Horizontal Axis Trackers with Bifacial Modules in PVsyst

10\textsuperscript{th} PVPMC Workshop

1-2.5.2018 Albuquerque NM, USA

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Overview

• **Bifacial Models in PVsyst**
  – Fixed Tilt Sheds
  – Horizontal Axis Trackers

• **Bifacial Tracker Simulations**
  – Bifacial Gain
  – Impact of Pitch (GCR), and Height
  – Impact of Latitude and Climate

• **Summary and Outlook**
Introduction

Bifacial Shed Model was introduced in PVsyst V6.60
- 2D Model for fixed tilt sheds
- Can be used for long regular rows

Bifacial Tracker Model since PVsyst V6.70
- 2D Model for horizontal axis trackers
- Generalization of shed model with varying tilt

Unlimited trackers: first step towards horizontal bifacial tracking model (since V6.6.7)

Bifacial tracking for horizontal axis (since V6.7.0)
Using the Bifacial Models in PVsyst

Bifacial PV Module

Choosing a bifacial PV module gives access to bifacial model

Configuration of Bifacial Model (horizontal axis trackers in this case)
Bifacial Shed Model in PVsyst

Bifacial calculation steps

1. Ground Acceptance of direct light
2. Ground acceptance of diffuse light
3. View factors
4. Sky diffuse and direct on back side

Irradiance on Ground

- Ground Acceptance of direct light
- Ground acceptance of diffuse light

Irradiance on Module

- View factors
- Sky diffuse and direct on back side

*Standard PVsyst simulation
Bifacial Tracker Model in PVsyst

Irradiance on Ground
- Direct (Beam) Fraction
- Sky Diffuse Fraction

Reflection from Ground
- To back side
- To front side
- Lost to sky

Additional contributions
- Direct (beam) fraction on rear side
- Sky diffuse fraction on rear side
- IAM losses for each contribution

This bifacial model can be used for horizontal axis trackers. The tracking algorithm minimizes the Angle of Incidence!
Simplified Preliminary Calculation

Monthly breakdown of irradiances

On Ground

Absolute

On PV module rear side

Absolute

Relative

Relative

Fraction, Beam / Diffuse

Fraction, Global / Beam

Reflections:
- Reflected on back: 213 kWh/m²
- From sky on back: 41 kWh/m²

Beam fraction: 27.3%
Diffuse fraction: 15.8%
Bifacial Simulation and Results

Additional contributions with Bifacial Models

- Global incident on ground
- Ground albedo
- View factor rear side  
  (irradiance renormalization for ground and module surface)
- Sky diffuse on rear side
- Beam effective on rear side
- Shading loss on rear side
- Total irradiance on rear side
- Ground reflection on front side

IAM losses are included in View Factor
Studying Bifacial Behavior with PVsyst

Optimization Tool

Allows quick parametric scans to optimize Irradiance or Yield

Batch Mode

Parametric scans with many parameters and output to CSV files for further analysis

Hourly Results

Completion results in hourly steps for > 80 different variables

The following results were obtained with PVsyst 6.71 batch mode and hourly result files
Bifacial Gain and Tracker Gain

Bifacial Irradiance Gain ($BG_{Irr}$)

The full Bifacial Gain $BG$ includes also bifaciality factor and bifacial mismatch. It is smaller than $BG_{Irr}$.

$$BG_{Irr} = \frac{\text{Rear Side Irradiance}}{\text{Front Side Irradiance}}$$

Tracker Irradiance Gain ($TG_{Irr}$)

Tracker irradiance gain with respect to Fixed Tilt Sheds, same width, pitch (GCR) and height over ground.

$$TG_{Irr} = \frac{\text{GlobEff Tracker}}{\text{GlobEff Shed}}$$
Comparisons of Gain Factors

Monofacial
Fixed Tilt Sheds  \( \rightarrow \)  Bifacial
Fixed Tilt Sheds

Monofacial
Trackers  \( \rightarrow \)  Bifacial
Trackers

Fixed tilt sheds oriented towards equator

Horizontal axis trackers Axis pointing to equator

Bifacial Irradiance Gain  \( \rightarrow \)  Tracker Irradiance Gain

Parameters used here:
Site: Albuquerque NM, 35.05°N, 106.62°W, 1614m ASL
Weather data: Meteonorm 7.1, typical year
Geometry: Pitch=6.6m, width 3m, GCR 45%, height 3m
Ground albedo 30%
Impact of Layout on Irradiance Gain

Parameters used here:
Site: Albuquerque NM, 35.05°N, 106.62°W, 1614m ASL
Weather data: Meteonorm 7.1, typical year
Geometry: Pitch=6.6m, Width 3m, GCR 45%, Height 3m
Ground albedo 30%

**Ground Covering Ratio GCR:**

![Irradiance Gain as Function of GCR](image)

**Height over Ground:**

![Irradiance Gain as Function of Height](image)
Bifacial Gain for different Latitudes (Clear Sky)

Parameters used here:
Site: Artificial points from Equator to 70°N, 0m ASL
Weather data: Clear sky model
Geometry: Pitch=6.6m, Width 3m, GCR 45%, Height 3m
Ground albedo 30%

Irradiance Values

Bifacial Irradiance Gain (BG_{Irr})
**Bifacial Gain in different Climates (Trackers)**

<table>
<thead>
<tr>
<th>Site</th>
<th>Stockholm</th>
<th>Sharorah</th>
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<th>Kuala Lumpur</th>
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<tr>
<td>Latitude</td>
<td>59.35</td>
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<td>-23.42</td>
<td>3.12</td>
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<tr>
<td>Diff/Glob</td>
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<td>26.1%</td>
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<td>58.9%</td>
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<tr>
<td>GlobEff</td>
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<td>2999</td>
<td>2889</td>
<td>1753</td>
</tr>
<tr>
<td>GlobGnd</td>
<td>435</td>
<td>1059</td>
<td>1008</td>
<td>804</td>
</tr>
<tr>
<td>GlobBak</td>
<td>137</td>
<td>286</td>
<td>276</td>
<td>236</td>
</tr>
<tr>
<td>$BG_{irr; TR}$</td>
<td>11.2%</td>
<td>9.5%</td>
<td>9.5%</td>
<td>13.5%</td>
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With horizontal axis trackers the bifacial gain is always larger for the diffuse component.
Bifacial Gain in different Climates (Trackers)

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With horizontal axis trackers, the bifacial gain is always larger for the diffuse component.

Hourly Bifacial Gain
Horizontal Axis Trackers

Tracker stroke limits

Diffuse BG_{Irr}
Clear Sky BG_{Irr}
Bifacial Gain in different Climates (Fixed Tilt)

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<tr>
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<td>1384</td>
<td>2375</td>
<td>2327</td>
<td>1384</td>
</tr>
<tr>
<td>GlobGnd</td>
<td>474</td>
<td>1282</td>
<td>1214</td>
<td>924</td>
</tr>
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<td>137</td>
<td>327</td>
<td>313</td>
<td>251</td>
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<tr>
<td>BG_{irr} FT</td>
<td>12.5%</td>
<td>13.8%</td>
<td>13.5%</td>
<td>18.2%</td>
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With fixed tilt sheds, the two gain curves intersect. There is no general rule for the yearly bifacial gain.
Summary and Outlook

• **Summary**
  – Bifacial model for horizontal axis trackers was implemented in PVsyst
  – Detailed simulations and parametric studies are possible
  – Bifacial gain for trackers is smaller than for fixed tilt sheds
  – Diffuse contributions have higher BG in trackers than clear sky conditions

• **Open Questions, Next Steps**
  – Validation against measurements
  – Model the mismatch due to non-uniform irradiance on back side
  – Bifacial model for vertical fixed tilt installations
  – General bifacial model based on near shading 3D drawing