PVSYST SOFTWARE

Shading mismatch loss calculation in PVsyst 6

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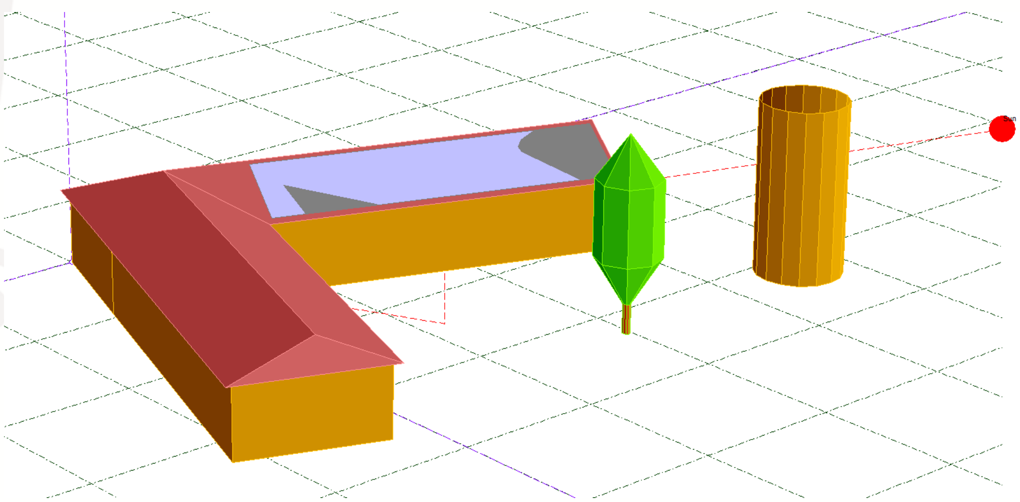
- Application to sheds (rows) arrangement

Near shadings: shading factor

"Near shadings" definition: the obstacles draw visible shades on the array



Definition of the Shading Factor :

Ratio of the Shaded area to the total sensitive area

(for a given sun's position)

Acts on the beam component

PVsyst creates a

Table of shading factors

for any direction of the space

Shading factor table (linear), for the beam component

Azimuth / Height	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.088	0.057	0.070	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10°	Behind	Behind	Behind	Behind	0.000	0.000	0.033	0.471	0.314	0.191	0.172	0.071	0.017	0.057	0.083	0.083	0.000	Behind	Behind
2°	Behind	Behind	Behind	Behind	Behind	0.000	0.033	0.479	0.335	0.195	0.172	0.217	0.498	0.719	0.759	0.165	Behind	Behind	Behind

Shading factor on diffuse

If we assume that the diffuse is isotropic

i.e. the received irradiance is identical whatever the direction of the space
(This is a reasonable hypothesis when considering the diffuse all over the year, i.e. including covered weathers)

⇨ The shading factor for diffuse is calculated as an integral of the shading factor over all sky directions "seen" by the plane of the array
(orange slice between the horizontal and collector planes)

This is independent on the sun's position and therefore:

- constant over the year
  (to be applied to the diffuse component at each simulation time step)
- characteristic of the geometry of the system itself (not the latitude)

NB: This integral is computed using the shading factor table

Shading factor on albedo

- Hypothesis: the albedo is from far ground reflexions
  ⇨ if an obstacle is on the ground, no albedo from this direction

- By analogy to transposition models : albedo is proportionnal to the incidence angle of the ground for this given direction,

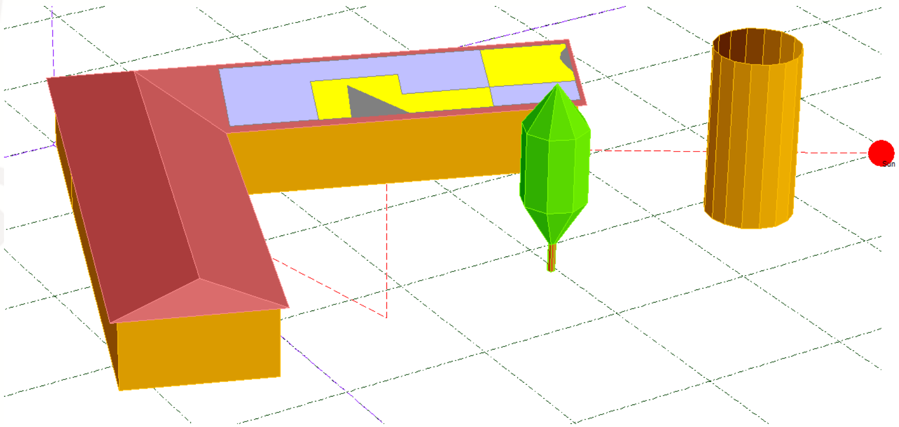
⇨ Shading factor on albedo = integral of this "ground shading factor" over the portion of sphere between the ground and the prolongation of the collector plane below ground

As for diffuse factor, this is independent on the sun's position, therefore:
- ➢ constant over the year
  (to be applied to the albedo component at each simulation time step)
- ➢ characteristic of the geometry of the system

NB: For rows arrangement the SF on albedo is (n-1) / n (n = nb of rows)

Shading factor "according to strings"

Strong Hypothesis: when one cell of a string is shaded, the whole string becomes electrically inactive



Shading Factor "according to strings"

The array is partitioned into rectangles, each rectangle represents a full string (yellow)

SF according to strings =
yellow + grey areas / total area

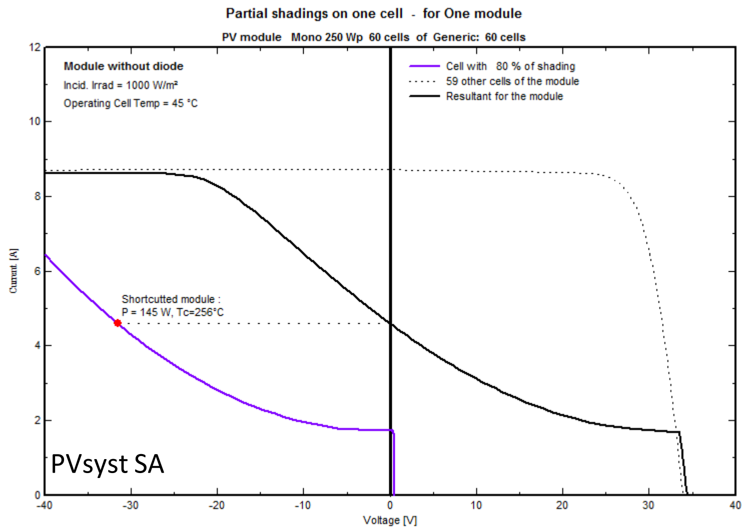
Acts on the beam component

"Linear" or "irradiance" losses: effect of grey areas

Electrical losses: effect of yellow areas (weighted by a parameter "Fraction for electrical shadings")

Shading on one cell in a module

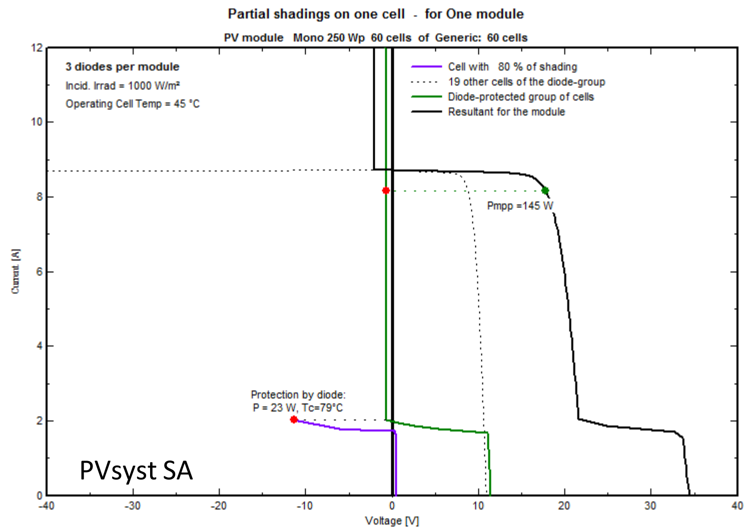
One cell shaded at 80% ⇨ the Isc of the cell drops by 80%



When the current exceeds Isc :

⇨ the cell is reverse-biased

⇨ the absorbed power becomes very high (hot spot)



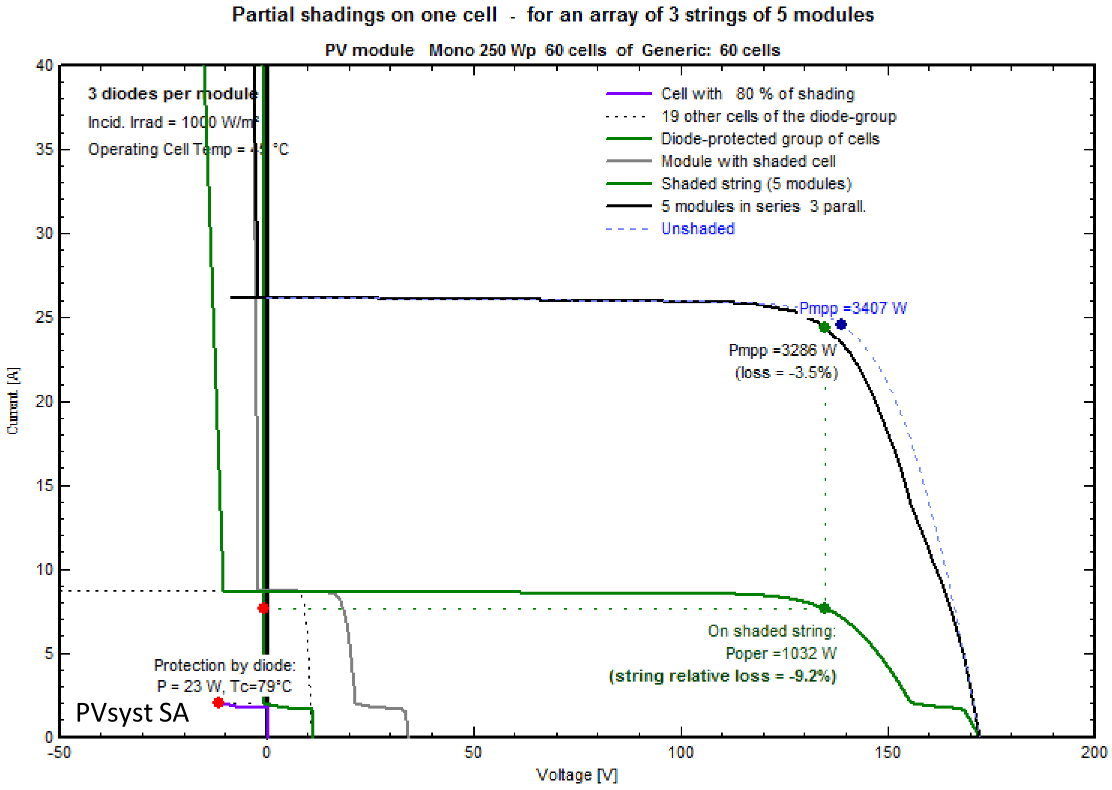
By-pass diodes: derive the current in this sub-module

The I/V characteristics is about the same for 1 or several shaded cells

⇨ We should treat each I/V curve at the sub-module level

Shading on one cell in an array

One cell shaded in an array of 5 modules in series and 3 modules in parallel: 900 cells



1 shaded cell :   0.09% of cells
=> 3.5% loss on Pmpp !

The Pmpp operating point is chosen by the inverter

The reverse current in the submodule may be very high

The string resulting I/V depends on the number of shaded sub-modules

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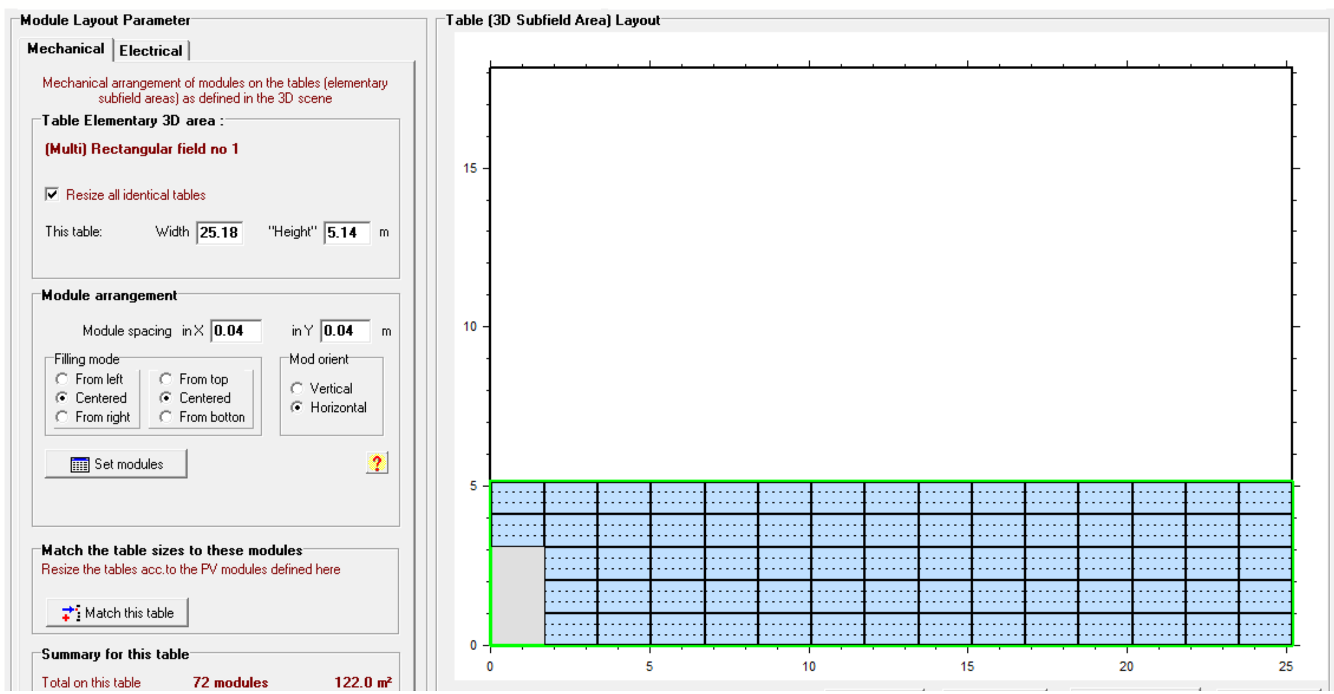
Module Layout definition

Calculation requires positioning all modules (sub-modules) on all shading areas defined in the 3D part

Modules may be automatically positioned:

in portrait/landscape orientation

- with specified spacing
- specified nb. of diodes in each module
- specify orientation of submodules



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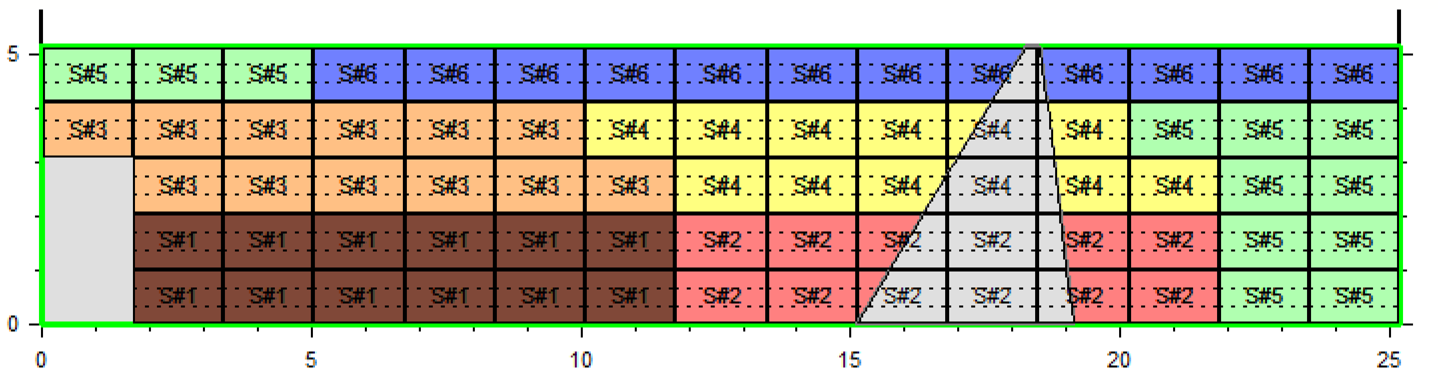
"Irradiance" or "Linear" shading factor

The 3D calculation identifies the shading state of each corner of each sub-module

Sub-modules with 1 corner shaded: 25% shaded
2 corners shaded: 50% shaded
3 corners shaded: 75% shaded

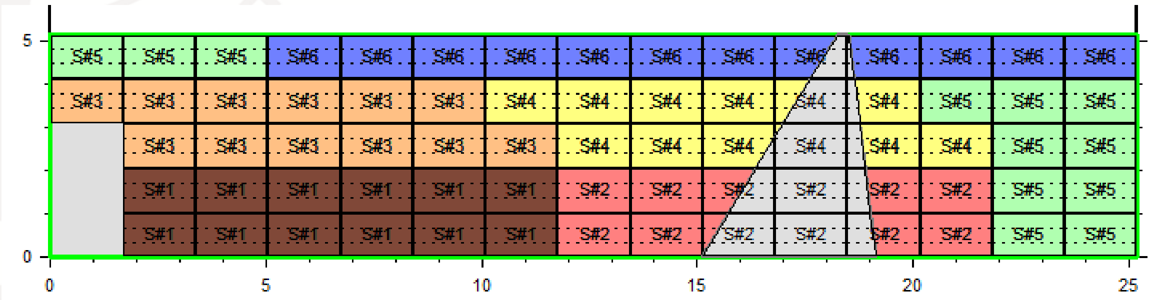
NB: ⇨ little uncertainty on sub-modules of the shade border
Resolution: with 6" cells, 1 sub-module ≈ 0.5 m²



Linear Shading Factor = Nb of shaded sub-modules / Total nb. of sub-modules

Electrical shading calculation

Attribute each module to an electrical string   (i.e. to an inverter input)



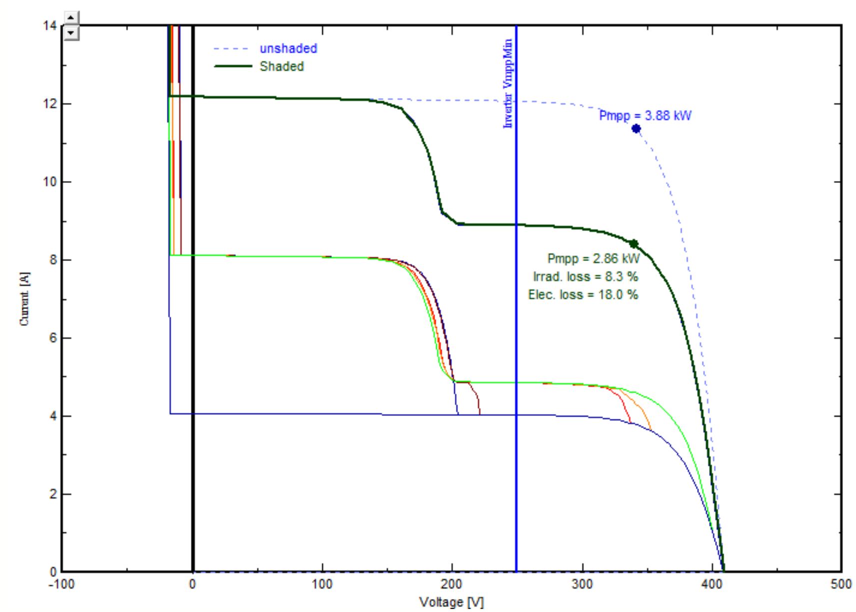
Here: Inv. 1   S#1, S#2, S#3
          Inv. 2   S#4, S#5, S#6

Calculate the I/V curve
for each input of each inverter:

- Add the voltage of each sub-module
  => I/V curve of each string
- Add the current of each string
  => inverter input's I/V curve

Calculate the   Pmpp

Compare to unshaded Pmpp



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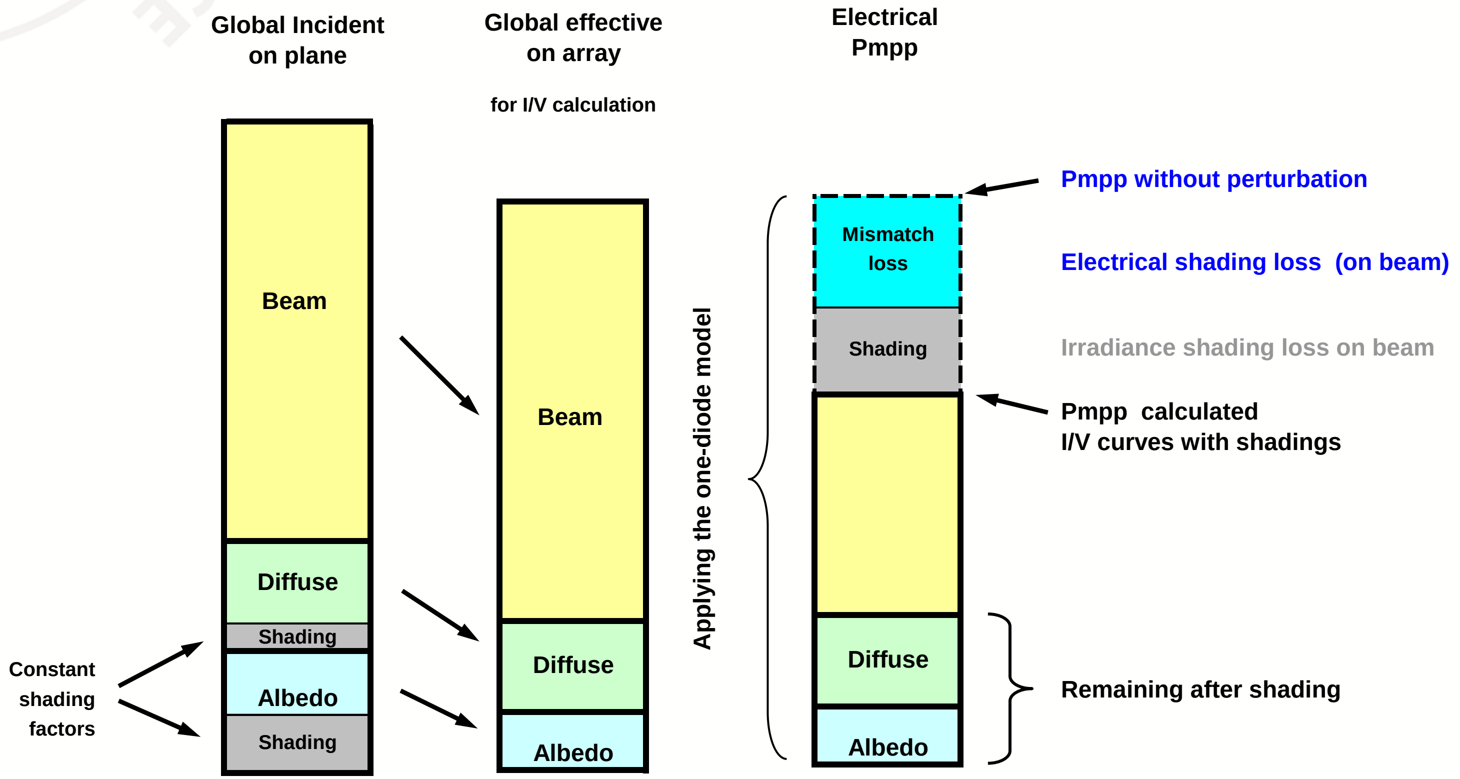
Detailed Shading Loss calculation

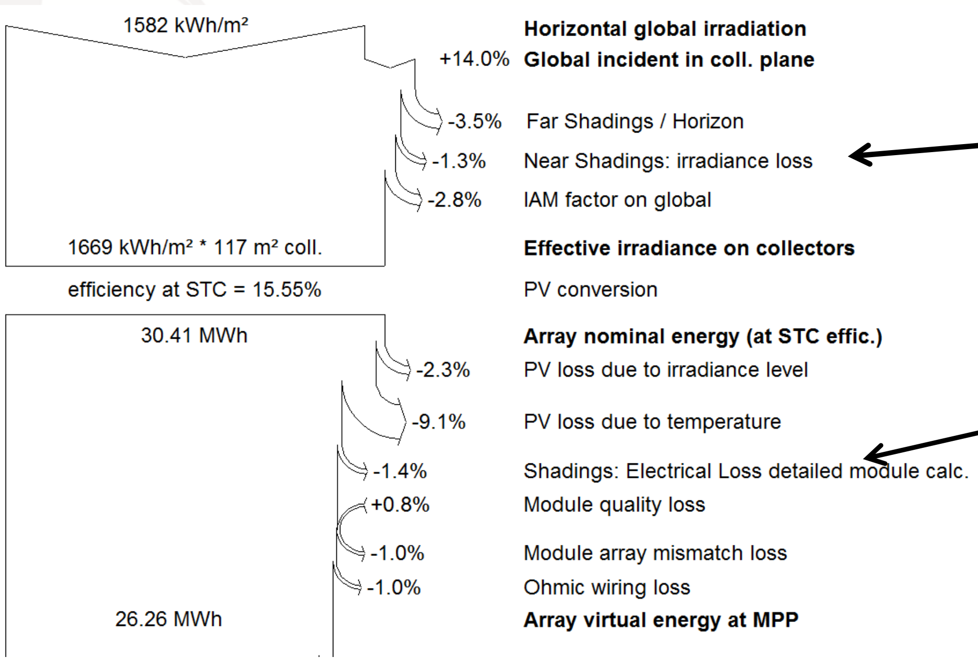
The calculation and interpretation involves the irradiance components in different ways :



Linear or Irradiance loss = Diffuse + Albedo + Beam losses (grey contributions)

Electrical shading loss = calculated as the balance of all these losses

Simulation results



Irradiance (linear) loss: due to deficit of irradiance on the array

Electrical (mismatch) loss : loss at the array level

The "Module Layout" approach is suited for little systems (say, < 50 kWp)

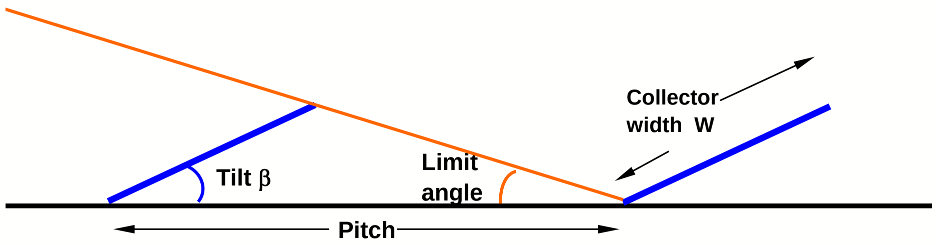
The shading calculation "according to strings" should be used for big systems.
(It will produce an array "electrical loss" contribution in the same way).

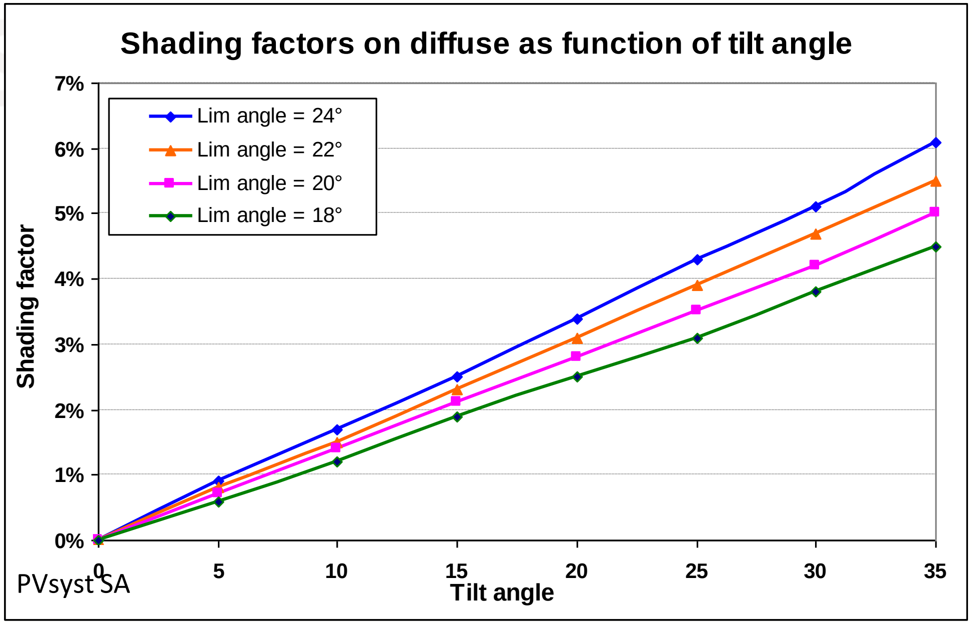
Comparing results of both methods allows a determination of the "Fraction for electrical shadings" involved in the strings approach

Application: Sheds (rows) arrangement

Relevant parameters :

- plane tilt
- Limit Angle
- GCR = Width / Pitch





Shading factor on diffuse:
depends on the geometry only !

Factor independent on Latitude

Loss = Diffuse · Factor

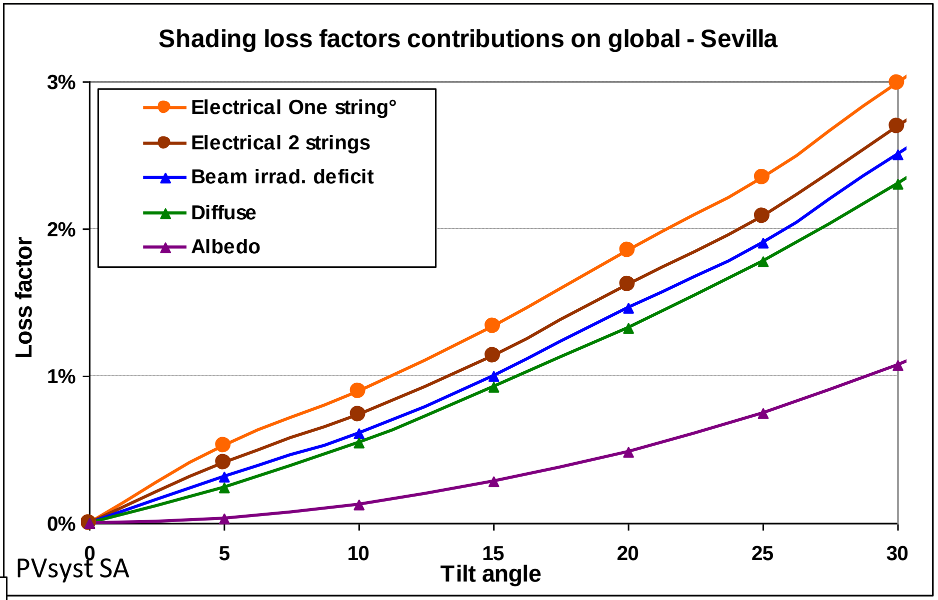
dependent on the climate
(due to Diffuse/Global ratio)

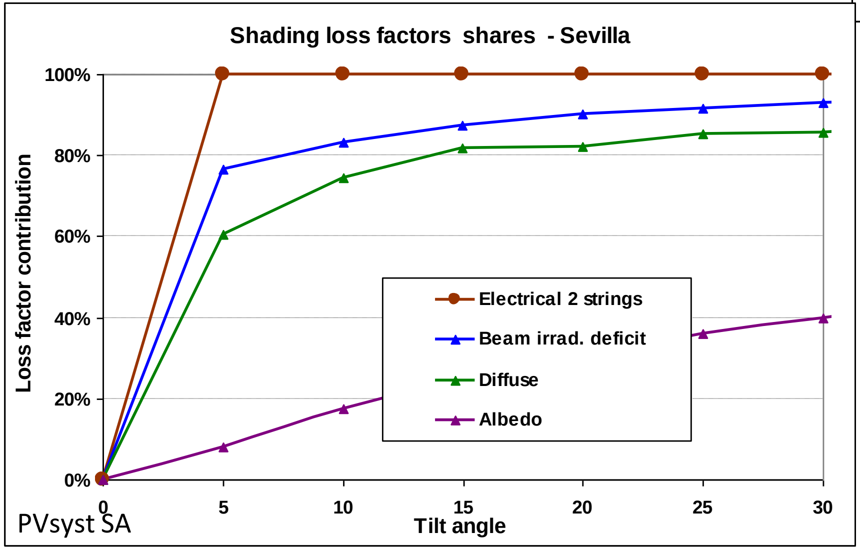
Losses contributions in Sevilla

Example : Sevilla (Spain) :
$Glob_{horiz}$ = 1750 kWh/m²/year
D / G ratio = 36%

Albedo: prop. to (1 – cos Ta) / 2
≈ Completely lost: SF = (n-1) / n

Diffuse : SF applies on D/G
Leading contribution





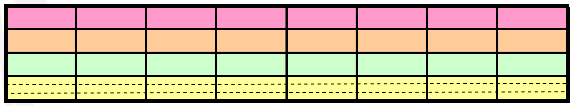
"Linear" on beam: low contribution < 10%

Electrical loss (applies on beam):
2 strings in width: low contribution

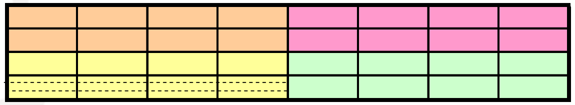
Electrical loss in sheds

Different string layouts with
4 modules in width :

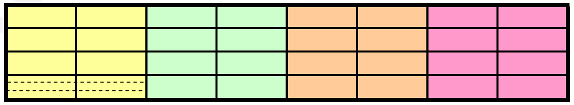
Case A



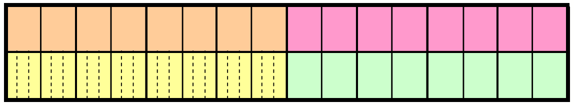
Case B



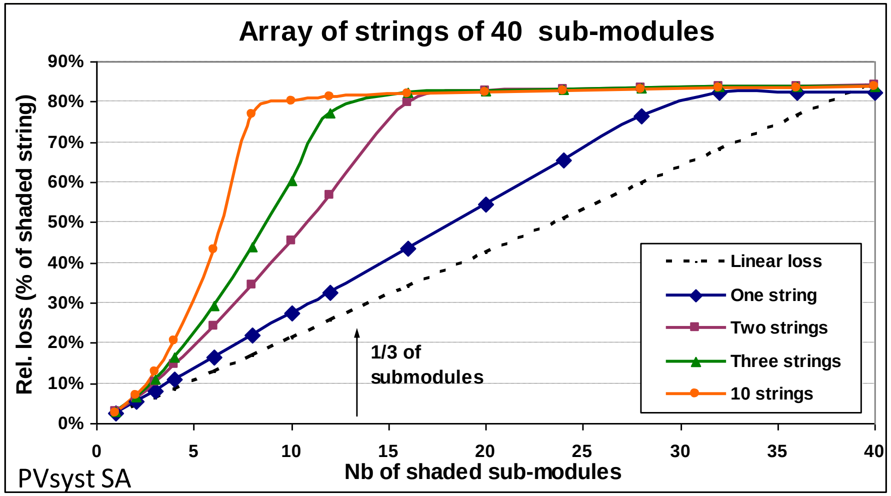
Case C



Case D



As soon as 1/3 of sub-modules shaded
⇨ the string is electrically inactive
⇨ "Fraction for electrical loss" = 100%



	Linear shadings	Calculation mode "Acc to strings"	Calculation mode Module layout	Submod bottom
Case A	3.40%	0.43%	0.41%	33%
Case B	3.40%	0.92%	0.69%	17%
Case C	3.40%	1.50%	0.61%	8%
Case D	3.40%	0.92%	1.04%	100%

Calculation in "Module strings" mode:

- Case A and D: fits correctly
- Case B and C: not all submodules shaded at a time => Fractions for electrical loss < 100%

Conclusions

- The shading calculation is based on a geometrical calculation for Beam
- Model for applying to Diffuse and Albedo components (⇨ assumptions)
- Electrical mismatch only applied to the Beam component
- Module Layout: calculation at the sub-module level, for each inverter input
- 2 ways of calculating the electrical loss:
  According to String — to be used for big systems
  Module layout — suited for "little" systems (< ≈50 kWp)
- "Fraction for electrical loss" may be estimated on little parts of the system
- Model uncertainties: more important on diffuse/albedo estimation
  than on the electrical calculations