Occupation ratio depends essentially on the plane tilt, not on the limit angle:

\[ \text{Occupation ratio} = \frac{P}{W} \]

or GCR – Ground covering ratio:

\[ \text{GCR} = \frac{W}{P} \]

- Depends on the orientation: gain lowered to 3–4% at S–W azimuth
- Global yield gain by respect to horizontal is 7 to 8%.
- String: optimum around 24°
- After irradiance shading losses: optimum = 26°
- Evaluated by simulations over a full year

Relevant parameters:

\[ \beta \quad (P – \sin \beta) \]

\[ \text{Depends on the geometry of the system only} \]

\[ \Rightarrow \text{identical shading factor at any time and site!} \]

---

### 2. Yield Optimizations

Evaluated by simulations over a full year:

- Transposition: gain on the tilted plane: optimum around tilt = 32°
- After irradiance shading losses: optimum = 26°
- Electrical loss depends on the number of modules in the width of the string: optimum around 24°
- Global yield gain by respect to horizontal is 7% to 8%
- Depends on the orientation: gain lowered to 3–4% at S–W azimuth

---

### 5. Shading loss on Albedo component

- Albedo is a very little part of the incident energy
- Increases with the plane tilt according to \(1 – \cos \beta / 2\) (e.g., 0.001 for 30°, 0.5 for façade).
- Only “seen” by the first row: shading factor \(SF = (n-1)/n\)
- Increases with the plane tilt according to \(1 – \cos \beta\)
- Albedo contribution completely lost for big plants.

---

### 6. Shading loss contribution shares

- Diffuse + Albedo losses largely dominate
- Beam is less than 9% of the global losses
- Electrical effect rather low, depends on the number of strings in width.

---

### 8. Electrical detailed calculation

- “Unlimited sheds” approximation, with hypothesis that the sheds are of infinite length, very simple analytic expression.
- 3D shadings with “Modules strings” approximation, hypothesis that as soon as a string is hit by a shade, it becomes inactive.
- Detailed electrical calculation according to “Module Layout”: the full I/V characteristics is computed for each MPPT input of each inverter.

Results for different layouts.

<table>
<thead>
<tr>
<th>Calculation mode</th>
<th>Strings</th>
<th>Mod Layout</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case A</td>
<td>0.45%</td>
<td>0.37%</td>
<td>3.77</td>
</tr>
<tr>
<td>Case B</td>
<td>0.92%</td>
<td>0.46%</td>
<td>3.89</td>
</tr>
<tr>
<td>Case C</td>
<td>1.5%</td>
<td>0.57%</td>
<td>3.97</td>
</tr>
<tr>
<td>Case D</td>
<td>0.92%</td>
<td>0.82%</td>
<td>4.22</td>
</tr>
</tbody>
</table>

Table 1 – Results for the different cases.

The irradiance shading loss is 3.4% in all cases.

---

### Conclusion

We have analyzed the different contributions of the shading losses for PV power plants in row (sheds) arrangement.

The main observation is that, according to our hypothesis of isotropic diffuse - the losses are dominated by the diffuse and albedo contributions.

The loss on the beam component is very small (less than 9% of the total losses), and the electrical mismatch losses represent a third of the total when there is one only string in width, 18% with 2 strings and 9% with 4 strings in the width of the row.

We also confirm that in row arrangements, when the bottom cells of a string are shaded, the whole string is affected by this shade, and losses the full part corresponding to the incident beam. That is, the by-pass diodes are not operating for the recovery of energy.