Available online at www.sciencedirect.com
SCIENCE DIRECT®
Solar Energy Materials & Solar Cells
ELSEVIER
Solar Energy Materials & Solar Cells 90 (2006) 329–340
www.elsevier.com/locate/solmat

Experimental study of mismatch and shading effects in the *I–V* characteristic of a photovoltaic module

M.C. Alonso-García[a,*], J.M. Ruiz[b], F. Chenlo[a]

[a]*CIEMAT – DER. Av. Complutense 22, 28040 Madrid, Spain*
[b]*Instituto de Energía Solar – UPM. E.T.S.I.T., Ciudad Universitaria s/n, 28040 Madrid, Spain*

Received 11 February 2005; accepted 2 April 2005
Available online 23 May 2005

Abstract

A conventional photovoltaic module has been prepared with the purpose of accessing its cells either individually or associated. Measurements of every cell and of the whole module have been performed in direct and reverse bias, with the objective of documenting the scattering in cell parameters, working point of the cells and shading effects. Several shading profiles have been tested, and the influence of the reverse characteristic of the shaded cell in module output is stressed.

Keywords: Characterisation; Shading; Hot-spot; PV modules

1. Introduction

When a module or a part of it is shaded some of its cells become reverse biased, acting as loads instead of generators. If the system is not appropriately protected, hot-spot problem can arise and, in severe cases, the system can be irreversibly damaged.

*Corresponding author. Tel.: +34 91 346 6360; fax: +34 91 346 6037.
E-mail address: Carmen.alonso@ciemat.es (M.C. Alonso-García).

0927-0248/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.solmat.2005.04.022

Nowadays, there are newer cell designs, a growing increase in average cell size and modules that are specially manufactured for their integration into buildings where partial shading can be frequent. This tendency makes the study of partial shading of modules and cell reverse characteristics a key issue. In fact, hot-spot protection has been recently studied through international projects [1] and workshops [2]. Nevertheless, there is still a lack of information related to the behaviour of commercial photovoltaic (PV) cells operating in reverse bias and their effect in case of partial shading. Most of recent works are addressed to the evaluation of maximum temperatures and current distributions in cell surface [3–7] comparing it with the maximum admissible temperatures in common encapsulating systems. The objective is to prevent the shaded cell to reach the thermal breakdown, point in which it could be irreversibly damaged. The characterisation of reverse I–V curves is fundamental to extract conclusions in relation to that topic.

Besides, it has been pointed out that the classification of the different cell reverse characteristics is important to determine the worst case with respect to the hot-spot heating [6–8].

The objective of the work presented in this paper is in relation to the hot-spot researching that is being conducted in order to improve current standards, trying to give a experimental background based in real measurements with available commercial PV devices. With this purpose, a commercial PV module has been used as intermediate unit between the elementary solar cell and the PV system, as it permits to establish relations between cell studies and system effects. Several measurements of the I–V characteristic of the cells that form the module and of the whole module have been performed both in direct and reverse bias, and the effect of partially shading cells with different reverse characteristic has been examined. The evaluation of this last effect is important to supply information to technicians and programmers, since most commercial PV simulation programmes including shading effects usually do not approach to the cell level and, in case they do, rarely consider the great variability that can be found in reverse characteristics of similar cells [9,10].

Besides, to count on data from a PV module and its cells gives information about the scattering of commercial cells that supposedly have been classified before being inserted in the module, and makes it possible to evaluate the working point of each cell when the module is connected to a load.

2. Experimental details

A conventional PV module has been prepared with the purpose of accessing each one of the cells. The module initially counts on 33 m-Si cells, 100 cm^2 each one, serially connected. In order to measure each one of the cells either individually or associated, rear side tedlar has been cut on cell tabs, and cables have been soldered to an external plug. In this way it is possible to measure each cell or different series associations. Parallel associations are also allowed in 11 cell strings. The scheme of