-based crystalline silicon modules (poly, single) and two thin film modules (CIS, CdTe).

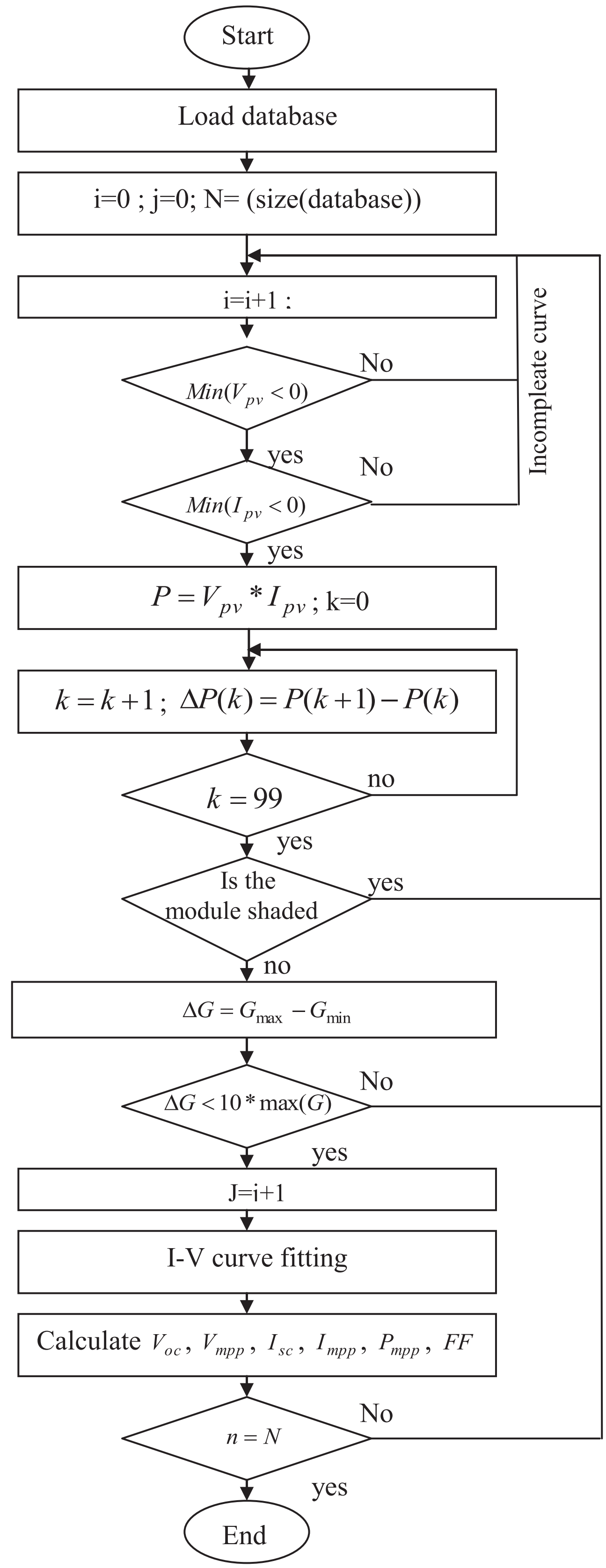

Fig. 2. Flowchart of the analysis procedure for the database.