Shingled bifacial photovoltaic modules

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Introduction

Double-glass bifacial PV modules:

- Higher energy yield: 10-20% gain is achievable in outdoor conditions by using albedo from surroundings.
- Improved reliability (double-glass)
- Levelized cost of electricity (LCOE) can be reduced
Introduction

Bifacial PV module performance and challenges:

- Key performance indicator for bifacial PV modules
  - Module front side power
  - Rear side current response (bifaciality)

- Key challenges
  - Measurement and characterization methods
  - Higher optical and electrical losses compared to monofacial modules.
  - Bifacial solar cells and modules are measured, rated and sold at front side power only.

- For wide acceptance of bifacial PV technology, losses in bifacial modules must be minimized
Losses in bifacial modules: optical

- Reflection (1, 2 and 3) and absorption (4 and 5): same as standard glass/backsheet modules
- Long wavelength light transmission through bifacial cell and rear glass (6)
- Transmission through cell-gap area (7)
Bifacial cell transmittance losses: \( \sim 1.30\% \) compared to the glass/backsheet structure.

Cell-gap losses: 2-3\% compared to glass/backsheet modules.

Losses in bifacial modules: resistive

- Current flow pattern is different for monofacial and bifacial cells
- Higher resistive losses in bifacial modules are mainly due to rear side cell and ribbon resistances.

Approaches for loss reduction#1

- Selective white reflective coating in the cell-gap region
- Half-cut cells
- Additional issues with glass alignment and stringing.
- Bifaciality reduces (5-7%)
Approaches for loss reduction#2
Shingled bifacial PV modules

- Recently, shingled concept becoming popular for monofacial modules: high power density

- Shingled type interconnection is suitable option for bifacial modules
  - Minimizes the optical and resistive losses
  - High power density, further reducing the module cost.
Shingled bifacial module: design optimization

- In-house developed simulation tool Griddler is used for simulations of shingled and standard interconnections of bifacial cells.
- First, bifacial cells were optimized for grid metallization (number of fingers, busbar width, etc.).
- Same cell parameters were used except the cell metallization (optimized for shingled interconnection).
- The shingled bifacial interconnection design is optimized for
  - number of cell cuts
  - cell-overlap

<table>
<thead>
<tr>
<th>Electrical parameters of 5-BB bifacial cell</th>
<th>$I_{sc}$ (A)</th>
<th>$V_{oc}$ (mV)</th>
<th>$FF$ (%)</th>
<th>$\eta$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.45</td>
<td>648.0</td>
<td>78.47</td>
<td>19.74</td>
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</tbody>
</table>
Shingled bifacial module: design optimization

- Number of cell cuts is limited by throughput and cutting losses.
- Cell overlap is limited by lay-up and stringing m/c capability.
Optical losses: shingled vs standard

- Standard bifacial: 5-BB, 0.9 mm ribbon width, 2.5 mm cell-gap, 3 mm string gap.
- Shingled bifacial: 5-cut, 1 mm cell-overlap, 3 mm string-gap
- Shingled module have ~ 2.1% less optical loss
FF losses: shingled vs standard

Standard: 5-BB, 0.9mm ribbon, Shingled: 5-cut and 1mm cell overlap

<table>
<thead>
<tr>
<th>Component</th>
<th>FF [%]</th>
<th>Standard</th>
<th>Shingled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front contact</td>
<td>81.85</td>
<td>.35</td>
<td>.47</td>
</tr>
<tr>
<td>Front ribbon</td>
<td>81.36</td>
<td>.69</td>
<td>.31</td>
</tr>
<tr>
<td>Front semiconductor</td>
<td>.62</td>
<td>.46</td>
<td>.87</td>
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<tr>
<td>Front finger</td>
<td>81.85</td>
<td>1.12</td>
<td>1.12</td>
</tr>
<tr>
<td>Rear contact</td>
<td>81.85</td>
<td>1.21</td>
<td>0</td>
</tr>
<tr>
<td>Rear ribbon</td>
<td>81.85</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rear semiconductor</td>
<td>.62</td>
<td>1.34</td>
<td>0</td>
</tr>
<tr>
<td>Rear finger</td>
<td>81.85</td>
<td>.31</td>
<td>.31</td>
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<tr>
<td>ECA contacts</td>
<td>81.85</td>
<td>.25</td>
<td>.25</td>
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<tr>
<td>Module FF</td>
<td>81.85</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: The diagram shows the comparison of FF losses for standard and shingled bifacial modules. The values are given in percentage.
Shingled bifacial vs standard bifacial

- Bifacial shingled module performance is ~ 3.6% higher
- For the same glass-size, the module power will be even higher (higher packaging density, 68 cells)
Summary

- Shingled bifacial modules can improve the front side power due to reduced optical and resistive losses: higher selling price.

- Module power can be enhanced further by using more number of cells, further reducing the cost.

- For shingled modules, cell metallization design and modules design should be optimized.

- Module design (cell-cut, overlap) can be optimized by considering the throughput and the performance. (our study: 5-cut with 1.0mm)

- Losses in cell-cut process and shingled interconnection (e.g. cost of ECA, alignment) are the main challenges for shingled bifacial modules.
Thank you for your attention!

More information
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