SUNPOWER®

SUNPOWER® PV-SYST MODELING GUIDELINE

For Performance Product Line Modules

August 21, 2020, V2

1. SunPower Technologies: Special Modeling Guidelines

SunPower technologies have premium performance characteristics which require special attention when modeling energy production in PVSyst. The sections of PVSyst input guidance provided below are specifically defined for P19, P3 COM, P3 UPP and P5 Bifacial modules:

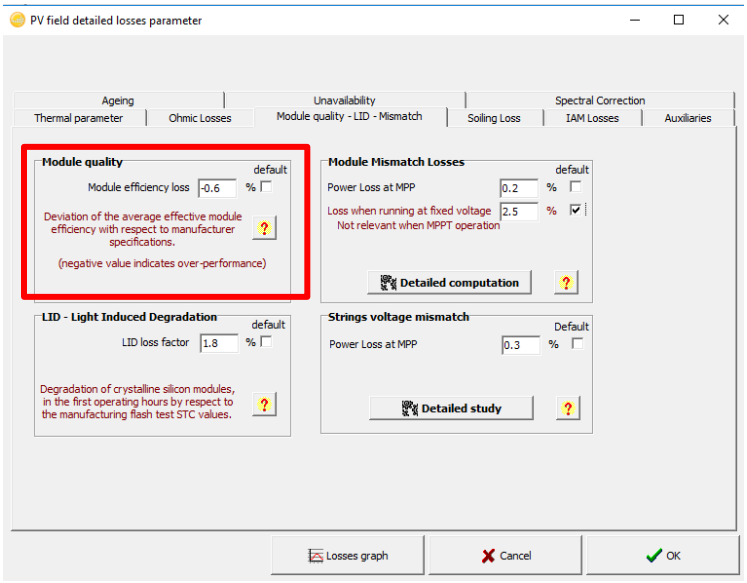
1.1 Module Quality

Module Quality = -0.6%

The "Module Quality" setting in PVSyst defines the expected collective power rating of the modules delivered to a project, pre-LID.

The industry tolerance standard on module flash have improved, and most manufacturers should be delivering modules which flash—on average—very close to their nameplate rating with a distribution of no greater than 0%/+5%.

The Module Quality should be set to -0.6% for Performance modules to represent the expected nameplate + 5W flash rating.



1.2 Light-Induced Degradation

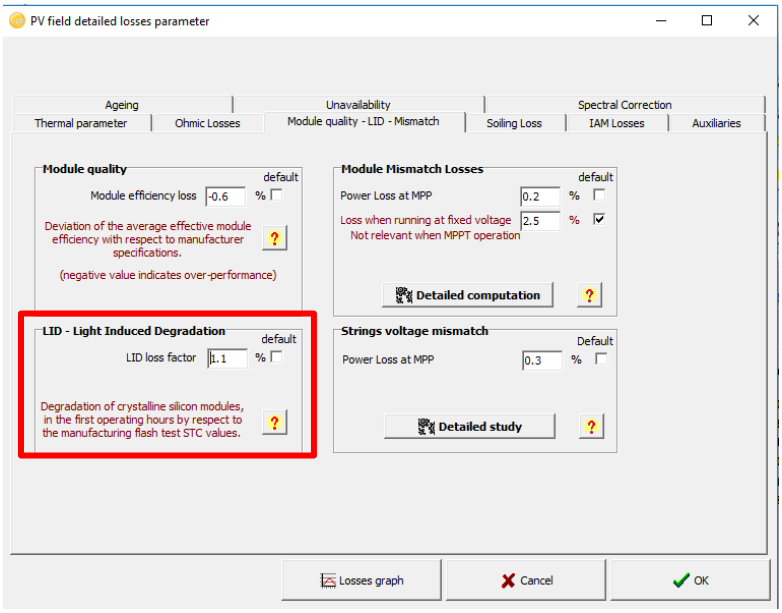
LID = 1.8 (P19 COM)

LID = 1.2% (P3 COM)

LID = 0.5% (P3 UPP & P5 Bifacial)

Light induced degradation (LID) is post-installation degradation mode which reduces the output power of conventional p-type wafer technologies after the first several hours of sun exposure.

Independent lab tests demonstrate that SunPower Performance modules experience approximately 1.2% LID following initial exposure for P3 COM modules.



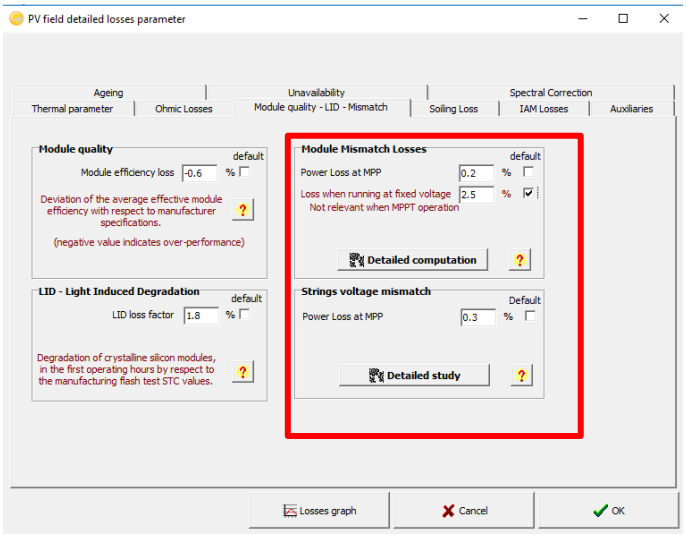
For P3 UPP and P5 Bifacial modules, LID loss improved to 0.5% due to the wafer doping technology improvements.

1.3 Mismatch Loss

Total Mismatch = 0.5%

Research has demonstrated that the voltage mismatch associated with current module tolerance standards will result in a loss in system power of significantly less than the PVSyst default of 1%. When Performance modules are used with Micro Inverters or Buck/Boost DC Optimizers, DC mismatch is 0%.

SunPower delivers tight Gaussian distributions of module flash ratings to our customers. We therefore recommend using a total, conservative mismatch value of 0.5% for our Performance modules when configured for string/central inverters.

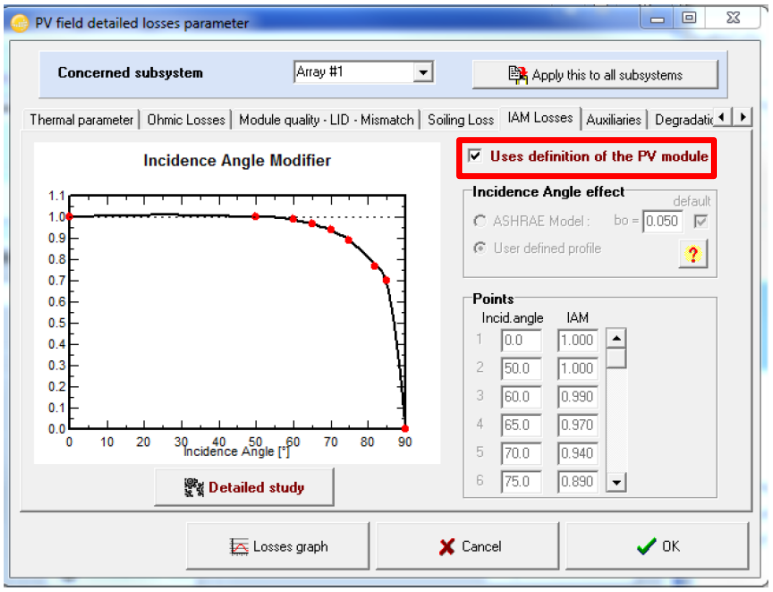


- Module current mismatch = 0.2%
- Strings voltage mismatch = 0.3%

1.4 IAM Profile

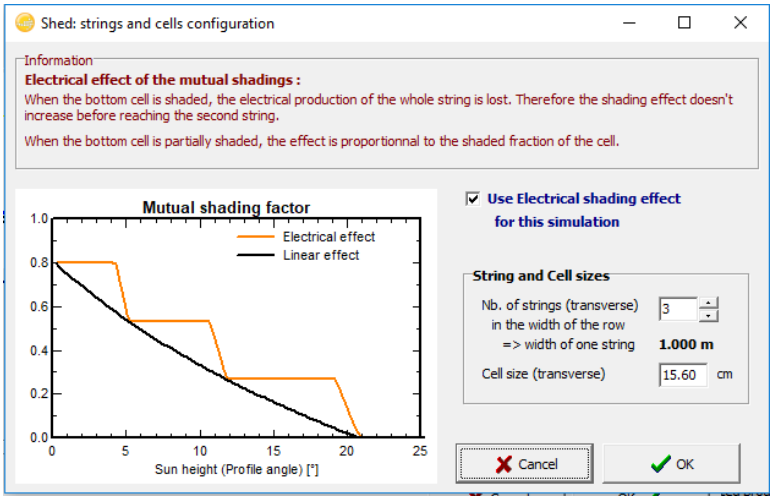
SunPower IAM profiles defined in PAN file

SunPower module technologies are laminated with a high-quality, high-performance, anti-reflective glass, which absorbs significantly more direct and diffuse light than a standard glass surface. The IAM points defining the incidence angle response of the SunPower anti-reflective glass are provided in the PAN file for each module product. IAM tables are also available in Appendix A at the end of this guideline.



1.5 Near Shadings

SunPower Performance modules have superior performance under shaded conditions, due to the linear shade response of the shingled cell technology and multiple integrated bypass diodes. PVSyst offers various methods for characterizing response of shaded SunPower modules. The results from the both options are similar. Option 1 is a quicker way to approximate the near shading and Option 2 is a more detailed way.



1. Unlimited Sheds : select « Electrical Effect » in Shades Parameters window

If Landscape:

P3 COM and P19 modules :

- Nb. Strings = 6 x #modules/row in north-south direction
- Cell size = 16.0cm

P3 UPP modules :

- Nb. Strings = 7 x #modules/row in north-south direction
- Cell size = 16.0cm

P5 Bifacial modules :

- Nb. Strings = 5 x #modules/row in north-south direction
- Cell size = 21.0 cm

If Portrait:

P3 COM, P3 UPP and P19 modules :

- Nb. Strings = 3 x #modules row in north-south direction
- Cell size = 16.0cm

P5 Bifacial modules :

- Nb. Strings = 3 x #modules row in north-south direction
- Cell size = 21.0 cm

2. All other Field Types requiring user-defined Shading Scene --> Construction/Perspective

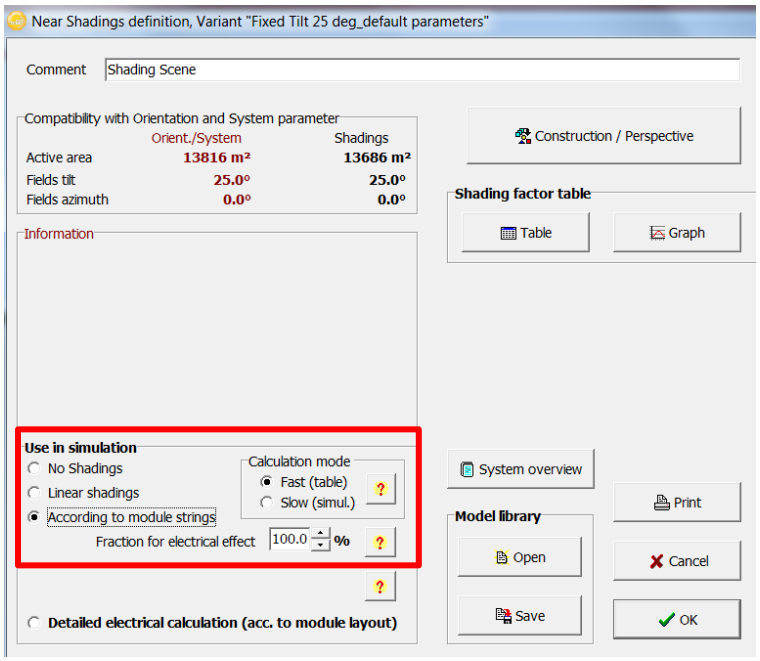
To reflect the excellent shade response of Performance modules in PV-Syst in both the portrait and landscape orientations, create a shading scene in the Near Shadings section and:

If Portrait:

- Select the 'According to module strings' option.
- Fraction for Electrical Effect = 50%

If Landscape:

- Select « Linear Shadings »



1.6 Ageing (Degradation)

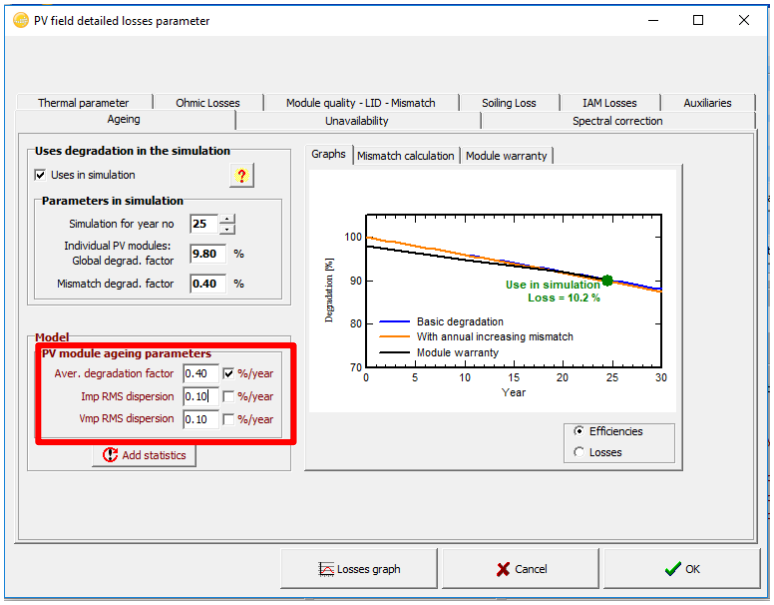
Average Degradation Factor = 0.4%/yr

Imp RMS dispersion = 0.10%/yr

Vmp RMS dispersion = 0.10%/yr

SunPower modules set the industry standard for low degradation at 0.4% per year. This also means that the variance in current and voltage also does not change significantly over time, resulting in very low RMS dispersion rates (estimated 0.1%/yr).

The resulting long-term degradation for SunPower modules is consistent with the low degradation rate in the Sunpower module warranty.

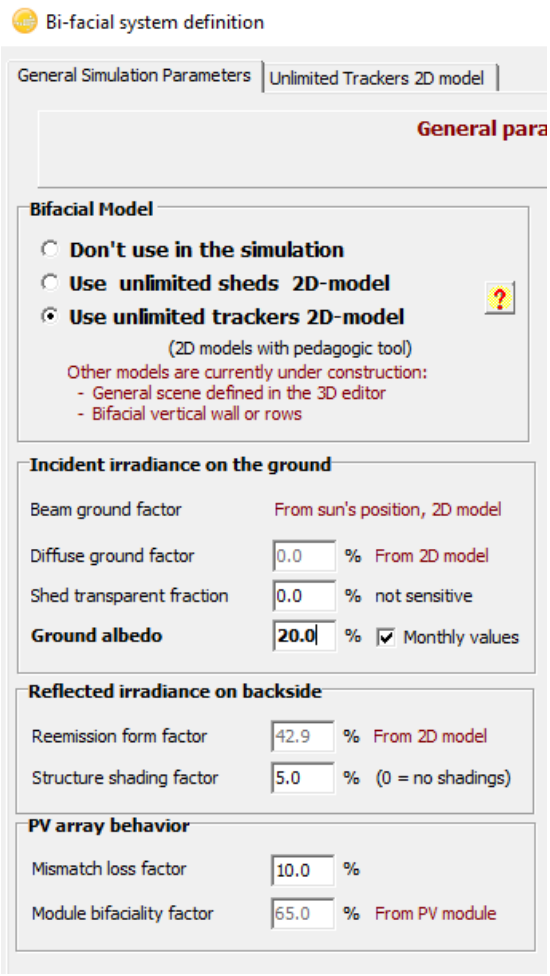


1.7 Bifacial Parameters

1. Use Bifacial model in the simulation from the “Systems” tab.
2. Check orientation: tracker or fixed tilt and ground parameters.
3. Ground Albedo: Set the albedo factor according to:

Surface	Albedo
Grass	0.15 – 0.25
Fresh snow	0.82
Wet snow	0.55-0.75
Dry asphalt	0.09-0.15
Concrete	0.25-0.35
Aluminum	0.85
New galvanized steel	0.35
Very dirty galvanized	0.08

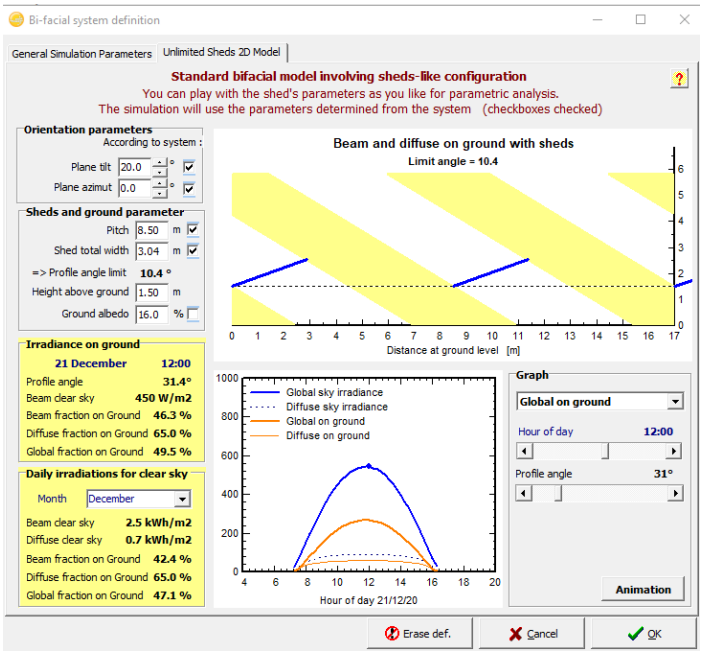
Source: PVsyst



- The site inspection (ground color, texture) and check reference Albedo table above. In general *20% albedo* is used as default where there is no field data available.
- Site measurement with an albedometer (one year) is recommended for better accuracy
- Satellite data i.e. SolarGIS or similar in which monthly albedo values are available

SunPower Testing Facility

4. **Structure Shading Factor:**
   This parameter depends on the type of tracker which includes the details of rail thickness & width, no. of rails per module. Please check with your tracker manufacturer on the recommended structure shading factor. Several tracker manufacturers are optimizing the racking systems compatible with bifacial PV modules. If the shading factor is not available, use 5% of shading factor (PVsyst default) for trackers that are compatible with bifacial modules.



5. **Shed transparent fraction:**
   This parameter depends both on the bifacial module and tracker type. There may be spacings between the cells and between the modules, that allow additional sunlight to reach to the ground. For SunPower P5 bifacial modules set as 2% of shed transparent fraction and also check with your tracker manufacturer for additional shed transparent fraction value.

6. **Rear Mismatch Loss:**
   This parameter depends on the albedo, elevation of the module and type of tracker. The uniformity of the rear irradiance will increase with the height above the ground. This is important because irradiance uniformity impacts the mismatch loss. Typical mismatch loss calculated and recommended by several tracker suppliers is approximately 3%.

General Parameters for Best Modeling Practices:

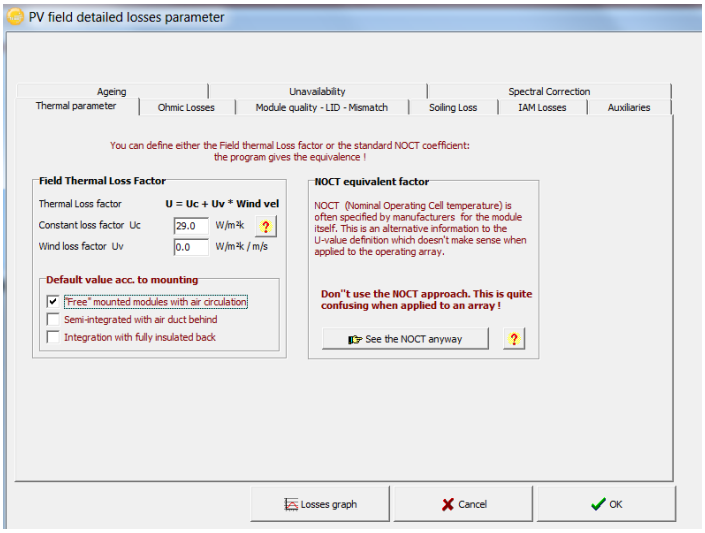
Several modeling parameters in PVSyst are important to understand for proper modeling of systems, but are not typically unique to individual technologies. The following guidelines may be applied to systems using any module technology:

2.1 Transposition Model Selection

SunPower has determined that the Perez tilted-plane (transposition) model can significantly improve the accuracy of calculated plane-of-irradiance (POA) irradiance accuracy in solar array applications. Therefore, select the Perez-Ineichen physical model under *P*

2.2 Thermal Parameter Selection

System Type	Uc	Uv
Open Rack (SAT, GFT)	29.0 (PVsyst Default)	0.0 (PVsyst Default)
Single Tilt	26.0	1.2
Dual Tilt	20.0	1.0
Flush / Invisi-Mount	20.0	0.0



For Open Rack systems SunPower recommends to use Pvsyst default values. SunPower has conducted a study to determine the best thermal response coefficients for use in PVSyst, based on thermal performance of a subset of the SunPower fleet in which the thermal loss coefficients are aligned with Pvsyst.

2.3 Soiling Loss

Soiling and dust impact on PV plant performance may be assessed in a dynamic way using rainfall data, manual washing dates, and information about the local climate and environmental air quality.

Set the annual soiling loss to *1%* for rainy regions and *2%* for dry regions (with a number of washes to be defined).

Appendix A

Incidence Angle Modifier points for Performance modules :

AOI [°]	IAM
0	1.000
50	1.000
60	0.992
70	0.935
80	0.745
90	0.000