High efficiency roof-top solar: progress and pilot installation in the HIPERION project

Steve Askins[1], Guido Vallerotto[1], César Dominguez[1], Gaël Nardin[2], Mathieu Ackerman[2], Delphine Petri[2], Matthieu Despeisse[2], Jacques Levrat[3], Xavier Niquille[3], Christophe Ballif[3,4] Juan F. Martinez[5], Marc Steiner[5], Gerald Siefer[4], and Ignacio Antón[1]

[1] Instituto de Energía Solar, Universidad Politécnica de Madrid, Madrid, Spain; [2] Insolight SA, Renens, Switzerland; [3] CSEM PV-Center, Neuchâtel, Switzerland; [4] EFPL PVLAB, Lausanne, Switzerland [5] Fraunhofer ISE, Freiburg, Germany

1. Introduction

The Swiss start-up Insolight together with the Hiperion consortium of partners are developing a state of the art static micro-CPV module within the *Hiperion* project. [1]-[4] The Insolight/Hiperion panel applies three different technologies, previously seen only in laboratory prototypes, to a full-size solar device: microscale concentrator photovoltaics, planar micro-tracking, and diffuse capture. The consortium, which includes research centers, industrial leaders, solar installers, and PV manufacturers, will finish a pilot-scale manufacturing facility as well as multiple pilot installations by the end of 2023. The Solar Energy Institute at Madrid Technical University (IES-UPM), along with the Fraunhofer Institute for Solar Energy (ISE) and the PV-center at the Swiss Center for Electronics and Microtechnology (CSEM) are charged with characterizing new module designs developed within the program, as well as creating new measurement methods, standards, and equipment adapted for the specifics of this new technology. Here we present the results of indoor and outdoor measurement of modules of the first batch of "*Gen2"* modules, the final design to be produced on the Hiperion pilot line, as well as a full year's worth of field data at two pilot installations installed at IES-UPM and Fraunhofer ISE.

2. Design Changes

As has been previously disclosed [3,4], a major design change from "*Gen1*" to "*Gen2*" has been a new optical stack, where the bi-convex lens, previously a single part attached by adhesive to a protective window, was replaced with two PMMA parts sandwiching a glass substrate (Figure 1). The performance improvement, as well as the reliability improvement, has now been confirmed by measurements made by the IES, as presented in the next section. Additional improvements in tracking range made possible by improved software and mechanical design are also presented.

3. Experimental

In spring 2021 22 modules were produced employing Gen2 optics and tracking hardware were produced by Insolight and CSEM. These modules represent nearly all aspects of the final design for the 100s of modules to be produced on the HIPERION pilot line, only the secondary silicon solar cells for diffuse capture were not incorporated (mechanical design changes made changes to the cell layout necessary). All modules were flash-tested on the solar simulator provided for the pilot line by the IES and installed at CSEM in June, and it was found that, except a few outliers, the distribution of the power output was reasonably narrow. (Figure 2) Indoor and outdoor tests were performed on one of these modules at IES, including outdoor I-V measurement on a two-axis tracker. (Figure 3). We found that CSTC efficiency has been improved significantly from Gen1, and now approaches 30% at AM1.5D. It should be noted that efficiency is significantly higher for red-shifted spectra that make up the energy-weighted average for many areas [5]. That module, along with three others from the same batch, were then installed on an 8-module rooftop installation that has been operational at the IES since March 2021 (Figure 4). The new modules were very easy to commission (self-tracking initialized automatically, only requiring that the installers set the correct values of latitude, longitude, and tilt angle), and they were found to have a much larger tracking range (Figure 4). We feel that these results are very promising. In late 2021, the first batch of Gen2 modules including diffuse capture will be produced, using the full pilot line, and we expect to report results on these modules. We will present a performance characterization of these modules, as well almost a year's worth of pilot production, including 9 months of data on the Gen2 modules, which will be analyzed for any sign of degradation related to the outward facing PMMA lens, and compared to the prediction of the PVlib-based model developed by IES [3].

References

[1] G. Nardin *et al.*, "Towards industrialization of planar microtracking photovoltaic panels," *CPV-16,* 2019
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[3] G. Nardin *et al.*, "Industrialization of hybrid Si/III–V and translucent planar micro-tracking modules," *Prog. Photovolt. Res. Appl.*, vol. 29, no. 7, pp. 819–834, 2021, doi: 10.1002/pip.3387.
[4] S. Askins *et al.*, "HIPERION: Scale-up of hybrid planar micro-tracking solar panels," *CPV-17,* 2021
[5] R. Núñez et al., "Spectral study and classification of worldwide locations considering several multijunction solar cell technologies," *Prog. Photovolt. Res. Appl.*, vol. 24, no. 9, pp. 1214–1228, doi: 10.1002/pip.2781.

Figure 1: Design change of optical stack from Gen1 (a) to Gen2 (b)

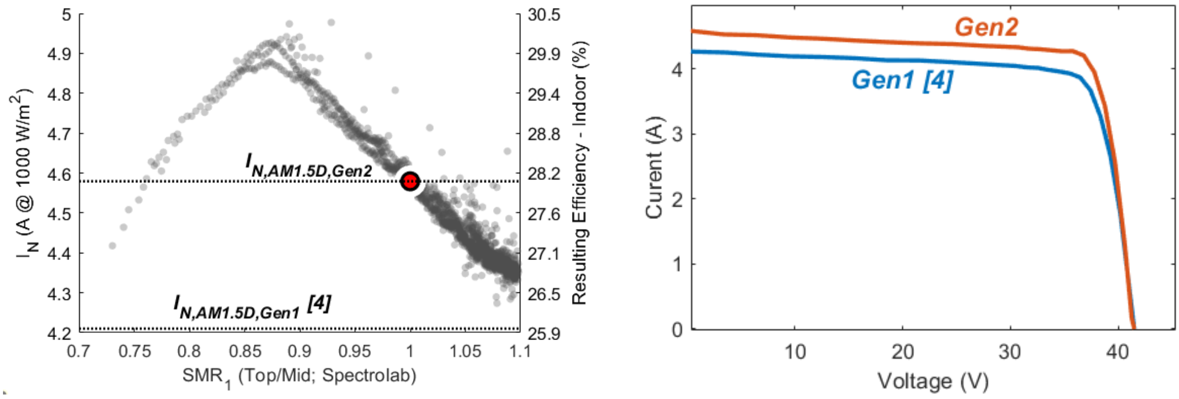

Figure 2: a) Outdoor measurement of normalized current ($I_N = I_{SC}$ / DNI) versus Spectral Matching Ratio. This value is used to calibrate the indoor I-V curves shown in b). In these two figures, we appreciate CSTC efficiency has improved from 26% for Gen1 to over 28% for Gen2. For lower values of SMR (spectra that are red-shifted with respect to AM1.5D) the normalize current increases to nearly 5A, which would correspond to a CSTC efficiency of 30%

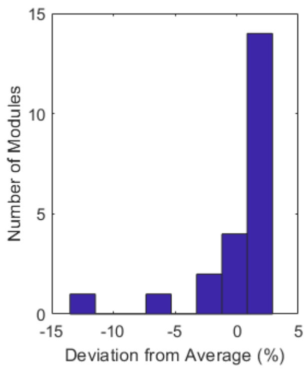

Figure 2: Histogram of 22 modules measured at CSEM in June 2021

Figure 3: 8 module pilot installed at the IES in March 2021. The four outer panels are Gen2 translucent panels. The four inner panels are Gen1 hybrid panels.

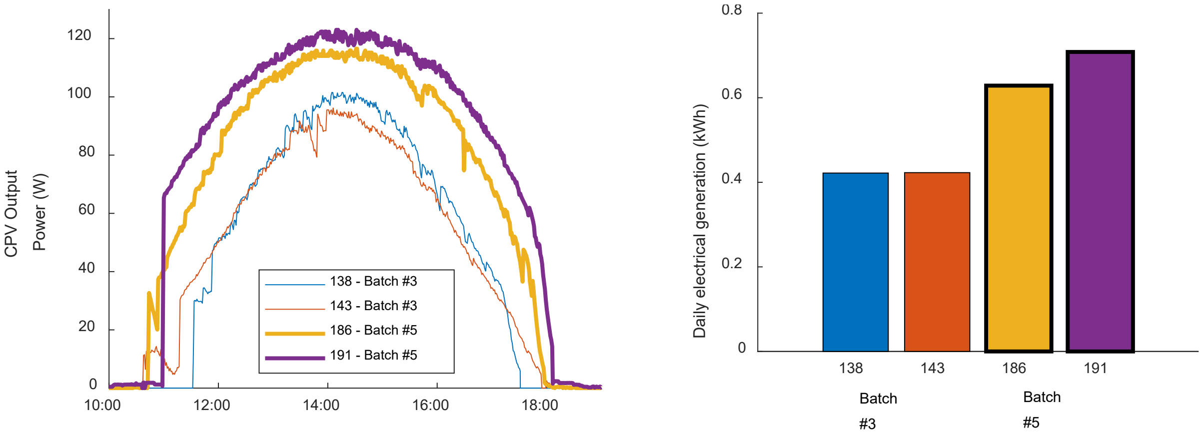

Figure 4: Increase in performance of Gen1 ("Batch 3") versus Gen2 ("Batch 5") modules installed on the IES pilot. The graph compares the power produced (a) as well as the energy generated (b) from the CPV cells over the course of a single clear day. Due to better tracking performance, the real-world power increase is greater than that predicted by CSTC results, and daily energy is increased by up to 75%.