First Solar

PVsyst Modeling Guide for Thin Film Technology

Nov 2016 (v.5)

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PVsyst Outline

1. Required software
2. Component Library
3. System Defaults / Global Parameters
4. Meteo
5. Project description
   a. Project weather and site (variant)
   b. Orientation
   c. Horizon
   d. Near shading
   e. System (inverters, modules, strings, detailed losses)
   f. Simulation
6. Additional adjustments

Limitations

- This guide is a “how-to”, and does not explain in-depth how certain parameters used in the simulations are derived, nor the algorithms used “behind the scenes”
- See extensive PVsyst help for further information for PVsyst functionality

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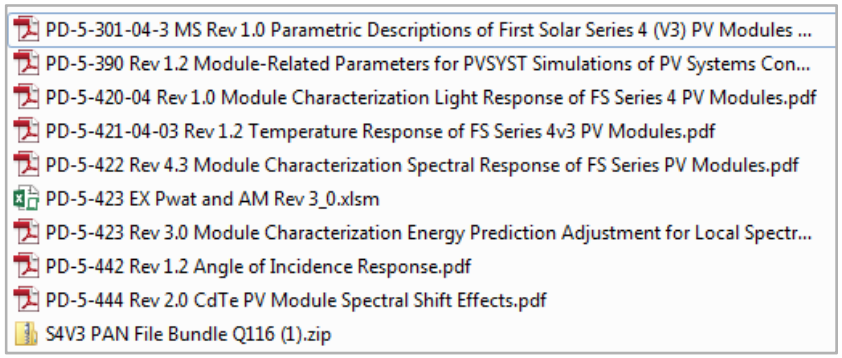
Tools

- Required
  - PVsyst V6.46 www.PVsyst.com
  - NOTE: V6.27-6.29 are affected by a bug which results in an error in the electrical model calculation for CdTe PV modules

- Optional
  - Google Earth http://earth.google.com
  - METEONORM http://www.meteonorm.com/pages/en/meteonorm.php

- Additional Documents and Aids for First Solar CdTe module technology modeling can be downloaded here. The Energy Bundle package contains:



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Component Library

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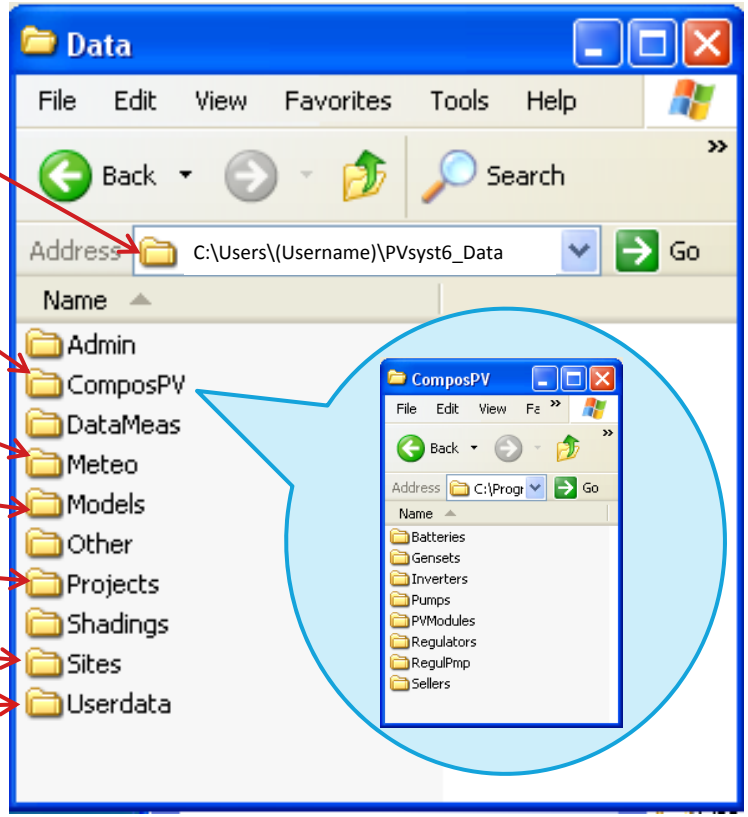
PVsyst Files in the Component Library

C:\Users\(Username)\PVsyst6_Data

- Inverter ***.OND*** and module ***.PAN*** definitions; copy custom files here in appropriate subfolders*
- Imported hourly weather ***.MET***
- Output variable selection model for hourly output ***.SFI***
- Project ***.PRJ*** & ***.VCx***
- Geographic site definition ***.SIT***
- '8760' ***.CSV*** hourly output



Important

- User must restart PVsyst after adding components for it to appear in the database.

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System Defaults/Global Parameters

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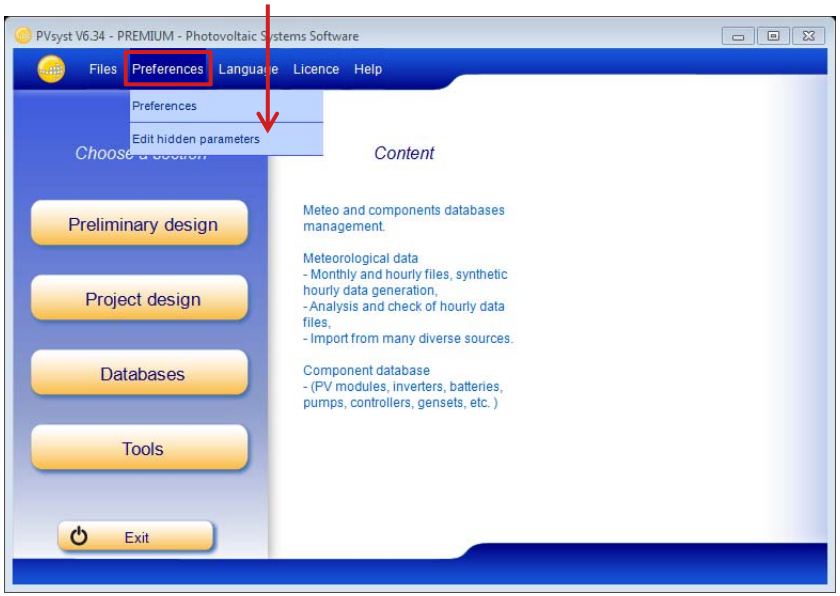
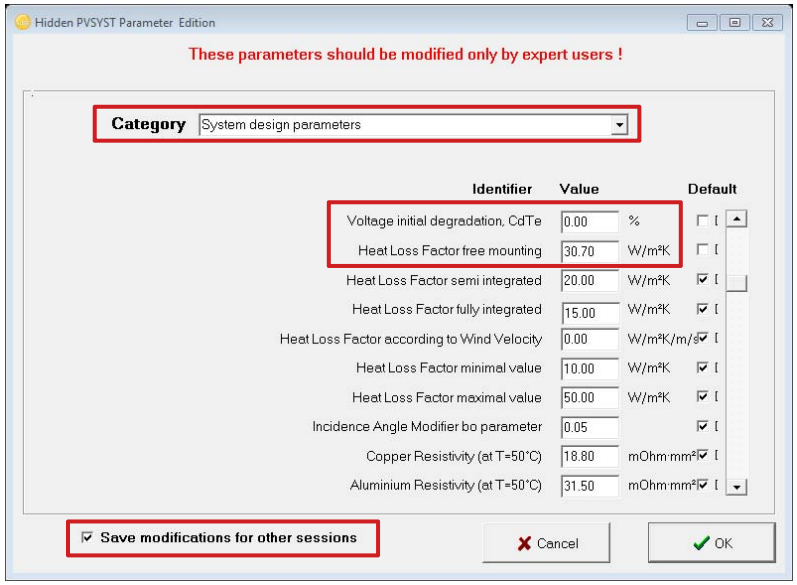
Set Up Hidden Parameters

Select “Edit hidden parameters”





Important

- For simulation of **First Solar Thin Film modules**, set defaults to align with First Solar module technology guidance (see summary on slides #8 and #9).

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Summary of Typical Parameters

Category	Parameter	Unit	Value or Setting
Thermal Parameters	Constant loss factor K_c	W/m^2-K	30.7
	Wind loss factor K_v	W/m^2-K/m/s	0.0
Module Quality-Mismatch	Module Quality[4]	%	0.0
	LID – Light Induced Degradation[5]	%	0.0
	Power Loss at MPP	%	1.0
	Loss when running at fixed voltage	%	0.0
Soiling	Select User defined profile Yearly soiling loss factor	[unit less] %	Site Specific Input
Spectral Loss	Monthly spectral shift factor[6]	%	Use First Solar Spectral Adjustment Calculation Aid PD-5-423 EX and insert resulting values (Typically -1% to +5% as delivered from local meteo data)
IAM Losses	bo	[unit less]	Defined in module file

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Summary of Typical Parameters

Category	Parameter	Unit	Value or Setting
Tracking Parameters	Axis Tilt	Degrees	0.0
	Phi Min/Max (min/max tracking angle)	Degrees	Dependent on chosen structure
	Backtracking	Yes/No	No (unchecked)

More details on module related parameters can be found in "**Module related parameters for PVsyst Simulations of PV Systems**" included in the Energy Prediction Bundle package.

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Meteo

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Weather Data Sources

Hourly Meteo Data

- US TMY3 - (typical meteorological year) compilation of measured hourly data chosen among 1991-2005 from over 1400 US locations
- Solar Power Prospector – (NREL) click 'Download', location on map, 'TMY Format', 'Typical Meteorological Year' to download interpolated TMY3 for any US location using various GIS datasets
- SolarAnywhere – (Clean Power Research) 10 km tiles from 1998-2009 (public data for the US, free through 2012 only, nominal fee for current data, includes GHI/DNI/DHI only)
- Other sources include Helioclim-2, GeoModel Solar, CIMIS, EnergyPlus (DOE), AZMET (U of A), 3Tier, etc.

Monthly Meteo Data

- WRDC **(World Radiation Data Center)** – provides monthly irradiance from 1195 international sites, averaged from 1964-1993. Does not include temperature.
- NASA-SSE* – (Source Meteorological Data Center) Satellite data for 1˚ x 1˚ grid for a ten year period (1983-1993)
- METEONORM*– hourly values are synthesized using a similar method to PVsyst's internal monthly to hourly data generator

*available in PVsyst database

For more detail on weather resources, please refer to NREL's "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications" TP-5D00-63112.

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Weather Data Considerations

- Use the highest resolution data available (choose hourly TMY3 files over monthly data sources when possible).
- Comparable altitudes should be sought, and geographical features, etc., should be considered (ex. intervening mountain ranges or information regarding microclimate anomalies).
- When using tools such as METEONORM that interpolate weather data for the desired site, beware of coastal stations that may pull down the average annual insolation of nearby inland sites.

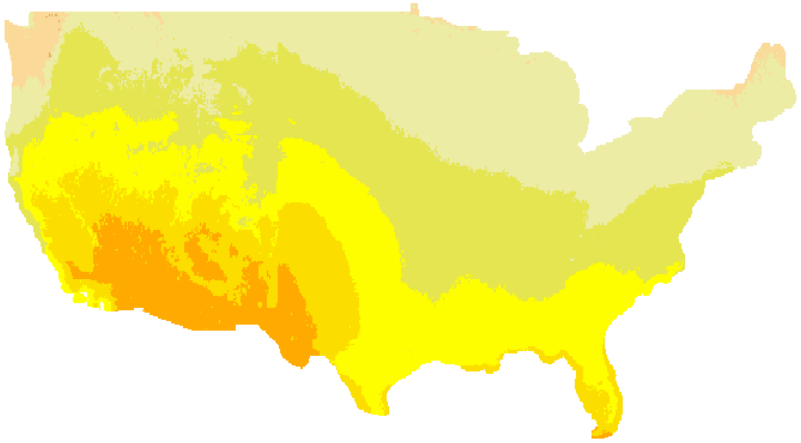

Image from http://maps.nrel.gov/prospector

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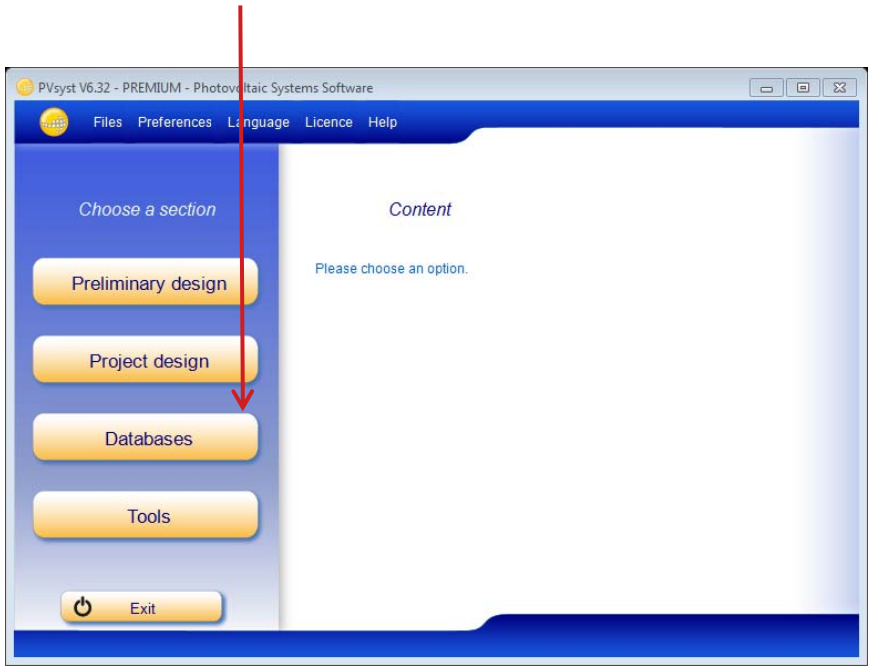
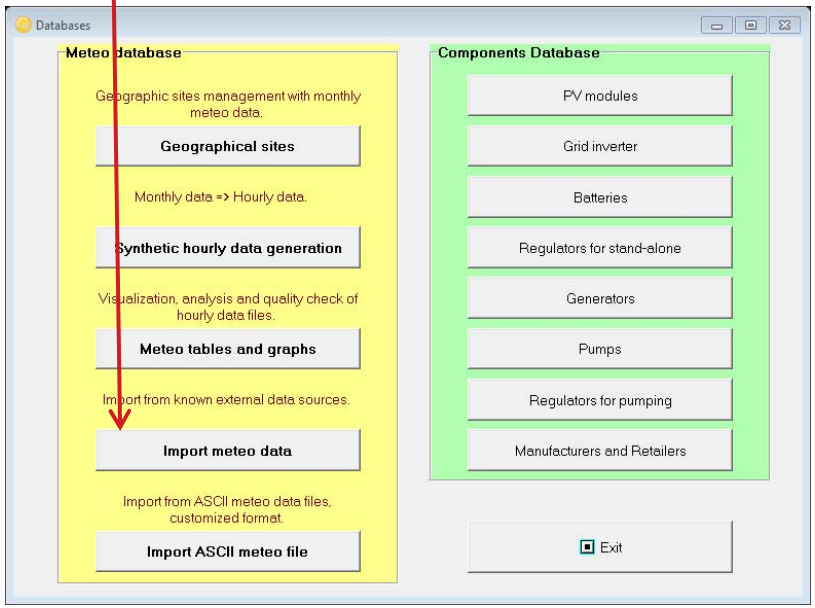
Importing Weather Data

Choose Databases



Click on Import meteo data



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Importing Weather Data, continued

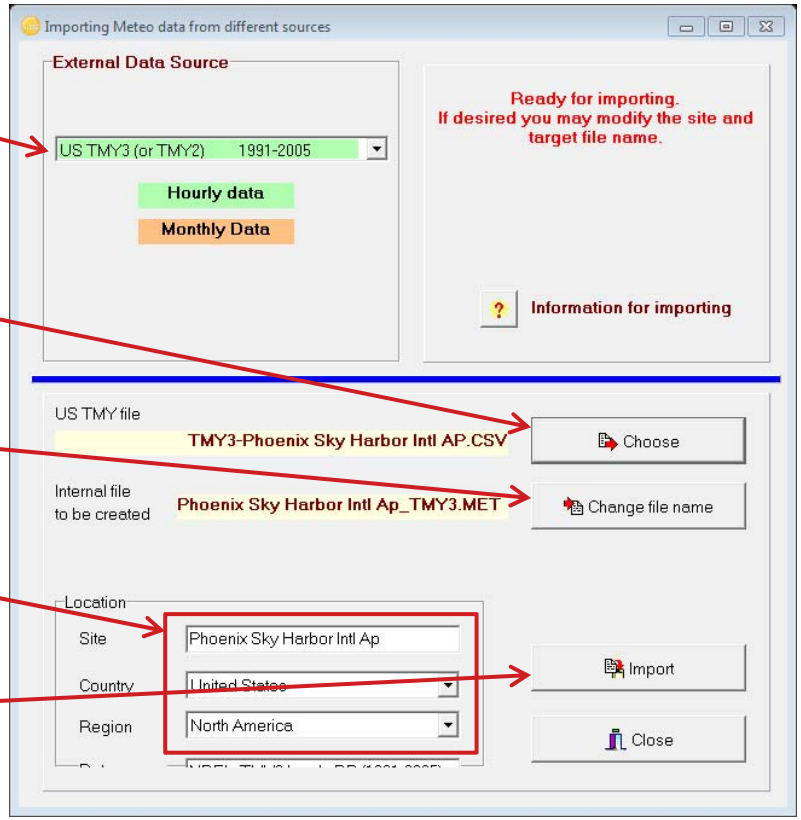
Select external source type to match the downloaded meteo data.

Browse for desired TMY3 .csv or METEONORM .dat file

Choose .MET file name

Define country/region and site name

Import



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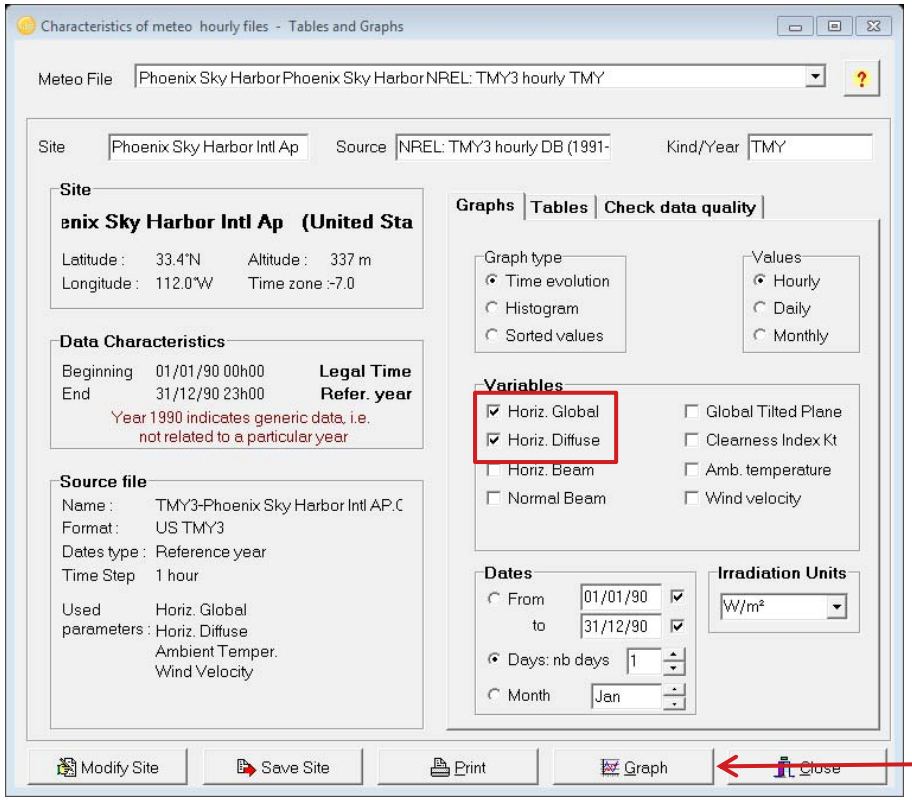
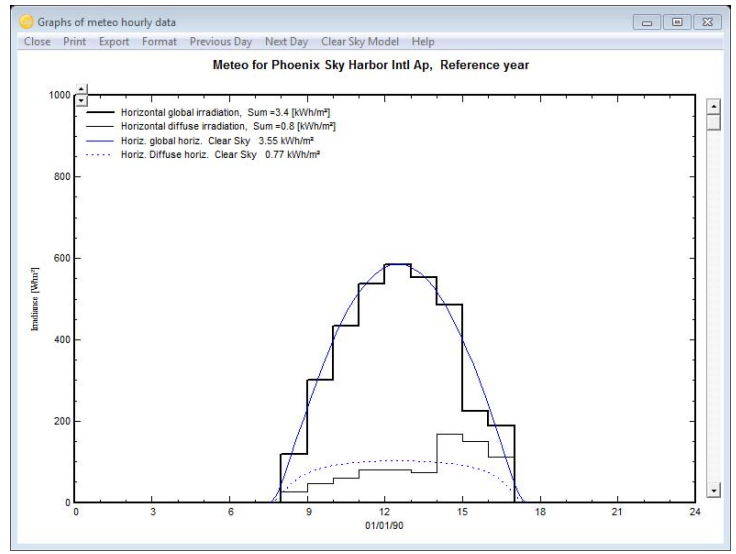
Reviewing Weather Data





Click Graph to check GHI against clear sky model

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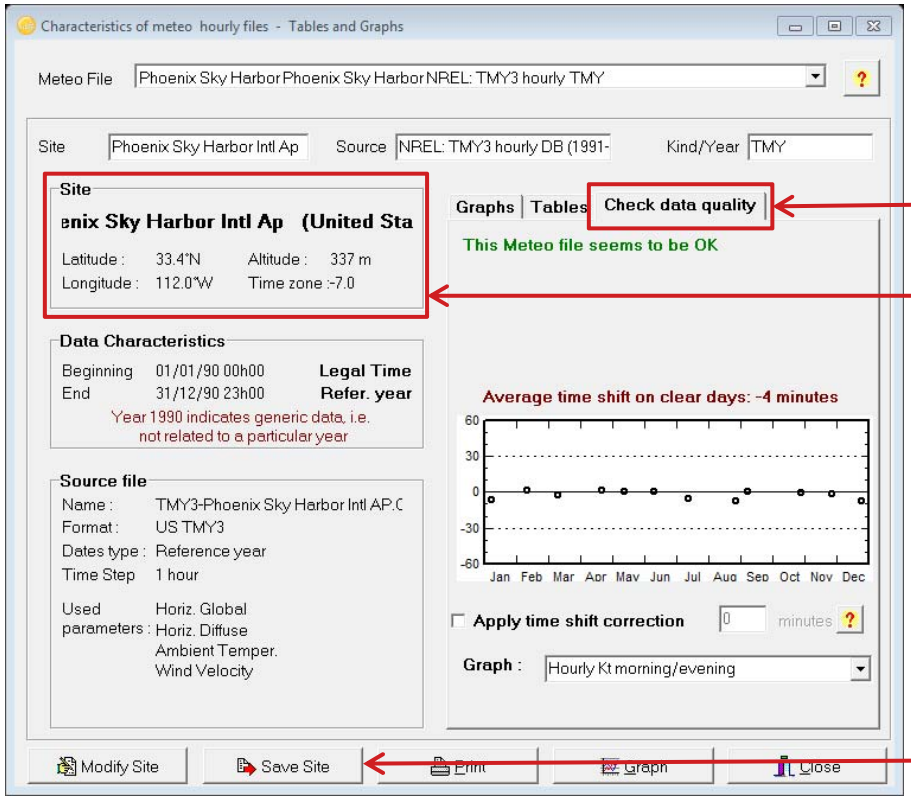
Reviewing Weather Data



Check time shift

Check site info

Save site

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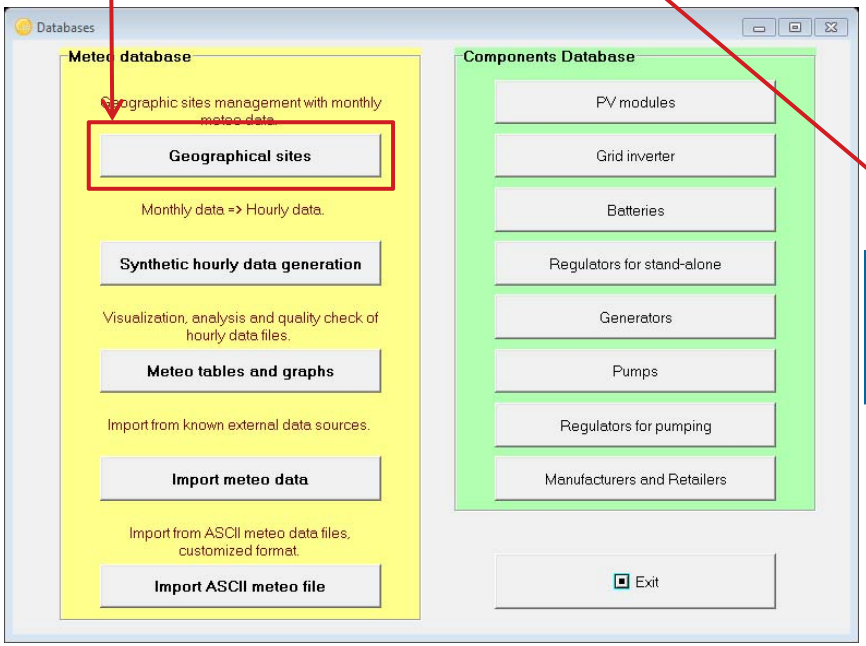
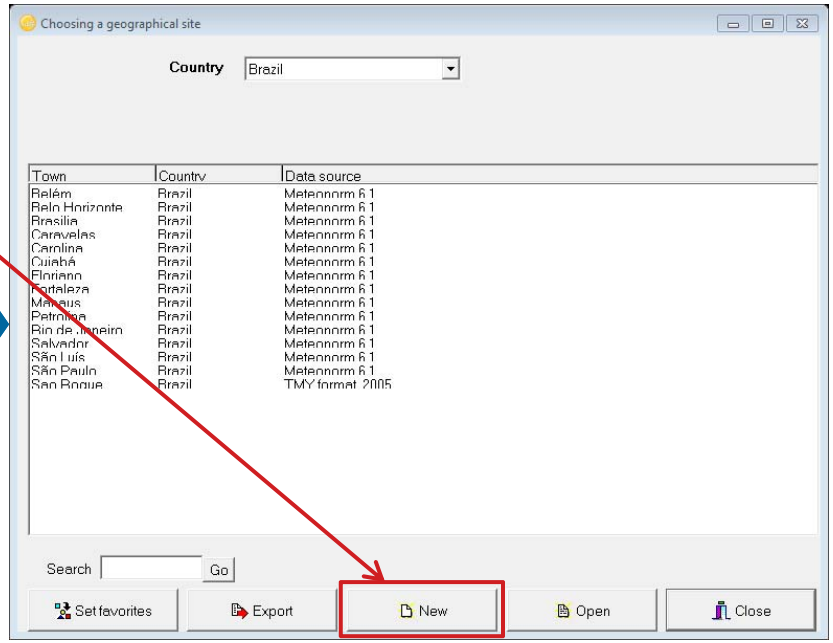
Creating Site

- If meteo file is not colocated with power plant site, create new geographic site, by going to Geographical Sites then click New.





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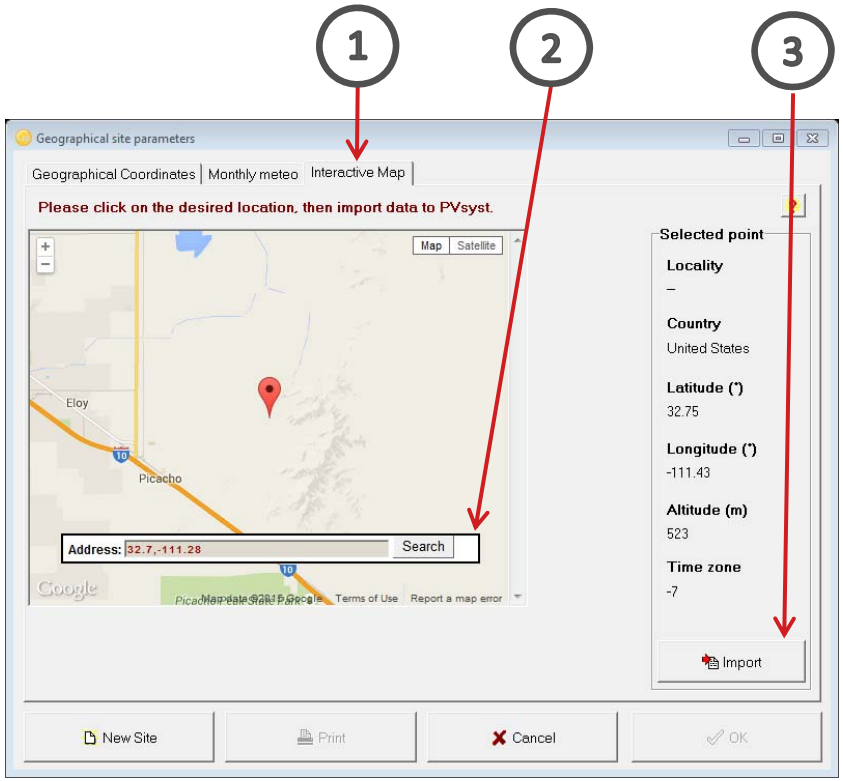
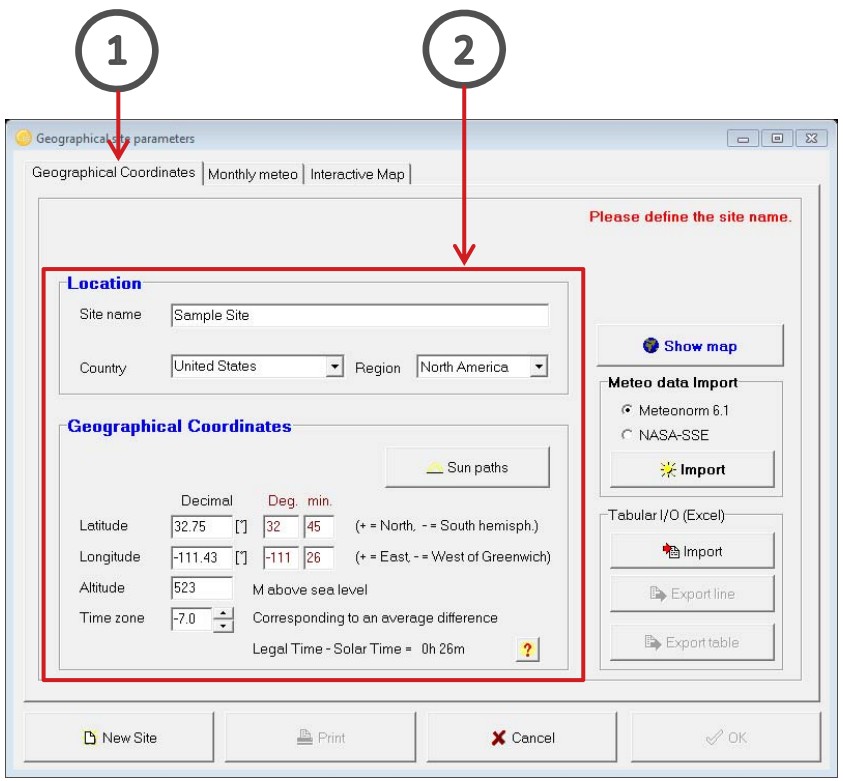
Creating Site

Either select from INTERACTIVE MAP or Enter it MANUALLY





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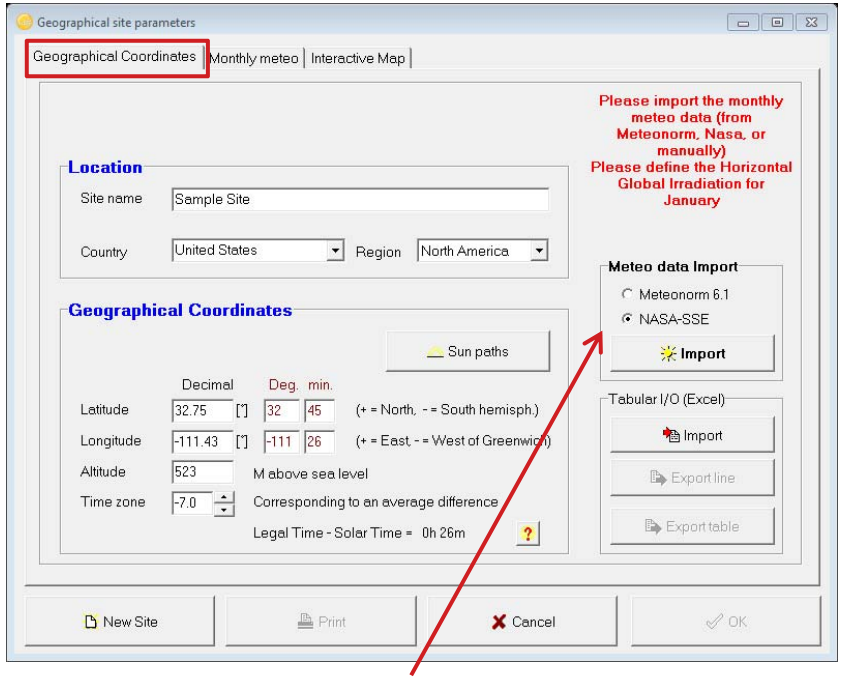
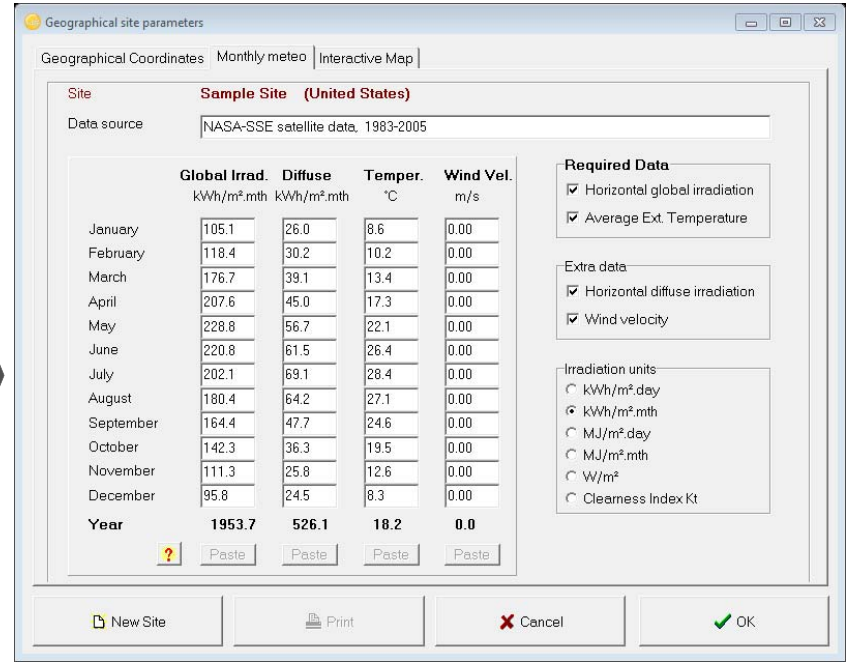
Creating Site



Choose either NASA-SSE or Meteonorm and click Import. You can change meteo source later if needed.



This will populate the monthly meteo data. Ideally, there will be an hourly meteo file used in the simulation, because it is more accurate.

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Project Description

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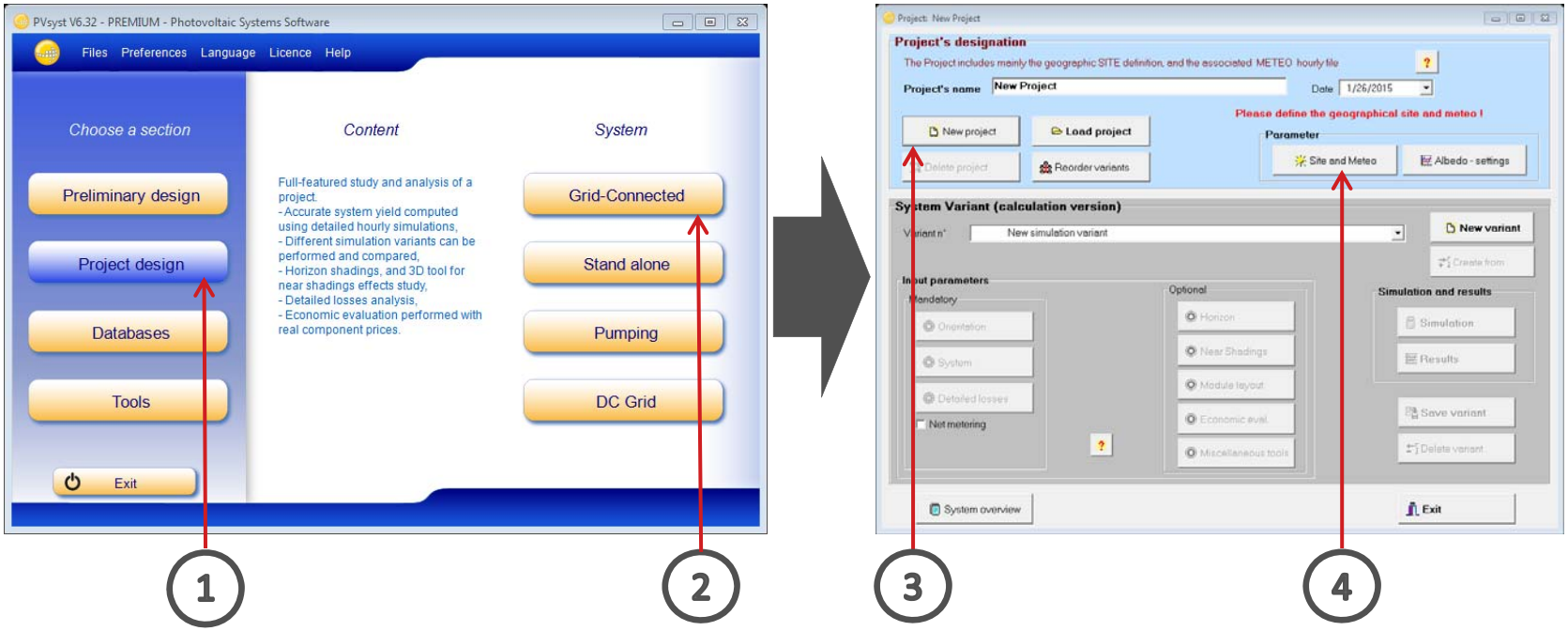
Creating a New Project

Always grid connected!



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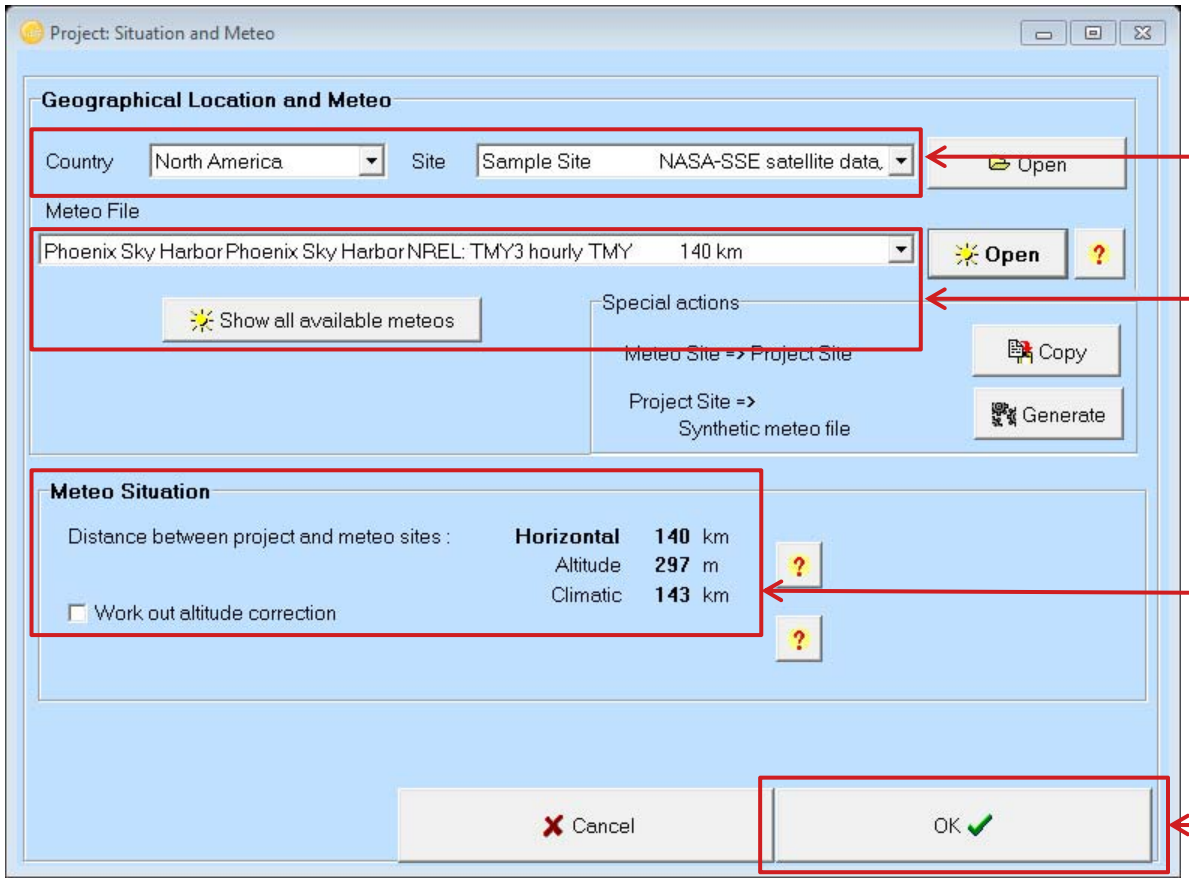
Choose Site and Meteo



- Choose site
- Choose meteo file
- Check distance between site and meteo
- Click OK

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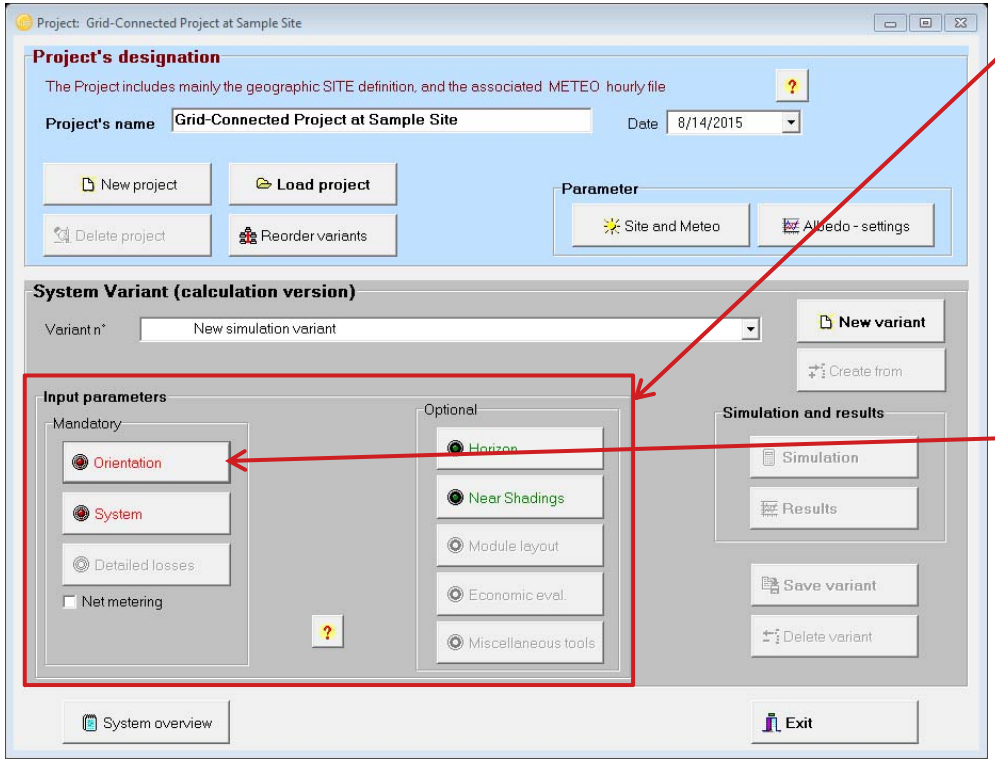
Define Project Parameters



- Colors of Input Parameters menus indicate status:

  Red = incomplete or error

  Orange = warning

  Green = complete

- Choose Orientation.
- The save dialogue will appear.

- See slide #24 for saving the project.

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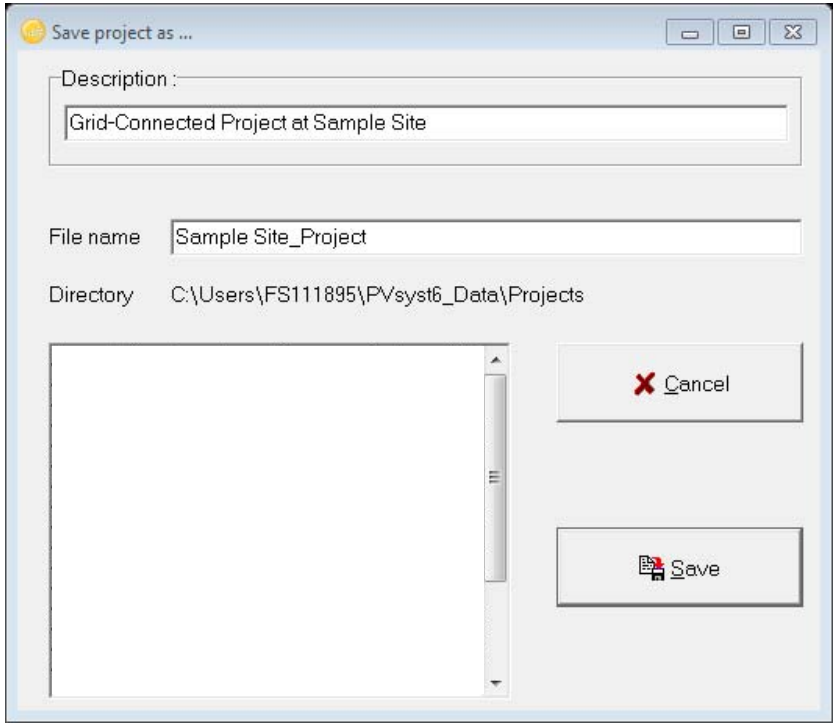
Saving a New Project

Files will be saved in:
C:\Program Files\PVsyst6_data\Projects

- For any given site/meteo pair, multiple simulations can be run under one project file (.prj)
- Additional simulations may vary parameters, such as azimuth , inverter, etc.
- These files are saved as "project variants" (.VCx) with the same root as the project file
- Limit on number of variants is 36



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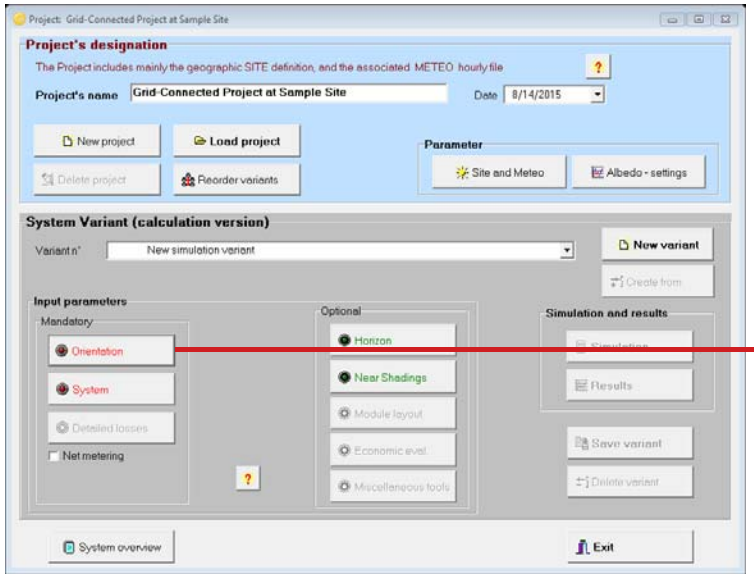
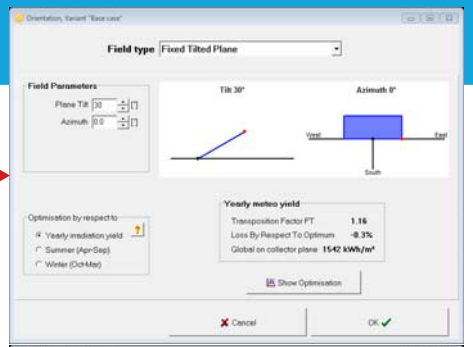
Array Orientation

Three common configurations

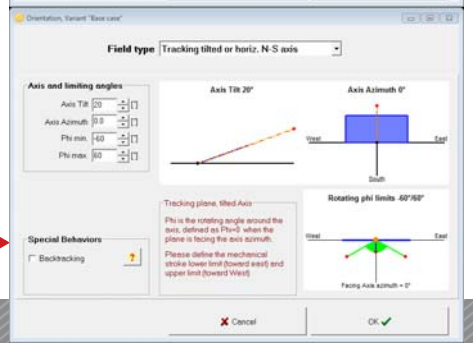
1. Roof flat mount
2. Fixed tilt ground mount
3. Single-axis E-W tracking





Roof Flat Mount (uncommon)

Fixed-Tilt Ground Mount



Single-axis E-W Tracking

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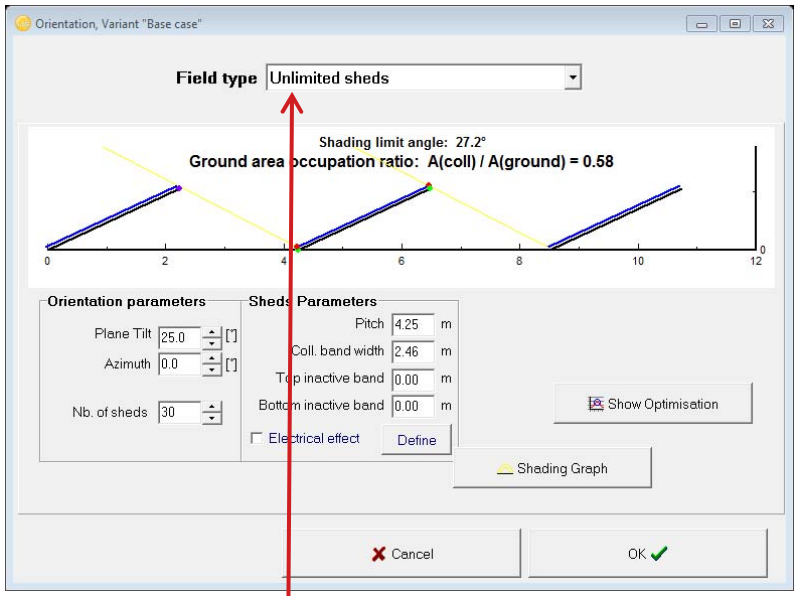
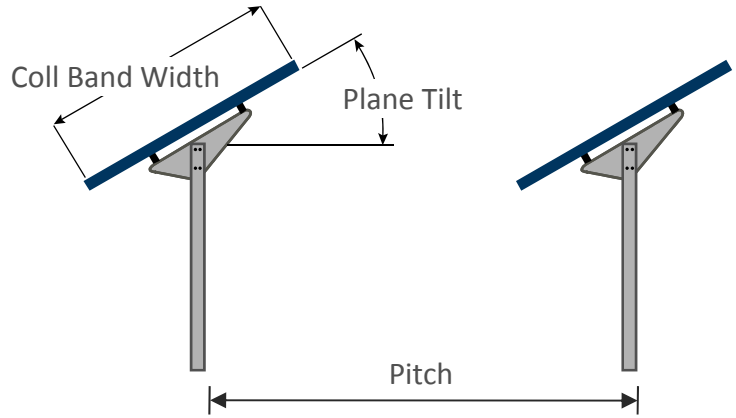
Array Orientation (Fixed-Tilt Ground Mount)



- Unlimited sheds simulates infinitely long rows, typical for large utility scale projects.



- Azimuth will typically be 0 (due south); westerly is positive, easterly is negative
- Number of sheds corresponding to number of rows in the array layout
- Collector bandwidth includes the gap between the modules
- Pitch = row spacing
- Ground coverage ratio (GCR) = Collector bandwidth/pitch
- Typical GCR for fixed tilt is ~40-60%

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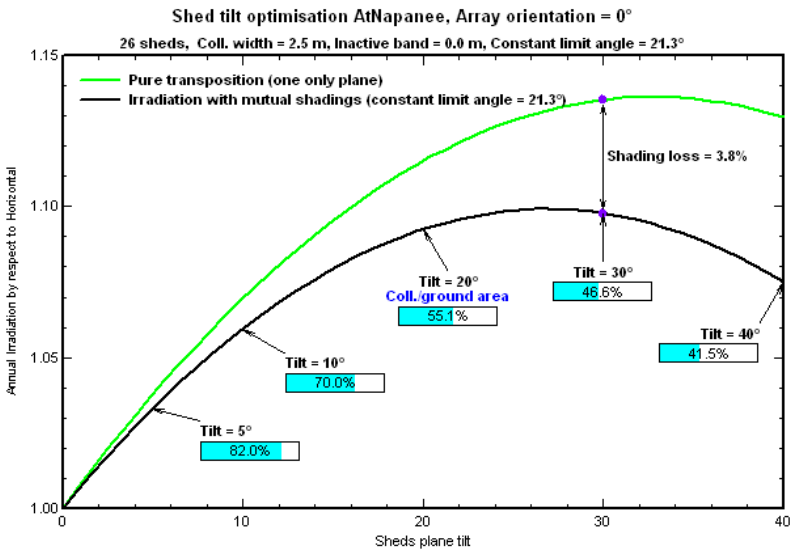
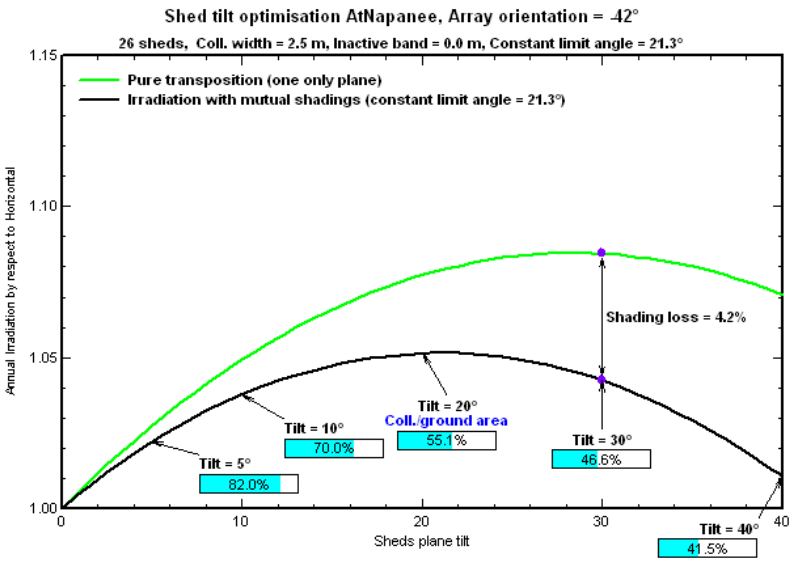
Array Orientation Optimization (Fixed Tilt Ground Mount), continued

- Choice of array tilt depends on the site latitude (fixed!), row pitch & array azimuth (layout constraints), and the maximum acceptable shading loss





- (Click: 'Show Optimisation')
- Example shows effect of changing array from 0° to 42°SE
- Optimal tilt (interpreted as peak of black curve) shifts from 25° (left) to 20° (right)

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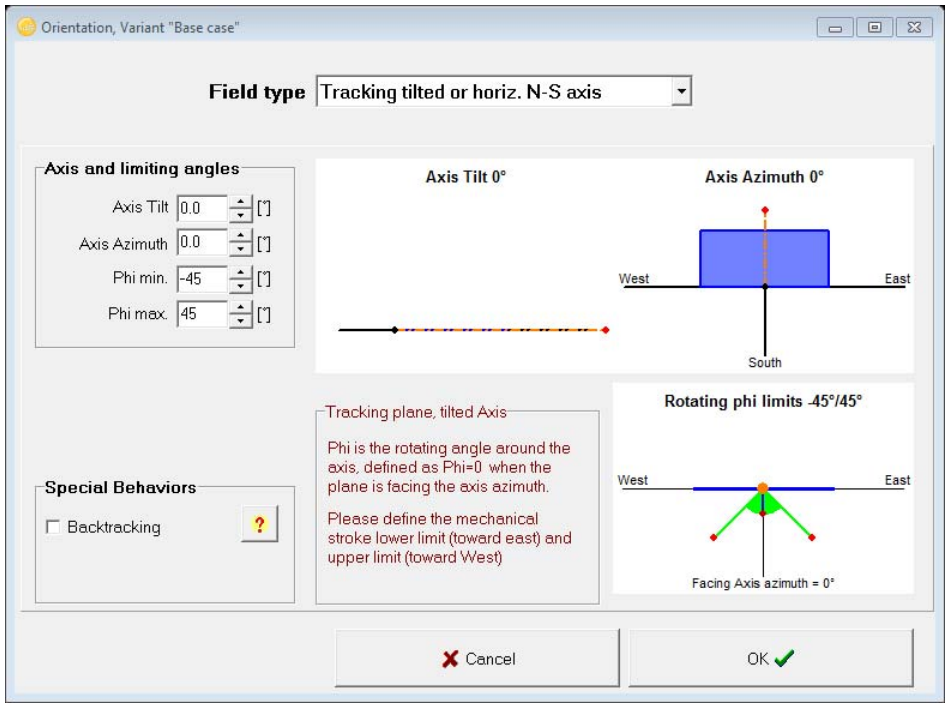
Array Orientation (Single Axis E-W Tracking)



- Rows are oriented on a north-south axis, and the array tracks east-west
- For a “horizontal tracker” where the panels are flat at noon, set the Axis Tilt to 0
- If each tracker is tilted-up towards the south at a fixed tilt, set the Axis Tilt accordingly
- GCR typical for tracker: ~30-50%
- Tracker range dependent on manufacturer
- No backtracking

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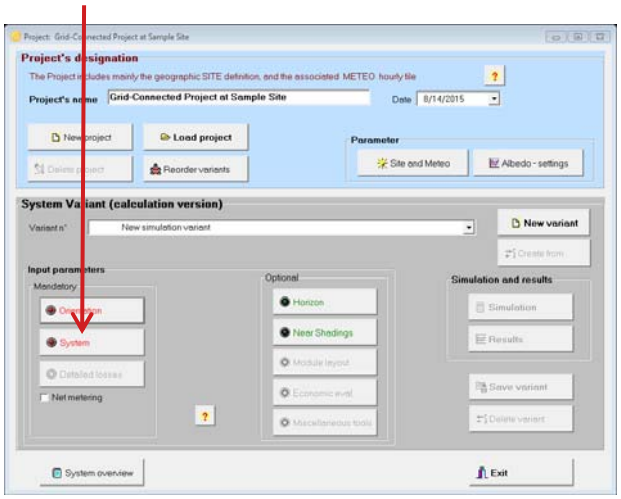
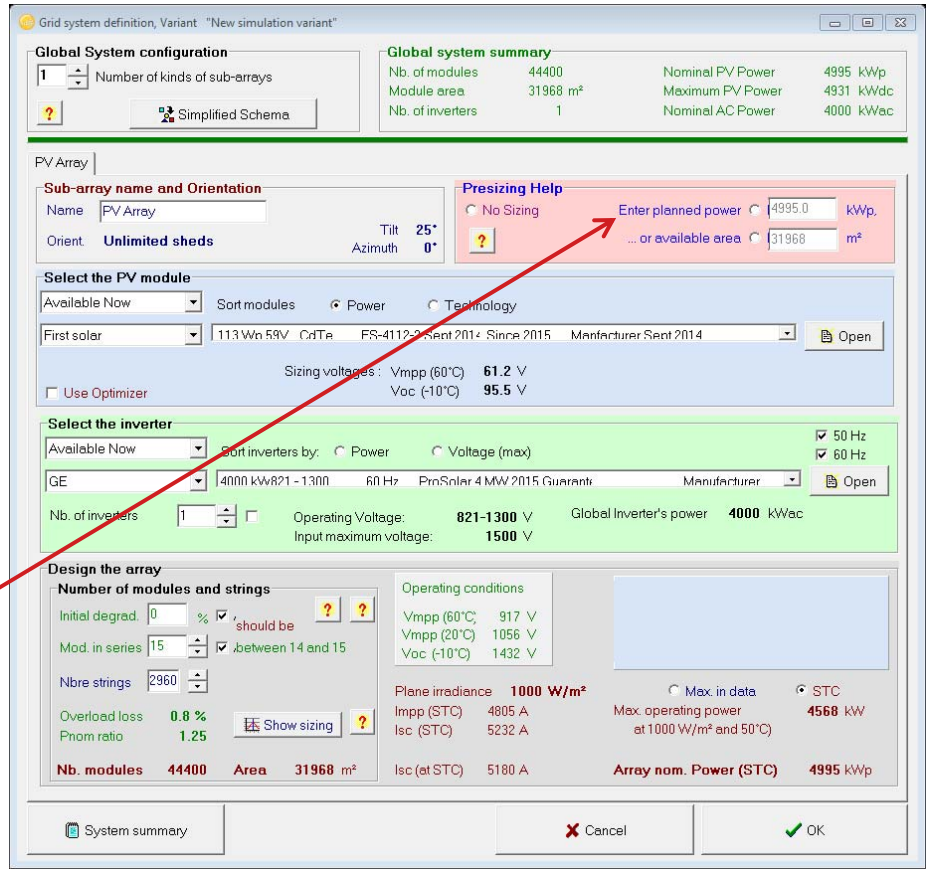
System Design

- Select System button to define components and system size



- By entering a nominal DC rating, PVSyst will recommend quantity of inverters, number of modules in series, and number of strings in parallel for inverter selected



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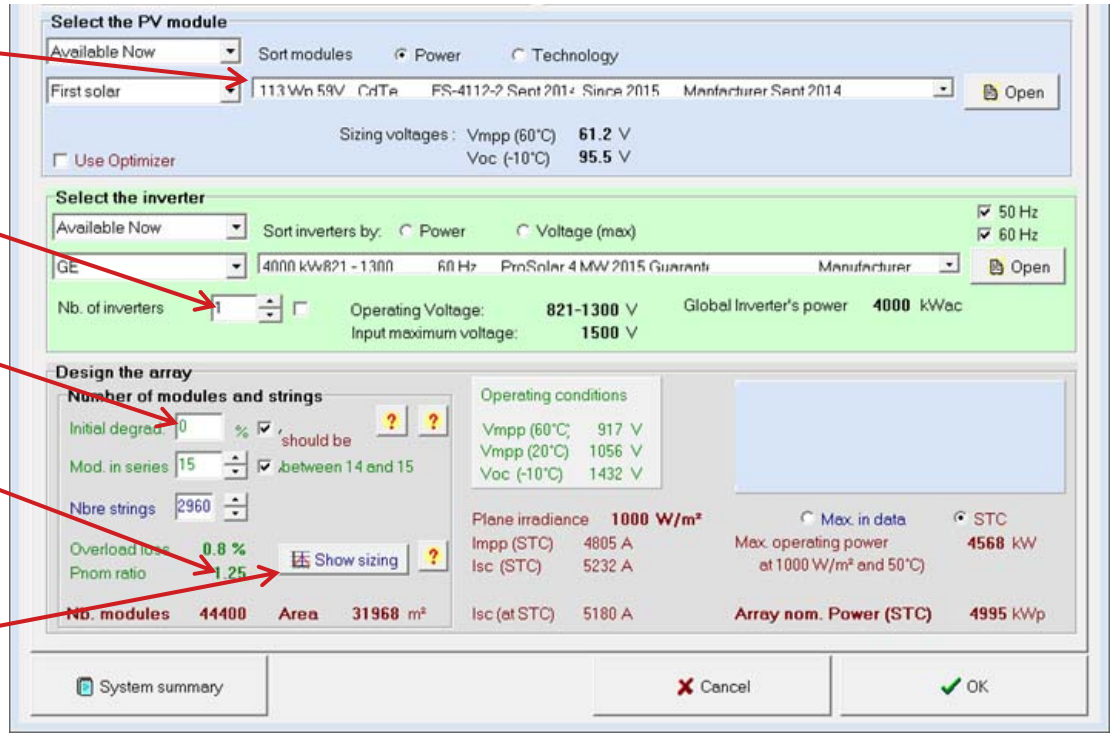
System Design (Parallel & Series Strings)

- Select First Solar CdTe module.
- Enter number of inverters per PCS*
- FSLR nameplate already includes initial degradation, so set to zero
- DC:AC ratio is shown here, with estimate of “clipping loss”
- Toolbox to show the effect of the chosen string configuration on the min/max parameters



*Example number of inverters per PCS: 1 x GE 4MW; 2 x SMA 800kW; 2 x ABB 2MW

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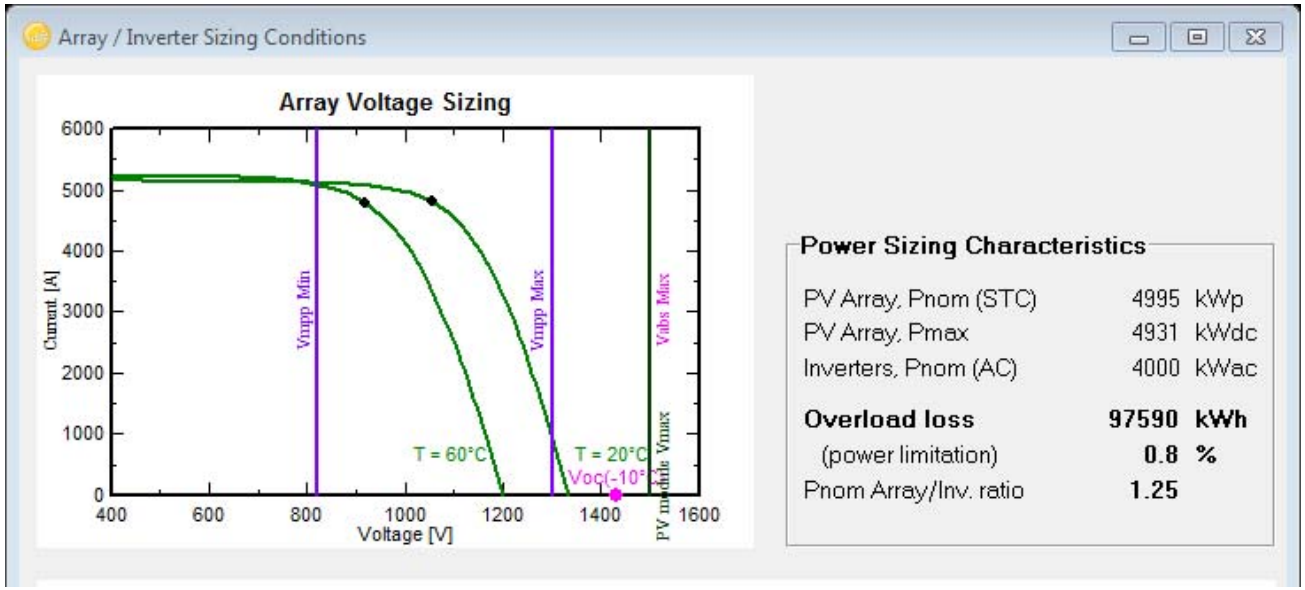
System Design (Parallel & Series Strings), continued



- Graphical tool useful for determining over & under-voltage conditions at min and max module temperature, as the number of modules in a series string is changed
- Inverter clipping occurs when the MPP point lies above the Inv. Pmax DC curve

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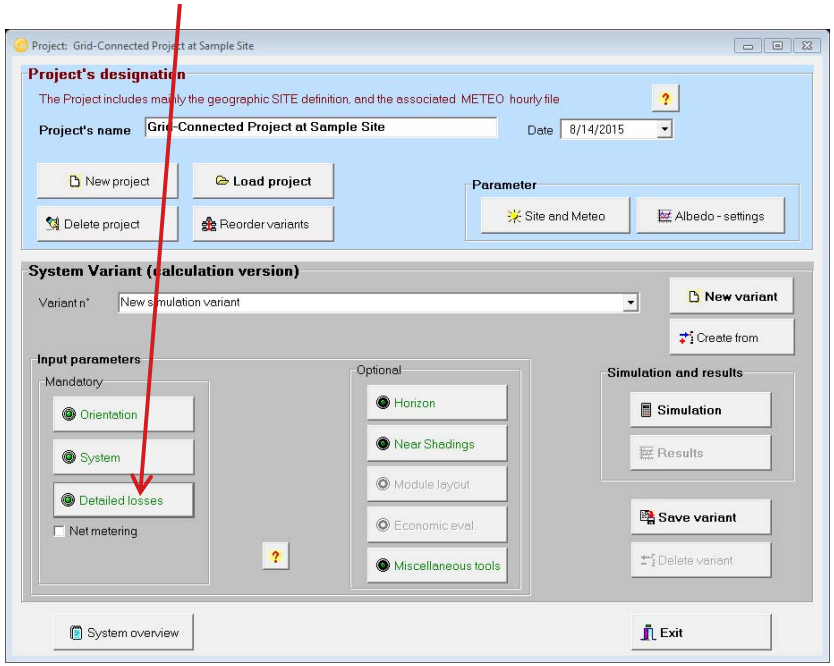
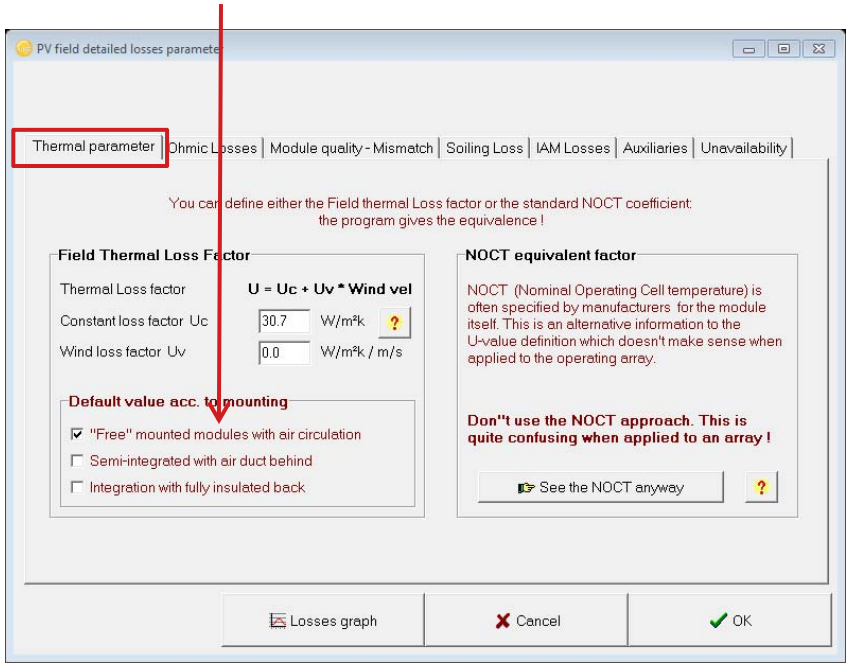
System Detailed Losses

- Check system default loss factors against the defaults *



- Thermal factors can be varied according to rooftop vs. free-field



*Refer to Application Note: "*System Parameter Specifications for PVSYST Simulations of PV Systems Constructed with FS Modules*". The application note is included in the Energy Prediction Bundle package.

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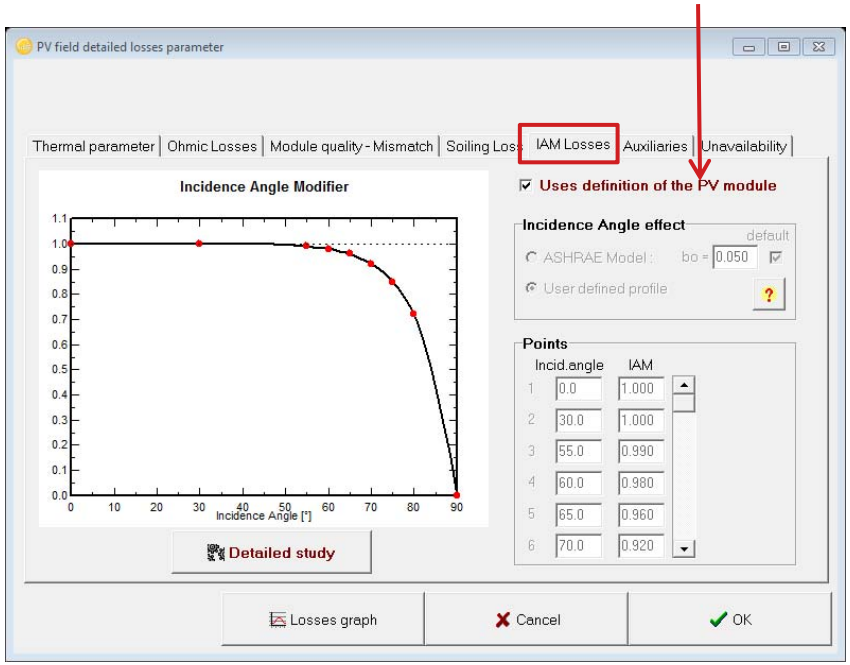
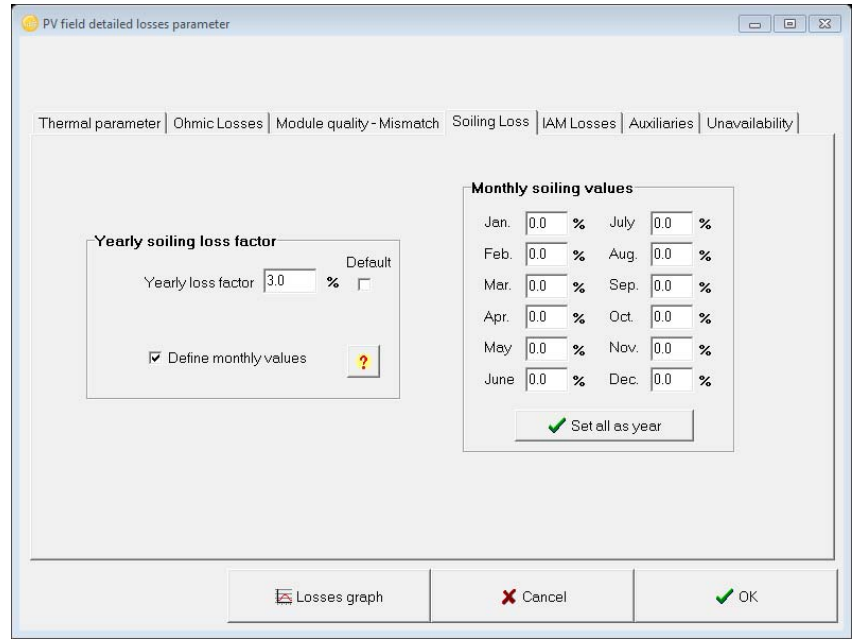
System Detailed Losses, continued

- Incidence Angle Modifier transfer function – defined in PAN file
- Must check Uses definition of the PV module



- Soiling factors:
  - Annual or monthly
  - Used for soiling and snow + spectral



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Calculating Monthly Spectral Shift from TMY3 file

- Use "PD-5-423 EX Pwat and AM Rev 3.0"* to calculate numbers for monthly soiling input.

*The documents are included in the Energy Prediction Bundle package.

Inputs				Product Type		FS-4XXX-2	PVsyst Module Efficiency loss (%) FS DC Health
Calculated Fields				Model Method		Pwat	
PVsyst Inputs				DC Health/Module Quality Assumed		1.0%	1.0%
Month	CdTe Useful GHI (kWh/m²)	GHI (kWh/m²)	CdTe Useful GHI (%)	Monthly Spectral (M_{sp})	Monthly Soiling	Monthly Soiling + Monthly Spectral	PVsyst Monthly Soiling Values
1	0	0	0.0%	100.0%		100.0%	100.0%
2	0	0	0.0%	100.0%		100.0%	100.0%
3	0	0	0.0%	100.0%		100.0%	100.0%
4	0	0	0.0%	100.0%		100.0%	100.0%
5	0	0	0.0%	100.0%		100.0%	100.0%
6	0	0	0.0%	100.0%		100.0%	100.0%
7	0	0	0.0%	100.0%		100.0%	100.0%
8	0	0	0.0%	100.0%		100.0%	100.0%
9	0	0	0.0%	100.0%		100.0%	100.0%
10	0	0	0.0%	100.0%		100.0%	100.0%
11	0	0	0.0%	100.0%		100.0%	100.0%
12	0	0	0.0%	100.0%		100.0%	100.0%
Annual	**0**	**0**	**0.0%**	**100.0%**	**0.0%**	**100.0%**	**100.0%**
CdTe Useful GHI (W/m²)	CdTe Useful GHI (%)	Day	Month	Date	GHI (W/m²)	Pwat (cm)	Pwat (cm)
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	
0	90%	1	1	1/1/1999		0.0	

- **NOTE:** Refer to color code in upper left hand corner to distinguish between inputs (blue), calculated fields (grey), and PVsyst inputs (green)
- Input Product Type (variable) and Model Method (generally Pwat)
- Paste TMY GHI and Pwat data into blue columns
- Input monthly soiling values assumed
- Input Monthly Soiling Values and Module Efficiency loss (if changed) into PVsyst

Limitations

- PVsyst does not allow negative soiling values; as a result, if spectral gain causes negative soiling + spectral values the module efficiency loss is used to compensate.

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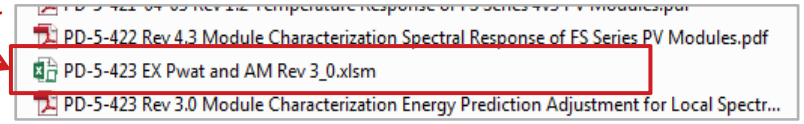
Spectral Response Translates into Real Energy Gains

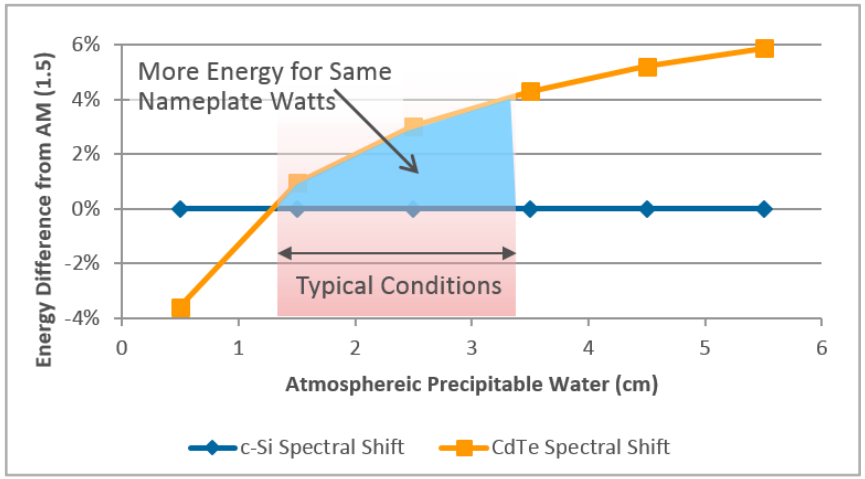
Spectral Shift can be upwards of a 6% effect for CdTe compared to pSi!

To calculate the spectral shift, use Spectral Adjustment Calculation Aid included in the Energy Bundle.



- **Spectral Shift calculation is often omitted by customers, but it should not be ignored.**
- First Solar has published[1] and demonstrated that spectral corrections not included in standard performance modeling tools (i.e. PVsyst), are necessary to capture the full expected performance.

1. L. Nelson, M. Frichtl, and A. Panchula, "Changes in cadmium telluride photovoltaic performance due to spectrum," *IEEE Journal of Photovoltaics*, vol. 3, No. 1, pp. 488-493, 2013.



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Post Inverter Losses Processing

- May compute auxiliary losses under Detailed Losses → **Auxiliaries**
- If not computed in PVsyst, the following must be accounted for if applicable to the project, either hour-by-hour, or by a given constant loss factor:
  - HVAC losses
  - Auxiliary power losses (PLC, lighting, heating)
  - Medium-voltage transformer losses
  - Intra-power plant AC line losses (at distribution voltage)
  - High-voltage transformer losses
  - Transmission lines losses
  - Time-of-delivery weighting
- Post-inverter losses generally "tax" plant energy by 1.5-3%.

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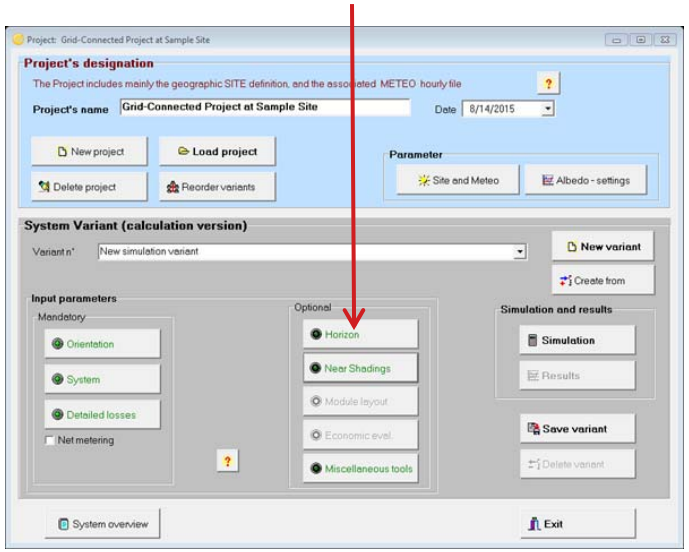
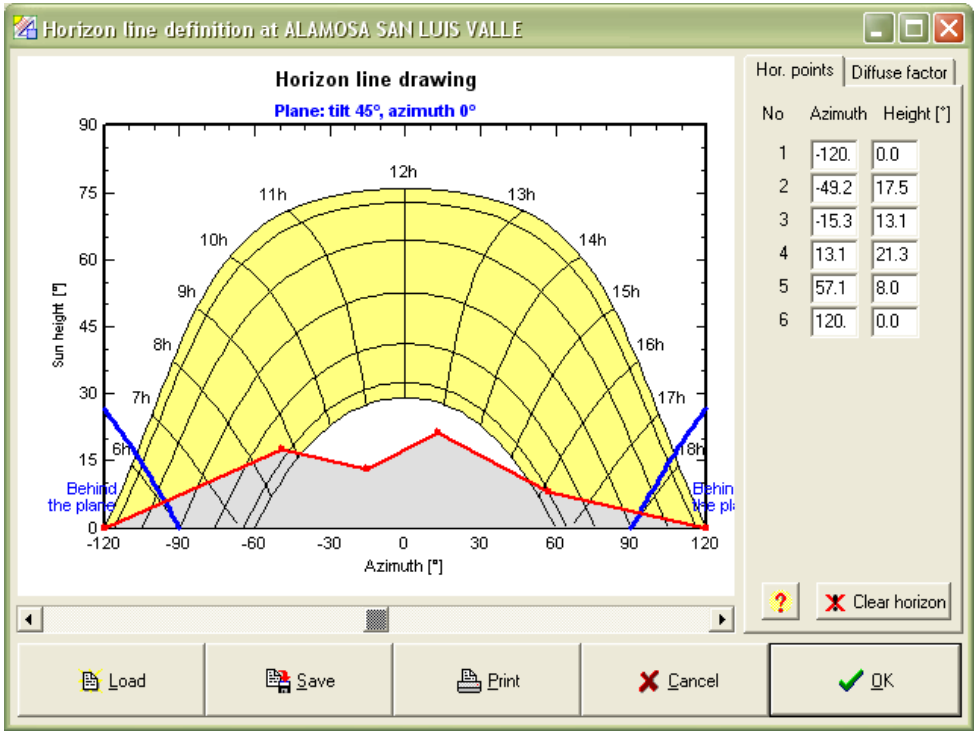
Horizon Shading

- If there is a local structure or other obstruction (mountain range, etc.), shading effects can be modeled using Horizon Button (uncommon)



- Drag red line to reflect actual horizon
- Right click to add points



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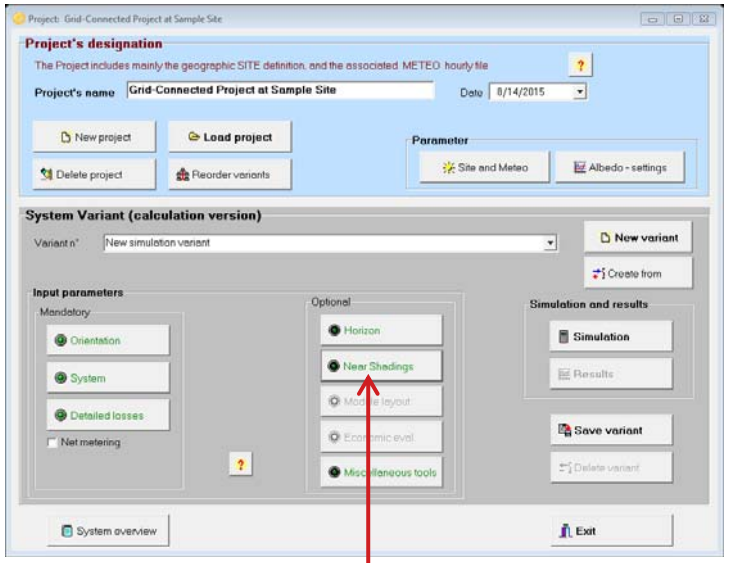
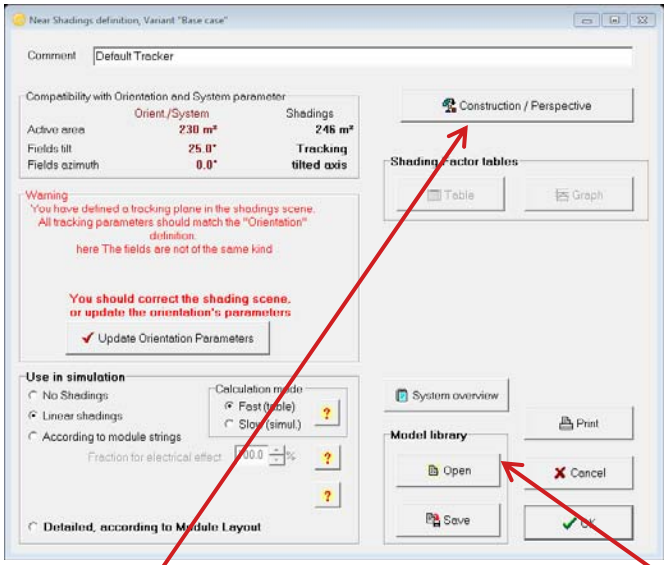
Near Shading (for Tracking Systems)

Either open Near Shadings Dialogue or create new shading scheme.



- Open the 'Near Shadings' dialogue



- To modify or create new shading scheme, press 'Construction/Perspective'
- In the 'Near Shadings' dialogue: Open .SHD file for array

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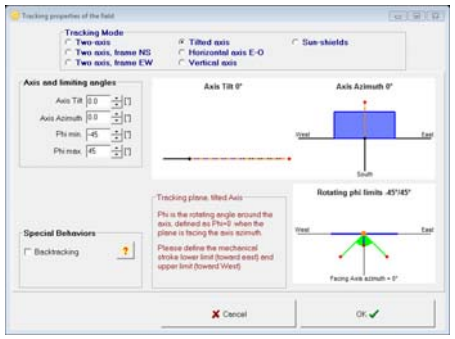
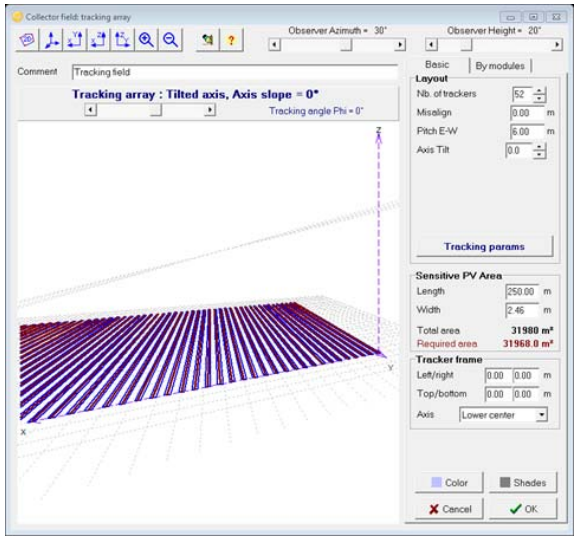
Near Shading (for Tracking Systems), continued





To create new shading typical scheme:

- Right click → new → Tracking PV plane
- Select 'Tilted axis' and rotating limit angles (same as in 'Orientation' dialogue)

To modify existing shading typical scheme:

- Select sketch → right click → modify
- Nb. Of trackers: roughly, number of rows
- Pitch E-W: calculate row spacing based on desired ground coverage ratio
- Axis Tilt = 0
- Width = collector bandwidth (2.46 m for 4 high S4, 1.85 m for S5)
- Tracker frame = 0
- Modify length until Total area and Required area match

Press ok, click 'Table' and compute linear shading factor

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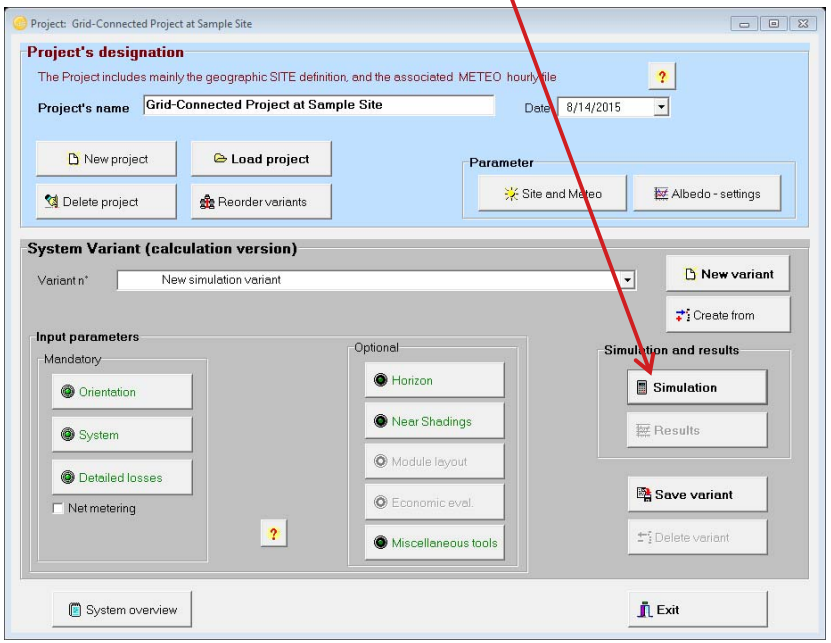
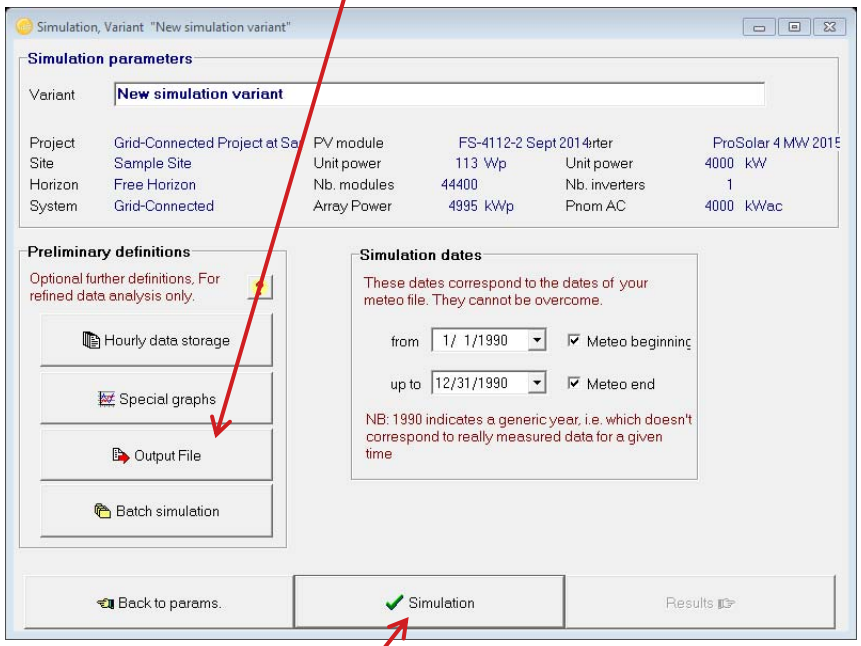
Simulation

- To run Simulation, select button below



- Custom output files can be generated by selecting Output File button (see slide #42 for more detail on output file)



- Run Simulation

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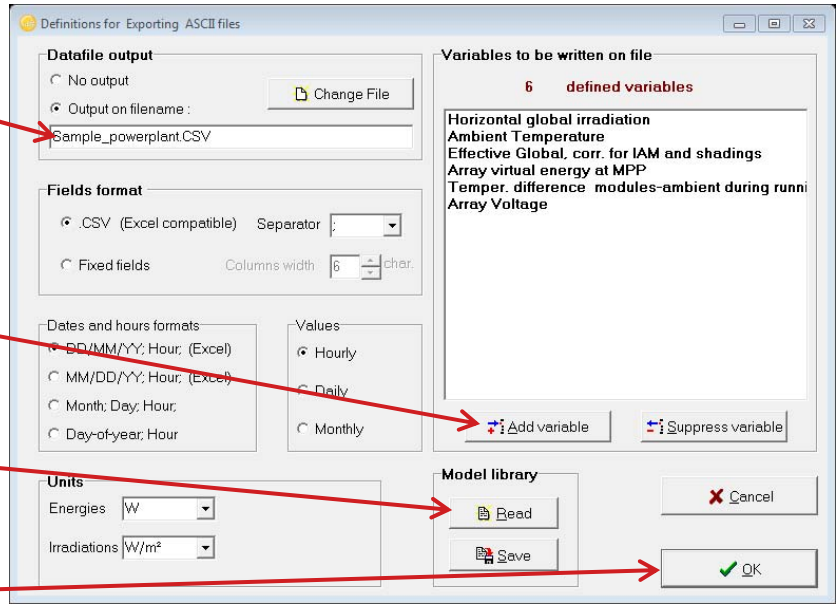
Simulation (Output File)

- Select name for output file
- By default, output files will be saved to :
  C:\Users\(Username)\PVsyst6_Data\UserData
- Add or Remove variables to be reported in output file
- Commonly used sets of output variables can be saved and reused.
- Click OK



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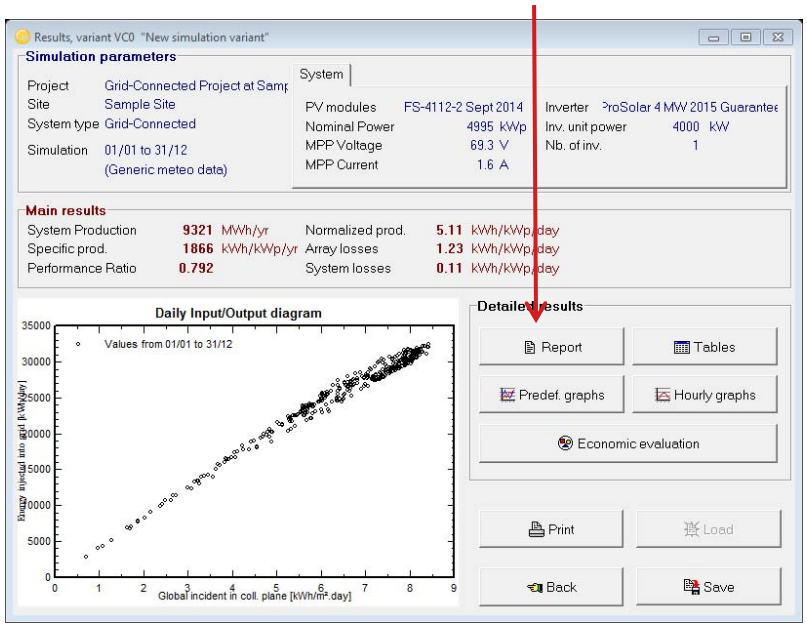
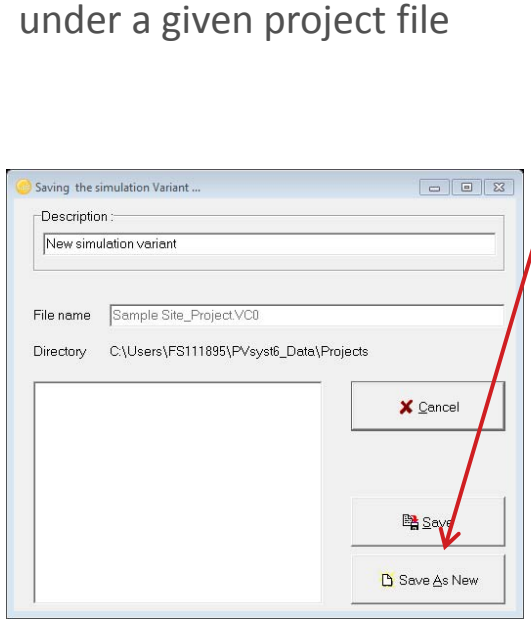
Simulation (Saving)

- After you run Simulation results are written to a .csv file
- Printer-friendly summary report



- To save simulation variant, click "Save As New" or the save will overwrite the previous variant. Up to ~36 variants can be created under a given project file



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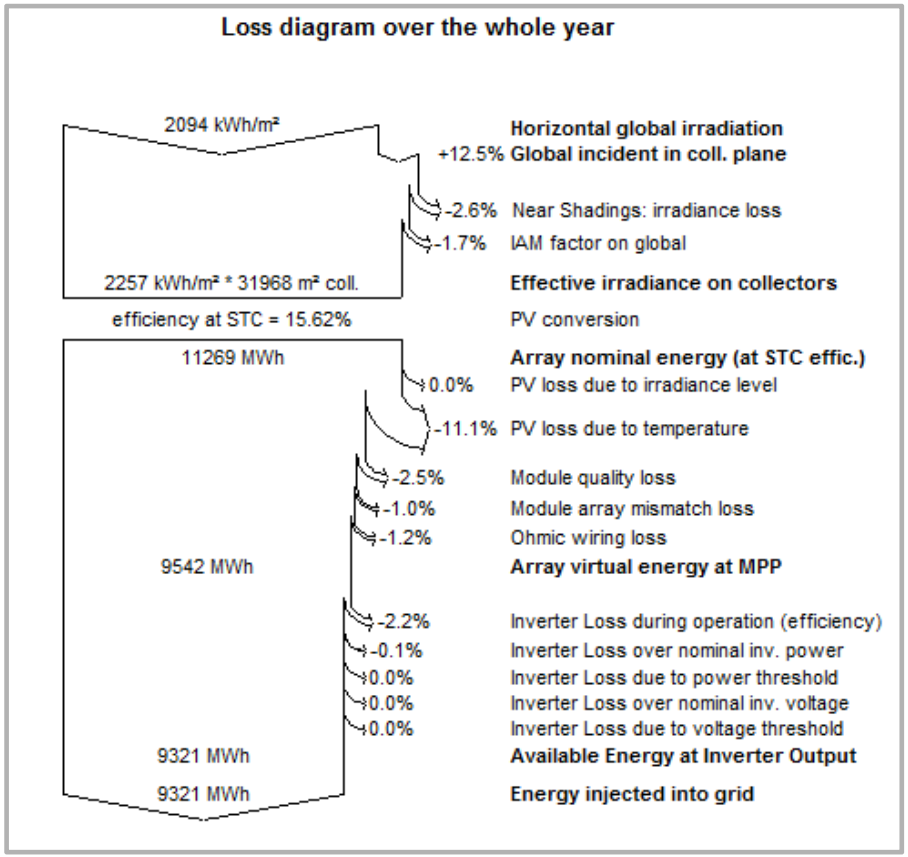
Simulation (Loss Breakdown Report)



- "Waterfall" diagram, excerpt from last page of PVsyst report

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