Albedo enhancing materials -
Striving for highest cost-efficiency of bifacial tracker arrays

30 April 2020
5 PM - 6 PM | CEST, Berlin
8 AM - 9 AM | PDT, Los Angeles
10 AM - 11 AM | CDT, México City
11 AM - 12 PM | EDT, New York

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CONSIDERATIONS FOR BIFACIAL BANKABILITY

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30 April 2020
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500+ UL Renewable Energy Experts

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FORECAST PROVIDER for 72+ GW of installed renewable energy projects

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*since 2012
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- 159 UL sites (offices, labs)
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UL SERVICE ALIGNMENT

DESIGN REVIEW

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PLANT CERTIFICATION

TECHNICAL DUE DILIGENCE

YIELD ASSESSMENT/ANALYSIS

FAILURE ANALYSIS

BANKABILITY

PERIODIC INSPECTION/MEASUREMENT

KNOWLEDGE ACCESS THROUGH UL

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BIFACIAL PV TECHNOLOGY

• It is expected that 60% of crystalline silicone modules will be bifacial by 2029

• Bifacial product are mostly based on mono Passivated Emitter Rear Contact (PERC) technology. PERC solar cell brings 0.5-1% higher efficiency with little more cost for additional production equipment

• Manufacturing from conventional mono to mono PERC is relatively easy and sets the base for future bifacial technology development

• The standard at the moment is to use 5-BB design or multi bus bars (MBB) reducing resistance losses.
PERC TECHNOLOGY / LETID LOSS

• LeTID (Light and Elevated Temperature Induced Degradation)
  • The effect is more pronounced in locations with high operating temperatures (> 50ºC)
  • The degradation observed is progressive over time and its impact is not as fast as LID (initial degradation in operating conditions). This phenomenon eventually stabilizes and efficiency may improve over time but there are not many studies in this regard.
  • There is no wide track record regarding the operation of PERC, publications suggest losses around 7% in high temperature environments and 2.5% in colder climates.

MANUFACTURERS MUST PROVIDE TEST RESULTS TO DEMONSTRATE THAT MITIGATION TECHNIQUES IN THE MANUFACTURING PROCESS SUPPRESS OR MINIMIZE THIS EFFECT.
BIFACIAL MODULE QA TOWARDS BANKABILITY

Bifacial Power Measurements
• Monofacial test conditions: standard test conditions (STC), single sided exposure at 1000 W/m²
• New draft bifacial test conditions:
  Bifacial nameplate irradiance (BNPI)
    • Used to assess performance levels before and after stress tests (UL/IEC 61215)
    • 1000 W/m² on the front and 135 W/m² (or frontside irradiance of 1000 + φ*135 W/m²)
  Bifacial stress irradiance (BSI)
    • A reference condition for stress tests simulating higher rear-side contribution to total current
    • 1000 W/m² on the front and 300 W/m² (or frontside irradiance of 1000 + φ*300 W/m²)
    • BSI does not address all possible field scenarios, but is expected to cover typical installations that could result in high current generation over short periods.
    • $I_{SC}$ at BSI irradiance level proposed for use in bifacial stress tests: hot spot endurance, temperature cycling, bypass diode test (used in both 61215 and 61730)
CHARACTERIZING SOLAR RESOURCE

Albedo measurements are recommended for bifacial.

Modeled data sources (PSM, Meteonorm, SolarGIS, NASA-Power) have more uncertainty.

Ground Conditions in the albedometer’s field of vision should be prepared and maintained on a regular basis to closely match the future PV system’s anticipated ground conditions.

A 3% increase in annual albedo can result in up to a 10% increase in back-side energy, corresponding to about a 1% increase in the bifacial system’s overall energy.
ALBEDO MEASUREMENT CONSIDERATIONS

Height Above Ground.
Approximate the PV array’s height. Avoid shading on upward facing instrument.

Azimuthal Orientation. 180° orientation (sunward side) to prevent shadows.

Data Validation. Filtering process is required to flag out range values and shading effects. Early morning and late afternoon measures might be discarded depending on the Project site due to low irradiance.
ALBEDO ANNUAL MEASUREMENTS

17%

19%

23%

37%
# MONOFACTORIAL VS BIFACIAL DESIGNS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Monofacial Example</th>
<th>Bifacial Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-AC Ratio</td>
<td>1.15 - 1.30</td>
<td>1.05 – 1.15</td>
</tr>
<tr>
<td>Ground Cover Ratio</td>
<td>30 - 40%</td>
<td>28 - 35%</td>
</tr>
<tr>
<td>Structure Height</td>
<td>Minimal impact on energy</td>
<td>Influences back-side irradiance</td>
</tr>
<tr>
<td>Module-to-Module Clearance</td>
<td>1-2 cm is typical</td>
<td>May be expanded for light to pass through</td>
</tr>
<tr>
<td>Trackers</td>
<td>Traditional</td>
<td>Design minimizes back-side shading</td>
</tr>
<tr>
<td>Albedo</td>
<td>Low impact</td>
<td>Terrain coverage affect production levels of the back side</td>
</tr>
<tr>
<td>Bifacial Advantage</td>
<td>4-10%, realized as DC system cost reduction and/or energy gain</td>
<td></td>
</tr>
</tbody>
</table>

Source: RWTH Aachen University - ISC
BIFACIAL MODULE QA TOWARDS BANKABILITY

• Electrical design, should consider bifacial contribution. Also key for fuse rate sizing!! Minimum fuse rating would be recommended to be $1.56 \times I_{sc\_bifi}$

• Contractual performance testing: PR or Capacity Test?

• Standard PVsyst calculation provides a PR only referred to front side irradiance. Therefore, in general >85% due to back side energy contribution.

• Lack industry standard PR definition for commissioning tests considering bifaciality factor, albedo and rear side irradiance.

• IEC 61724-2 draft version provide back irradiance measurements guidelines to address bifacial performance
# BIFACIAL COST COMPARISON

## CAPEX

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cost Increase (USD / Wp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Modules</td>
<td>$0.002 - $0.01</td>
</tr>
<tr>
<td>BOP</td>
<td>$0.015 - $0.04</td>
</tr>
<tr>
<td>Terrain Preparation</td>
<td>$0.02 - $0.04</td>
</tr>
<tr>
<td>Total</td>
<td>$0.04 - $0.10</td>
</tr>
</tbody>
</table>

## OPEX

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cost Increase (USD/kWp/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Modules Cleaning</td>
<td>$0.10 - $0.20</td>
</tr>
<tr>
<td>Vegetation Control</td>
<td>$0.125 - $0.175</td>
</tr>
<tr>
<td>Total</td>
<td>$0.225 - $0.375</td>
</tr>
</tbody>
</table>

- Vegetation control to avoid further shading losses on the rear side
- Frequent terrain maintenance to ensure a uniform albedo over the PV plant
- Back side PV module cleaning evaluation depending on the project conditions
The success and bankability of a solar PV Project using bifacial modules would strongly depend on

- Proper characterization of albedo at the site conditions and modelling following best industry practices considering albedo seasonality.
- Design optimization considering the right equipment for the right GCR to maximize Project generation.
- Accurate PV plant modelling through adequate characterization of albedo, bifaciality factor and calculating properly PV Project KPIs (such as PR) as they are key for performance review and contractual warranty definition.
- Independent lab testing for LeTID and bifaciality factor recommended. In addition, best practices include batch testing and witnessing module manufacturing.
- Typical bifacial advantage of 4-10%, realized as energy gain.

CONCLUSIONS
THANK YOU!

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