Performance characterization of grid-connected monofacial and bifacial PV modules in Tahiti

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The current role of bifacial cells and modules in the market cannot be understated with a reported cell share of 90% [1], expected to remain stable for the next ten years, and a module share of 63% expected to grow to ~73%. The prediction is that TOPCon on n-type cell will gain market share from ~29% in 2023 up to 53% within the next 10 years while the silicon heterojunction cell will increase from ~ 5% to ~19% within the same time frame. For this reason, their performance characterization under real-life conditions is paramount as field operation can vary significantly from that under Standard Test Conditions (STC). In addition to this, the performance of photovoltaic (PV) modules in islands has not yet been widely explored despite the potential benefit they may present [2].

In this work, a preliminary performance characterization of a grid-connected PV installation located in Tahiti (17.6ºS, 149.6ºW) is presented. The installation is comprised of 24 modules, of which 20 are bifacial. All modules are based on crystalline technology but have different cell structures, such as: TopCon, heterojunction (HIT), and interdigitated back contact (IBC). Additionally, there are three front-facing and three rear-facing c-Si reference cells as well as a horizontal c-Si reference cell and a pyranometer. Temperature of each module type is measured. The installation configuration is shown in Figure 1.

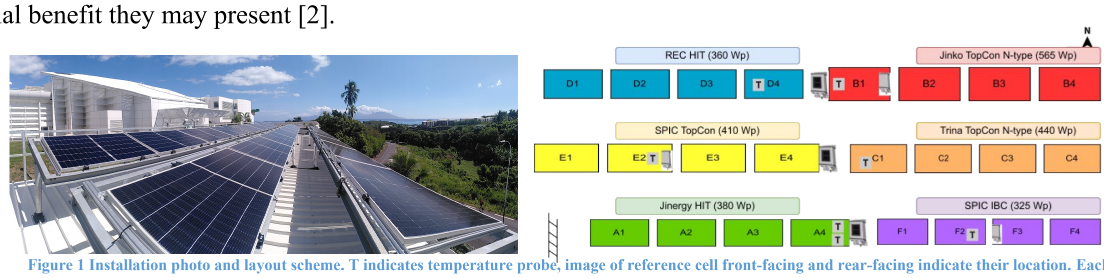

Figure 1 Installation photo and layout scheme. T indicates temperature probe, image of reference cell front-facing and rear-facing indicate their location. Each PV module is connected to an optimizer

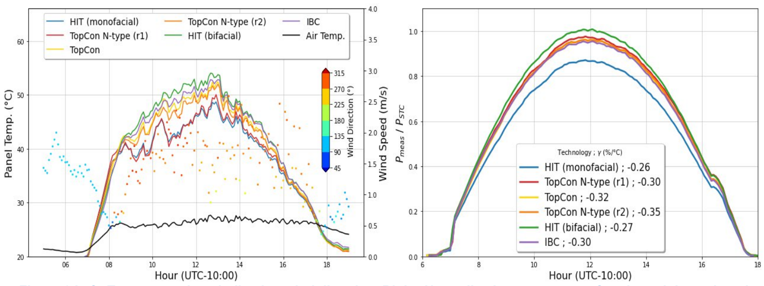

Figure 2 Left: T_{mod} comparison indicating wind direction. Right: Normalized power output of each module equipped with a temperature probe for each technology. Line color corresponds to the technology as shown in Figure 1.

In Figure 2, a comparison of module temperature (T_{mod}) and power output (P_{meas}) for a sunny day is shown. The left frame shows the T_{mod} for the HIT monofacial and TopCon N-type modules located in the front row is lower than the others. This is due to the air breeze coming from the sea between 08h-17h as indicated by the color. On the right frame, the difference in power output between the monofacial and bifacial modules (except HIT) is ~10%. The higher output from the HIT bifacial module is partially attributed to its higher bifaciality and lower temperature coefficient.

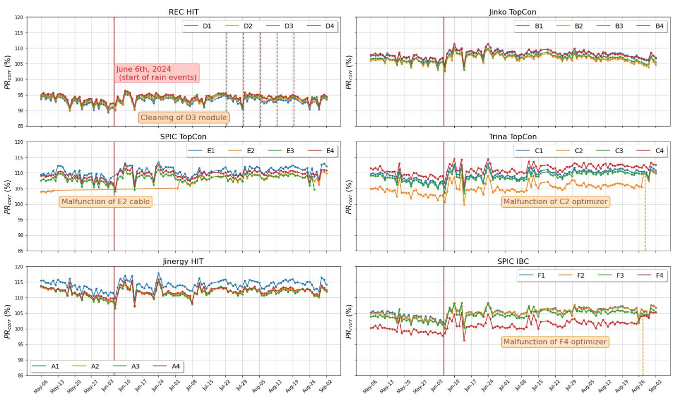

Figure 3 Daily averaged PRcorr of each module in installation. Indicated are the start of rain events as well as periods where there were connection issues.

In Figure 3, the daily averaged temperature-corrected performance ratio (PR_{corr}) is presented for each module in an effort to remove the effect of temperature. First, a decrease of up to 5% can be observed for all modules between May 5th and June 5th which coincides with a period with no rain. This decrease is reversed after June 6th where there were consistent and significant rain events until July 30th, suggesting the lower performance was due to soiling which was confirmed by photos taken on-site. Further evidence is that consistent rain events render the weekly cleaning of module D3 inconsequential as there is no noticeable increase in PR_{corr}. Next, the advantage of bifacial modules over monofacial is made evident by their up to 15% higher PR_{corr}, even more so when analyzing the PR_{corr} of the edge modules as the difference with the rest of the modules in the string can be of up to 3%. This is attributed to a lack of obstacles infront of or next to the modules which leads to higher reflected irradiance. Finally, the consistently higher PR_{corr} of the HIT bifacial modules is due to not only a higher bifaciality (87% instead of 65-74% for the other technologies) but also to a power capacity 2% higher than the one reported by the datasheet, revealed by flashtests. The lower performance of the C2 and F4 modules was due to problems with their optimizers, which was solved after being replaced.

In Figure 4, the difference in bifacial gain for a sunny and cloudy day is shown. While for a sunny day there is a gain of 8-18% depending on the technology, it can almost double during cloudy conditions.

These preliminary results show how environmental factors, and installation layout, can have an important impact on the energy production of the installation

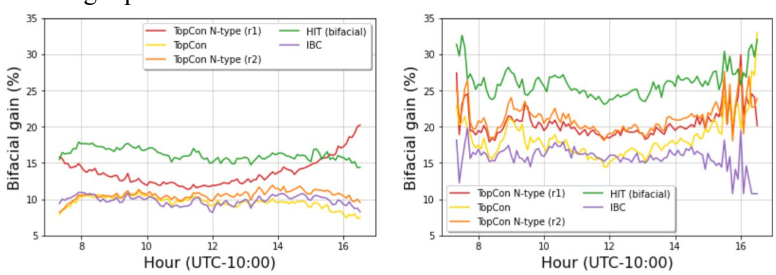

Figure 4 Bifacial gain for each central bifacial module with respect to central monofacial module (D4). Left is under sunny conditions and right under cloudy conditions.

References:

[1]"International Technology Roadmap for Photovoltaics (ITRPV) 2023 Results," VDMA, May 2024.
[2]M. Hopuare, L. Lucas-Svay, P. Ortega, F. Lucas, and V. Laurent, "Assessing solar resource and photovoltaic production in Tahiti from ground-based measurements," E3S Web Conf., vol. 107, p. 01003, 2019, doi:10.1051/e3sconf/201910701003