On the Effect of Misalignment Distributions on the I-V Curve of Micro-CPV Modules

Luis San José[1, a], Guido Vallerotto[1], Zubair Abdullah-Vetter[2], Rebeca Herrero[1], Ziv Hameiri[2] and Ignacio Antón[1]

1 Instituto de Energía Solar, Universidad Politécnica de Madrid, Avda/Complutense 30, 2040 Madrid, Spain

2 School of Photovoltaic and Renewable Energy Engineering, The University of New South Wales, Sydney, NSW 2052, Australia

[a] luis.sanjose@ies.upm.es

1. Introduction

Hybrid micro concentrator photovoltaic (CPV) modules that combine conventional and concentrator PV technologies [1] have demonstrated higher efficiency and less installation complexity compared to PV and CPV modules, respectively [2]. Higher efficiency is achieved as the diffuse light is harvested by the conventional PV cells while the direct light is concentrated into highly efficient multijunction solar cells. Higher installation simplicity is reached through module elements downsizing [3] and integrated tracking [4]. The integrated tracking is an embedded system that translates the receivers backplane a few millimeters with respect to the lenses (thanks to the elements' reduced sizes) for obtaining an on-axis condition as the light angle of incidence varies, allowing installing these fixed modules on rooftops instead of mounting them onto a tracker. However, the high efficiency and excellent performance of CPV modules depend on precise alignment between the lenses and receivers. Misalignments between these elements can significantly reduce the cells current generation [5]. The mounting process has a strong impact on the alignment: the high number of involved lens-receiver units, small mounting tolerances, and difficulties in the integrated tracking positioning can lead to misplacements between lenses and receivers. The distribution of misaligned lens-receiver units impacts the current-voltage (IV) module performance. The severeness of this effect depends on the cells' interconnection (series/parallel) and bypass diodes location; although in conventional modules each cell has a bypass diode, micro-CPV modules use a single bypass diode for a cells' string. There are methods to characterize misalignments between the lens-receiver units in a micro-CPV module [6] that can be implementable into production lines, but they are time and resource consuming. Since the misalignments affect the IV curves, a characterization method that is based on IV data and that does not require additional measurements can be highly valued if information about the misalignments can be extracted from its evaluation. In this study, we investigate the relationship between misalignments and the module electrical performance using simulations that reproduce IV curves resulting from given misalignment distributions. We expect that in the future this method, together with machine learning, will serve as a powerful quality control tool [7].

2. Methodology

Two hybrid micro-CPV Insolight technology modules [8] composed of 572 (Gen0) and 2,940 (Gen1) lens-receiver units have been used in this study. Since the misalignments are translated into current losses, to properly reproduce the effect of misalignments on the cells' current, we have experimentally measured the current losses as a function of the lens-cell distance from the optimum position (*i.e.*, the lens focal length) [Fig. 1(a)]. The angular transmission function (ATF) of the lens-receiver unit has also been experimentally measured [Fig. 1(b)]. The ATF provides the amount of light intensity that the cell receives as a function of the light angle of incidence, which is equivalent to the cell's current loss due to the angular misalignment. The modules electric scheme has been implemented in LTSpice to simulate their IV curves as a function of a misalignments distribution [Fig. 1(c)], calculating the currents distribution [Fig. 1(d)] associated with the misalignments. The calculated currents distribution along with the implemented electrical scheme [Fig. 1(e)] allows simulating IV curves linked to different misalignments distributions [Fig. 1(f)].

3. Results

Validation of the proposed simulation model has been achieved by comparing measured and simulated IV curves for the Gen0 technology (Fig. 2). The IV curves have been measured indoors through a Helios 3198 [9] solar simulator, that allows controlling the conditions under which the module electrical characteristic is obtained. The shown curves correspond to a unique module with the integrated tracking placed in its **optimum** position (Measurement 1) and **displaced** (*y*-axis, Measurement 2). Afterward, a module units' misalignments characterization has been carried out for both tracking positions [6]. The measured misalignment distributions have been used as simulation model inputs for generating two IV curves (dashed lines on Fig.2). Although effects such as non-idealities of the solar simulator (*e.g.*, light non-uniformities), cells current mismatches, and current losses due to different lens-cell distances in the units have not been considered, the obtained simulations fit the measurements quite well. Hence, it seems that identifying misalignments using the measured IV curves is possible. Reproducing faithfully the effects of misalignments on the module electrical output will allow gene an input training set of IV curves with known misalignments distributions that may serve to train a neural network that automatically predicts them from IV information. Thus, these results will serve as a first step in the development of a machine learning tool that extracts misalignments' information from an IV curve measurement.

References

[1] L. Li et al., "Highly-integrated hybrid micro-concentrating photovoltaics." 2018 7th World Conference on Photovoltaic Energy Conversion (WCPEC).

[2] S. Askins et al., "Performance of Hybrid Micro-Concentrator Module with Integrated Planar Tracking and Diffuse Light Collection." 2019 46th IEEE Photovoltaic Specialists Conference (PVSC).

[3] C. Domínguez et al., "A review of the promises and challenges of micro-concentrator photovoltaics." AIP conference proceedings. Vol. 1881. No. 1, 2017.

[4] H. Apostoleris et al., "A simple, semi-empirical performance modeling approach for partially transparent tracking-integrated concentrator photovoltaics." 2021 48th IEEE Photovoltaic Specialists Conference (PVSC).

[5] R. Herrero et al., "Experimental analysis and simulation of a production line for CPV modules: impact of defects, misalignments, and binning of receivers." Energy Science & Engineering 5.5 (2017): 257-269.

[6] L. San José et al., "Misalignments measurement of CPV optical components through image acquisition." Optics express 28.10 (2020): 15652-15662.

[7] Y. Buratti, C. Eijkens, and Z. Hameiri. "Optimization of solar cell production lines using neural networks and genetic algorithms." ACS Applied Energy Materials 3.11 (2020): 10317-10322.

[8] G. Nardin et al. "Industrialization of hybrid Si/III–V and translucent planar micro-tracking modules." Progress in Photovoltaics: Research and Applications 29.7 (2021): 819-834.

[9] C. Dominguez, et al., "Characterization of five CPV module technologies with the Helios 3198 solar simulator." 2009 34th IEEE Photovoltaic Specialists Conference (PVSC).

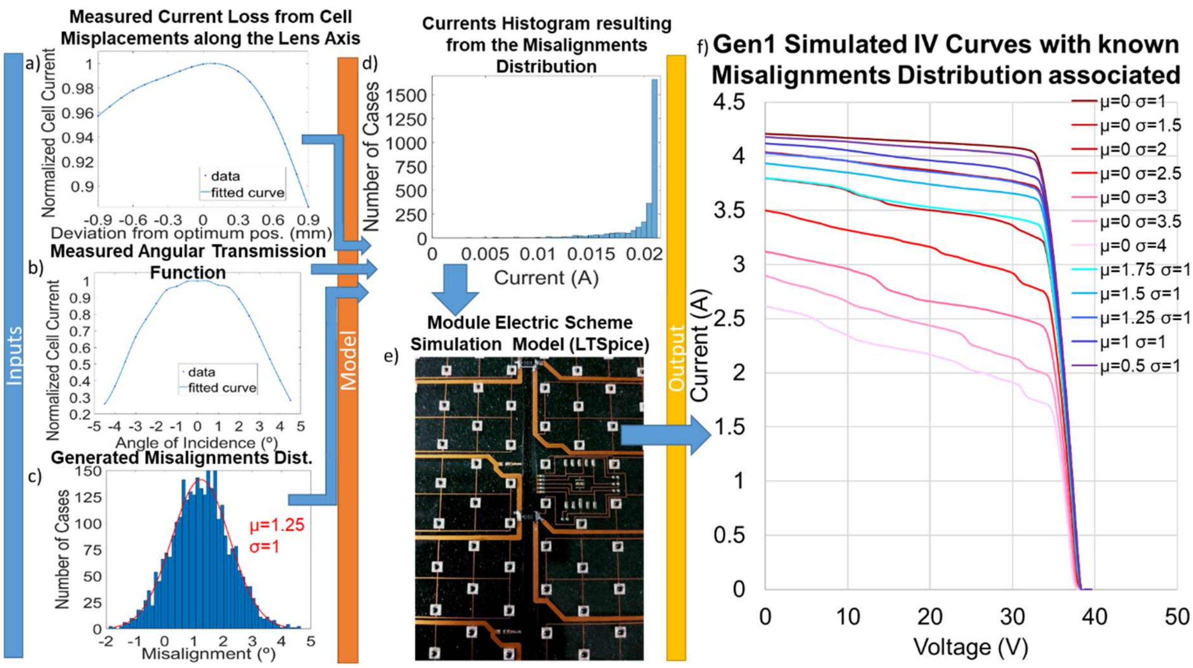

Figure 1. Model inputs: (a) current loss due to cell misplacements, (b) measured ATF, (c) misalignments distribution, (d) generated currents distribution, (e) LTSpice modelling, and (f) Gen1 IV curves for different misalignments (Gaussians with different mean and deviation).

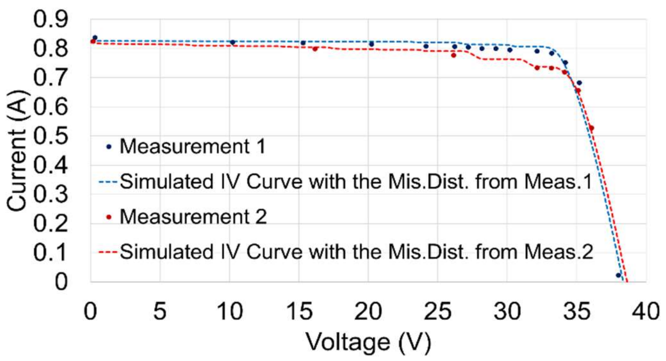

Figure 2. Measured and simulated indoor Gen0 IV curve.