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Enhancing Agrivoltaic Efficiency

Performance Analysis of Design Modifications in a Chilean Case Study

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INTRODUCTION

Bifacial photovoltaic (PV) technology has seen significant cost reductions over the last decade, driving its adoption in mid- to large-scale systems in Chile [1]. Technological advancements have also enabled novel applications, such as Agrivoltaics (AV), which integrates agricultural production with PV energy generation [2]. Implementing AV systems necessitates design adaptations that differ from traditional PV configurations, affecting bifacial module performance [3]. Present research examines the impact of such design adaptations on bifacial PV performance through a quantitative simulation based on a real-world case in Rancagua, Chile. The study aims to deliver insights into bifacial module performance under AV specific conditions, contributing to optimization efforts and expanding knowledge within this emerging field.

METHODOLOGY

1. Case Study

The research analyzes Ayla Solar, a 9 MWp$_{AC}$ AV system operated by Oenergy in Rancagua, Chile (Oenergy SpA, 2023). The system employs double portrait bifacial modules with East-West tracking and a bifaciality factor of 0.7.

Figure 1: AV system Ayla Solar (Oenergy SpA, 2023).

2. Simulation Approach

The study employs two advanced simulation tools to model system performance under varying design configurations.

2.1. PVsyst 8: An industry-standard software widely used for PV system performance modeling.

2.2. NREL's Bifacial Radiance Tool: A Python-based wrapper for RADIANCE, specifically designed for bifacial PV research. Respective enhances the precision of bifacial performance assessment based on a raytracing approach.

3. Design and Performance Metrics

To understand the impact of design variations in AV, we alter row distance and tracking axis height incrementally. We vary pitch distance from 10 – 18 m within 2 m increments whereas the Oenergy design reflects the case study base scenario with 14 m. Tracking axis height is modelled within two scenarios (1.5 m and 2.5 m). The 2.5 m scenario reflects the Oenergy design.

3.1. Annual Energy Yield: Total energy generation per year.

3.2. Bifacial Ratio: Ratio of backside to frontside incident irradiation multiplicated by the bifacial factor.

RESULTS AND CONCLUSION

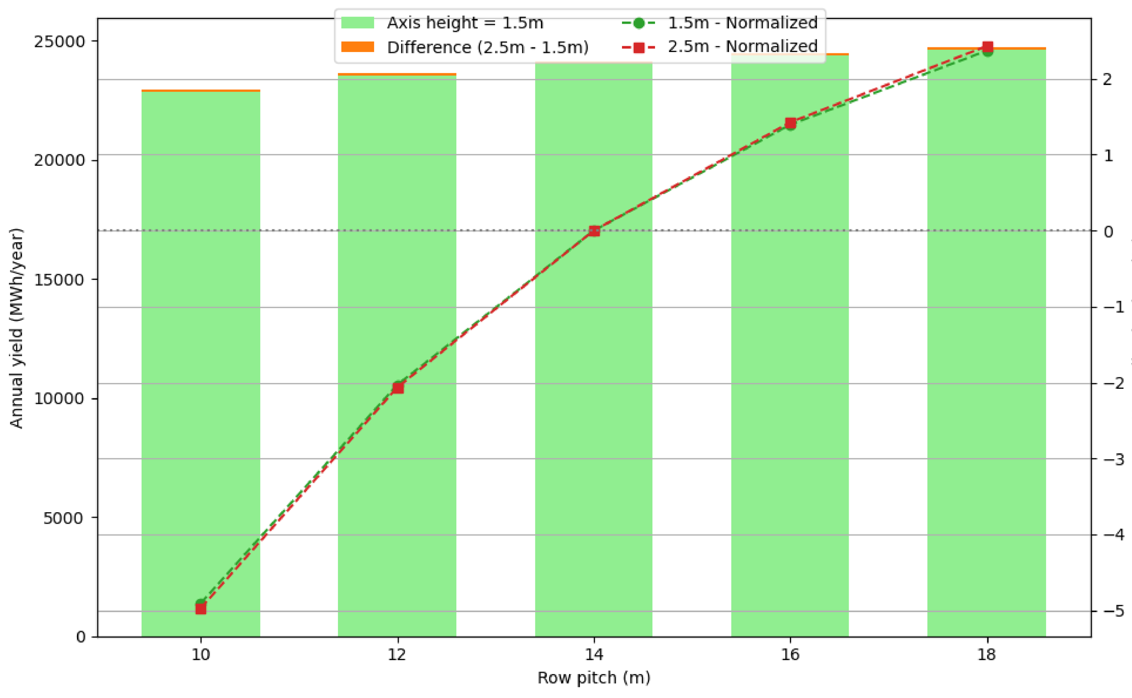

Figure 2: PVsyst simulated annual energy yield for row pitch and axis height scenarios (left axis: annual yield (MWh), right axis: normalized to 14 m scenario).

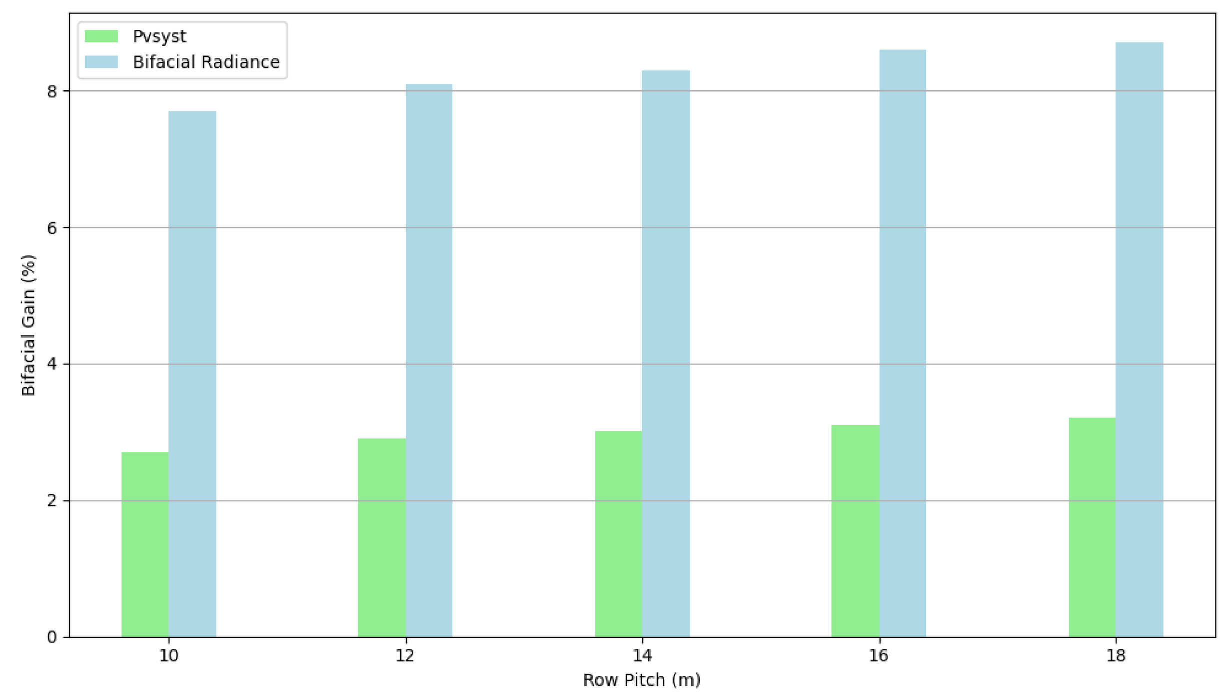

Figure 3: Comparison of simulated bifacial gain in Pvsyst and Bifacial Radiance for 2.5 m tracking axis height and varying row pitch scenarios.

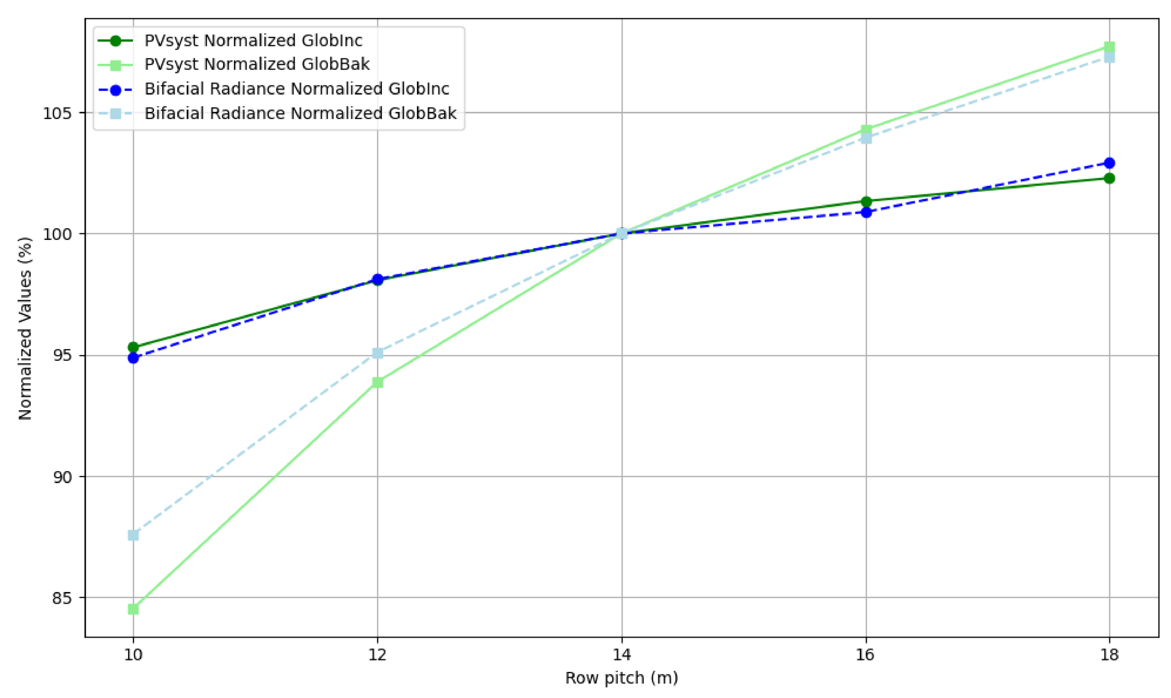

Figure 4: Normalized annual values (to 14 m row pitch and 2.5 m tracking axis) for global incident irradiation on the frontside (GlobInc) and backside (GlobBak) on the PV array.

- **Critical Role of Row Pitch:** The findings confirm that row pitch is a key factor and opportunity in maximizing bifacial performance in AV systems. Wider row pitches significantly enhance overall energy capture varying from 22 922 MWh/a for 10 m to 24 707 MWh/ha for 18 m in the 2.5 m axis height scenario.
- **Moderate Impact of Axis Height:** Changes in tracking axis height demonstrate in Pvsyst less relevant influence on energy yield, emphasizing the importance of prioritizing row spacing in system design.

- **Consistency Within Between Tools:** Both, NREL's Bifacial Radiance Tool and Pvsyst, exhibit consistent trends across different row pitches, indicating consistent internal calculations within each tool.
- **Significant Difference Between Tools:** The absolute bifacial gain values differ significantly, with PVsyst systematically underestimating compared to NREL's Bifacial Radiance Tool.
- **Implication:** The observed differences reflect the increased complexity of ray-tracing models like NREL's Bifacial Radiance Tool compared to simpler view factor approaches in tools like PVsyst.

- **Row Pitch Sensitivity:** Simulation environments consistently show similar results, with negligible variation in the relative difference of irradiance on the front and backside planes. Consequently, changes in row pitch have a uniform impact across the tools.
- **Stronger Relative Sensitivity of Back Irradiance on Row Pitch:** Both simulation environments demonstrate a relatively greater impact on backside irradiation compared to frontside irradiation.

Conclusions

- Optimizing row pitch is crucial for enhancing bifacial system efficiency in AV designs.
- Tracking axis height has a minor impact in the present specific case on energy yield, making row spacing the priority in system design.
- Raytracing tool result in higher absolute bifacial gain estimations compared to view factor model.
- Consistent internal trends in both tools validate their application for comparative analysis of relative values.
- Next, the findings will be validated through comparative analysis with empirical energy generation data from Oenergy in Rancagua, Chile**.**

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