PHOTOVOLTAIC SOFTWARE

Version 8

Grid Connected Systems

My first project

PVsyst SA
www.pvsyst.com

Introduction

PVsyst is a comprehensive software tool designed for the simulation and analysis of photovoltaic systems. It allows users to design and optimize solar energy projects by providing detailed assessments of system performance, energy yields, and financial viability.

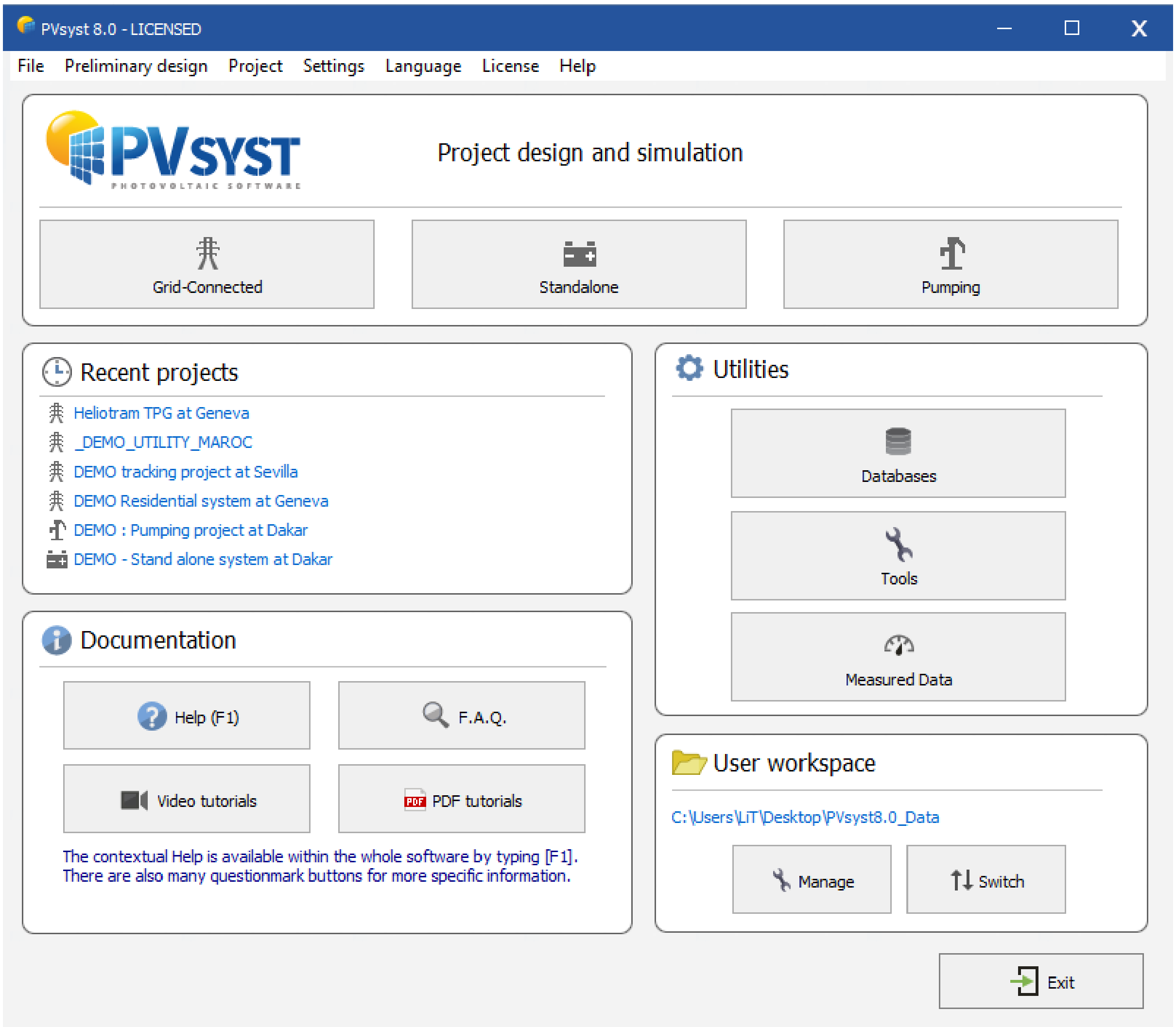
With PVsyst, users can model various types of PV installations with location-specific climate data and component specifications, while considering factors such as shading effects on the system, battery storage, grid unavailability and panel degradation.

This document can be seen as a user's manual, aiming to describe the different windows and feature of the software. The complete reference manual for PVsyst is the online help that is accessible from the program through the "Help" entry in the menu, by pressing the F1 key or by clicking on the help icons inside the windows and dialogs.

Contents

1 PVsyst Main page

At the first main page you have an overview of the different main components in the software, such as the Project design and Simulation, Utilities, Documentation as well as your recent projects and your workspace.



1.1 Project design and Simulation

Project design and simulation is the main part of the software and is used for the complete study of a project. It involves the choice of meteorological data, system design, shading studies, losses determination, and economic evaluation. The simulation is performed over a full year in hourly steps and provides a complete report and many detailed results.

Within the project design and simulation section, PVsyst allows you to create and simulate three types of systems.

- **Grid-Connected** allows you to create a system design that is connected to the grid. You also have the possibility to define a self-consumption profile and battery storage with various strategies are possible.

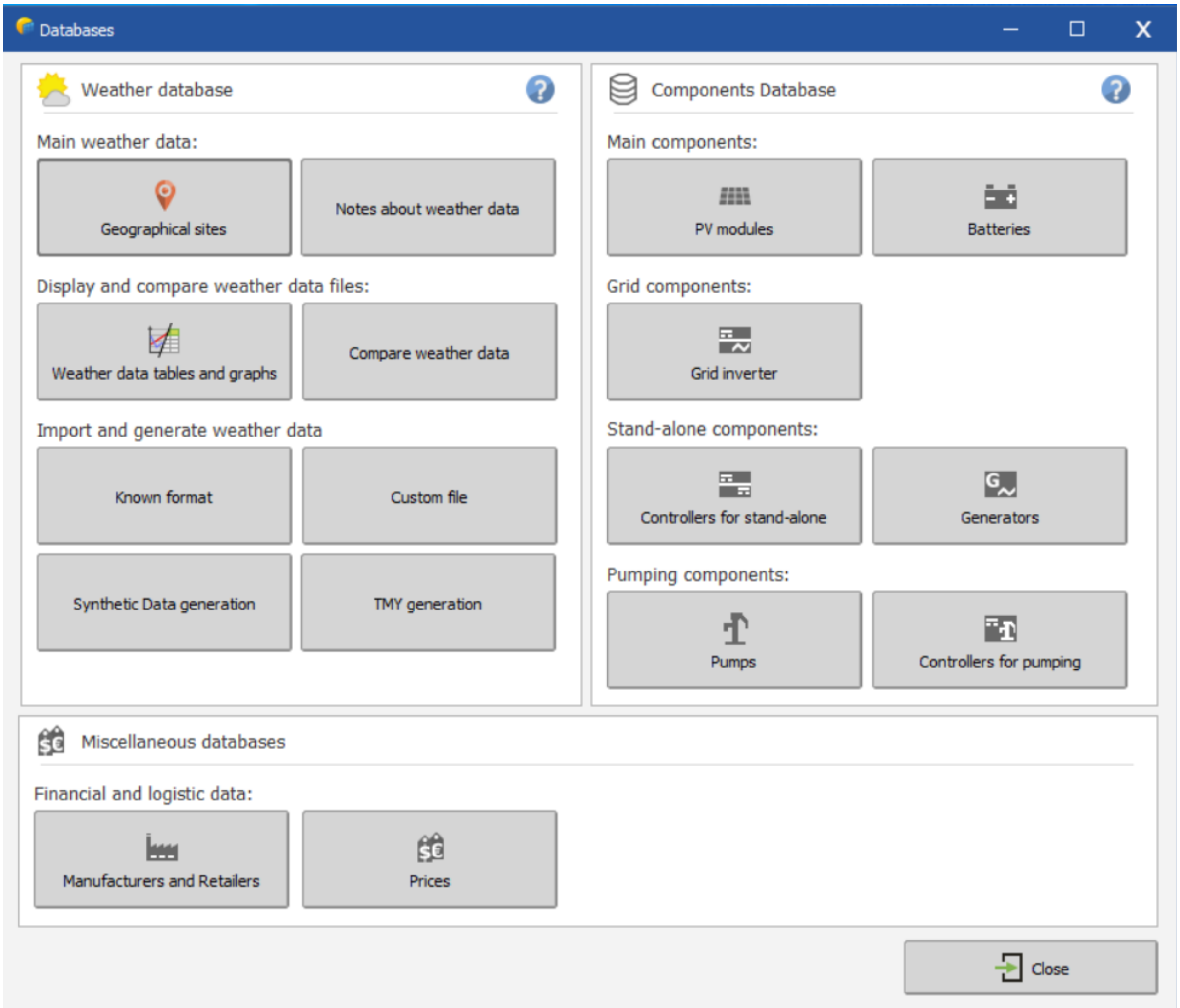
- **Standalone** is reserved for a system unconnected to the grid, you are forced to have a storage option. Production that you cannot utilize, or store will be curtailed.
- **Solar pumping systems** are common in certain areas where solar panels are used to run a pump from a well or a lake that then can be stored in an elevated tank and the water can then be used for various things at various times.

Recent projects will allow you to quickly find and modify your recent projects.

1.2 Utilities

The Utilities section in PVsyst offers a range of tools and functions designed to enhance the understanding and the precision of your PV system analysis.

- In **Databases** you can find all the sites and components already stored in PVsyst. You can also generate new sites, import weather data and create new components.



- In **Tools** you have some advanced parameters for solar geometry and electrical optimization instruments.
- In **Measured data** it is possible to add measured data and to compare simulations with measurements.

1.3 Documentation

In the Documentation section you find a direct access to the PVsyst Help, the complete reference manual for PVsyst, also accessible from pvsyst.com/help. Throughout the software, context-sensitive online help is available via the F1 key and small question mark icons inside the windows and dialogs, providing more specific information in certain cases. By using the F1 key, or clicking at the question mark icon, you arrive at the PVsyst help tool where you can find useful articles with precise information, explanations and step by step description of how to use different function the PVsyst software.

You also find the access to the PVsyst forum where you can post your questions and PVsyst collaborators and other Pvsyst users will guide you forward.

In the PVsyst video channels you find educative videos and tutorials. You also find these printable users manuals and tutorials here.

1.4 Toolbar and Workspace

It is from the Main page that the settings are made for your entire workspace.

When files are saved, they will automatically be saved in the **workspace**, in a precise folder structure. In the workspace you also find a set of templates with the correct configuration, to be used for instance to define a self-consumption profile. PV components will be saved to ComposPV, project files will be saved to Projects, etc.

- Under **File** you find the for example the options to import and export projects and components.
- The **Preliminary design** is an easy and basic simulation tool for small and simplified projects.
- You can start a new project through the **Project** tab. Here you also find a fourth type of project not visualized in the Project design and simulation window, that is the DC-grid project, for the use case of certain public transport companies. From the Project tab you can also load a project in your workspace or a DEMO project defined by Pvsyst, that showcase various features and examples of utilization.
- In the **Settings** you have Preferences where you could for instance define user info, units to be used as default and possible API keys for certain weather file providers. In the Advanced parameters, almost all the default values and thresholds that generates error messages can be modified, but should be modified only by experts.
- **Language** can be changed in this language tab, or by clicking the F9 button.
- In the **License** tab you find all the information about your Account, activation key etc.

- The **Help** will guide you to the various documentation possibilities available.

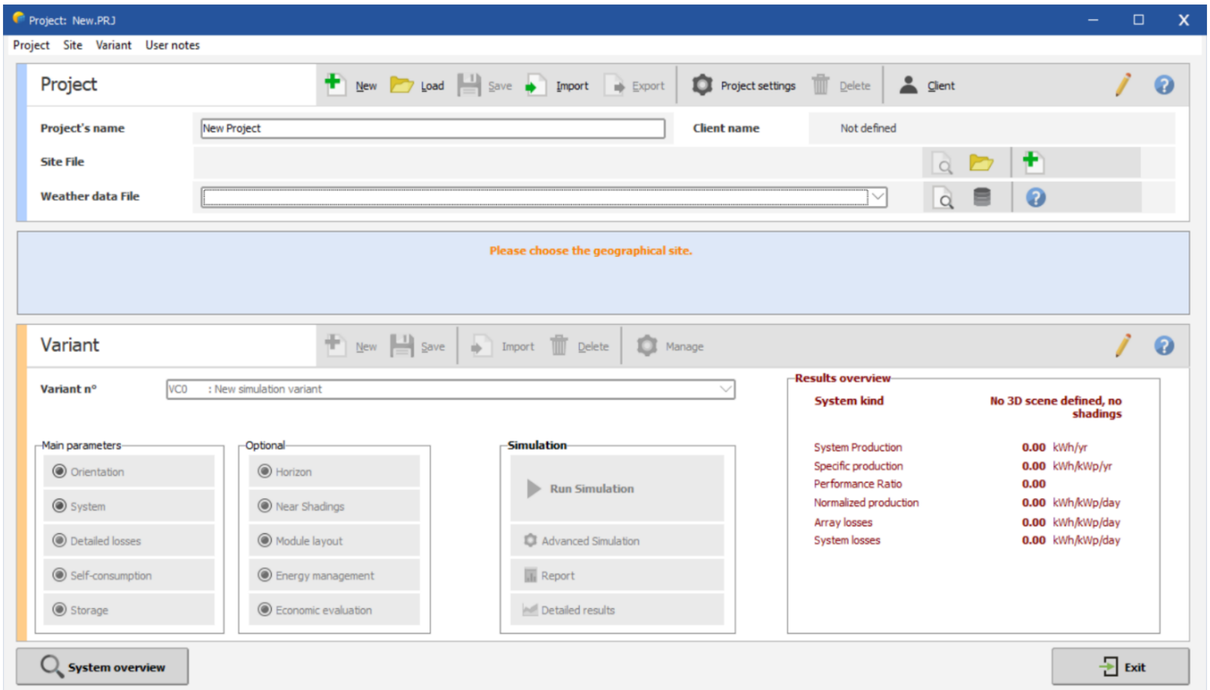
2 My first simulation

For this first explanatory tutorial, we choose a Grid connected system, but the majority of steps and information will be relevant also for standalone and pumping systems.

The Workflow in PVsyst is to work in Projects and in Variants. This also illustrates the hierarchy of the software.

Project contains the geographical site of your system, the reference to a file with the meteorological data and some general parameters like the albedo definition and parameters specific to this project. The project will be the central object that allows the basic definitions in which you then will construct different variants of your system.

The system variant contains all the detailed definitions of your system, which will result in a simulation calculation. These definitions include the choice and number of solar panels and inverters, geometrical layout and possible shadings, electrical connections, different economic scenarios, etc.



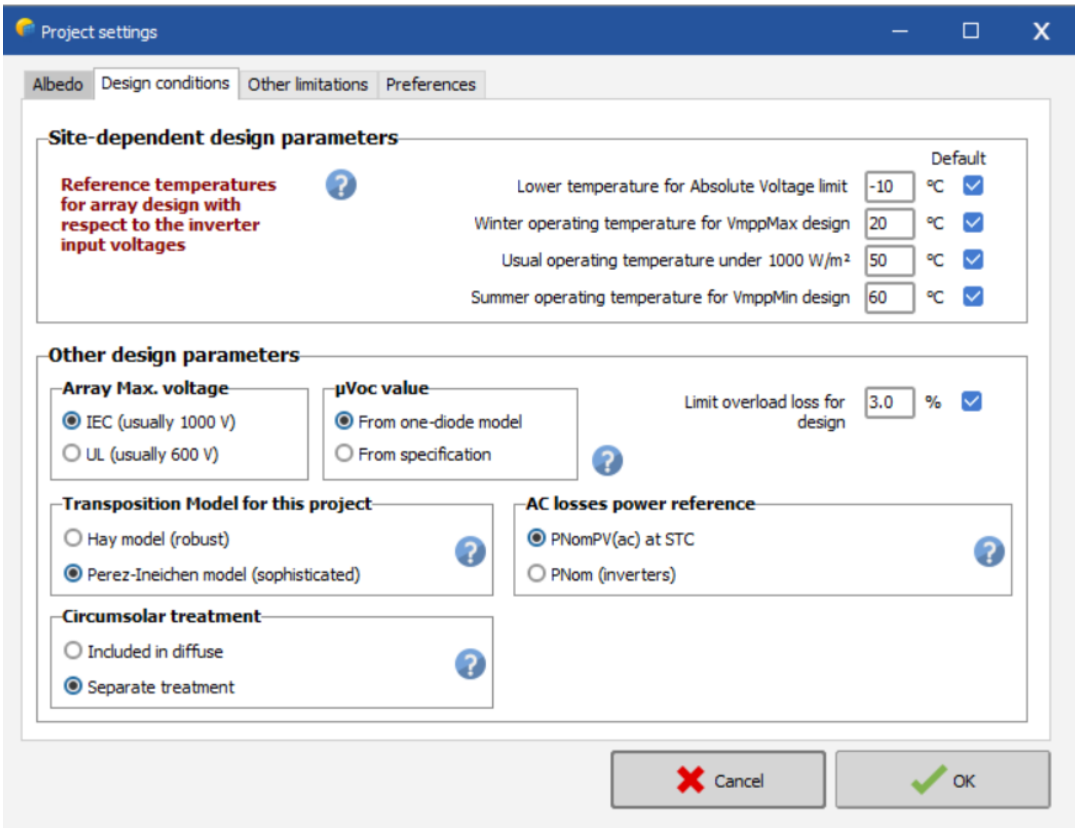
2.1 Project definition

By Clicking *Grid connected System* on the welcome page, PVsyst will automatically open the most reason project (It's possible to change the default behavior for opening new projects. Go to "Settings - Preferences - Default Values," then modify the "Automatic Project Loading" section).

You can start a new project by clicking **New**. You can Load existing projects through the **Load** option. You can Import or Export projects through the **Import** and **Export**. You also have the possibility to define a **Client** for the project and later choose if you wish to print the Company details on the report.

In the **Project settings** you can define overall parameters and preferences for the project. Note the difference between the Project settings here, that will affect only this specific project, and the *Advanced parameters* in the Main page that will be implemented in all the Projects in your workspace.

In the Project setting you can define for instance the far Albedo, e.g. the albedo around your site (the albedo under the panels will be defined in the system window in case of bifacial panels). In the Design conditions you can among other values set the lowest possible temperature at your site to generate a warning message for the Absolute Voltage limit, other relevant temperatures to generate graphs in the sizing tool (note that the simulation will use temperatures from your site, these values is to help you define your system).

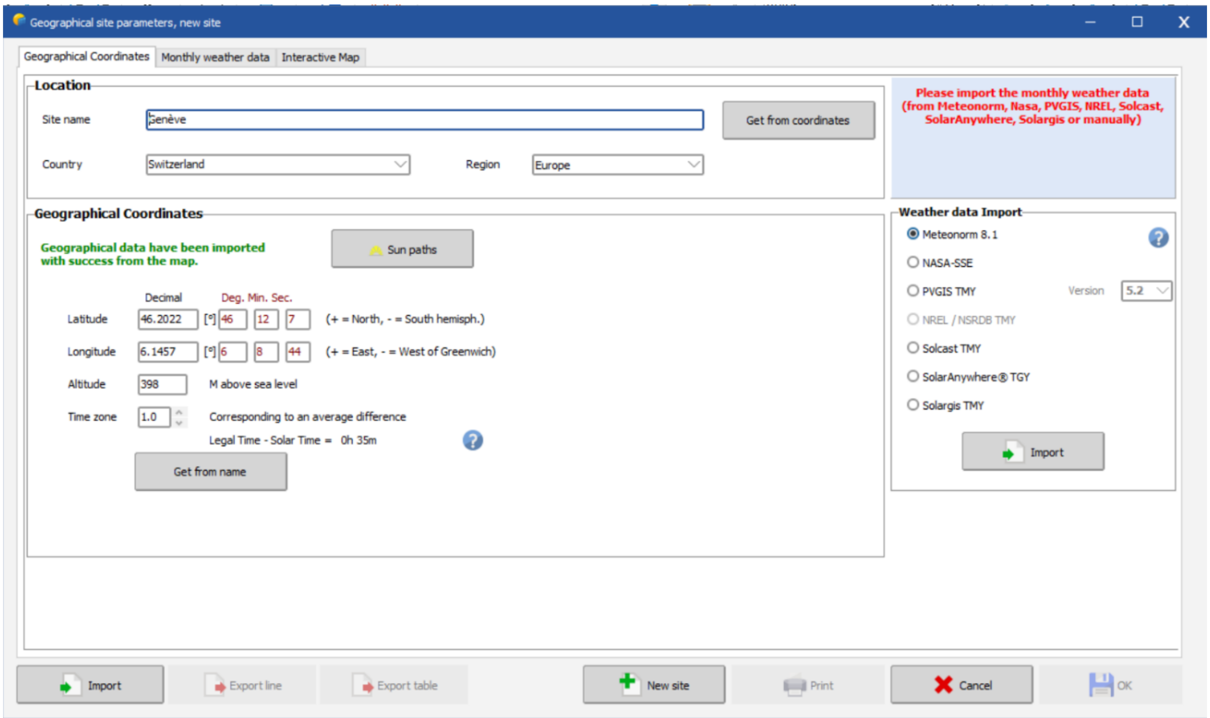


It is in the Project settings you set the limit overload loss for your design, that per default is set at 3%. If you wish to design a system with a high Pnom ratio, you can increase this value to avoid warning messages. You here also have the possibility to change other design parameters, such as the transposition model.

In the Project you must first define the Project's name, choose your site and define a weather data File. The site file contains the coordinates of your project, that is used to calculate the sun position each hour of the calendar year. The site file created will also include a fallback monthly weather data which is used for fast and rough calculations in the design part of the program.

There are 2 ways to define a **project site**. You can either *choose a site* from the list or create a *new site* by typing the name or using the interactive map. You can also import site if you have data from somewhere, or from another project.

In the *Geographical Coordinates* dialog, you can verify the coordinates for the chosen site and the sun paths corresponding to this site. The sun paths illustrate the position of the sun at each hour throughout the year.

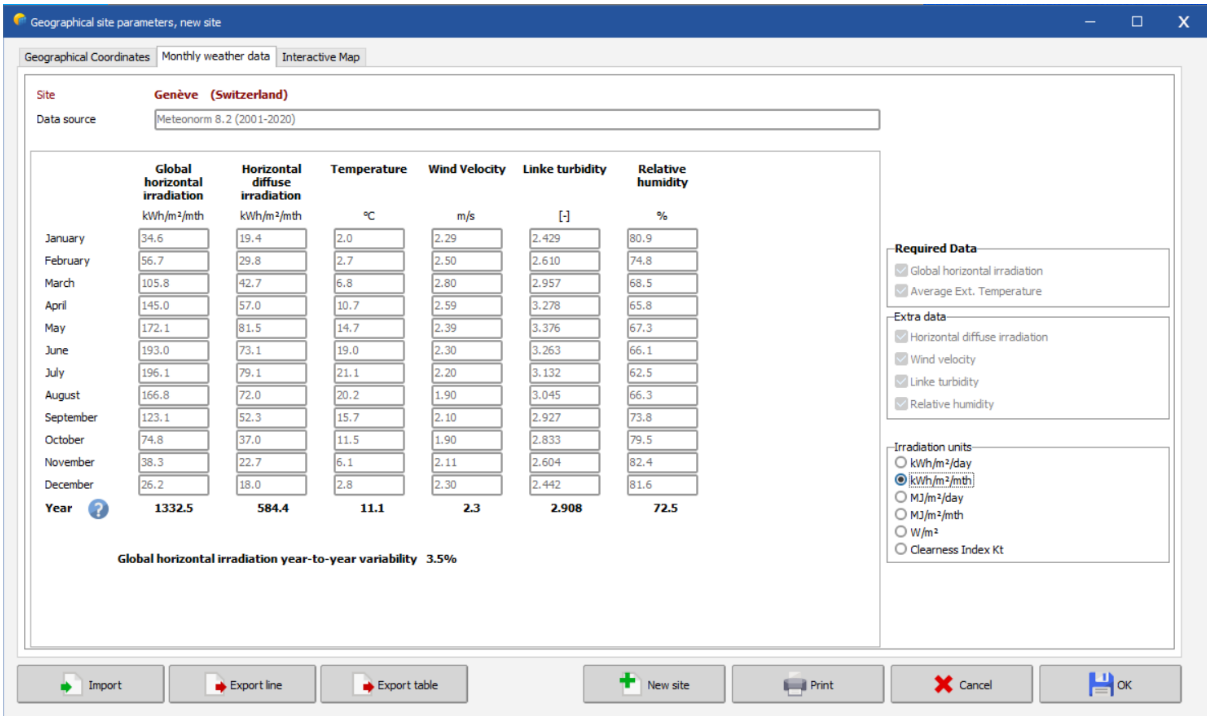


When creating a geographical site, you can directly import **Weather data** from a list of weather data providers, such as Meteonorm, PVGIS, Solcast, Solar Anywhere and Salargis. For the import to work, you need to have a working internet access. The imports are automatic based on the coordinates of your site.

It is up to you as a user to evaluate which weather source provider that is most accurate for your project. For certain providers you need an additional license to have access. Meteonorm data is included with the PVsyst license, using ground and satellite data and utilizes monthly averages to create synthetic hourly values using stochastic models. TMY (Typical Metrological Year) data on the other hand are meteorological **hourly** data files constructed on the basis of real measured data series chosen among at least 10 years of real measurements, according to several statistical criteria.

The data imported are in hourly values, the values are then averaged and displayed as monthly values. Depending on weather source, you are also provided with *Global horizontal irradiation year-to-year variability*, thus the natural fluctuations in the amount of solar energy received on a horizontal surface from one year to another, that can be used to calculate statistical analysis such as P50 and P90 of the energy yield predictions of solar PV systems.

By clicking OK, you will be prompted to save the geographical site, and the synthetical hourly weather data that have been generated (if your weather source is based on synthetic data). By clicking open a summary of your weather data is available. Note that PVsyst is labeling a generic year as *1990*.

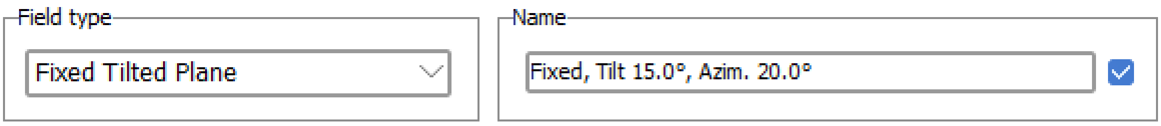


	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	34.6	19.4	2.0	2.29	2.429	80.9
February	56.7	29.8	2.7	2.50	2.610	74.8
March	105.8	42.7	6.8	2.80	2.957	68.5
April	145.0	57.0	10.7	2.59	3.278	65.8
May	172.1	81.5	14.7	2.39	3.376	67.3
June	193.0	73.1	19.0	2.30	3.263	66.1
July	196.1	79.1	21.1	2.20	3.132	62.5
August	166.8	72.0	20.2	1.90	3.045	66.3
September	123.1	52.3	15.7	2.10	2.927	73.8
October	74.8	37.0	11.5	1.90	2.833	79.5
November	38.3	22.7	6.1	2.11	2.604	82.4
December	26.2	18.0	2.8	2.30	2.442	81.6
Year	**1332.5**	**584.4**	**11.1**	**2.3**	**2.908**	**72.5**

3 Orientations

To define the orientation, you must choose the **field type**. There are 3 categories of field types, Fixed orientation Planes, One Axis tracking plane as well as a Two Axis tracking planes.

You may define multiple field types by clicking Add Orientation at the top of the dialog. To define an Orientation, choose the Field type in the drop down list. The header will show the name of this orientation. If the box on the right is checked, this will define a name according to the main parameters of the orientation; but you may give any customized name.



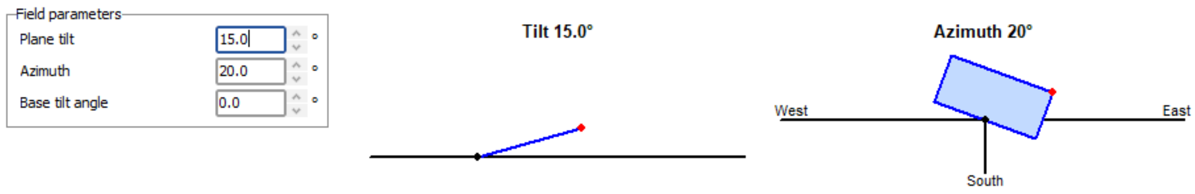
The field types have in common that you must define the *plane tilt* and *azimuth*. In general, the plane tilt is defined as the angle between the collector plane and the horizontal. The plane azimuth is the angle between the collector plane and the direction toward the equator. In the northern hemisphere, this means the azimuth is measured from due south (toward the equator), with positive values toward the west (counterclockwise): south = 0°, west = 90°, north = 180°, and east = -90°. In the southern hemisphere, the azimuth is measured from due north (toward the equator), with negative values toward the east (clockwise): north = 0°, west = 90°, south = 180°, and east = -90°.

3.1 Fixed orientations

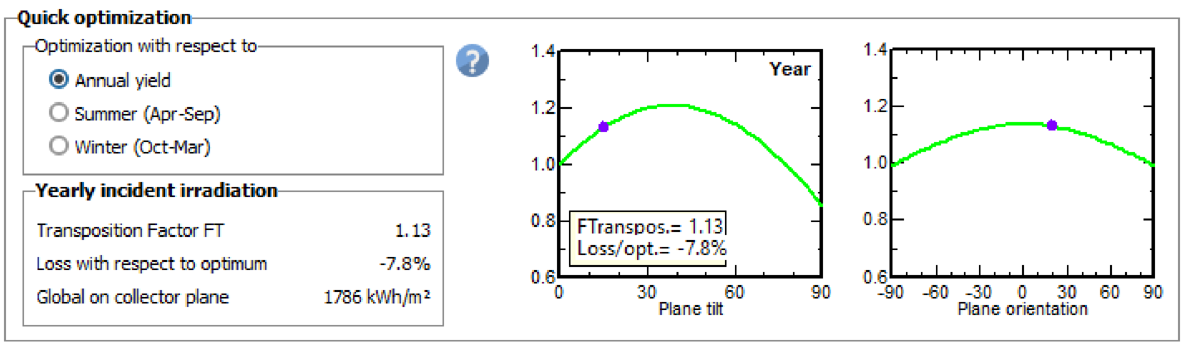
3.1.1 Fixed plane systems

This is the simplest kind of orientation, it defines the plane tilt and the plane azimuth.

If tables (rectangular fields) are defined in the 3D scene, the base of these tables may be inclined with respect to horizontal: this is the Base tilt angle, which is usually named base slope in the 3D scene. In this case the real plane orientation is altered.

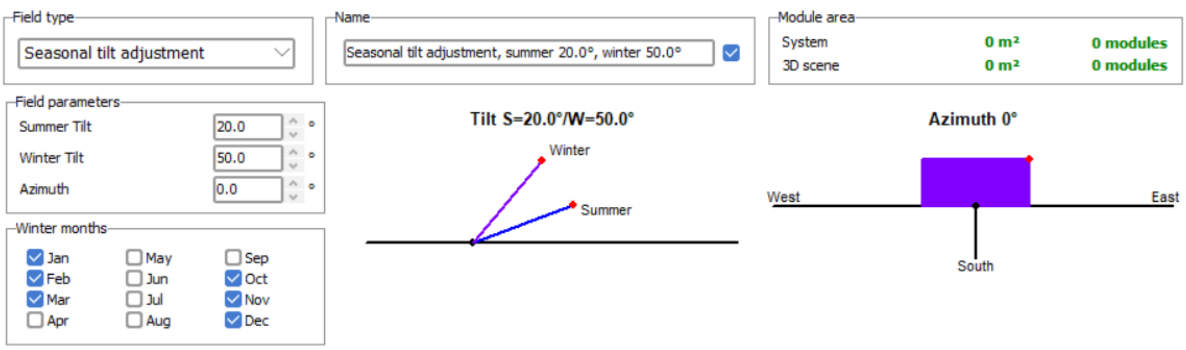


In the fixed planes definition, PVsyst displays a quick optimization tool, indicating the energy yield as a function of the tilt and the azimuth. This is a rough estimation meant for judging how your orientation choice (violet point) will affect the yield with respect to the optimum. This may show the annual, summer or winter yield.



3.1.2 Seasonal tilt adjustment

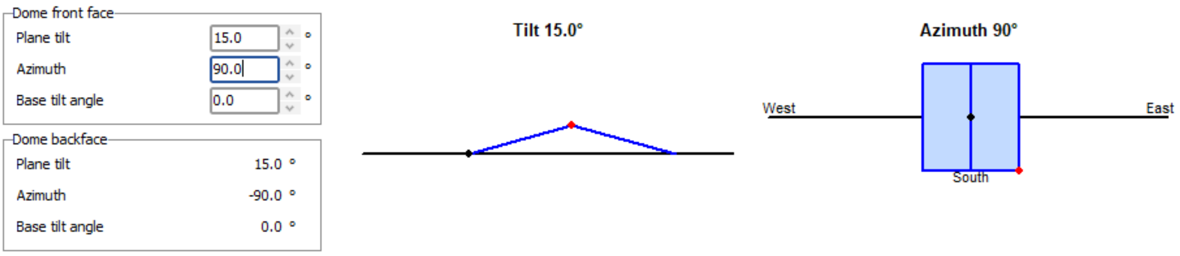
In the seasonal tilt adjustment, you have the possibility to optimize the PV production, by modifying the tables tilt depending on the season. This option allows to define two seasons with a corresponding plane tilt and you must specify the months for the winter and the summer position.



3.1.3 Domes

Domes corresponds to a system with two opposite arrays of tables. In this case, PVsyst automatically creates a second orientation for the opposite part of the array.

The spacing between the 2 rows of domes is usually very small and no significant irradiance will be allowed to fall on the ground underneath the dome. Therefore, such a configuration is not suited for bi-facial systems.

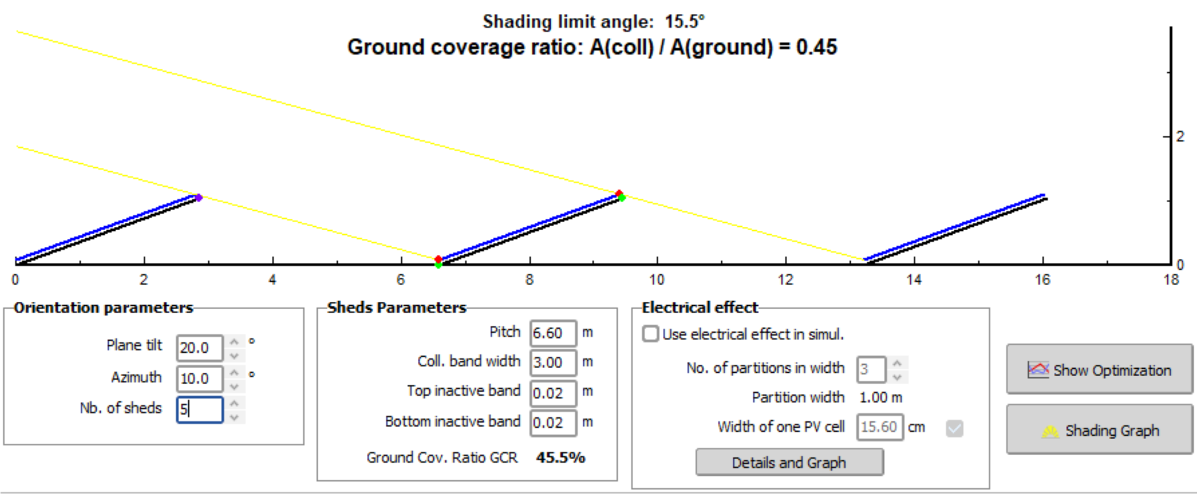


3.1.4 Unlimited sheds

The *unlimited sheds* are an extension of the *fixed tilted plane* orientation that adds geometrical parameters defining the tables arrangement (in regularly arranged rows).

This allows the application of a simplified 2D model of mutual shadings based on these parameters. This approach is generally faster than defining a 3D shading scene and can therefore be used for example in more preliminary studies. “Unlimited sheds” refers to the 2D representation, where the extremities of the rows are ignored in the calculations.

Besides the orientation, this mode specifies parameters describing the PV system, such as the number of rows (*sheds*) and parameters such as the width of the (active) *collector band*, mechanical top and bottom *inactive bands*, and the *pitch*. The number of rows is necessary for the calculation to take into account that the first row is not shaded. The collector band width is the width of your sensitive area. For instance, if you have one row of modules where the panel measures 1x1.5m, if the panels are placed in landscape this will be 1m, and in portrait this will be 1.5m. The inactive band refers to a physical structure extending out past the modules, which will cast shadows. The pitch is the distance between rows.



The ground covering ratio (GCR) and the limit angle (the profile angle for which you begin to have mutual shadings) is calculated based on the parameters you choose and shown in the top of the window. As there are shadings, this tool also allows for some advanced options to define number of partitions for the calculation of the electrical shading effects.

3.1.5 Unlimited sun-shields

It is possible to define unlimited sun-shields on a façade. The sun-shield rows parameters are defined in a similar way as the unlimited sheds.

3.2 Tracking plane definitions

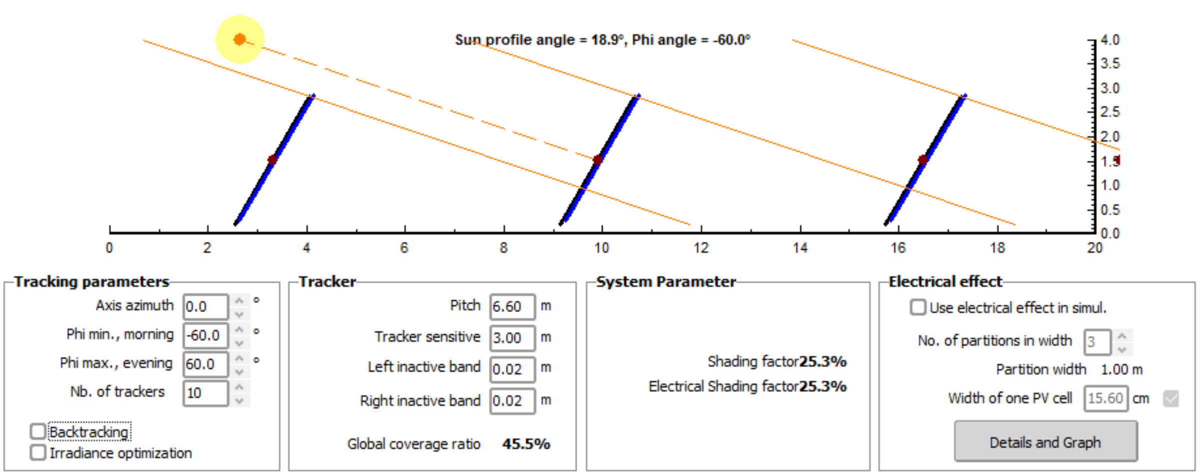
3.2.1 Unlimited trackers, horizontal axis

In a similar way as for unlimited sheds, you may define "unlimited trackers" for parametric study of a PV trackers system, without using the 3D scene construction.

The axis azimuth refers to the orientation of the axis, where an azimuth of 0 correspond to an axis running in the north to south direction. The rotation angle around the axis is called Phi. Mechanical limits on the Phi stroke are required. Phi 0 corresponds to a horizontal axis; the minimum phi is the lowest angle authorized (counter clockwise from the horizontal axis) and the maximum phi contrary is the highest angle authorized (clockwise from the horizontal axis).

The backtracking option will prevent shading between rows of panels by adjusting their tilt angle based on the sun's position. The irradiance optimization option will evaluate the optimal tracking angle on the basis of the transposition model: the angle is adjusted in order to get the best transposition result of *GlobInc*, considering the Beam and Diffuse components.

The other parameters are the same as for "Unlimited sheds". Note that the electrical shading parameters are only visible when the backtracking is not activated, as by definition there are no mutual shadings in backtracking mode.

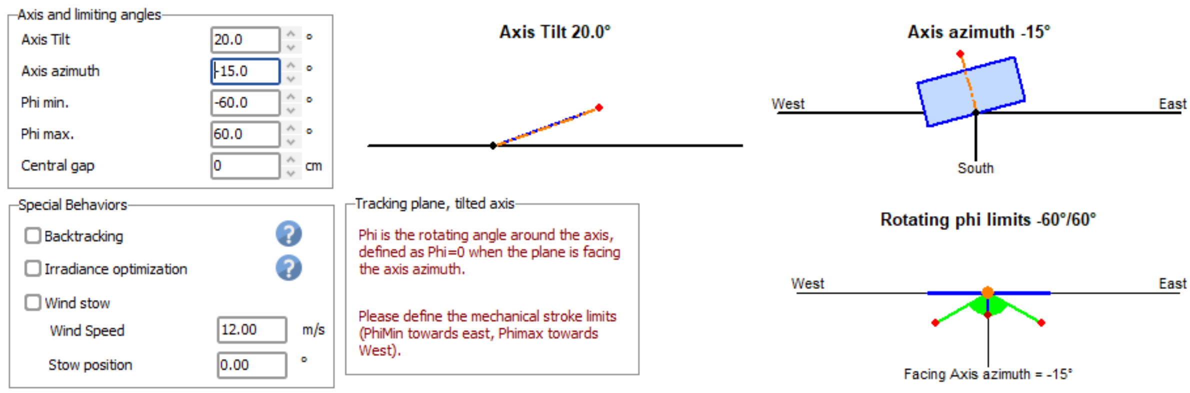


By dragging the sun, you have the opportunity of visualizing the tracker's behavior according to the sun position. This tool will show, namely, the behavior of the backtracking mode.

3.2.2 Tracking, horizontal and tilted axis

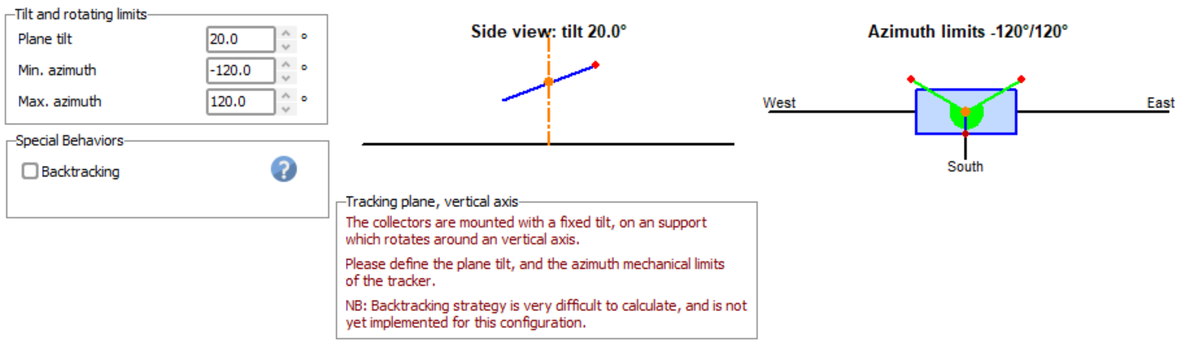
As in "Unlimited Trackers", you must define the axis orientation and tracking limit angles. You also have the possibility to add an Axis tilt. You must define the Phi limits (mechanical stroke), the backtracking strategy, and the tracking calculation mode (astronomic calculation or irradiance optimization) to be used during the simulation. An additional parameter, Wind stow defines a security rest position, to be set during the simulation when the wind speed is too high.

When defining an array of trackers, the construction in the 3D scene is mandatory, as this is the only way of calculating the mutual shading losses.



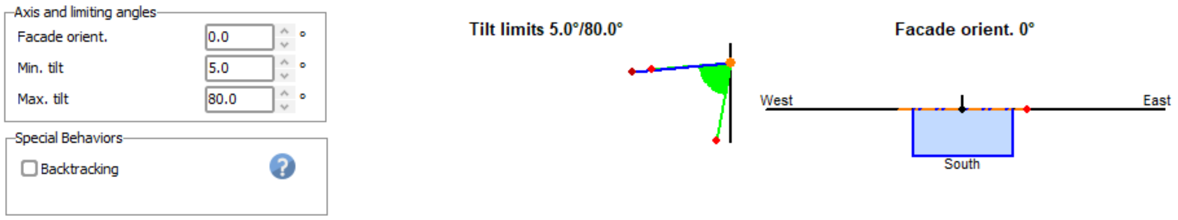
3.2.3 Tracking, vertical axis

With trackers with a vertical axis, the collector is kept at a fixed tilt but rotating according to the sun azimuth. This configuration may be used with "dish" arrangements, when a big rotating support holds several rows of modules; this particular case is made possible as the rotating axis of one row may be displaced with respect to the collector. The plane tilt and the azimuth mechanical limits of the tracker must be defined.



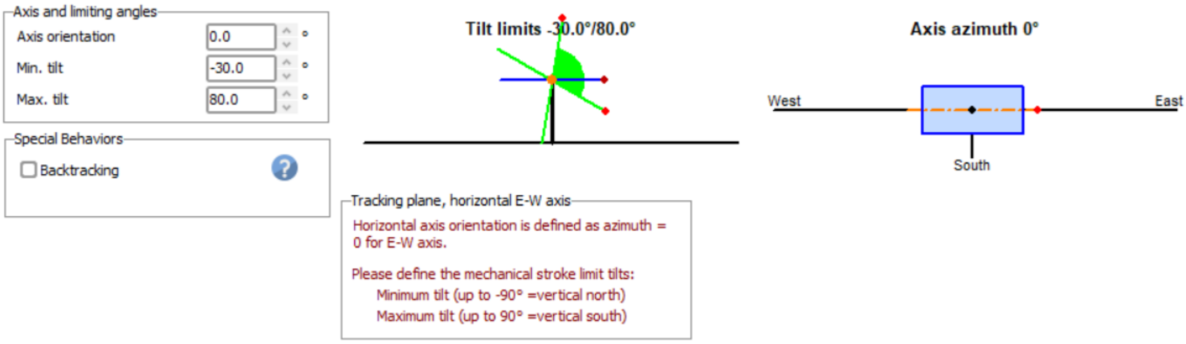
3.2.4 Tracking sun-shields

It’s possible to define a tracking sun-shield. You need to specify the facade orientation, as well as the minimum and maximum tilt. Optimizing the balance between sun protection and PV production is challenging. The backtracking strategy is likely the only reasonable approach for operating sun-shield trackers.



3.2.5 Tracking, horizontal axis East/West

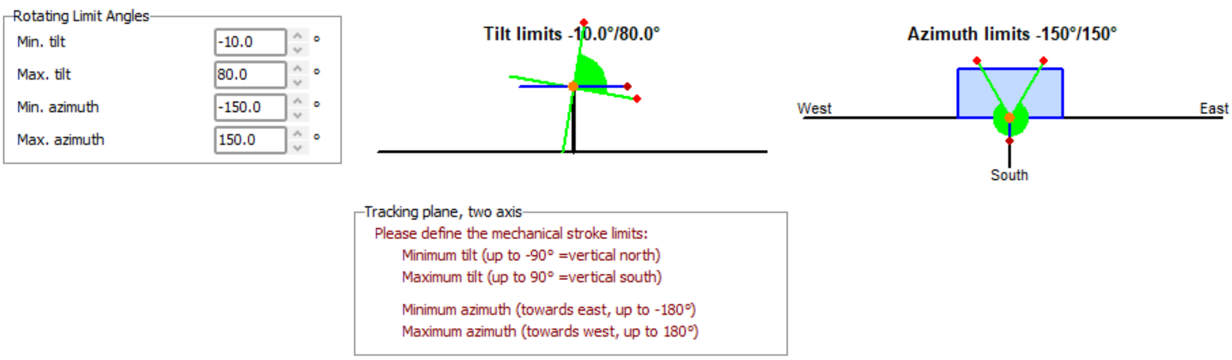
The tracking horizontal East/West refers to system where the rotation axis normally is running east/west. With an Axis orientation of 0° in the northern hemisphere, the panels will be oriented south and the minimum and maximum tilt will define the mechanical strokes to follow the height of the sun in the southern direction, i.e. mainly the seasonal variations. This is available in PVsyst, though is only used in very special situations.



3.3 Two axis trackers

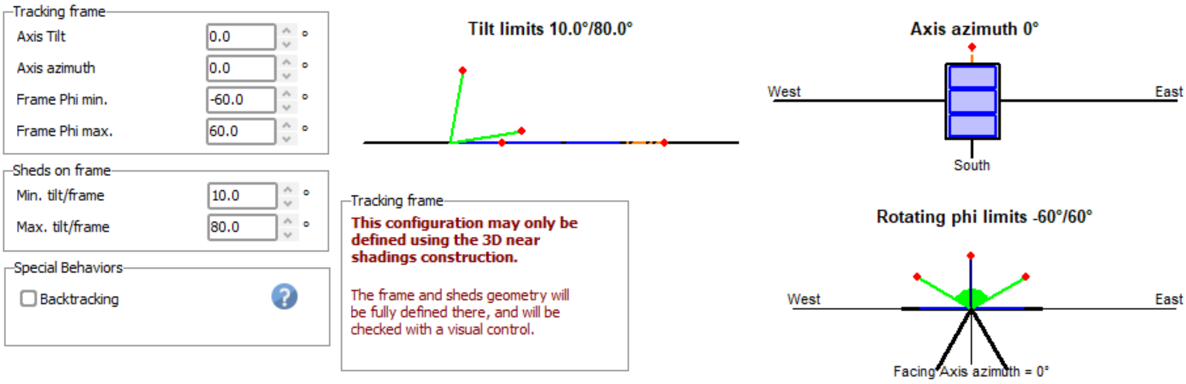
3.3.1 Tracking two axis

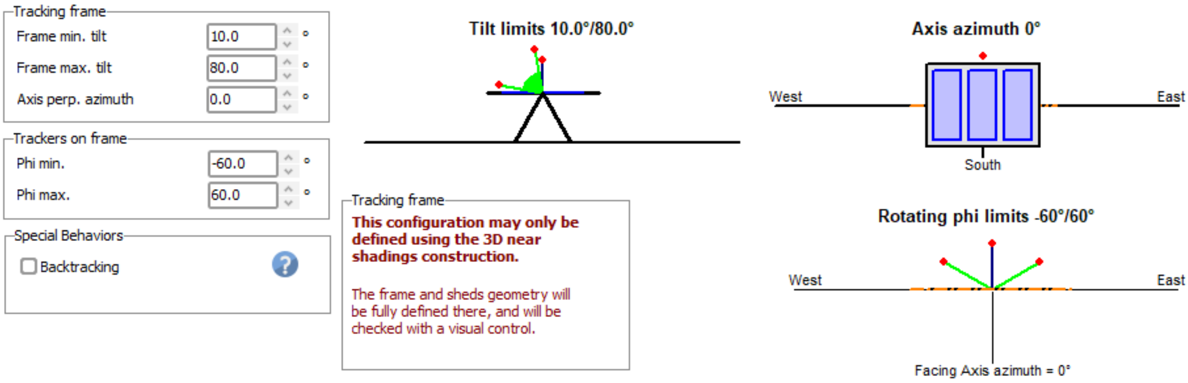
Two-axis solar trackers adjust both the tilt and orientation of solar panels to stay perpendicular to the sun's rays throughout the day. You must define the stroke limits for both the tilt and the azimuth.



3.3.2 Tracking 2-axis, frame North/South and East/West

There are specific scenarios of 2-axis tracking system. The plane is always perpendicular to the sun's rays, the tracker orientation within this plane is different. This may lead to different mutual shadings. You have to define here the parameters related to the orientation. The mechanical frame characteristics (size, width, etc) will be defined when creating the 3D field representation. The backtracking may be done between trackers within the frame, not between adjacent frames.





4 System

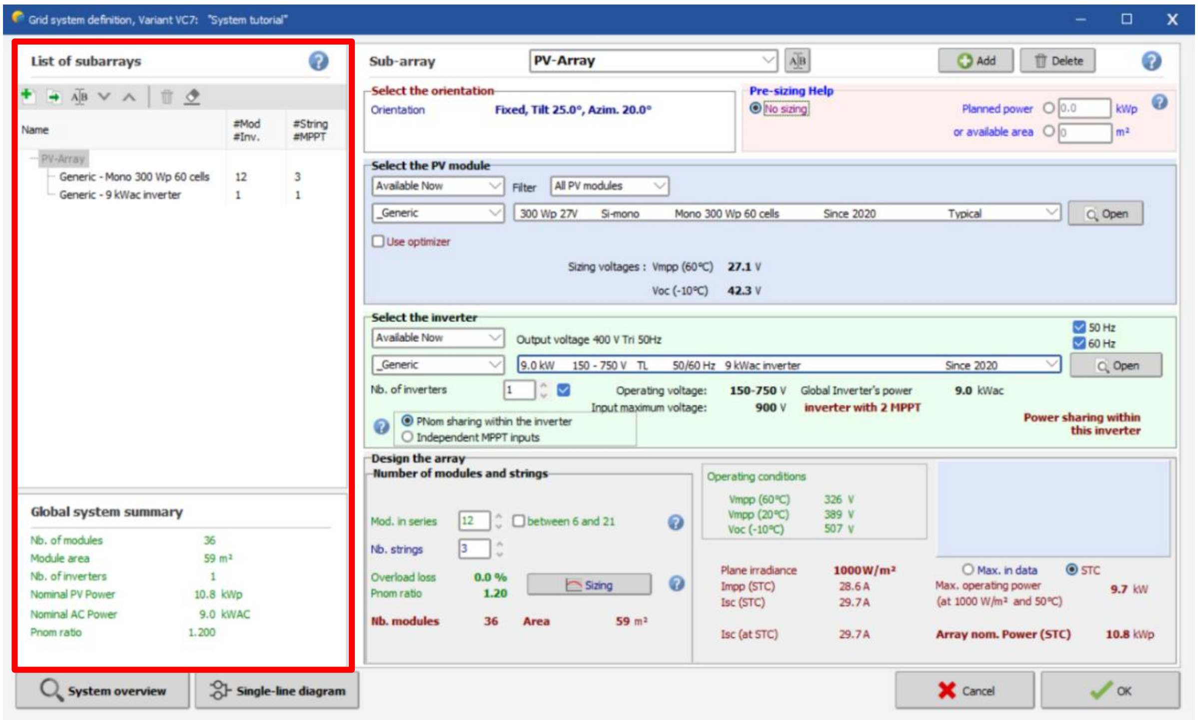
In a grid-connected projects, the *system* is defined as the set of components constituting the PV-array, i.e. the PV modules, inverters and the design of the array, here separated in the different background colors.

4.1 Sub-arrays

The system is organized as a set of sub-arrays: one sub-array is constituted of

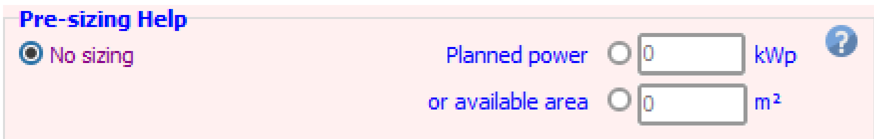
- A PV module model, chosen in the database,
- An inverter model, chosen in the database,
- The number of inverter inputs,
    - either full inverters or

- number of MPPT inputs,
- The number of modules in series, and the number of module strings.
  - The number of strings should ideally be a multiple of the number of MPPT inputs. However, PVsyst will accept uneven number of strings, and will distribute them in the most balanced way across the MPPT inputs. A warning will be issued when the imbalance is too high and you should consider precising the distribution for a balanced system.
- In some cases, additional devices may be added to the sub-array: for example Module or String Optimizers.



You can manage (add, copy, rename, move and delete) in the list on the left of the dialog.

There is a *Pre-sizing help* available, in the upper right corner in the system window. This tool will suggest an automatic sizing of each sub-array, where you can specify either the desired nominal power, or the available area for your modules.



As a consequence of this organization in sub-arrays, all the strings of modules connected to the input of an inverter (or a MPPT input) are homogeneous, identical modules and inverters, same number of modules in series, same orientation. These homogeneity requirements in PVsyst are a general rule for any real installation, for instance not to put a different number of modules in series on a same inverter input since this could have negative consequences on the operating conditions of your system (namely for the MPP research). Nor is mixing different module models on a MPPT input advised. Studying arrays with different module kinds (for example a mix of power classes) is not possible in PVsyst in the present time.

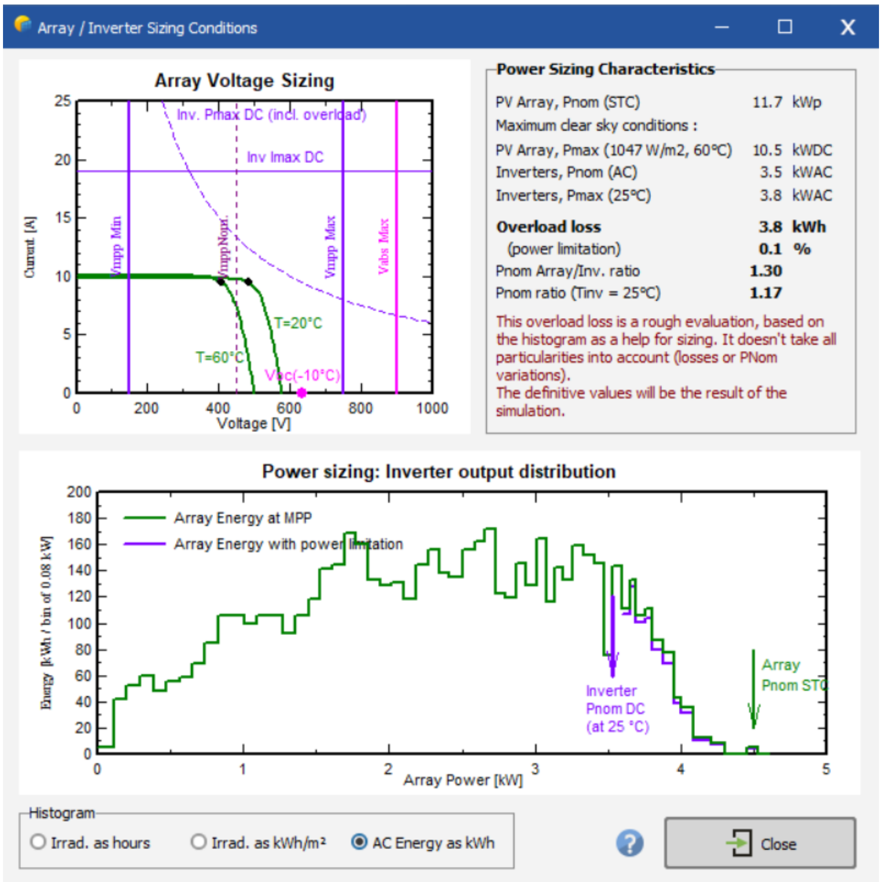
Each sub-array will be associated to an orientation. Normally all modules of a sub-array should be in the same orientation. Mixing PV modules of different orientations within a given string is not acceptable, as you may have big mismatch current losses due to different irradiances (the current of a string is governed by the worst cell). However, you can mix strings in different orientations, because the mismatch in voltage (strings in parallel) is usually very low. PVsyst allows the creation of sub-arrays with 2 orientations on a same inverter input.

4.2 Design the array

PV panels have a temperature coefficient, which indicates how their output voltage and current change with variations in temperature. Typically, as the temperature increases, the output voltage of the panels decreases.

Voltage at Maximum Power Point (VMPP) changes with temperature due to the temperature coefficient, so it's crucial to consider the temperature while sizing the voltage for the PV system.

Inverter Performance: The inverter converts the DC power generated by the PV panels into AC power for use in the electrical system. Inverters also have temperature limits and efficiency considerations. If the voltage is not appropriately sized for the temperature conditions, the inverter may not operate optimally, leading to reduced energy production or even potential damage to the inverter.



When designing the array, the number of modules in series has to stay within the requirements of

- Staying above the minimum inverter's operation voltage Vmin of MPPT range (i.e. at max. module operating temperature, 60°C by default)
- Staying below the maximum inverter's operating voltage (i.e. at min. module operating temperature, 20°C by default)
- To stay below the absolute maximum inverter's input voltage (i.e. Voc at min. temperature, -10°C by default)
- Not exceed the maximum system voltage specified for the PV module.

By clicking Sizing, you find a specific tool that gathers all the constraints relating to the sizing of a specific system.

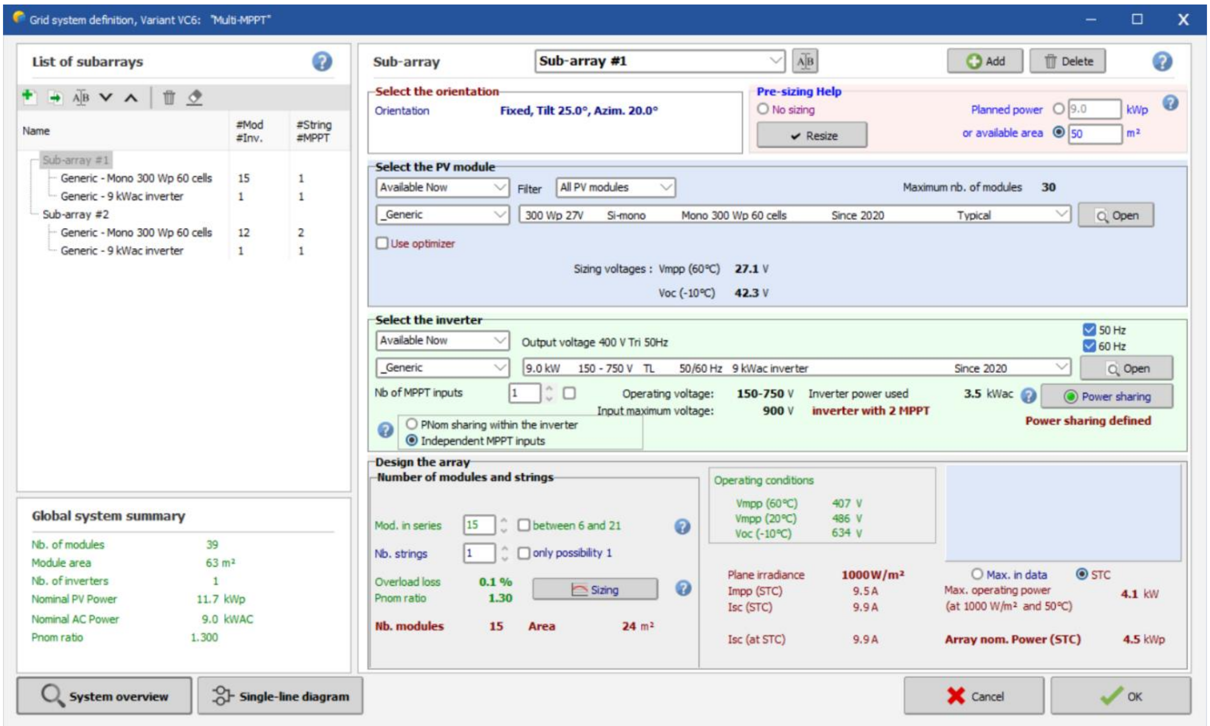
- **For the number of modules in series and strings**: the upper diagram shows the I/V curve of the PV array, together with the MPPT range, voltage, power, and current limits of the inverter. The little black dot should be within the safety limits. In Project setting, these numbers can be modified if needed, this will not affect the simulation, but the sizing and the IV curve.
- **For the inverter sizing**: the second graph, known as the system output power distribution graph, illustrates the annual distribution of power generated by the photovoltaic system. The horizontal axis displays power intervals, while the vertical axis shows the total energy produced within each interval. This graph highlights the most common power ranges, offering insights for optimizing inverter sizing and assessing possible overload losses.

The optimal sizing of the inverter is based on the acceptable overload loss throughout the year. It usually leads to over-size the power ratio (PV array nominal power with respect to the inverter nom. AC power), by a factor of 1.25. Note that this is a first rough estimation and that you later can define different losses such as near and far shadings. Specialized tools are also provided to evaluate different losses due to wiring, module quality, mismatch between modules, soiling, thermal behavior, mechanical mounting, system unavailability, etc.

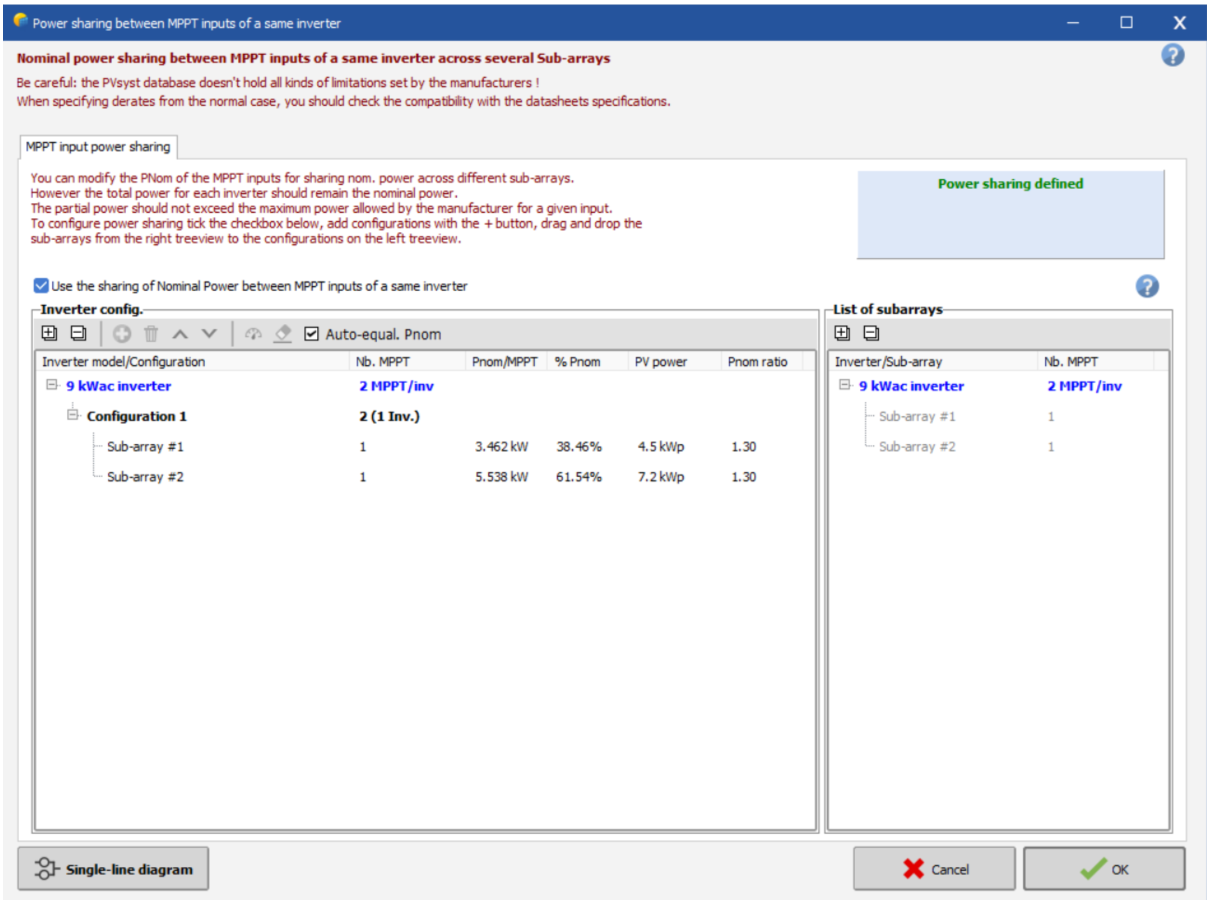
4.3 Multi MPPT and Power sharing feature

The MPPT technology, short for Maximum Power Point Tracking, enables a solar inverter to independently track the maximum power point for each string or group of panels. Thus, in the case of different length of strings or panels oriented differently on your site, in the case of partial shading due to objects nearby or in the case of soiling; the multi-MPPT allows the system to mitigate the impact by adjusting the operation of the affected strings without affecting the others.

Choosing the option *Pnom sharing within the inverter*, PVsyst will equally distribute the Power over the MPPT inputs automatically. If you have different configurations at the input of Multi-MPPT inverters, you should define a sub-array for each kind of configuration.



By selecting *Independent MPPT inputs* it is possible to consider the single MPPT inputs. Below the inverter model selection, one thus selects a given number of inputs instead of a number of inverters. If the inverter has the capability to shift part of the nominal power between the MPPT inputs, this can be configured in the *Power Sharing* window. The Power sharing ensures that the power generated by each MPPT controller is efficiently distributed across the different strings or groups of panels by assigning each sub-array to a power sharing group.



To the left in Power sharing window, you have the inverter configuration. By dragging a subarray from the list to from the right the Inverter configuration window we can associate sub-arrays for the same inverter. A summary of the characteristics of the sub arrays will appear, that is the number of MPPTs, the nominal power at the specific MPPT, the % of the total nominal power of the inverter, the installed PV power in the subarray as well as the nominal power ratio in the sub-array. The power sharing will be balanced automatically if “Auto-equal. Pnom” is checked. You also the option to manually balance and/or adjust the power allocated to each sub-array if you untick this option. By clicking the weight icon, the Pnom ratio is balanced and by clicking the rubber it re-sets the pnom ratio.

5 Detailed losses

There are several parameters that are initialized by PVsyst with reasonable default values for the first simulation, but that you should modify according to the specificities of your system to add more accuracy to the simulation. These parameters are accessible with the button "Detailed losses" in the project dashboard.

5.1 Thermal parameters

The thermal behavior of the array is computed in each simulation step by a thermal balance. This establishes the instantaneous operating temperature used for the modeling of the PV modules.

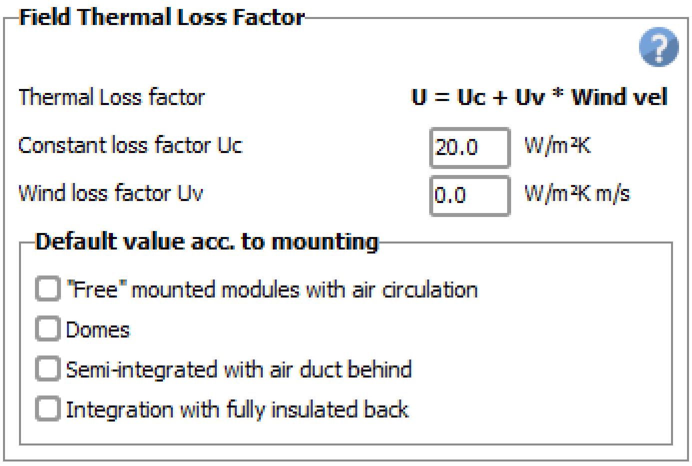
The thermal balance involves the *Heat loss factor:*

U = Uc + Uv · WindSpeed [$W/m^2 \cdot K$]

In practice, we advise not to use the wind dependency, as the wind speed is usually not well defined in the weather data, and the parameter Uv is not well known. Therefore, we put Uv = 0 and include an average wind effect in the constant term.

According to our own measurements on several systems, PVsyst proposes:

- Uc = 29 W/m^2K for completely free air circulation around the collectors (free-standing collectors).
- Uc = 27 W/m^2K for domes, a manufacturer has measured the U-value on several installations (height about 40 to 70 cm above the ground)
- Uc = 20 W/m^2K for semi-integrated modules with an air duct on the back.
- Uc = 15 W/m^2K for integrated modules (back insulated), as only one surface participates to the convection/radiation cooling.



The thermal loss effect is shown on the array loss diagram in the final report.

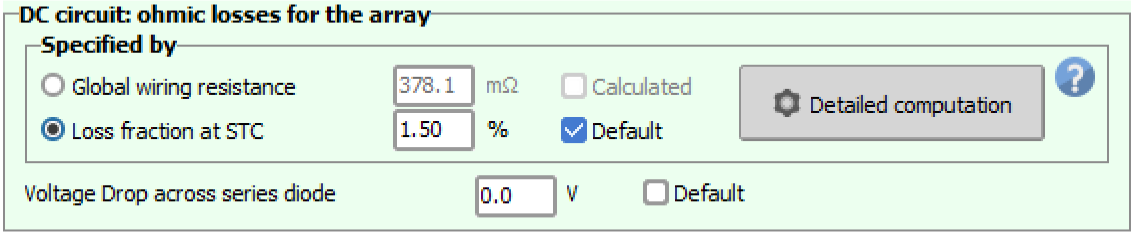
The 'Standard NOCT factor' (Nominal Operating Cell Temperature) is the temperature that the module reaches in equilibrium for very specific surrounding and operating conditions. It can often be found together with the module specifications supplied by the manufacturers. It has no real relevance for the simulation because the conditions for which it is specified are far from a realistic module operation. PVsyst only mentions it for completeness and for comparison with the manufacturer's specifications.

5.2 Ohmic Losses

The wiring ohmic resistance induces losses ($R \cdot I^2$) between the power available from the modules and that at the terminals of the array. These losses can be characterized by just one parameter R defined for the global array.

5.2.1 DC circuit: ohmic losses for the subfield

The program proposes a default global wiring loss fraction of 1.5% with respect to the STC running conditions. But you have a specific tool to establish and optimize the ohmic losses through the *Detailed computation* button. This tool asks for the average length of wires for the string loops and between the intermediate junction boxes and the inverter and helps the determination of the wire sections.

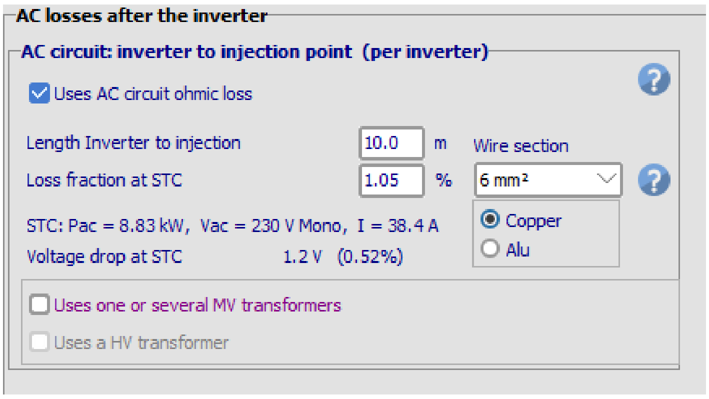


NB: remember that the wiring loss behaves as the square of the current. Therefore, operating at half power will lead to only a quarter of the relative loss. The effective loss during a given period will be given as a simulation result and shown on the loss diagram. It is usually of the order of 50-60% of the above specified relative loss when operation at MPP.

In older PV installations, it was common practice to include a blocking diode in series with each string to prevent reverse current from neighboring strings in the event of a mismatch. However, this approach is now considered unnecessary. Even when a string is heavily shaded, its voltage typically remains near its open-circuit voltage (Voc), rendering the diode ineffective. Additionally, these diodes were prone to failures, which often went undetected. As far as we know, the use of blocking diodes in modern systems has been largely abandoned and the *Voltage drop across series diode* can be left at 0.

5.2.2 AC losses after the inverter

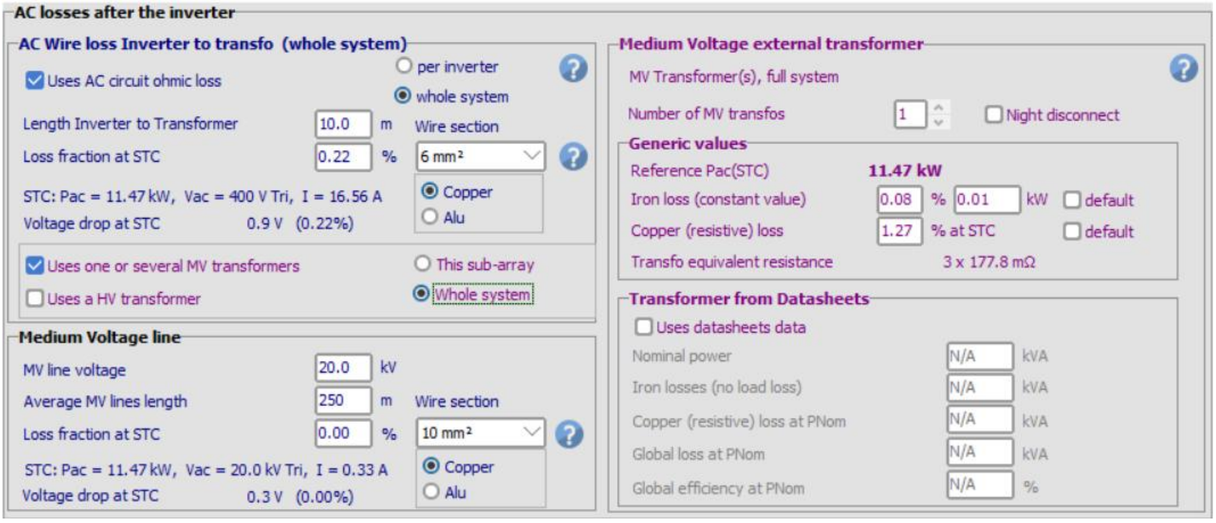
It is also possible to include losses between the output of the inverter and the injection point (energy counter). You just have to define the distance, and the loss will also appear in the loss diagram.



In many large PV installations (in the MWp range), the transformer is not part of the inverter, but an external device directly connected to the MV or even the HV grid.

- One or several Medium Voltage transformers for the whole system. PVsyst will distribute equally the power output of all inverters to all transformers.
- One Medium Voltage transformer in each sub-array. The transformer properties may be different in different sub-arrays, but each sub-array has to have one transformer.
- There is the possibility to add a High Voltage transformer that steps up the voltage before the injection point.

Note that, when including transformers, the distance from the inverter to injection instead correspond to the distance from inverter to Transformer.



The main losses associated with a transformer are:

- The iron losses, which are mostly due to hysteresis and eddy currents in the transformer core, are proportional to the square of the core flux, i.e. to the square of the voltage. Since the grid voltage is constant, this will also be a constant loss. As default value, PVsyst will use 0.1% of the reference nominal power.
    - Night disconnect: The iron loss remains active and constant as long as the transformer is connected to the grid, and this may represent a significant energy loss. In the simulation results, this will show up as negative a E_Grid system yield during the night. It may be economically profitable to foresee a switch that disconnects the transformer from the grid during the night. To activate this behaviour in the simulation, please check the option "Night disconnect" next to the number of transformers. This option is global for all transformers in the system.
- The ohmic losses, also named copper losses, are originated by the resistance of the primary and the secondary windings of the transformer coils. These may be represented by a single equivalent resistance R, and in the simulation this loss will be computed as $R * I^2$. Like for the cable losses, this means that the relative loss is proportional to the current (or power).

You can also specify the actual parameters of the selected transformer (recommended). The essential information needed includes:

- the Nominal power,
- the Iron loss (often referred to as "no-load loss"),
- and the Copper loss.

Datasheets may provide either the overall loss at PNom or the total efficiency, from which PVsyst can calculate the copper loss. Setting these real parameters based on the transformer's datasheet will override the generic values.

Note: The generic Iron and Copper losses used in the simulation differ from the transformer datasheet values, as they relate to PVsyst's Reference PNom rather than the transformer's Nominal power.

5.2.2.1 AC ohmic losses: reference power

PVsyst proposes a generic Ohmic loss initial relative value, for the early stage of the project's development. You can choose the reference power as either:

- **PNomPV(ac)**: The nominal power of the PV array at STC (PNomPV [kWp]), adjusted by the inverter's efficiency. This was the default option in PVsyst before version 7.2.
- **PNom(Inv)**: The nominal output power of the inverter(s), without applying a temperature correction.

This choice is done for each project, in the project's settings dialog.

In the main menu *Settings > Preferences > Physical models > AC Loss references*, you may define the default initial value when creating a new project.

5.3 Module quality – LID - Mismatch

5.3.1 Module quality loss

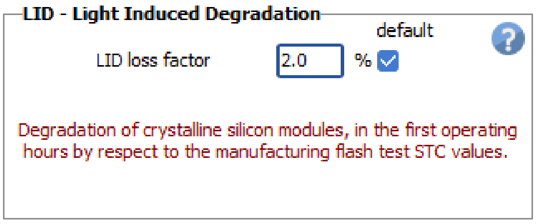
The aim of this parameter is to reflect the confidence that you put in the matching of your real module set performance with respect to the manufacturer's specification. By default, PVsyst initializes the "Module Quality Loss" according to the PV module manufacturer's tolerance specification. PVsyst will choose a quarter of the difference between these values. For example, with -3...+3%, it will be 1.5%, and with positive sorting 0..+3%, it will be -0.75% (i.e. a negative loss value, representing a gain). Note that, this value of a quarter between low and high tolerance is the PVsyst choice. We usually consider a conservative option (i.e. the modules will never be better than announced). It doesn't have any other background reasons.

5.3.2 LID – Light Induced Degradation

LID (Light Induced Degradation) is a loss of performances arising in the very first hours of exposition to the sun, with Crystalline modules. It may namely affect the real performance with respect to the final factory flash tests data delivered by some PV module providers.

It is unclear how it affects the performance with respect to the specified STC values. If the modules are sorted according to their final factory flash test for determining their Nominal Power class, the LID will indeed represent a loss with respect to STC.

The LID loss is related to the quality of the wafer manufacturing and may be of the order of 1% to 3% (or even more).



It is very difficult to obtain data about the LID effect on a given module sample. This is never referenced by the manufacturers of course. It depends on the origin of the Silicon wafers, and may vary from product to product, but also may depend on batches of a given production. As it is not sufficiently established, the LID loss is not proposed as default by PVsyst. If you specify it explicitly, the proposed default value is 2%.

The LID effect occurs only with conventional p-type boron-doped wafers. Alternative technologies using n-type doped wafers are not affected.

5.3.3 Module mismatch losses

Now when installing real modules in the field, the characteristics of each module are never rigorously identical. The *Module mismatch loss* is mainly due to the fact that in a string of modules (or cells), the lowest current drives the current of the whole string. This parameter acts as a constant loss during the simulation. It is lower for thin film modules. It can become almost zero if the modules are well sorted according to their real performance (flash-test results provided by the manufacturer).

PVsyst includes a tool for understanding, and statistically estimating the corresponding power loss (Detailed calculation). This tool first creates a statistical sample of modules, setting Voc and Isc values according to a gaussian or square distribution. Then it adds the I/V characteristics of each module in each string (add voltages) and then gathers the strings in the array (add currents). Finally, it draws the resulting I/V curve of the array, and identifies the MPP value, which is then compared to the MPP value of an array with identical modules.

NB: There is probably a correlation between the Module mismatch losses and the Module quality loss and LID. The Module quality loss is rather related to the average of the module's distribution, while the mismatch refers to its width.

5.3.4 Strings voltage mismatch

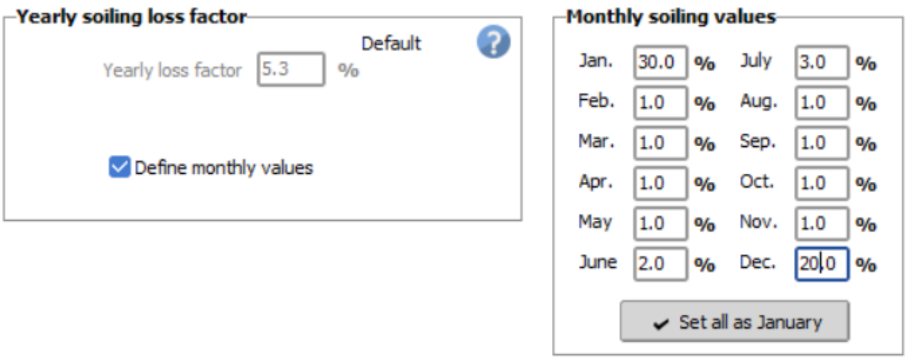
The mismatch between strings is related to the voltage differences and involves a displacement on the I/V curves. This results in general in very low power losses. Reasons for voltage mismatch can be:

- That the string wire length is different from string to string, especially with big systems (centralized inverters).
- That the temperature may be different from part to part of a big system (colder at the edges).
- With big systems, the irradiance may be varying from part to part of a system in case of clouds etc passages.

This is a transient effect, affecting usually some few seconds or minutes within the hour. PVsyst neglect this in the present time.

5.4 Soiling loss

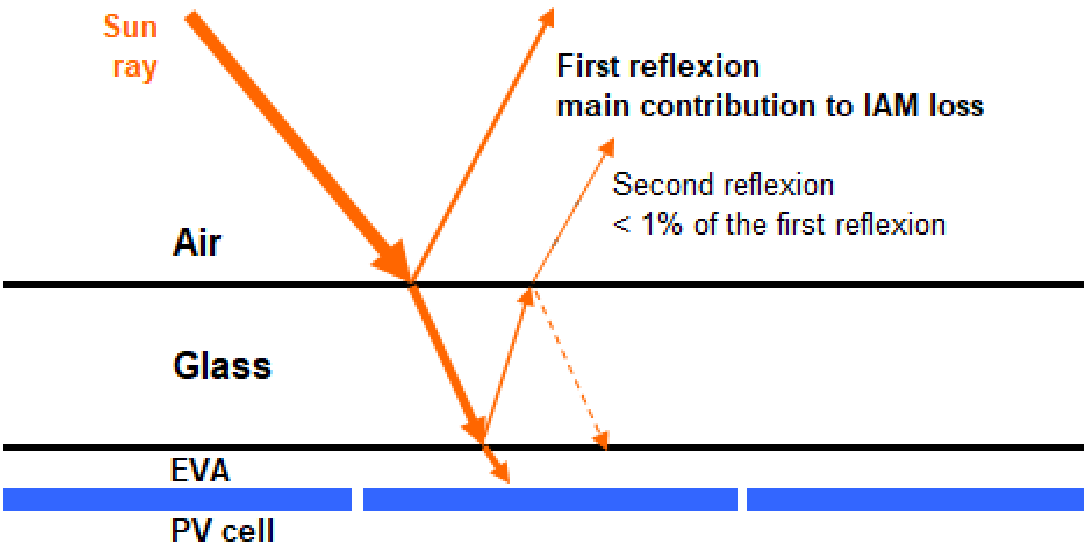
Accumulation of dirt and its effect on the system performance is an uncertainty which strongly depends on the environment of the system, raining conditions, etc. Soiling loss may become significant in some industrial environments or in desert climates. The soiling loss can be defined individually for each month to consider periodical cleaning or rainy periods. This parameter may also be used for describing the effect of snow covering the panels.



5.5 IAM Losses

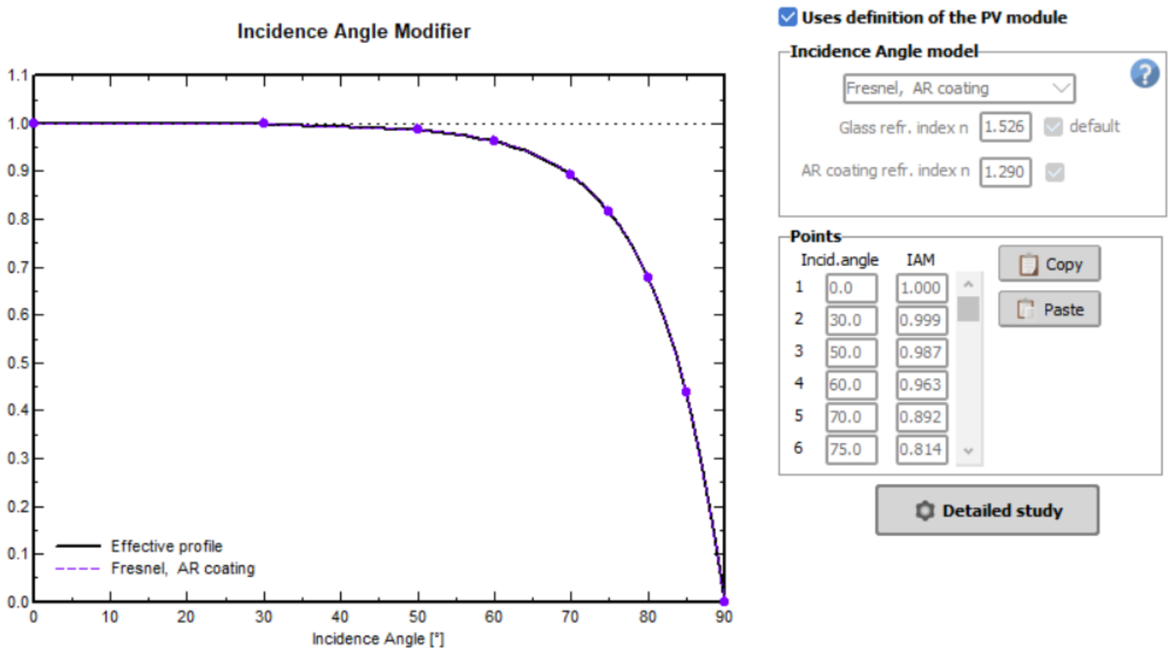
The incidence effect (the designated term is IAM, for Incidence Angle Modifier) corresponds to the decrease of the irradiance really reaching the PV cells' surface, with respect to irradiance under normal incidence. This decrease is mainly due to reflections on the glass cover, which increases with the incidence angle.

The transmission loss (passage of light through materials) is a general phenomenon, due to the reflection and transmission of the sun's ray at each material interface (air-glass, glass-EVA, EVA-cell), as well as some absorption in the glass. The IAM only concerns the angular dependency of this effect, i.e. it is normalized to the transmission at perpendicular incidence (0° incidence angle).

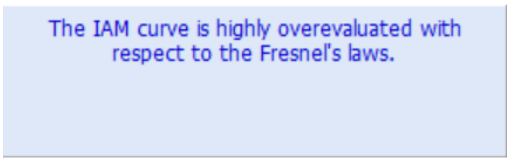


PVsyst uses an IAM function, which describes the deficit of transmission as a function of the incidence angle. This function is applied to the beam component, and to the diffuse and albedo, using an integral over all *seen* directions, supposing an isotropic distribution of the diffuse irradiance.

In principle, this phenomenon obeys the Fresnel's Laws describing transmission and reflections at the interface of two transparent materials of different refraction indexes. This is a very general behavior, derived from the general Maxwell's equations describing all electric phenomena. These laws allow to calculate the light effectively reaching the cell's surface below the protective layer (usually glass), as a function of the incidence angle. Now you can add an anti-reflective coating on the top interface air-glass. This thin layer has a lower refraction index than the glass, which limits the first reflection.



The IAM model is defined with the PV module parameters, page *Additional data*, *Customized IAM*. If the IAM curve is highly over evaluated with respect to the Fresnel's laws, you will have a warning message while opening the .PAN file. An over evaluated IAM curve could lead to an overestimation of your system's production.

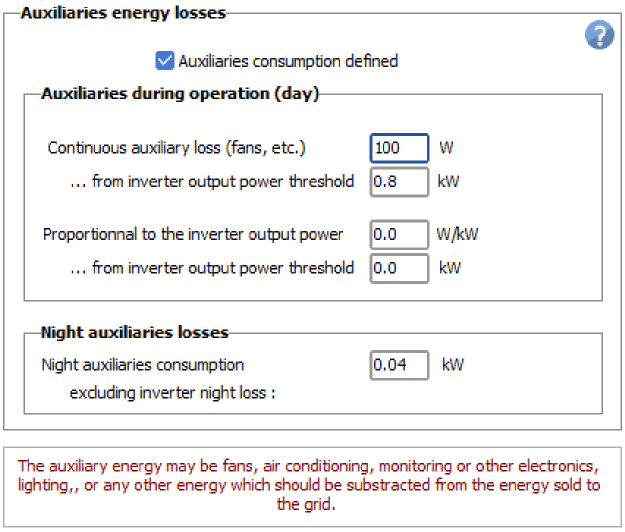


In the Additional Data, Customized IAM you can modify an over evaluated IAM curve by choosing the Default Fresnel. This manipulation can also be done through the detailed losses window, IAM Losses tab.

5.6 Auxiliaries

Auxiliary consumption refers to the energy required to operate the system, including components such as fans, air conditioning, electronic devices, lighting, or any other energy usage. This consumption must be subtracted from the PV energy produced before it is injected into the grid.

It is defined globally **for the entire system** and is only taken into account in the simulation if the "Auxiliaries consumption defined" option is activated.



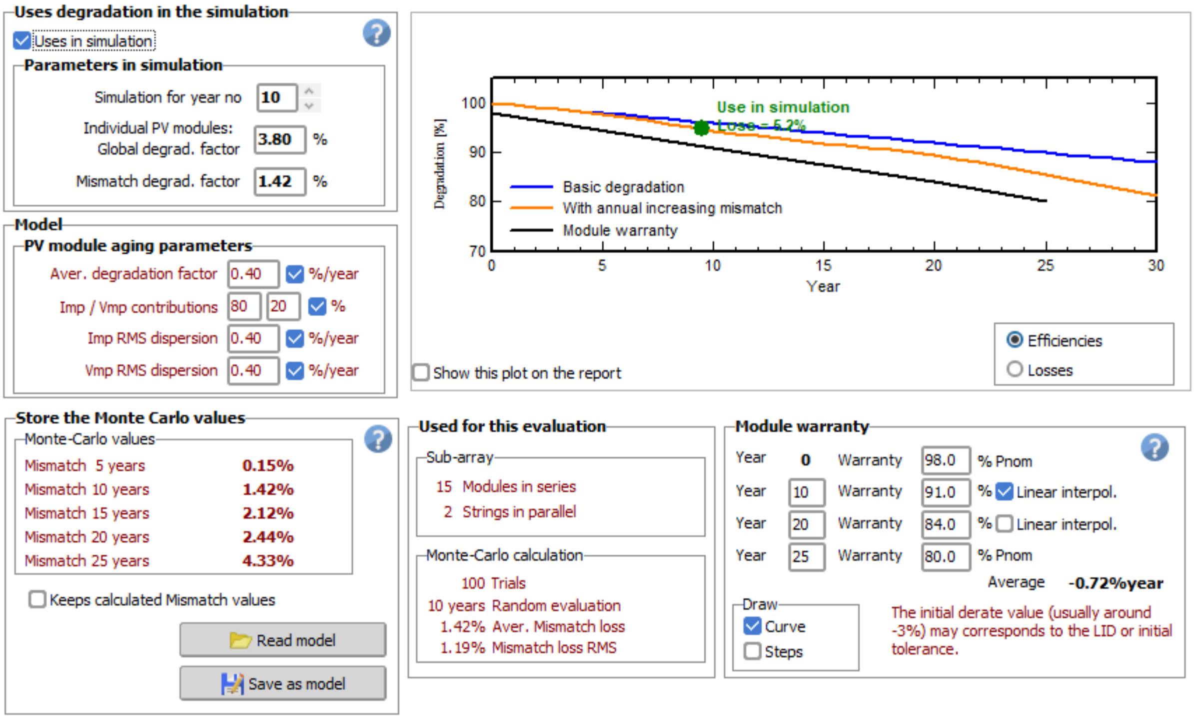
5.7 Aging

The PV module degradation gives rise to a progressive loss of efficiency, which we will characterize by a *Degradation Loss factor*.

The simulation may be run for a specified year of the PV system life and will apply the degradation for this year. The degradation means a decrease of the PV array yield. It may sometimes have some "positive" effect on the full system behavior, which may lessen a little bit the degradation effects. This may be namely a diminution of the overpower losses when the inverter is strongly undersized.

The Manufacturer's warranty should be understood as a lower limit for any individual PV module. In this tool we define an average degradation rate (for a set of modules). This loss value may be much lower than this guaranteed limit. Some experimental studies mention degradation rates of the order of -0.3%/year measured as an average on several modules (and measured with very old modules manufactured in the years 80-90, with old technologies). Long-term degradation rate measurements are relatively scarce.

NB: Nothing prevents to limit the lifetime of the PV modules to 25 years. A well-maintained PV system may probably stay operational over much longer periods.



Moreover, all the modules will not degrade with the same rate. If you have a distribution of loss rates around this average, this will produce an additional loss due to mismatch, increasing with time.

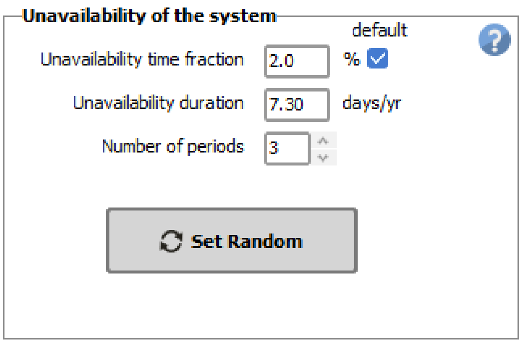
In PVsyst, you can specify the RMS of this distribution (supposed gaussian), and the program will evaluate the mismatch as function of the age of the system. This calculation is performed using a Monte-Carlo method (choice of a great number of random distributions), with the following hypothesis:

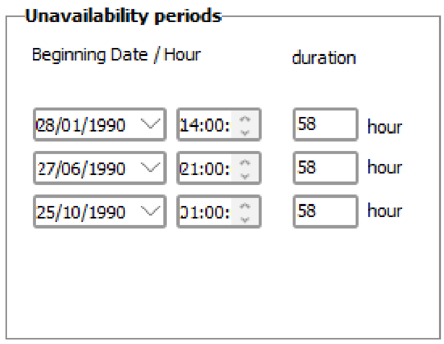
- the degradation rate of each module is constant over the years,
- the distribution choice is limited to 2 sigmas (95% of the hits); because high discrepancies result in very high mismatch losses.

You can choose to tick the box *Keep calculated Mismatch* values, to ensure that you run the same Monte Carlo generated values in every simulation. You can also save them as a model and apply the same random distribution to other projects.

5.8 Unavailability of the System

It is sometimes useful to consider system failures or maintenance stops in the production expectations. You can define system unavailability as a fraction of time, or number of days. As this is usually unpredictable, you have the possibility to define specific periods of unavailability of the system and generate these periods in a random way. The effective energy loss depends on the season and the weather during the unavailability periods. Therefore, the unavailability loss has only a statistical meaning.



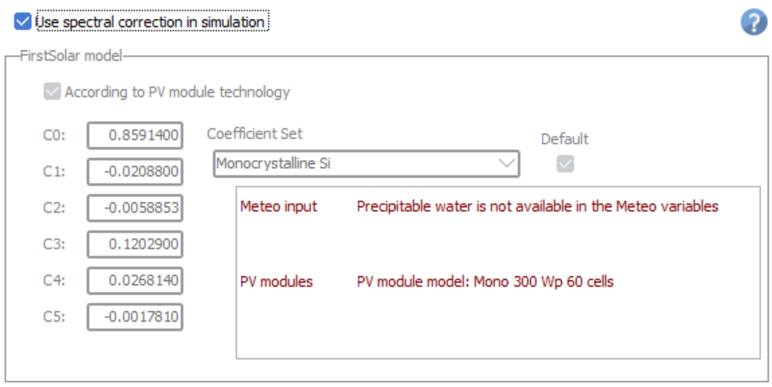


5.9 Spectral correction

Spectral correction accounts for changes in the solar spectrum caused by scattering and absorption in the atmosphere. These changes depend on factors such as atmospheric water content, aerosols, and the distance light travels through the atmosphere—expressed as Air Mass (AM).

PVsyst implements several models to describe spectral correction:

1. **The CREST model**: Used for amorphous silicon modules, this correction is applied automatically when spectral correction is activated.
2. **Spectral correction for PV modules in the Sandia database**: This correction is also applied automatically when spectral correction is activated.
3. **The FirstSolar spectral correction model**: Disabled by default, but it can be enabled by the user.



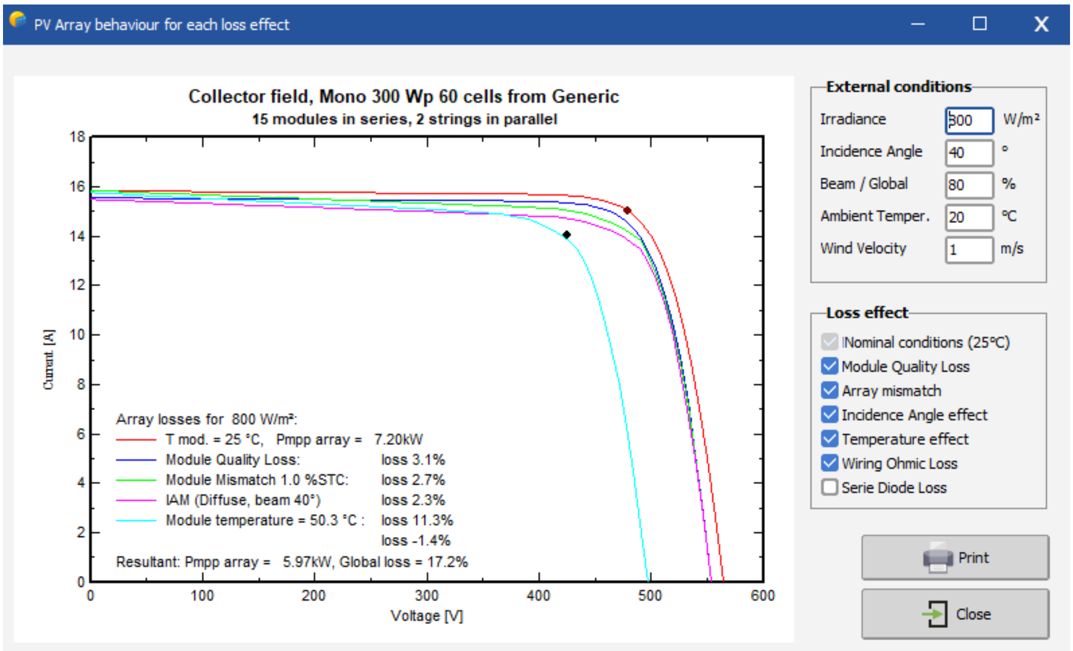
When spectral correction is enabled, the simulation by default uses the set of coefficients associated with the PV module technology. However, it is possible to modify this setting by unchecking the corresponding box and selecting another set of coefficients from the available options. In this case, the coefficient set will no longer adapt to any changes in the PV module in the system definitions, and it is the user's responsibility to ensure a relevant set is chosen for the simulation.

The FirstSolar spectral correction model uses the Air Mass and Precipitable Water Column as input variables. The air mass is computed from altitude and sun position, while the precipitable water has either to be present in the weather data file, or be estimated from relative humidity. Therefore, this correction can only be applied in the simulation, if either the precipitable water or the relative humidity are present in the weather data variables. For synthetic hourly weather data files created with PVsyst 6.7.4 or later, the relative humidity is always present.

If the spectral correction is used in the simulation, this will be mentioned on the final report. The system summary will list the set of coefficients that was used, and the loss diagram will feature a contribution called 'spectral losses'.

5.10 Losses graph

To visualize the impact of losses on the I/V behavior of the PV system, click on "Loss Graph" located at the bottom of the detailed losses settings window. This will open a new window titled "PV Field Behavior for Each Loss effect." In the new window, at the top right, you can define the external conditions of the array. In the field below, select the type of loss you wish to display. The red curve indicates the nominal conditions, representing the upper limit of the system's performance. For each selected loss, a curve in a different color will appear.



6 Self-consumption

The self-consumption in PVsyst allows users to assess how much of the solar energy generated by the PV system is consumed locally within a specific building or facility. This analysis helps to understand the proportion of their electricity needs that can be met by solar energy. This type of system is connected to the grid, and any excess energy can be fed back into the grid when it is not being consumed by the user.

There are various options to define the load profile:

- **Fixed constant consumption** is the most straight forward method to define the user's needs. You simply specify a constant power or yearly energy.
- **Monthly values** allow you to define monthly averages, which the simulation will treat as constants throughout each month. There is no daily modulation.
  - Values are defined using the graphic tool in the "monthly values" tab.

- ***Daily profiles*** allow users define hourly values that can be modulated according to 4 different profiles:
    - **Constant over the year**: The same profile is used throughout the year
    - **Seasonal modulation**: Different daily profiles for each season
    - **Monthly normalization**: where a daily profile can be defined for each month
    - **Weekly modulation**: Separate daily profiles for "working days" and "weekends."
- ***Probability profiles*** allow you to establish the probability that you will consume a certain level of power
- ***Household consumers*** provide a list of common domestic appliances, including unit power and daily usage duration.
- **Load values from a CSV hourly/daily file** to define custom load profiles. You can select a template from a predefined list, which can be rescaled to match your specific consumption needs or upload your own profile, following the required format.
    - The first column should contain the date. For sub-hourly data, PVsyst will automatically convert it into hourly values for the simulation.
    - The date format must include the day, month, year, hour, and minute.
    - The second column should contain the load values, with the unit specified in the second row of this column.
    - The file must be a CSV format with semi-colon delimiters.

By running the simulation, we will get results concerning the non consumed energy that is injected to the grid, the energy consumed by the user and the energy consumption from the grid, representing the energy needed when there is not sufficient production, for instance at night.

7 Storage

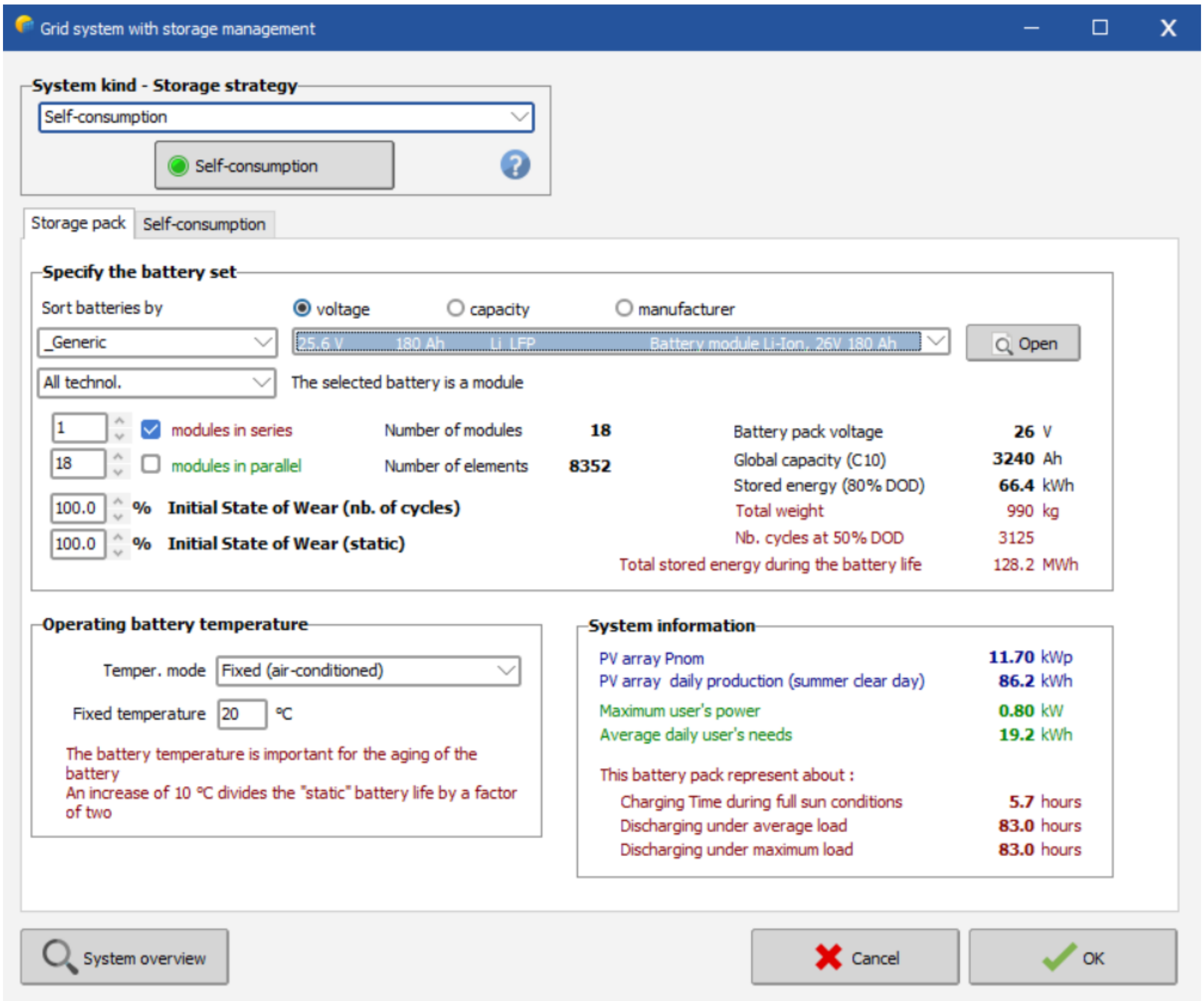
The battery storage implementation in PVsyst include to 3 storage strategies:

- Increased Self-consumption
- Peak shaving, when the grid-injection power is limited
- Weak grid recovery, for ensuring an electricity supply when the grid is failing.

Each of these strategies have different constraints. For instance, the self-consumption and Weak grid recovery require the definition of a user's needs hourly profile, where Peak shaving doesn't involve a user's needs profile. The battery energy will not be used for feeding the grid, except with peak shaving. The time of release of the battery energy (discharge) may be different according to the strategies, cost optimizations, etc.

The sizing of the different parts of the system (PV array, battery pack, as function of the load profile and the electricity price), is a complex problem, specific to each of these strategies. PVsyst provide rough sizing rules until some experience has been accumulated.

After selecting a strategy, you will have one window for the Storage Pack and others for the specific strategy. The Storage pack window is consistent across all strategies. To specify the battery set, begin by choosing the battery technology, and selecting a specific battery from the database. Next, define the number of batteries in series and parallel to configure a battery pack with the characteristics required. The configuration suggested by PVsyst will be based on the size of your system, the strategy, the consumption profile etc and should not be seen as the optimum configuration, but a suggestion.



On the right side of the battery configuration, you can see several figures that summarize the properties of the battery pack.

- The Battery pack voltage will be rounded to an integer value.
- The global capacity (C10) of a battery refers to the battery's total energy storage capacity when discharged over a 10-hour period. In this context, "C10" indicates the amount of energy in ampere-hours (Ah), the battery can supply continuously for 10 hours before its voltage drops below a specified threshold. This value helps characterize the battery's performance under a moderate discharge rate, commonly used for evaluating storage systems.

- Stored energy at 80% depth of discharge (DOD) refers to the amount of energy that can be drawn from a battery when it is discharged to 80% of its total capacity. In this context, the term highlights the battery's usable energy when 80% of its capacity is utilized, leaving 20% as reserve. The state of Charge (SOC) can be defined in the next window. If you change the Minimum discharge (OFF) from the default value of 20%, the DOD in the storage pack window will adapt accordingly. For Lithium-Ion batteries the charging cycle should never be 100% DOD, since a deep discharge or an overcharge reduce the battery lifetime or can even cause irreversible damage.
- The total weight is also displayed for information, to give a rough idea of the physical size of the battery.
- The next line shows the number of cycles that can be performed at 50% Depth of Discharge, before the battery reaches the end of its life.
- Finally you can read off the total energy that can be stored over the battery lifetime.

In the bottom left box, you can choose the battery operating temperature that will be used in the simulation. The battery temperature is used in the aging model of the battery. An increase of 10°C in the operating temperature reduces the "static" battery life by a factor of two. In the System information box, you find additional information about your defined system as well as some estimation about the behaviour of the battery pack.

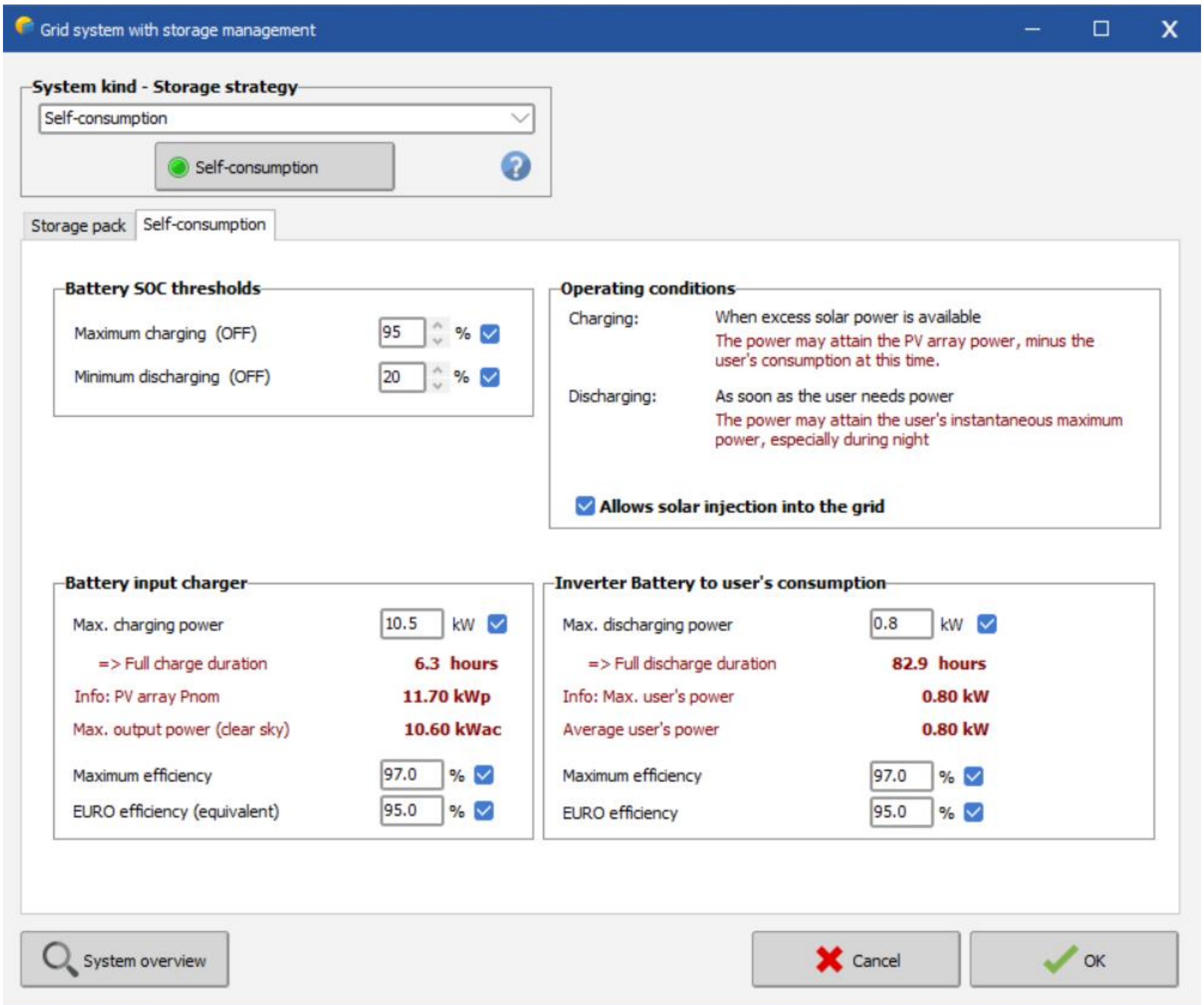
7.1 Self-consumption with storage

The self-consumption strategy with storage has the objective to increase self-consumption by storing excess energy, that can be consumed when the production is not enough to fulfill the users need. Excess energy from PV generators can also be injected into the grid when the batteries are fully charged, but in this strategy, the energy in the batteries will only be for self-consumption and will never be injected into the grid. The load profile must be defined beforehand, and the battery charging will start as soon as there is an excess PV generation.

By default, PVsyst set up the battery state of charge thresholds for maximum charging and minimum charging such that when the battery attains 95 percent of his capacity, we will stop charging and we will discharge, after 20 percent of his capacity, we will stop discharging.

In Operating conditions, we can read an explanation on how batteries will be charged and discharged. Also, you have the option to allow or not to inject solar energy to the grid.

In Battery input charger, PVsyst suggests a default value of the maximum charging power based on the possible charging power at maximum irradiance value and charging time during full sun conditions. Increasing the Maximum charging power will reduce the time of full charge duration. The battery should not charge too fast: for Lithium-Ion batteries, a full charge in 1 hour is the minimum reasonable to not compromise the lifetime of the battery. The possible excess power will be injected into the grid. By default, PVsyst sets the maximum discharge power based on the load profile predefined in self-consumption. In order to optimize the lifetime of the battery, please refer to the datasheet to know the adequate discharge time without damaging the battery. If you for instance reduce your discharging power and increase the discharge duration of the batteries, when you need more power, your system will take it from the grid.



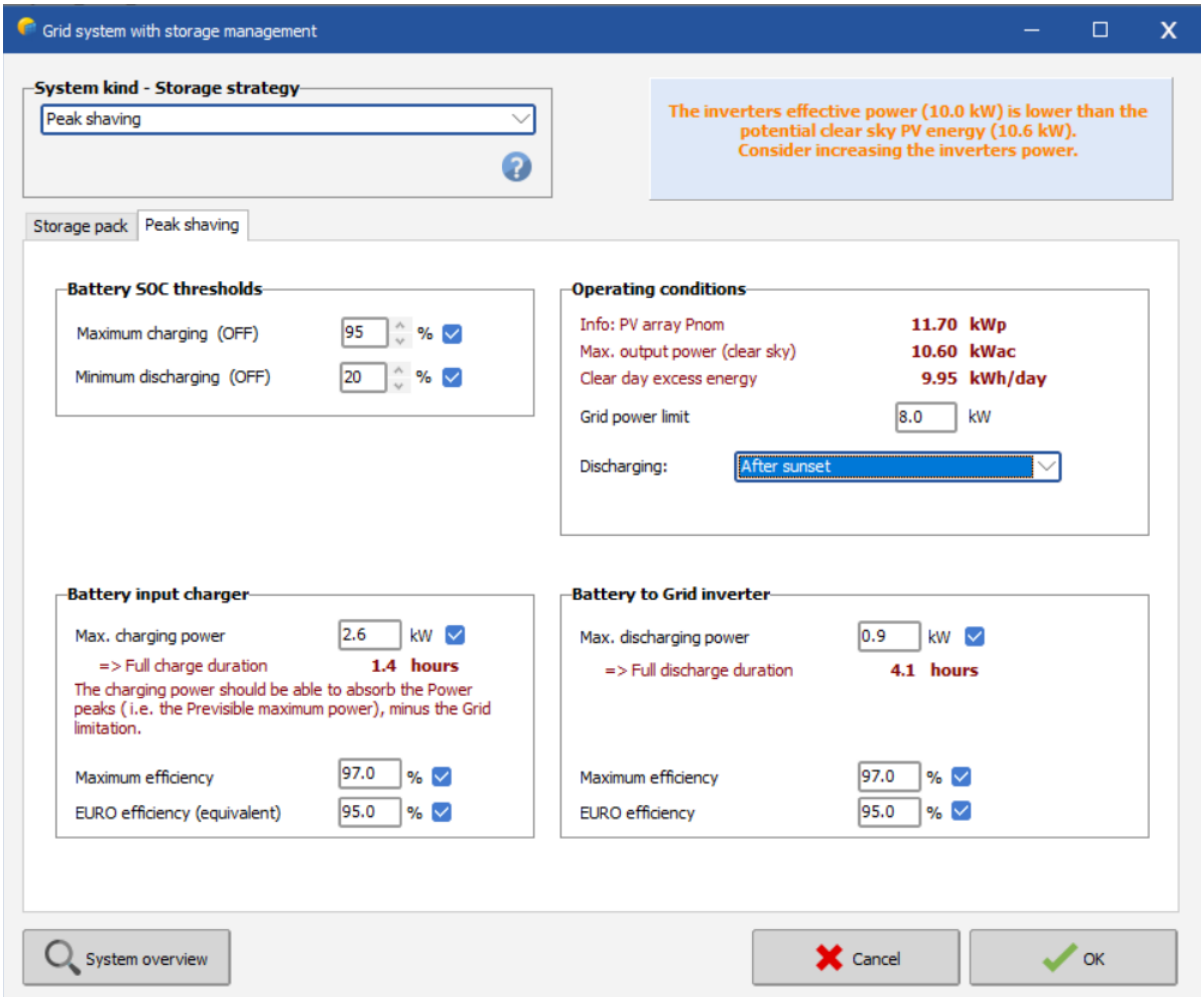
7.2 Peak shaving

If the grid operator limits the power that can be injected into the grid, a battery pack can store energy during periods of overproduction and inject it at a time when the PV generation drops below the injection limit. The Peak shaving strategy cannot be used in combination with a self-consumption profile.

In the Operating condition you must define a Grid power limit and a discharging strategy, you can choose between 4 options:

- The first option, which is also the default, is “As soon as power is needed”. With this option selected, the battery will start injecting energy to the grid as soon as the generated AC power is less than the grid power limit
- The second option is “after sunset”. Here, the grid injection only starts when the PV generation has dropped to zero at the end of the day.
- The third option is “from a specified hour”. If you select this option, a field will appear, allowing you to input an hour of the day. Injection from the battery to the grid will only happen from that hour onwards

- The fourth and last option is “during a specified hourly period”. With this option two fields will appear, allowing you to input specific hours of the day. The battery discharging will only be possible between these two values.



7.3 Weak grid islanding

This option concerns regions where the grid is not reliable (numerous cuts due to load shedding). This strategy requires the definition of a consumption profile and of a schedule of grid unavailability.

The PV energy is stored in a battery and returned to the user when the grid is unavailable. Technologically, this is far from being simple, as the usual solar inverters for feeding the grid require the presence of the grid for working. There may be several ways for avoiding this problem.

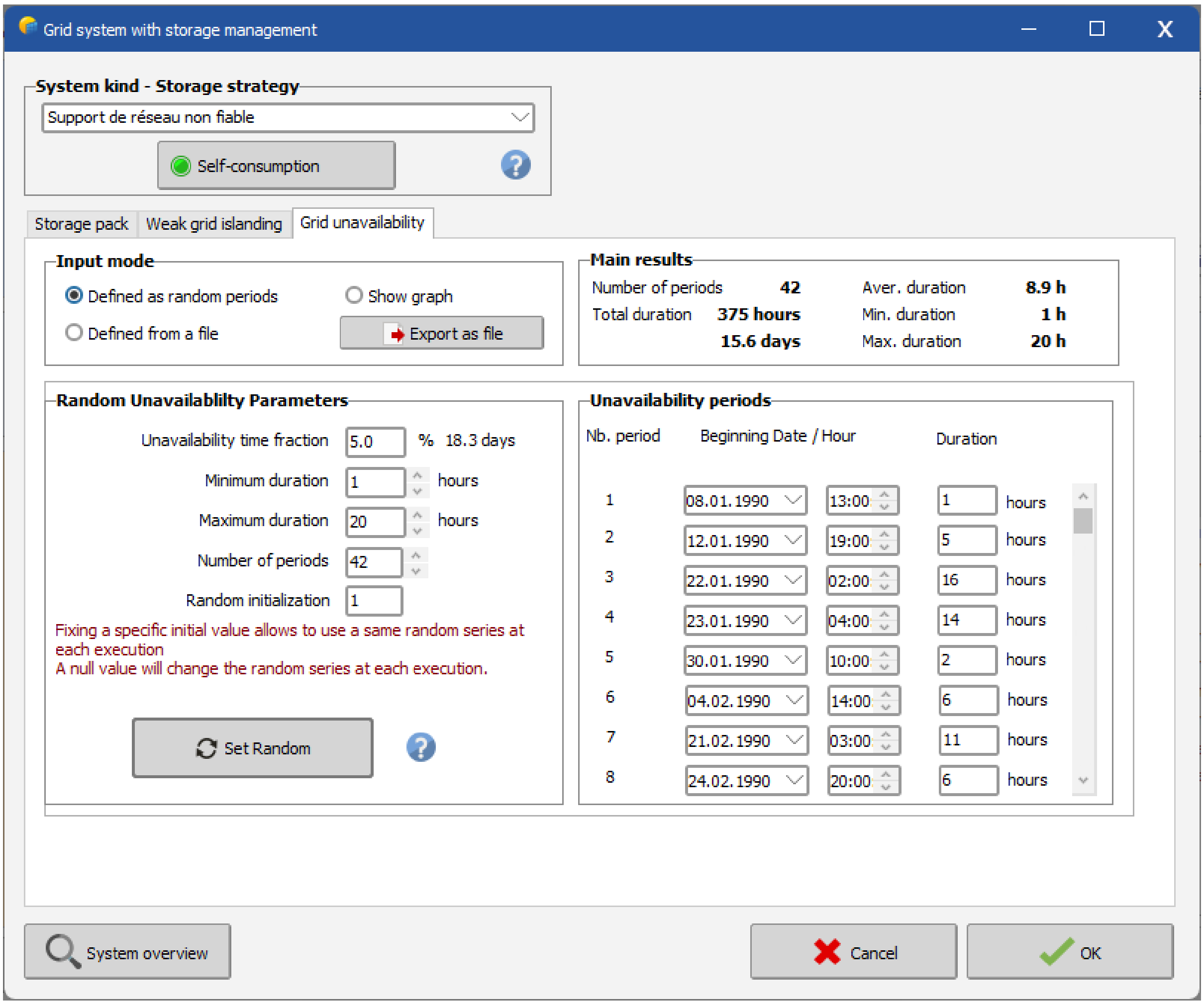
For the energy fluxes

- When the sun power is sufficient for feeding the user's needs, the rest is used for charging the battery. If the battery is full the excess will be injected into the grid if this is allowed, otherwise this energy will be lost (i.e. the inverter will operate at reduced energy level).

- When the sun is not sufficient (or during night) the user may be fed by the battery. However we should keep a storage reserve for the case of grid unavailability. Therefore we have to define a limit DOD for using the energy in any case, and another one for supplementing the grid when it is down.
- In case of grid failure, the switch should immediately open, and the user will be fed by the sun's energy + battery through the SA inverter.
- The control device should be able to limit the solar inverter's power if the injection into the grid is not allowed.

You have first to define the grid unavailability. This may be done:

- either by specifying the unavailability fraction of time, the number of periods and the minimum / maximum duration of each period. Then the program can propose a random distribution of unavailability periods along the year.
- or define an hourly sequence of unavailability for the whole year in a CSV (msExcel) l file.



The battery pack capacity is closely related to the user's needs. Ideally, the remaining energy below the SOC higher level should allow to cover the maximum needs for the longer unavailability period. You can obviously diminish this capacity, at the risk of feeding failure.

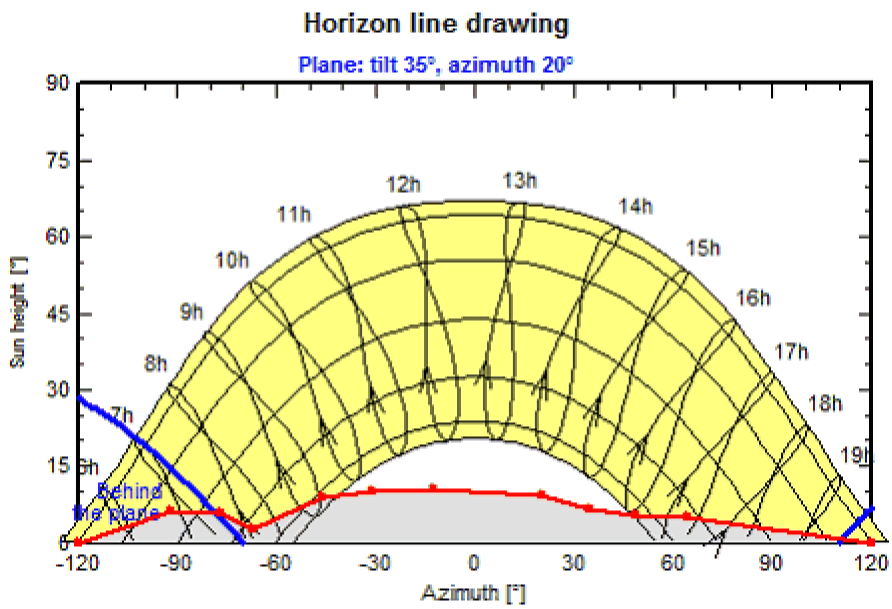
You can choose to define the unavailability as random periods or by reading a file. By clicking on "Show graph," you can visualize the unavailability periods throughout the year.

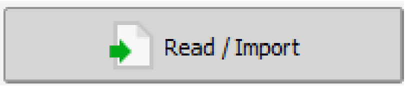
8 Horizon

The horizon profile is suited for shading objects that are located sufficiently far away from your PV system, so that the shadings may be considered global on your array. This is the case when the distance of the shading object is more than about 10 times the PV system size. The Horizon Profile is a curve that is defined by a set of (Height, Azimuth) points.

The Far Shadings operate in an ON/OFF mode: i.e., at a given time, the sun is or is not present on the field. When the sun is behind the horizon, the beam component becomes null. The effect on the diffuse component will be explained below.

Clicking the "Horizon" button will open a graph of the sun paths for the site of the project.



The horizon profile may be defined manually by a set of (Azimuth/Height) points in degrees. These may be from on-site measurements (using land-surveyors instruments like compass and inclinometer). They can be imported from several sources, either as a file or from web sources by clicking: 

A PVsyst internal file is a horizon line already saved in your workspace. A standard CSV can be any text file containing properly structured data. PVsyst will recognize files as valid horizon profiles if they meet following characteristics:

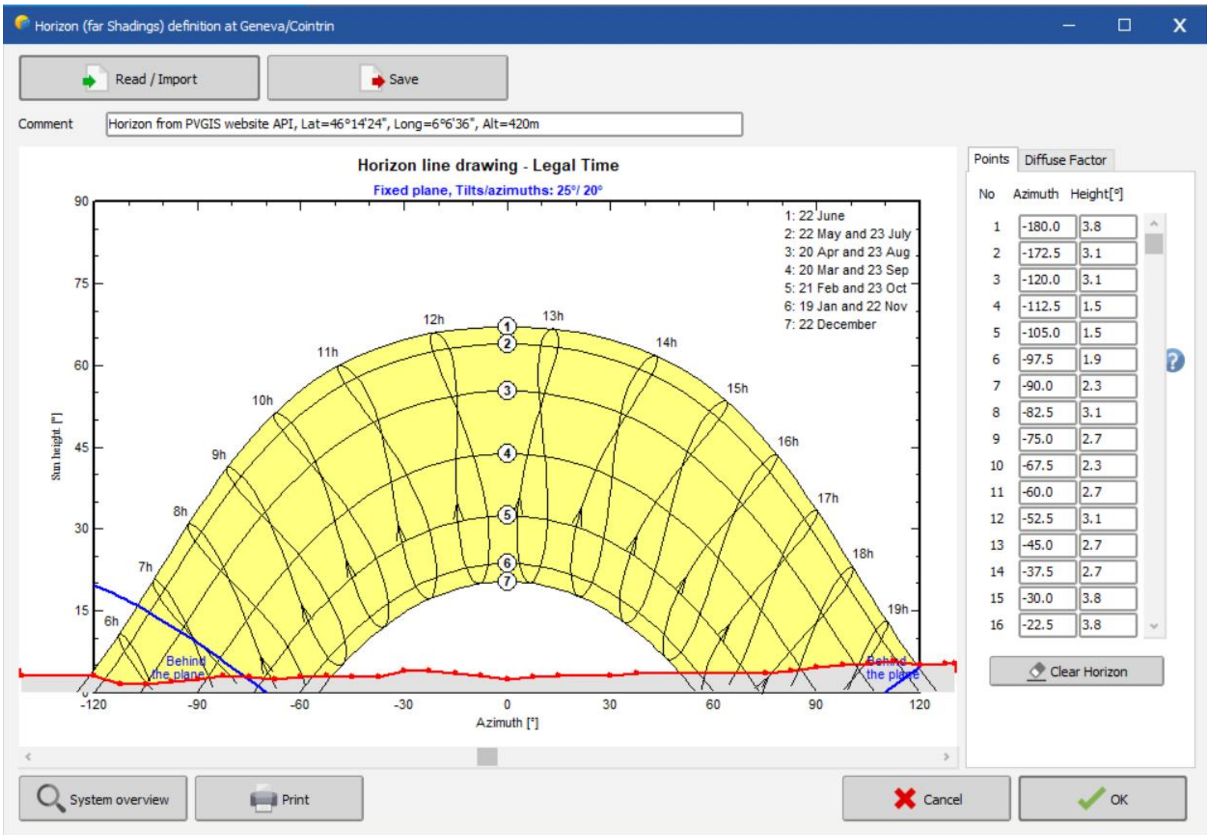
- File with text or CSV format, containing columns separated with comma, semicolon, tabulation or space.
- Header/comments:
  - All lines containing text are considered comment lines

- Comment line containing text such as "Latitude 25.3°, Longitude 44.1°" will be used as a comment for the generated horizon. This comment can later be manually edited.

- Data:
  - One line per defined point. Each point defined as an Azimuth and a Height value, expressed in degrees.
- Before import, you can define the angular reference for your file with the Direction of rotation of azimuth as Clockwise or Counterclockwise and the North azimuth angle.
  - The Meteonorm software produces Horizon profiles, which you can also import in PVsyst. The file name of these profiles holds the exact coordinates of the site evaluated.

The horizon line can also be imported from web sources directly (with an active internet connection):

- The free service **PVGIS** provides worldwide horizons. This service is completely integrated in PVsyst, manually downloading the profile from the web page is not necessary. Simply choose "PVGIS Horizon From WEB" and press the Import from web button.
- The included Meteonorm web service for horizon profiles provides worldwide horizons.

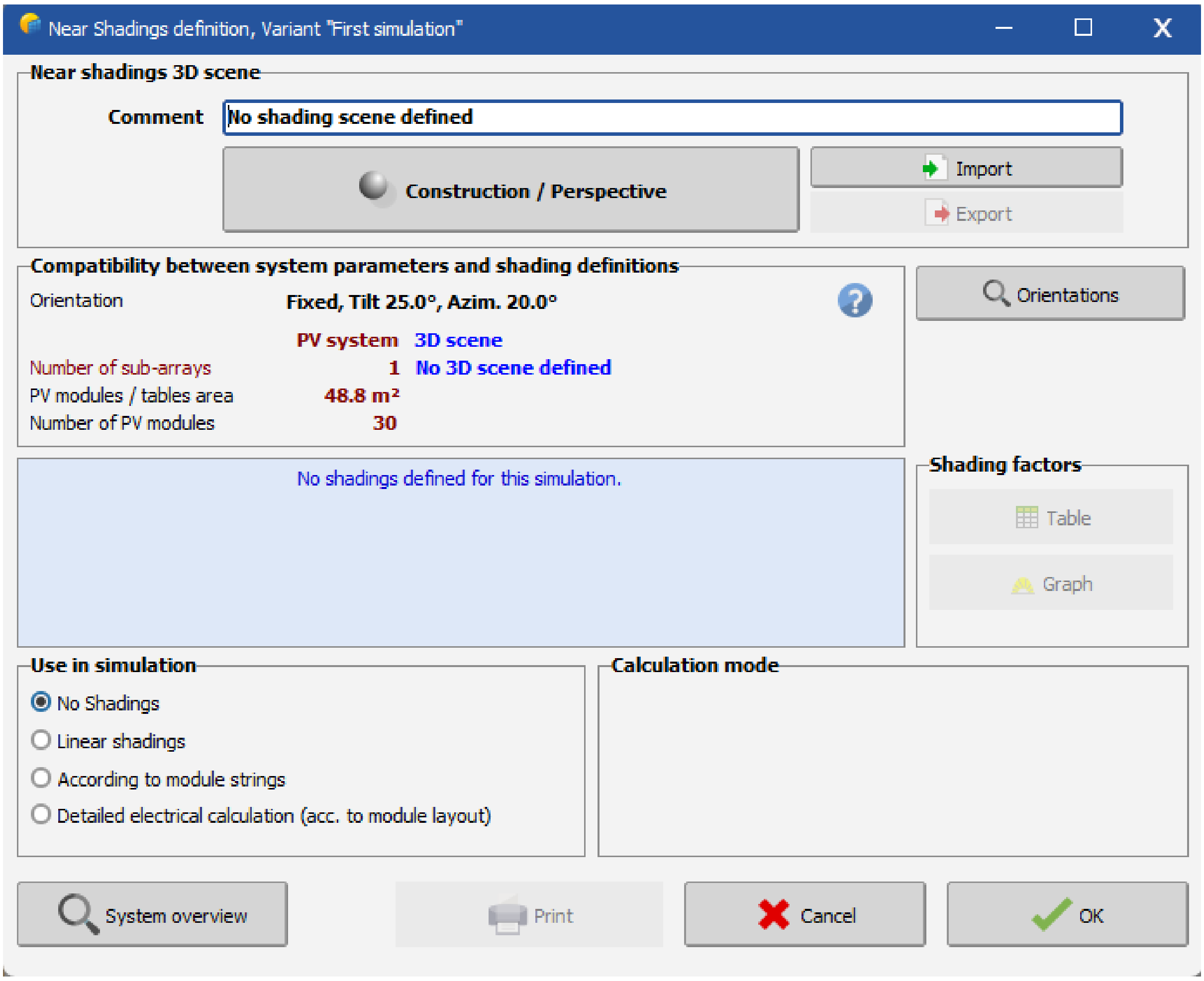


For horizon profiles established using a geo-reference grid (like PVGIS and Meteonorm), the exact location should be carefully defined. You can edit the latitude and longitude in this window to be as precise as possible: keep in mind that a degree in latitude is 111 km, the second decimal is 1.1km and the 4th decimal is 11m. The 4th decimal can still have a big impact in places with high slope.

9 Near shading

The "Near Shading" window is the main dialog providing access to the 3D editor for constructing scenes representing nearby shading. This functionality is essential for simulating the shading impact on photovoltaic (PV) modules, thereby calculating the resulting energy losses.

The "Construction/Perspective" button is the key element for accessing the 3D scene editor. This allows defining surrounding objects that may create shading, such as buildings, trees, or other obstacles, to accurately model the PV modules' environment.

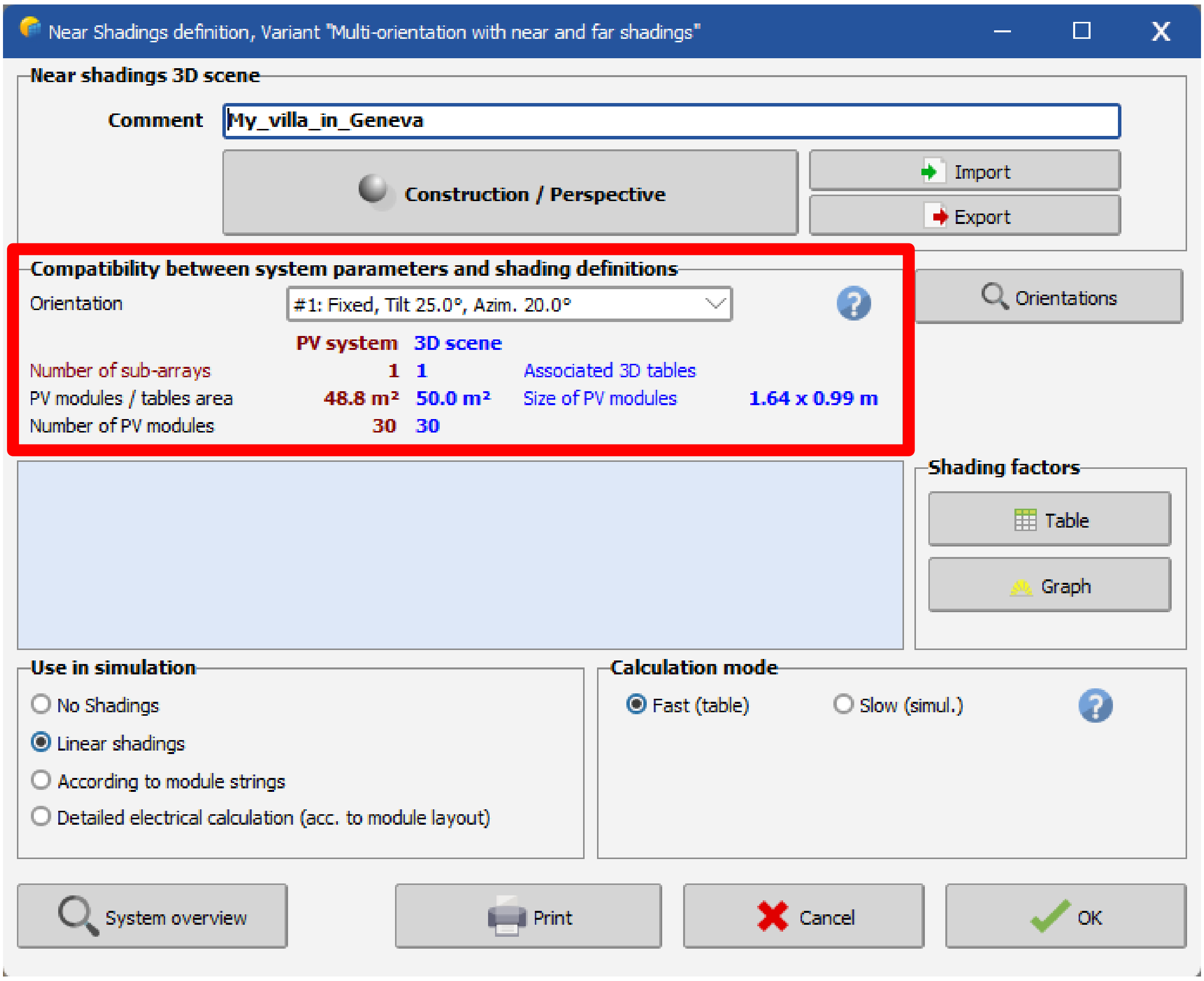


It is important to note that the primary objective of near shading is to precisely represent irradiance losses due to nearby objects and to help optimize the solar panel installation to minimize these losses. When defining objects that may create shading, as well as the topography, it is advised not to get too detailed and avoid spending time drawing every object precisely. The more detailed the 3D scene, the longer the software will take to calculate shading on the PV scene. Therefore, it is preferable to keep the drawing simple and representative of the project to ensure efficient calculations.

9.1 Compatibility between the 3D Scene and System-Orientation

Once the 3D scene is constructed, the program will check this construction's compatibility with the previously defined PV system parameters, such as the orientation and layout of the modules. This ensures a consistent and reliable simulation of losses due to near shading.

In this section, several important pieces of information allow control over compatibility between the 3D scene and the system definition, as well as orientation.



First, there is a dropdown list for the different existing orientations. Next, information about the number of sub-fields, the surface area of existing PV modules, and, finally, the total number of PV modules is displayed.

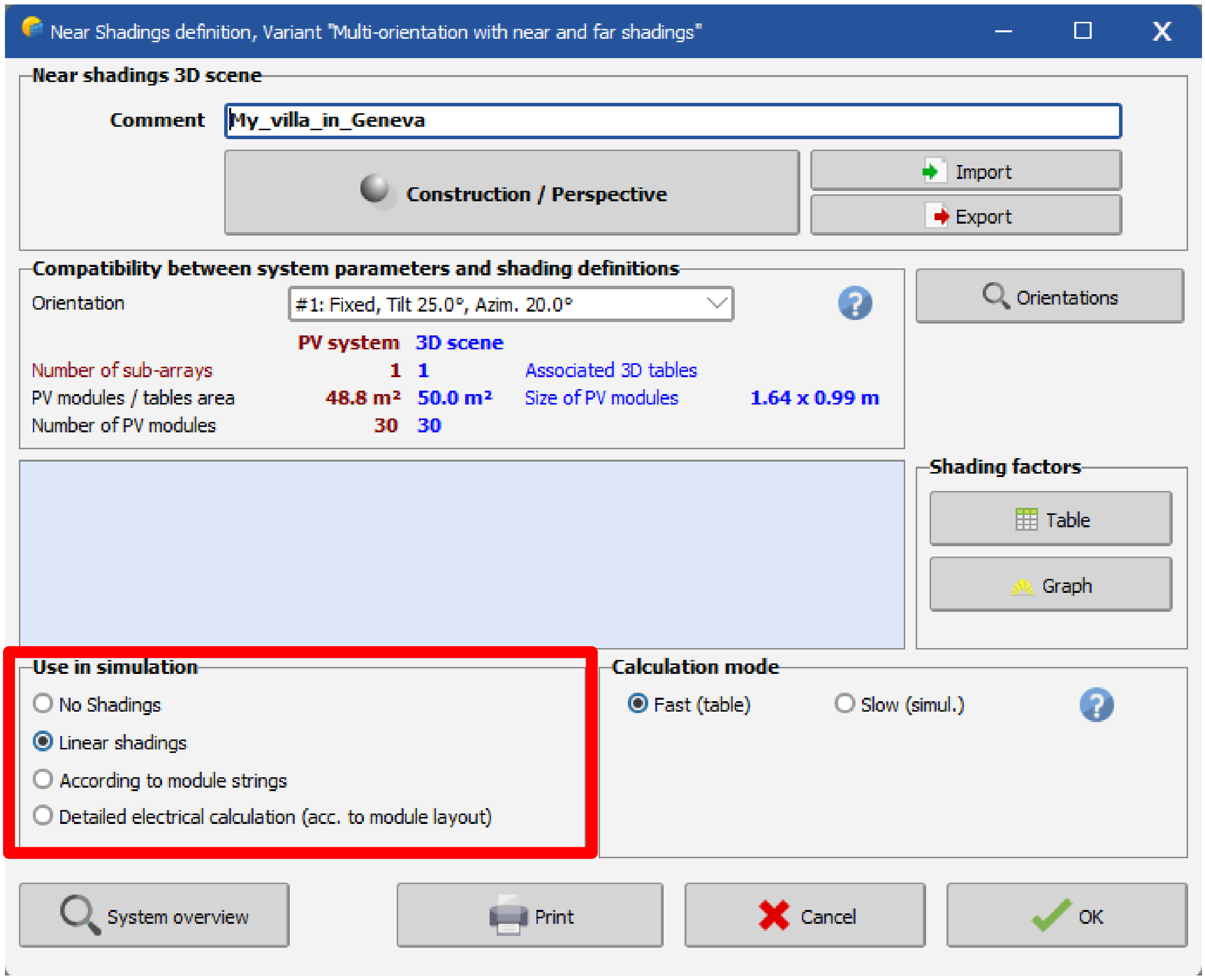
Matching orientation between the 3D scene and the orientation definition is mandatory. If an incompatibility is detected, the program will ask if you want to update the orientation definition to match the 3D scene.

Regarding the PV modules' surface area, the software accepts a tolerance for differences between the system definition and the 3D scene. This tolerance accounts for slight variations that may occur during scene construction while ensuring consistent surface areas.

Finally, the total number of PV modules should be close between the system definition and the 3D scene, with a small tolerance accepted.

9.2 Simulation Parameter

Three parameters calculate shading-related losses:

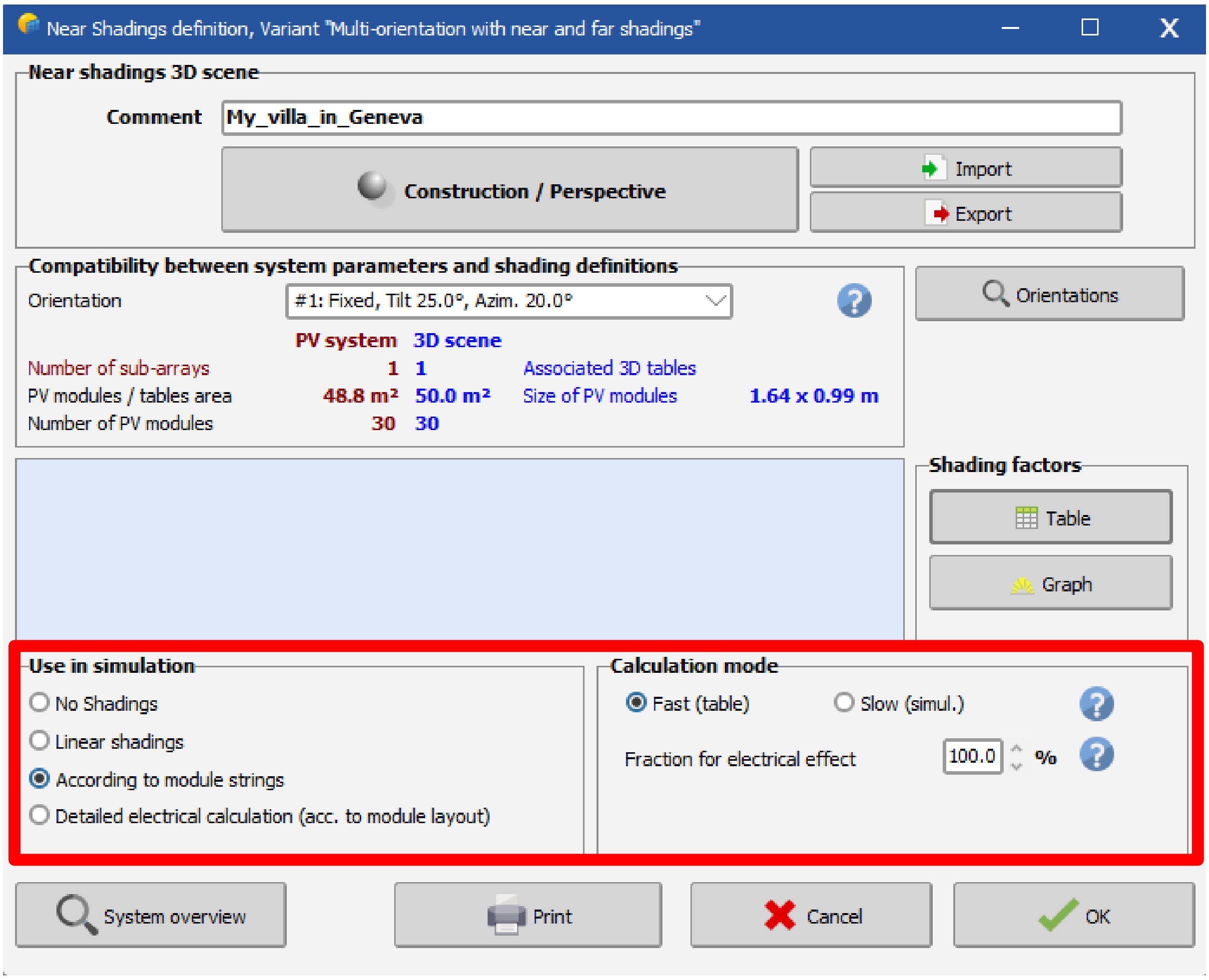


Linear Shading

This mode only considers the irradiance deficit on the PV field without electrical effect. It represents a lower limit of total shading losses. You can run this simulation quickly (by interpolating values from the shading factors table at each step) or more accurately but slower, calculating the complete shading factor at each simulation step.

By Module String

While creating the 3D scene, you can group the modules into distinct strings. With this option, a shading factor is calculated for each string, and the electrical losses related to shading on each string are estimated individually. This provides a more detailed estimate of the electrical effects than a simple linear shading calculation.



For a more precise result, you can specify the electrical effect fraction from "pure linear" calculation (fraction for electric effect of 0%) to full electrical effect (fraction for electric effect of 100%).

The partition model estimates electrical loss but does not account for module bypass diodes.

Detailed Electrical Calculation (acc. To module layout)

Finally, after specifying a detailed configuration of the "module arrangement" in the 3D scene, you can perform shadow calculations based on detailed electrical losses. The “module layout” tool is designed for precise mismatch shadow loss calculations.

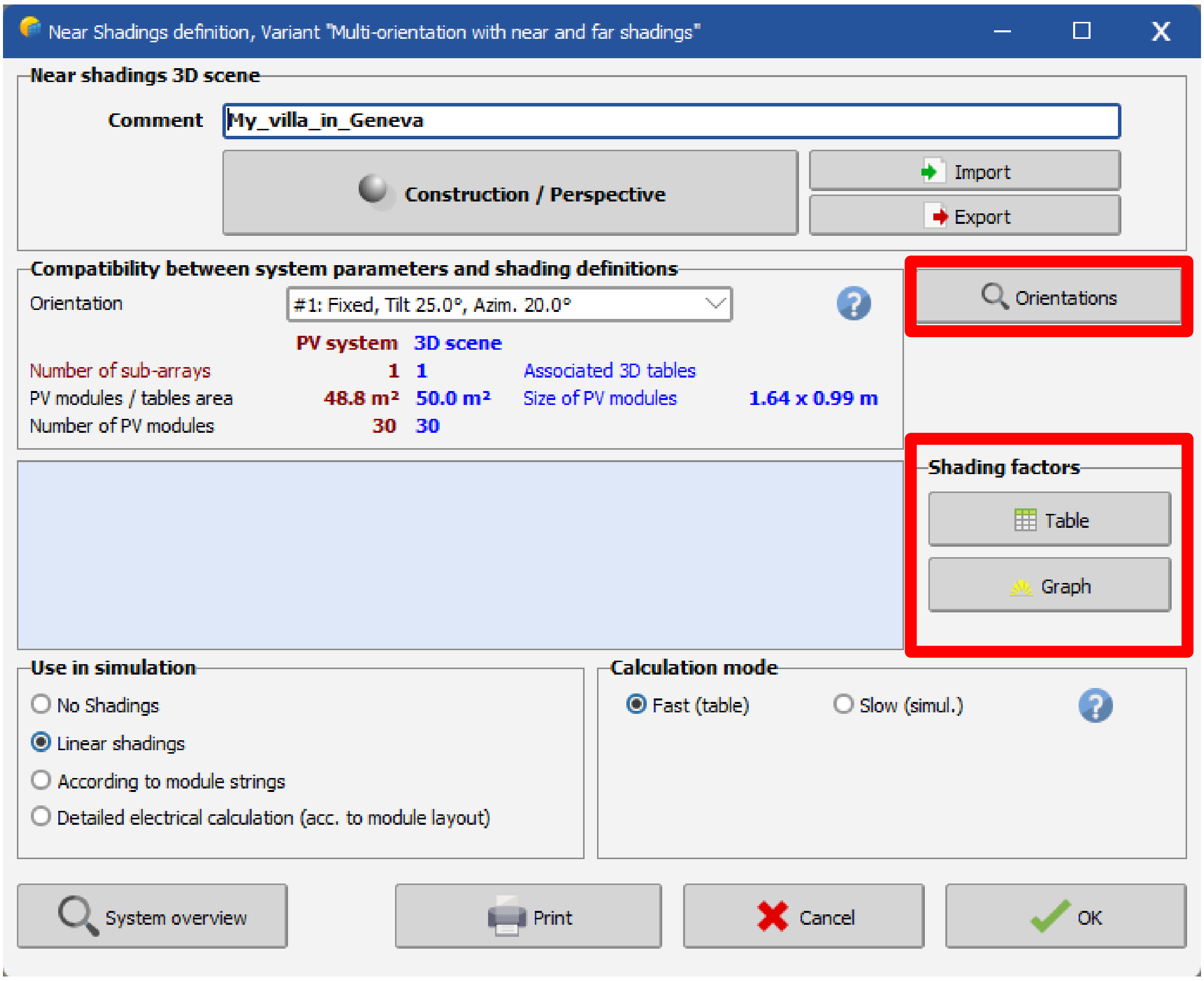
This simulation type requires a precise description of each PV module's position in the 3D scene and the interconnection of modules into strings according to the inverters defined in the "System" section. This allows highly accurate modeling of shading effects on each module, including losses due to current mismatches between strings.

The advantage of this model is that it calculates shading on inverter-connected strings and considers bypass diodes, which circumvent shaded zones and thus reduce power losses. This model allows for a more precise shading-related electrical loss calculation than the partition model.

9.3 Orientations, table, graph buttons

Orientations

The "Orientation" button opens the orientation management window without having to leave this window, enabling additional orientation management operations.



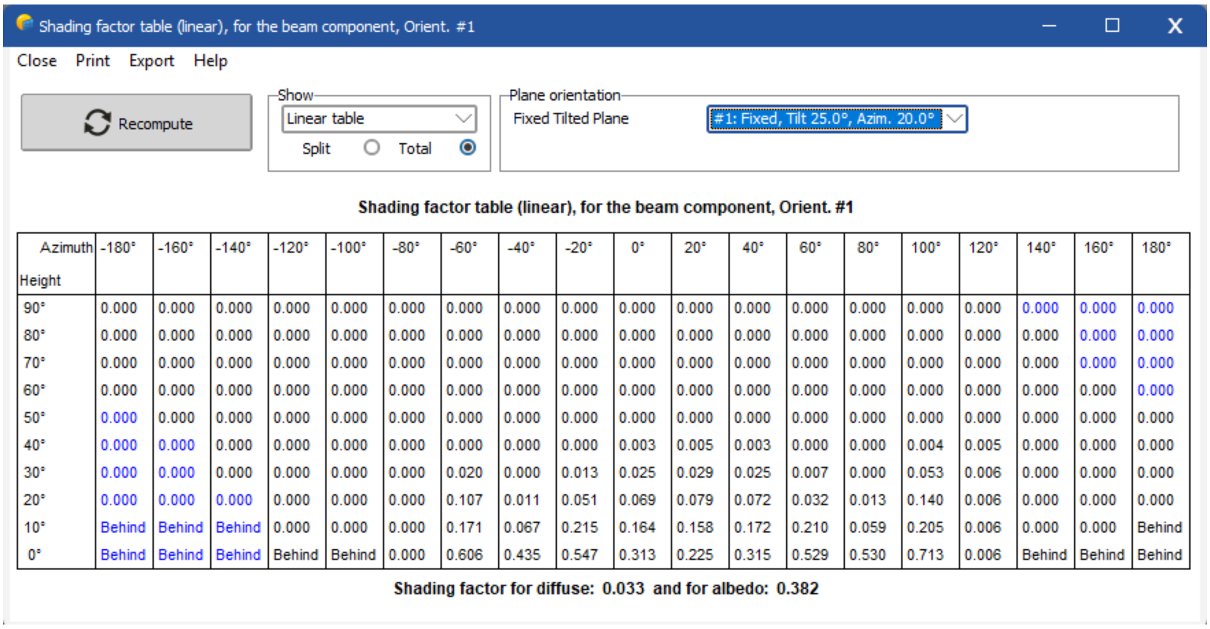
Table

The Table button enables you to build the shading factor table, which calculates the shading factor for different directions from which sunlight comes.

This process calculates the diffuse and albedo attenuation factors, which remain the same throughout the year.

Following this, you can view the Iso-shading diagram and start the simulation.

If you set up a partition in module strings when building your 3D model, two tables will be generated at the same time: one for the standard "irradiance" or "linear" shading factor, and another based on the module strings.



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	0.003	0.005	0.003	0.000	0.000	0.004	0.005	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.013	0.025	0.029	0.025	0.007	0.000	0.053	0.006	0.000	0.000	0.000
20°	0.000	0.000	0.000	0.000	0.000	0.000	0.107	0.011	0.051	0.069	0.079	0.072	0.032	0.013	0.140	0.006	0.000	0.000	0.000
10°	Behind	Behind	Behind	0.000	0.000	0.000	0.171	0.067	0.215	0.164	0.158	0.172	0.210	0.059	0.205	0.006	0.000	0.000	Behind
0°	Behind	Behind	Behind	Behind	Behind	0.000	0.606	0.435	0.547	0.313	0.225	0.315	0.529	0.530	0.713	0.006	Behind	Behind	Behind

Shading factor for diffuse: 0.033 and for albedo: 0.382

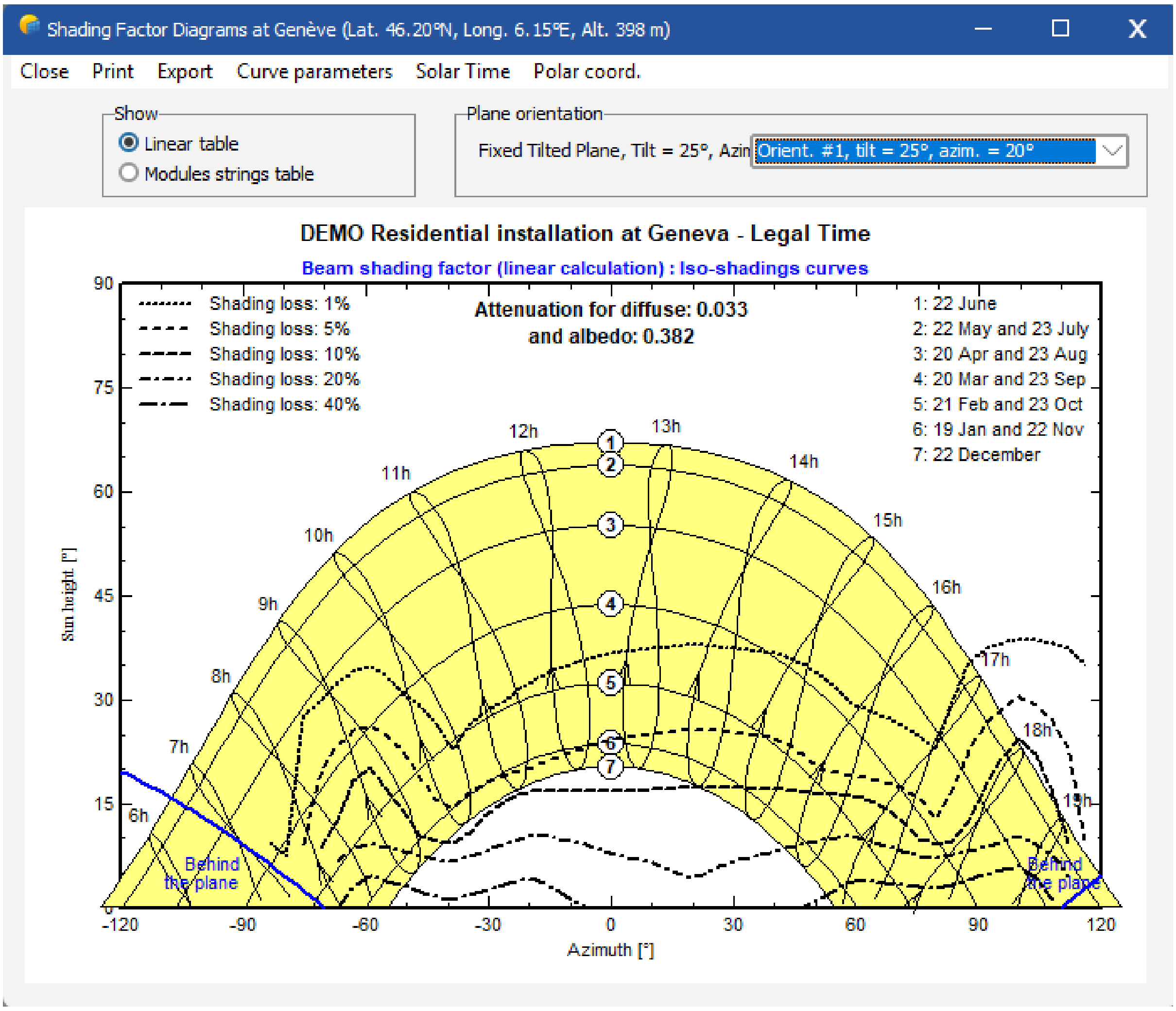
The Shading Factor represents the proportion of the PV field that is shaded relative to its total sensitive area, for a specific sun orientation (where 0 means no shading and 1 means completely shaded).

Calculating this at every step of the simulation could be time-consuming. To address this, the program creates tables with pre-calculated Shading Factor values at intervals of 10° for sun height and 20° for azimuth. These tables allow quick interpolation to determine the Shading Factor for any direction of sunlight, a method known as "Fast calculation" mode.

It's possible to calculate the Shading Factor at every step of the simulation to avoid errors from interpolation, referred to as "Slow calculation" mode. In this scenario, the pre-calculated tables are not used for determining the shading on the beam and circumsolar components.

Graph

The iso-shading diagram visually represents the shading factor table. It displays contour lines for specific shading factors, overlaid on the paths that the sun takes through the sky.



Blue lines on the diagram mark the points where the sun's rays are parallel to the surface.

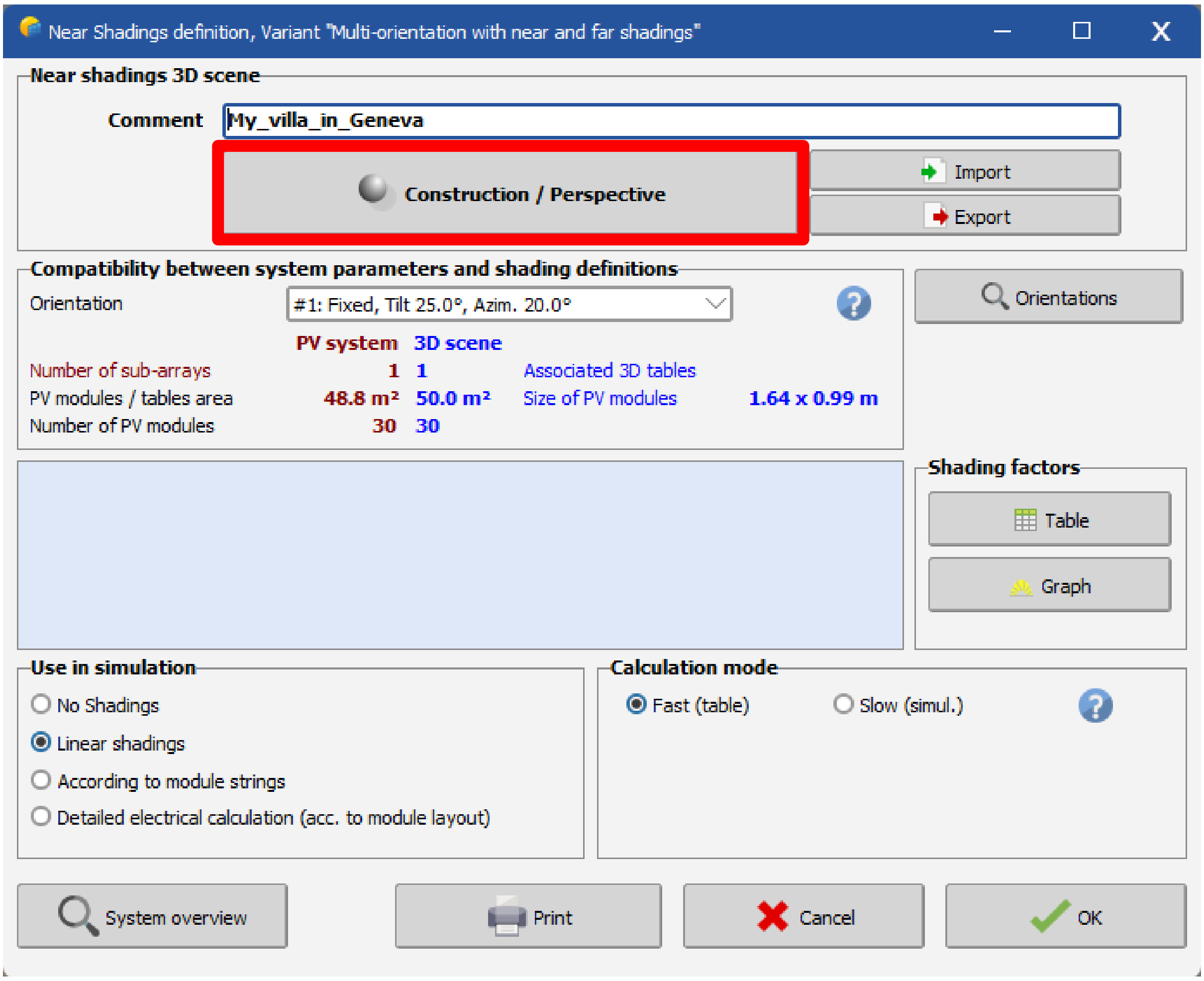
This diagram provides a concise overview of how shading varies with the seasons and times of day throughout the year.

The irregular look of the lines is due to the interpolations across discrete calculation points.

Remember that this loss factor applies to the beam component reaching the PV plane. When the incident angle is high, even high loss factors will act on very low irradiance component, giving rise to reasonable effects on the overall efficiency.

9.4 Construction/Perspective, 3D scene

Clicking on the "Construction/Perspective" button opens a new window where the 3D scene is located.

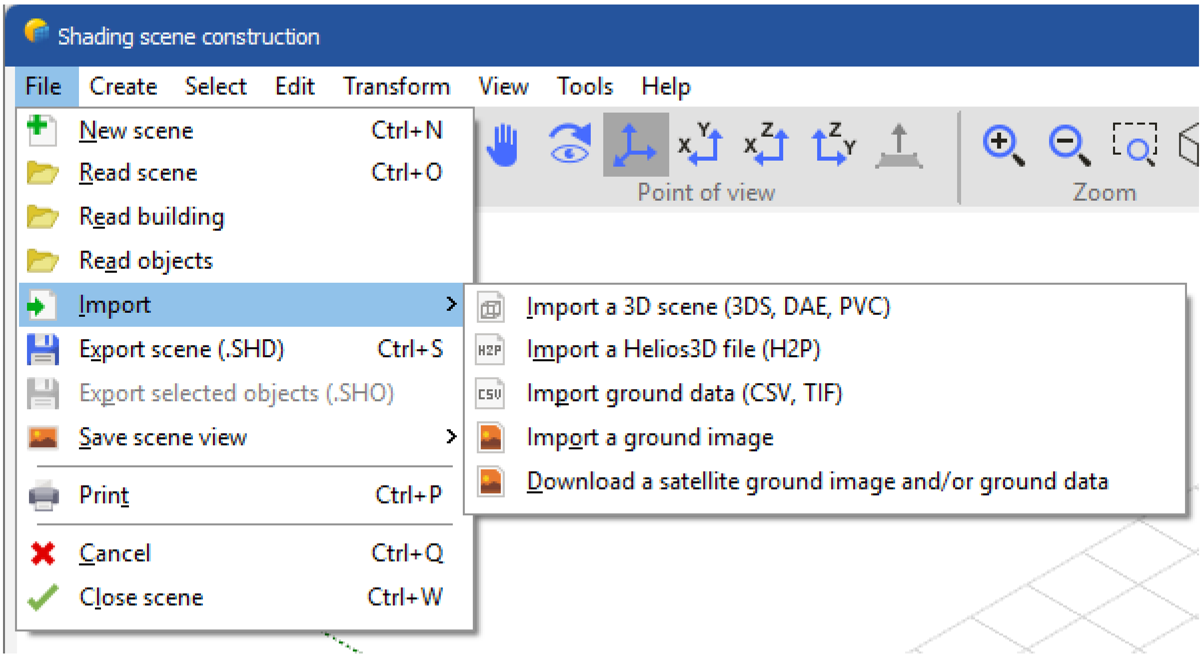


To begin, there are several strategies for creating a 3D scene in PV.

First Strategy: You can create your PV tables as well as objects that will cast shadows on the PV tables.

Second Strategy: You can import a 3D scene created with another software. The following formats are supported for import:

3DS, DAE, PVC, H2P.



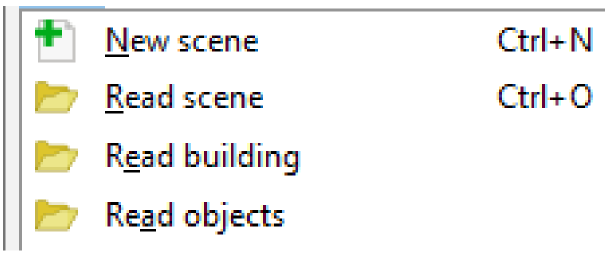
More information can be found in the tutorial "Exporting 3D Scene to PVsyst."

Third Strategy: This involves combining the first and second strategies. You can import a PV scene and then modify it in PVsyst by adding additional objects that may create shading.

It is also possible to import a topography with a satellite image of your site specified in the "Project" section.

File menu

Several actions are available:

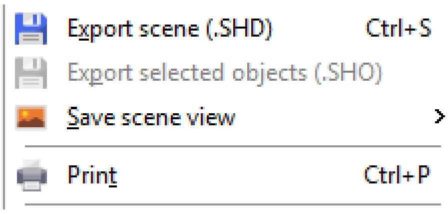


New Scene: Allows you to create a new scene by clearing the previous one.

Read Scene: Loads a previously exported scene using the "Export Scene" function.

Read Building: Loads a building exported with the "Export Selected Element" function.

Read Object: Loads an object exported with the "Export Selected Element" function.



Export Scene: Allows exporting the entire scene to save it for future projects.

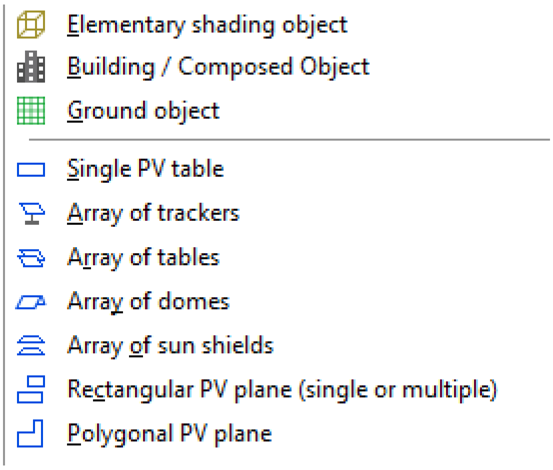
Export Selected Objects: Exports the selected object for later re-import.

Save Scene View: Saves the scene view to record it as an image.

Print: Prints the 3D scene.

9.5 Create Menu

The "Create" menu is divided into two main sections:

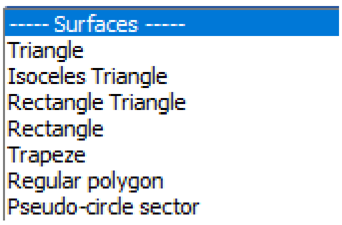


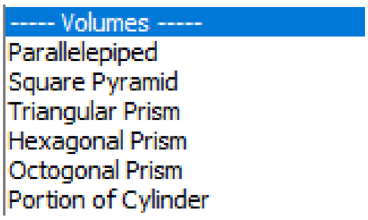
Object Creation

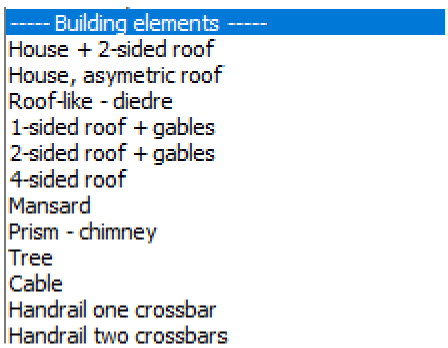
The first section is dedicated to creating different scene objects. PVsyst allows creating a variety of 2D and 3D objects to represent elements like buildings, trees, roofs, and other architectural obstacles. You can choose from a library of basic objects (2D and 3D shapes, construction elements) and assemble them to build more complex objects. It's also possible to customize the terrain topography by creating specific ground objects. Created objects can be adjusted in terms of dimensions and position to fit your PV installation layout.

In the shape type, several models are available:

First, there are surface models, which are simple, elementary 2D shapes, and surface models, which are elementary 3D models.

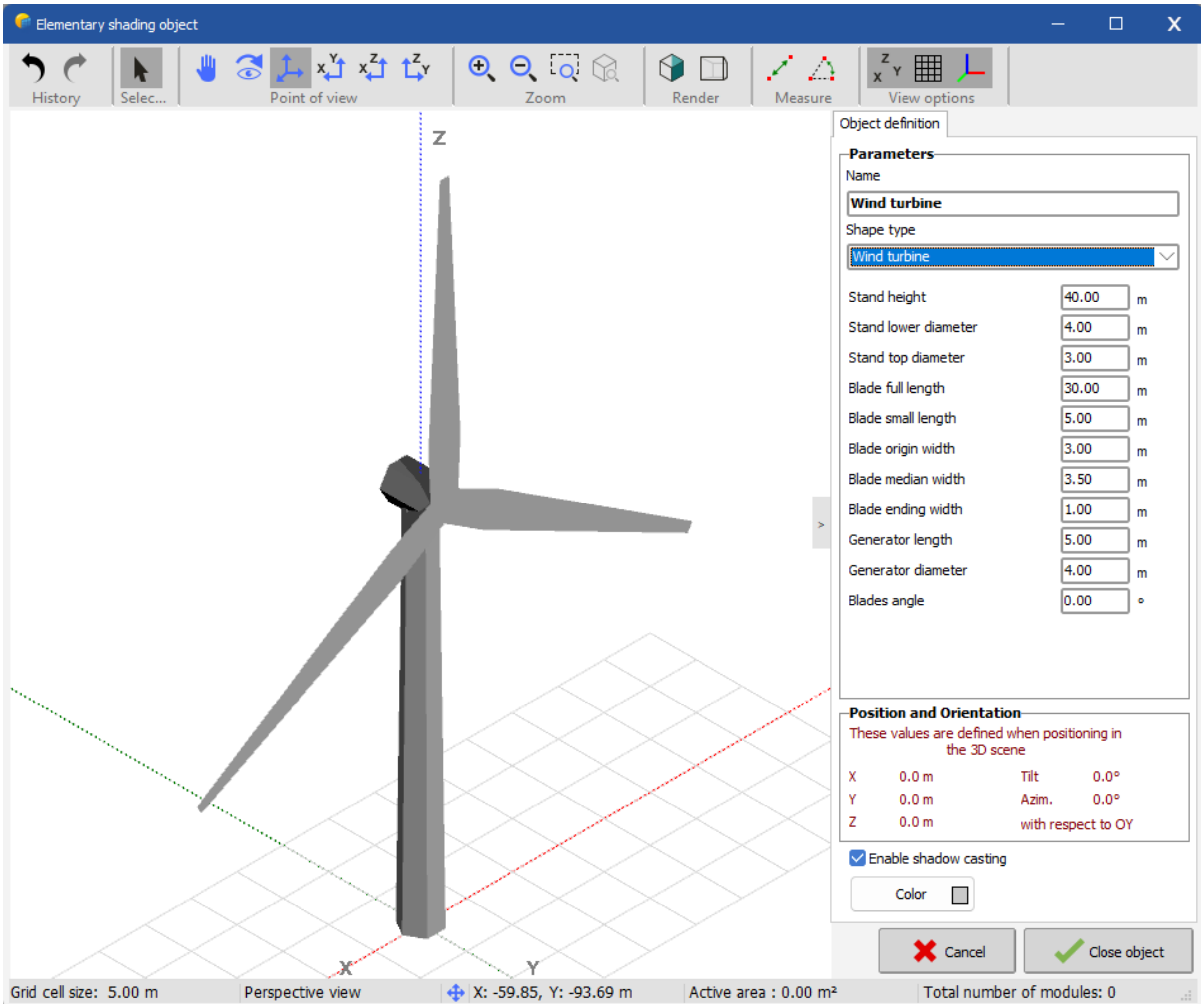




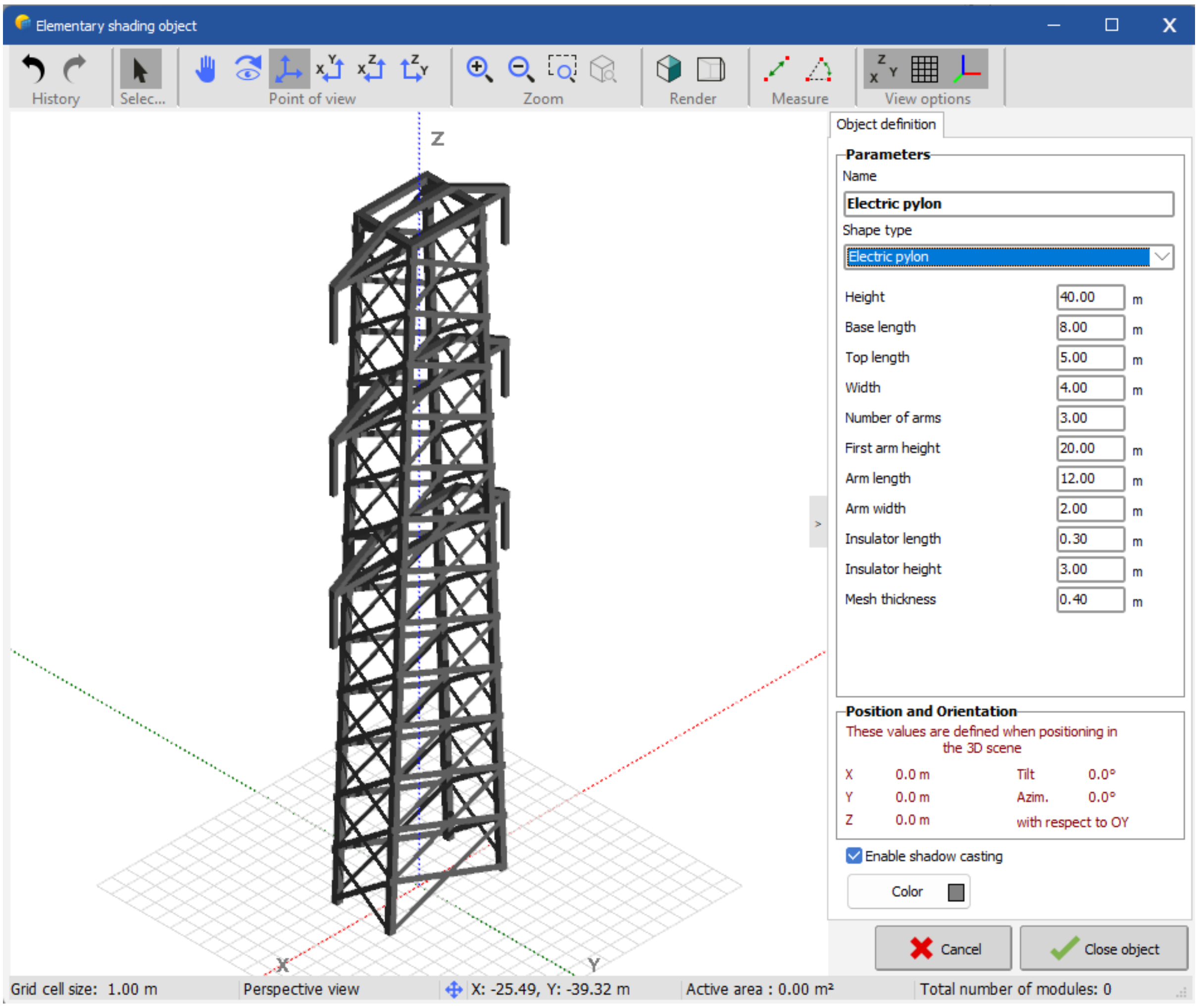


In this list, the construction objects are basic, with trees being a useful model example.

Lastly, there are special shapes like a **wind turbine**

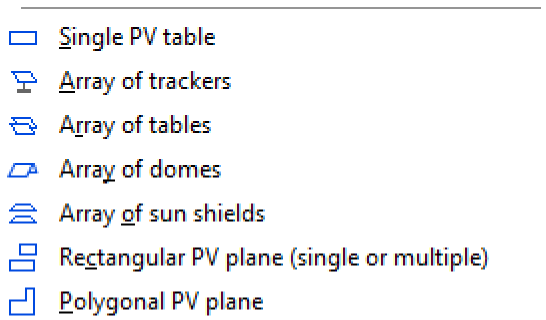


and an **electric pylon**.



PV Element Creation

The second part of the "Create" menu concerns creating photovoltaic elements. This includes creating different types of PV fields, such as:



Single PV Table: A rectangular area intended to host PV modules.

Tracker Row: One or more tables that follow the sun to maximize irradiance reception.

Table Row: Multiple tables placed one behind the other, commonly used in ground installations.

Dome Row: Groups of tables in an East-West opposing configuration.

Sunshade Row: Vertically aligned tables, suitable for facades.

Rectangular PV Plane (single or multiple): Frame-less sensitive rectangles that can be created in multiple instances within the same plane.

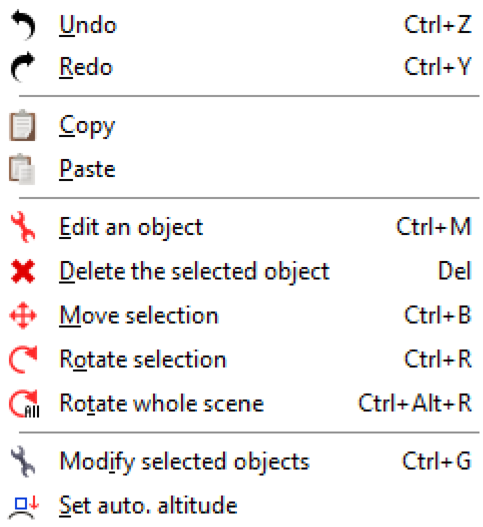
Polygonal PV Plane: A field of any shape drawn with the mouse, allowing maximum flexibility.

For each PV field type, you can define specific parameters like orientation, the number of tables, layout, spacing between tables, etc. These parameters can be adjusted to meet your installation's needs and optimize energy production.

The created objects and PV fields can then be integrated into the 3D scene to simulate shading effects and other environmental factors on your installation accurately.

9.6 Edit Menu

In the "Edit" menu, several tools allow you to manipulate a scene object.



Undo: Reverses actions, can be done with "CTRL+Z".

Redo: Reapplies an action that was undone, can be done with "CTRL+Y".

Copy: Copies an element, can be done with the "CTRL+C" shortcut.

Paste: Pastes a copied element, can be done with the "CTRL+V" shortcut.

Edit an Object: Allows modifying a scene object by double-clicking on it.

Delete the Selected Object: Deletes the selected object, can be done with the "DEL" shortcut.

Move Selection: Moves the selected item, also accessible from the main menu.

Rotate Selection: Rotates the selected item, also accessible from the main menu.

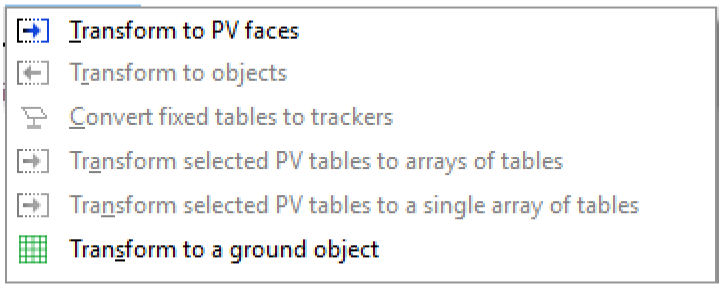
Rotate whole scene: Applies azimuth rotation to all scene objects.

Modify selected objects: Opens the "List and Object Management" window for grouped modifications, accessible with "CTRL+G."

Set Auto Altitude: Sets an object's automatic altitude based on another object, useful for automatically setting a PV object's altitude on a surface.

9.7 Transform Menu

The transform menu allows changing an object's surface into a PV surface.



Transform to PV Faces: Selected faces can be transformed into a PV surface.

Transform to Objects: Converts PV surfaces to non-PV objects.

Convert Fixed Tables to Trackers: Converts the selected PV table into a tracker.

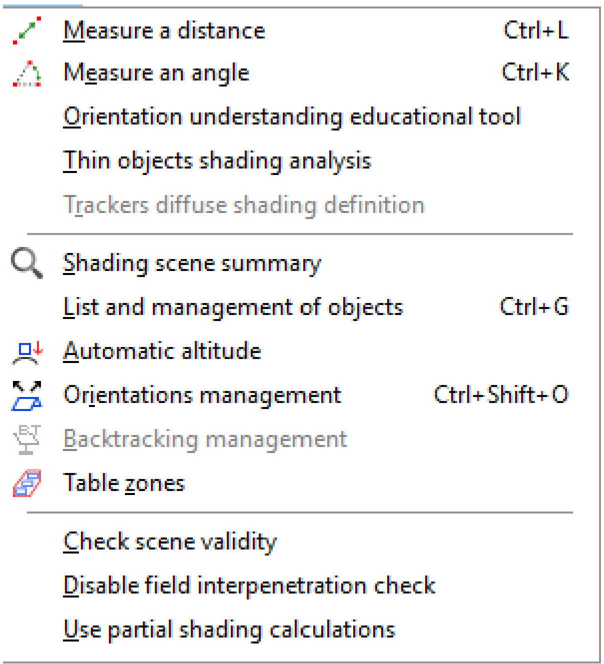
Transform Selected PV Tables to arrays of tables: Converts a single PV table into a PV table field.

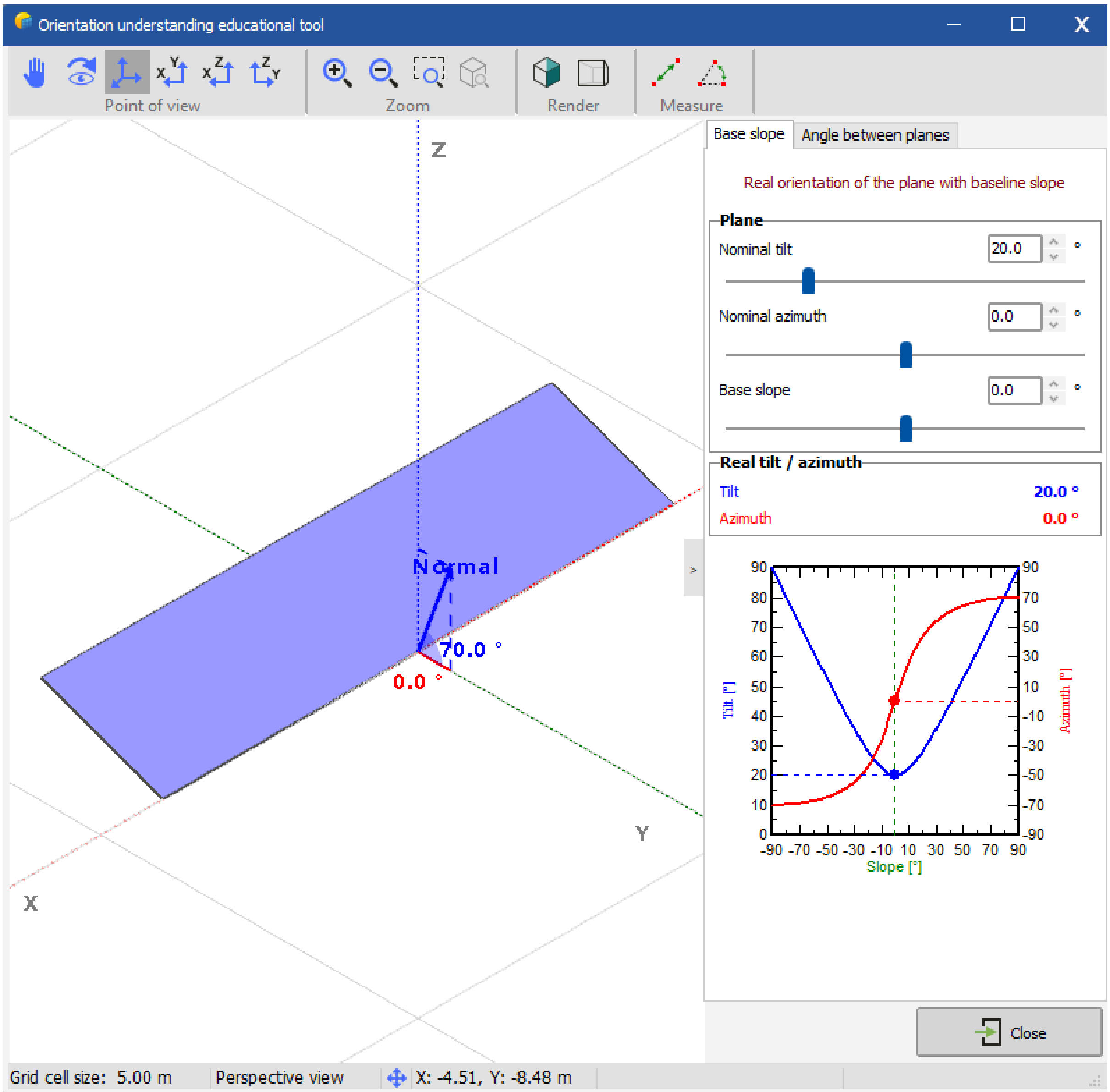
Transform Selected PV Tables to a Single array of table: Converts multiple single PV tables into a single table row.

Transform to Ground Object: Converts an object into a ground object.

9.8 Tools Menu

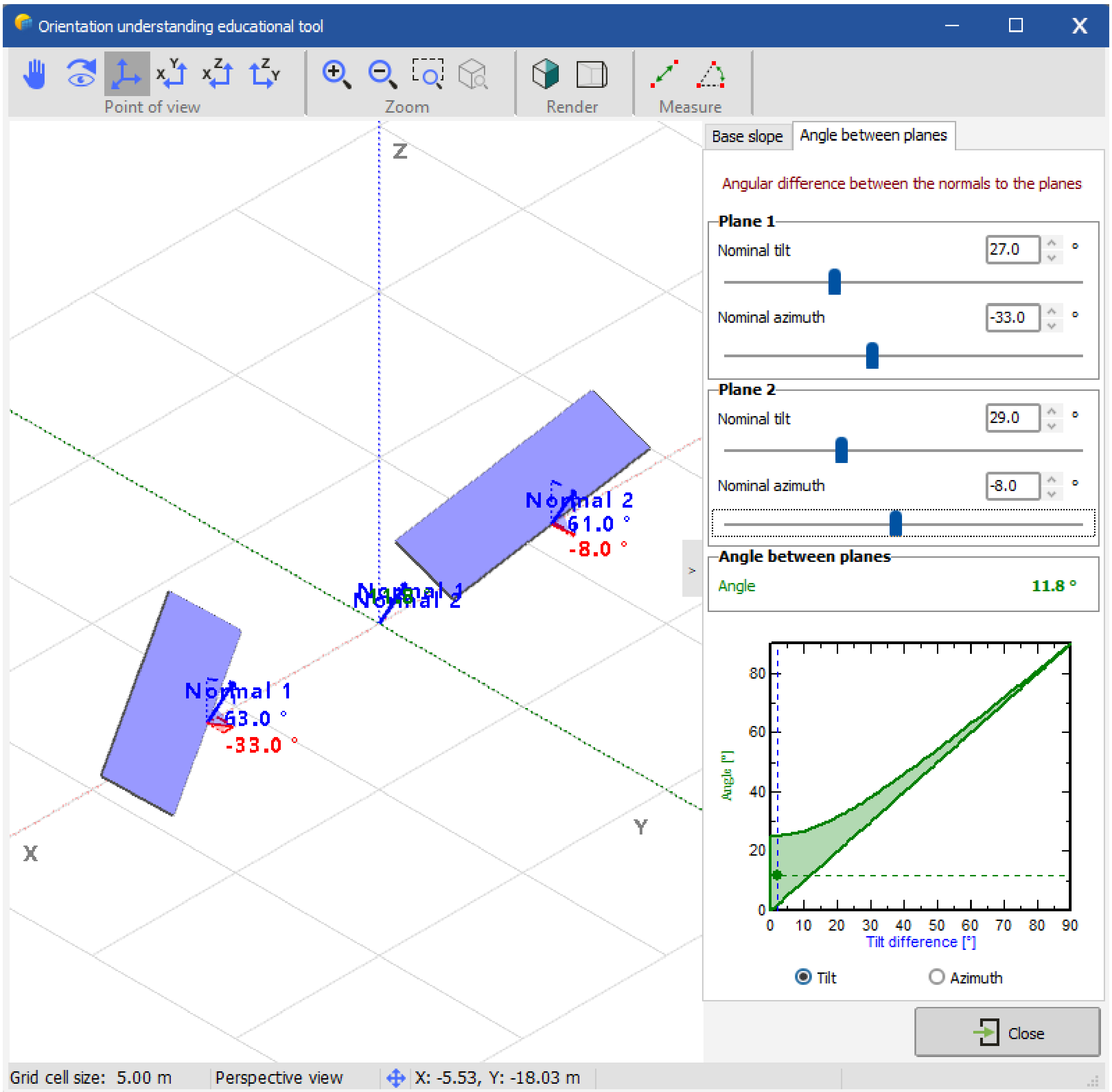
Orientation understanding educational tool: This tool opens an educational resource to understand the orientation of PV tables.





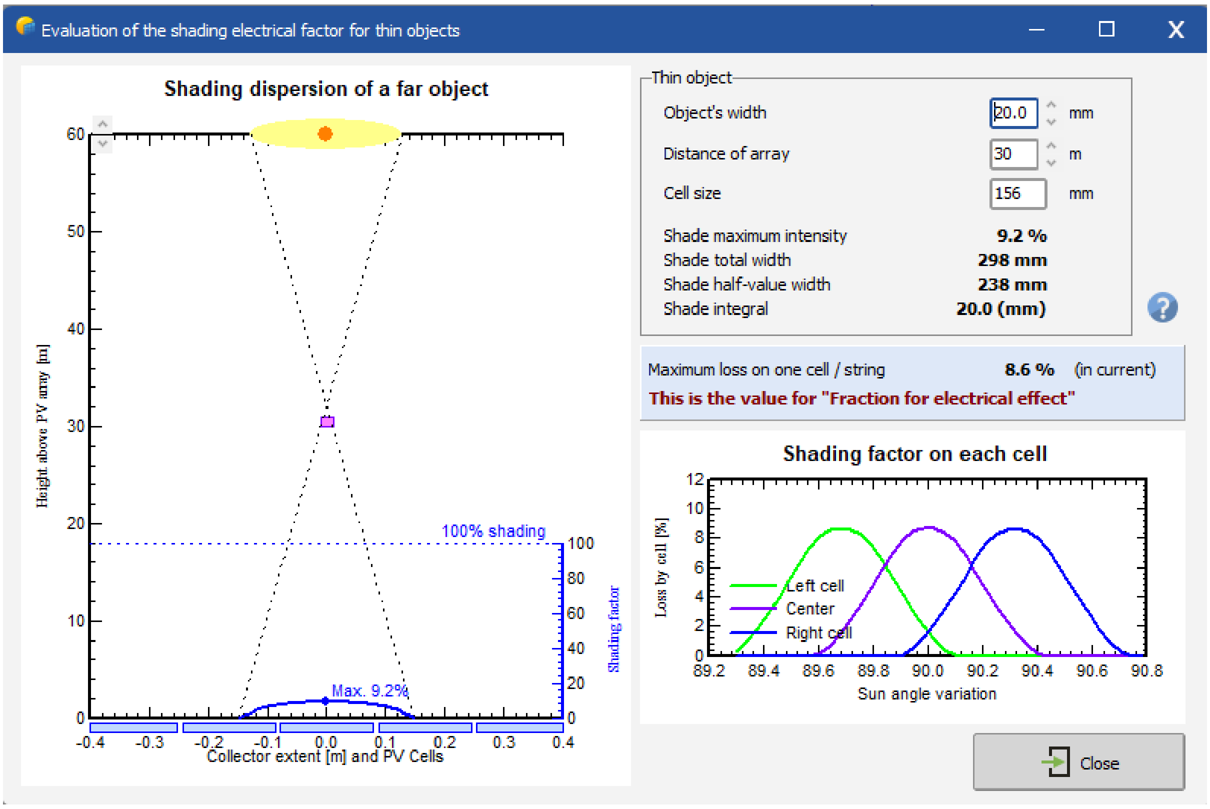
In the **Base slope** tab, users can view a PV table with an initial orientation and apply a base inclination, such as ground slope, to see the resulting tilt and azimuth. Users can experiment by inputting a "Nominal Inclination," "Nominal Azimuth," and adjusting the "Base Inclination," potentially representing terrain slope, to observe the final tilt and azimuth after applying the base inclination.

The **Angle Between Planes** tab helps users understand the angle value between the normal of two PV table planes by adjusting their orientations. Users can experiment to see the angle difference between two PV planes, which appears in the "Angle Between Planes" area.



Thin objects shading analysis:

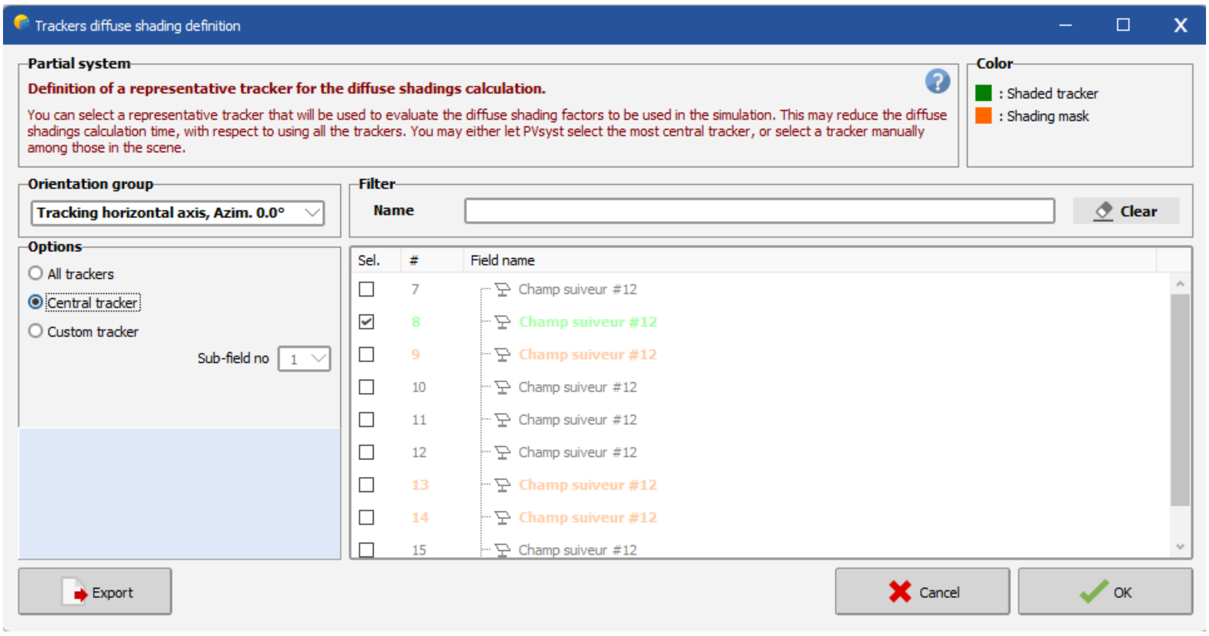
This tool demonstrates the effect of fine shading on a PV surface. Users can input variables like the width of a narrow object, the distance from the object to the PV surface, and the PV cell's size. This tool calculates and shows the maximum shading percentage on a PV cell based on these parameters.



Trackers diffuse shading definition:

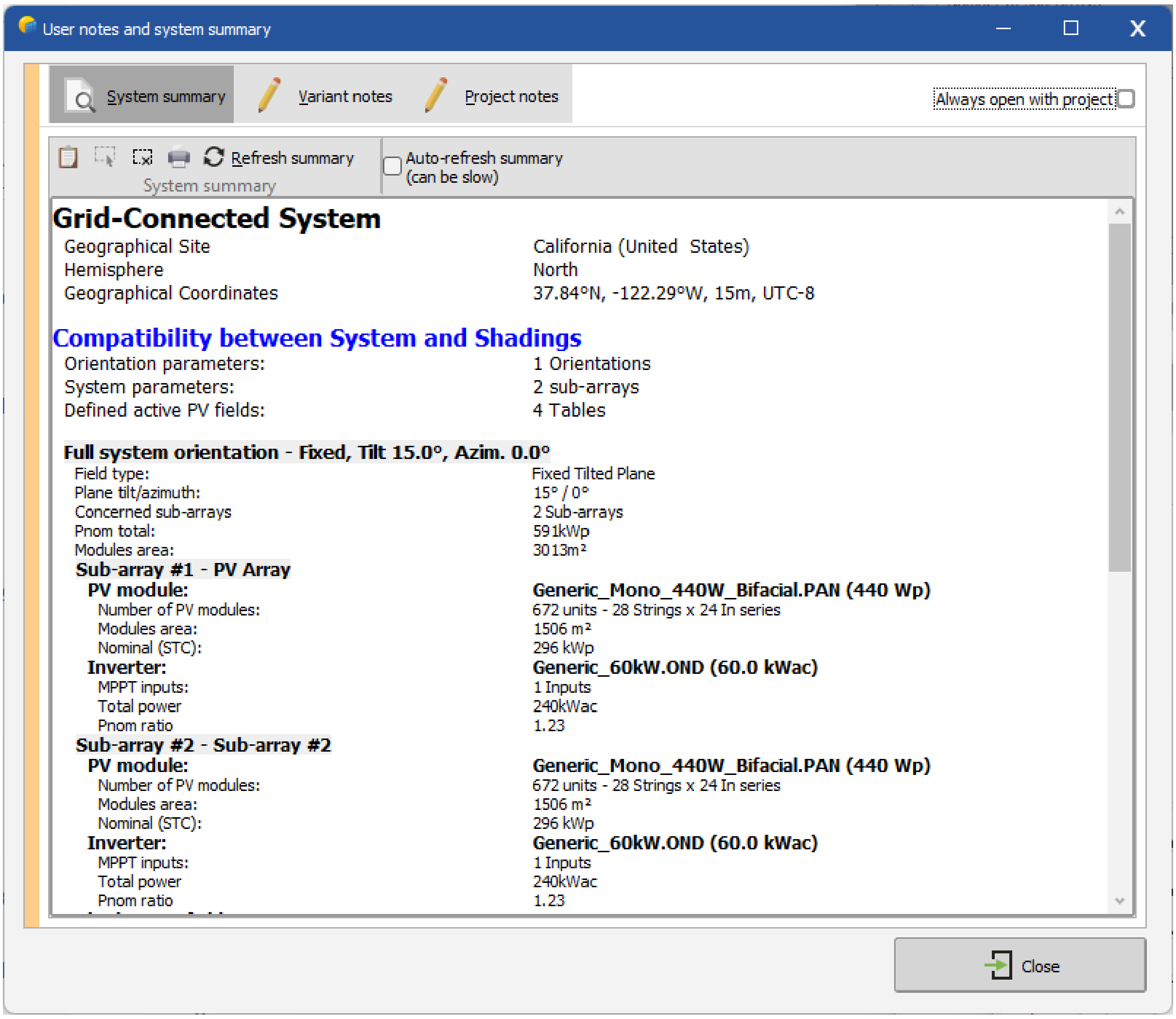
Dedicated to PV field trackers, this tool defines the contribution of diffuse light on PV tables. Users can set up a representative tracker to calculate shading factors for use in simulations, reducing diffuse shading computation time compared to using all trackers. Options include:

- select the central tracker in the scene
- select manually a tracker
- select all trackers



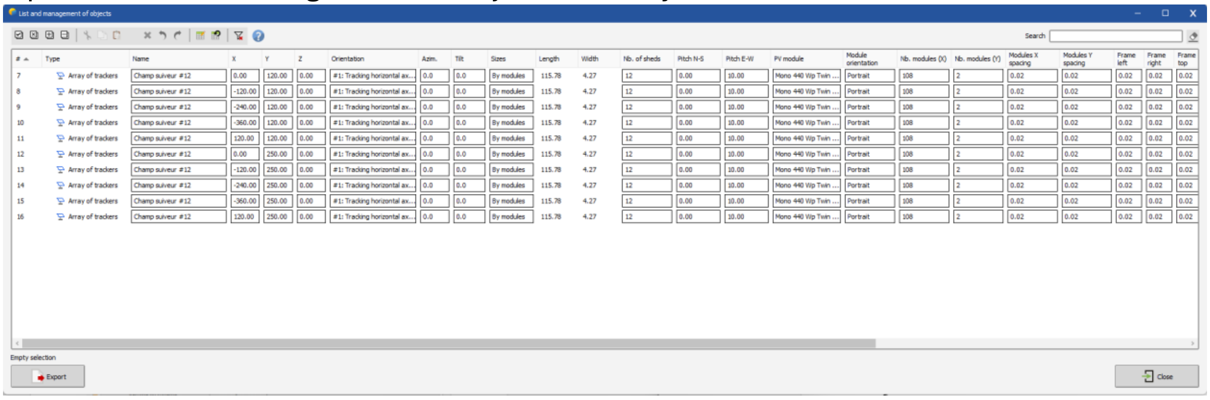
Shading Scene Summary:

Opens an informative window listing all objects in the project scene.



List and Management of object (Ctrl+G):

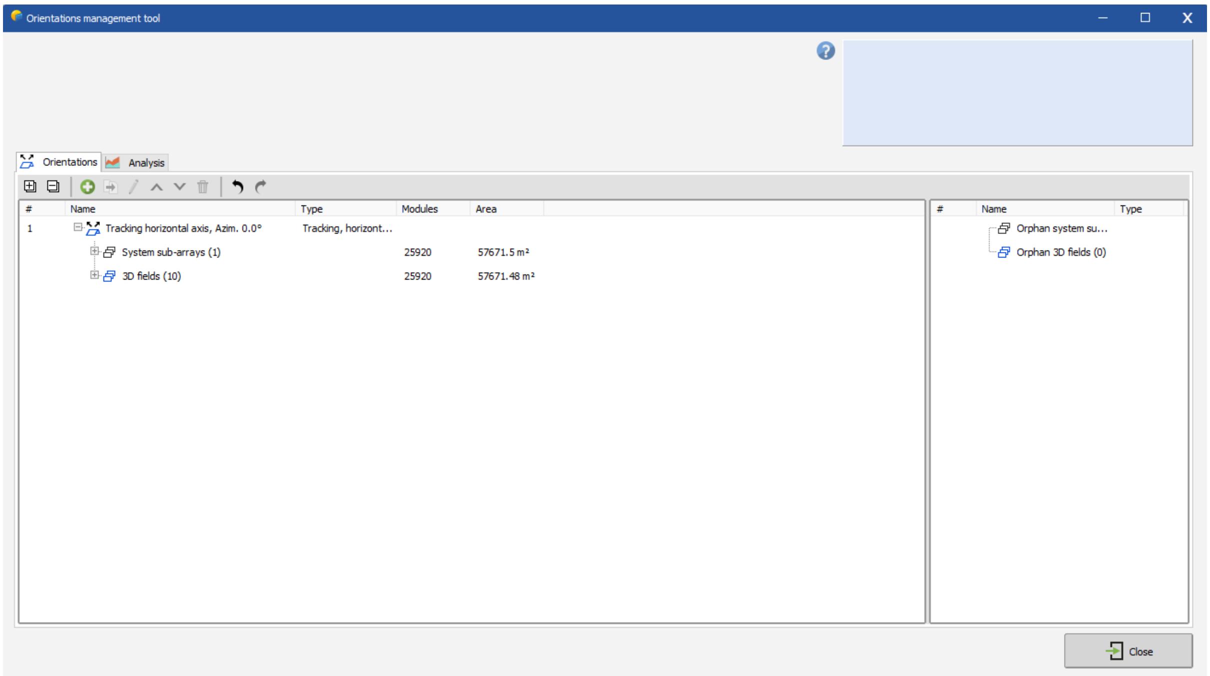
Opens a window listing all scene objects for easy modification.



Automatic Altitude: Opens a tool to place PV objects above other objects automatically.

Orientation Management (Ctrl+Shift+O):

The **Orientation Management** window lets users view a list of scene orientations and check for consistency between the 3D scene and system definition. Users can review the matching PV surfaces and module count between the definitions, reassign existing orientations to new ones, and see orphan orientations to reassign.

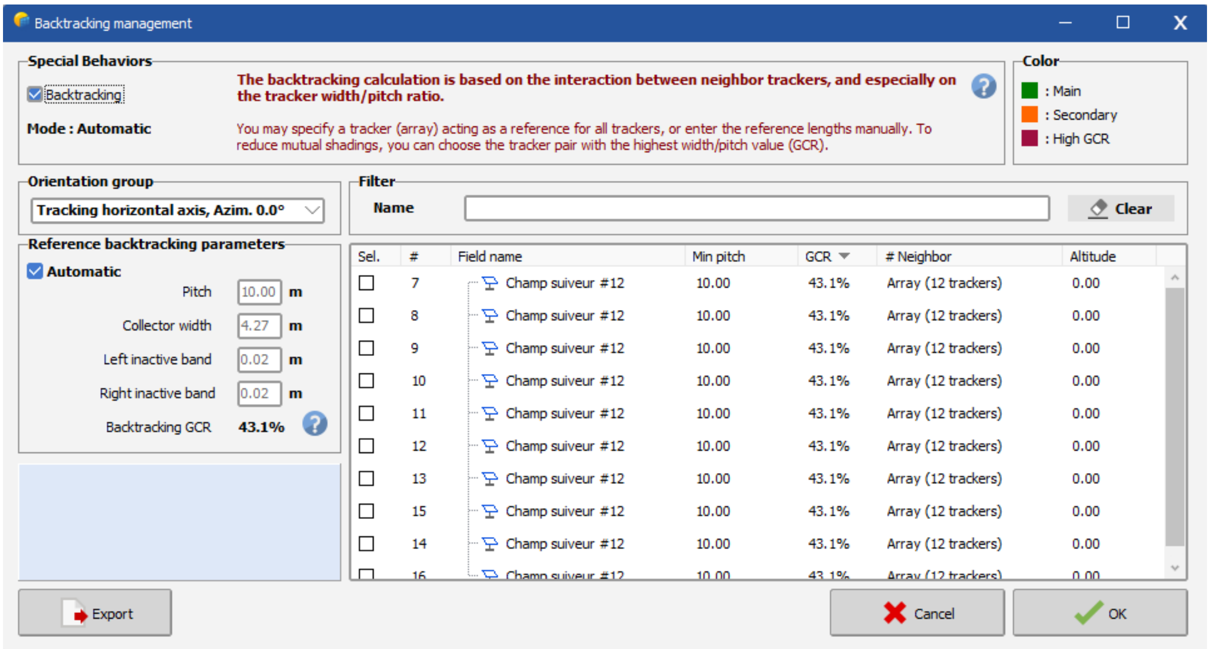


Backtracking Management

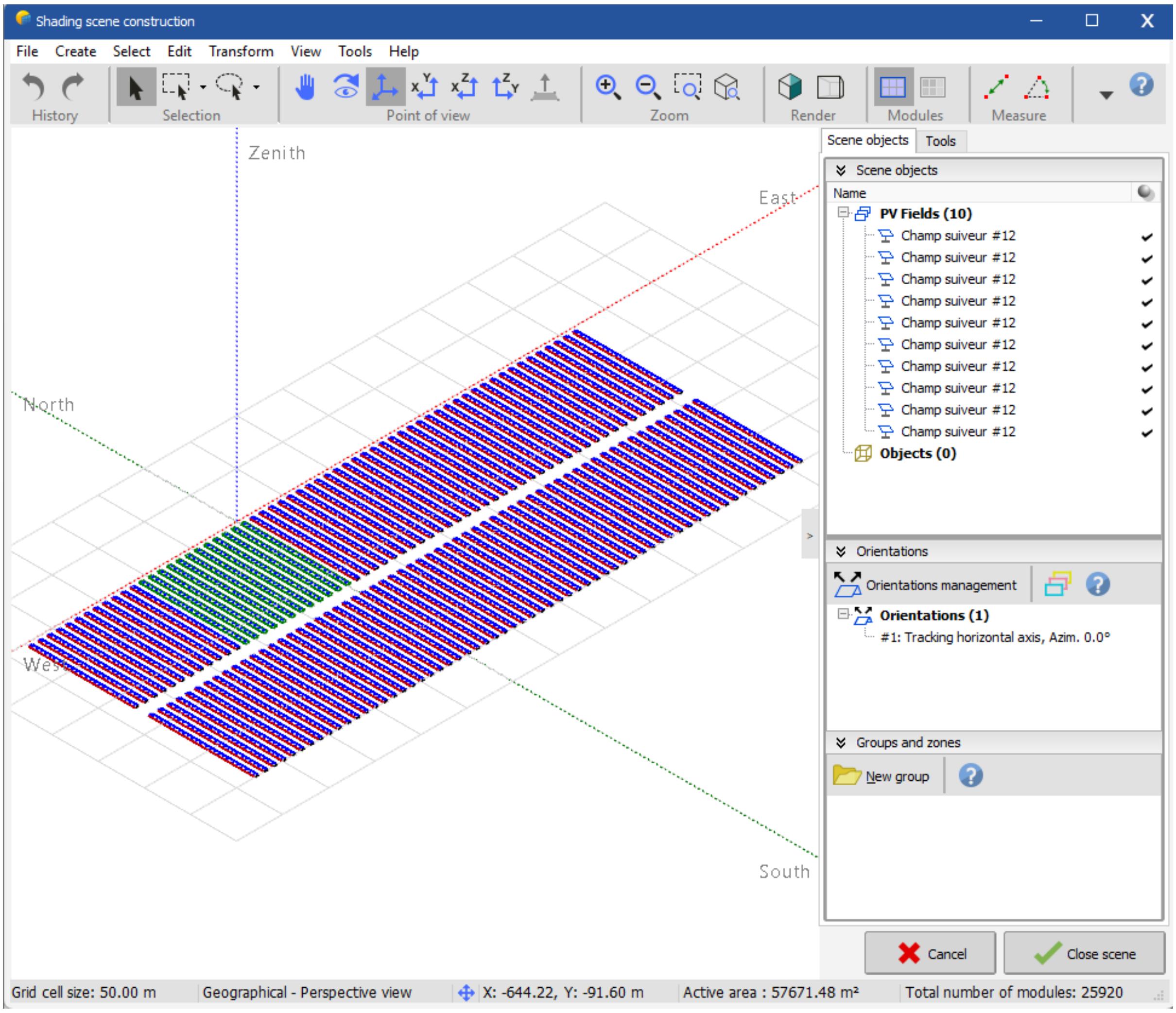
PVsyst's backtracking management tool optimizes the backtracking strategy to minimize mutual shading between PV trackers. It identifies two reference trackers to calculate the backtracking angle for all scene trackers. This tool is accessible in the PVsyst 3D editor, helping users select optimal parameters based on distances between trackers, supporting irregular configurations, and minimizing electrical losses from shading.

When defining a backtracking strategy, PVsyst identifies two reference trackers to establish the backtracking relationship (tracker width and distance). During simulation, the same backtracking angle applies to all trackers based on this reference.

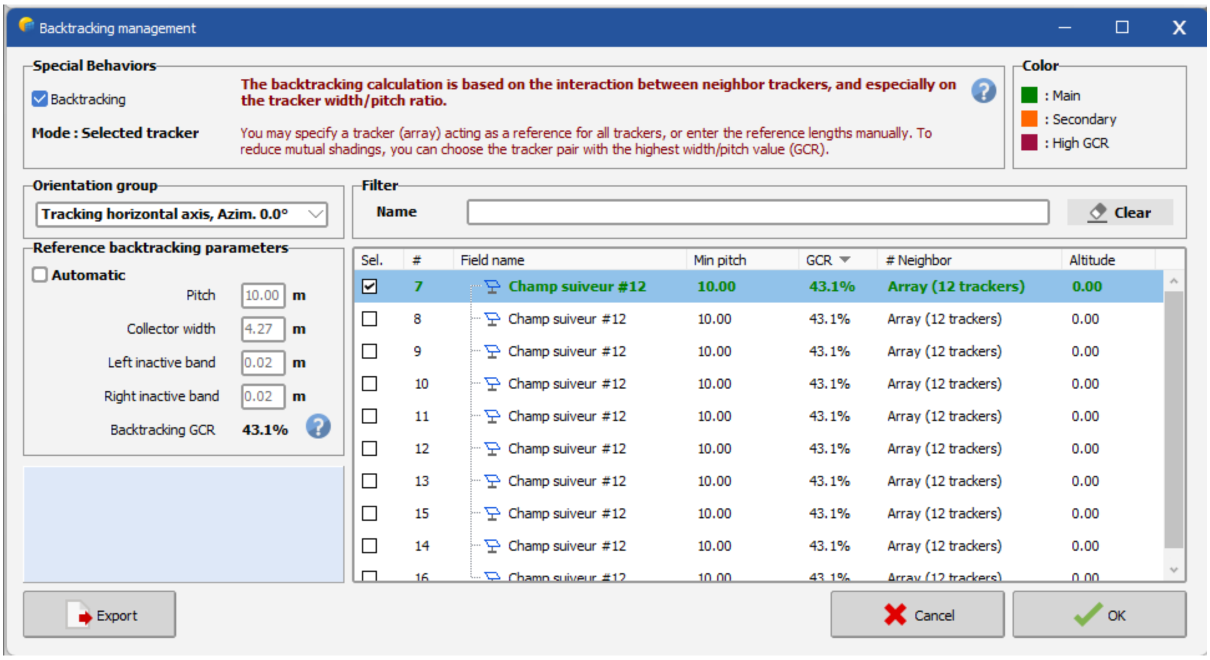
In 3D scenes, trackers are often defined independently in external CAD software, but PVsyst groups them into tables, making it necessary to identify a reference tracker pair for full backtracking calculations.



This tool lists distances between neighbouring trackers in descending order. Selecting a tracker with the highest ground coverage ratio (GCR) allows for a recommended neighbour tracker (highlighted in orange) to associate with. Users can set backtracking reference parameters automatically or select specific tracker fields in the list.



The selected tracker series appears in green, both in the scene and in the list.



Check Scene Validity: Verifies the validity of the 3D scene.

Disable Field Interpretation Check: Sometimes, objects touch PV surfaces in the scene, despite minimal spacing, such as a roof and PV module. PVsyst flags this as a 3D interpenetration error, which can be ignored by disabling this setting. Use caution as shading calculations may be impacted.

Use Partial Shading Calculations: Calculates shading on an entire scene over a small selected PV area. This reduces computation time for large, resource-heavy scenes and is useful for homogeneous shading scenes.

9.9 Main Menu

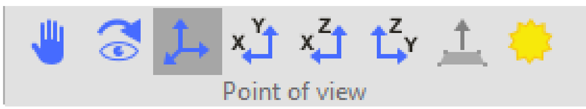
This chapter explains the main menu visible on the 3D scene window.

History: Actions like creating, selecting, or modifying objects are logged, allowing undo/redo.

- **Undo** : Ctrl+Z
- **Redo** : Ctrl+Y

Selection:

- **Default Selection**: Press Esc to deselect an object.
- Click any object to select it; click edges in technical view to select an object.
- **Rectangle Selection**: Shift+Ctrl+R
  - Click and drag to draw a selection rectangle.
  - You can specify whether you wish to select all objects touching the rectangle, or only those inside it.
- **Lasso Selection**: Ctrl+L
  - Click and drag to draw a selection area.
  - You can specify whether you wish to select all objects touching the area, or only those insides.
- Add to Selection: Hold **Shift**
- Remove from Selection: Hold **Ctrl**
- Select All: **Ctrl+A**



Point of view

Move View: Click and drag to move the viewpoint.

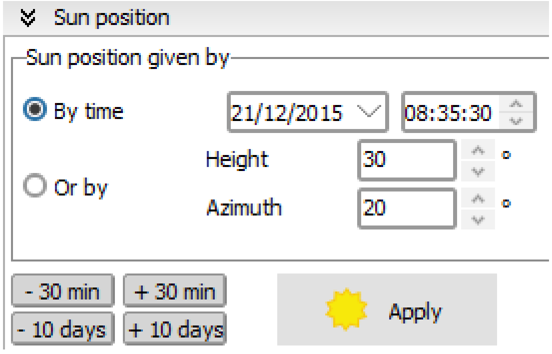
Rotate Camera: Click and drag to rotate around the current target.

Perspective View**: F2

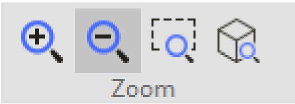
Top View: F3

Front View: F4

Side View: F5

Sun View: F6 - Aligns the view to the current sun position; adjust in the right-side "Tool" 

tab.



Zoom Options

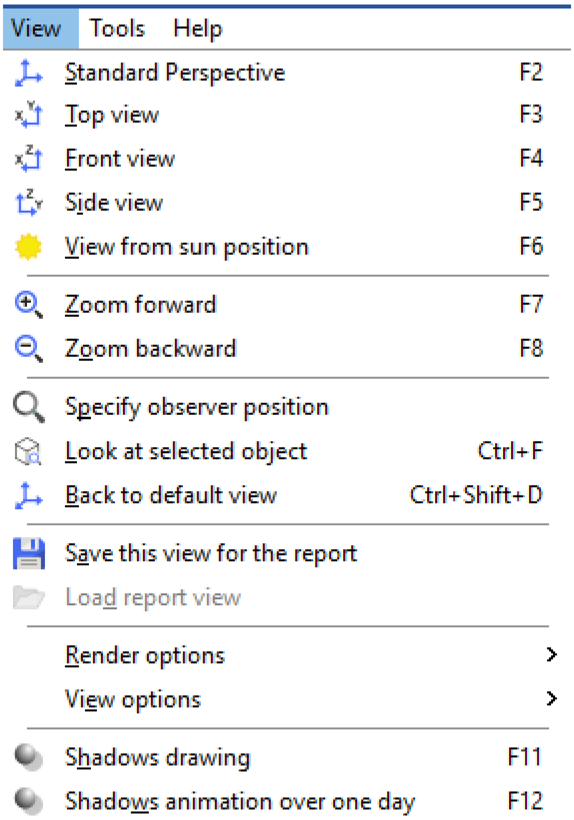
Zoom In: F7

Zoom Out: F8

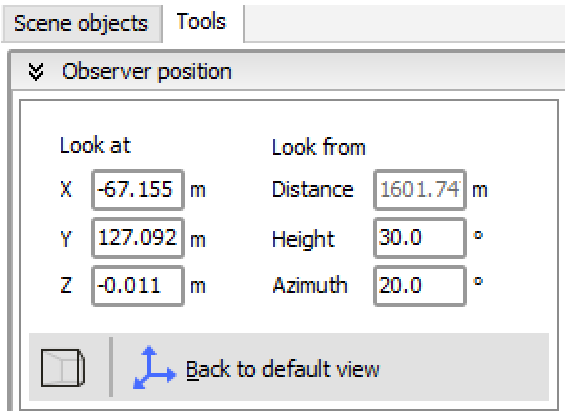
Zoom by Rectangle: Click and drag to define the viewing area.

Fit Zoom: Ctrl+F - Zooms to see all selected objects.

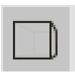
All these tools are also accessible in the **View** menu.



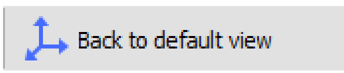
Additional Tools



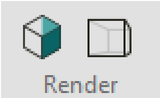
Observer Position: Opens the "tools" tab on the right, allowing a precise observer viewpoint.



Center on Selected Object: Centers the view on a selected object.



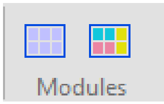
Back to Default View: Resets the observer to the default position, looking towards the scene origin (X=0; Y=0; Z=0).



Rendering Options

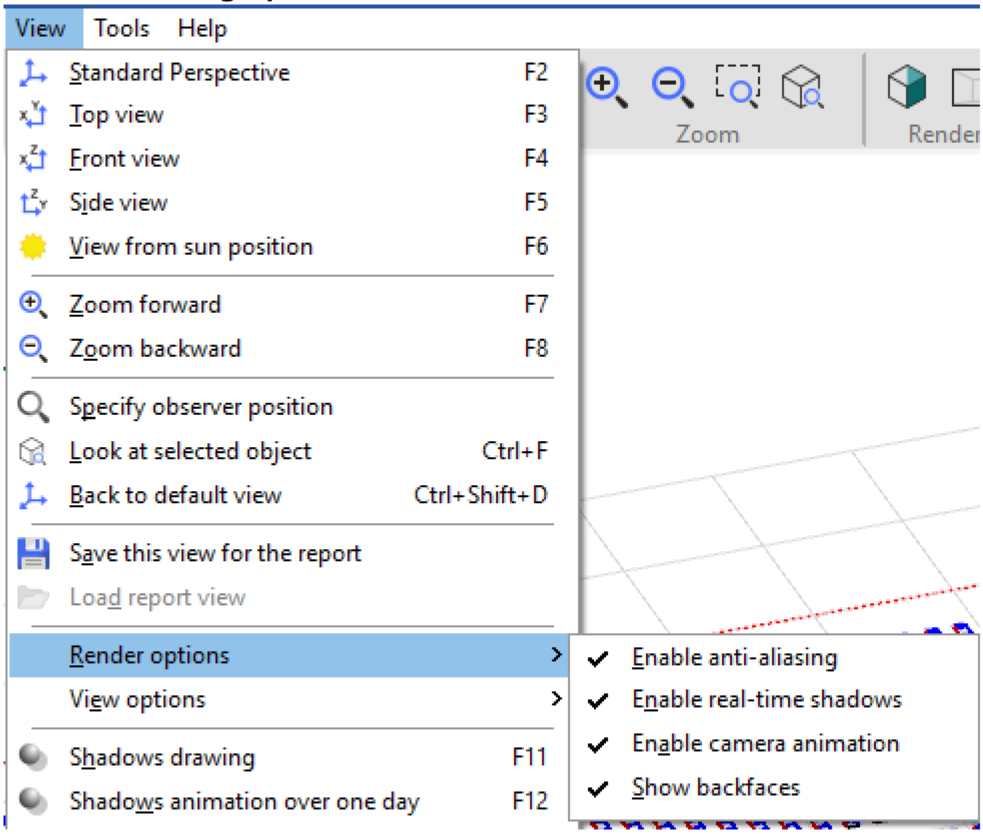
Technical View/Realistic View:

- Technical View:
  - Displays objects in wireframe; selectable by edges only. Colours are defined by object type and selection state, without real-time lighting or shadows.
- Realistic View:
  - Objects appear more realistic; selectable on any visible part. Colors are customizable for each object, with real-time lighting.
- **Perspective / Orthogonal Projection**
  - Orthogonal Projection: This is the default and is recommended when constructing the scene.
  - Perspective Projection: Provides a more realistic view of the scene, useful for creating shadow videos or reports.



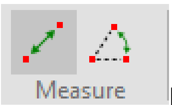
Module Chains: Displays the module chains defined in the module layout.

Other Rendering Options



In the "View / Rendering Options" menu, you can enable/disable the following:

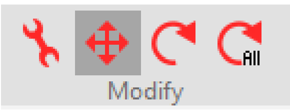
- **Enable anti-aliasing**: Smooths object edges. Availability may depend on your hardware and could reduce performance.
- **Enable real-time shadows**: Enables real-time shadow viewing. Activating this option may reduce performance.
- **Enable camera animation**: Animates the transition when switching views. Activating this option may slightly reduce performance.
- **Show backfaces**: Shows or hides the back faces of objects, meaning those not oriented toward the viewpoint. Hiding them increases performance.



Measure

Measure a Distance: Ctrl+L - Click to set the starting point, then click again to set the end point. Hold Ctrl to snap to an object vertex.

Measure an Angle: Ctrl+K - Click to set the vertex, then points #1 and #2. Hold Ctrl to snap to an object vertex.



Modify

Edit Objects: Ctrl+M

Move Objects: Ctrl+B

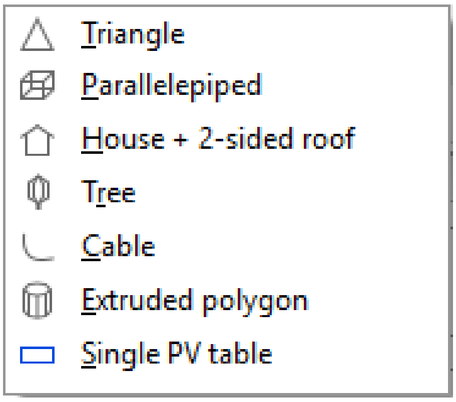
Rotate Objects: Ctrl+R

Rotate Entire Scene: Ctrl+Alt+R

Additional Tools

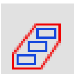
 **Drawing**: Draw objects with the mouse

The freehand drawing tool allows you to create objects directly in the scene using the mouse. This tool currently allows drawing the following objects:

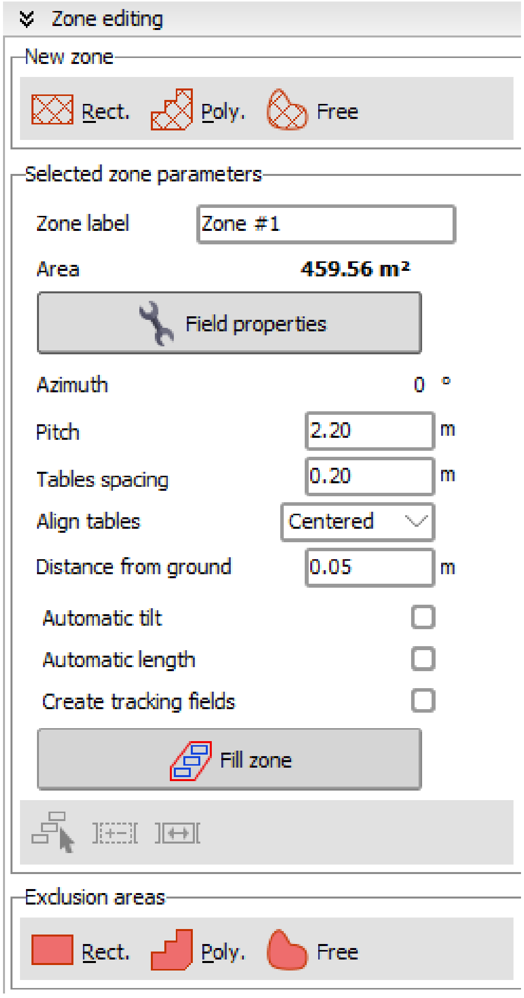


- Triangle
- Parallelepiped
- House
- Tree
- Cable
- Extruded Polygon (by defining the 2D outline and height)
- Rectangular PV Table

To start, click the button to open the object selection menu and choose the desired object type. Then follow the instructions in the tooltip for each object.

 **Field zones:** In the shading scene, you can define areas that will be filled with PV tables. These zones are defined on the X-Y plane as drawn on the ground, with tables dynamically placed in the scene. The tables are positioned based on the objects they lie on, so if a zone is drawn on a roof, tables will be positioned accordingly at the correct altitude. This also applies to zones on topographies. You can specify if you want the tables to automatically tilt according to the object they are on.

Creating Zones: To create or edit zones, click the **Zone tool**, then find the "Zone Editing" section on the right side of the window



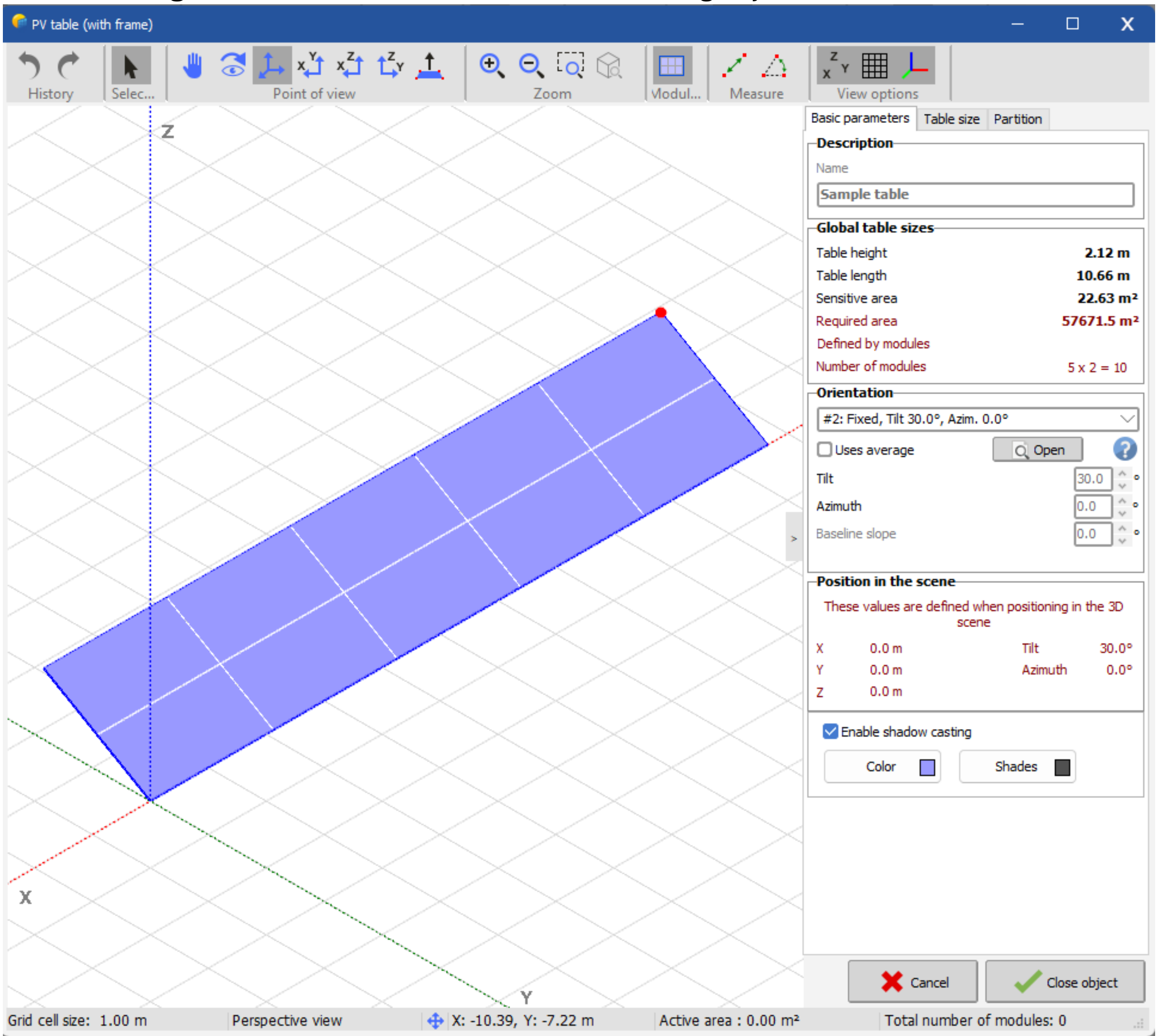
The button  to create a rectangular zone allows you to define the upper-left and lower-right corners of the rectangle in the scene.

The button  to create a polygonal zone lets you define new points by left clicking in the scene. To end the zone definition, right-click.

The button  to draw a freeform zone lets you click and drag the mouse. Right-click to finish defining the zone.

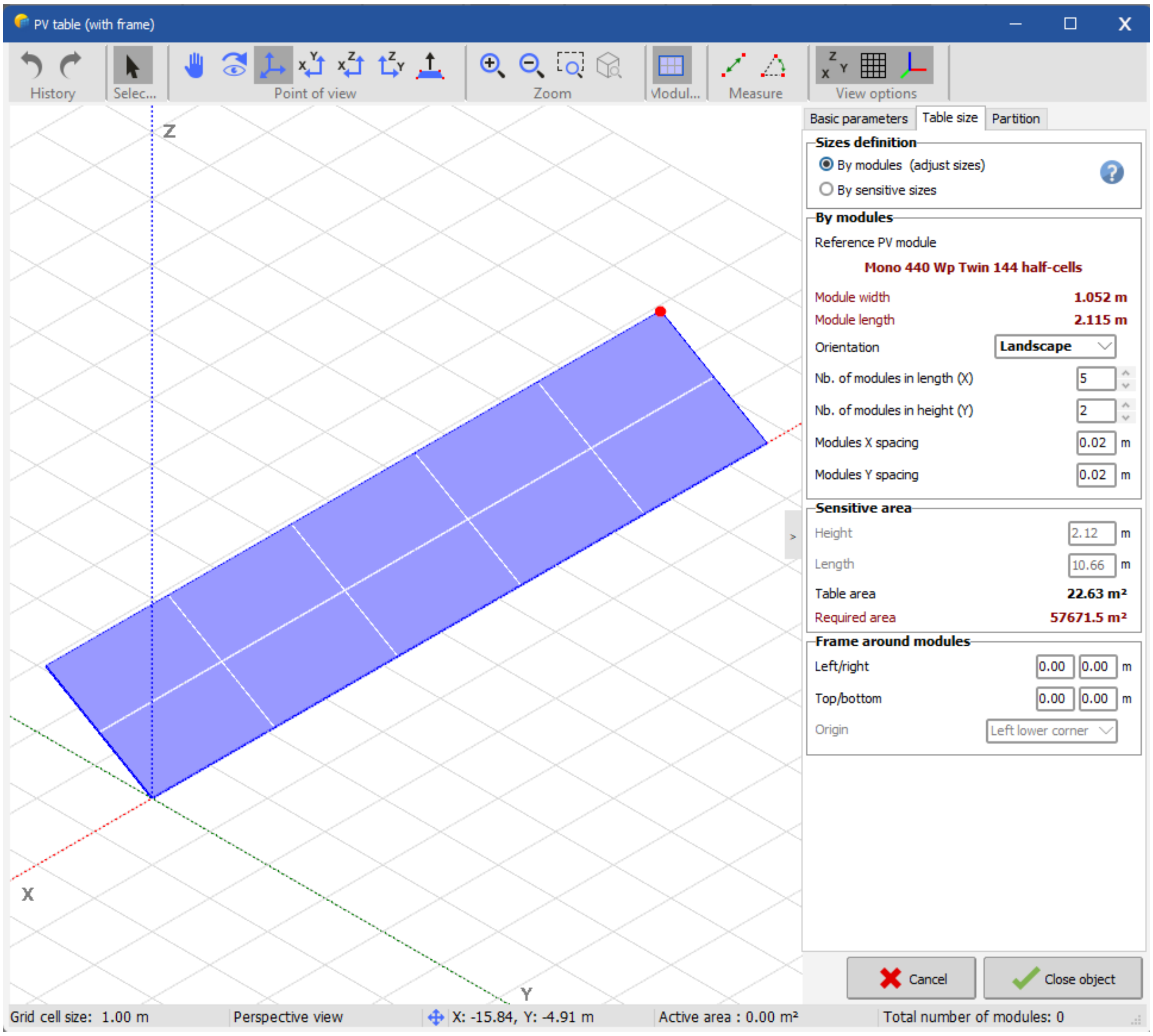
This button  opens the table field editing dialog to define parameters for the tables generated within the zone.

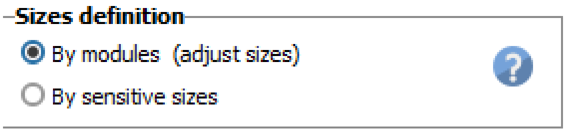
Basic Settings Tab: The initial tab allows the following adjustments:



- **Description**: Sets a custom label for the zone.
- **Global table sizes**: Summarizes the table's dimensions.
- **Orientation**: Choose the orientation for table generation.

Table size tab: The **Table size** tab includes a dedicated area for photovoltaic modules. When setting up a field, specify the associated PV module. A table can only hold PV modules of the same size.

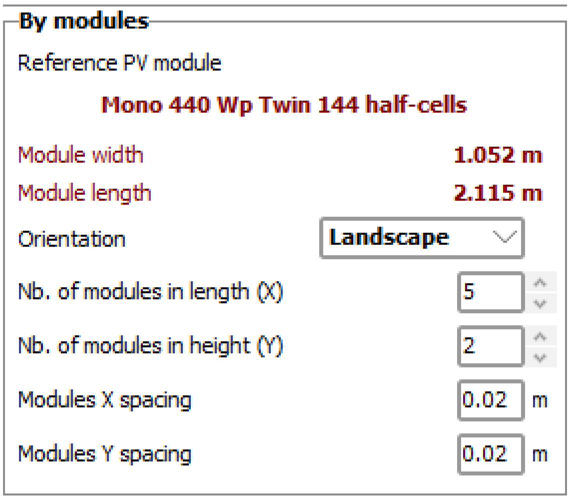




Sizes definition:

- **By Modules**: This recommended option defines an area exactly suited for the desired module count with specific spacing.
- **By Sensitive Area**: Specify the desired PV table size without constraints initially. Later, retrieve the exact size for your modules by selecting "By Modules."

Both options can be adjusted by dragging red points with the mouse, with modules filling the available space as sizes are modified.

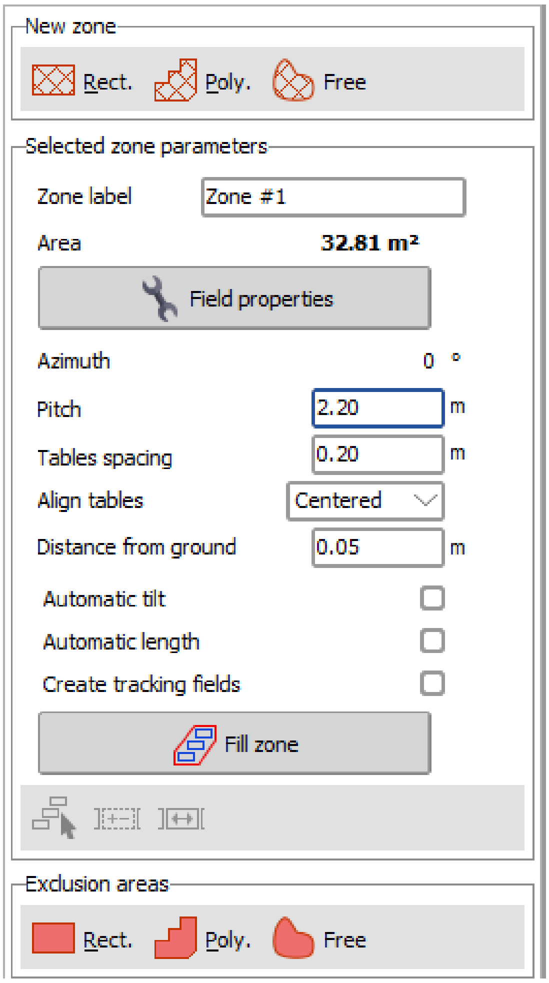


Section “by modules” shows information regarding the PV module chosen in the system definition.

It allows you to select the orientation of the module by “Landscape” or “Portrait”.

It also lets you define the number of modules the PV table will contain, as well as their spacing.

After completing this setup, return to the **Zone Editing** section:



Pitch: Distance between the bases of tables in consecutive rows.

Table Spacing: Distance between consecutive tables in the same row.

Align tables: Defines table alignment in each row within the defined zone.

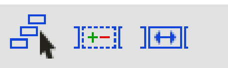
Distance from ground: Defines the height of the PV planes relative to the ground.

Automatic Tilt: Enabling this option overrides the tilt parameter, letting tables adopt the tilt of the surface they’re on.

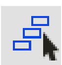
Automatic Length: Enabling this option overrides the length parameter, extending a single table in each row to fit the zone.

Create Trackers: When enabled, fills the area with trackers.

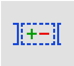
The "Fill Zone" button calculates the required space for PV tables based on the specified parameters.

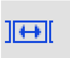


After positioning the tables, the following buttons allow further modifications:



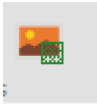
Select all tables.

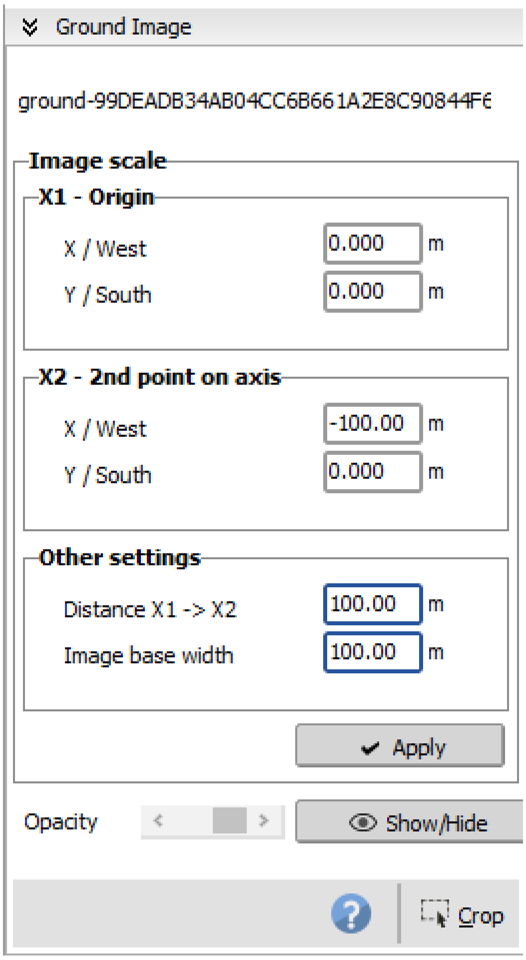
Add or remove tables.

Move tables along their axis.

Exclusion Zone: Finally, it is possible to define exclusion zones where tables won't be added. 

These zones can be drawn as previously described.

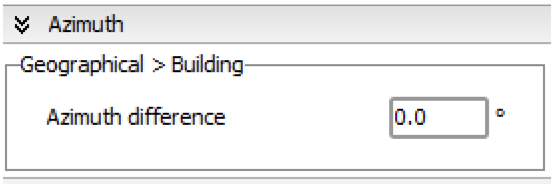
 **Ground Image**: Reopens a section allowing image scaling and opacity adjustments.



Geographic/Building Reference:

To ease complex system construction, you can build within a reference framework linked to the building, where coordinates (X, Y, Z) match the architectural plan. This framework enables scene rotation according to geographic coordinates, and you can toggle between coordinate systems using dedicated 3D editor toolbar buttons.

The construction reference includes the following section:



This tool modifies the azimuth of the entire scene.

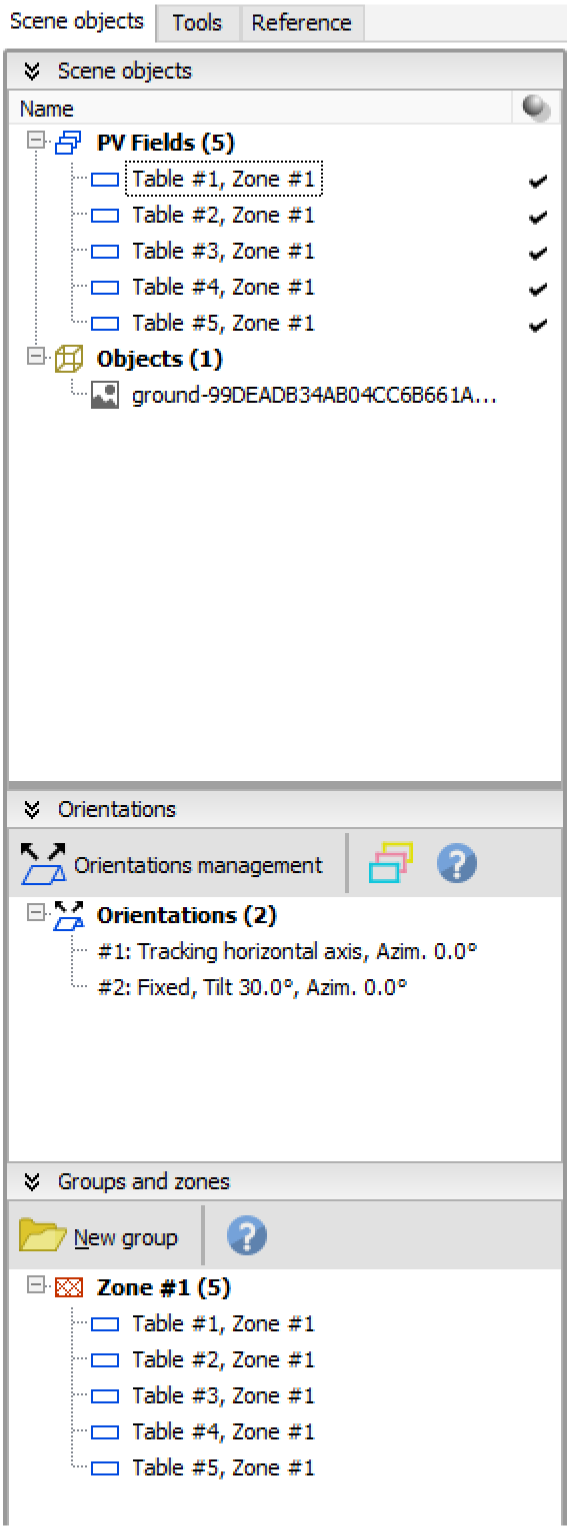
Global Reference Orientations

The global reference system for the shading scene aligns with cardinal points:

Northern Hemisphere: X-direction is west, Y-direction is south, and Z points upward (zenith). PV field azimuths are defined relative to the south (OY) and are positively oriented clockwise toward the west.

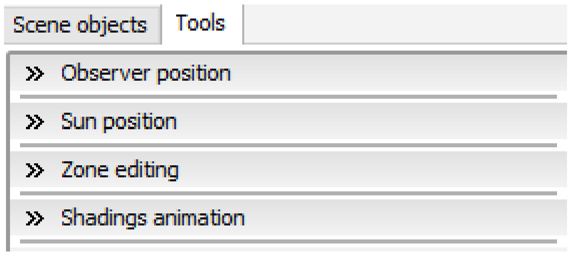
Southern Hemisphere: X points east, Y north. Azimuths are measured from north (OY) and oriented positively counterclockwise toward the west.

In the 3D scene window, the right section contains two tabs:



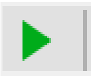
Scene Objects: View scene objects, existing orientations, and created groups, allowing zone selection.

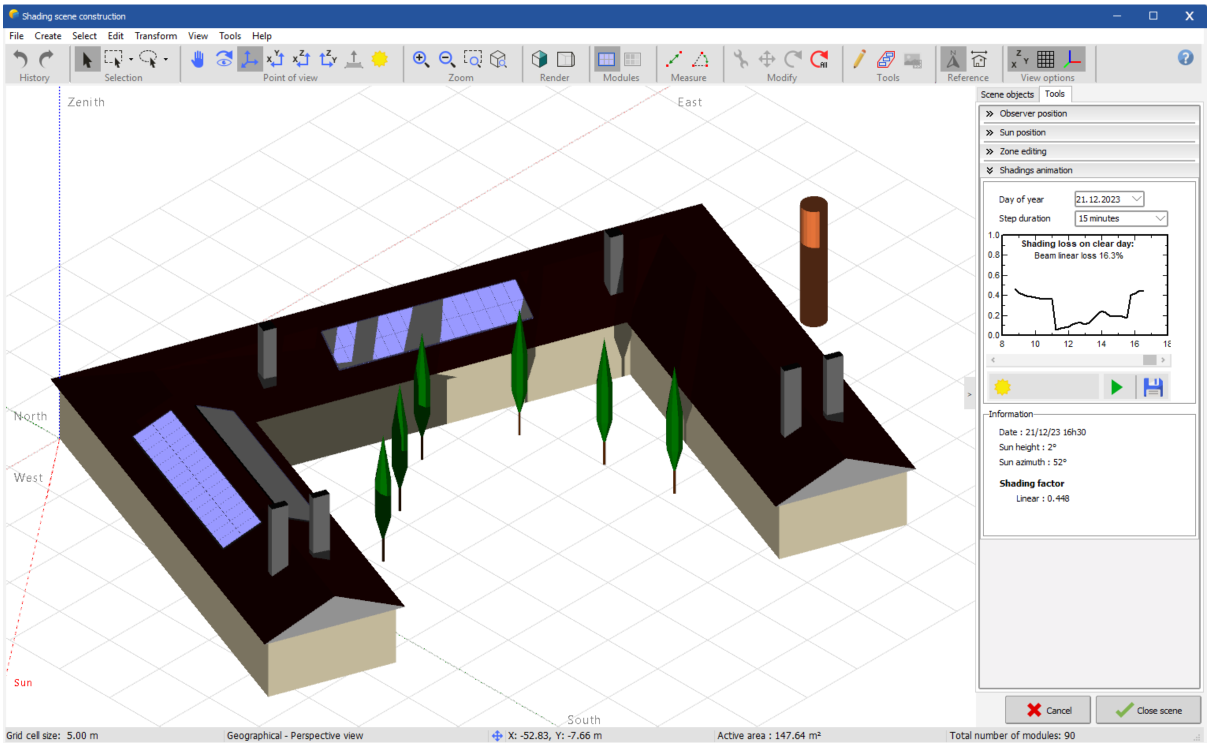
Tools: Access various tools previously mentioned.



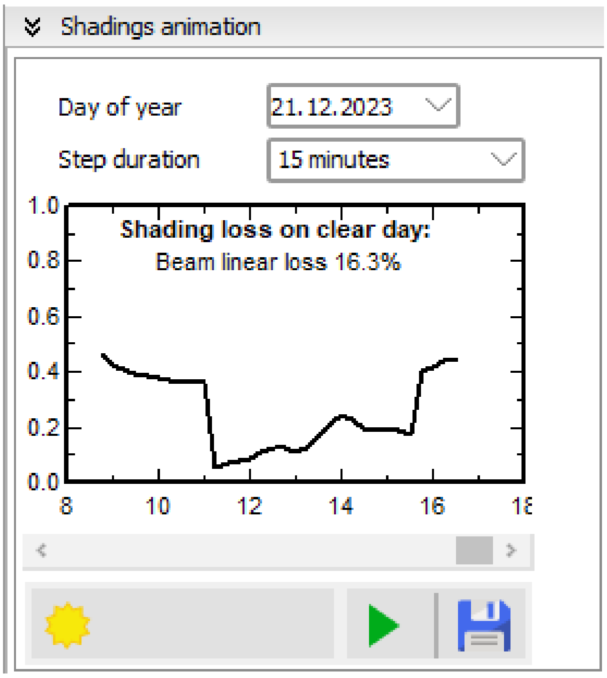
Shading animation:

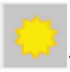
This tool displays the shadow animation in the scene for a given date. By default, it is set to December 21, the day of the lowest sun height in the Northern Hemisphere. The interval can be adjusted for a more precise shadow result.

Clicking this icon  starts the shadow animation.



For example, the linear shading on PV module surfaces on December 21 is 16.3%.



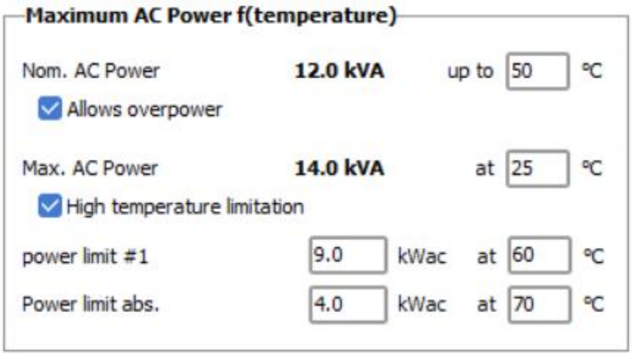
The sun icon locks  the view to the sun's position, and the horizontal scroll bar lets you navigate the hours of the day, adjusting the sun's position simultaneously. The save icon  enables video creation of the animation that can be saved.

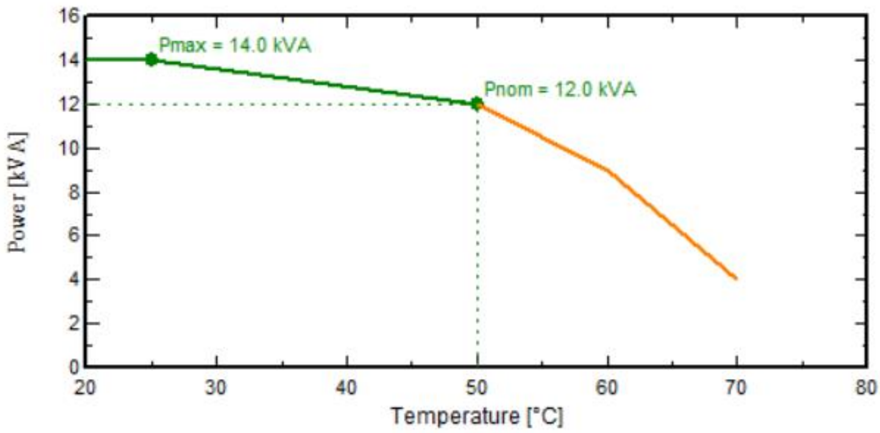
10 Energy management

In PVsyst, energy management encompasses functions related to the inverter temperature, power factor, grid power limitation, and P50/P90 energy yield analysis. These features collectively aid users in optimizing and managing the energy performance of photovoltaic systems in PVsyst.

10.1 Inverter Temperature

Inverters are responsible for converting the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity for use in the grid. Inverter efficiency decreases as its temperature rises. Higher temperatures can result in increased losses during the conversion process, leading to lower AC power output. By precisely choosing the temperature model approach for the simulation of the inverter temperature, you can more accurately estimate and evaluate the inverter's efficiency, system performance, safety and reliability. The inverter's temperature profil and evalauation for limits can be found in the PVsyst inverter file (.OND file) under *Output parameters* tab.

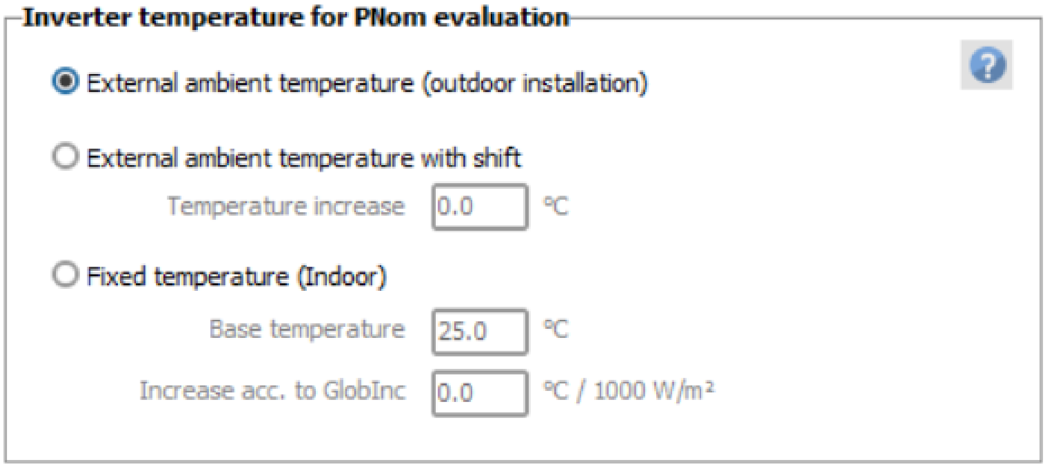




In the simulation, by default the inverter temperature is the external ambient temperature (outdoor installation). This strategy can be modified in Inverter Temperature page in the Energy management.

The reference inverter temperature may be specified in the output system parameters by:

- Ambient external temperature, the usual parameter admitted by manufacturers for outdoor installation.
- Ambient external temperature + specified shift
- Fixed temperature + linear increase proportional to the power (represented by the incident irradiance). This could be used for indoor inverters and not perfect cooling installation.



10.2 Power Factor

Power factor control in PV systems is a critical aspect of modern grid management, as it helps optimize the interaction between solar energy production and grid stability.

In alternating current (AC) circuits, power can be understood in three distinct forms: active power, reactive power, and apparent power.

- Active Power (P_{active}): This is the real power that performs useful work, such as producing movement or heat. It is the power that directly translates into energy consumption, measured in kilowatts (kW). In an AC circuit, active power is calculated by multiplying the effective values of voltage and current, and then multiplying by the cosine of the phase angle (φ) between them:

$$P_{active} = U_{eff} * I_{eff} * cos(\varphi)$$

- Reactive Power ($P_{reactive}$): This is "virtual" power, representing the energy temporarily stored and released by inductive (motors, transformers) or capacitive devices. Reactive power, expressed in kilovolt-amperes reactive (kVAr), does not contribute to actual energy consumption (no heat or movement is produced). It is calculated using the sine of the phase angle (φ):

$$P_{reactive} = U_{eff} * I_{eff} * sin(\varphi)$$

- Apparent Power ($P_{apparent}$): This is the combined effect of both active and reactive power. It represents the total power flowing in the circuit, measured in kilovolt-amperes (kVA), and is the product of voltage and current, irrespective of their phase difference:

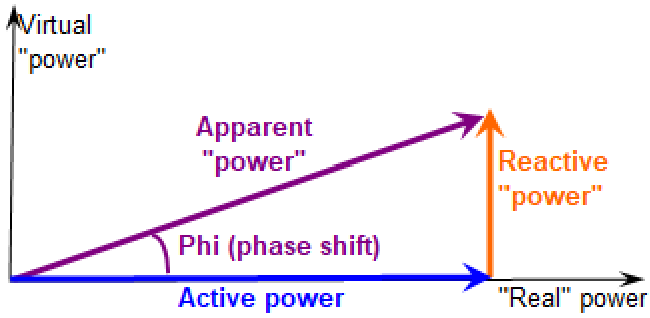
$$P_{apparent} = U_{eff} * I_{eff}$$

The relationship between active and apparent power is quantified by the power factor (PF), which is simply the cosine of the phase angle (φ). Power factor is crucial because it indicates how efficiently electrical power is being used:

$$PF = cos(\varphi) = \frac{P_{active}}{P_{apparent}}$$

In photovoltaic systems, inverters convert the direct current (DC) from solar panels into alternating current (AC) for grid integration. With modern inverter technology is possible to control the phase angle between voltage and current. This allows the inverter to generate reactive power without additional energy consumption. By adjusting the phase shift between voltage and current, PV systems can support grid needs for reactive power without compromising their active energy production.

Reactive power plays an essential role in compensating for the reactive loads, typically introduced by motors or transformers in the grid. This compensation is often a requirement set by grid managers to maintain grid stability. By adjusting the phase angle (φ), inverters can either "absorb" or "generate" reactive power, depending on the needs of the grid:



Lagging reactive power: When the current lags behind the voltage, with a positive phase angle, $\varphi > 0$. Defining a lagging PF in your inverter means the inverter will inject reactive power into the grid to help compensate for reactive power demand of inductive loads such as motors and transformers.

Leading reactive power: When the current leads the voltage, with a negative phase angle, $\varphi < 0$. Defining a leading PF in your inverter means the inverter will absorb reactive power from the grid (or “consume” it), helping to counterbalance the excess reactive power generated by capacitive loads.

When inverters are required to produce reactive power, it does not affect the active energy output directly. However, depending on whether the inverter’s nominal power (PNom) is defined as active power (kW) or apparent power (kVA), the inverter’s capacity to handle overloads may be affected. If PNom is based on apparent power, the maximum available active power will be reduced by a factor of the power factor:

$$P_{Nom(active)} = P_{Nom(apparent)} * \cos(\varphi)$$

Grid operators may impose power limits based on either active or apparent power. If the limit is set on apparent power, PV systems will need to adjust the power factor to comply, potentially reducing the amount of active energy delivered to the grid.

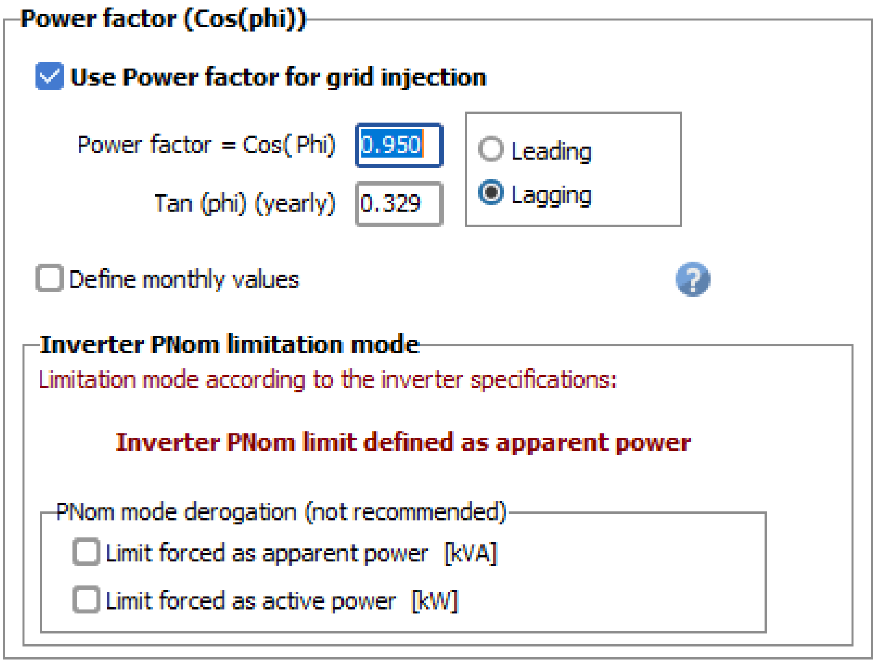
When the power factor decreases (i.e., more reactive power is produced), the current in the system must increase to maintain the same level of active power. Since ohmic losses in cables and transformers are proportional to the square of the current, this leads to higher energy losses in the system:

$$I_{eff(apparent)} = \frac{I_{eff(active)}}{\cos(\varphi)}$$

In PVsyst simulations, the power factor is an adjustable parameter, typically fixed for a given period or specified monthly. The simulation results focus on **active energy** (in kWh), but when a power factor is defined, the **apparent energy** (in kVAh) is also calculated:

$$E_{GridApp} = \frac{E_{Grid}}{\cos(\varphi)}$$

The apparent energy will always be greater than the active energy due to the inclusion of reactive power.



The nominal power rating of inverters may be an active power or apparent power:

- In the case of active power rating, reactive energy does not come at the cost of active power.
- In the case of an apparent power rating, reactive energy may come at the cost of active power, when close or at the maximum power threshold.

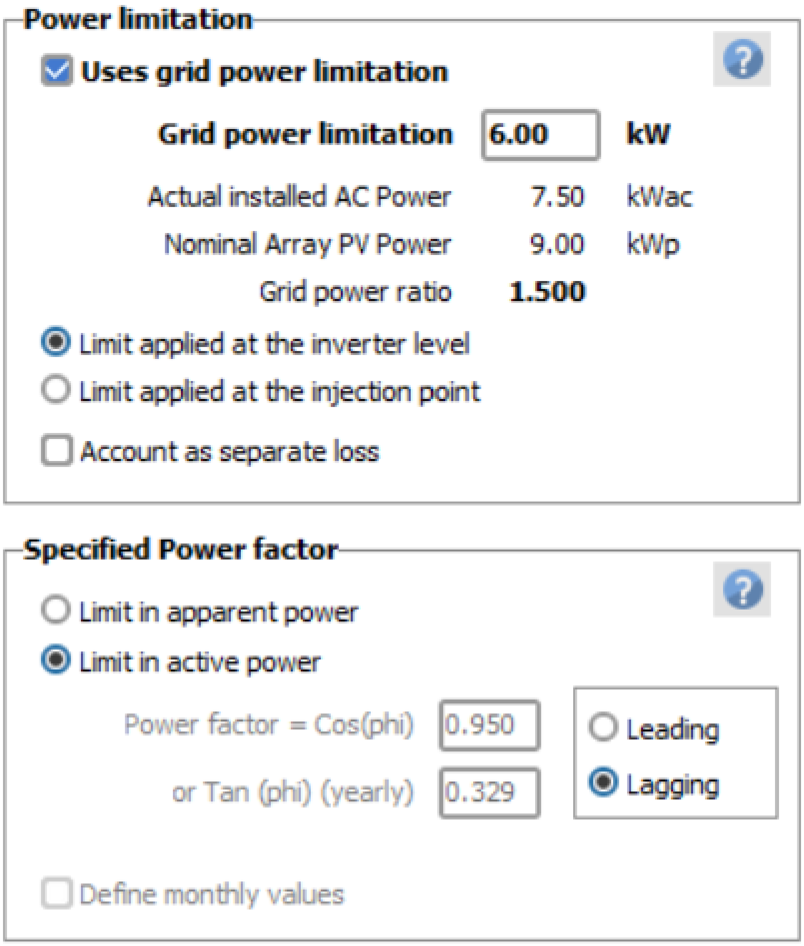
Force as apparent/active power" will force all inverters to operate under this conditions. This means that inverters may not operate like in the datasheet anymore.

This has been kept here for compatibility with old versions < 7.3.3, and for possible tests. It is not recommended.

10.3 Grid Power limitation

To maximize energy production, one strategy is to over-size the PV installation, accepting some energy losses during peak production hours (peak-shaving). The grid limitation feature in PVsyst allows you to set limits on the power that your PV system injects into the grid, based on requirements from the grid manager. This is often needed when grid operators request a maximum limit to prevent overloading.

The power limitation must occur at the inverter level by adjusting the operating point on the PV array's I/V curve to produce only the necessary power. The inverter will ensure that the power output matches the grid's required limit.



In the Power limitation dialog, you can define one value for the grid limitation that will be applied throughout the year. The limitation may be defined:

- either at the inverter level: the inverter power is limited to the rated value, and the power injected into the grid is further reduced by the losses defined after the inverter (auxiliaries, AC wiring, transformer).
- or at the injection point level: the maximum power delivered to the grid is indeed the rated limit, the inverter will have to deliver a higher power for compensating the losses after the inverter.

This limitation may be required:

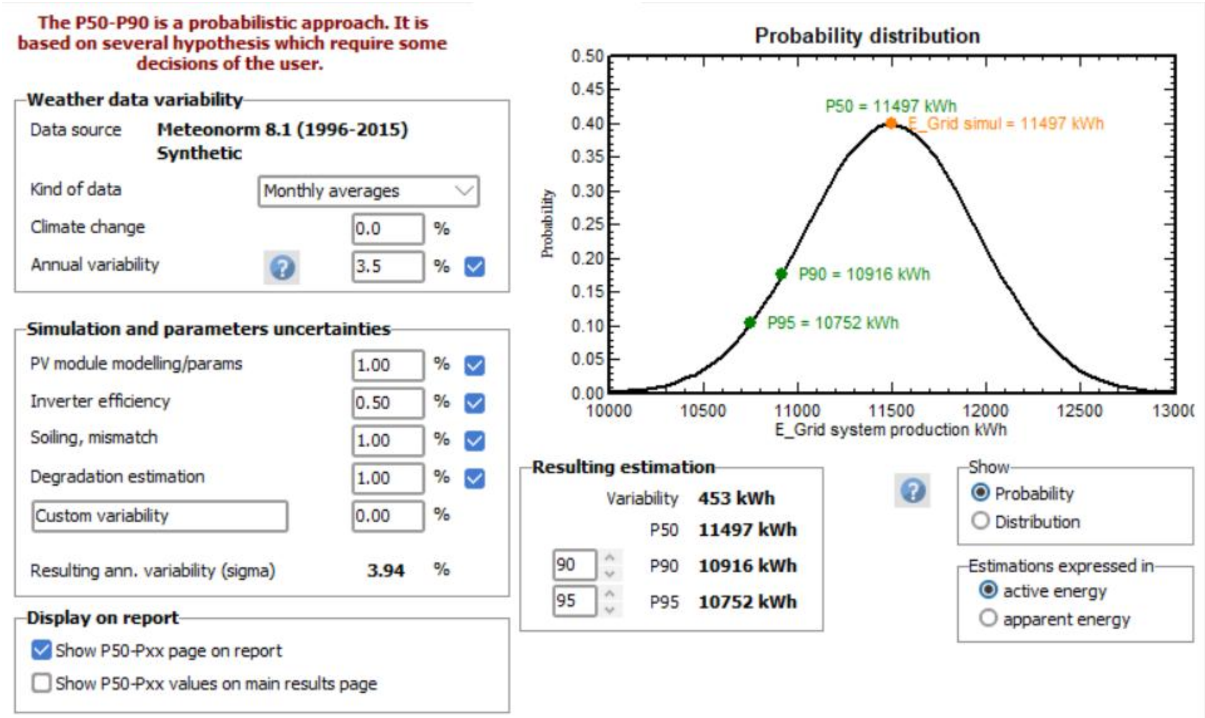
- either as active power (expressed in kW),
- or as apparent power [kVA]: in this case the effective active power [kW] is limited at a lower value than the apparent power limit [kVA]. The Cos(Phi), specific for the grid limitation, may be specified in yearly or monthly values.

The excess energy will be accounted as "Inverter loss over nominal power" or when checking "Account as separate loss", the results will show separately the loss due to the inverter limitation itself, and the loss (named EUnused) due to the additional condition of grid limitation. This does not correspond exactly to the physical behavior of the system, which will always clip at the inverter level, but it is meant to show explicitly the part of the clipping losses due to the injection limitation.

10.4 P50 - P90 Estimation

The P50 - P90 evaluation is a probabilistic approach for the interpretation of the simulation results over several years. This approach supposes that over several years of operation, the distribution of the annual yields will follow a statistical law, which is assumed to be the Gaussian (or "normal") distribution.

The normal/gaussian distribution describes the tendency for data to cluster around a central value, this value is the mean. Some data will then fall below the mean and other above the mean. The standard deviation Sigma describes the spread of the normal distribution. The larger the Sigma, the more spread out the distribution will be. And the contrary, with a smaller Sigma, the distribution is less spread out, accumulating more data near the mean.



The P50-P90 evaluation of the energy yield potential of a site, represent a statistical level of confidence for which the probability that the production of a particular year is over this value is 50%, resp. 90%.

The annual variability will be dominated by the weather year-to-year variability. Several weather data providers can now deliver multi-year weather data (sets of 15 to 25 years), that you can directly import in PVsyst (for example SolarGIS, 3-Tiers Vortex, Soda-Helioclim, or other). If you avail of such weather data for your site, you can calculate the RMS of the annual GlobInc distribution. You have a tool for doing this in PVsyst: please use "Databases > Compare Weather Data", and choose the corresponding .MET files for different years. You have an option "Histo and Probabilities" which shows the gaussian distribution, average and RMS.

If the data are representative of an average over several years (like monthly averages or TMY), the result of the simulation can be considered as the average, and corresponds to P50 (mean value of the Gaussian). If the data are for a specified year, these cannot be considered as representative of the P50 value. In absence of further information you cannot determine a reliable P50-P90 indicator. But if you have some information about the usual average of the site, you can introduce an estimation of the deviation of this particular year with respect to the average.

Additional uncertainties in the simulation process could eventually be taken into account. These deviations should represent random variability of the uncertainty from year to year, not absolute uncertainty.

The P50-P90 statistical estimations are based on **yearly** values. P90 for hourly or daily values (or even for monthly accumulations) doesn't provide meaningful results due to the high variability of short-term weather patterns.