Optimization of row - Arrangement in PV systems, shading loss evaluations According to module positioning and connexions

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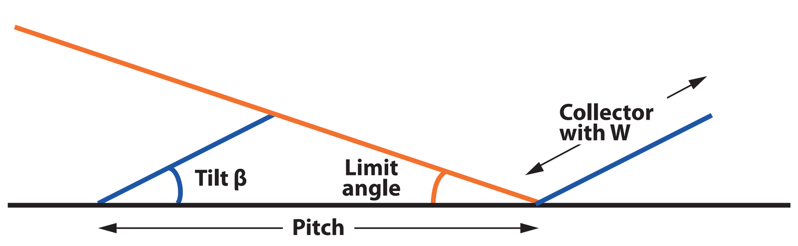
Abstract

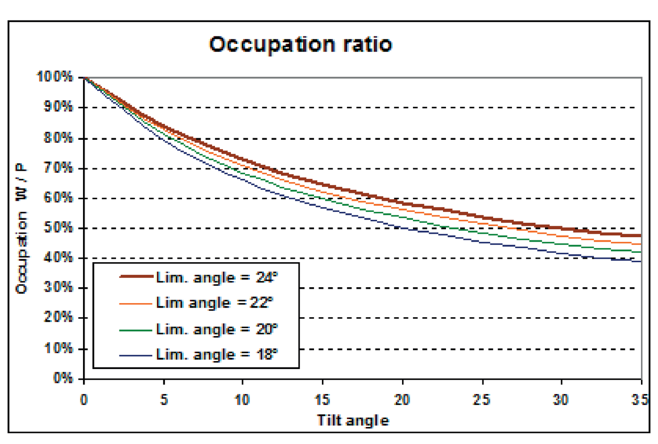
We present an analysis of the mutual shading effects in PV power plants in rows arrangement (sheds). We identify the main parameters involved in the optimization, mainly the plane tilt and shading Limit angle, and their implication on the plant yield and GCR (Ground covering ratio). We performed a deep analysis of the shadings effect of different components (Beam, Diffuse, Albedo and mismatch Electrical effects) and observe that the Diffuse and Albedo losses are dominating. The beam loss is very small, and the electrical effects are important essentially with one only string in the width of the rows.

1. Basic definitions

Optimization based on 3 variables: Plane tilt - Collector width – Pitch



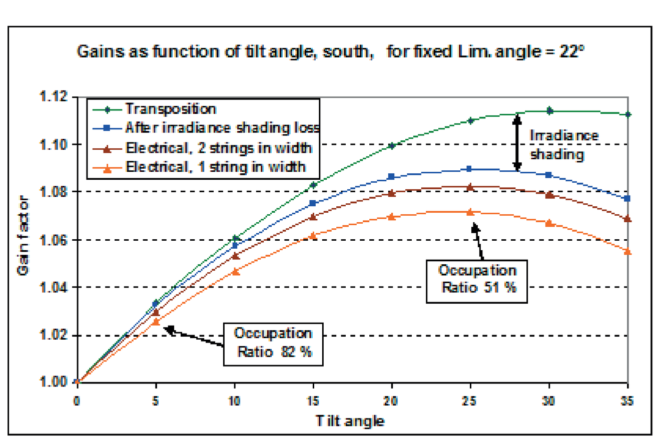
Relevant parameters: **LimAngle** = ArcTan (W • cos β/ (P – sin β))
Occupation ratio **OR** = W / P
or GCR – Ground covering ratio: **GCR** = P / W



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

2. Yield Optimizations

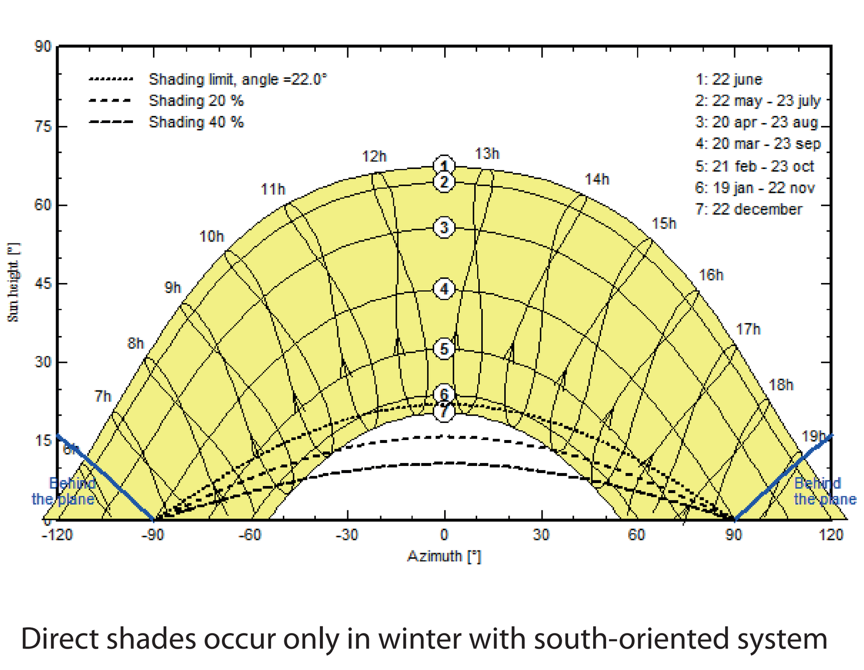
Evaluated by simulations over a full year



System gain as function of Plane tilt

- 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

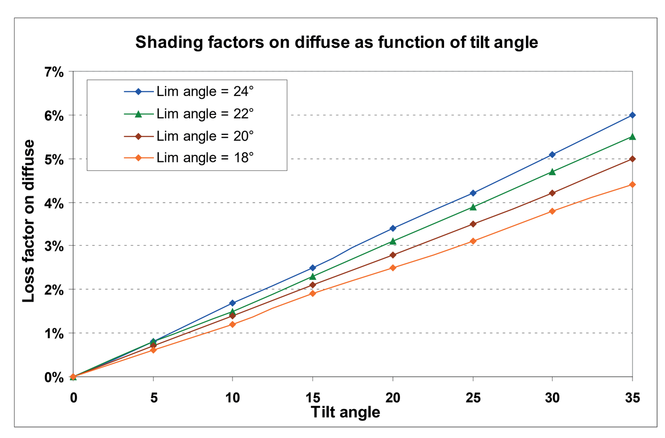
3. Shading loss on beam component



Direct shades occur only in winter with south-oriented system

4. Shading loss on Diffuse component

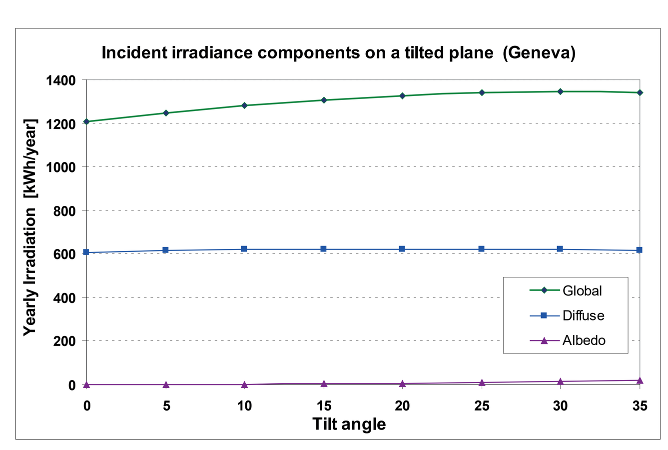
- Computed using hypothesis of isotropic irradiance distribution (identical from any direction).
- Integral of the shading factor, over the parts of the celest vault "viewed" by the collectors.
- Depends on the geometry of the system only
  => identical shading factor at any time and site !



Shading loss Factor on diffuse: "universal" curves

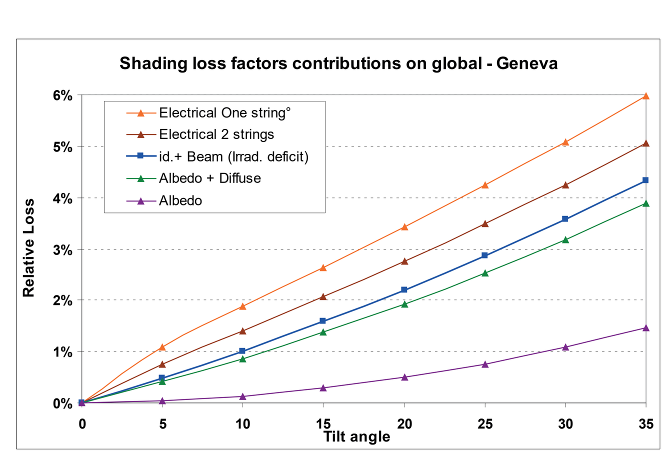
5. Shading loss on Albedo component

- Albedo is a very little part of the incident energy
- Increases with the plane tilt according to (1 – Cos β) / 2
  (i.e. 0.067 for 30°, 0.5 for façade).
- Only "seen" by the first row: shading factor SF = (n-1)/n
  (n = number of sheds).
- Albedo contribution completely lost for big plants.



irradiance components as function of Plane tilt

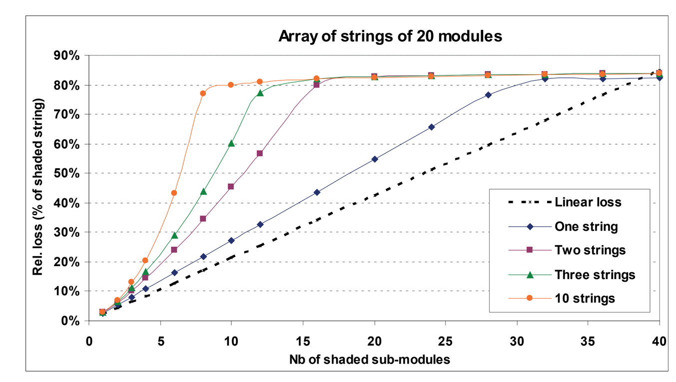
6. Shading loss contribution shares



Different contributions to shading loss

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

7. Electrical effect



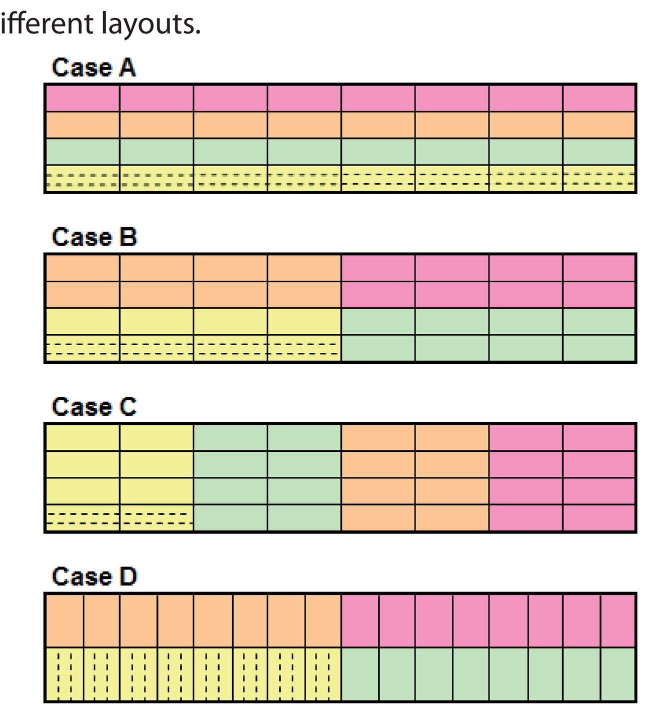
Loss function of number of sub-modules shaded in a string, and number of strings in parallel.

8. Electrical detailed calculation

In PVsyst V6, 3 ways of computing shading losses for row-arrangement:

- "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 hitten by a shade, it becomes inactive.
  Gives an upper limit to the shading loss, realistic with row arrangements and several strings in parallel.
- 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.



	Electrical loss		Total
Calculation mode:	Strings	Mod.Layout	Loss
Case A	0.43%	0.37%	3.77%
Case B	0.92%	0.48%	3.88%
Case C	1.5%	0.57%	3.97%
Case D	0,92%	0.82%	4.22%

Table 1. - Results for the different cases.
The irradiance shading loss is 3.4% in all cases.

The electrical component is rather low in the global losses.

Conclusion

We have analysed 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 rows arrangements, when the bottom cells of a string are shaded, the whole string is affected by this shade, and looses the full part corresponding to the incident beam. That is, the by-pass diodes are not operating for the recovery of energy.