PVSYST

PHOTOVOLTAIC SOFTWARE

Version 8

Grid Connected Systems

User's manual

PVsyst SA

www.pvsyst.com

Introduction

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

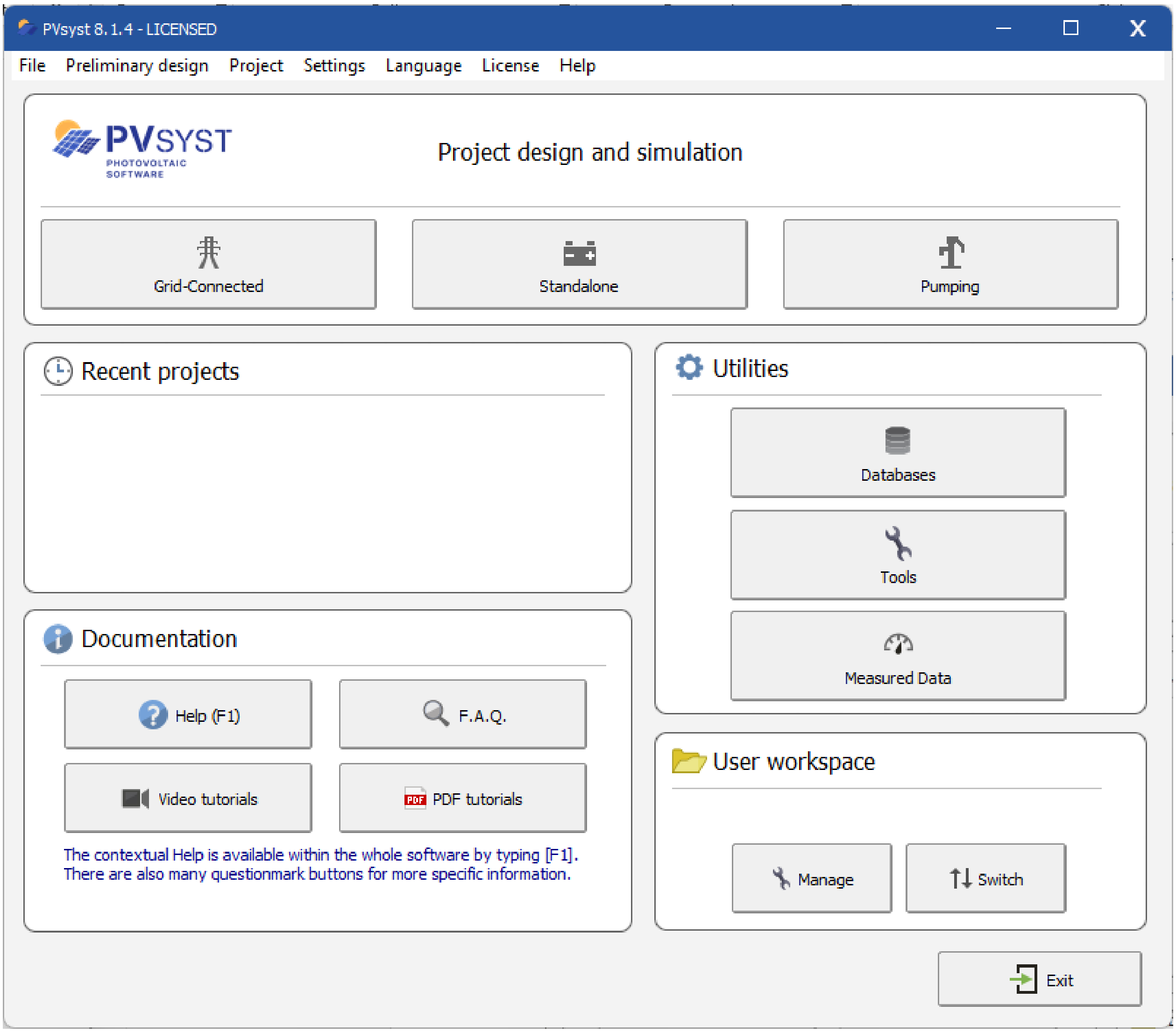
With PVsyst, users can model various types of PV installations using site-specific meteorological data and component specifications, while taking into account factors such as shading effects, battery storage, grid unavailability, and module degradation.

This document can be considered as a user manual, intended to describe the different windows and functionalities of the software. The complete reference manual for PVsyst is available through the online help, accessible from within the program via the “Help” menu, by pressing the F1 key, or by clicking on the help icons in the various 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**.



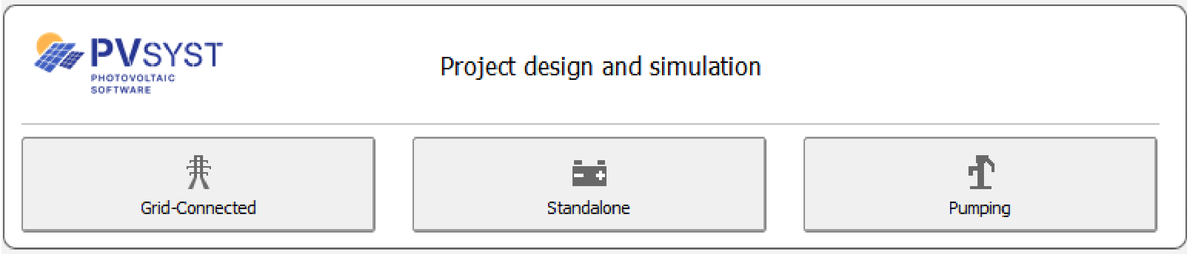
1.1 Project design and Simulation

Project design and simulation constitute the core functionality of the software. They are used for the complete study of a project. This includes:

- selection of meteorological data,
- system design,
- shading analysis,
- loss evaluation,
- and economic assessment.

The simulation is performed over a full year, providing a detailed report and numerous numerical results.

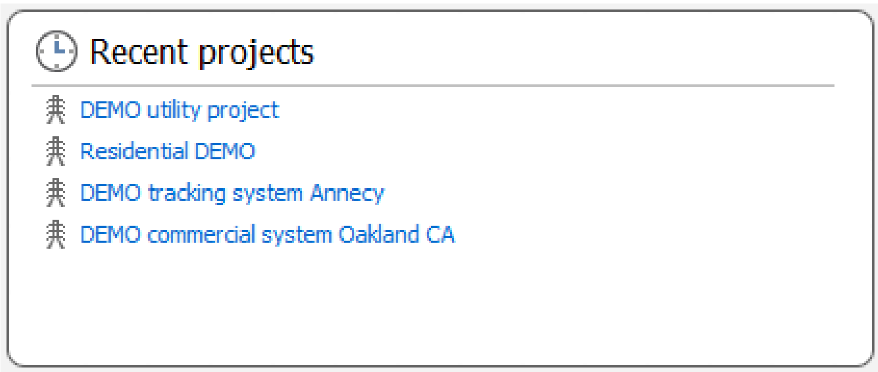
In the **Project Design and Simulation** section,



PVsyst allows users to create and simulate three types of systems:

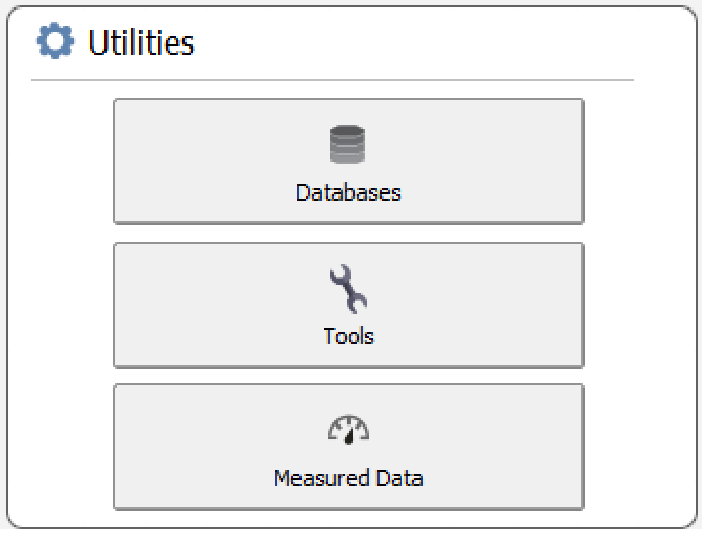
- **Grid-connected**: used to design systems connected to the utility grid. It is also possible to define a self-consumption profile and to include battery storage according to various strategies.
- **Stand-alone with batteries**: intended for systems not connected to the grid, where storage is mandatory. Any unused or unstored energy production is curtailed.
- **Pumping**: used in certain regions to power a solar pump that draws water (from a well or a lake), which is then stored in an elevated tank for various uses.

The **Recent Projects** section allows users to quickly access and edit their recent projects.

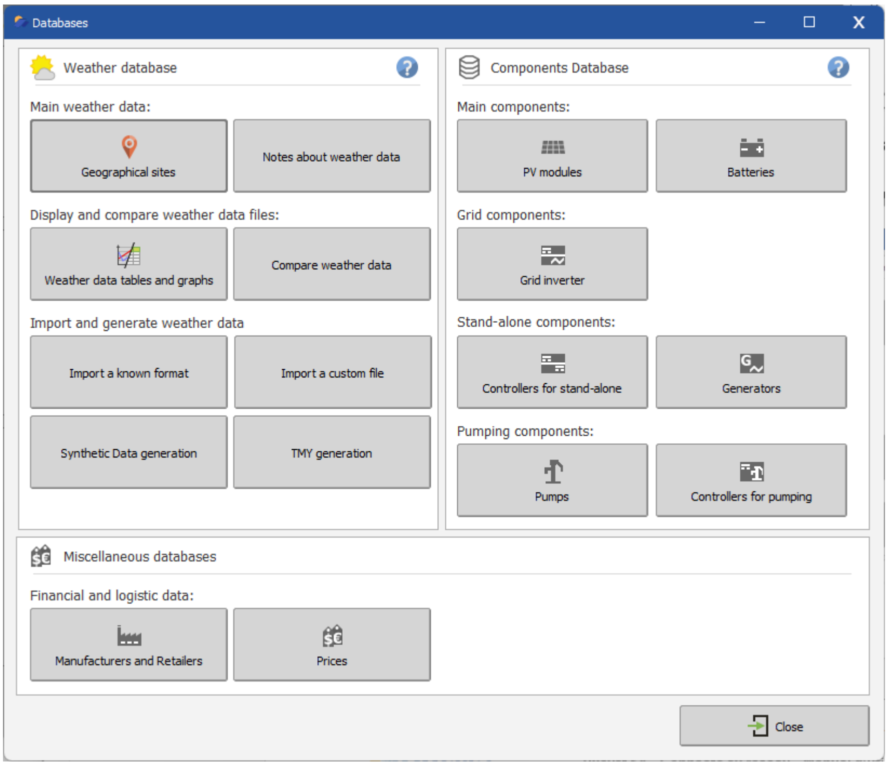


1.2 Utilities

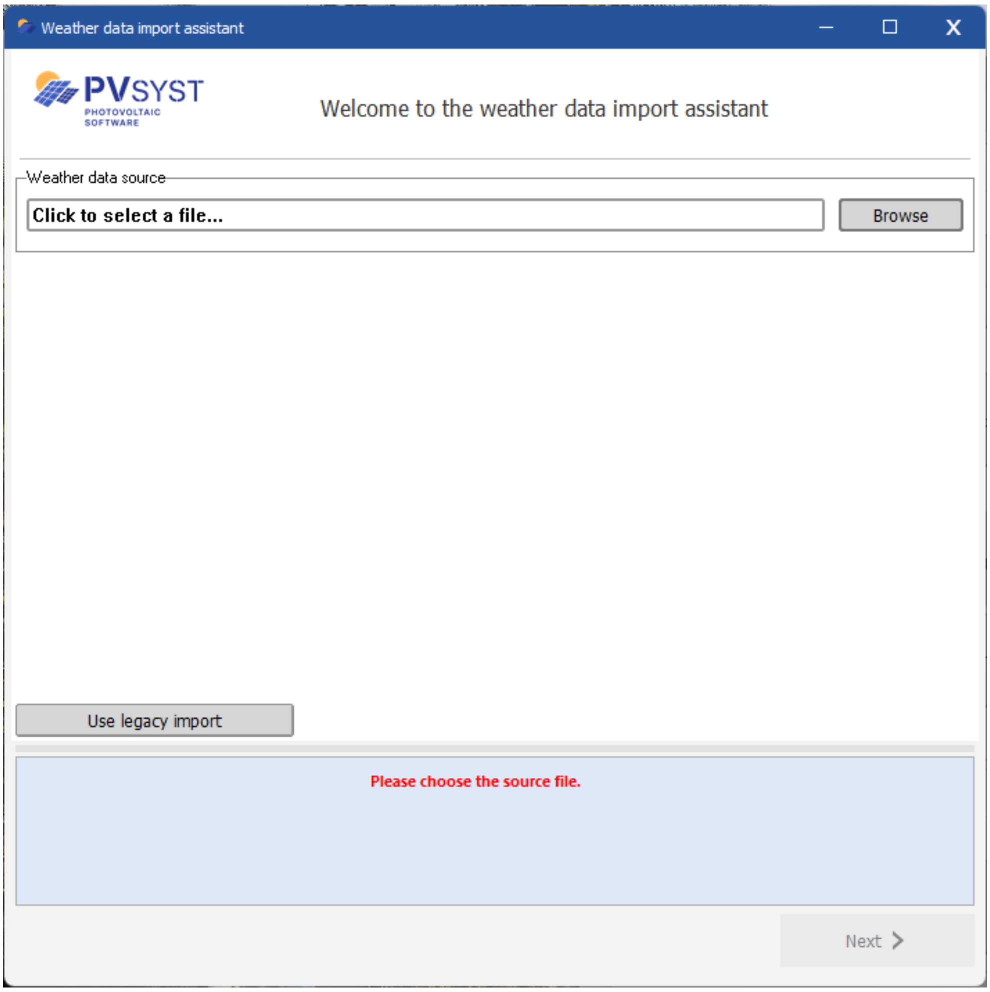
The **Utilities** section in PVsyst offers a range of tools and functions designed to enhance the understanding and the precision of your PV system analysis:



- 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.



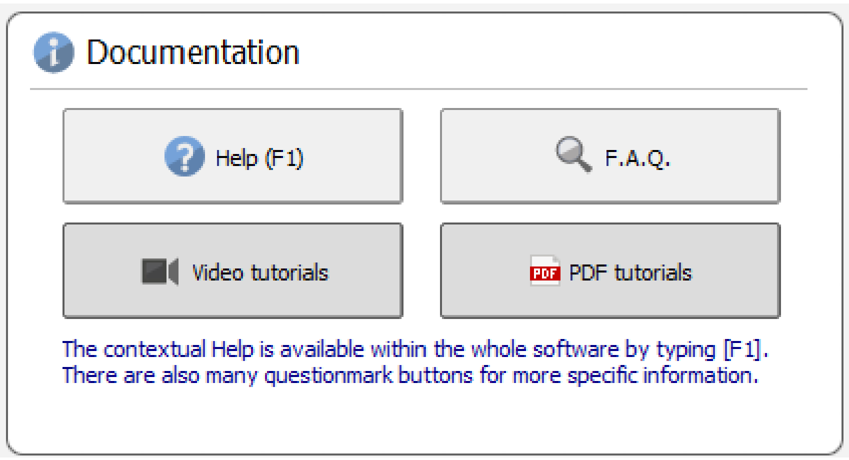
- **Import a custom file:** This option, available in the Databases section, opens an assistant window for importing a CSV weather data file. Once opened, the assistant appears as shown below:



- 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

The **Documentation** section provides direct access to the PVsyst help, which is the complete reference manual for the software (also available at www.pvsyst.com/help).



Context-sensitive online help is available:

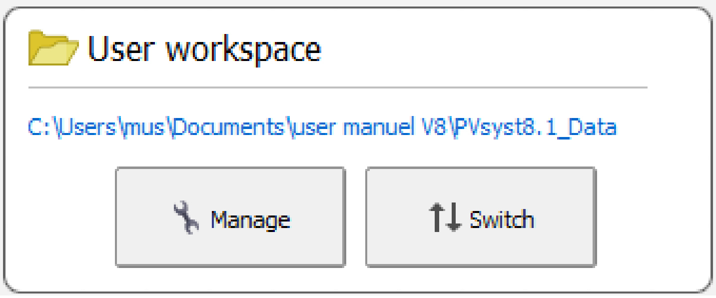
- via the **F1** key,
- or via the question mark icons in the windows and dialog boxes.

This opens the PVsyst help tool, which provides specific articles, detailed explanations, and step-by-step guides.

In the **Settings** > **Preferences** menu, under the **Help** section, you can modify how the integrated help is displayed so that it opens directly in your computer's default web browser. Using your browser allows you to take advantage of its automatic translation feature, enabling you to view the help in French (or any other language) from the original English version.

1.4 Toolbar and Workspace

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

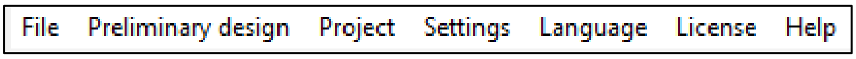


When files are saved, they are automatically stored in the workspace according to a predefined folder structure:

- **ComposPV** for PV components,
- **Projects** for projects,
- **User hourly** for accessing hourly results in CSV format.

You will also find ready-to-use templates, for example to define a self-consumption profile.

Main functions accessible from the toolbar:



- **File**: import/export projects and components.
- **Pre-sizing**: simple simulation tool for small projects.
- **Project**: allows you to start a new project. A fourth type of project, not displayed in the Project Design and Simulation window, is also available: the DC Grid project, intended for specific use cases such as public transport applications. You can also load a project from your workspace or open a DEMO project provided by PVsyst, which showcases various features and use cases.
- **Options**: includes Preferences, where you can define user information, default units, and API keys for certain weather data providers. In Advanced Settings, most default values and thresholds that trigger warning or error messages can be modified.
- **Language**: allows you to change the interface language (or use the F9 key to toggle between English and another language).
- **License**: provides information about your account and activation key.

2 Introduction to Simulation in PVsyst

For this first tutorial, we will focus on a **grid-connected system**, but most of the steps and information are also applicable to stand-alone and pumping systems.

The workflow in PVsyst is based on working with **Projects** and **Variants**. This also reflects the software's hierarchy.

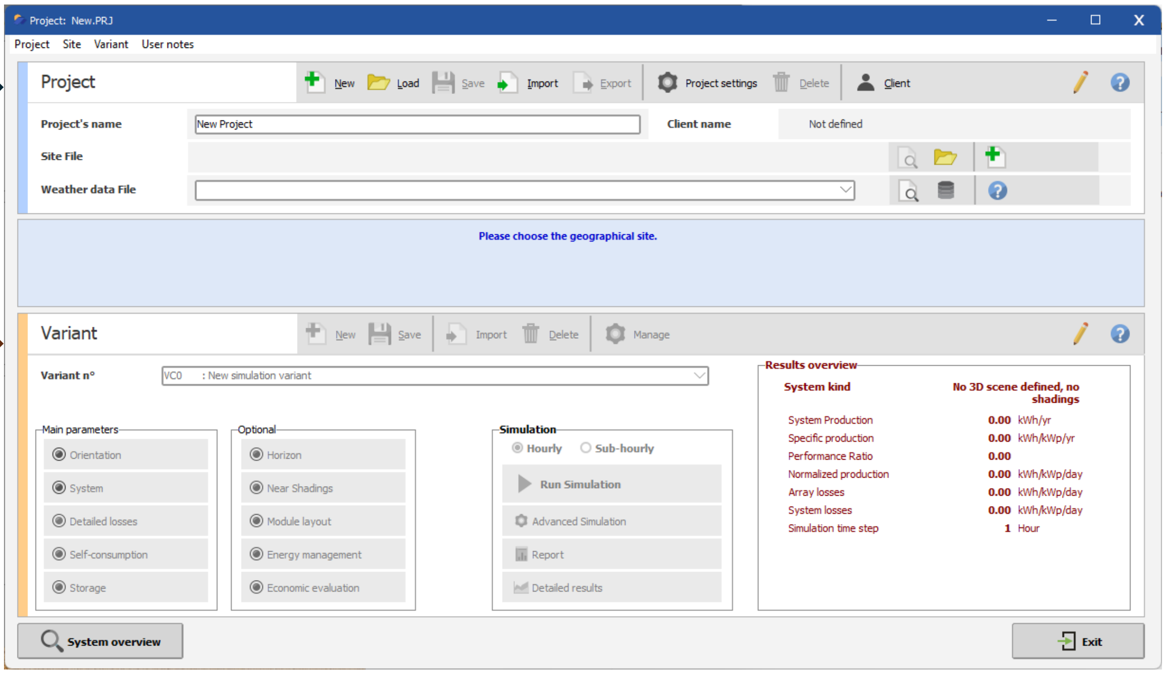
Project: contains the general information, including:

- the geographical site of the system,
- the reference meteorological file,
- certain global parameters (albedo, design conditions, etc.).

Variant: each variant corresponds to a complete system configuration. It includes:

- the selection and number of PV modules and inverters,
- the geometric layout and possible shading,
- the electrical connections,
- economic scenarios, etc.

Each variant leads to a simulation calculation.



2.1 Project definition

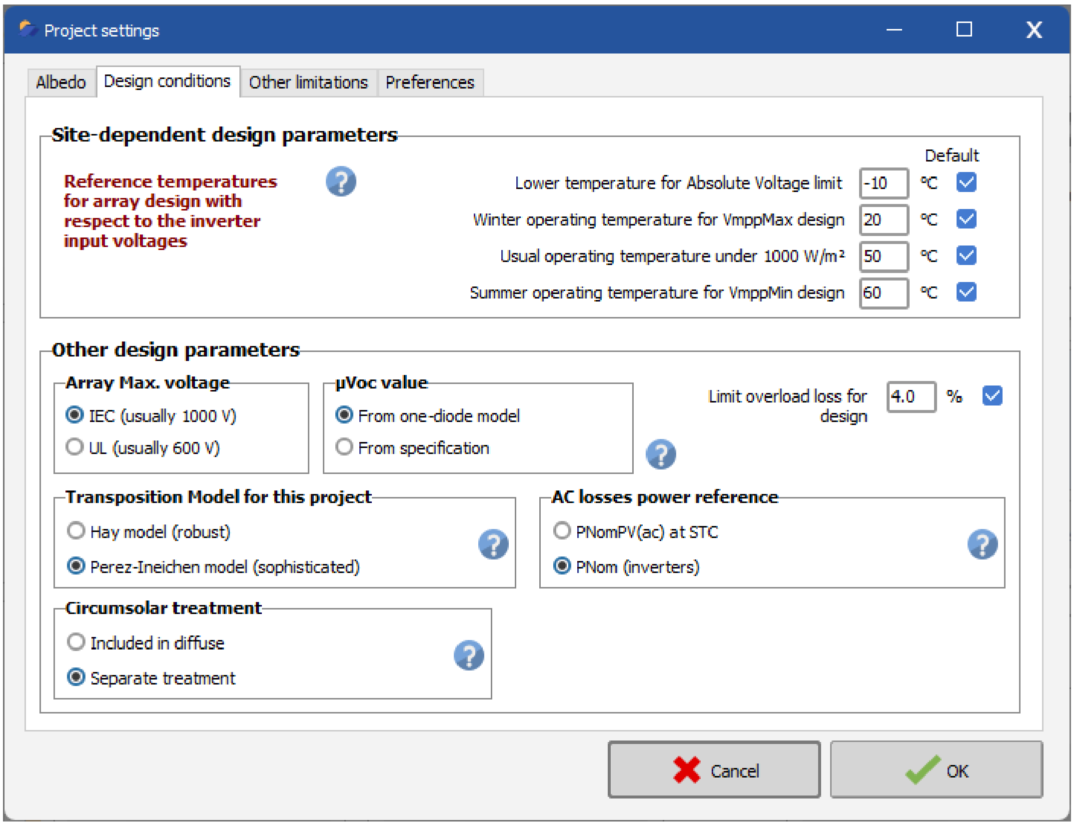
By clicking on **Grid-connected system** on the home page, PVsyst automatically opens the most recent project. (This default behavior can be modified: **Settings → Preferences → Default values → Automatic project loading**.)

In the main toolbar, several actions are available:

You can:

- start a new project (**New**),
- load an existing project (**Load**),
- import or export a project (**Import/Export**),
- define a Client (to customize the report with company information).

In the **Project Settings**, you can define global parameters and preferences for the project. Note the **difference** between the project settings defined here, which apply only to **this specific project**, and the **Advanced Settings** from the main page, which apply to **all projects** in your workspace.

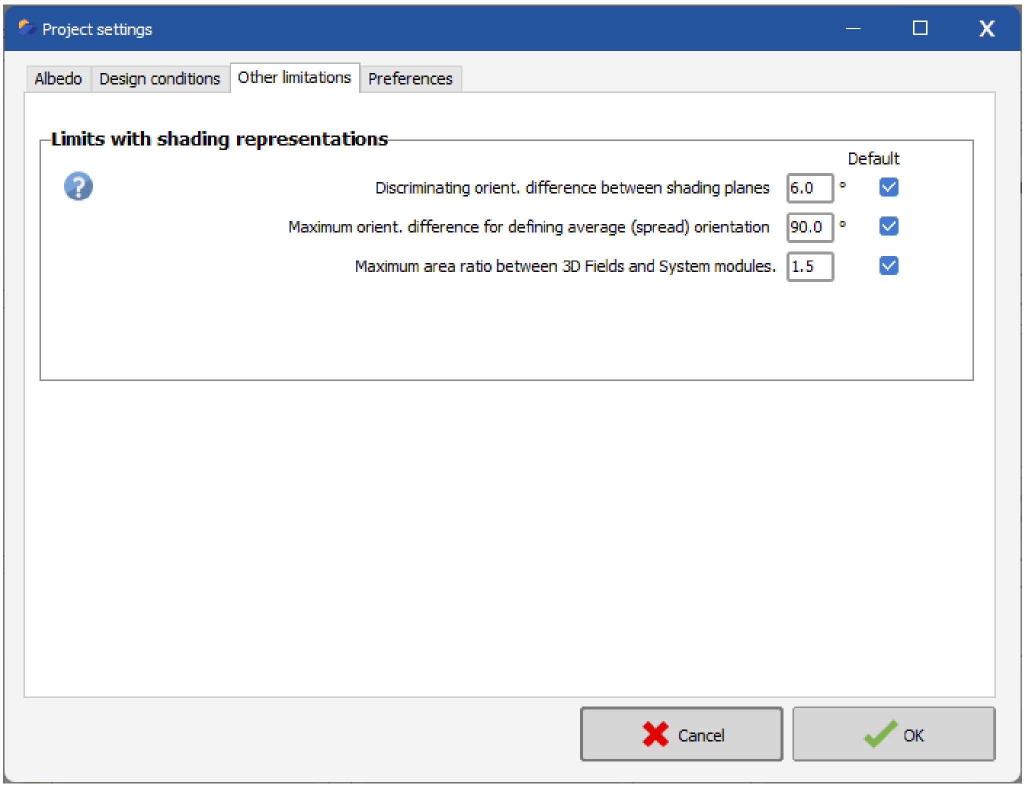


In the Project Settings, you can define, for example, the far **albedo**, i.e. the albedo surrounding your site (the albedo under the modules is defined in the System window for bifacial modules).

In the **Design Conditions**, you can specify, among other things, the minimum temperature expected at your site in order to trigger a warning related to the absolute voltage limit, as well as other relevant temperatures used to generate graphs in the sizing tool. (Note that the simulation itself uses the actual site data; these values are intended to assist in system design.)

The **overload loss limit** parameter is used to size the inverter based on an acceptable annual loss, set by default to 3%. Increasing this value allows for greater oversizing of the PV array relative to the inverter.

In the **Other limitations** tab, several parameters can be defined related to thresholds used for shading analysis and for consistency checks between the 3D scene and the system definition. These settings help ensure the stability and accuracy of the calculations.



Discriminating orientation difference between shading planes

This parameter defines the maximum angular deviation between planes for them to be considered as having the same orientation. Beyond this tolerance, the planes are treated as having distinct orientations in the calculations.

Maximum orientation difference for defining average (spread) orientation

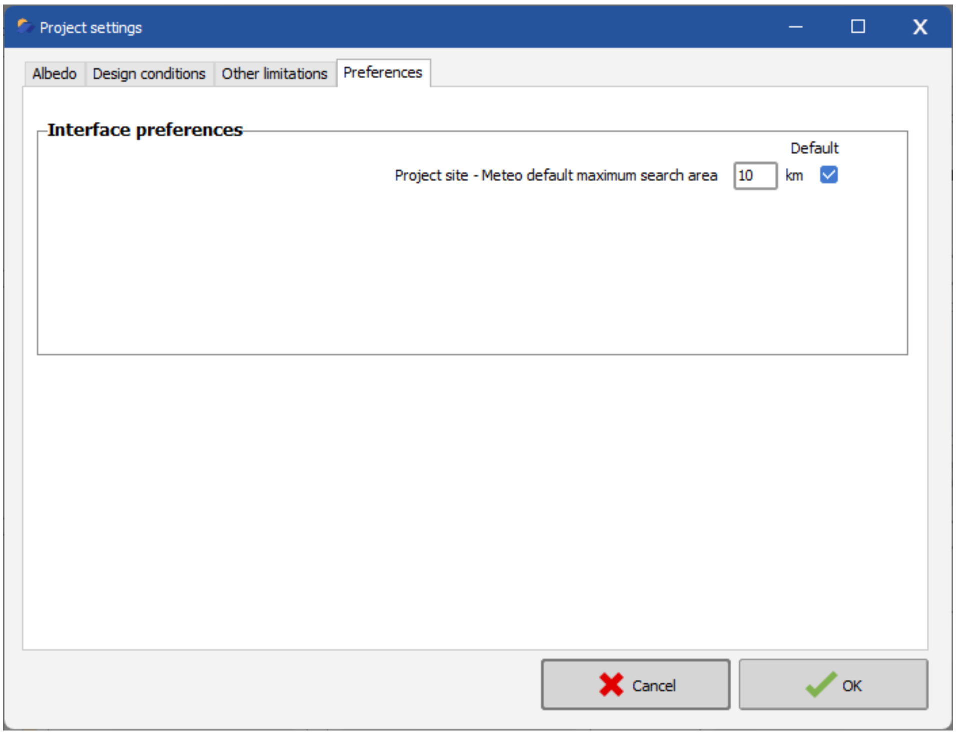
This value determines the maximum angular deviation allowed to group several nearby planes into a single average orientation. If the difference exceeds this threshold, the system is considered to have multiple orientations (heterogeneous field).

Maximum area ratio between 3D fields and system modules

This parameter controls the consistency between the total module area defined in the System section and the area represented in the 3D scene. Exceeding this ratio may indicate a modeling inconsistency (e.g., widely spaced modules or incorrect geometry).

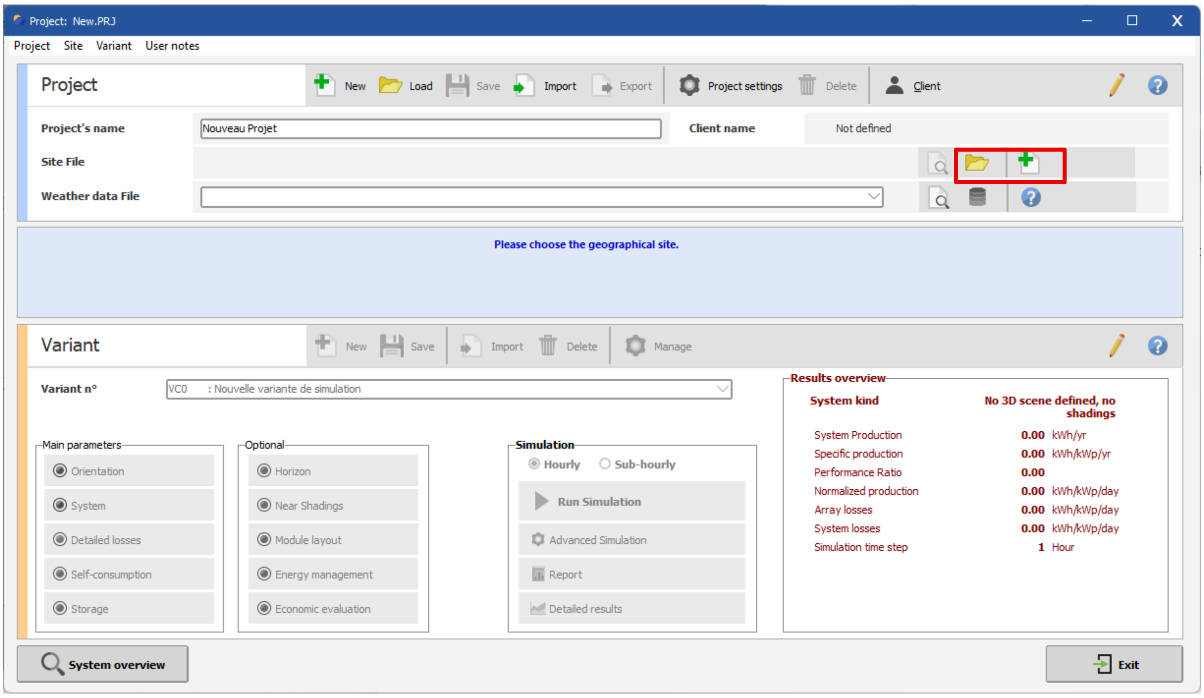
In most cases, the default values are appropriate and do not need to be modified, except for specific configurations or complex geometries.

In the **Preferences** tab, you can define the radius within which the program searches for meteorological data files around the project site. It is recommended to keep this value low to prioritize data representative of local conditions, and to increase it only if no nearby data is available.

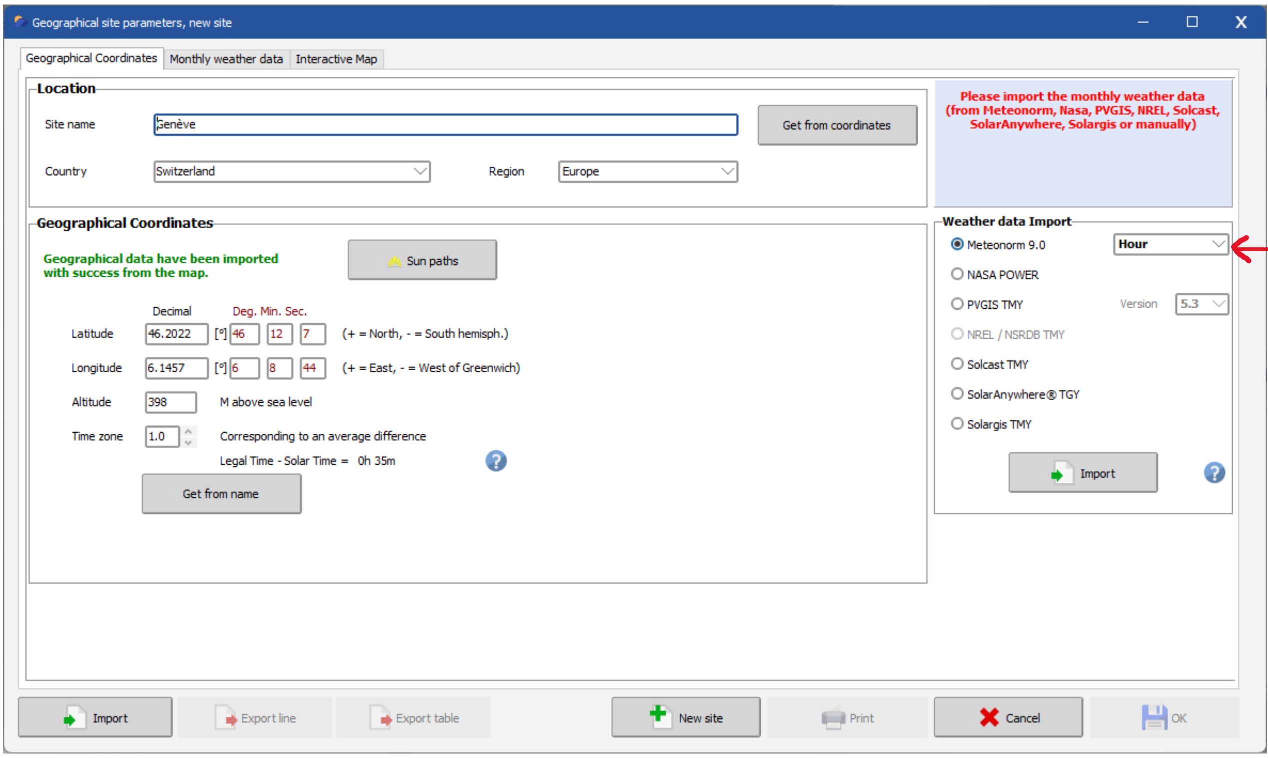


In the **Project** section, you must first define the project name, select the site, and assign a meteorological data file. The site file contains the coordinates of your project, which are used to calculate the sun's position for each hour of the year. The created site file also includes monthly meteorological data, used for quick and approximate calculations during the design phase of the software.

To define a **project site**: you can either select an existing site from the list or create a new one by entering its name or using the interactive map.



In the **Geographical Coordinates** dialog box, you can verify the coordinates of the selected site and view the corresponding sun paths. The sun paths illustrate the position of the sun at each hour throughout the year.



When creating a geographical site, you can directly import **meteorological data** from a list of data providers such as Meteonorm, PVGIS, Solcast, SolarAnywhere, and Solargis. An active internet connection is required for the import to work. The data is automatically retrieved based on the coordinates of your site.

As a user, it is your responsibility to select the meteorological data source to be used in your project. For some providers, an additional license may be required.

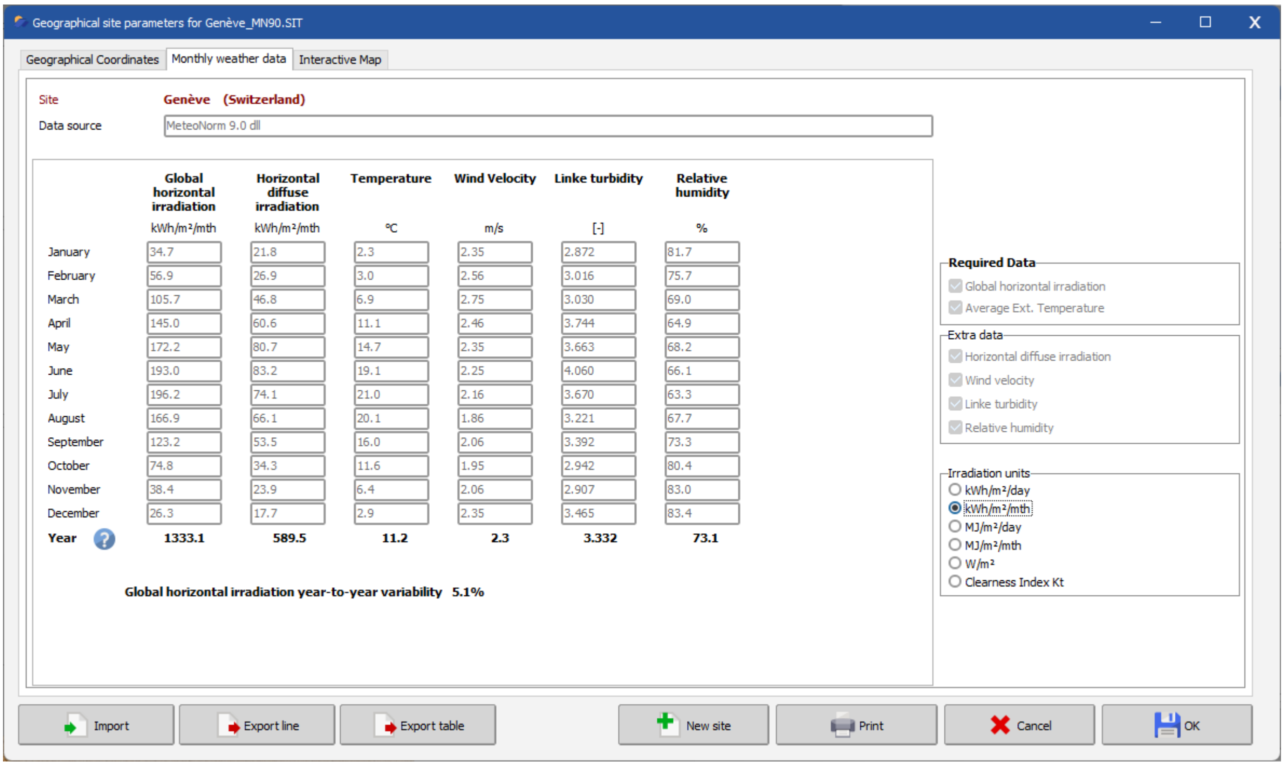
Meteonorm data is included with the PVsyst license. It combines ground-based measurements and satellite observations, and uses monthly averages to generate synthetic time series—mainly at an **hourly resolution**, or allowing the generation of **minute-level** data.

It is possible to select meteorological data with an hourly or minute time step, depending on the desired level of accuracy. Hourly data allows for faster simulations but provides lower temporal resolution. In contrast, minute-level data requires longer computation time but enables a more detailed analysis of certain dynamic effects, such as inverter clipping.

TMY data (Typical Meteorological Year), on the other hand, consists of hourly meteorological data files constructed from real measured data series over at least 10 years, based on various statistical criteria.

The imported data is displayed as monthly averages. Depending on the meteorological data source, you may also access the **interannual variability of global horizontal irradiation**, i.e. the natural fluctuations of solar energy received on a horizontal surface from one year to another. This information can be used to perform statistical analyses such as **P50** and **P90** for energy yield predictions of photovoltaic systems.

By clicking **OK**, you will be prompted to save the geographical site and the hourly/minute meteorological data (if your data source is based on synthetic data). By clicking **Open**, a summary of your meteorological data will be displayed. Note that PVsyst assigns a generic year labeled as 1990.


Geographical site parameters for Genève_MN90.SIT
Geographical Coordinates
Monthly weather data
Interactive Map
Site
Genève (Switzerland)
Data source
MeteoNorm 9.0 dll

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	34.7	21.8	2.3	2.35	2.872	81.7
February	56.9	26.9	3.0	2.56	3.016	75.7
March	105.7	46.8	6.9	2.75	3.030	69.0
April	145.0	60.6	11.1	2.46	3.744	64.9
May	172.2	80.7	14.7	2.35	3.663	68.2
June	193.0	83.2	19.1	2.25	4.060	66.1
July	196.2	74.1	21.0	2.16	3.670	63.3
August	166.9	66.1	20.1	1.86	3.221	67.7
September	123.2	53.5	16.0	2.06	3.392	73.3
October	74.8	34.3	11.6	1.95	2.942	80.4
November	38.4	23.9	6.4	2.06	2.907	83.0
December	26.3	17.7	2.9	2.35	3.465	83.4
Year	1333.1	589.5	11.2	2.3	3.332	73.1

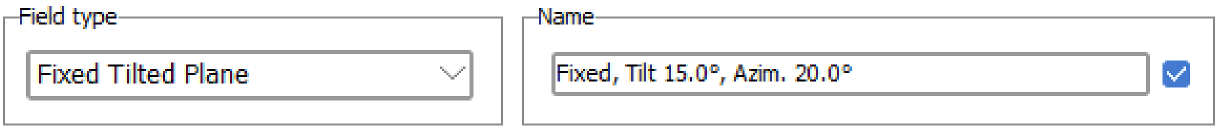
Global horizontal irradiation year-to-year variability 5.1%
Required Data
Global horizontal irradiation
Average Ext. Temperature
Extra data
Horizontal diffuse irradiation
Wind velocity
Linke turbidity
Relative humidity
Irradiation units
kWh/m²/day
kWh/m²/mth
MJ/m²/day
MJ/m²/mth
W/m²
Clearness Index Kt
Import
Export line
Export table
New site
Print
Cancel
OK

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**
- **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):

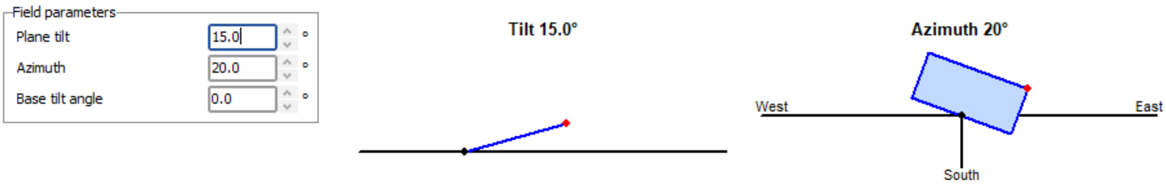
- north = 0°, west = 90°, south = 180°, and east = -90°.

3.1 Fixed orientations

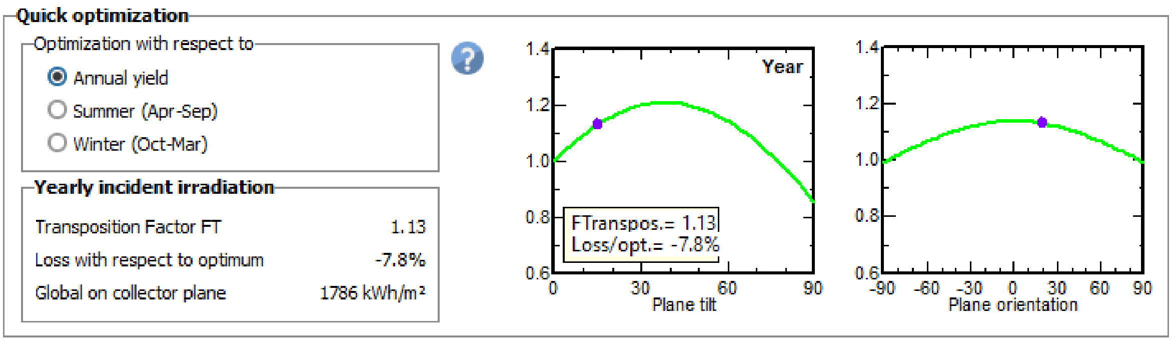
3.1.1 Fixed plane systems

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.

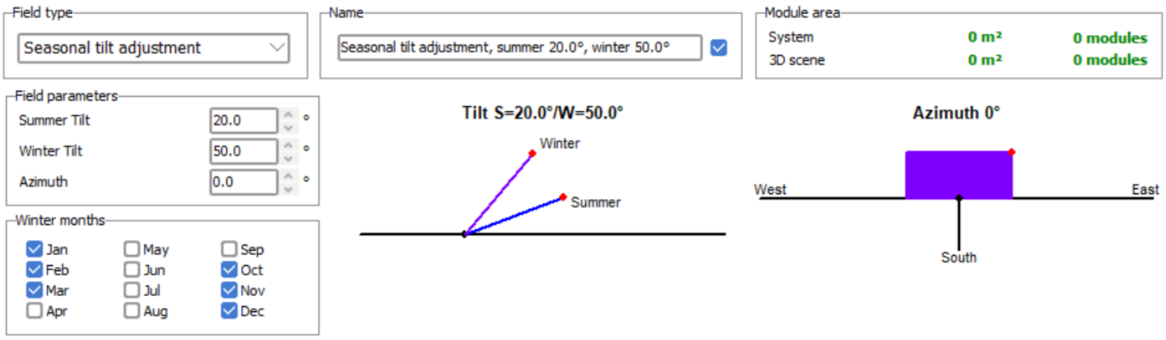


In the fixed planes definition, PVsyst displays a quick optimization tool, indicating the energy yield as a function of the tilt and the azimuth. This is a rough estimation meant for judging how your orientation choice (violet point) will affect the yield with respect to the optimum. This may show the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



3.1.2 Seasonal tilt adjustment

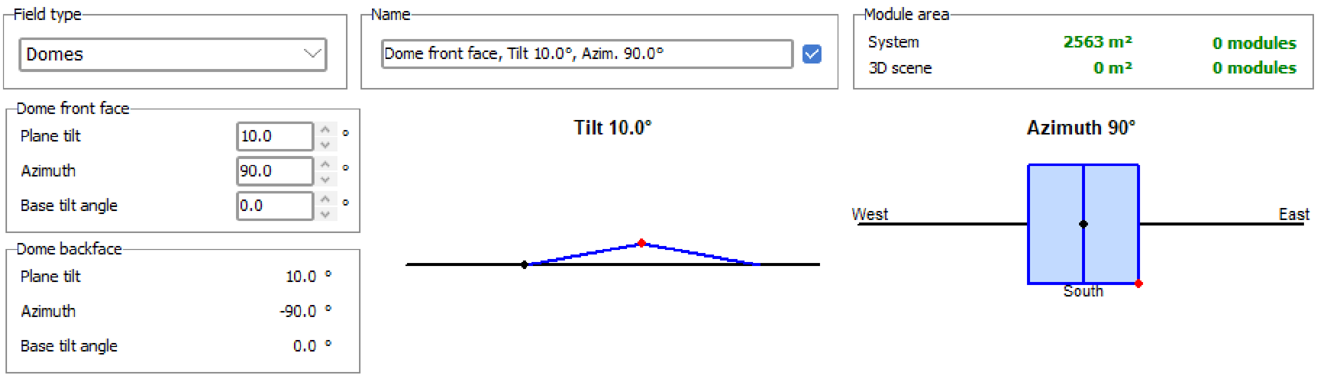
In the seasonal tilt adjustment, you have the possibility to optimize the PV production, by modifying the tables tilt depending on the season. This option allows to define two seasons with a corresponding plane tilt and you must specify the months for the winter and the summer position.



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**.

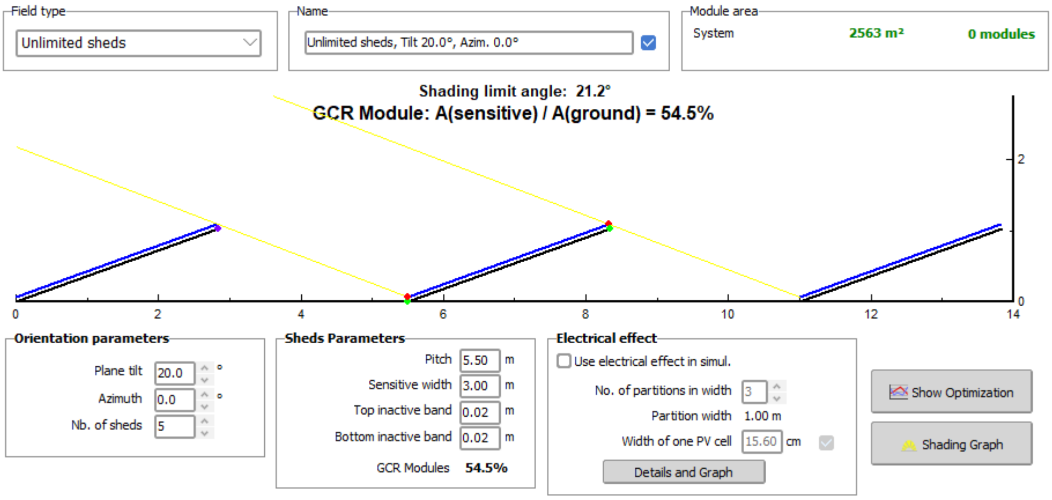


3.1.4 Unlimited sheds

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

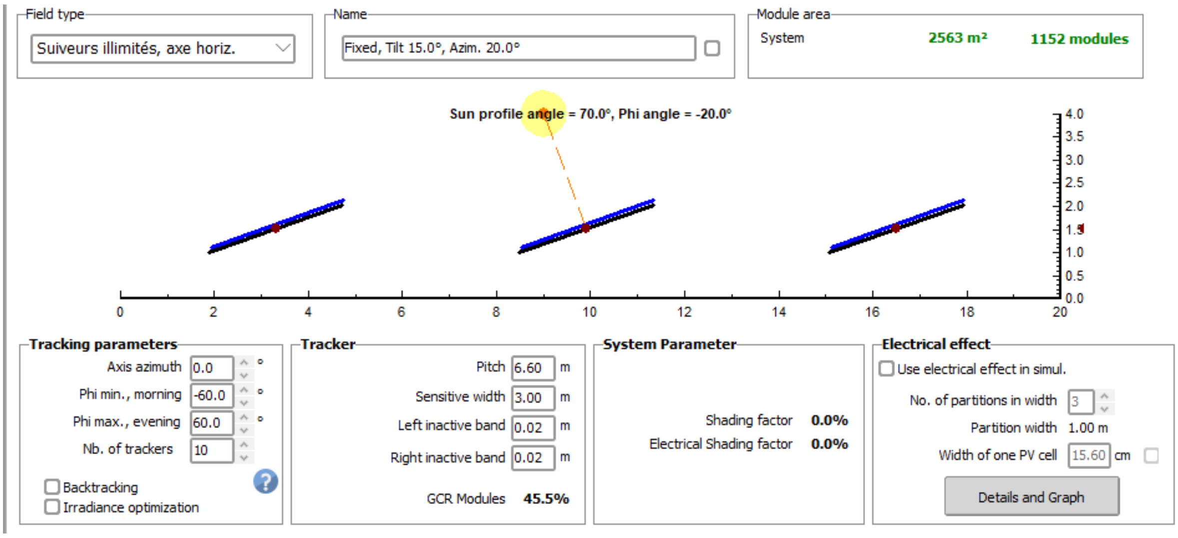
3.2.1 Unlimited trackers, horizontal axis

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.

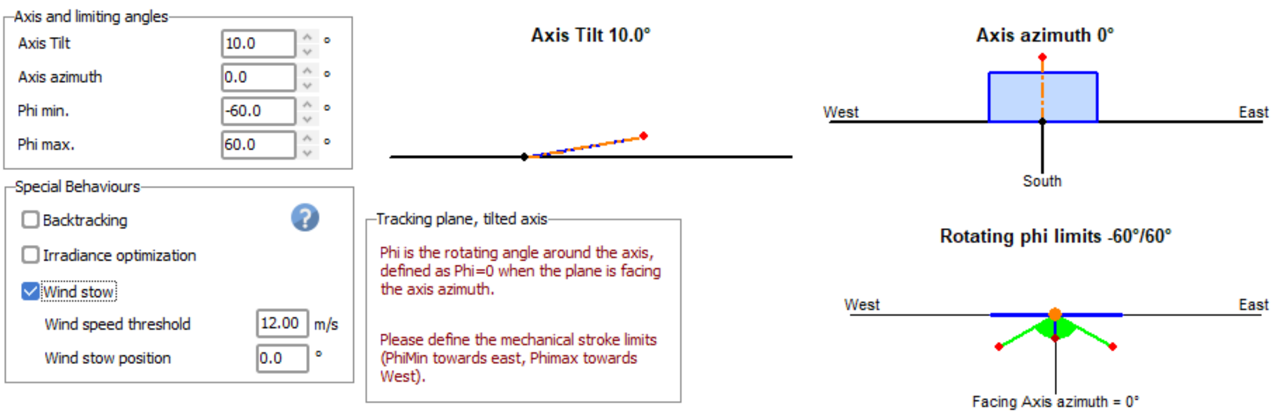


By **dragging** the sun, you have the opportunity of visualizing the tracker's behavior according to the sun position. This tool will show, namely, the behavior of the backtracking mode.

3.2.2 Tracking, horizontal and tilted axis

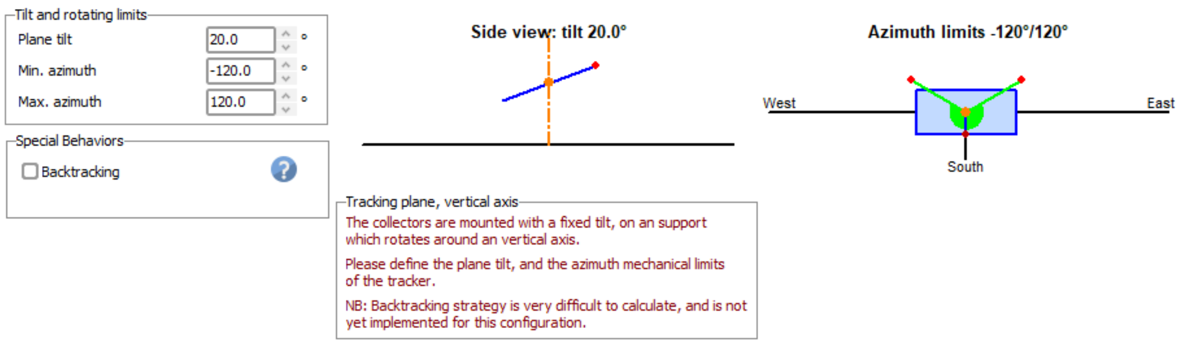
As in **Unlimited Trackers**, you must define the axis orientation and tracking limit angles. You also have the possibility to add an Axis tilt. You must define the Phi limits (mechanical stroke), the backtracking strategy, and the tracking calculation mode (astronomic calculation or irradiance optimization) 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.



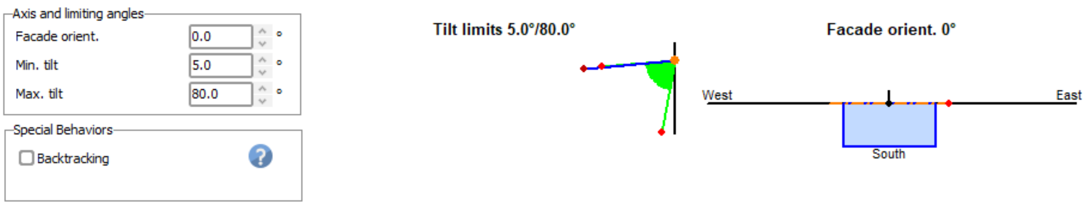
3.2.3 Tracking, vertical axis

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.



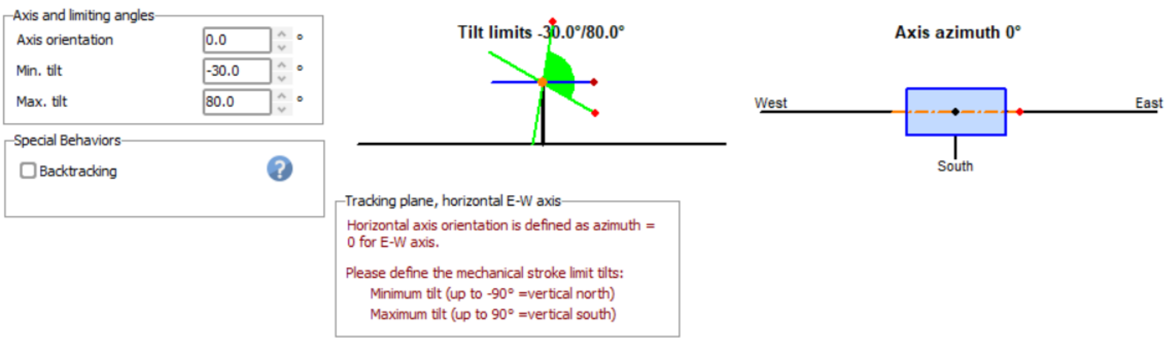
3.2.4 Tracking sun-shields

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

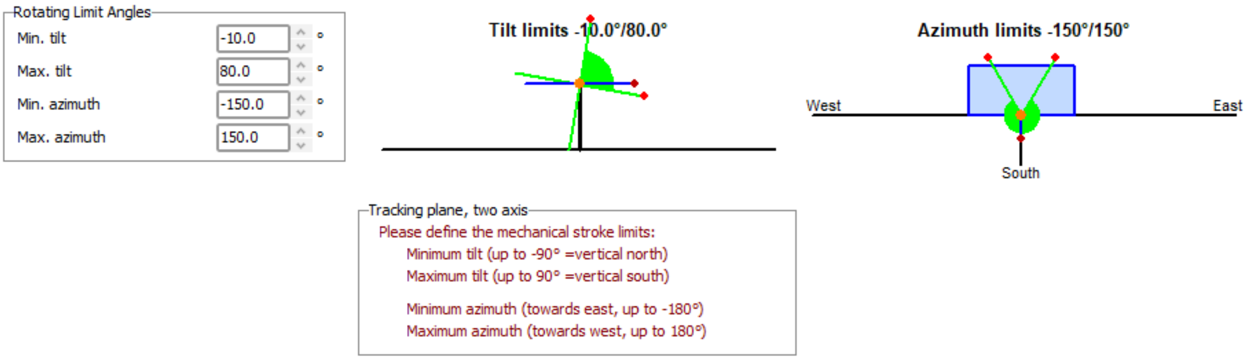
The tracking horizontal East/West refers to system where the rotation axis normally is running east/west. With an Axis orientation of 0° in the northern hemisphere, the panels will be oriented south and the minimum and maximum tilt will define the mechanical strokes to follow the height of the sun in 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

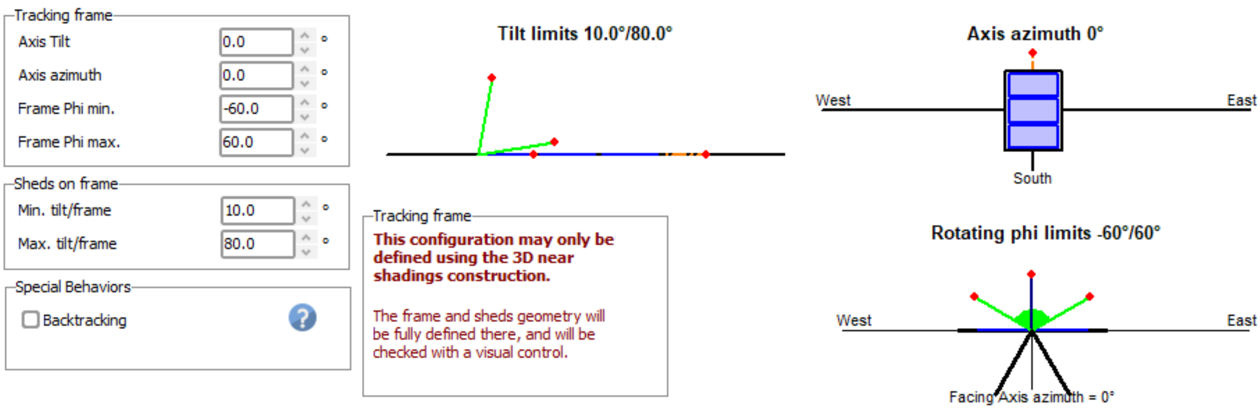
3.3.1 Tracking two axis

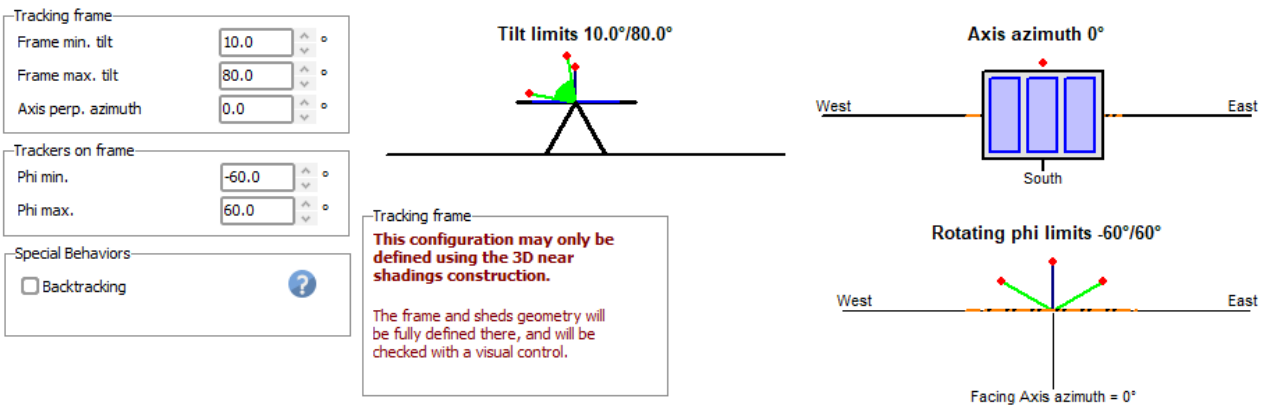
Two-axis solar trackers adjust both the tilt and orientation of solar panels to stay perpendicular to the sun's rays throughout the day. You must define the stroke limits for both the tilt and the azimuth.



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.



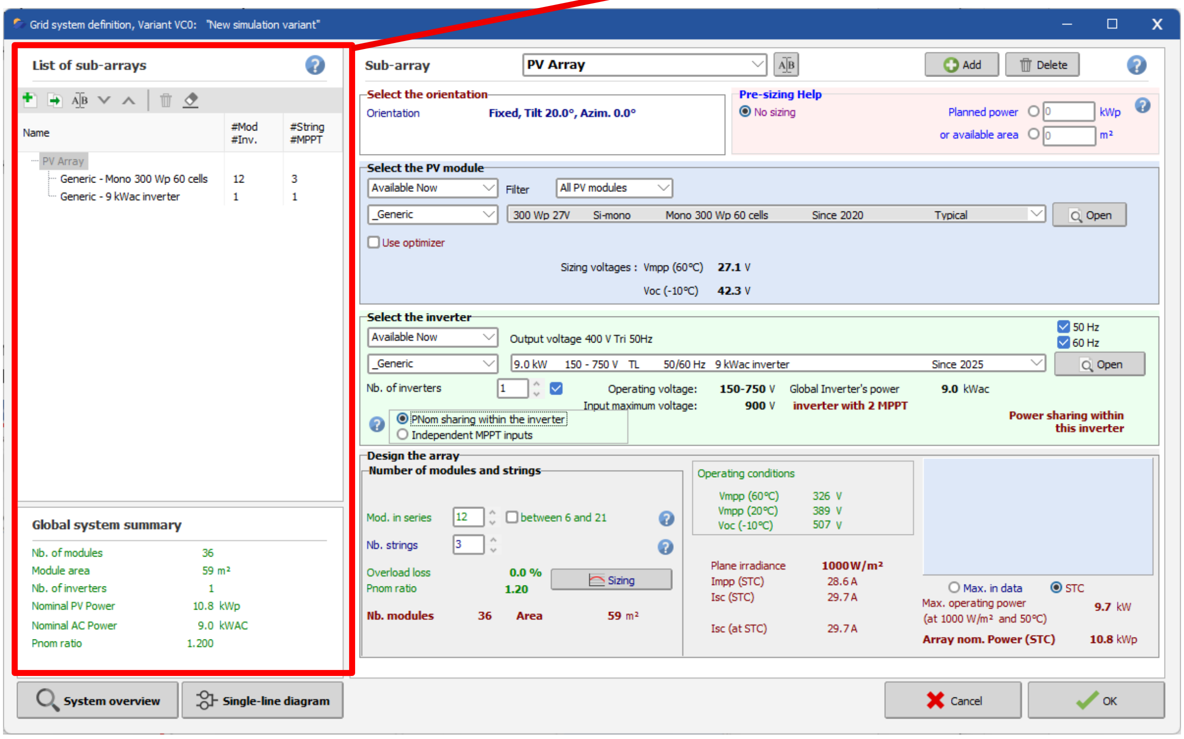


4 System

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 List of Sub-arrays

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

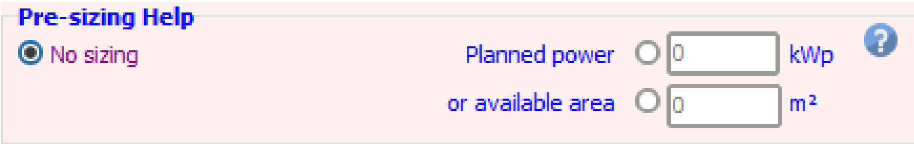


- A PV module model, chosen in the database,
- An inverter model, chosen in the database,
- The number of inverter inputs,
    - either full inverters or
    - number of MPPT inputs,
- The number of modules in series, and the number of module strings.
    - The total number of strings should ideally be a multiple of the number of inverter MPPT inputs.
    - This allows the strings to be evenly distributed across the different MPPT inputs (same number of strings per MPPT), ensuring a balanced DC power distribution.
    - If the number of strings is not divisible by the number of MPPTs, PVsyst will automatically distribute the strings as evenly as possible among the inputs. However, this may lead to a power imbalance between MPPTs.
    - If this imbalance becomes too significant, a warning will be displayed. In such cases, it is recommended to manually define an appropriate distribution or adjust the number of strings to achieve an electrically 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 reflect general best practices for any real installation.

For example, it is not recommended to connect a different number of modules in series on the same inverter input, as this may negatively affect the operating conditions of the system (particularly the MPP tracking). Similarly, it is not advisable to mix different module models on the same MPPT input. The simulation of arrays with different types of modules (e.g., a mix of power classes) is currently not supported in PVsyst.

Each sub-array is associated with a specific orientation. In principle, all modules within the same sub-array should have the same orientation. Mixing PV modules with different orientations within the same string should be avoided, as it leads to significant current losses due to irradiance differences, since the current of a string is always limited by the weakest module.

Moreover, **PVsyst explicitly prevents** the definition of multiple orientations within a single string, automatically avoiding any non-compliant configuration.

However, it is possible to connect strings with different orientations in parallel, as the resulting voltage mismatch is generally very small.

PVsyst also allows the creation of sub-arrays with two different orientations connected to the same inverter input, and the potential mismatch losses between orientations will be displayed in the loss diagram.

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.

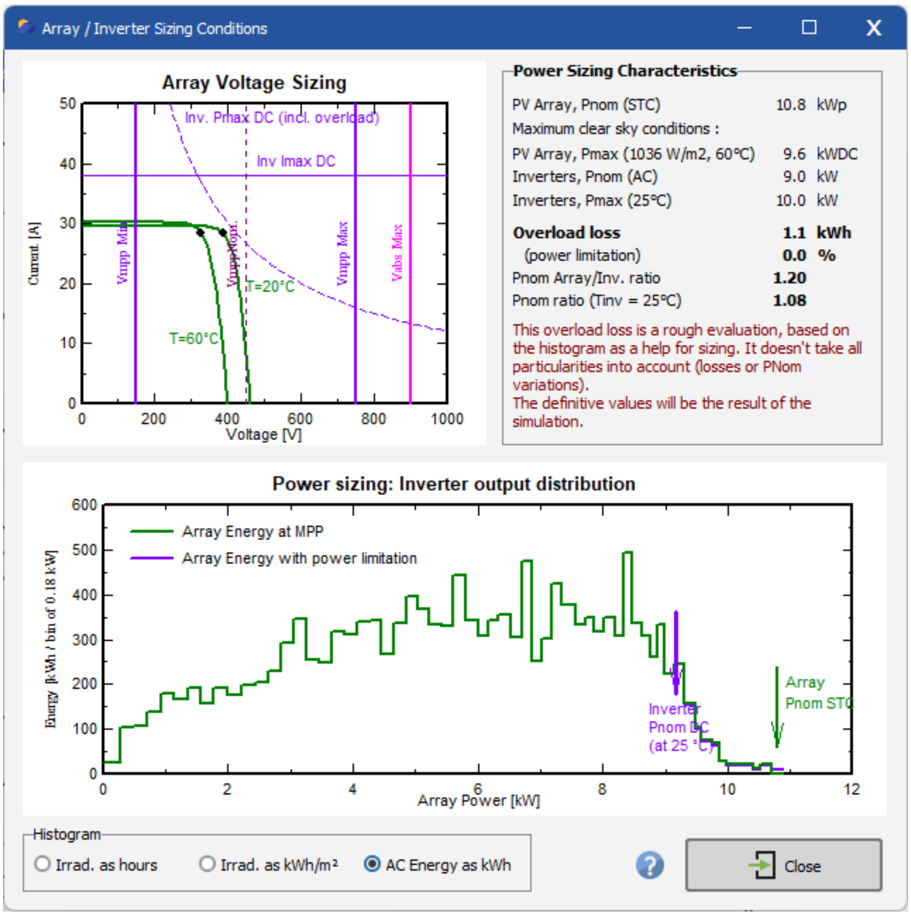
Inverter Performance: The inverter converts the DC power generated by the PV panels into AC power for use in the electrical system.

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.

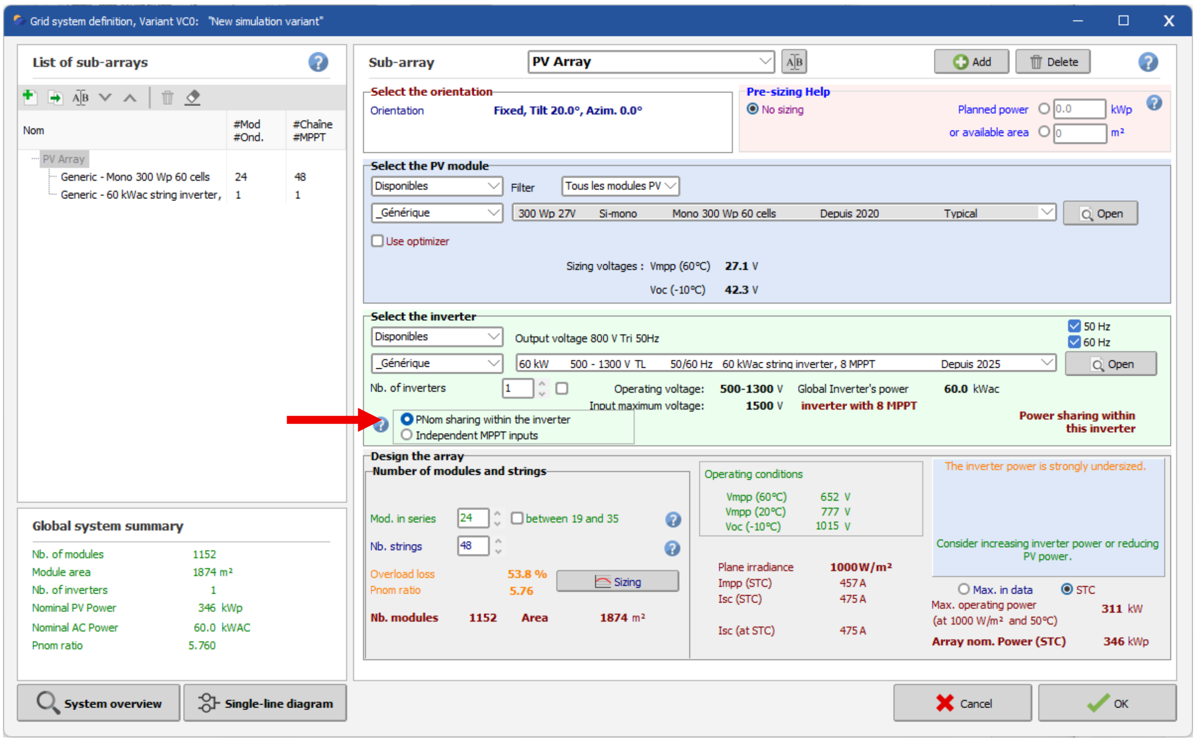
The optimal sizing of the inverter is based on the acceptable overload loss throughout the year. It usually leads to over-size the power ratio (PV array nominal power with respect to the inverter nom. AC power), by a factor of 1.25. Note that this is a first rough estimation and that you later can define 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.

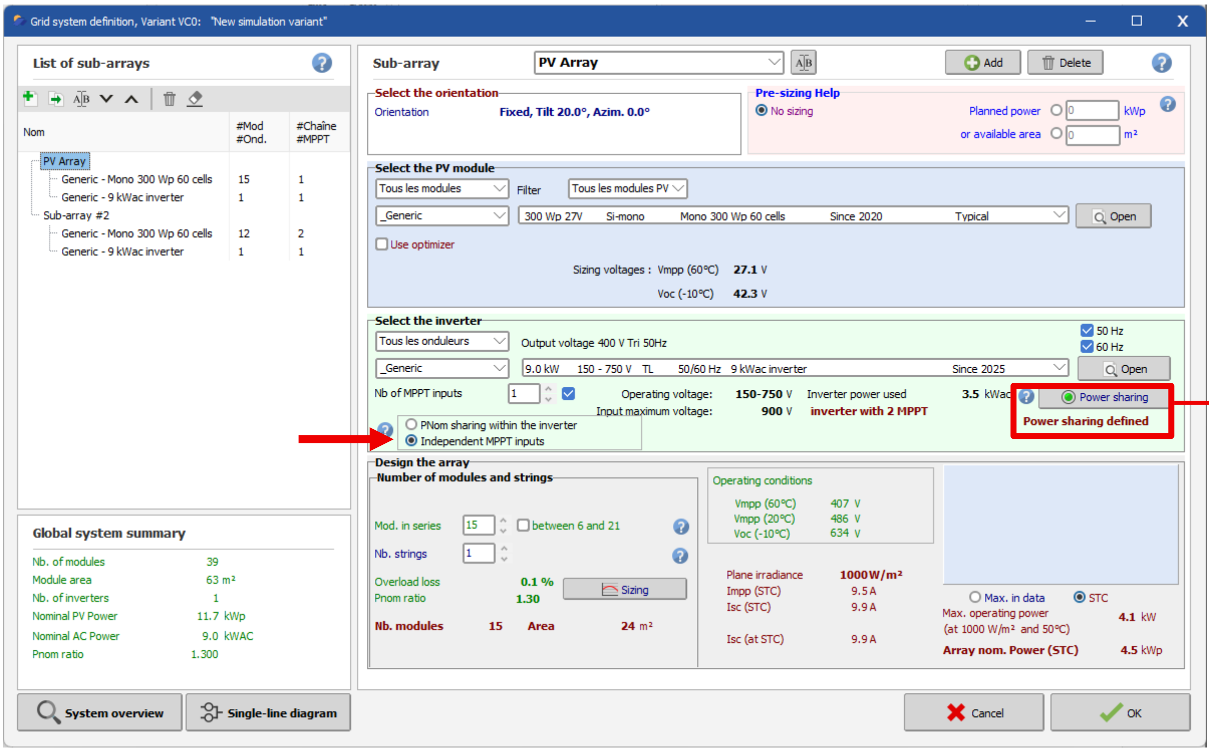
Thus, in the case of different length of strings or panels oriented differently on your site, in the case of partial shading due to objects nearby or in the case of soiling; the multi-MPPT allows the system to mitigate the impact by adjusting the operation of the affected strings without affecting the 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,**



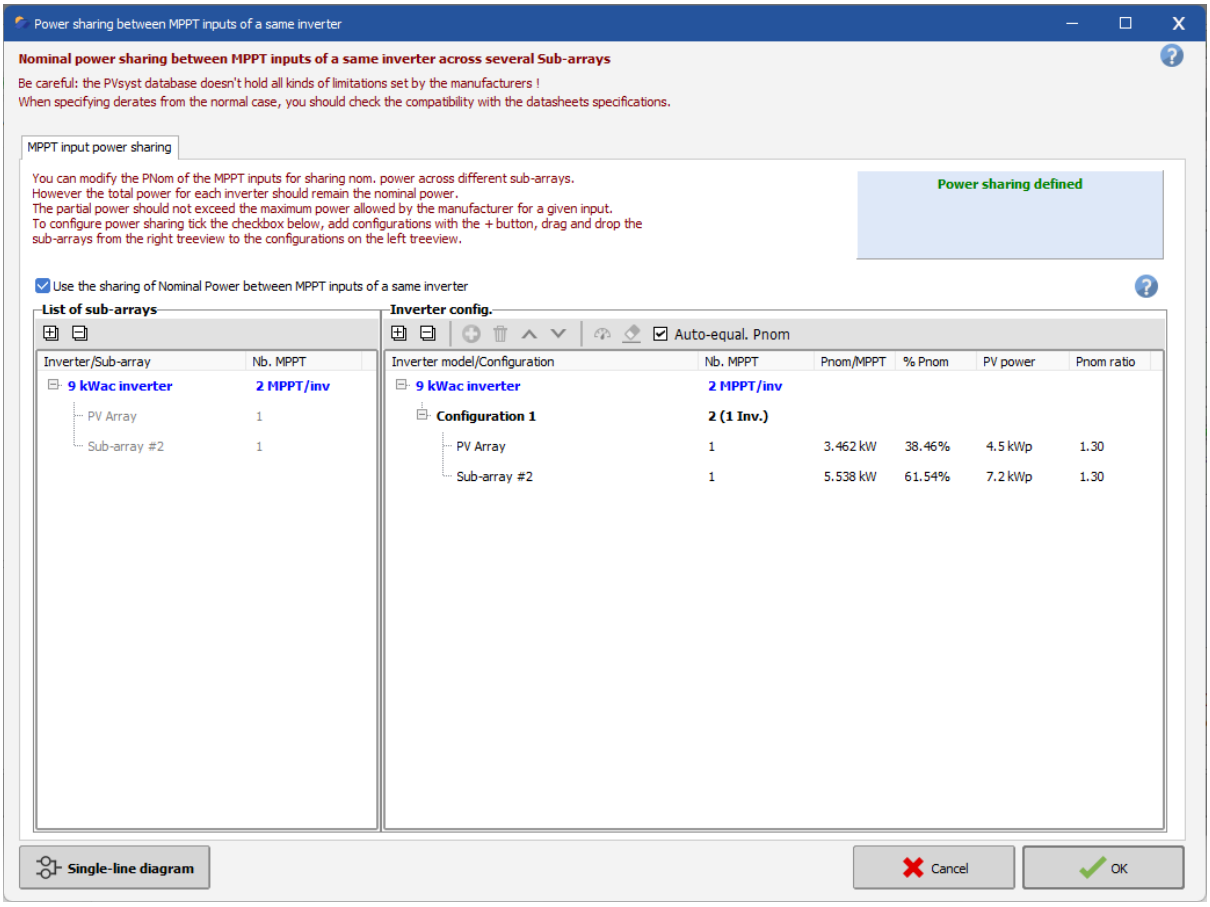
it is possible to consider the single MPPT inputs.

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.

Power sharing ensures that the power generated by each MPPT controller is efficiently distributed among the different strings or groups of modules by assigning each sub-array to a power sharing group.

On the right side of the power sharing window, you can find the inverter configuration. By dragging a sub-array from the list on the right into the inverter configuration window, you can assign multiple sub-arrays to the same inverter.

A summary of the sub-array characteristics will be displayed, including the number of MPPTs, the nominal power for each MPPT, the percentage of the inverter's total nominal power, the installed PV power in the sub-array, and the nominal power ratio within the sub-array.



Power sharing is automatically balanced when **Auto-equalize Pnom** is checked. You also have the option to manually distribute and/or adjust the power assigned to each sub-array by unchecking this option.

By clicking on the **weight icon**, the Pnom ratio is balanced, and by clicking on the **eraser icon**, the Pnom ratio is reset.

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:*

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

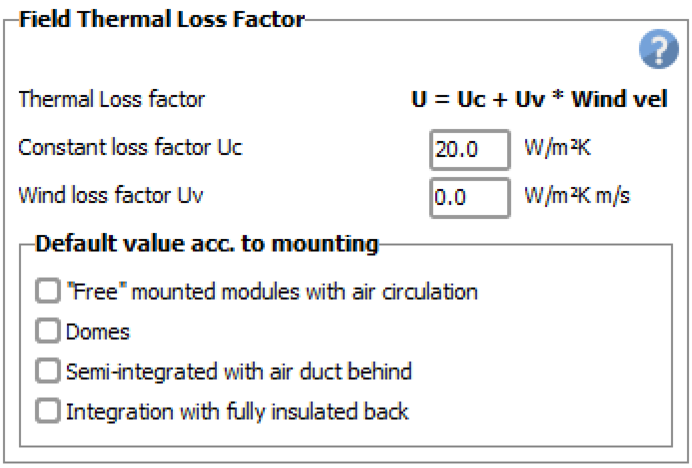
The thermal loss factor, or U-value in PVsyst, represents the ability of the photovoltaic system to dissipate heat. The more efficiently heat is removed, the lower the module temperature, and the lower the associated performance losses.

Free-standing modules, benefiting from better air circulation, dissipate heat more effectively and therefore have higher U-values. In contrast, building-integrated modules retain more heat, resulting in lower U-values and higher performance losses.

In practice, we recommend not using wind dependence, as wind speed is generally poorly defined in meteorological data, and the Uv parameter is not well known. Therefore, Uv is usually set to 0, and an average wind effect is included in the constant term.

Based on our own measurements on several systems, PVsyst provides default values depending on the mounting type:

- **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.

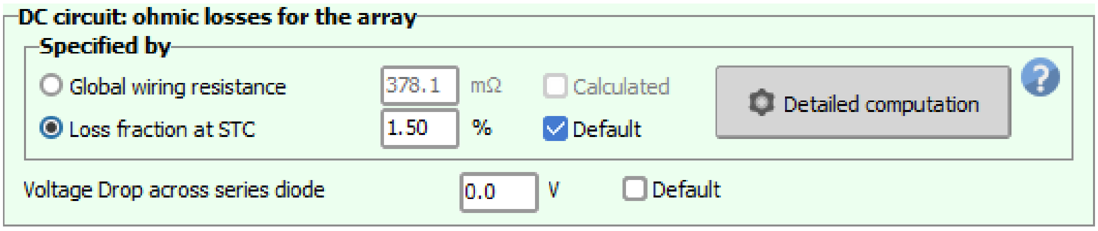
5.2 Ohmic Losses

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.

It is also possible to define DC ohmic losses by directly specifying a global wiring resistivity. This approach can be used when the wiring layout is designed in third-party software that allows this value to be extracted and then imported into PVsyst.

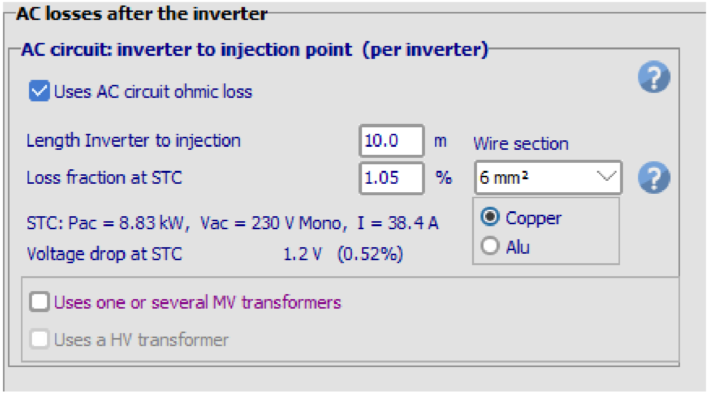


NB: remember that the wiring loss behaves as the square of the current. Therefore, operating at half power will lead to only a quarter of the relative loss. The effective loss during a given period will be given as a simulation result and shown on the loss diagram. It is usually of the order of 50-60%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

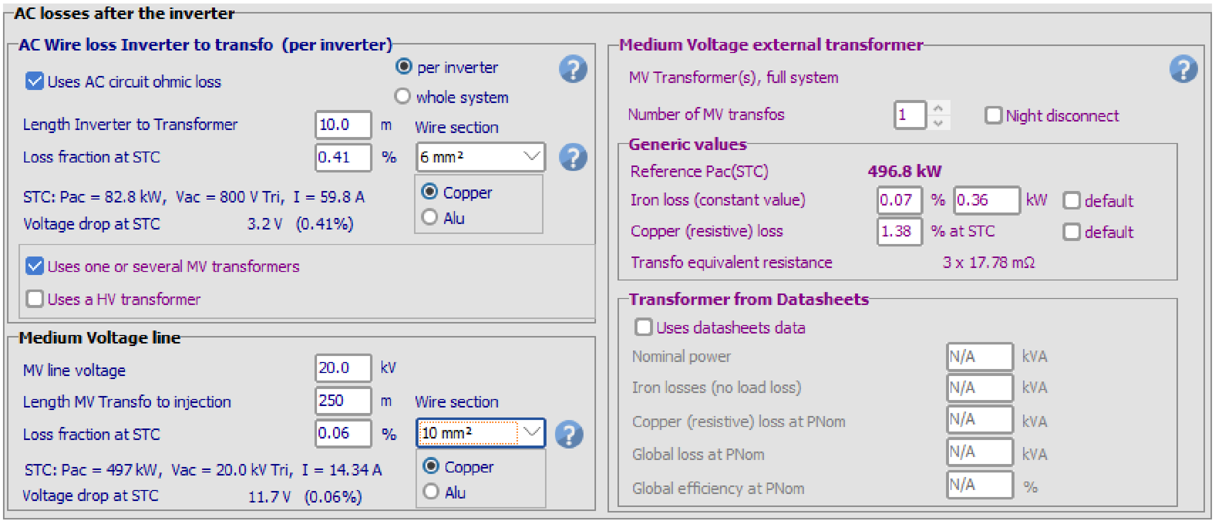
It is also possible to include losses between the output of the inverter and the injection point (energy counter). You just have to define the distance, and the loss will also appear in the loss diagram.



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).

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).

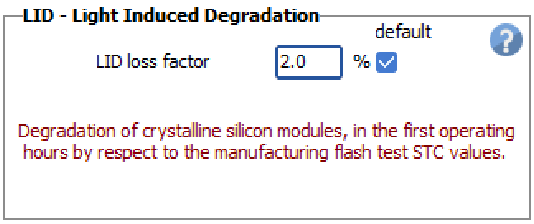
Note that, this value of a quarter between low and high tolerance is the PVsyst choice. We usually consider a conservative option (i.e. the modules will never be better than announced). It doesn't have any other background reasons.

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.

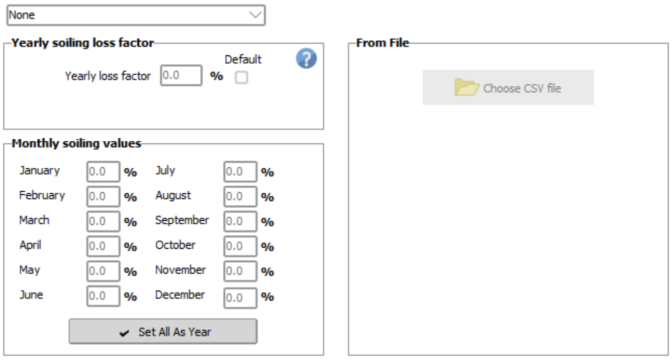
This is a transient effect, affecting usually some few seconds or minutes within the hour. PVsyst neglect this in the present time.

5.4 Soiling loss

Soiling buildup and its impact on system performance is an uncertainty that strongly depends on the system environment, rainfall conditions, etc. Soiling losses can become significant in certain industrial environments or in desert climates.

Soiling losses can be defined individually for each month to account for periodic cleaning or rainy periods. This parameter can also be used to represent the effect of snow covering the modules.

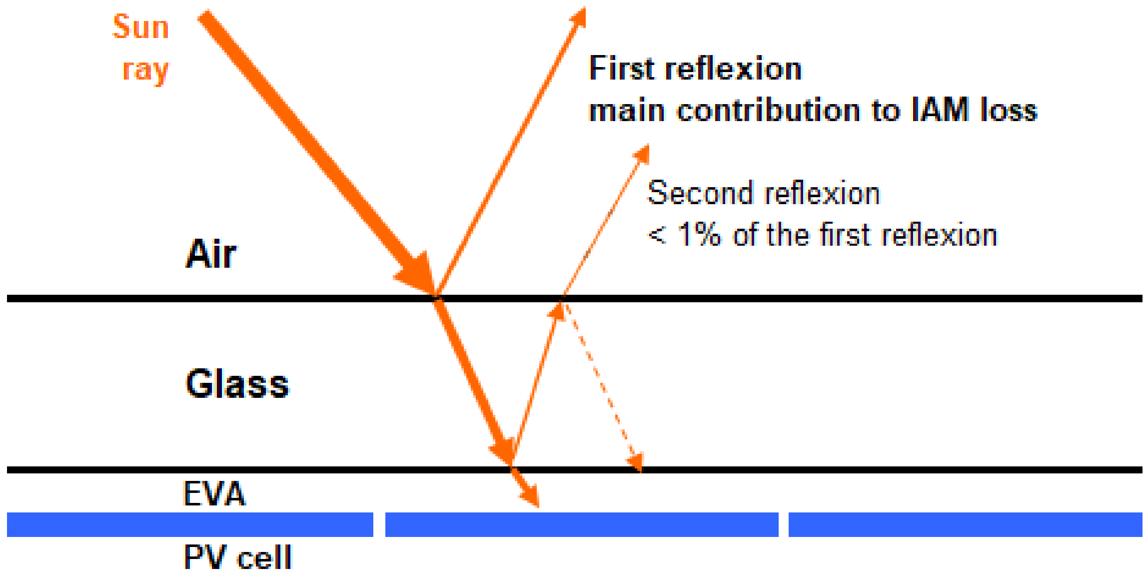
It is also possible to import soiling values at an hourly resolution from a CSV file.



5.5 IAM Losses

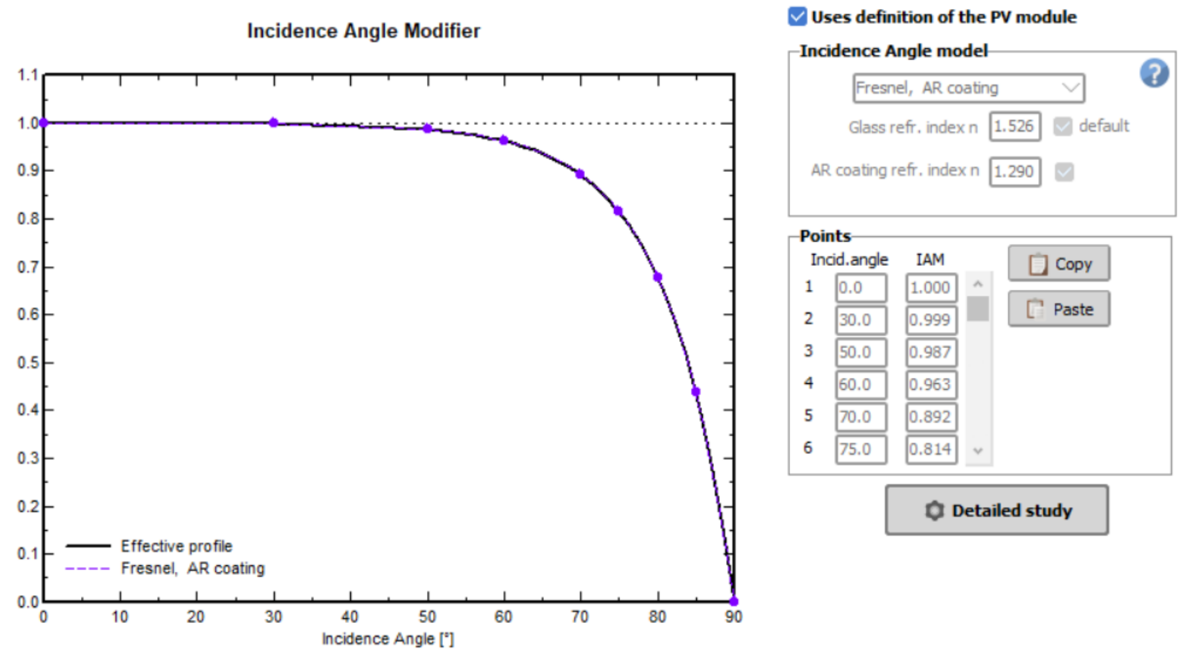
The incidence effect (the designated term is IAM, for **Incidence Angle Modifier**) corresponds to the decrease of the irradiance really reaching the PV cells' surface, with respect to irradiance under normal incidence. This decrease is mainly due to reflections on the glass cover, which increases with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

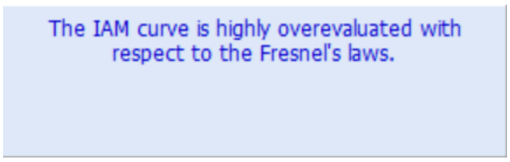


PVsyst uses an IAM function, which describes the deficit of transmission as a function of the incidence angle. This function is applied to the beam component, and to the diffuse and albedo, using an integral over all *seen* directions, supposing an isotropic distribution of the diffuse irradiance.

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

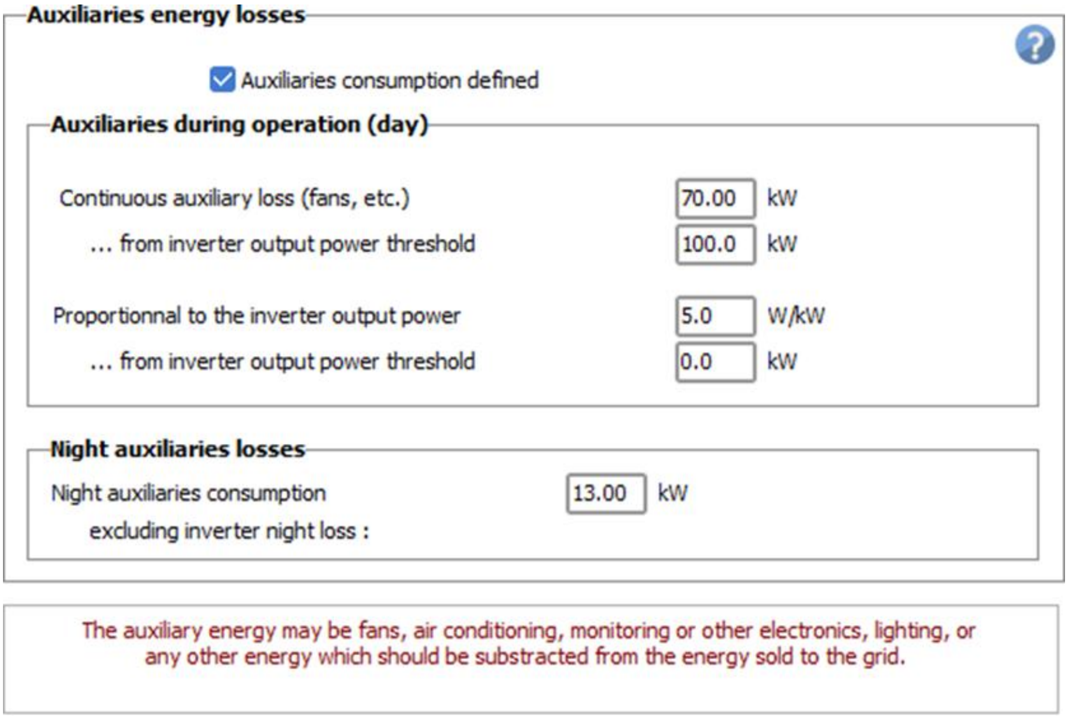
Auxiliary consumption corresponds to the energy used for the operation and management of the system. This may include fans, air conditioning, electronic equipment, lighting, monitoring, or any other consumption that must be deducted from the PV energy produced before it is delivered to the grid.

Some inverters already include auxiliary consumption (for example for cooling). This value can be automatically taken into account.

Warning: if this consumption is already included in the inverter efficiency, it should not be added here in order to avoid double counting.

It is only taken into account in the simulation if the **Auxiliary consumption defined** option is checked.

Example (100 MW plant)



During the day:

There is a constant power loss (e.g., 72 kW) that becomes active only when the system output exceeds 100 kW.

There is also a consumption proportional to the output power (e.g., adaptive cooling), expressed in W/kW.

Both contributions are independent and additive.

During the night:

The nighttime consumption is constant (13 kW in this example). It does not include the inverter's intrinsic nighttime loss (defined in the inverter as IL_Night loss).

The total auxiliary consumption (day + night) is accumulated in the variable **Aux_Lss**.

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.

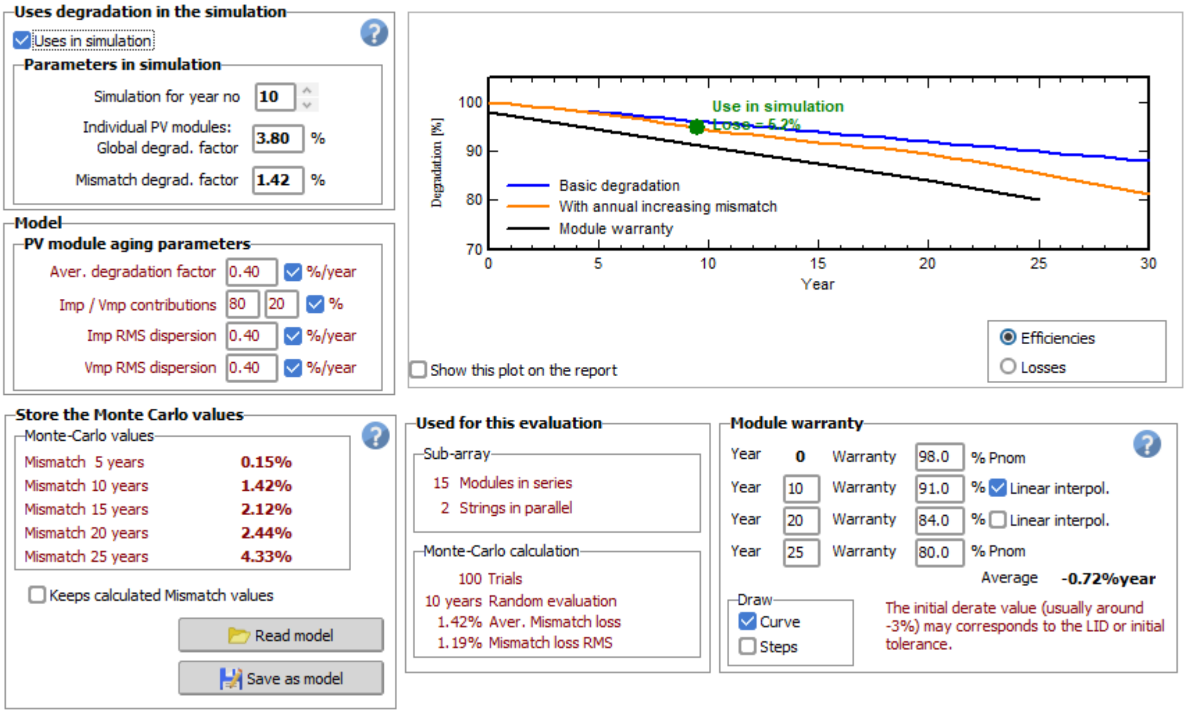
The Manufacturer's warranty should be understood as a **lower limit** for any individual PV module.

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.

Moreover, not all modules will degrade to the same extent. If there is a distribution of degradation rates around the average, this will lead to additional mismatch losses, which increase over time.

In PVsyst, you can specify the RMS value (standard deviation) of this distribution (assumed to be Gaussian), and the program will evaluate the resulting mismatch as a function of system age. This calculation is performed using a Monte Carlo method (based on a large number of random distributions), with the following assumptions:

- The degradation rate of each module is assumed to be constant over the years.
- The distribution is limited to 2 sigma (95% of values), as larger deviations would result in very high mismatch losses.



You can choose to check the **Keep calculated mismatch values** option to ensure that the same Monte Carlo–generated values are used in each simulation. You can also save them as a template and apply the same random distribution to other projects.

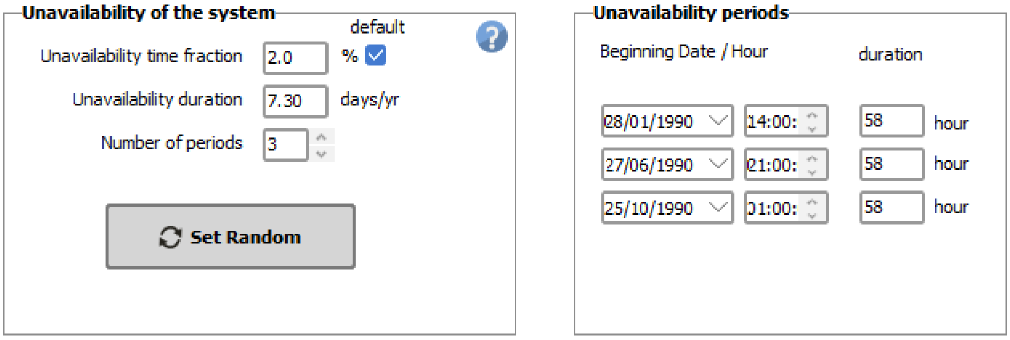
These parameters allow for a realistic representation of the PV array performance over the system lifetime, as well as the progressive increase in mismatch losses between modules.

In practice, average degradation rates between **0.3%/year** and **0.5%/year** are commonly used. The **RMS dispersion on current (Imp)** is typically in the range of **0.3%/year to 0.6%/year**, while the **RMS dispersion on voltage (Vmp)** is generally lower, often between **0.1%/year and 0.4%/year**.

Default values are suitable in most cases and should only be modified for specific analyses or when field data is available.

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.

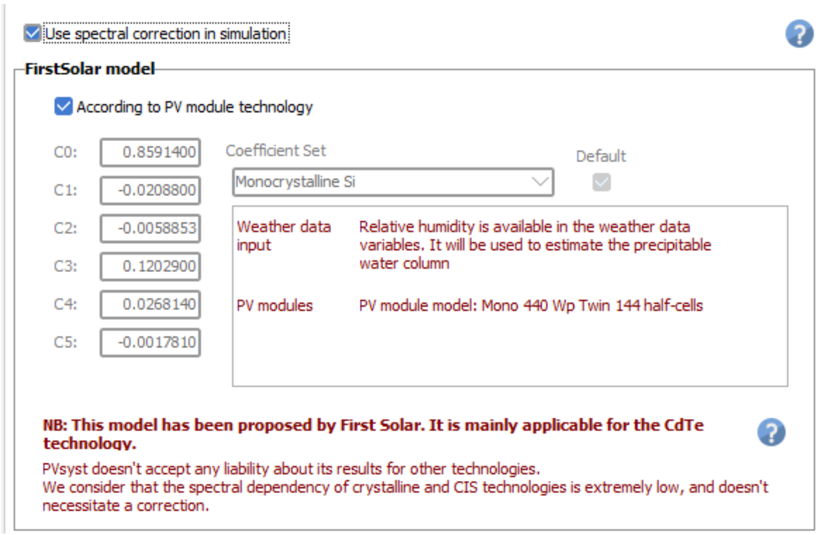


5.9 Spectral correction

The First Solar spectral correction model accounts for variations in the solar spectrum caused by atmospheric scattering and absorption. These variations depend on factors such as water vapor content, aerosols, and the optical path length, quantified by the Air Mass. Since different photovoltaic technologies have distinct spectral responses, spectral corrections can influence performance modeling.

PVsyst offers the option to apply the spectral correction model developed by First Solar. Although this model is particularly relevant for First Solar modules, users may choose to apply it to other technologies at their discretion.

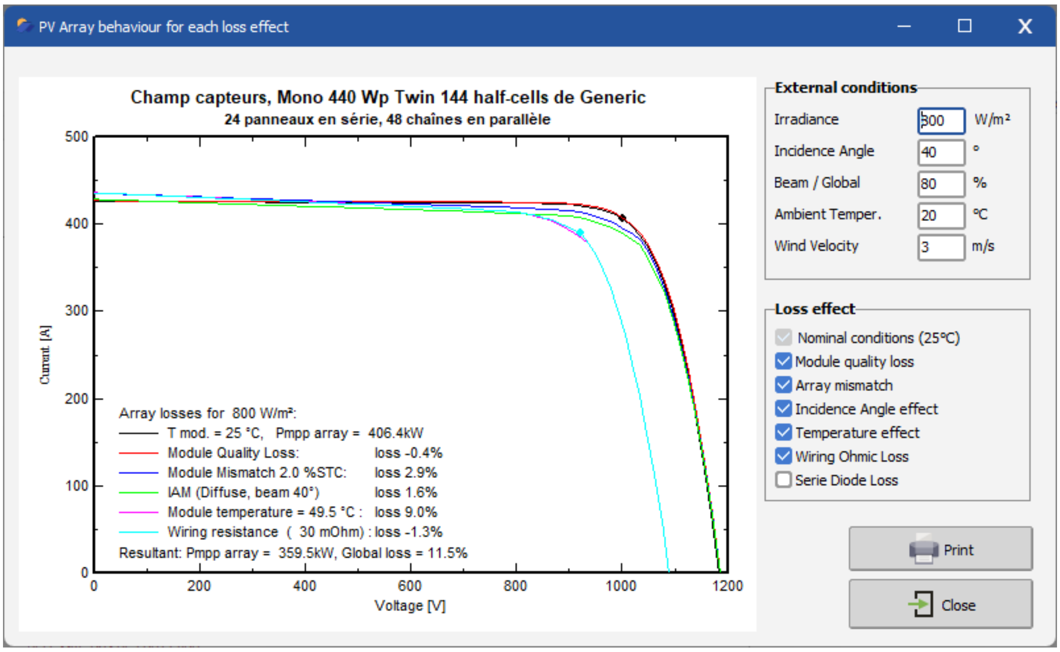
Please note that, to use this correction in the simulation, the meteorological data must include **precipitable water** and **relative humidity**. PVsyst implements several models to describe spectral correction:



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.

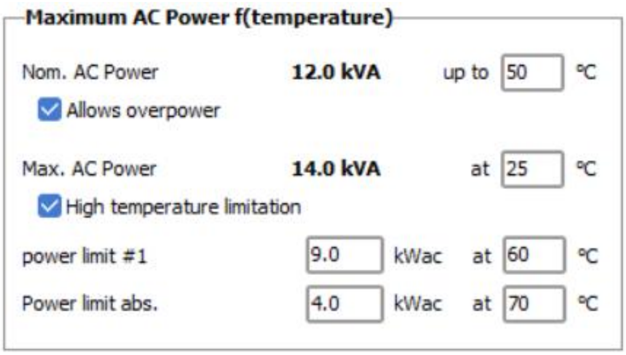


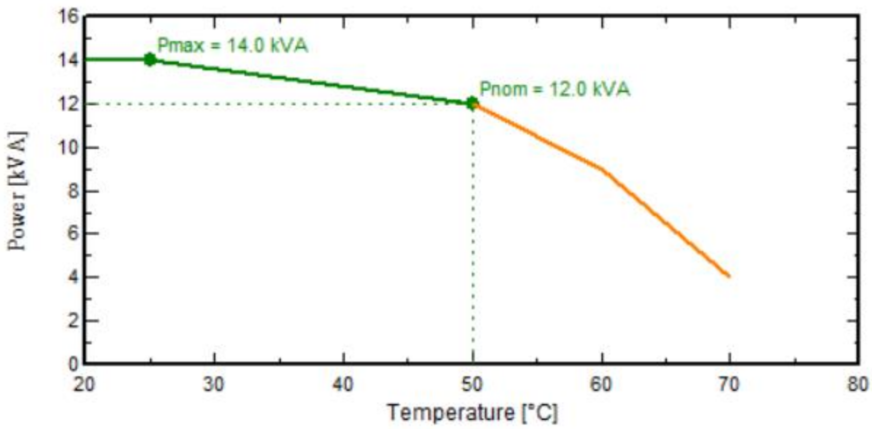
6 Energy management

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.

6.1 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.



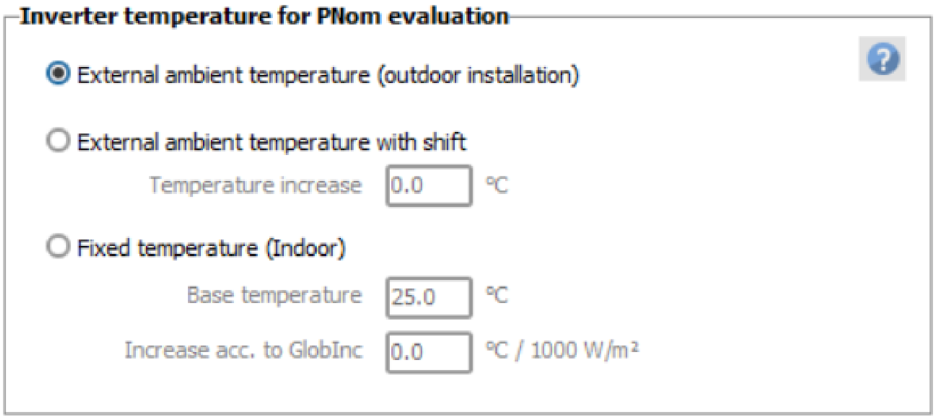


In the simulation, by default the inverter temperature is the external ambient temperature (outdoor installation). This strategy can be modified in Inverter Temperature page in the Energy management.

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.



6.2 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:

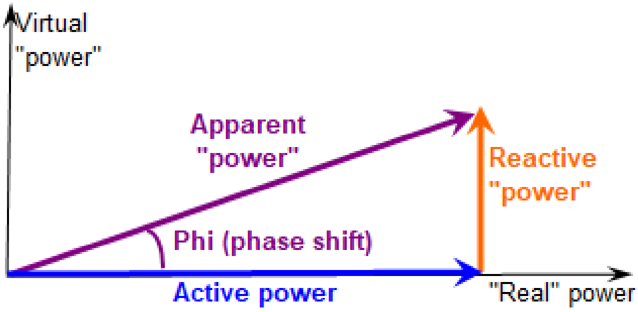
$$P_{apparent} = U_{eff} * I_{eff}$$

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.

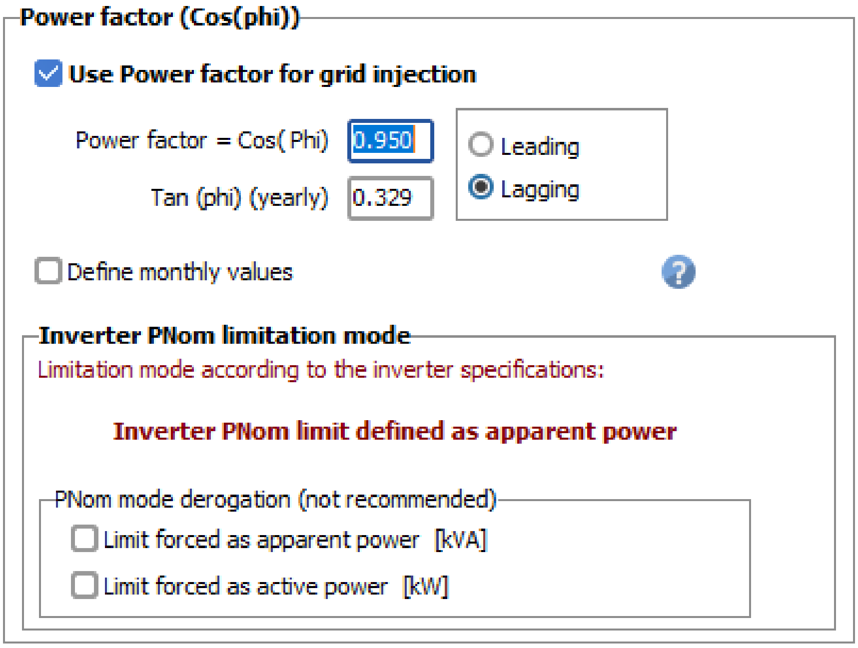
When the power factor decreases (i.e., more reactive power is produced), the current in the system must increase to maintain the same level of active power. Since ohmic losses in cables and transformers are proportional to the square of the current, this leads to higher energy losses in the system:

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

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.

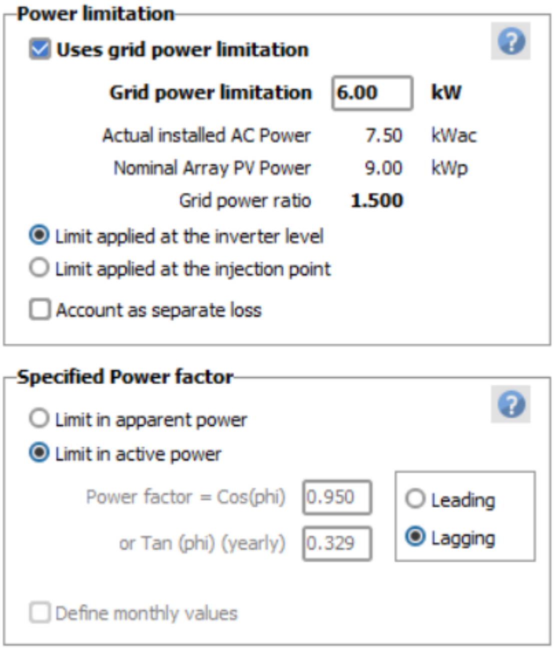
Force as apparent/active power" will force all inverters to operate under this conditions. This means that inverters may not operate like in the datasheet anymore.

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

6.3 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.

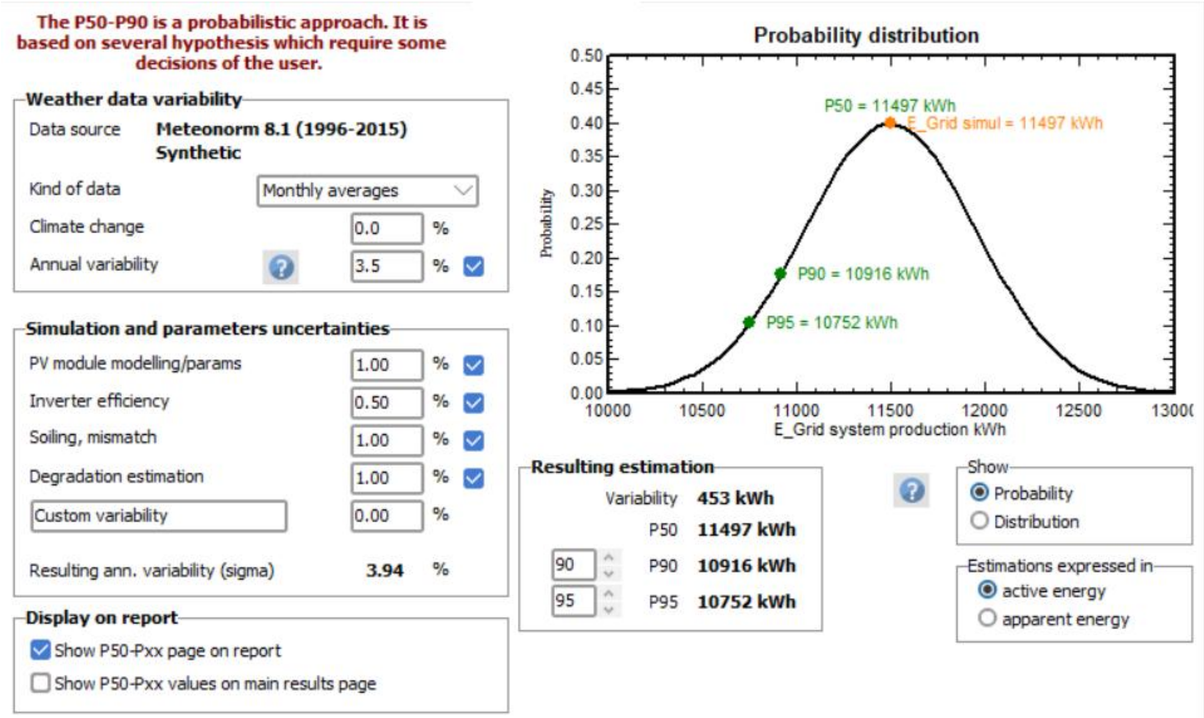
The excess energy will be accounted as "Inverter loss over nominal power" or when checking "Account as separate loss", the results will show separately the loss due to the inverter limitation itself, and the loss (named EUnused) due to the additional condition of grid limitation. This does not correspond 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.

6.4 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.

7 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.

Important: the CSV file must be based on a 365-day year (February with 28 days). Using a leap year may cause errors in the interpretation of profiles in the simulation.

By running the simulation, results will be obtained for the unused energy injected into the grid, the energy consumed by the user, and the energy drawn from the grid, representing the energy required when production is insufficient, for example during the night.

8 Storage

The battery storage implementation in PVsyst includes 4 storage strategies:

- **Increased Self-consumption**
- **Energy shifting** consists of storing part of the PV energy available during the day and releasing it later.
- **Peak shaving**, when the grid-injection power is limited
- **Weak grid recovery**, for ensuring an electricity supply when the grid is failing.

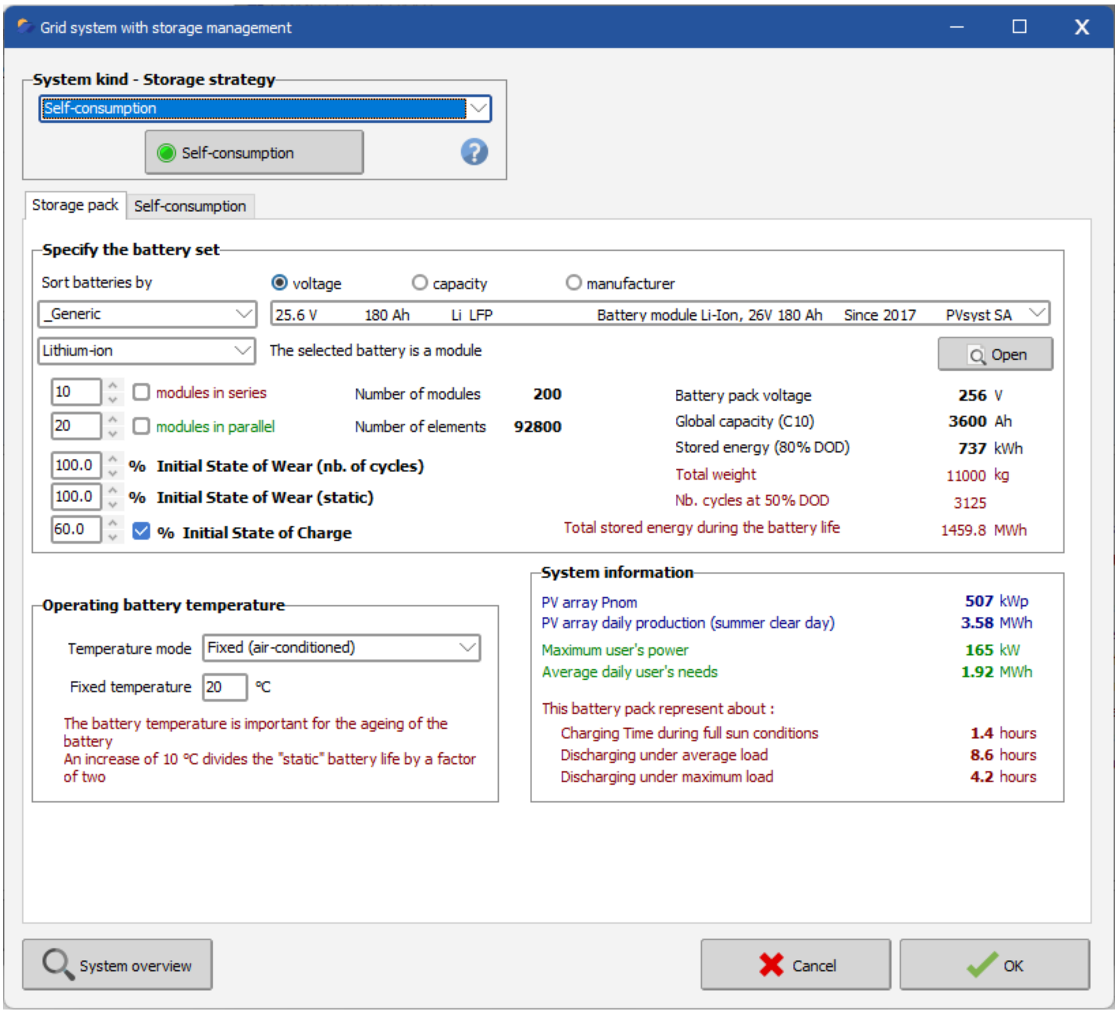
Each of these strategies have different constraints.

- **Self-consumption and Weak grid recovery** : These modes require a detailed hourly load profile of the user's consumption. For weak grid support, a grid availability schedule must also be defined. Depending on the configuration, the injection of excess PV energy into the grid may or may not be allowed.
- In both strategies, the battery never feeds the grid. It only starts charging when PV production exceeds the instantaneous demand.
- **Peak shaving and energy shifting**: these strategies are focused on interaction with the grid and do not depend on a user load profile. The timing of battery discharge varies depending on the chosen strategy, electricity costs, or optimization objectives.

The sizing of the PV array and the storage system—based on energy needs, load profile, and electricity prices—remains a complex task and is highly dependent on the selected strategy. PVsyst only provides simplified guidelines to support this process.

8.1 Battery pack

This battery pack definition window is identical for the different storage strategies available in PVsyst.



The first step is to select a battery model from the database. Once the model is chosen, the pack configuration must be defined by specifying the number of modules in series and in parallel, which determines the system voltage and total storage capacity.

Initial battery state

Several parameters are used to define the initial state of the battery pack:

- **Initial state of wear (number of cycles):**

  Represents battery aging due to usage. A value of 100% corresponds to a new battery, while a lower value simulates a battery that has already undergone a certain number of charge/discharge cycles.

- **Initial state of wear (static):**

  Corresponds to calendar aging of the battery (independent of cycling), mainly related to time and storage conditions. Again, 100% represents a new battery.

- **Initial state of charge (%):**

  Defines the battery charge level at the beginning of the simulation. For example, 50% means the battery starts half charged.

Operating temperature

It is also possible to define the operating temperature of the batteries. 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.

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 **System information** box, you find additional information about your defined system as well as some estimation about the behaviour of the battery pack.

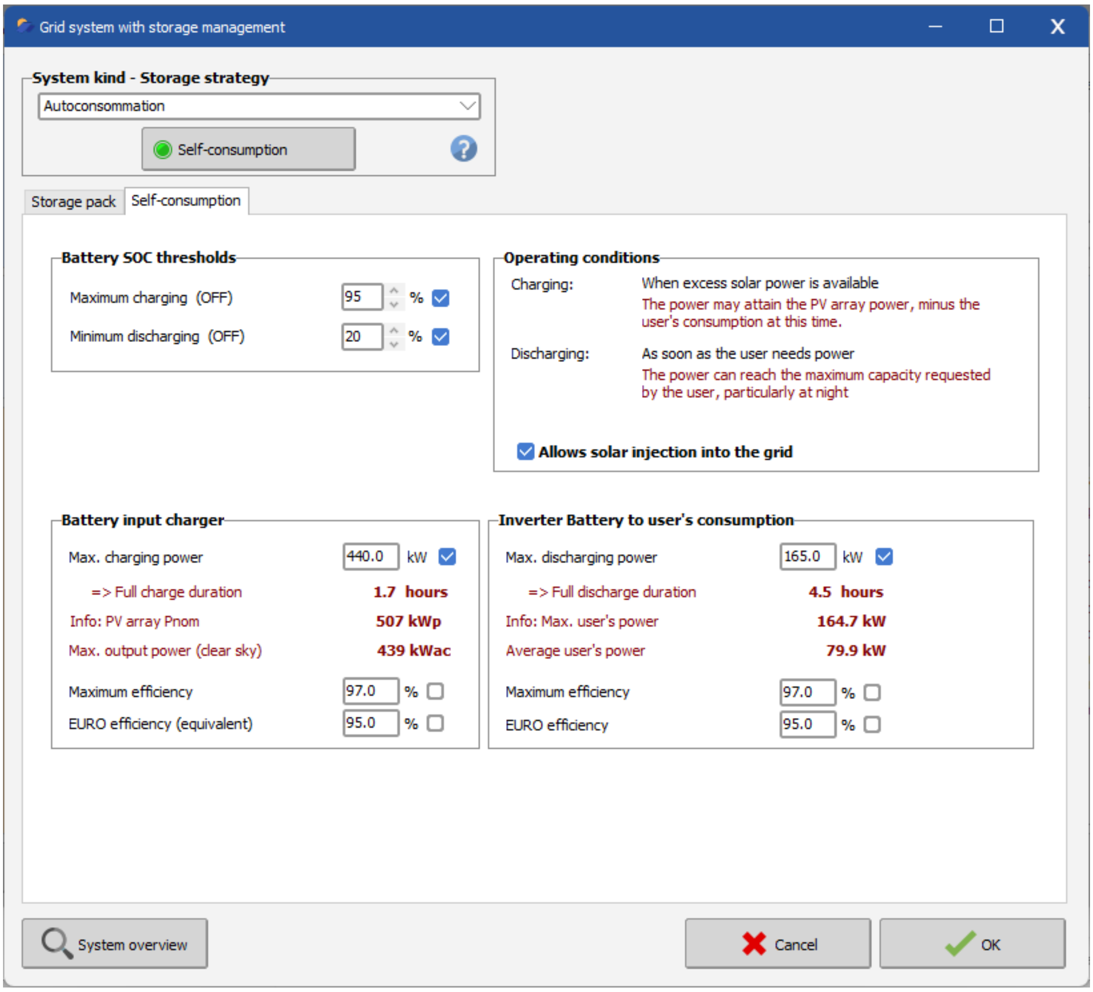
8.2 Self-consumption with storage

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.



8.3 Power shifting

This strategy consists of storing part of the PV energy produced during the day in order to release it later, during periods when electricity tariffs are higher.

> **Principle:** The user defines charge and discharge time windows and power levels. Energy is stored during the day and then released during high-tariff periods or upon request from the grid operator. No local consumption is considered: the operation is similar to "peak shaving."

In the presence of injection limits, excess PV energy exceeding the allowed threshold can be diverted to the battery, giving the system a partial peak-shaving function. This strategy is mainly intended for large-scale grid-connected installations to optimize energy valorization. It does not yet handle self-consumption in PVsyst.

The economic viability depends directly on the difference between peak and off-peak tariffs, as well as on the actual cost of stored energy.

Charging and discharging strategies: Three charging strategies are available and can be defined on a daily or hourly basis:

- **Fraction of PV production:** a fixed fraction of the available PV power is directed to the battery.
  Note: the fraction is applied to the nominal production **EArray**, not to **EoutInv**.
- **Fixed charging power:** the battery is charged at a constant predefined power. Any excess PV production, if available, is injected into the grid. If PV production is lower than the setpoint, all produced energy is sent to the battery, but the target power will not be reached.
  Note: losses apply; for example, sending 50 kW to the battery implies losses, and the actual stored energy will be slightly lower.
- **Fixed export to the grid:** a fixed power is injected into the grid, and any excess PV production is used to charge the battery. If PV production is lower than the fixed export power, all energy is sent to the grid, but the target export will not be reached.

The table below illustrates (without losses) how PV power is distributed between the battery and the grid for each strategy. This distribution assumes that the battery can accept charge; when it is full, any excess energy is sent to the grid.

Note: charging is also limited by the maximum charging power of the charger.

PV Production [kW]	**Fixed grid export: 100 kW**		**Fixed charging: 100 kW**		**Fraction: 40%**	
	Grid [kW]	Battery [kW]	Grid [kW]	Battery [kW]	Grid [kW]	Battery [kW]
50	50	0	0	50	30	20
100	100	0	0	100	60	40
150	100	50	50	100	90	60
300	100	200	200	100	180	120

Note: The "power shifting" mode is compatible with grid limitations. The **fixed export** strategy can be used as a peak-shaving mechanism.

Two discharge strategies are defined to control when and how the battery releases the stored energy:

- **Specified hours**: the battery discharges at a fixed power during the selected time periods. Different discharge power levels can be assigned to different time slots.
- **During the night**: the battery discharges during nighttime, with night hours determined from the meteorological (.MET) data used in the simulation. During dusk and dawn, the battery discharges for the corresponding fraction of the hour after sunset.

Procedure and sizing

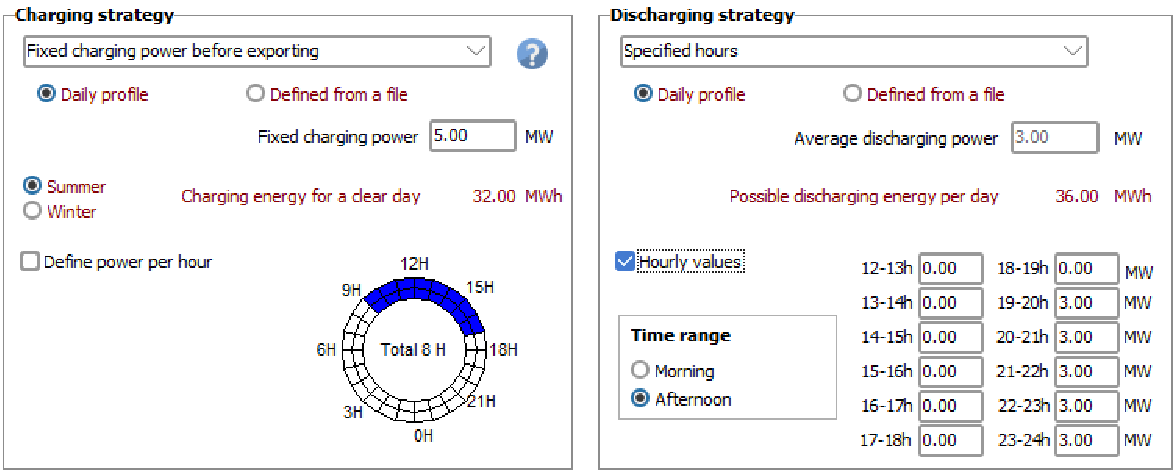
- **Define charging conditions:** select the charging periods (hourly or half-hourly) as well as the associated strategy:
  - either a fraction of the available PV production,
  - or a fixed charging power.

Charging fractions or power levels can be defined for each time interval.

For sizing purposes, PVsyst displays the expected charging energy **during a clear summer or winter day**, providing a reference for sizing the battery system.

- **Define discharging conditions:** similarly, select the discharging strategy, the discharging periods, and the corresponding power, which can be fixed or variable depending on the time.

For sizing purposes, the daily discharge energy should be close to or greater than the charging energy in order to ensure a complete daily cycle.



- **Battery pack definition:** in the "Battery pack" tab, select a battery model and define the number of cells/modules in series (operating voltage to match the charger/inverter requirements) and in parallel (storage capacity).
- **Sizing**: the battery size depends on the amount of energy to be stored during the day for later use (for example in the evening). This sizing results from an economic trade-off between storage cost and the associated benefits. Optimization typically involves running several simulations to compare tariff differences (direct kWh vs. stored kWh over the battery lifetime) with the cost of the battery system. Since energy shifting is limited to daily cycles, the battery capacity should not exceed the maximum daily charging energy.
- **Define the maximum charging power:** once the battery pack is defined, specify the nominal charger power in the **power shifting** tab. The default value is derived from the charging strategy for a clear day and is limited by the battery's maximum charging power. Oversizing should be avoided, as efficiency depends on the operating point relative to the efficiency curve. The maximum charging power should be higher than the target charging power, as losses occur.
- **Define the maximum discharging power:** finally, specify the nominal output power of the battery inverter. The default value is based on the maximum discharge power defined in the strategy and is limited by the battery's maximum power. The maximum

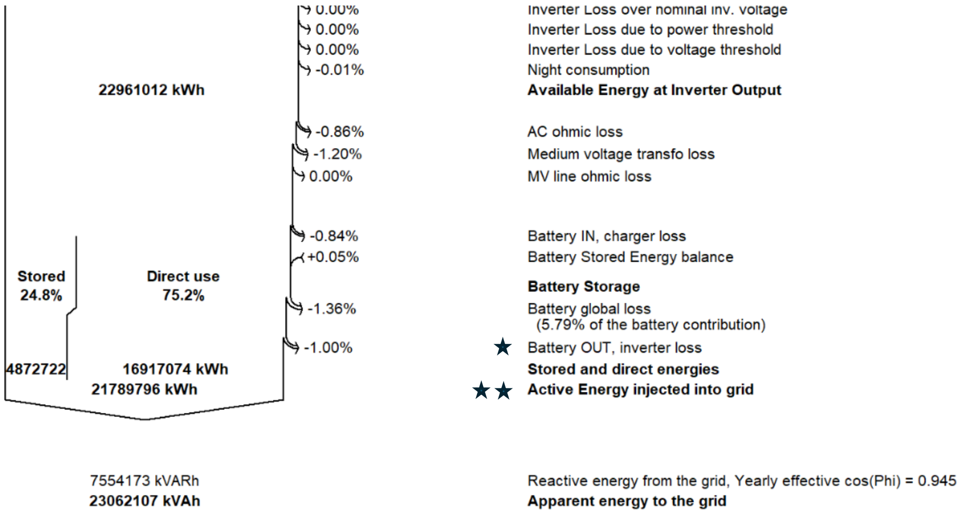
discharging power should be higher than the target power delivered to the grid, as losses also occur during discharge.

Grid limitation

Grid limitations (if any) must be applied at the point of grid connection, not at the inverter level. If the battery is full and the grid limitation is reached, the curtailed energy will be accounted for as **EGridLim**. Note that in the peak shaving strategy, this energy is accounted for as **EUnused**.

Simulation

The battery operates on daily cycles: it is discharged during the night and recharged during the day according to the selected strategy. After the simulation, energy flows are displayed in the loss diagram:



- **"Stored and direct energies" fraction**: portion of the available energy stored in the battery.
- **Battery energy – overall balance**: difference between charging and discharging energy (due to coulombic efficiency, internal resistance, self-discharge, or gassing in lead-acid batteries). This indicates the round-trip efficiency.
- ★ CL_Chrg, CL_InvB: efficiency losses of the charger and the battery inverter.
- Stored and direct energies: energies at the grid injection level. This is the main result for tariff-based evaluations.
- ★★ E_Grid: total energy delivered to the grid.

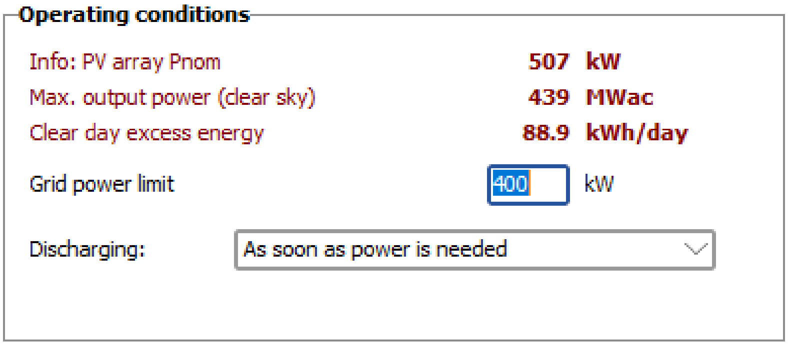
8.4 Peak shaving

If the grid injection capacity is limited by the operator, a battery system can store excess energy produced during periods of high production and release it when PV production falls below the allowed injection limit.

In addition, the peak shaving strategy can only be used in combination with a self-consumption profile.

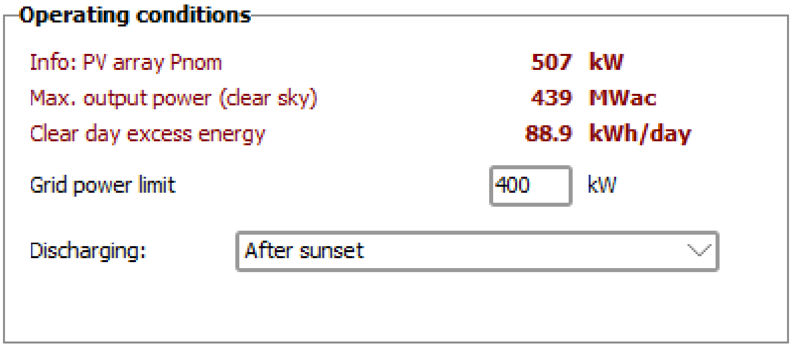
In the operating mode, you must define a grid power limit as well as a discharge strategy. Four options are available :

- The first option, which is also the default, is **As soon as power is needed**.



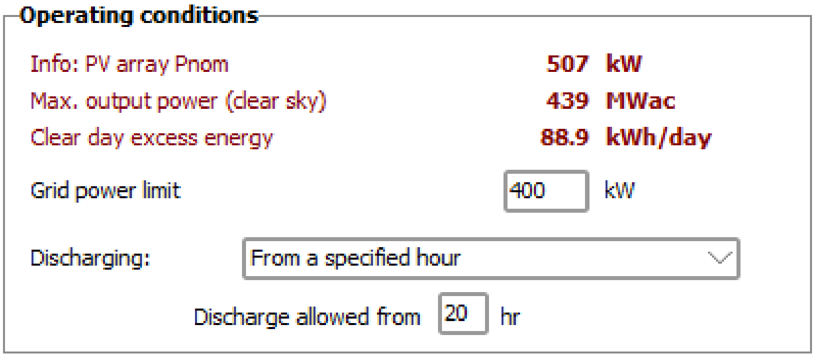
With this option selected, the battery will start injecting energy to the grid as soon as the generated AC power is less than the grid power limit

- The second option is **after sunset**.



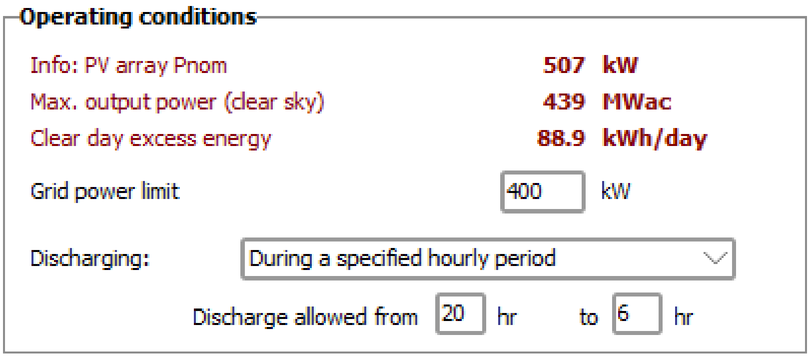
Here, the grid injection only starts when the PV generation has dropped to zero at the end of the day.

- 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**.



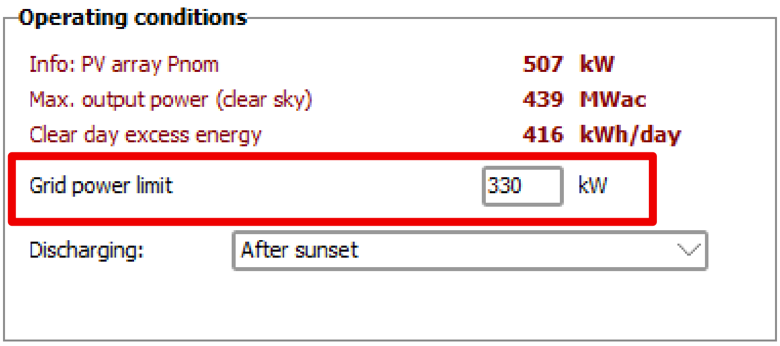
With this option two fields will appear, allowing you to input specific hours of the day. The battery discharging will only be possible between these two values.

Determine the battery capacity

Choose a battery pack able, ideally, to absorb the maximum excess energy during a clear day. A smaller capacity may be selected for budget reasons. Run simulations to identify the optimal size according to the economic requirements, while taking into account costs related to cycle aging.

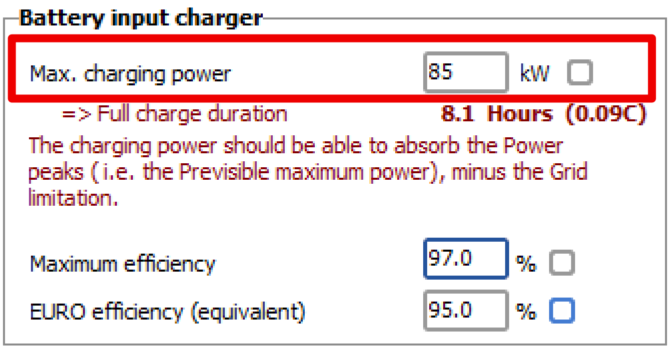
Define the grid injection power limit

The maximum PV power under clear-sky conditions is displayed in the window. Choose a grid power limit lower than this value.



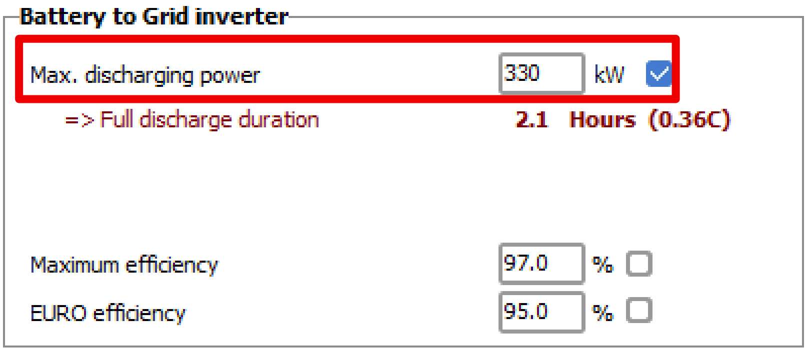
Specify the maximum charger power

Define the maximum input power of the charger by subtracting the grid power limit from the maximum PV power under clear-sky conditions.



Define the battery inverter power

The battery inverter power can be lower than the charger power, as discharging may extend over the night.



When using this strategy, it is essential to define the **corresponding battery pack** in the storage settings. Indeed, in order for the excess energy produced—when PV power exceeds the defined injection limit—to be effectively stored and later released, a battery with appropriate capacity and power must be selected.

8.5 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.

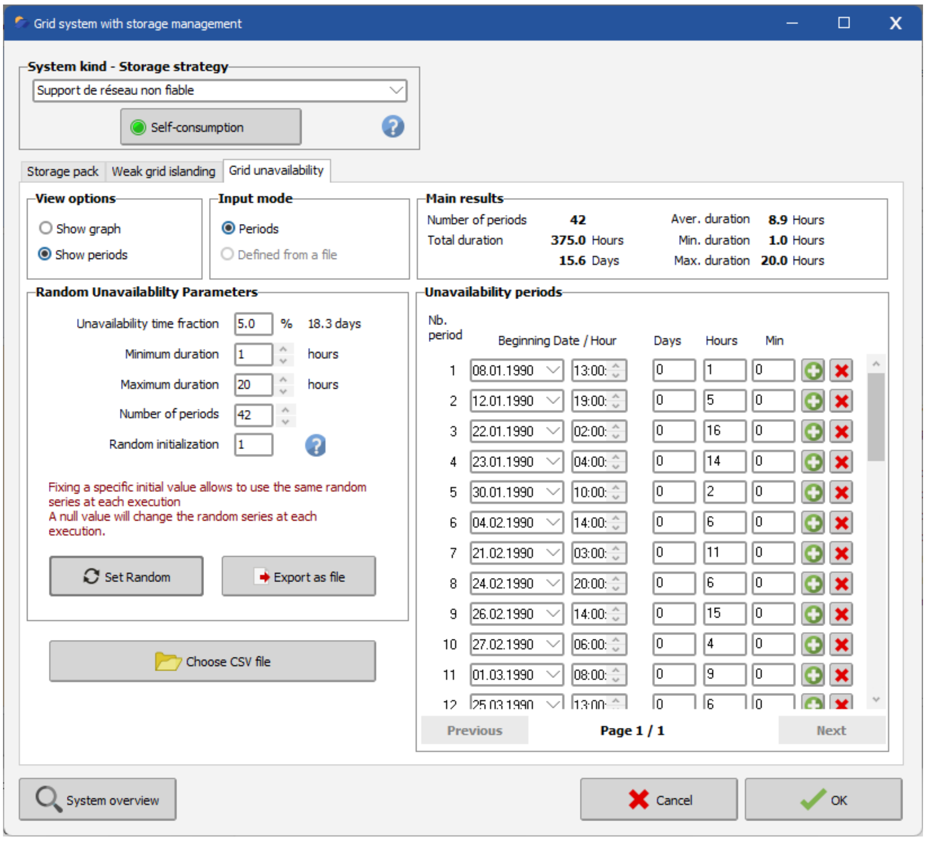
The PV energy is stored in a battery and returned to the user when the grid is unavailable. Technologically, this is far from being simple, as the usual solar inverters for feeding the grid require the presence of the grid for working. There may be several ways for avoiding this problem.

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.

9 Horizon

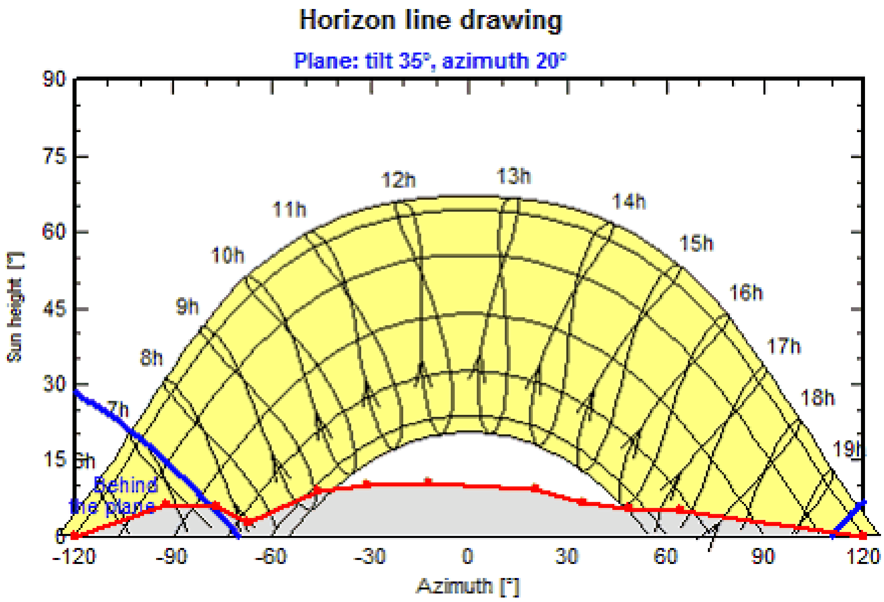
The horizon line allows the representation in PVsyst of **distant shading** objects that may block direct sunlight over the entire photovoltaic system, such as mountains, terrain features, or large buildings.
This shading is treated as a **global and instantaneous** effect: when the sun falls below the horizon line, the **direct** and **circumsolar** components of the irradiance are canceled for the entire PV field. The diffuse component remains partially available.

The horizon should only be used for **distant obstacles** whose effect can be considered uniform across the entire installation. For the horizon to be relevant, the shading objects should be located at a distance of at least **10 times** the size of the PV field.

Example: for a field 20 m long, obstacles should be located **more than 200 m away**.

In the case of very large PV plants, a global horizon may lose accuracy: the angle seen from one end of the site may differ from that seen from the other. In such cases, it is preferable to model the terrain in the 3D scene rather than using a single horizon line.

When the horizon includes points higher than **2°**, the green LED associated with the Horizon button is activated.



Click on the **Horizon** button to open the site's solar diagram.

This diagram represents the sun's altitude and azimuth throughout the year.

Two methods are available to generate a horizon line:

Manual drawing

- Move existing points using the mouse.
- Add/remove points with a right-click.
- Enter Azimuth / Height values directly in the table.
- The Clear horizon button allows you to start from scratch.

Import an existing profile

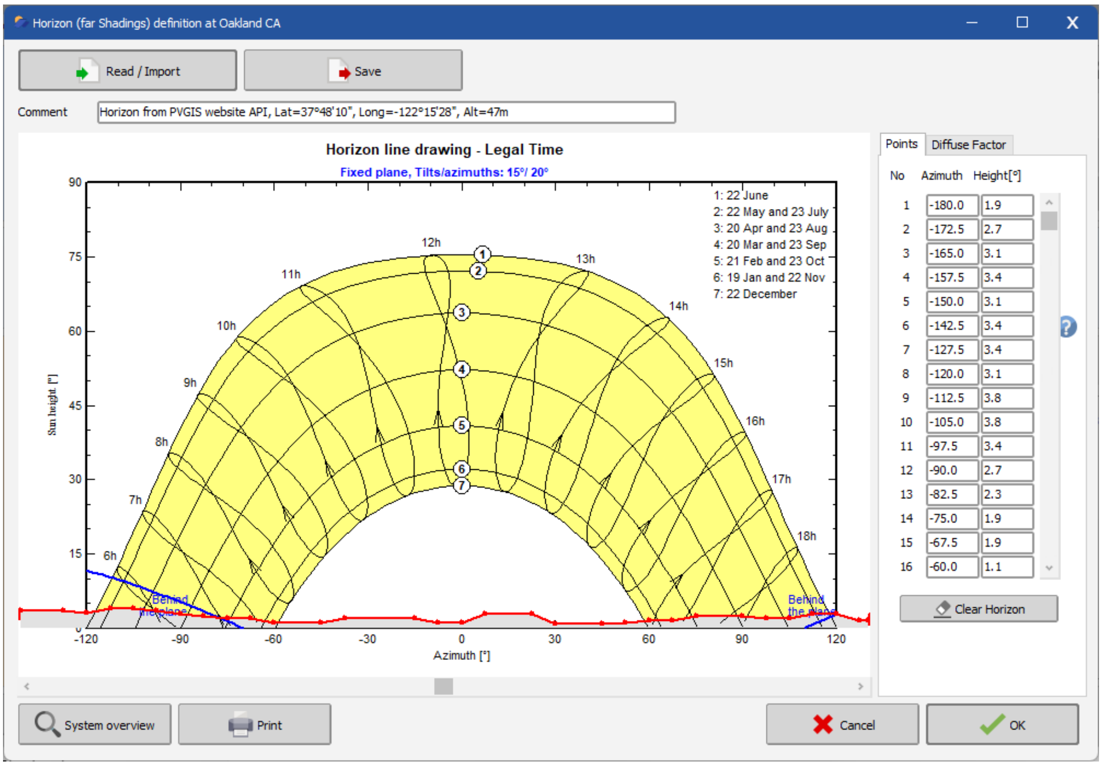
- a PVsyst internal file (.HOR),
- a structured CSV file (Azimuth, Height in degrees),
- a horizon generated by Meteonorm,
- an automatic horizon via PVGIS or Meteonorm Web.

When importing a CSV file, it is possible to define:

- the north reference angle,
- the rotation direction (clockwise / counterclockwise).

For profiles derived from geo-referenced databases (PVGIS, Meteonorm), it is essential to verify the exact **latitude and longitude**.

A precision of 0.0001° corresponds to approximately 11 meters, which can significantly affect the horizon in uneven terrain.

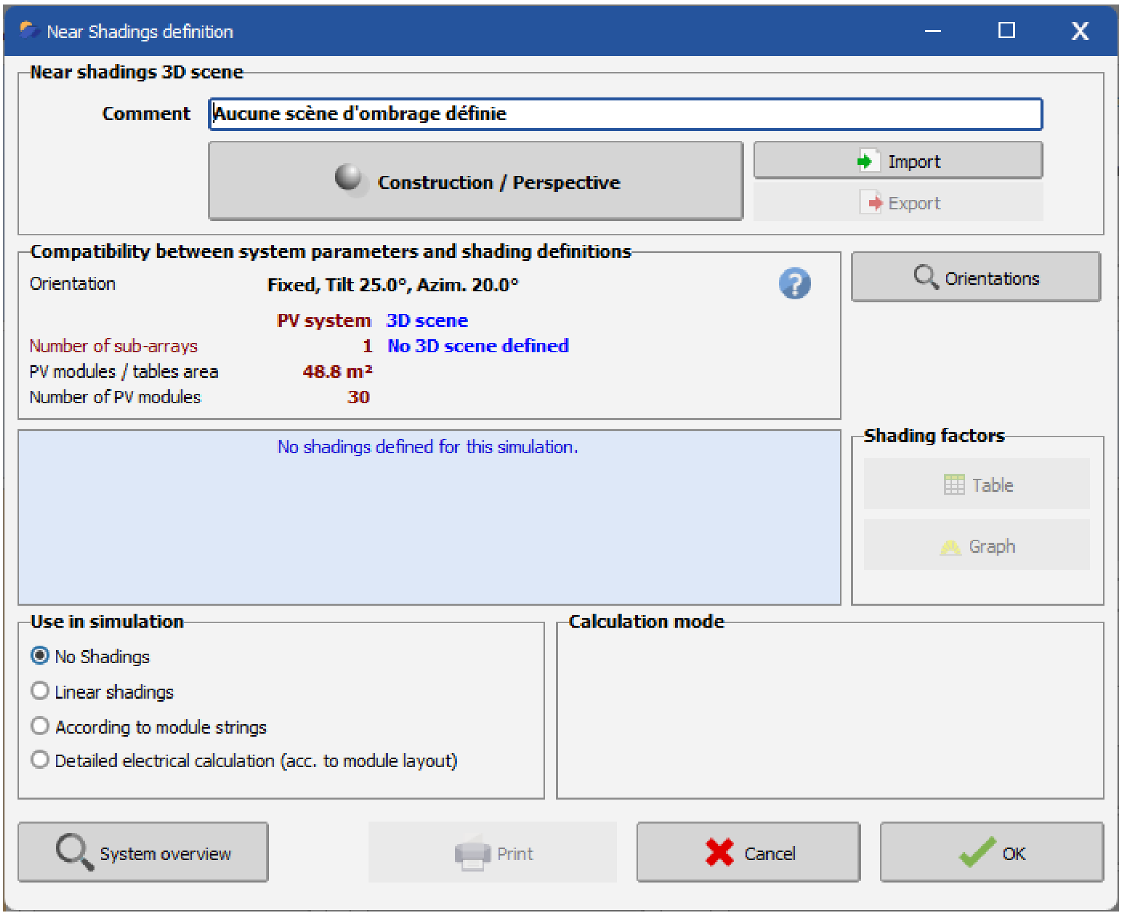


The horizon will then be taken into account during the simulation, and distant shading losses will be displayed in the report in both table and graphical form.

10 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.

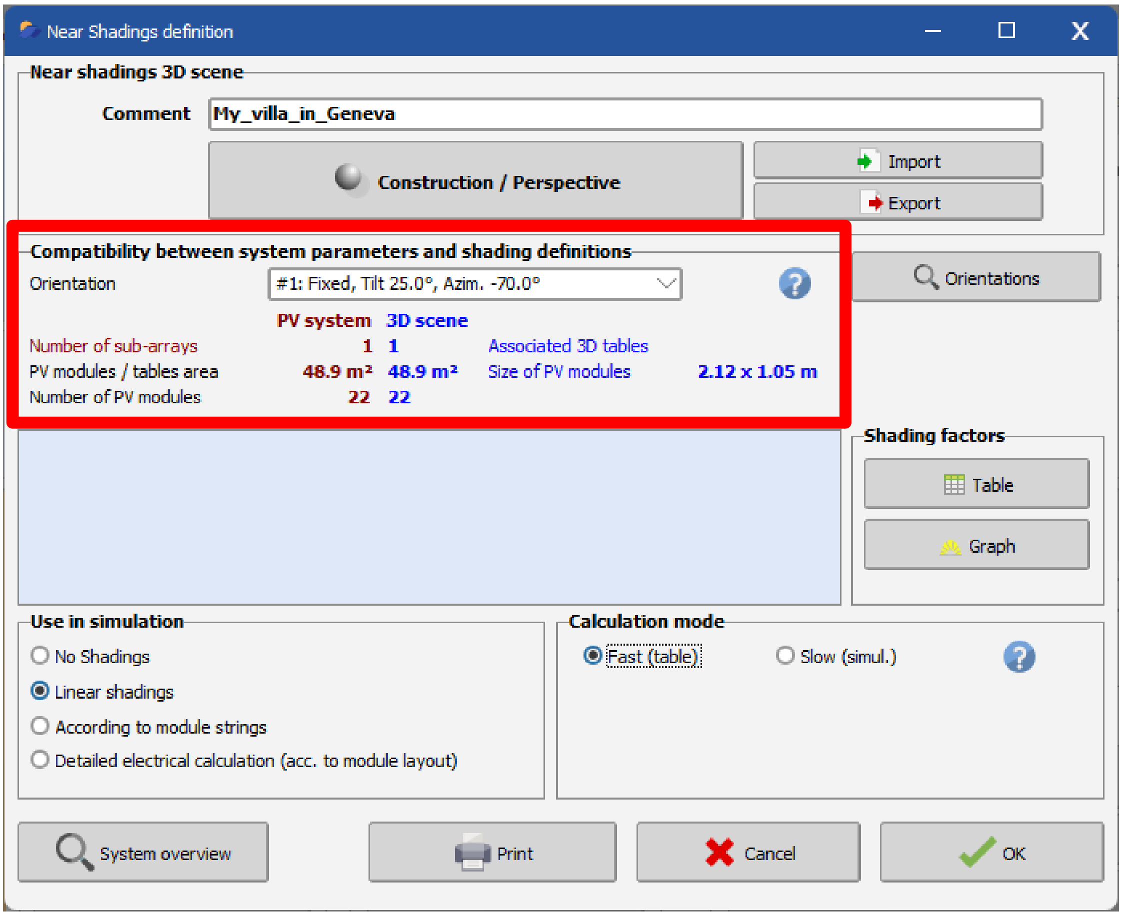


It is important to note that the primary objective of near shading is to precisely represent irradiance losses due to nearby objects and to help optimize the solar panel installation to minimize these losses. When defining objects that may create shading, as well as the topography, it is advised not 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.

10.1 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.



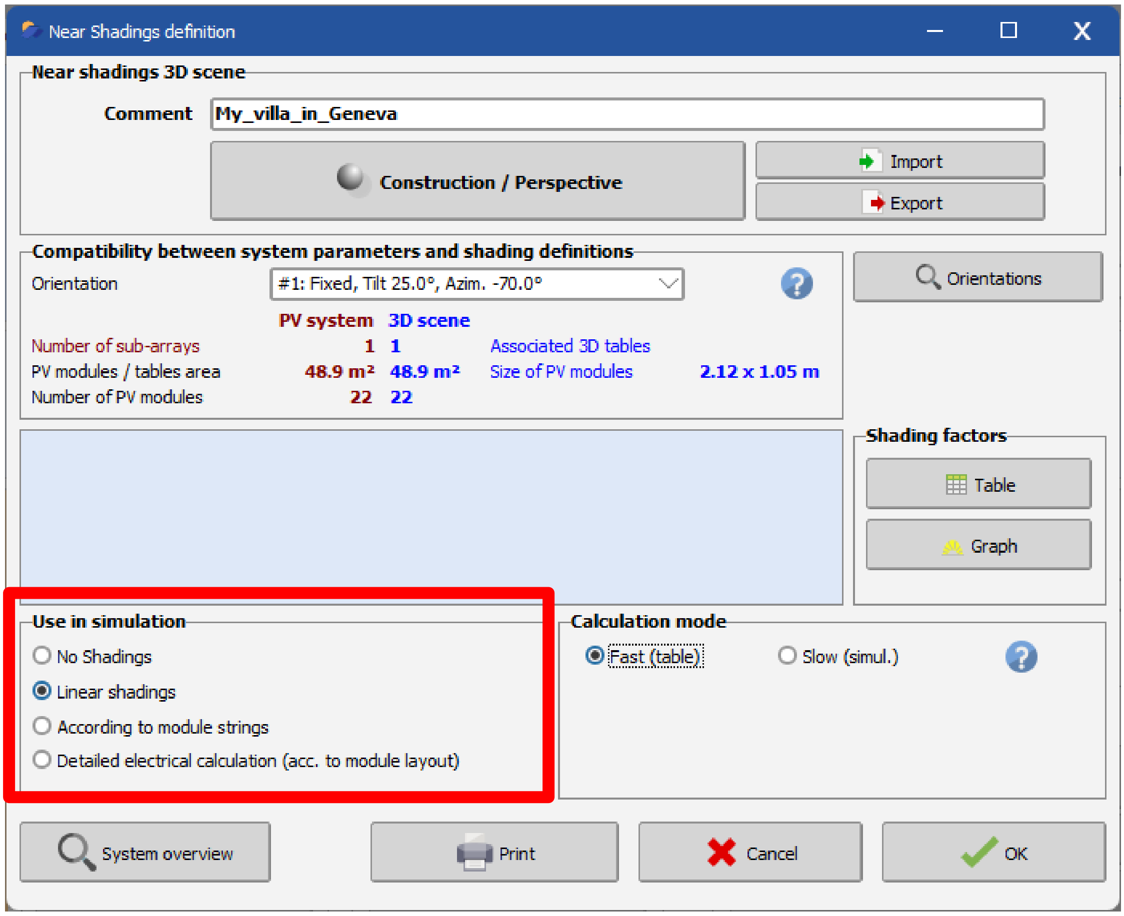
First, there is a dropdown list for the different existing orientations. Then, information about the number of sub-arrays, the surface area of the PV modules, and finally the total number of PV modules is displayed.

Regarding the PV module area, the software allows a tolerance for differences between the system definition and the 3D scene. This tolerance accounts for slight variations that may occur during the construction of the scene while ensuring consistent surface values.

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

10.2 Simulation Parameter

Three parameters calculate shading-related losses:



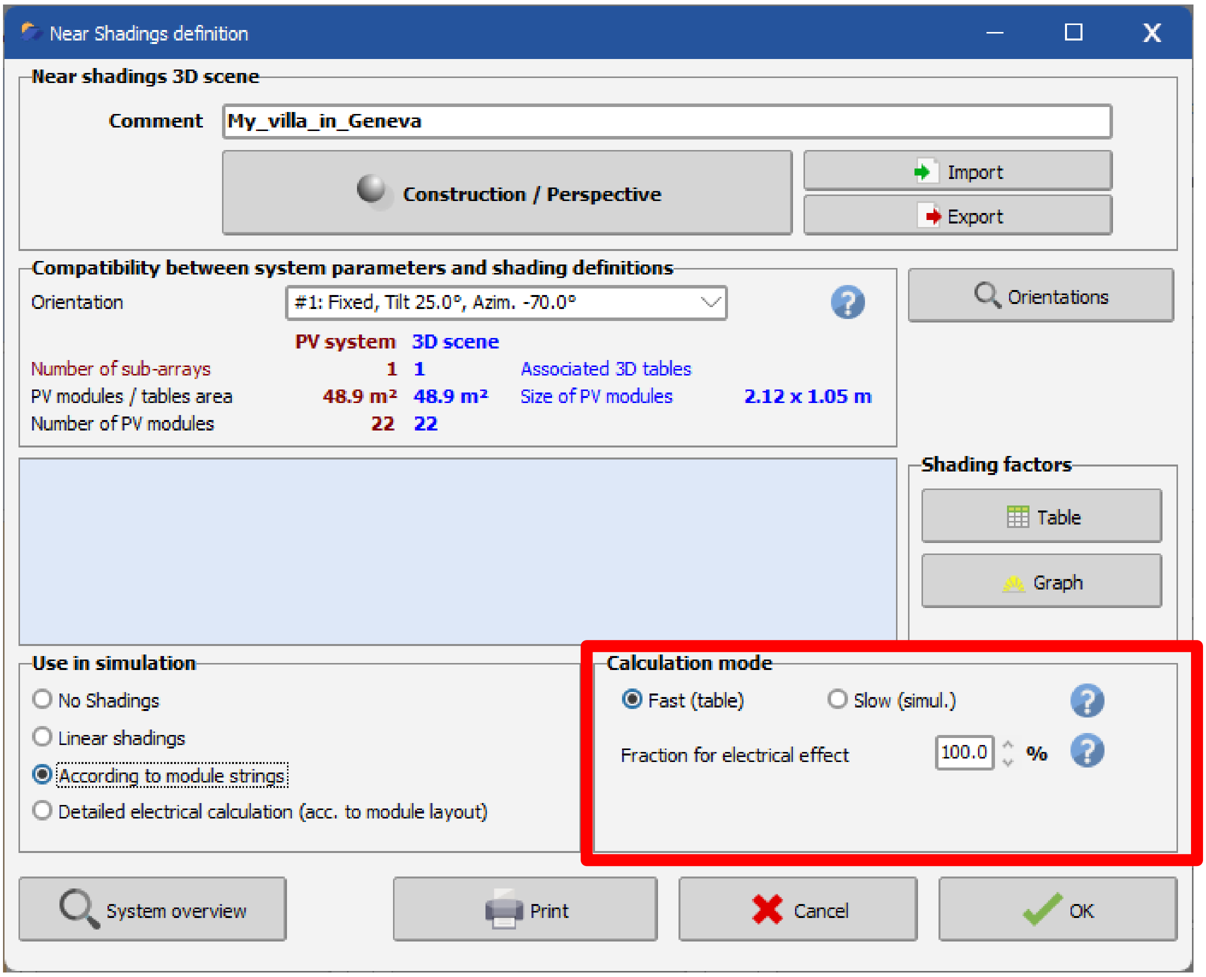
Linear shading

This mode only considers the reduction of irradiance on the PV field due to geometric shading, without accounting for the associated electrical effects (mismatch, bypass diodes, etc.). It therefore provides a minimum estimate of total shading losses, as additional electrical losses are not included.

The simulation can be performed quickly by interpolating values from the shading factor table at each time step, or more accurately—but more slowly—by recalculating the full shading factor at each step of the simulation.

According to module strings

During the creation of the 3D scene, you can group modules into separate strings. With this option, a shading factor is calculated for each string, and the electrical losses due to shading are estimated individually for each string. This provides a more detailed estimation of electrical effects than a simple linear shading calculation.



To refine the results, PVsyst allows the use of a factor called **Electrical effect fraction**, which adjusts the share of electrical losses calculated in the partition model. This fraction can range from a **purely geometric effect** (0%) to **a fully applied electrical effect** (100%). It is used to adapt the calculation to situations with irregular shading.

Detailed electrical calculation (according to module layout)

Finally, after defining a detailed **module layout** configuration in the 3D scene, you can perform shading calculations based on detailed electrical losses. The **module layout** tool is designed for accurate calculations of mismatch losses due to shading.

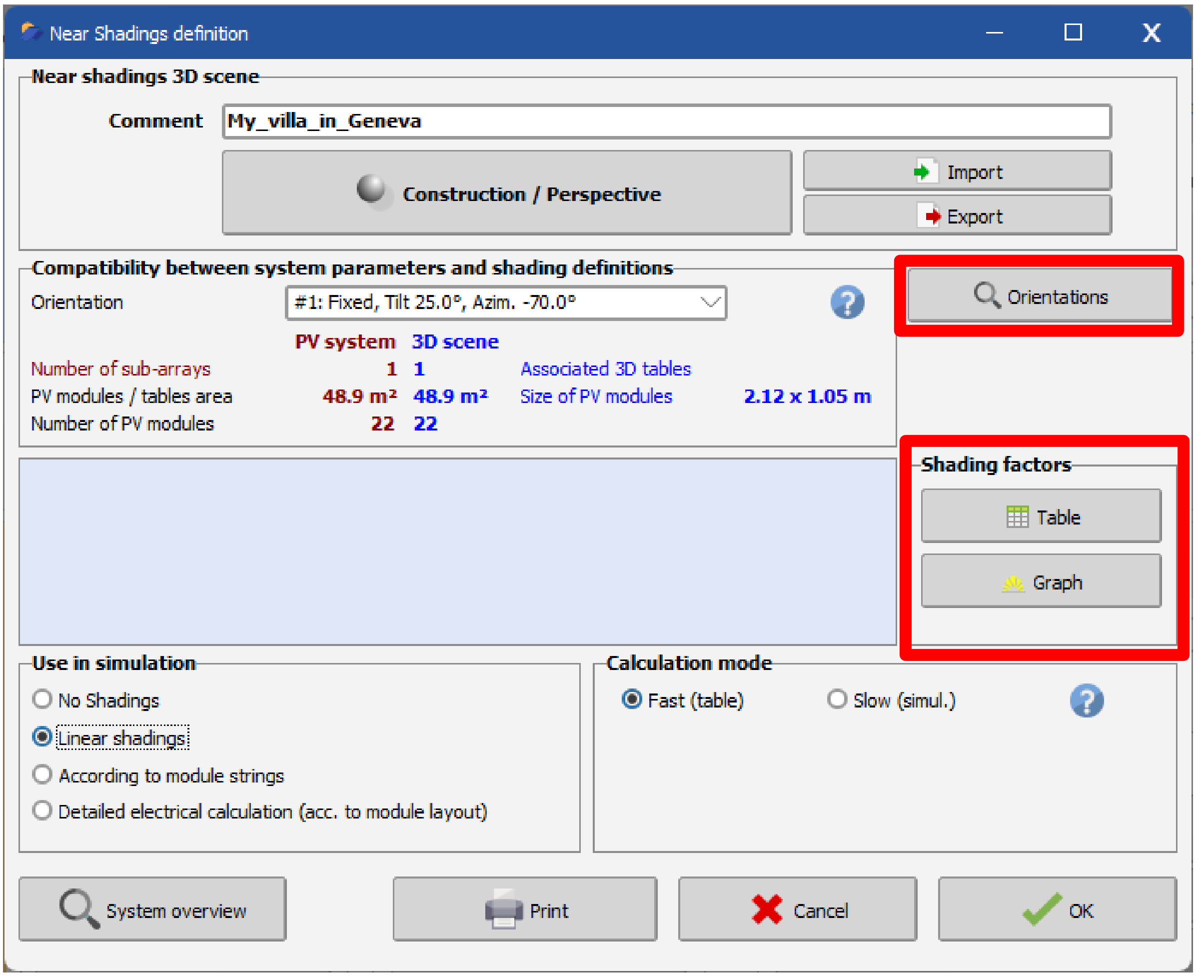
This type of simulation requires a precise description of the position of each PV module in the 3D scene, as well as the interconnection of modules into strings, consistent with the inverters defined in the **System** section. This enables highly accurate modeling of shading effects on each module, including losses due to current differences between strings.

The advantage of this model is that it calculates shading effects on the strings connected to the inverters and takes into account bypass diodes, which bypass shaded areas and thus reduce power losses. This model provides a more accurate calculation of electrical losses due to shading than the partition model.

10.3 Orientations, table, graph buttons

10.3.1 Orientations

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



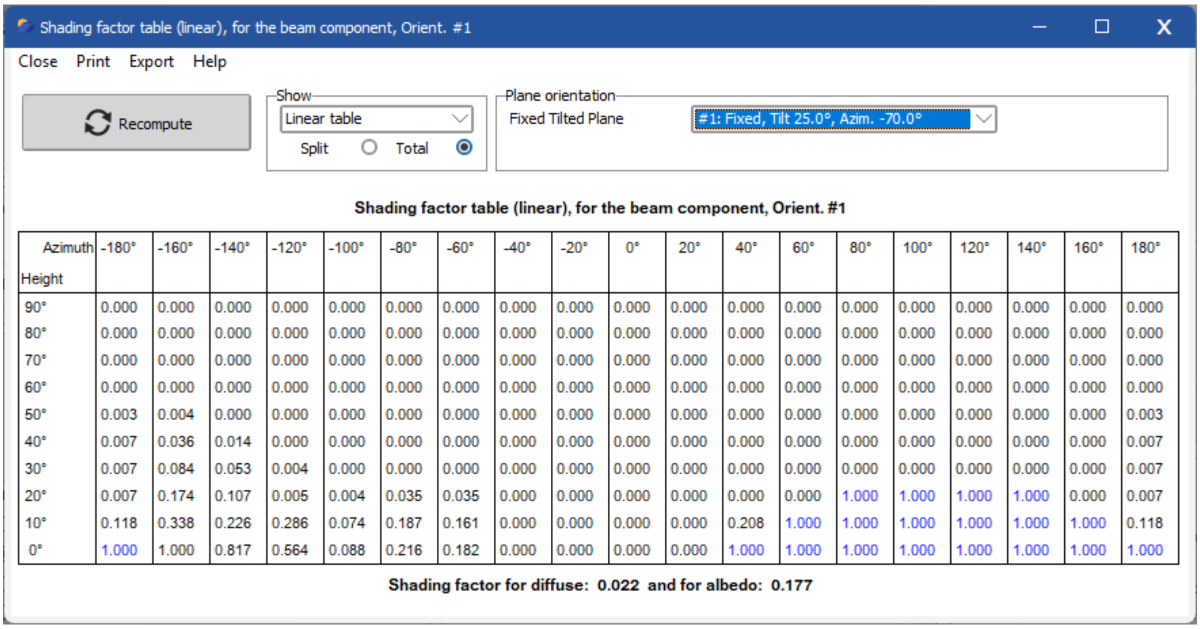
10.3.2 Table

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°	0.003	0.004	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	0.003
40°	0.007	0.036	0.014	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	0.007
30°	0.007	0.084	0.053	0.004	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	0.007
20°	0.007	0.174	0.107	0.005	0.004	0.035	0.035	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	0.000	0.007
10°	0.118	0.338	0.226	0.286	0.074	0.187	0.161	0.000	0.000	0.000	0.000	0.208	1.000	1.000	1.000	1.000	1.000	1.000	0.118
0°	1.000	1.000	0.817	0.564	0.088	0.216	0.182	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Shading factor for diffuse: 0.022 and for albedo: 0.177

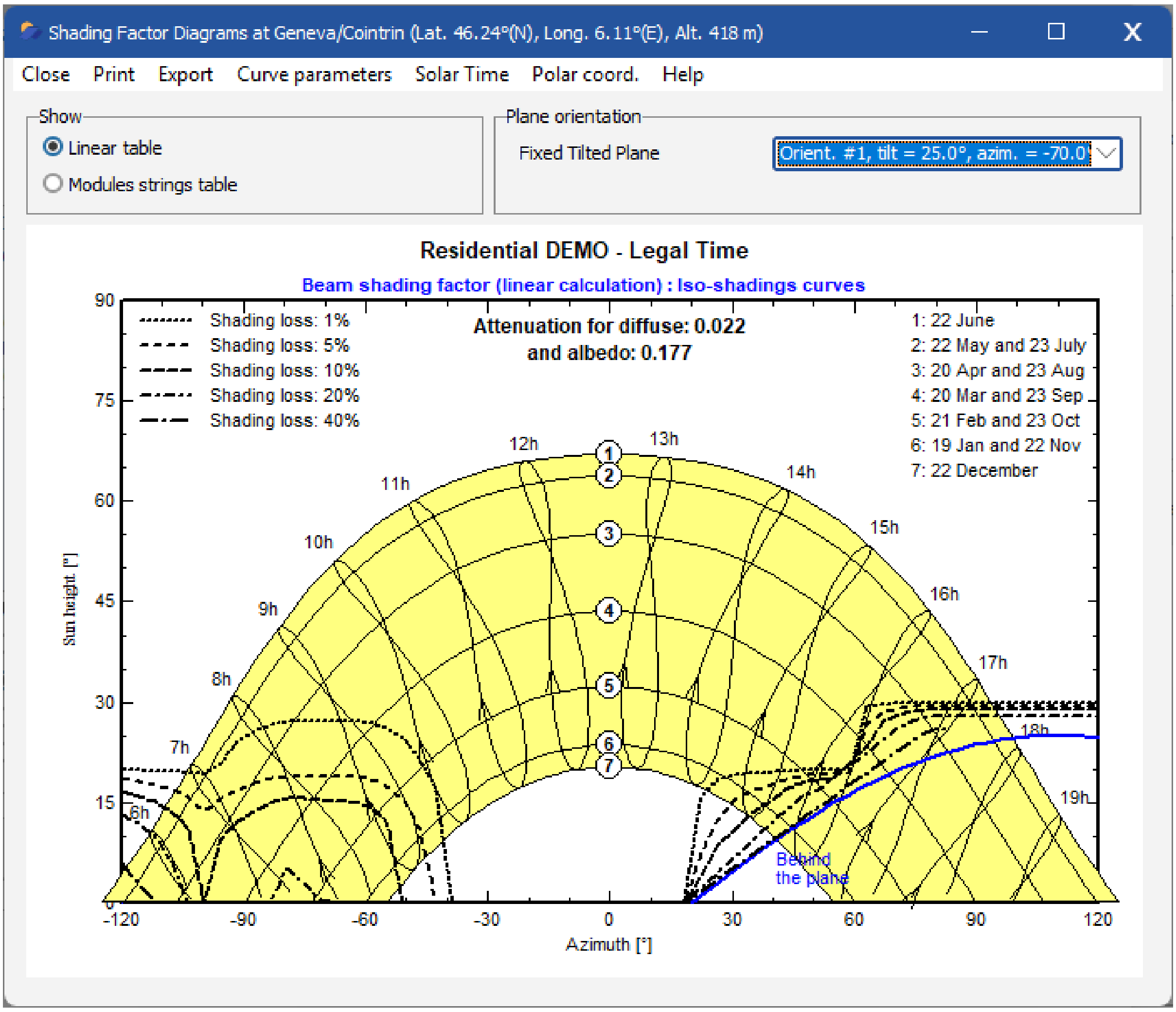
The Shading Factor represents the proportion of the PV field that is shaded relative to its total sensitive area, for a specific sun orientation (where 0 means no shading and 1 means completely shaded).

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.

10.3.3 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.

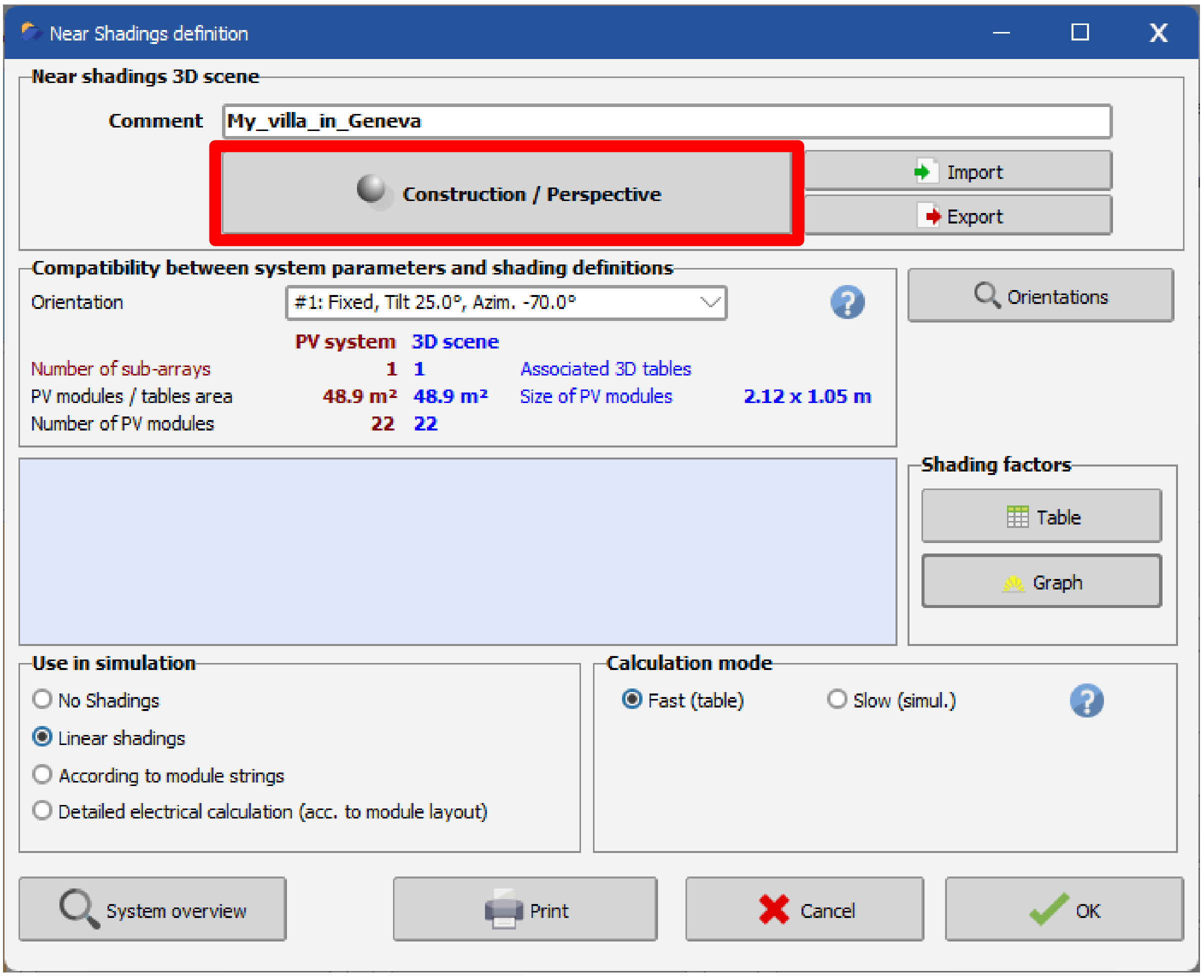
This diagram provides a concise overview of how shading varies with the seasons and times of day throughout the year.

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.

10.4 Construction/Perspective, 3D scene

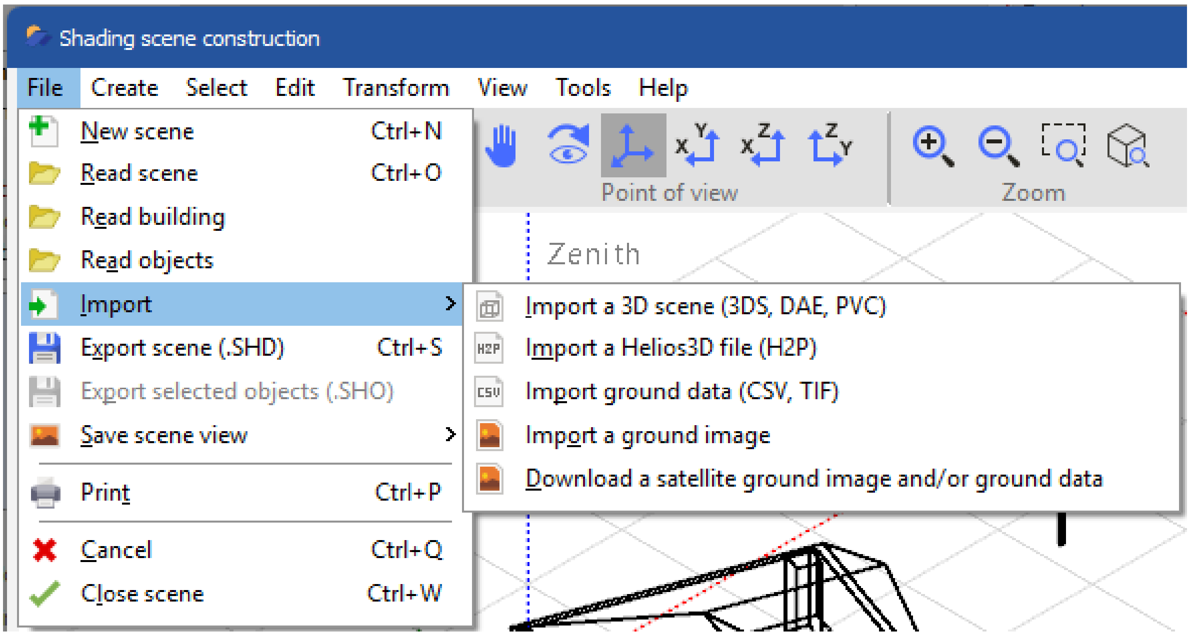
Clicking on the "Construction/Perspective" button opens a new window where the 3D scene is located.



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.

10.4.1 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.

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

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

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

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

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

Print: Prints the 3D scene.

10.4.2 Create Menu

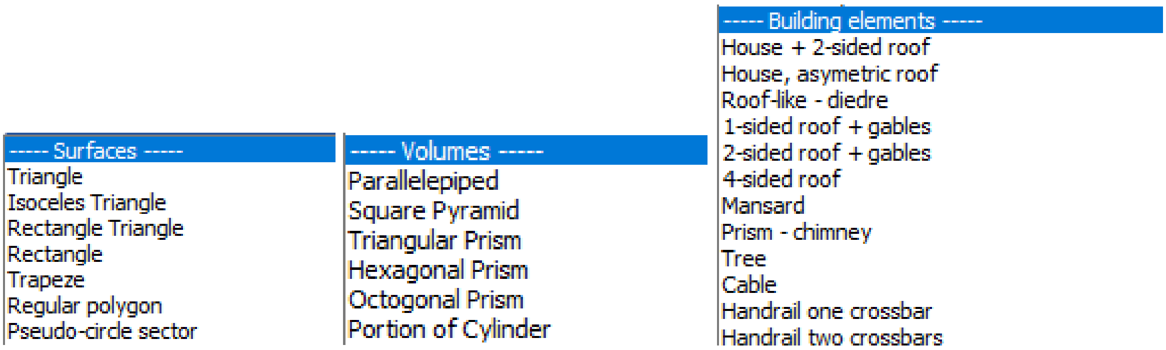
The "Create" menu is divided into two main sections:

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.

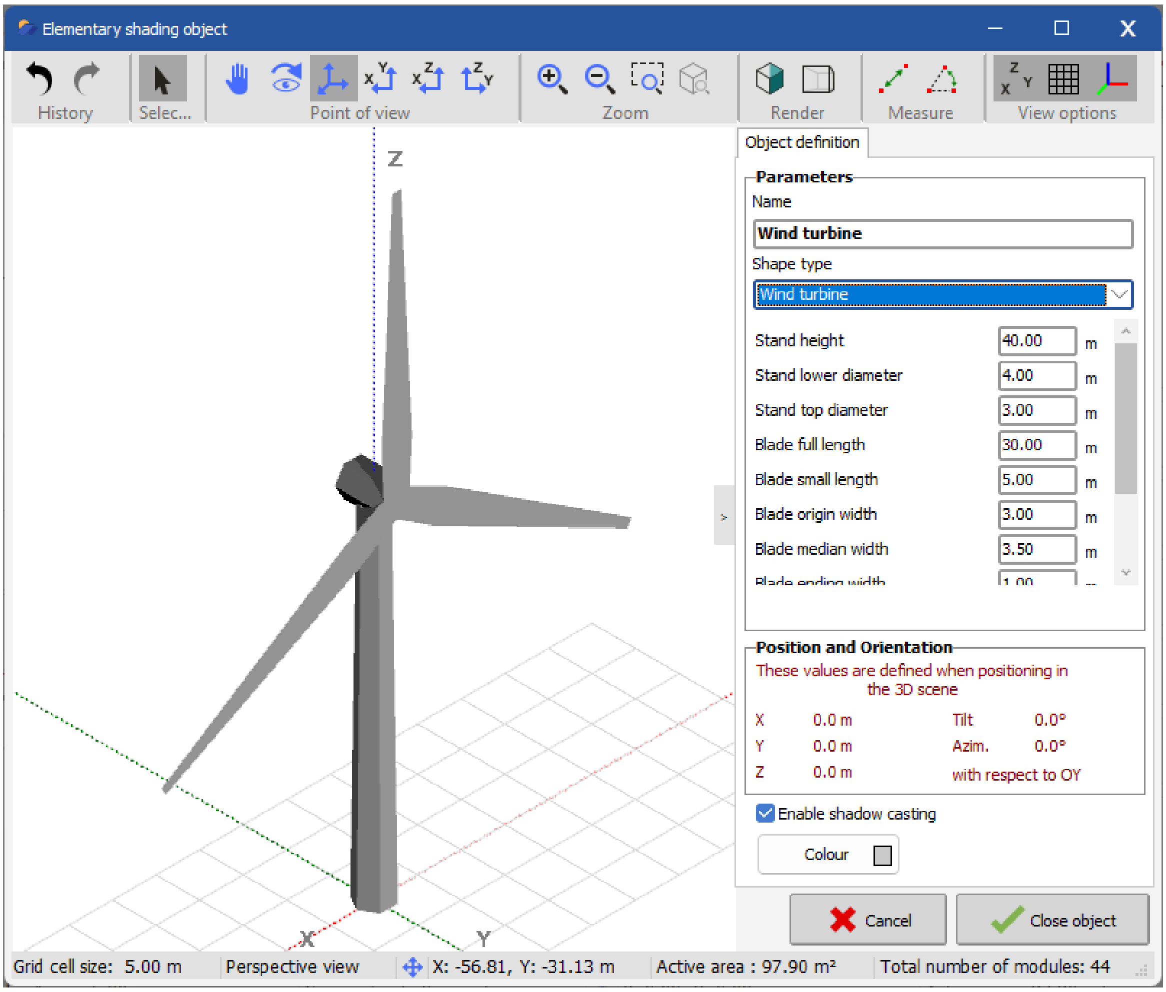
In the shape type, several models are available:

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

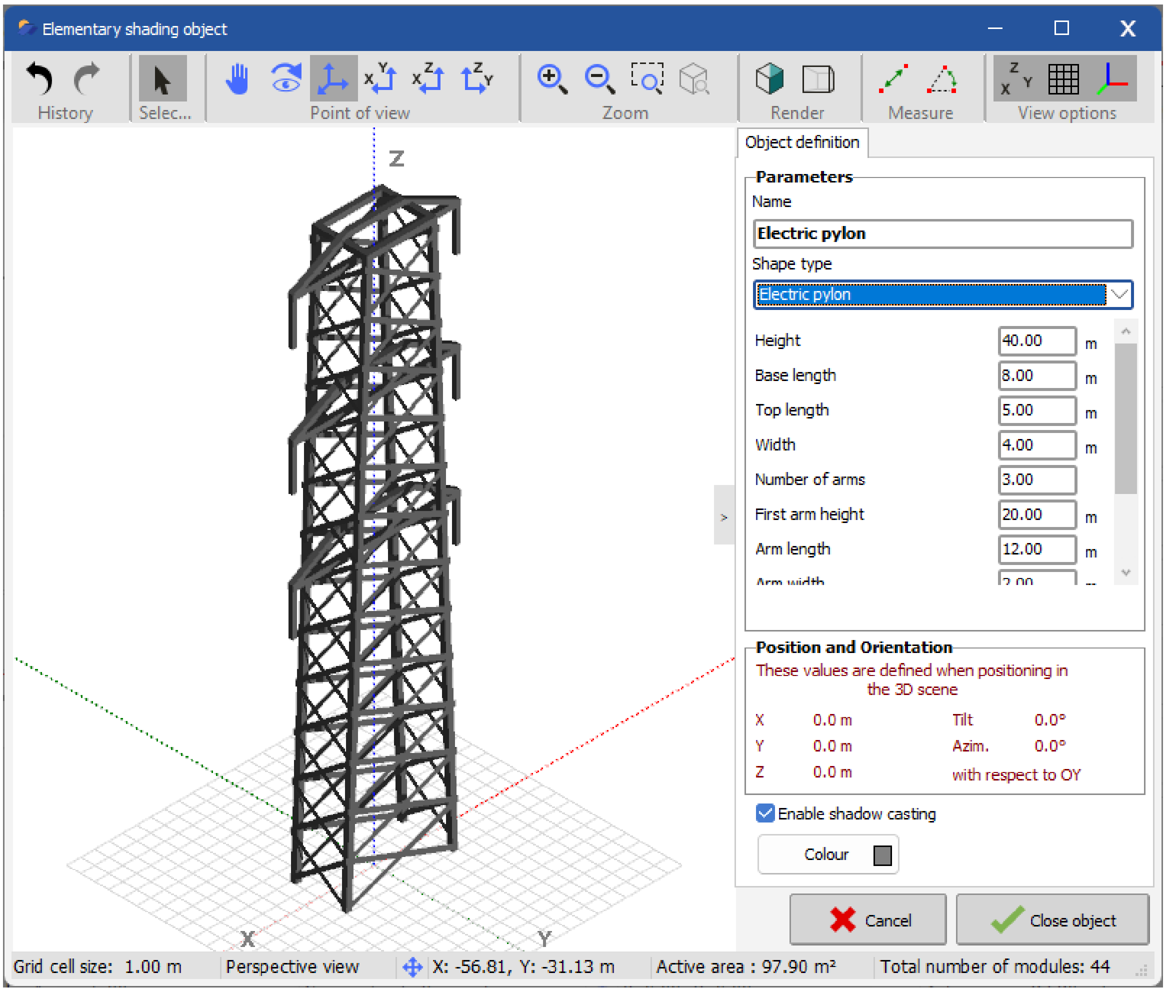


In this list, the construction objects are basic, with trees being a useful model example.

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.

10.4.3 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.

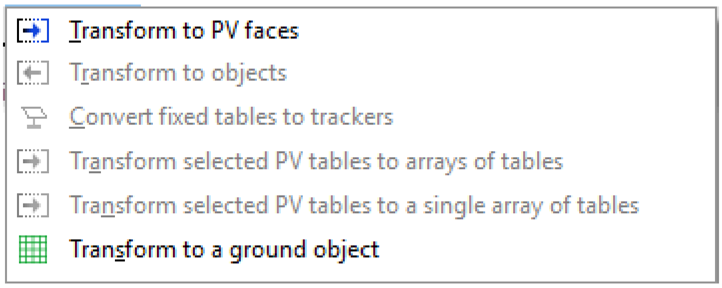
Rotate whole scene: Applies azimuth rotation to all scene objects.

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.

10.4.4 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.

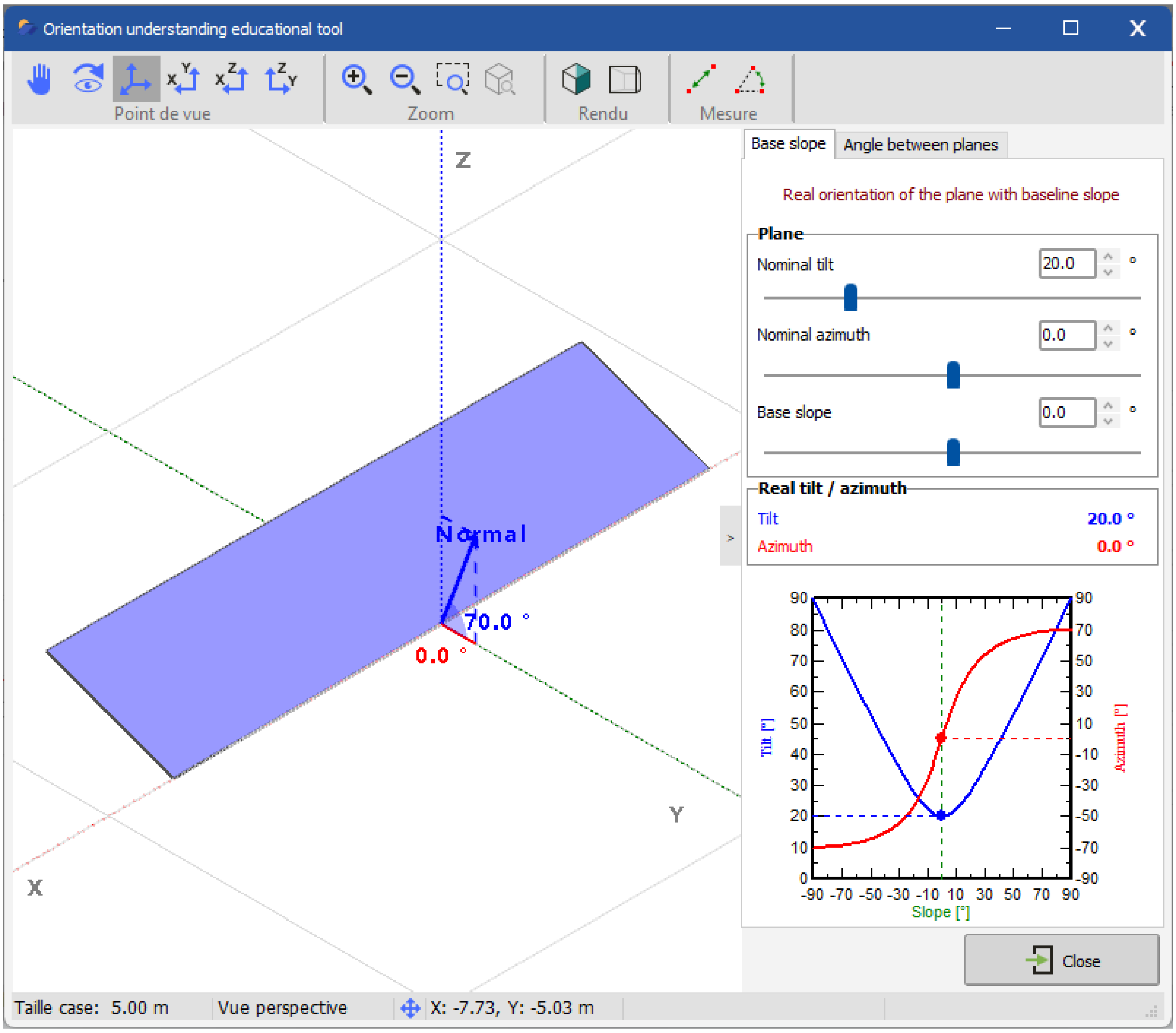
Transform Selected PV Tables to a Single array of table: Converts multiple single PV tables into a single table row.

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

10.4.5 Tools Menu

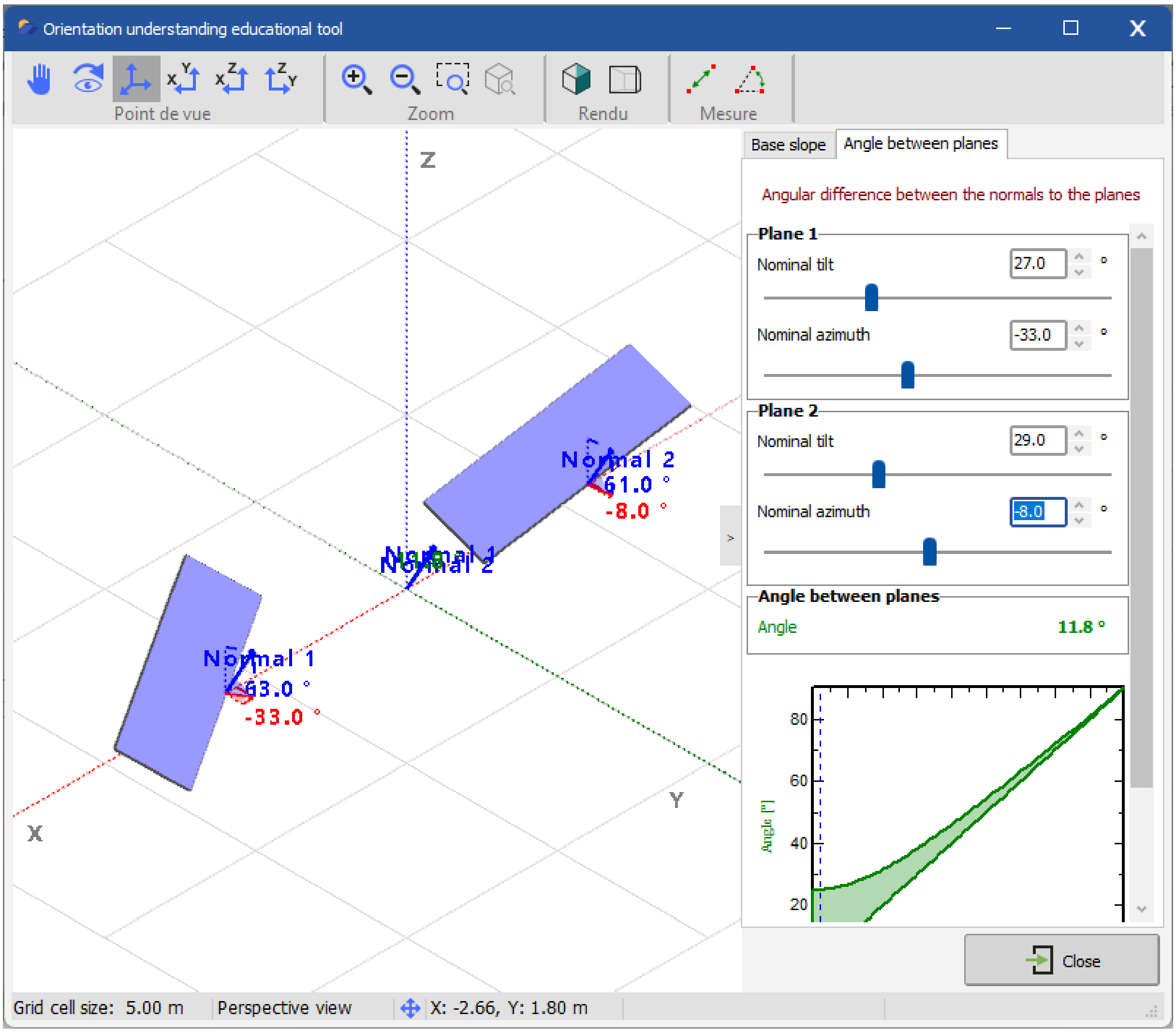
10.4.5.1 Orientation understanding educational tool:

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



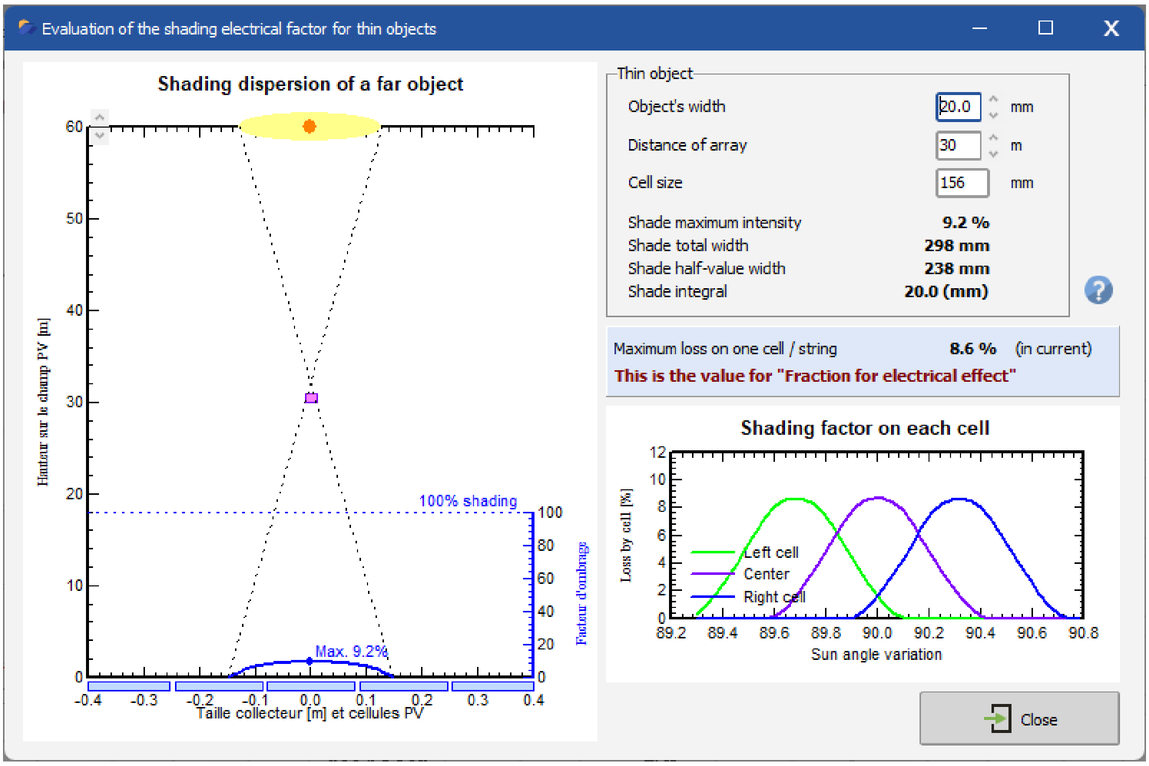
In the **Base slope** tab, users can view a PV table with an initial orientation and apply a base inclination, such as ground slope, to see the resulting tilt and azimuth. Users can experiment by inputting a "Nominal Inclination," "Nominal Azimuth," and adjusting the "Base Inclination," potentially representing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



10.4.5.2 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.



10.4.5.3 Trackers diffuse shading definition:

Dedicated to PV tracking systems, this tool defines the contribution of diffuse light on PV tables. Users can configure a representative tracker to calculate the shading factors used in simulations, thereby reducing the computation time for diffuse shading compared to modeling all trackers.

Calculation principles

Ideally, it would be necessary to:

1. build the complete shading table for all possible tracker orientations,
2. then evaluate the diffuse integral for each of these tables.

However, in practice, PVsyst evaluates the shading factor for diffuse and albedo components only for a selection of tracker orientations, and then generates an interpolation profile for these factors. These interpolated values are used during the simulation. This calculation may still be time-consuming.

"Representative tracker" approximation

For systems with a large number of trackers, it is often not practical to compute full shading tables for every position. PVsyst therefore offers an approximation that is acceptable in most cases when trackers are regularly distributed.

In this approximation scheme:

- PVsyst or the user selects a representative tracker located near the center of the field,

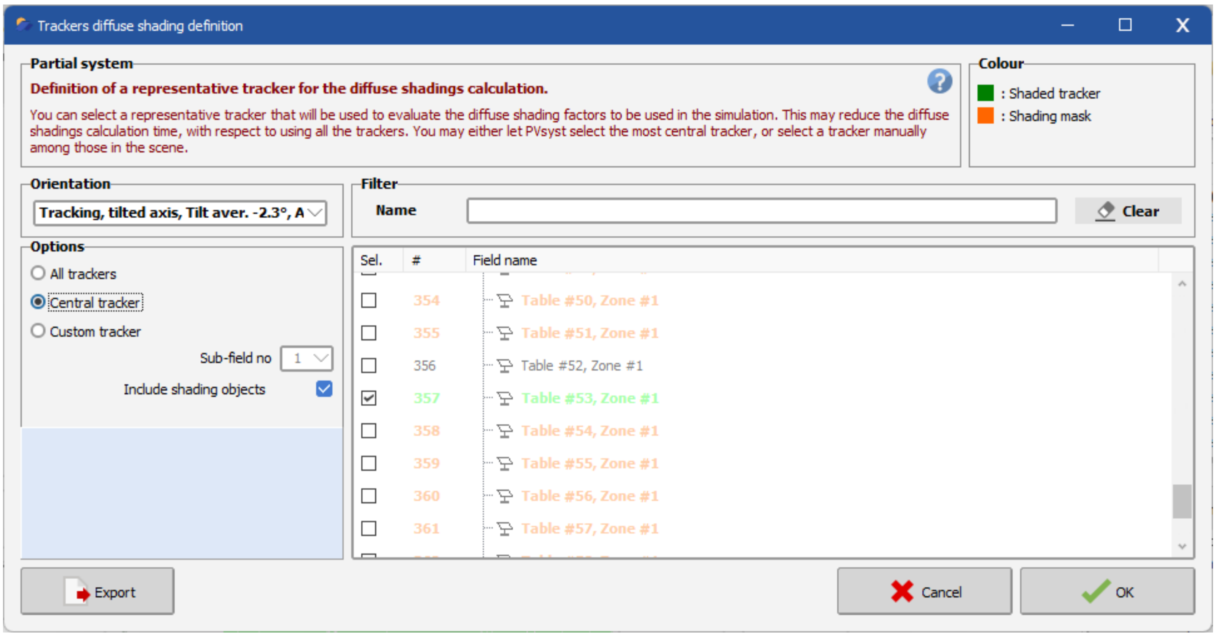
- the software evaluates the shading factor table only for this tracker,
- using neighboring trackers and objects to generate shading effects,
- while neglecting other shading sources.

This approach significantly reduces the computation time for diffuse shading. It can be summarized as the shading of a representative central tracker using a “partial scene” composed of neighboring trackers.

This approximation does not account for the finite size of the system: trackers located at the east/west edges do not experience mutual shading on one side. This may introduce an error on the order of 1/N rows if the representative tracker and its neighbors are not properly selected.

Diffuse shading calculation modes for trackers

The **Tracker diffuse shading calculation modes** window allows you to select the most appropriate calculation method for diffuse shading on trackers. It is accessible whenever trackers are defined in the 3D scene, via **Tools > Tracker diffuse shading definition**.



1. All trackers

In this mode, all trackers of the orientation are taken into account for the diffuse shading calculation. All shading objects in the scene, as well as other orientations, contribute to the shading.

This is the most accurate and recommended mode, but it can be computationally intensive for large or complex scenes.

2. Central tracker

In this mode:

- Among the most geometrically central trackers of the orientation, the one surrounded by the highest number of shading trackers is selected.

- This tracker is then used as a representative sample.
- It is highlighted in green in both the window and the scene (**Shaded tracker**),
- The neighboring trackers that generate shading are highlighted in orange (**Shading mask**).

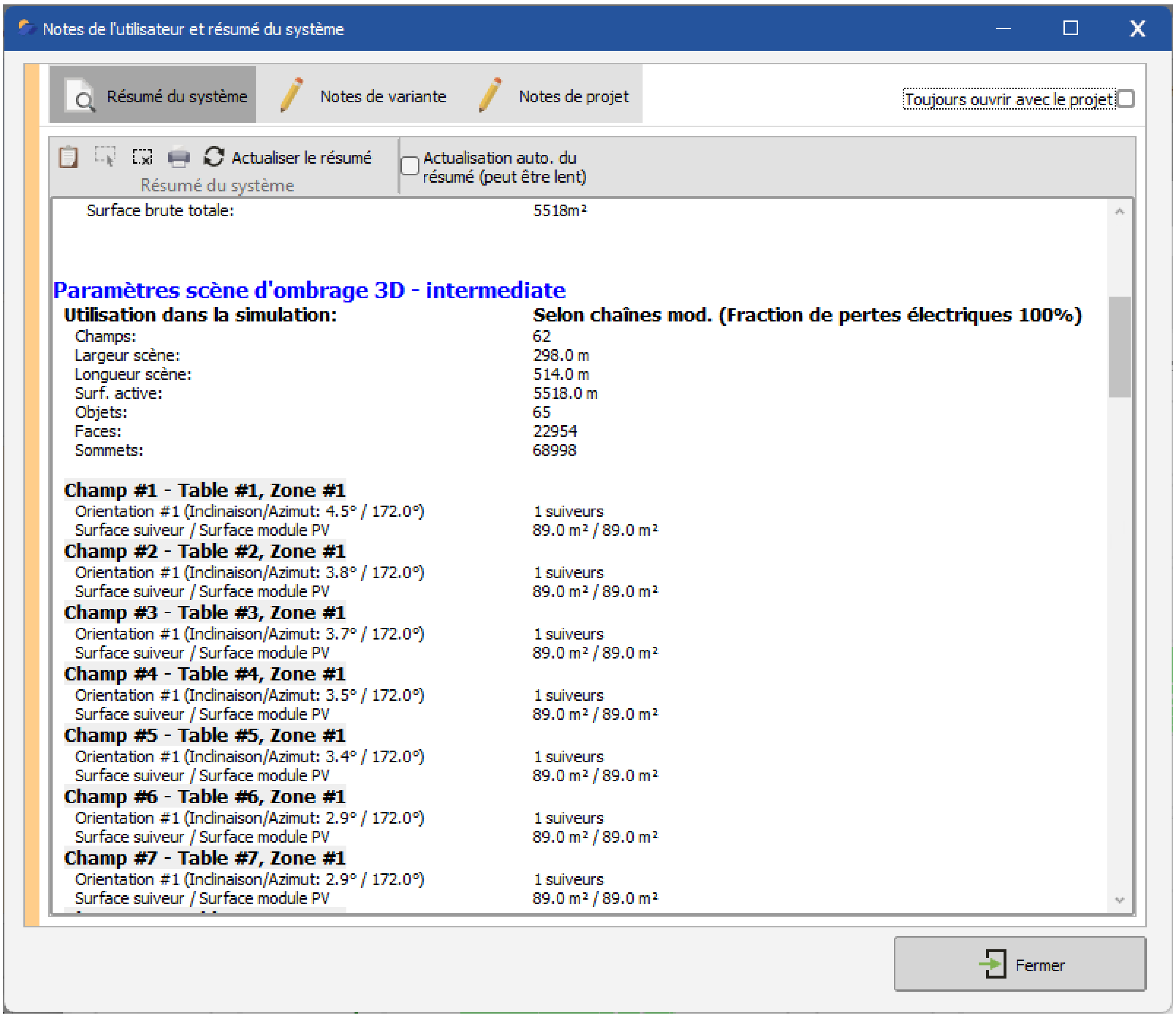
However, even with this approach, certain field configurations may reduce the accuracy of the central tracker selection (for example, if the central tracker is located at the edge of a patch).

3. Custom tracker

This mode is similar to the **Central tracker** mode, but allows the user to manually select a tracker to be used as the representative sample. The **shading mask** is then automatically defined around it.

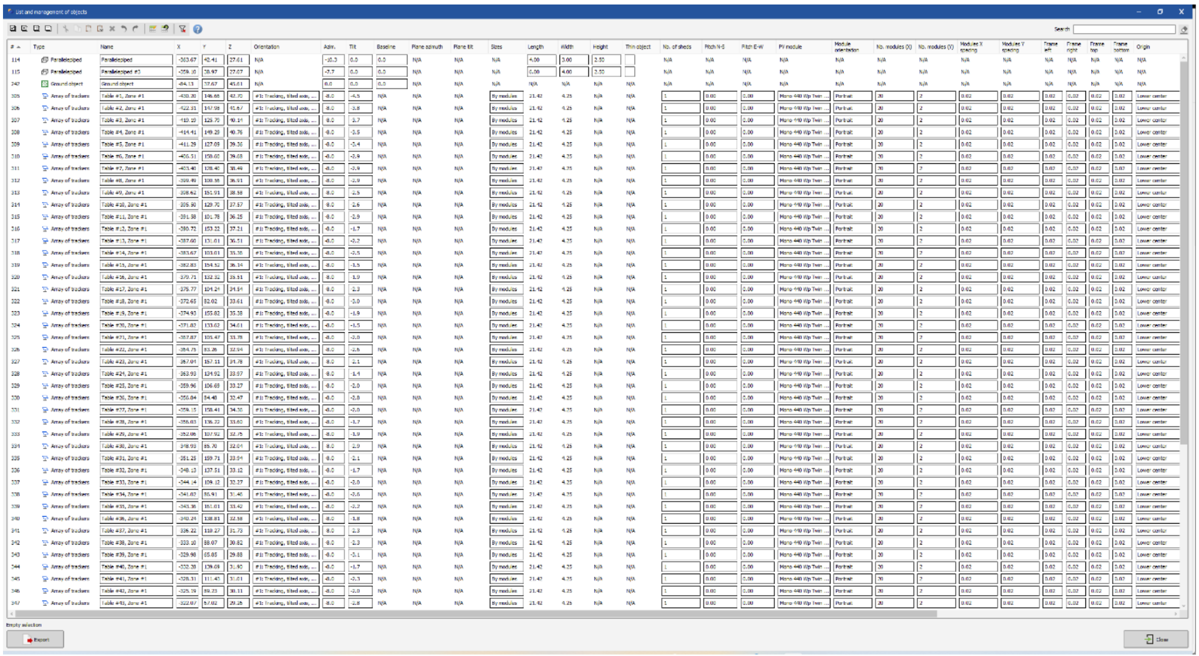
10.4.5.4 Shading Scene Summary:

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



10.4.5.5 *List and Management of object (Ctrl+G):*

In your 3D scene, all PV tables and shading objects are listed in the **List and manage objects** window. You can open this window from **Tools > List and manage objects** or by using the shortcut **Ctrl + G**.



The list provides sortable **and filterable columns** for easier navigation. Selecting an object in the list also highlights it in the shading scene. Fields are directly **editable**, and if multiple objects are selected, changes are applied to all of them simultaneously.

Search:

To search for specific objects in the shading scene, you can enter text in the **Search** field.

The search is performed on the **# (number), Type, and Name** columns.

To clear the search, delete the text in the search field or click the clear icon.

Filtering / Sorting:

Each column can be filtered and sorted.

To filter a column: hover over the column header and click the funnel icon that appears. You can then define filtering criteria in the pop-up window. It is possible to filter multiple columns at the same time.

To clear a filter, click the filter clear icon.

To sort a column, simply click on its header — sorting is performed in ascending or descending order, and a sorting indicator is displayed.

Selection:

- Select all displayed objects.
- Deselect all objects.

You can also select or deselect objects directly in the list by clicking on them while holding the **Ctrl** key. When you close the advanced selection window, the selected objects remain selected in the shading scene.

Expand / Collapse:

Expand all objects:

This command opens all nodes in the tree structure. All sub-objects become visible in the list, allowing a detailed view of the full scene structure.

Collapse all objects:

This command closes all nodes in the tree structure. Only the main objects remain visible, making the list easier to read when the scene contains many elements.

Copy / Paste:

- Copy all selected objects to the clipboard.
- Paste from the clipboard onto the selected objects. If no object is selected, the paste is applied to objects with the same number (**#**).
- Pasting applies only to visible columns.

Pasting can also be done from external spreadsheet software (such as Excel). In this case, make sure to include the header row and at least the first three columns (**#, Type, Name**).

Edit / Delete

- Opens the edit dialog for the selected object. Double-clicking an object also allows you to edit it individually.
- Deletes the selected objects.
- Undo.
- Redo.

Some fields can be edited directly in the list — these are the cells outlined with a rectangle. If multiple objects are selected, editing is applied to all of them simultaneously in group mode.

Column management

For better readability, it is possible to show or hide columns:

- Select/Deselect the columns to display. This option is also available by right-clicking on the column header.
- Show default columns.

Note that your selection is saved for future sessions.

Context menu

Some actions are also accessible via a context menu by right-clicking on one or more selected nodes in the tree structure.

Export to CSV

To use object-related data outside of PVsyst, you can export the displayed list in CSV format.

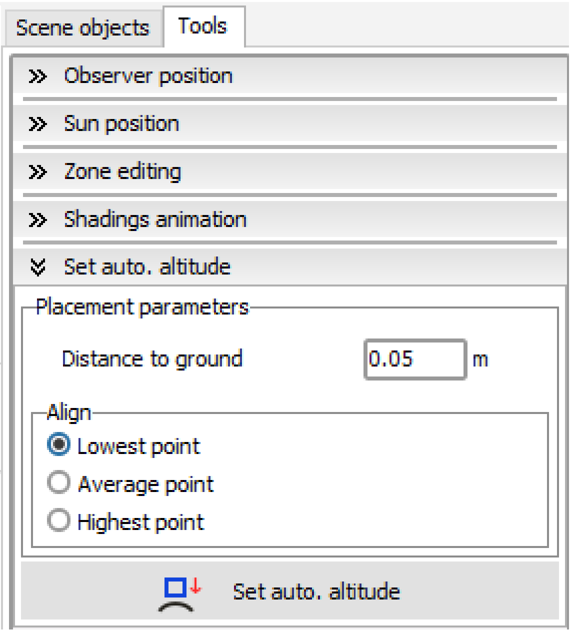
Click on the CSV export icon, then paste (**Ctrl + V**) into Excel or any other spreadsheet software.

10.4.5.6 Automatic Altitude:

Opens a tool that allows PV objects to be automatically placed on top of other objects. This tool is very useful for easy handling, especially when placing tables on a roof or terrain, in order to align PV tables with the surface while maintaining a predefined height distance.

Procedure:

Select a table, then click on "Tool — Automatic altitude". This opens an option in the right-hand menu, as shown below.



Choose the ground clearance as well as the alignment option, then click on the "Set automatic altitude" button.

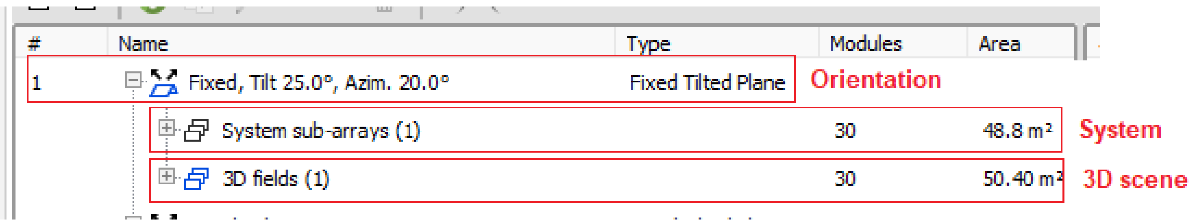
10.4.5.7 Orientation Management (Ctrl+Shift+O):

The **Orientation management** window allows users to view the list of orientations in the scene and to check consistency between the 3D scene and the system definition. Users can review the correspondence of PV areas and the number of modules between definitions, reassign existing orientations to new ones, and identify orphan orientations in order to reassign them.

The Orientation management window can be opened from the shading scene by clicking **Tools → Orientation management** or by pressing **Shift + Ctrl + O**.

The **Orientations** tab provides an overview of all orientations currently defined in the system, along with their corresponding shading configurations.

On the left side of the window, orientations are organized in a hierarchical tree structure. Each orientation can be expanded to display its sub-groups and associated 3D fields at the child level.



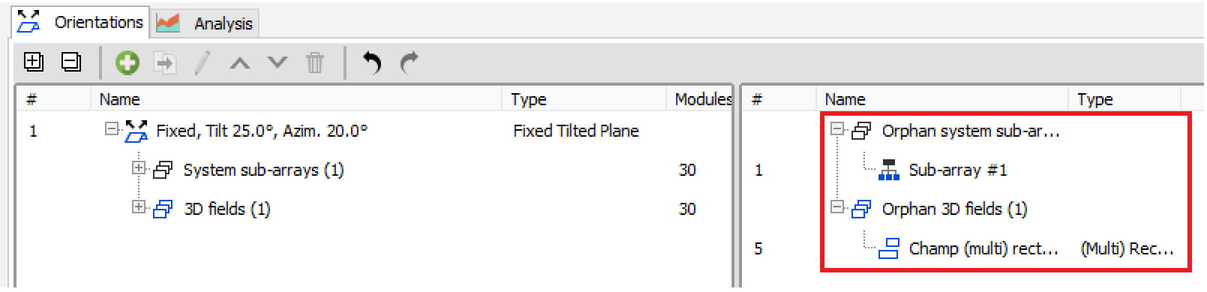
This makes it easier to verify the consistency between the number of modules defined in the system sub-arrays and those configured in the 3D scene.

You can also add or remove orientations, and easily move fields between orientations using the drag-and-drop functionality.

Selection and highlighting

When you select one or more orientations in the tree structure, the corresponding fields are also highlighted in the shading scene, providing a clear visual reference.

If you delete an orientation, the associated sub-arrays and 3D fields become orphaned and are displayed in the right-hand section of the window.



You can then **drag and drop** them to the left to reassign them to the appropriate orientation.

Delete an orientation

To delete an existing orientation, select it and click on the corresponding icon . This action removes only the orientation itself, **not the associated sub-arrays or 3D fields**. The associated elements will appear as orphaned and must be reassigned to another orientation using drag-and-drop.

Add a new orientation

To add a new orientation, click on the button located above the list. This opens the orientation editing window, where you can configure the parameters of the new orientation.

Edit an existing orientation

To modify an existing orientation, you can either double-click on it or select it and click on the edit button above the list. This will open the orientation editing window, where you can adjust its parameters.

Copy an orientation

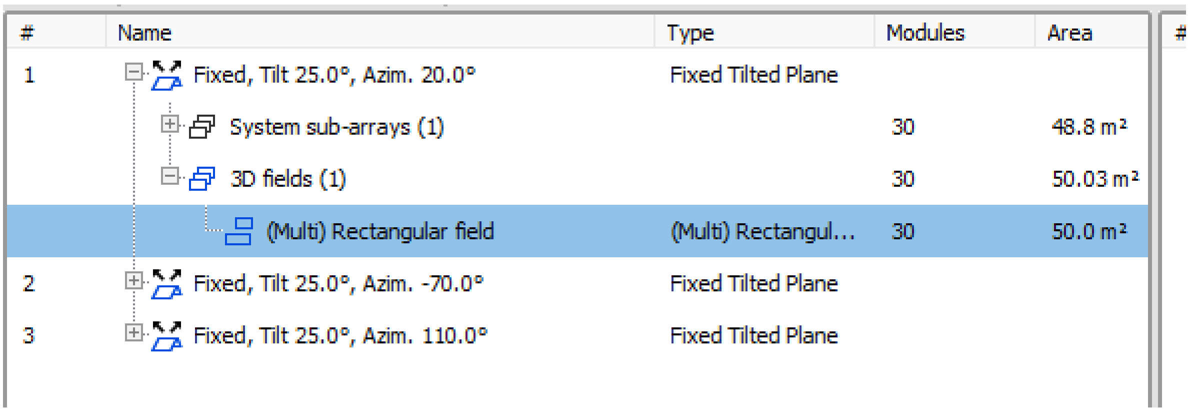
To copy an existing orientation, select it and click on the copy button . A **new orientation** will be created with the same parameters as the selected one. Note, however, that **the 3D fields of the copied orientation are not duplicated**: they remain attached to the original orientation.

Reorder orientations

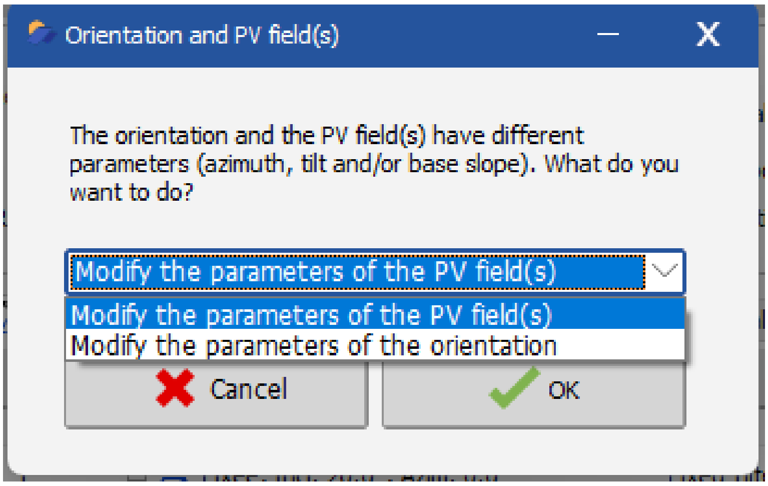
If you want an orientation to appear before or after another in the list, you can select it and use the move buttons (up/ down) to change its order.

Assign fields to an orientation

To change the assignment of a field already associated with an existing orientation, or to assign an orphan field to a new orientation, simply drag and drop the field onto the desired orientation.



If you move a field to an orientation with incompatible parameters (and if the orientation is not defined as an average), PVsyst will prompt you to choose whether you want to:



- **update the field properties** (azimuth, tilt, base slope) to match the orientation, or
- **define the orientation as "average",** which keeps the field parameters unchanged but treats the orientation as an average.

You can also move all 3D fields from one orientation to another—leaving the first orientation empty—or select multiple fields at once and move them together.

Orientation analysis

The Analysis section of the window displays the distribution of orientations and values for different types of data, such as plane orientations, deviation from the average, and azimuth/tilt relative to the base slope. Average values are also calculated and displayed in the analysis panel on the right.

10.4.5.8 Backtracking Management

When the backtracking strategy is enabled in PVsyst, the **same backtracking angle** is applied to all trackers of a given orientation. This angle is calculated based on the **width-to-spacing ratio** of a reference tracker, referred to as the **backtracking GCR**.

Scenes created directly in PVsyst (tracker rows)

When the 3D scene is built in PVsyst, it is generally composed of **tracker rows.**

In this case:

- **the spacing** is defined at the field level,
- there is only **one backtracking GCR value**,
- if multiple rows are present (with different spacing or widths), PVsyst automatically selects the **row with the highest GCR.**

The angle calculated from this GCR is then applied to all trackers, ensuring the absence of mutual shading.

Imported scenes or tracker zones

When the scene comes from a CAD tool or when the **"table zone"** tool is used, trackers appear as **independent tables** rather than as rows.

In this case, PVsyst must manually identify a **pair of reference** trackers.

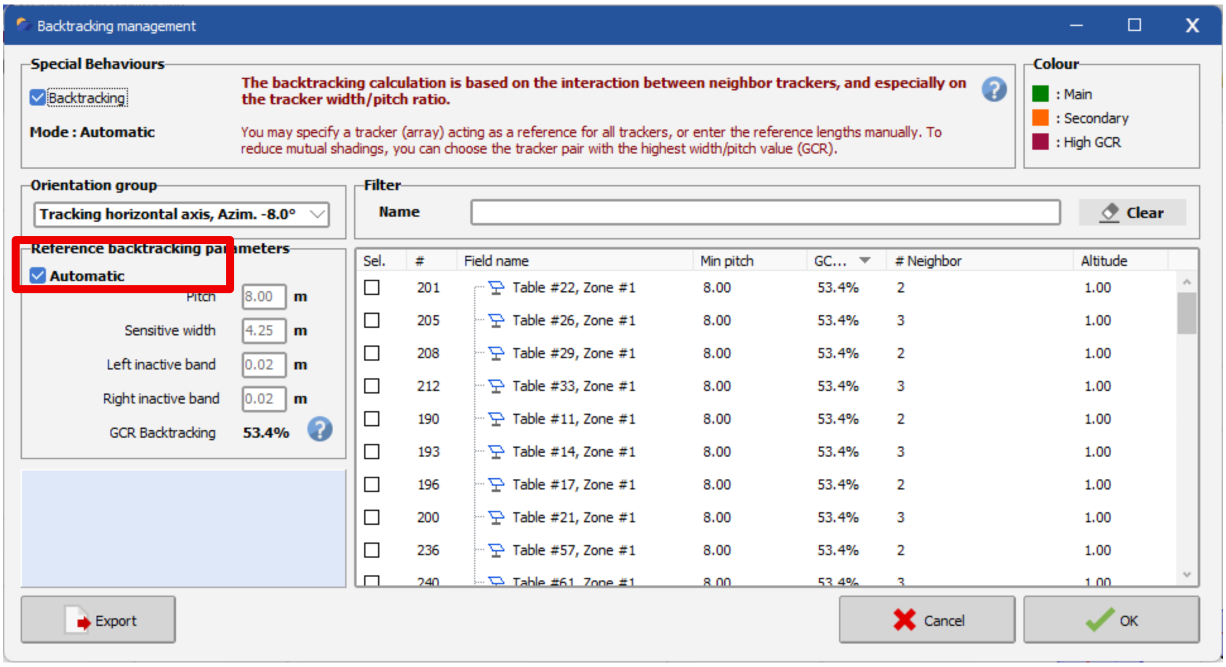
This is managed using the **Backtracking management** tool, accessible from the **Tools** menu in the 3D editor.

Automatic selection of reference trackers

The dedicated window displays all trackers belonging to the same orientation group, sorted by decreasing pitch.

By default:

- the mode is set to **Automatic**,
- the selected GCR is the highest one detected in the scene.

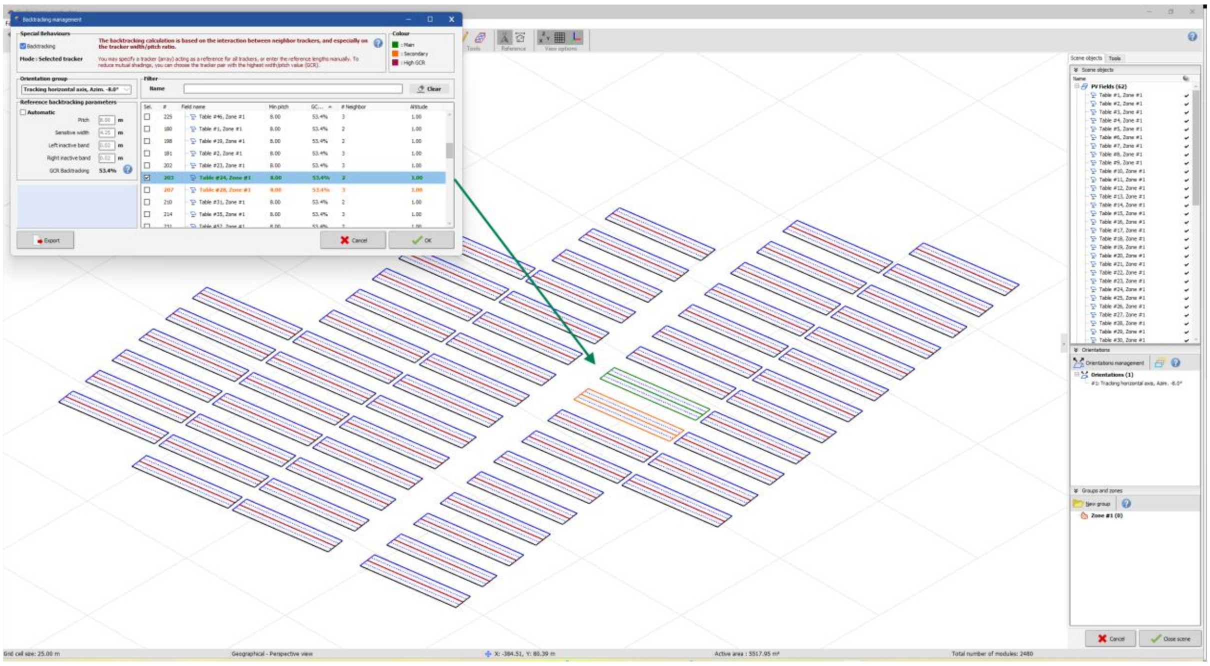


Manual selection

The automatic mode can be disabled to select a different reference tracker.

When you select a lower GCR:

- trackers with a higher GCR are highlighted in **red**,
- PVsyst displays a **warning**: these trackers may experience shading,
- the selected tracker is highlighted in the scene for visual validation.



Manual input

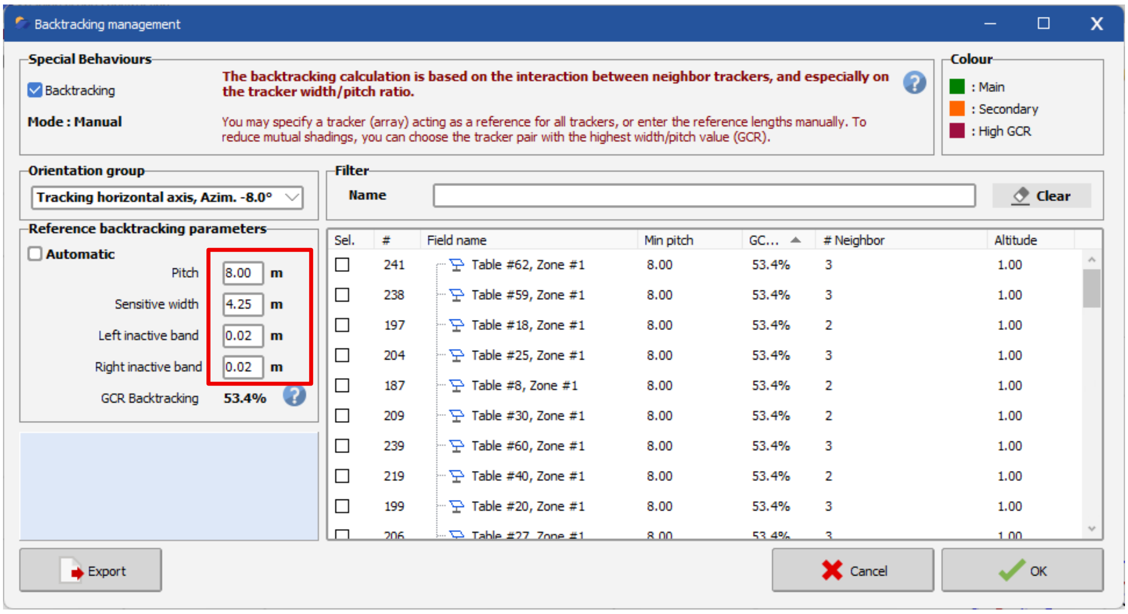
By deselecting the reference tracker pair, it becomes possible to define custom values. You can specify a particular spacing, width, or inactive bands.

These parameters are **used** only for calculating the backtracking angle and **do not modify** the 3D scene.

In most cases, it is recommended to adjust only the spacing. For more advanced needs, these parameters can be used to reproduce specific behaviors:

- Reducing the table width (for example, dividing it by two) allows simulation of a half-backtracking operation.
- Defining inactive bands on one side or the other of the reference tracker introduces different behaviors between morning and afternoon, which can be useful on sloped terrain.

Any custom definition should be validated by running a shading animation in the 3D scene. Do not forget to enable shading simulation if some trackers are likely to be shaded.



10.4.5.9 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.

10.4.5.10 Use Partial Shading Calculations:

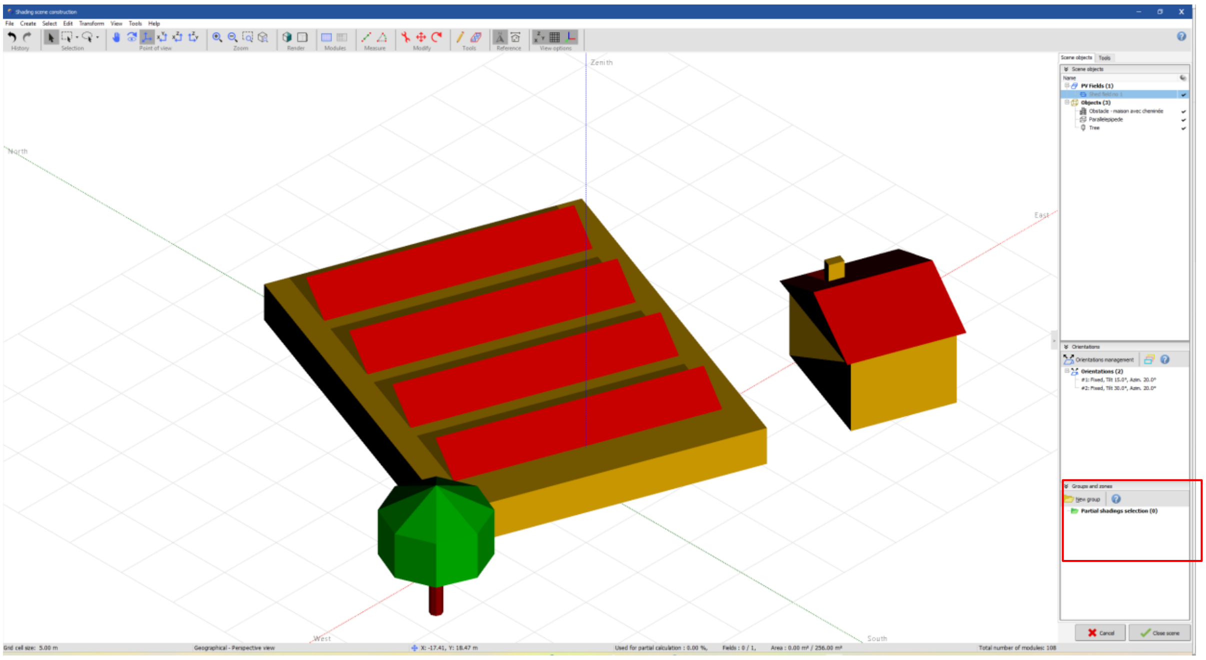
In large projects, it can be useful to limit shading calculations to a restricted part of the system. PVsyst provides a feature that allows shading calculations to be performed only on a **specific subset** of PV tables.

This approach is relevant when the full scene is too time-consuming to simulate or when analyzing a specific area with particular design characteristics.

In PVsyst, this function is called **Use partial shading calculations**—not to be confused with "partial shading," which refers to shading affecting only part of a PV field.

The **shading factors** obtained from this partial calculation are then extrapolated and applied to the entire photovoltaic system.

To **activate** this option, go to: **Use partial shading calculations**Once activated, a group named **“Partial shading selection”** appears in the **“Groups and zones”** panel on the right.

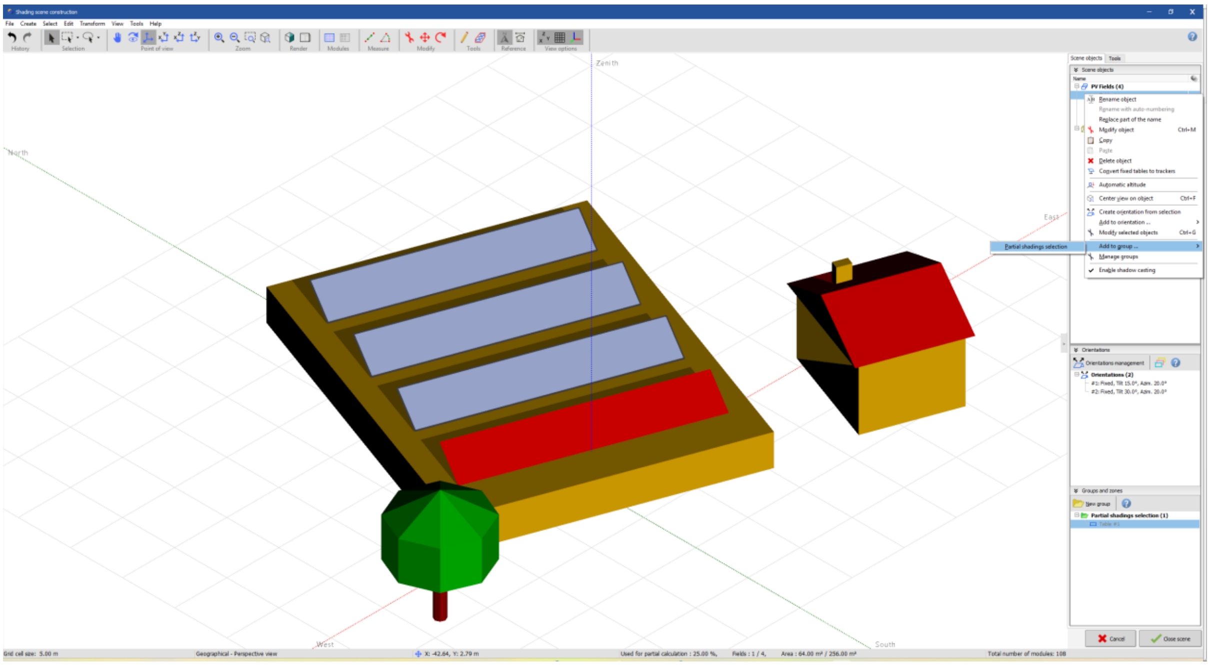


Two methods are available to add tables to this group:

1. **Right-click** on the group folder to display all PV tables in the scene, then select those to include.
2. Directly select PV modules in the scene (using rectangular or lasso selection), then in **“Scene objects”**, **right-click** → **Add to group → Partial shading selection**.

This group behaves like standard object groups, with the difference that it can only contain PV fields.

Other objects that may cast shadows (trees, buildings, obstacles) are still taken into account if they are configured with **active shading projection** enabled.



Important limitation

The **Module layout** mode (module-level shading calculation) is not compatible with the partial shading calculation mode.

If you are using **"Module layout"**, this option cannot be activated.

10.4.6 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

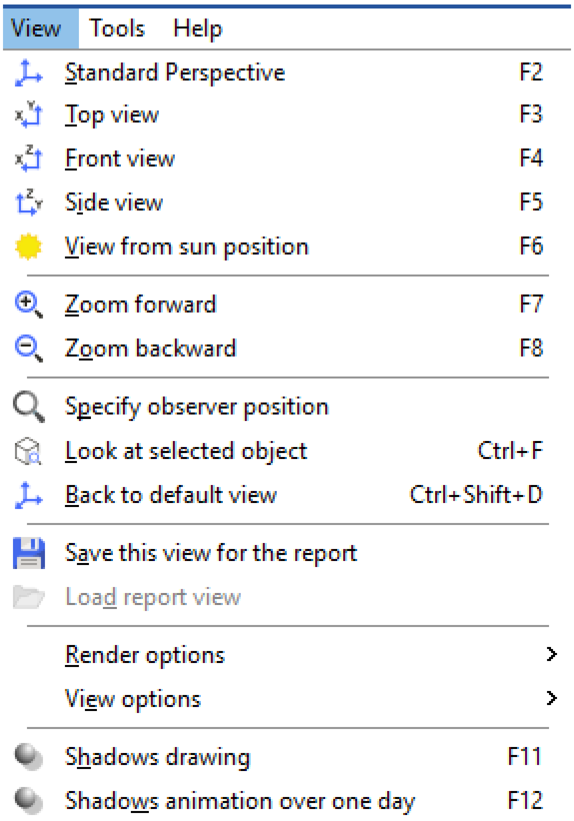
Zoom In: F7

Zoom Out: F8

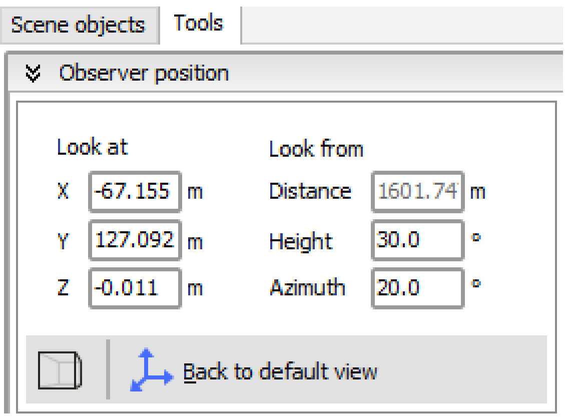
Zoom by Rectangle: Click and drag to define the viewing area.

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

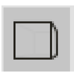
All these tools are also accessible in the **View** menu.



Additional Tools



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

Center on Selected Object 

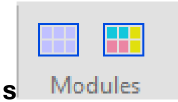
Back to Default View: Resets the observer to the default position, looking towards the scene origin (X=0; Y=0; Z=0).

Rendering Options

Technical View/Realistic View:

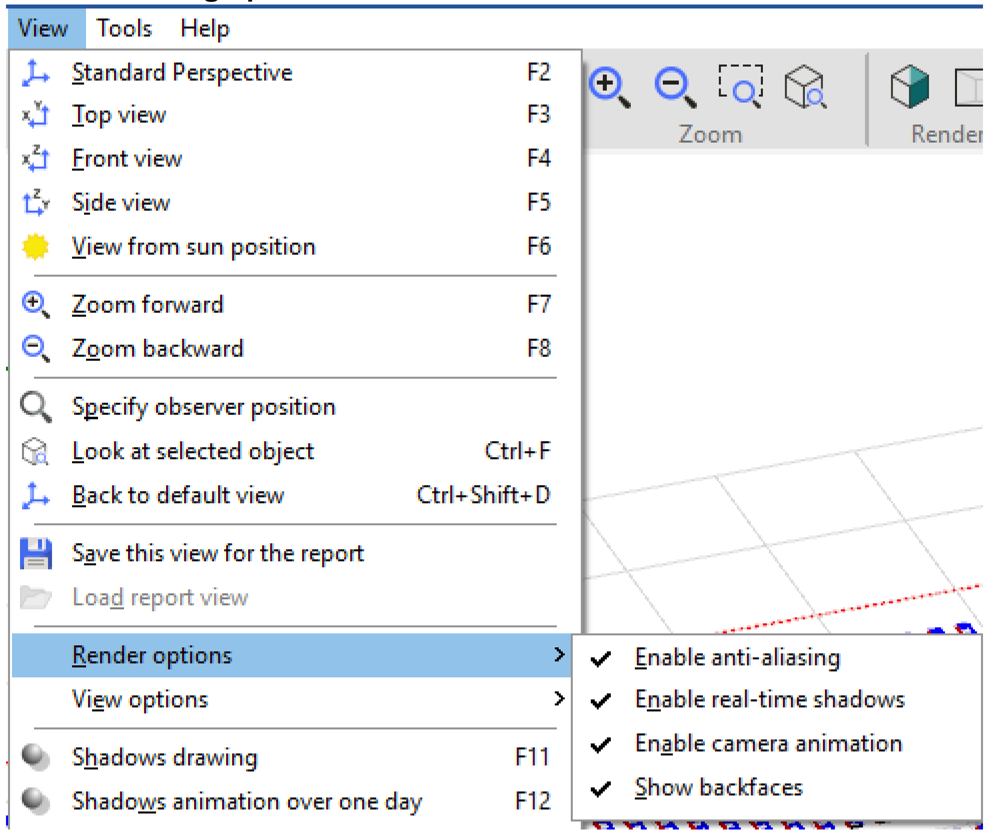
- Technical View:

- ○ 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.

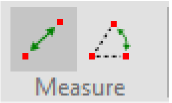
Other Rendering Options



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

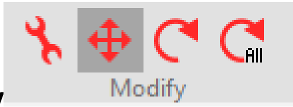
- **Enable anti-aliasing**: Smooths object edges. Availability may depend on your hardware and could reduce performance.
- **Enable real-time shadows**: Enables real-time shadow viewing. Activating this option may reduce performance.
- **Enable camera animation**: Animates the transition when switching 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 

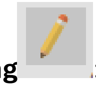
Edit Objects: Ctrl+M

Move Objects: Ctrl+B

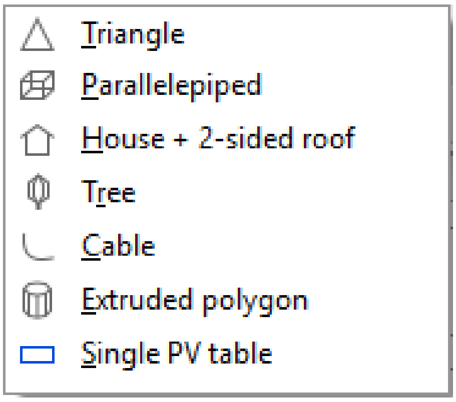
Rotate Objects: Ctrl+R

Rotate Entire Scene: Ctrl+Alt+R

Additional Tools

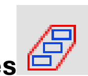
Drawing : Draw objects with the mouse

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

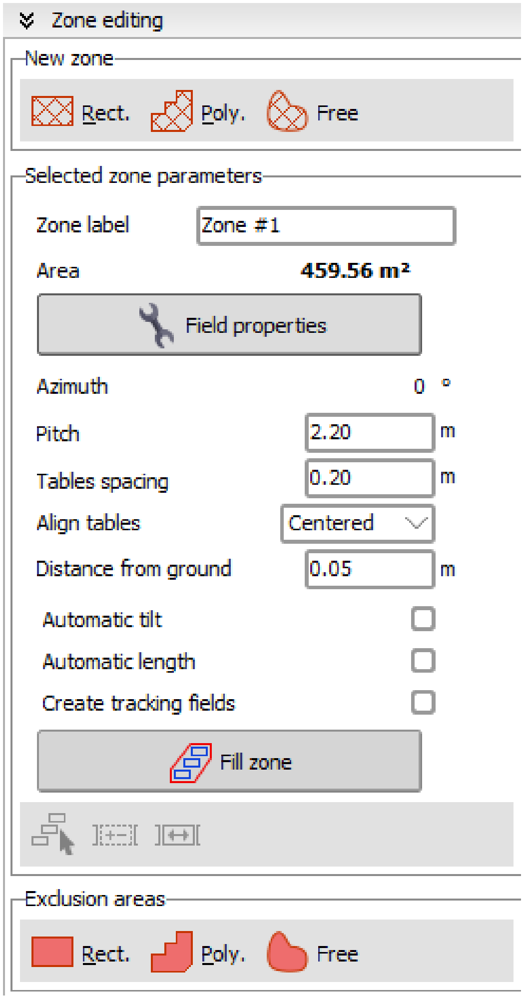


- Triangle
- Parallelepiped
- House
- Tree
- Cable
- Extruded Polygon (by defining the 2D outline and height)
- Rectangular PV Table

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.

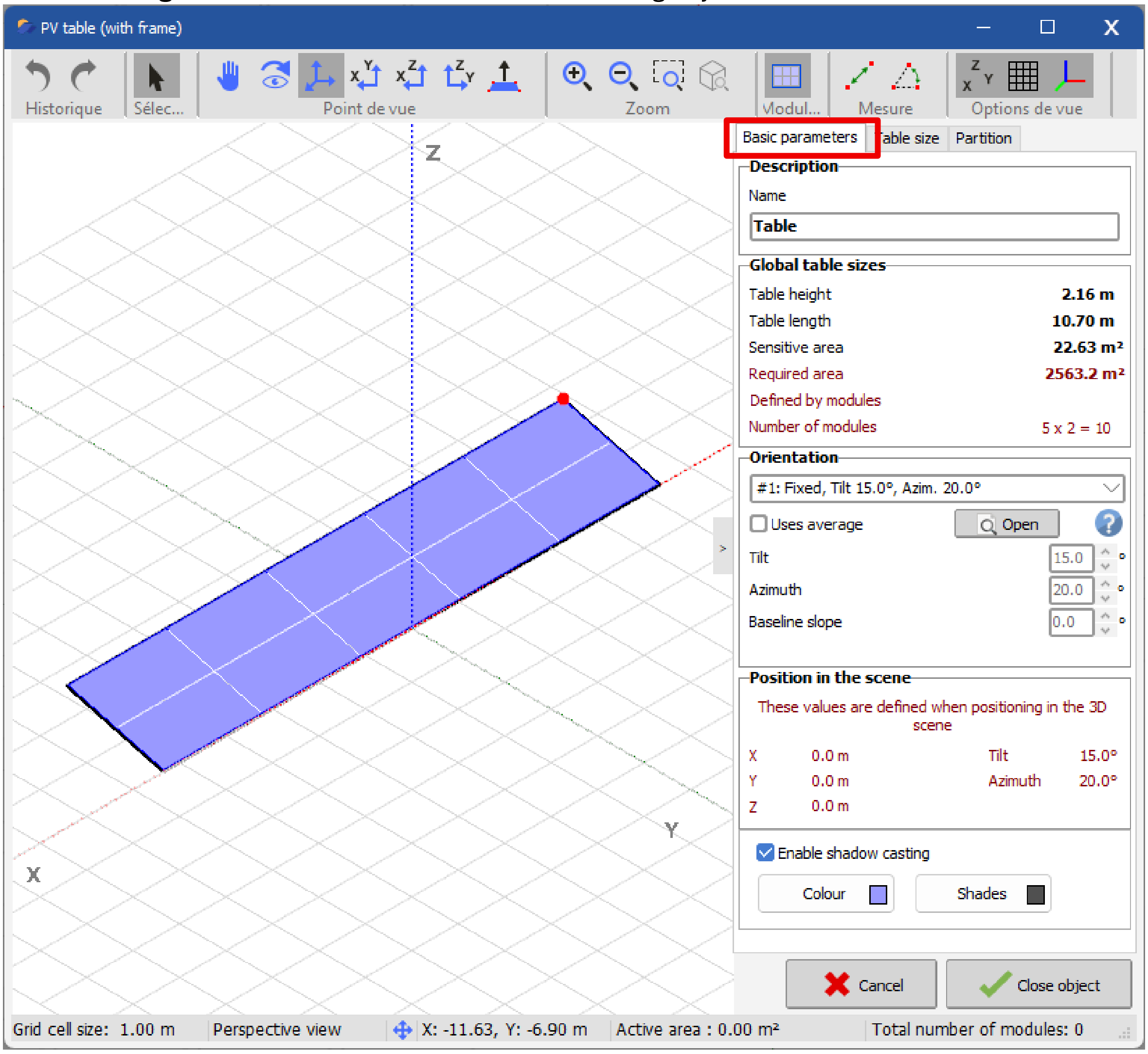
The button 

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

This button 

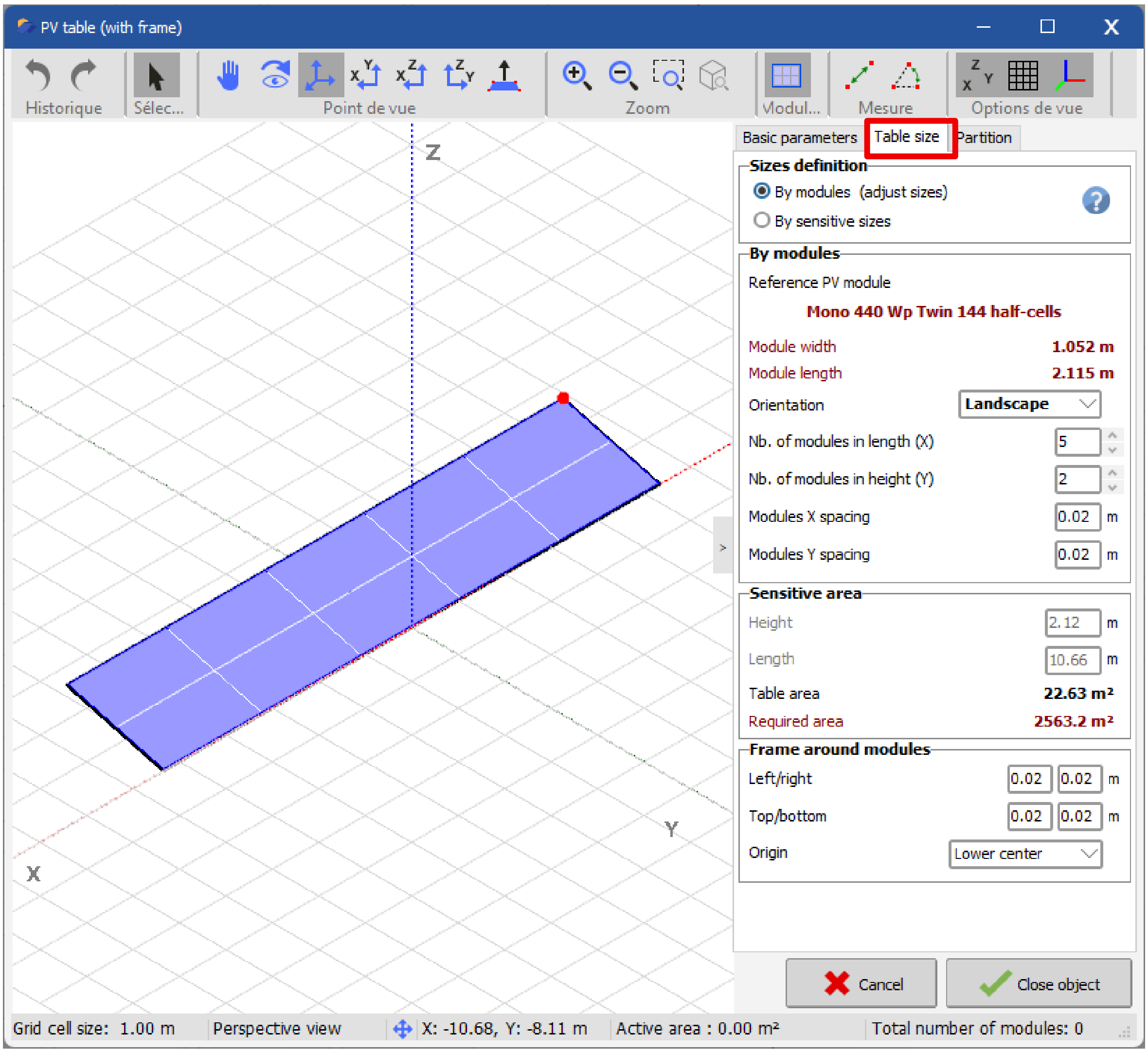
opens the table field editing dialog to define parameters for the tables generated within the zone.

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.

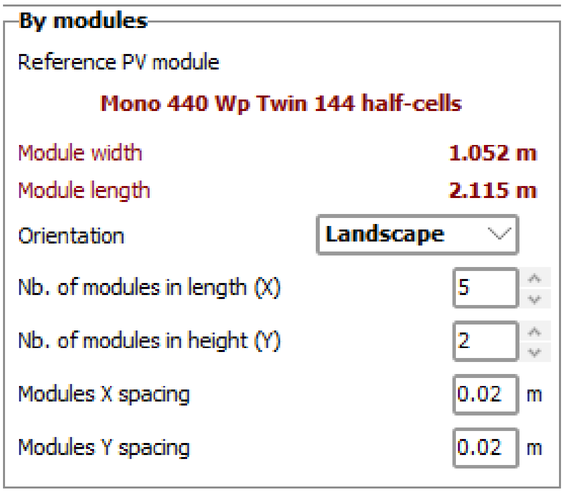
Table size tab: The **Table size** tab includes a dedicated area for photovoltaic modules. When setting up a field, specify the associated PV module. A table can only hold PV modules of the same size.



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.

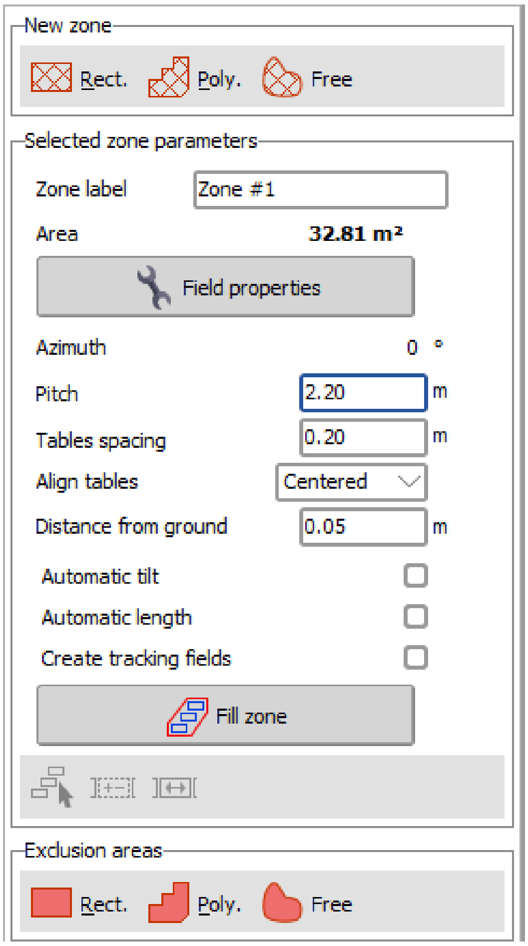


Section "by modules" shows information regarding the PV module chosen in the system definition.

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.

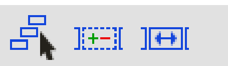
Distance from ground: Defines the height of the PV planes relative to the ground.

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

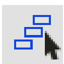
Automatic Length: Enabling this option overrides the length parameter, extending a single table in each row to fit the zone.

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

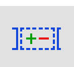
The "Fill Zone" button calculates the required space for PV tables based on the specified parameters.



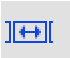
After positioning the tables, the following buttons allow further modifications:



Select all tables.

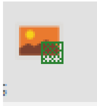


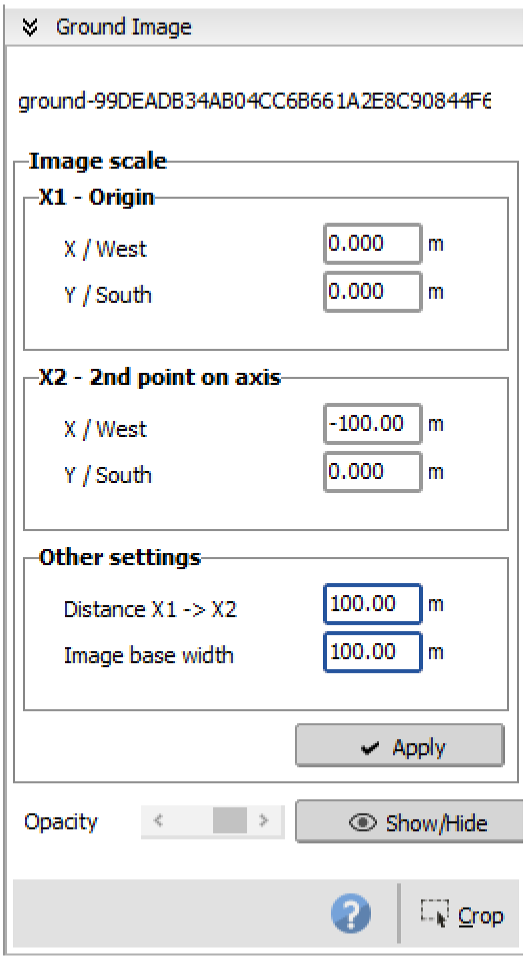
Add or remove tables.


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.

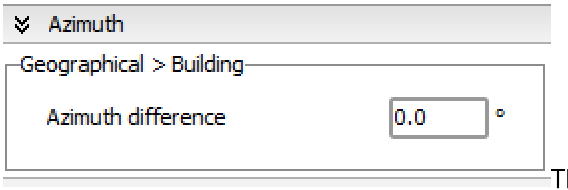

Ground Image: Reopens a section allowing image scaling and opacity adjustments.



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:



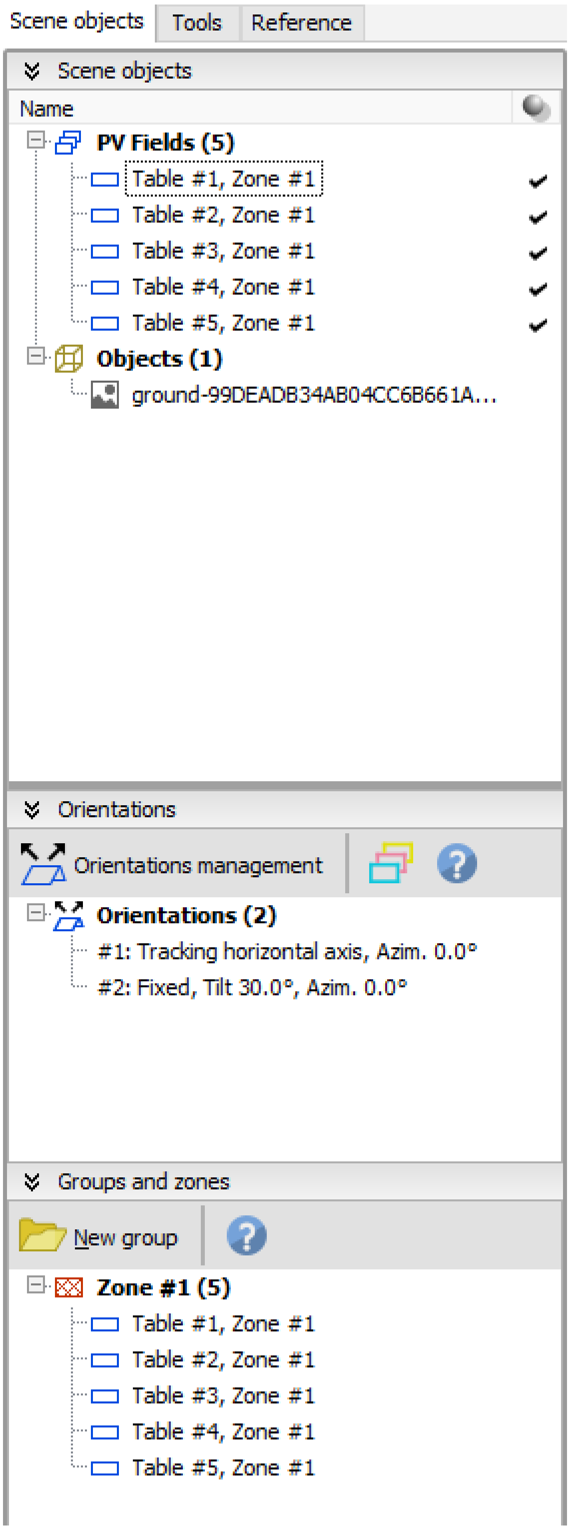
This tool modifies the azimuth of the entire scene.

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.

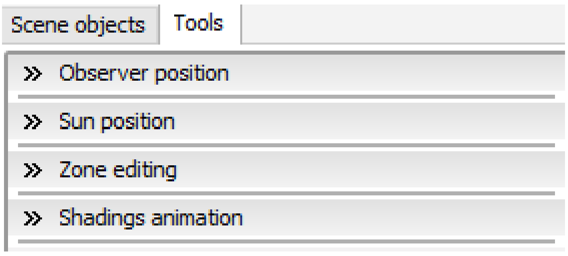
Southern Hemisphere: X points east, Y north. Azimuths are measured from north (OY) and oriented positively counterclockwise toward the west.



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

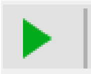
Scene Objects: View scene objects, existing orientations, and created groups, allowing zone selection.

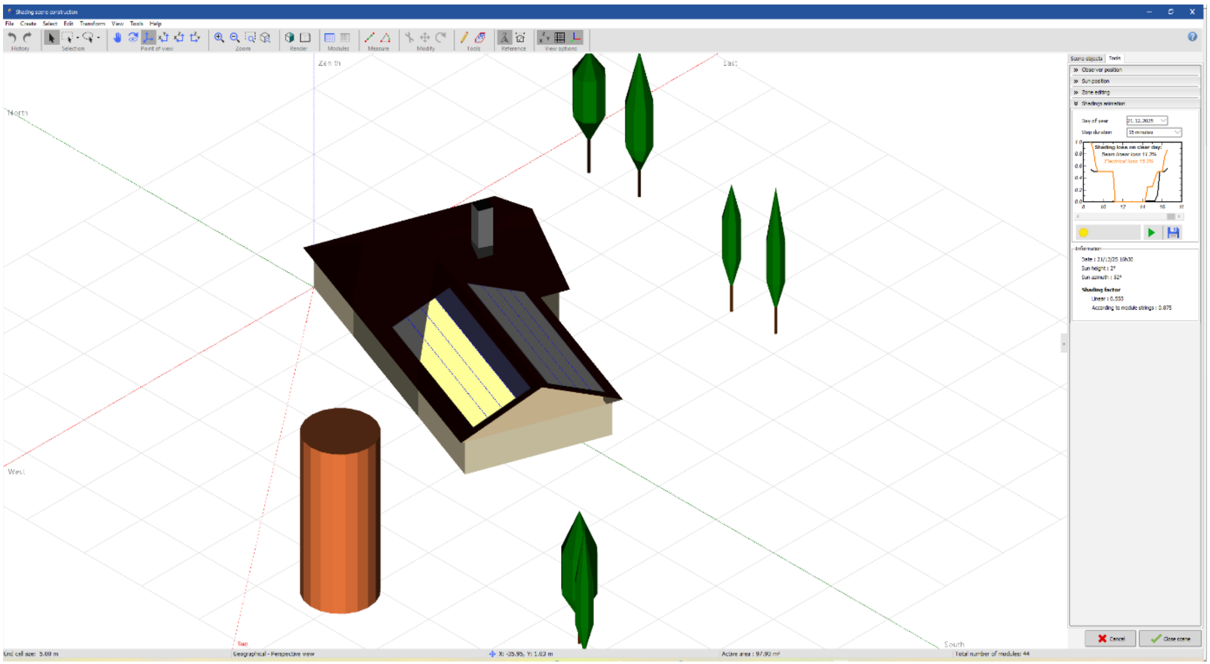
Tools: Access various tools previously mentioned.



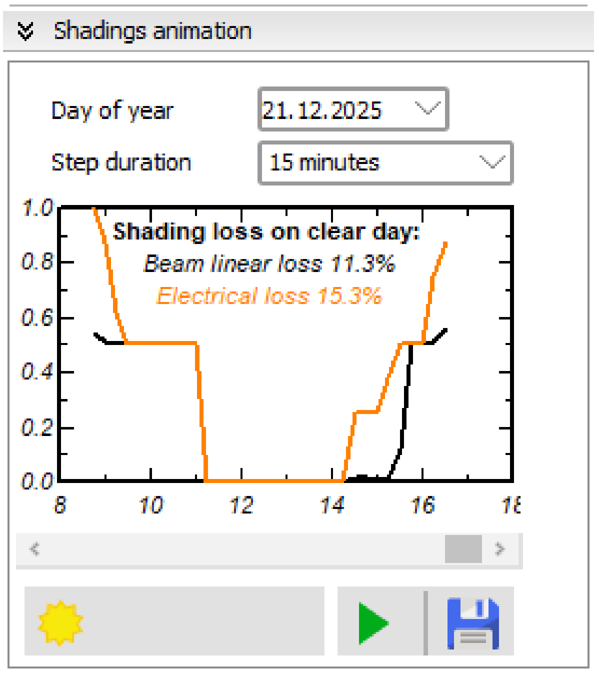
Shading animation:

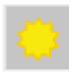
This tool displays the shadow animation in the scene for a given date. By default, it is set to December 21, the day of the lowest sun height in the Northern Hemisphere. The interval can be adjusted for a more precise shadow result.

Clicking this icon  starts the shadow animation.



For example, the linear shading on PV module surfaces on December 21 is 11.3%.



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.

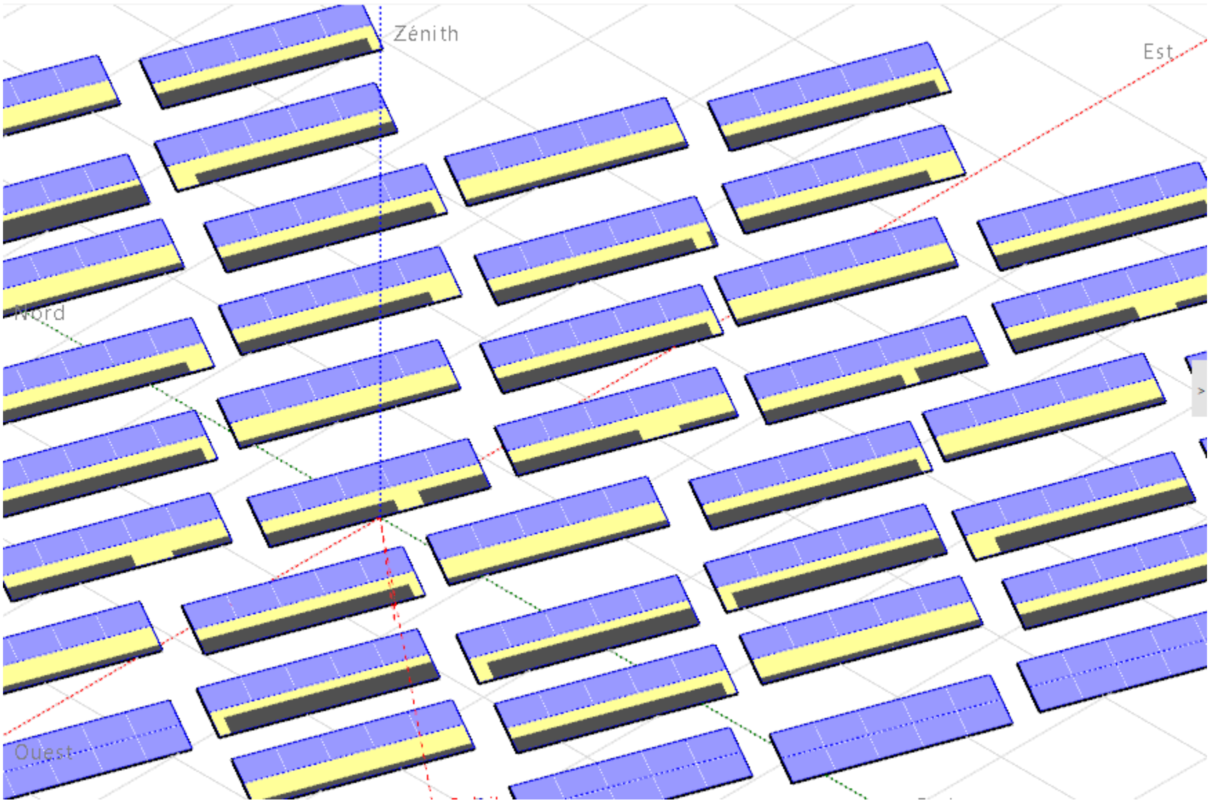
10.5 10.5 Module string partitioning

General definition

The partition model for electrical shading is an approximation that allows shading losses to be calculated more quickly than with the detailed "module layout" approach. This method works particularly well for regular systems arranged in rows.

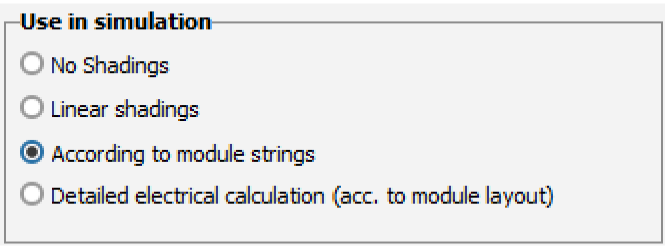
The partition model is based on the observation that a single shading point on a photovoltaic cell can cause significant losses, often to the extent of disabling an entire string of modules.

In each PV table of the 3D scene, rectangles called partitions are defined, each representing an area that can be affected by individual shading. When a partition is sufficiently shaded, it is considered inactive for the direct irradiance component. In 3D animations, these electrically shaded partitions appear in yellow.



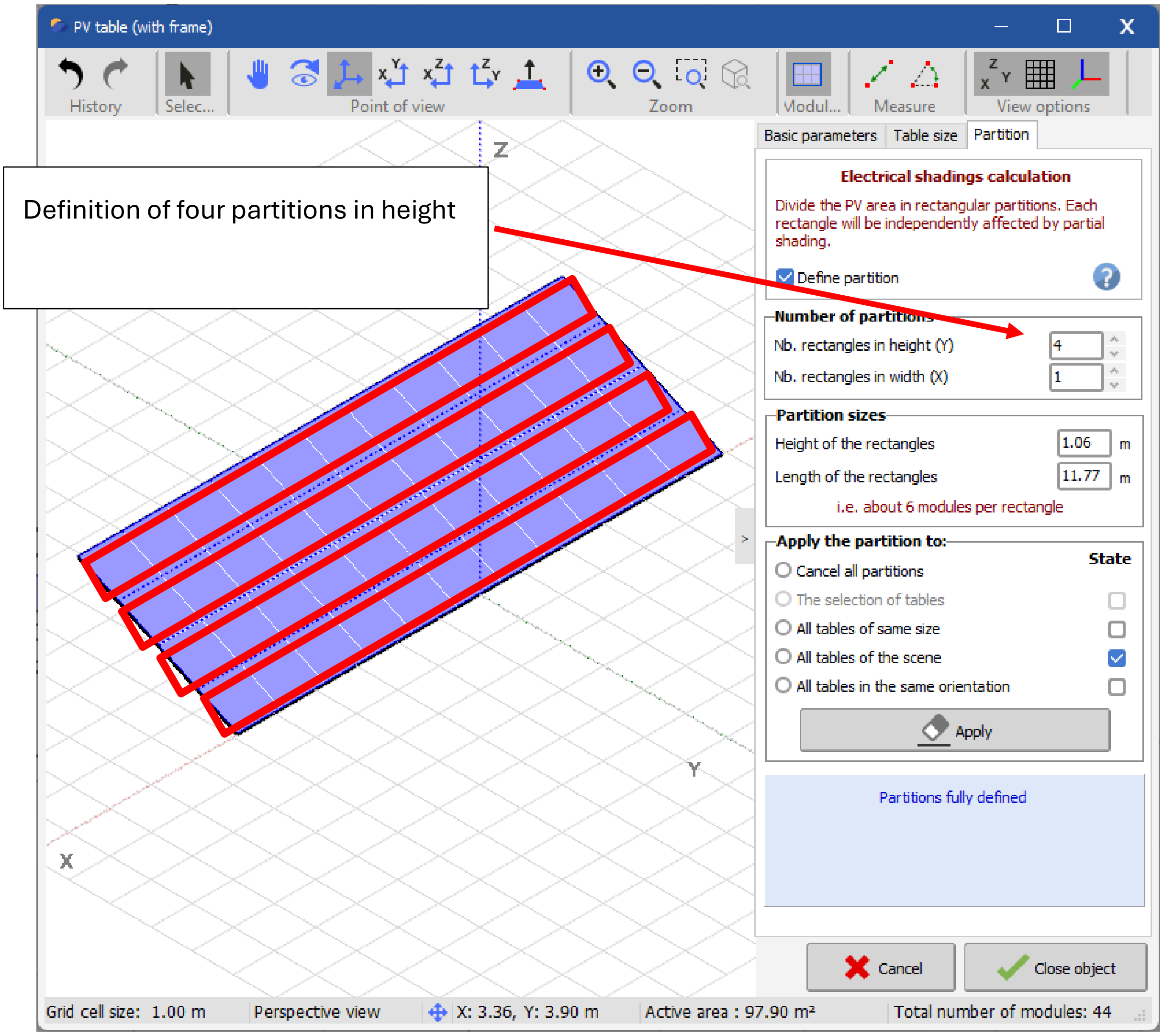
The electrical loss due to the direct component is then calculated by comparing the electrically shaded area (yellow partitions) with the geometrically shaded areas, shown in grey.

The partition model, also referred to as **"according to module strings"** in PVsyst, is the original method used to calculate the electrical effects of partial shading.



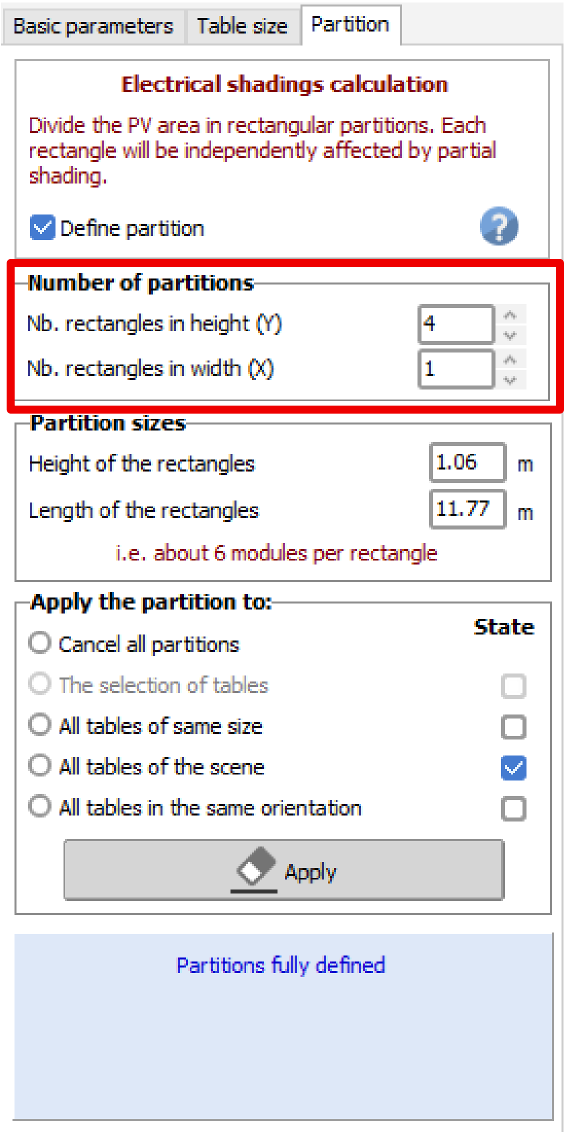
Procedure

In the 3D scene, open the PV table window by double-clicking on it. You must then define the **“Partitioning”** for each PV table or group of modules in the scene.



In the **“Partition”** tab, you can define:

The number of divisions in height and width :

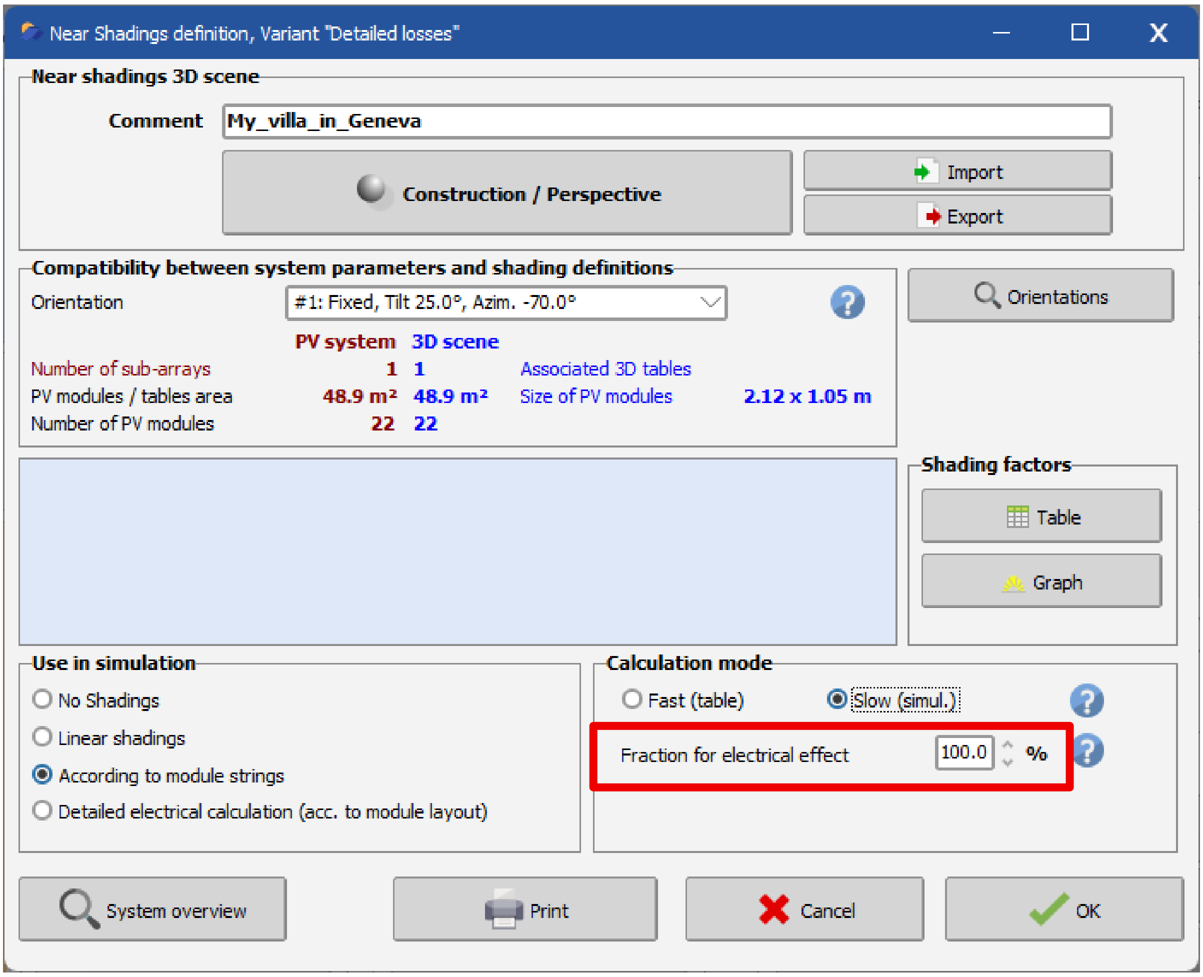


If the scene includes multiple PV tables or module groups, you have the option to transfer this partition size definition to all other PV tables/groups.

- **Remove all partitions**: deletes the definitions; electrical calculation is no longer possible.
- **Selection of tables**: if you have defined a multiple selection in the global 3D scene, you can apply this partition to all selected tables.
- **All tables of same dimensions**: the partition can be applied to a set of identical tables.
- **All tables in the scene**: sets all tables as **"Partition defined."**
- **All tables with the same orientation**: applies the partition definition to tables that share the same orientation.

Once these definitions are completed, in the main **"Near Shadings"** window, you can select **"Use in simulation > According to module strings"** and define the **"Electrical effect fraction."**

Fraction for electrical effect



During the simulation, PVsyst can reduce electrical shading losses in the partition model using a factor called the **"Electrical effect fraction"**, which can be defined in the 3D scene.

By default, this factor is set to 100%, meaning that the partition model is fully applied. However, to obtain a more realistic evaluation of electrical losses due to shading, the **"Module layout"** tool can be used. This tool allows you to:

- precisely position each module in the geometric layout,
- identify each electrical string in the system.

Combined with shading calculations, this tool evaluates the actual I/V curve of the entire PV array (for a given MPPT input) and provides a realistic estimation of mismatch losses.

By comparing the electrical losses calculated using the **"Module layout"** option with those obtained using the approximate **"according to module strings"** approach, you can determine the appropriate **"Electrical effect fraction"** to align the results with the detailed calculation.

For example, if the **"according to module strings"** option indicates 4% electrical losses and the **"Module layout"** calculation gives 3%, then the **Electrical effect fraction** should be set to 75%, calculated as: $\frac{3\%}{4\%} \cdot 100 = 75\%$

Partitioning rules – Practical guide

When modeling electrical shading in PVsyst, partitioning allows proper representation of mismatch effects between partially shaded modules.

The objective is simple:

- group within the same partition the modules that receive the same shading and therefore operate under similar conditions.

For simplicity, we describe string configurations using a standardized notation.

1. How to describe a configuration?

We use the following format:

x – Orientation – (optional U)

x = Number of rows in height

This corresponds to the number of rows occupied by the strings connected to the same MPPT.

If all modules in a string are on a single row → x = 1

If a string is distributed over 2 rows → x = 2

By default, one row is assumed.

Module orientation

Code	Meaning
L	Landscape modules
P	Standard portrait modules
T	Half-cut modules in portrait

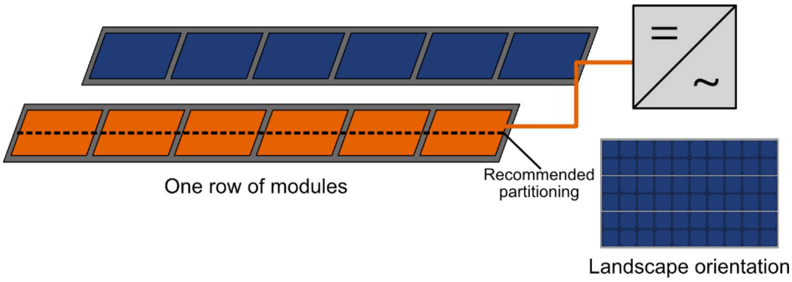
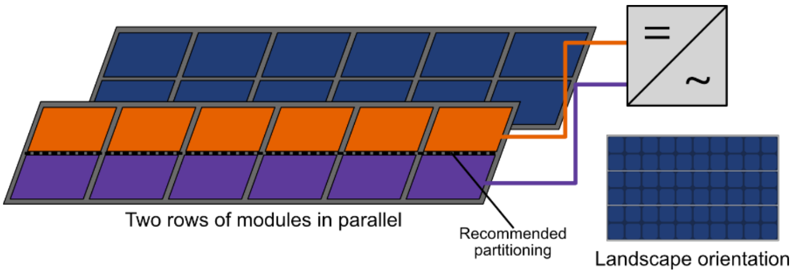
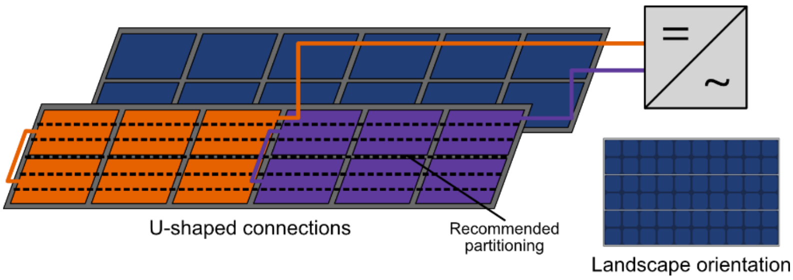
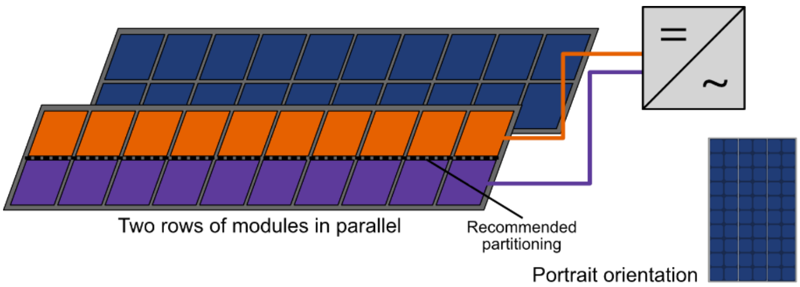
Option U (U-shaped wiring)

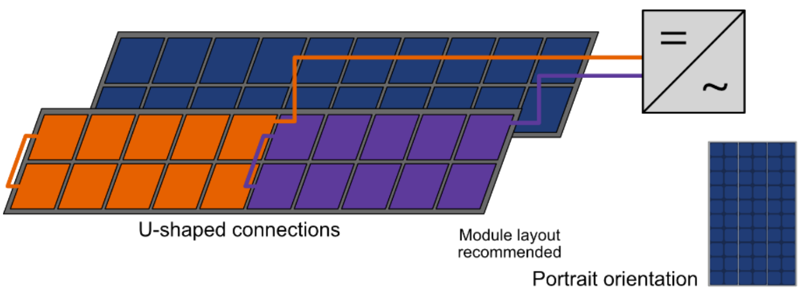
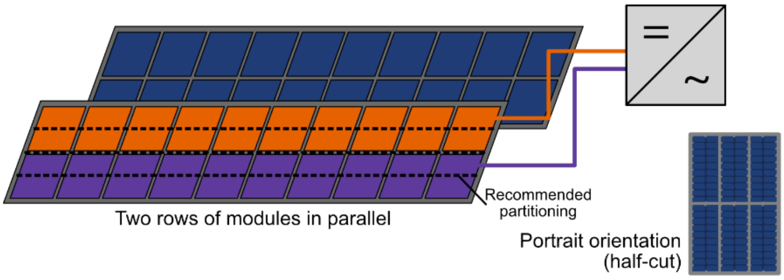
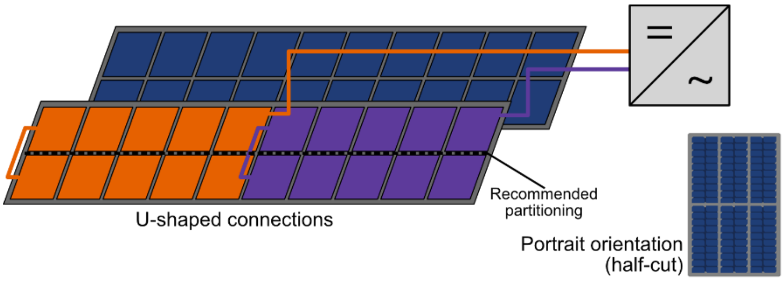
The letter **U** is added when the string is distributed over several rows with a back-and-forth (U-shaped) wiring layout.

This type of wiring modifies how shading is electrically distributed.

2. How many partitions should be defined?

The table below indicates the recommended number of partitions in height depending on the configuration.

Case	Recommended vertical partitions	Example
1L (Landscape orientation)	2 partitions	
In the 1L case, each table represents one string. To better estimate electrical mismatch losses, two vertical partitions are defined instead of just one. This original approach, validated by comparison with the module layout model, provides a better approximation of mismatch losses.		
xL	X partitions	 In the case of a table with x strings in landscape orientation, the number of partitions corresponds to the number of strings (x).
xLU	3x partitions	
xP	x partitions	

xPU	Module layout recommended	
xT	2x partitions	
xTU	x partitions	

When should "Module Layout" be used?

It is recommended to use the **Module Layout** tool when:

- strings are distributed irregularly,
- tables are complex or non-uniform,
- multiple rows are wired in U-shape in portrait orientation,
- the system is very large and mismatch is critical.

The module layout approach provides a more accurate electrical modeling than simplified rules.

Important note

The rules above are validated approximations that allow a realistic estimation of electrical losses due to shading, without systematically using the Module Layout.

They represent a good compromise between:

- modeling simplicity,
- computation time,
- accuracy of results.

11 Module Layout

The **Module Layout** tool is intended for detailed calculation of electrical mismatch losses due to shading.

It requires a precise description of the position of each PV module in the 3D scene, as well as the interconnection of modules into strings according to the inverters defined in the **System** section.

11.1 General description of the Module Layout

The evaluation of electrical losses due to shading requires calculating the I/V characteristics of the entire PV array. This is done by summing the voltages (I/V curves) of each module within a string, and then summing the currents of each string.

The I/V curves depend on the partial shading affecting each PV module. Therefore, your variant must correctly define:

- the exact geometric position of each module,
- the assignment of modules to strings and electrical sub-arrays.

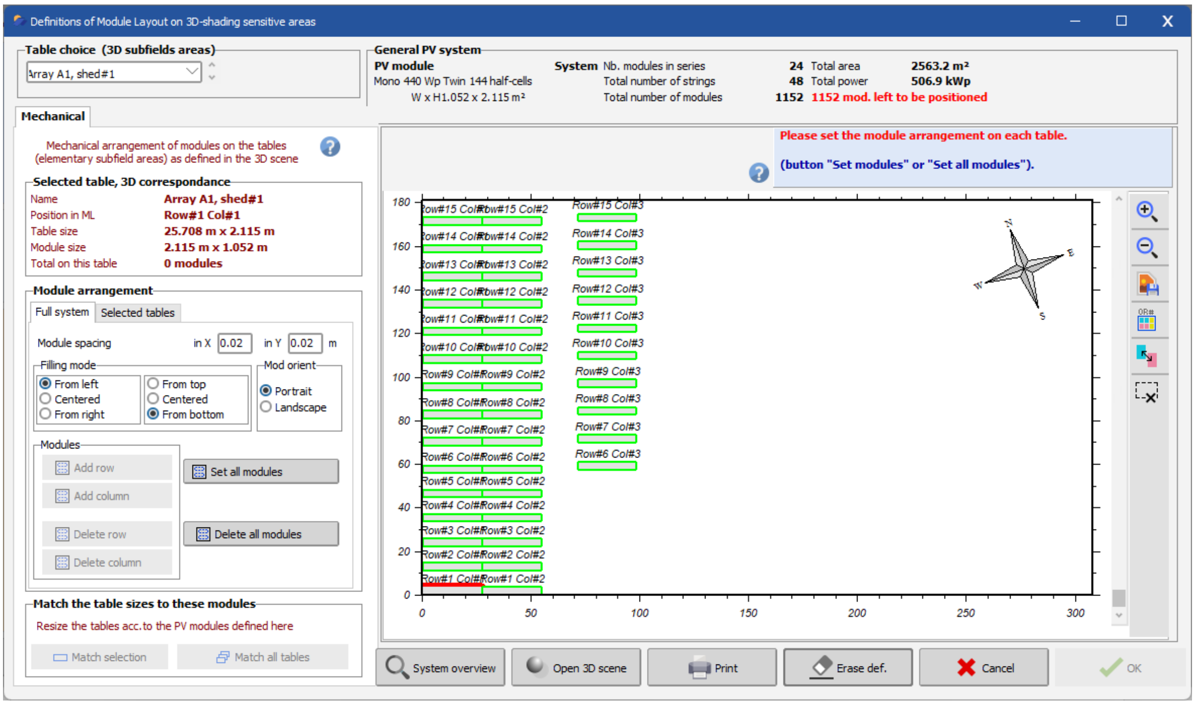
Thus, defining the **Module Layout** involves:

- building the 3D shading scene to properly position the modules,
- defining the electrical sub-arrays (PV modules and inverters) in the **System** section.

These two elements must be properly defined before using the Module Layout tool. Any subsequent modification of these parameters (shading or system definition) may affect the module arrangement and require a revision. For this reason, the Module Layout is usually the final step in the design of a PV system.

11.2 Procedure

The **Module Layout** window **displays a 2D representation of all PV tables** defined in the 3D scene. Each 3D sub-array element (for example, a fixed-tilt table or a tracker) is referred to as a **Table.**



If multiple orientations have been defined, they can be displayed separately. A dropdown menu allows you to switch from one orientation to another.

The blue panel in the top right provides information about the current status of the Module Layout definitions and gives guidance on the next action to take.

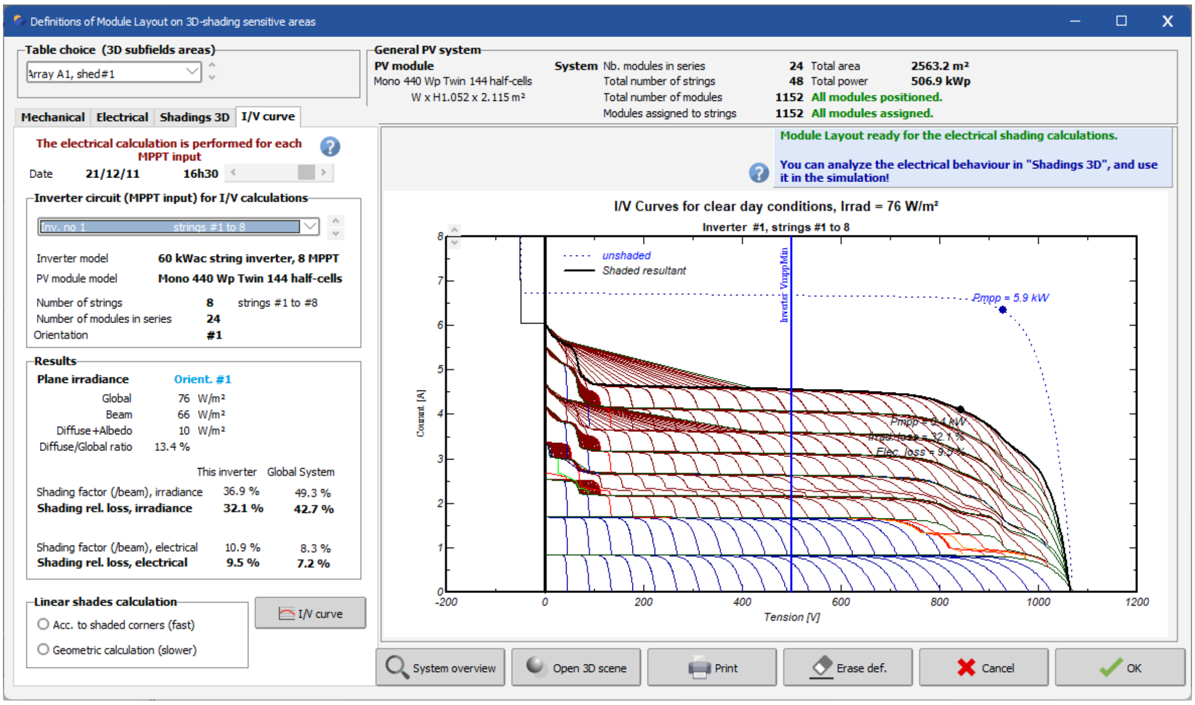
The 2 main steps:

1. “Mechanical” tab
    - Displays an approximate 2D representation of all tables from the 3D scene.
    - Allows positioning of all modules as defined in the “System” section, for each orientation.
2. “Electrical” tab
    - Allows assigning each module to a specific string according to the sub-array definitions in the “System” section.

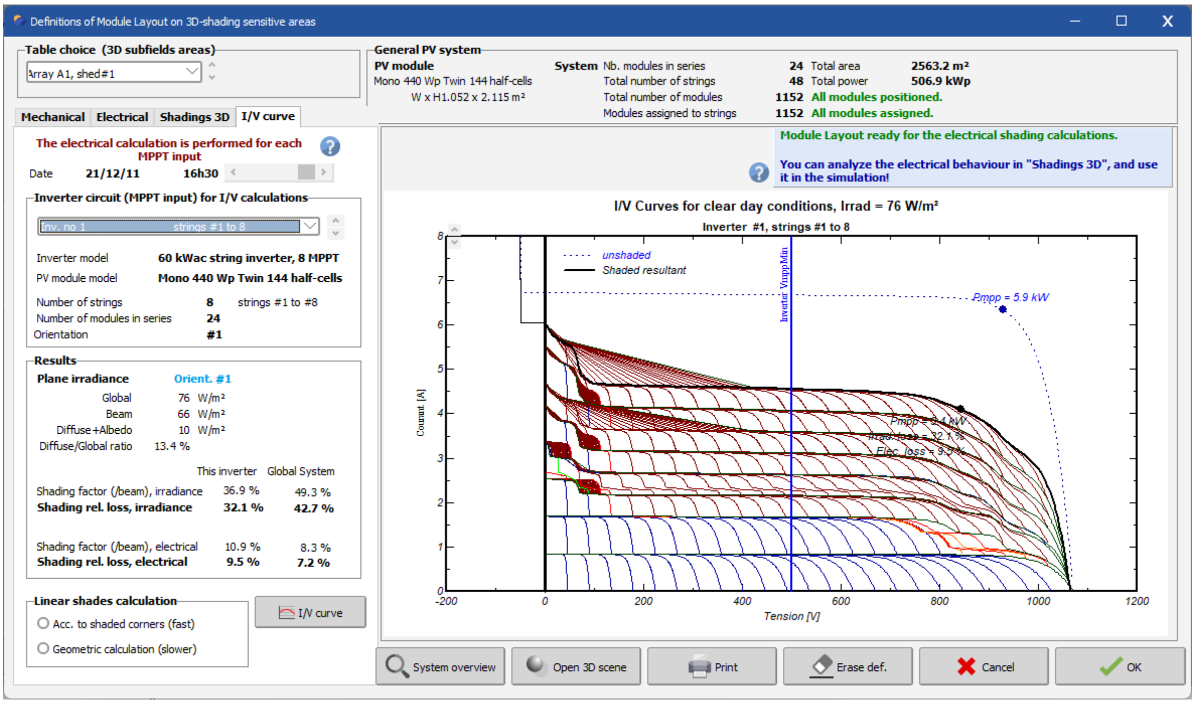
Additional learning tools:

Two additional tabs are available, but are not required for defining the Module Layout used in the simulation:

“3D Shading”: Displays the actual shading on all tables connected to a selected MPPT input, as well as the corresponding I/V curves for each shaded PV module.



“I/V Curve”: Displays the detailed I/V curves for the MPPT input, by summing the voltages of modules connected in series within each string and the currents of each string within the MPPT.



Electrical calculations and irradiance modeling

Electrical calculations take into account both direct and diffuse irradiance components. Even when a sub-module is fully shaded (in terms of direct irradiance), the remaining diffuse irradiance ensures a minimum current in the string.

- Since diffuse irradiance is omnidirectional, it is assumed to be uniform across the PV table and is affected by a constant shading factor, calculated once for the entire simulation.
- The albedo contribution is evaluated in the same way, using a constant shading factor.

The Module Layout definitions are mainly used in the simulation for a detailed calculation of electrical losses due to shading.

Output of the Module Layout definitions

This tool can also be useful for supporting the design of module wiring in your real PV system.

The Module Layout definitions can be:

- printed separately,
- included in the final simulation report in various predefined formats.

11.3 Limitations

Thin-film modules

The Module Layout tool is designed only for crystalline modules with standard rectangular cells. It is not applicable to thin-film modules, where each cell is a strip of about 10 mm wide running along the full length of the module.

In this case: electrical mismatch losses are negligible if the shading is perpendicular to the cells, meaning all cells are equally illuminated (cells arranged in portrait within a row). On the other hand, shading losses are maximal if the shadow is parallel to the cells, since a single shaded cell in series can block the current of the entire module.

This behavior cannot currently be represented in the Module Layout tool.

Thin shadows

The tool underestimates the impact of long and thin shadows (e.g., poles) due to the method used to detect shaded sub-modules.

If your 3D scene includes such objects, it is recommended to use the partition model instead.

Very large systems

The Module Layout tool is suitable for systems up to a few MWp at most.

Main limitations:

- Difficulty in defining the position of all modules when the interconnection is not regular.
- High computation time during simulation.

PVsyst sets a "reasonable" limit at around 1 MWp, with an upper limit that can be adjusted (up to 5 MWp) via the advanced settings:

- "Power limit for Module Layout warning"
- "Power limit for Module Layout error"

For very large systems, it is recommended to:

1. Define a representative sub-system (e.g., one central inverter).
2. Simulate this sub-system using both methods:
    - Module Layout
    - Partition model
3. Evaluate the **"Electrical effect fraction"** specific to your system (generally close to 100% for regular systems).
4. Simulate the entire system using the **"According to module strings"** option, applying the factor in **"Calculation mode – Electrical effect fraction."**

This latter method requires a computation time similar to the linear shading option.

11.4 Relevant advanced parameters

The Module Layout model is controlled by several advanced parameters available in **Settings → Edit advanced parameters**.

Min. shade area to count as shaded (default value: 0.024 m^2):

When a small shadow polygon covers a sub-module without specifically covering a corner, the shading is ignored if its area is below this value.

Min. shading factor for electrical calculation (default value: 1%):

If linear shading is below this fraction for the string field, electrical shading losses are considered zero, i.e.:

$P_{ele}c = 0$

Max. shading factor for electrical calculation (default value: 98%):

Above this value, the string field is considered fully shaded, i.e.:

$P_{ele}c = 0$

Frac. bottom cell for no shading (default value: 50%):

When a shadow covers only a fraction of a cell, the electrical loss varies linearly with the shaded portion of the cell.

Introducing a threshold at 50% of the cell width (expressed as the height of the shading polygon) to trigger electrical shading allows a more realistic modeling of mutual shading behavior.

In practice, the linear variation across the cell width is approximated by a step at 50% of the cell width.

Control parameters for warnings and errors:

These parameters limit the use of the Module Layout for systems that are too large or when the size of 3D tables has changed:

- Tolerance for size difference between Module Layout and 3D tables

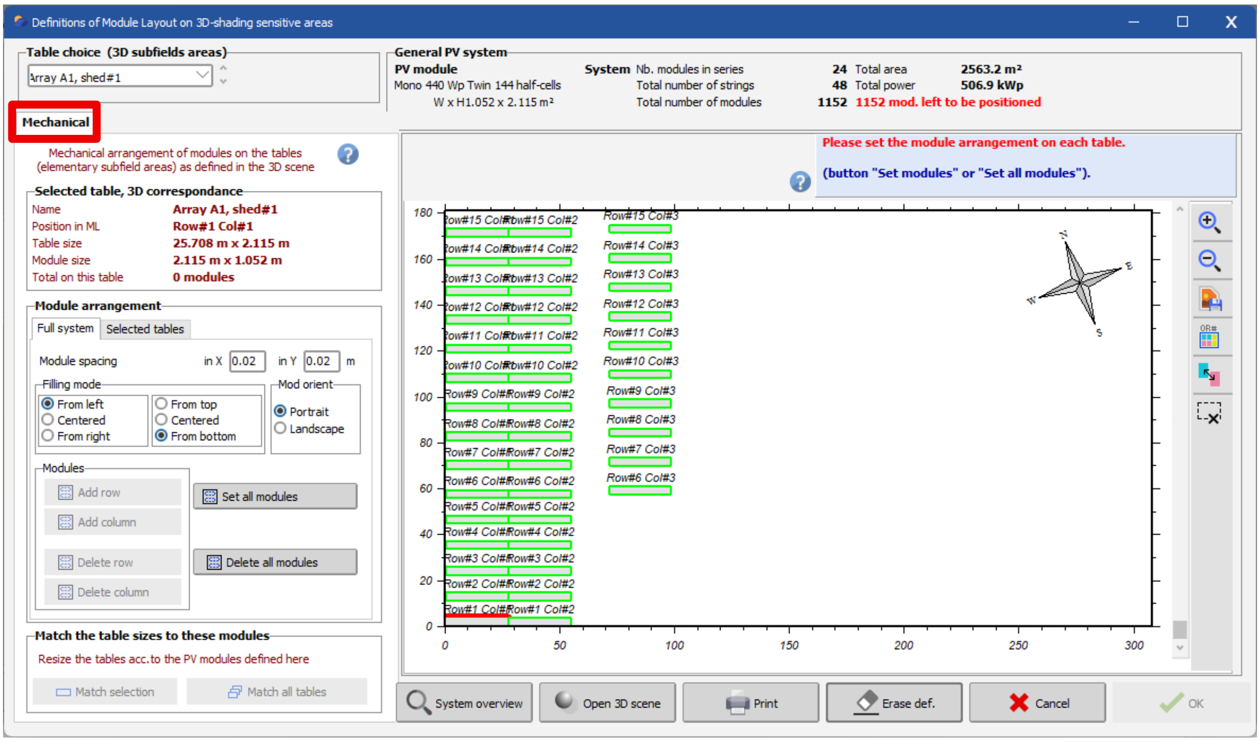
  → **Default value: 2%**
- Power limit for Module Layout warning

  → **Default value: 1000 kW (1 MWp)**
- Power limit for Module Layout error

  → **Default value: 5000 kW (5 MWp). Above this limit, the use of Module Layout is not allowed (modifiable in the advanced settings).**

11.5 Mechanical definition

The purpose of this tool is to distribute the PV modules (defined in the sub-arrays of the **"System"** section) across the Tables defined in the 3D shading scene editor.



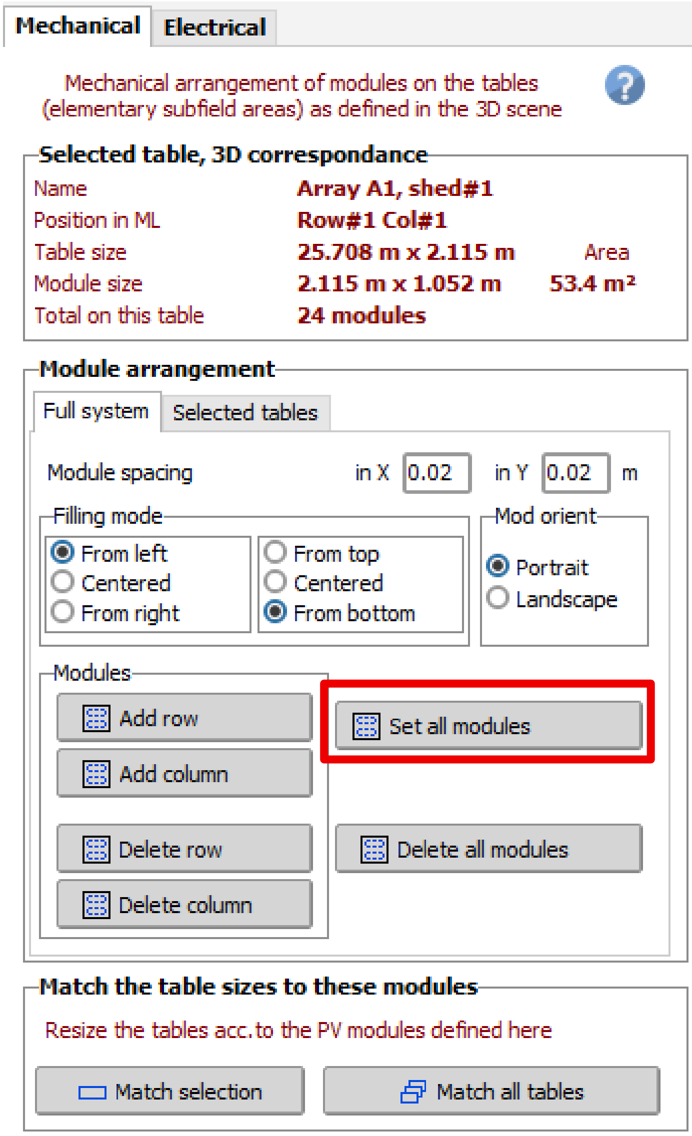
It is therefore necessary to have a well-defined 3D scene and a properly configured **System** before using the Module Layout tool.

The number of PV modules must match the number of modules defined in the sub-arrays, for each orientation. A dedicated view is available for each orientation.

In the **Mechanical** tab, under the **full system** section, click on the **Define all modules** button.

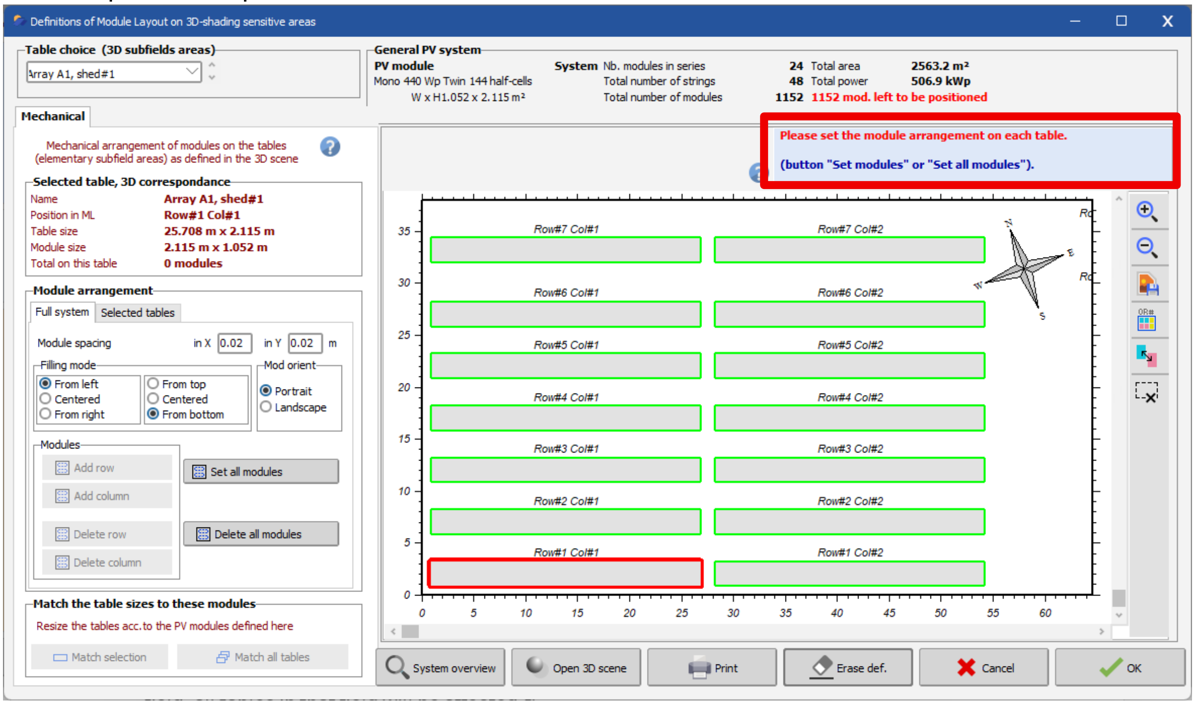
See its location in the screenshot below:

See its location in the screenshot below:



Panneau d'informations et paramétrage mécanique

Le panneau bleu (en haut à droite) informe en permanence sur l'état des définitions mécaniques ainsi que sur les actions à effectuer."



The **"Mechanical"** dialog, located on the left side of the window, allows you to:

- display the main characteristics of the selected table,
- assign modules to tables, either for the entire system, a specific orientation, or a selection of tables,
- define:
  - the spacing between modules,
  - the filling mode (if the table is larger than required),
  - the module orientation (portrait or landscape).

If the 3D space is insufficient, some modules required by the system sub-arrays may be missing. In this case, it is possible to add rows or columns of modules if needed. If a table belongs to a field, all tables in that field will be affected.

Removing modules

It is possible to remove a module by right-clicking on it.

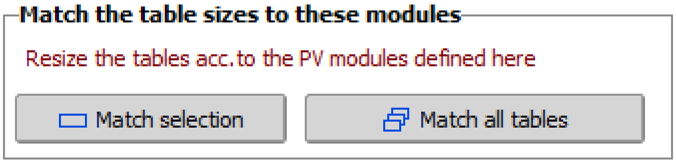
This allows precise adjustment of the required number of modules and avoids the use of unnecessary polygonal fields, which are reserved for specific BIPV cases.

However, removing too many modules may slightly affect shading calculations.

Adjusting tables to modules

Before proceeding to the next steps, the 3D tables must exactly match the PV modules.

If this is not the case, use the following buttons:



- **"Adjust selection"** to adjust a single table,
- **"Adjust all tables"** to adjust all tables.

Special case: 3D polygonal field

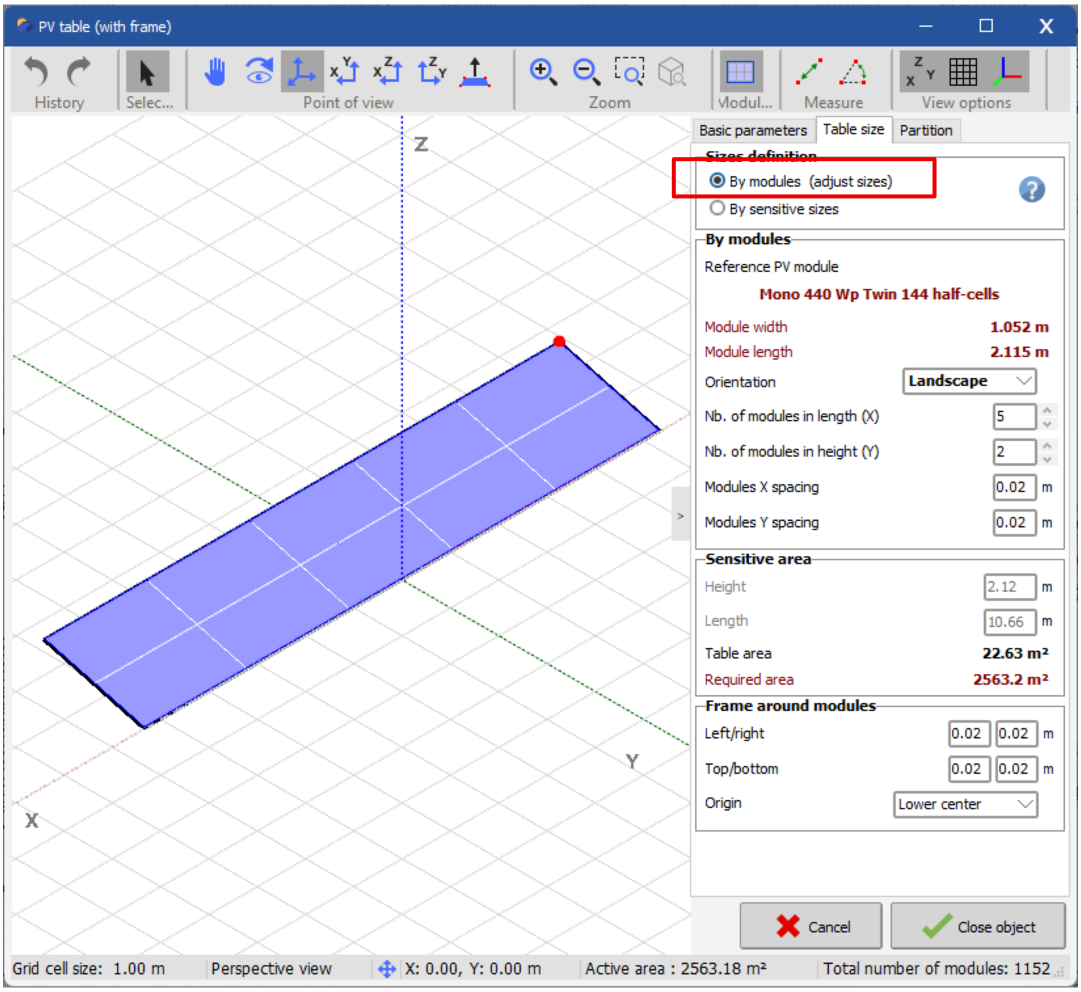
- The raw polygonal surface (e.g., available roof area) is initially filled with modules.
- Modules can be added or removed using the mouse.
- Once the layout is adjusted, use **"Match to Table"** to adapt the field perimeter around the modules.

Once all these steps are completed, you can proceed to the **"Electrical"** tool.

11.5.1 Definition of tables in the 3D scene (reminder)

Important reminder:

When defining PV fields in the 3D scene, it is recommended to use the **"By modules"** option so that table sizes are correctly predefined.



However, it is also possible to freely define tables with sufficient space to accommodate your modules. These tables will be automatically adjusted when exiting the tool.

11.5.2 Graphical view of module placement

After defining the spatial placement of all modules, the result is as follows:

- All tables for a specific system orientation are displayed as in the 3D scene.
- Tables are numbered in rows and columns for easy identification.
- This numbering is automatic, based on the geometric layout (it cannot be modified).
- A compass (top right of the drawing) indicates the orientation.
- If multiple orientations are defined, a dropdown menu allows you to select them.

Example: The compass indicates an azimuth of 0° (south).

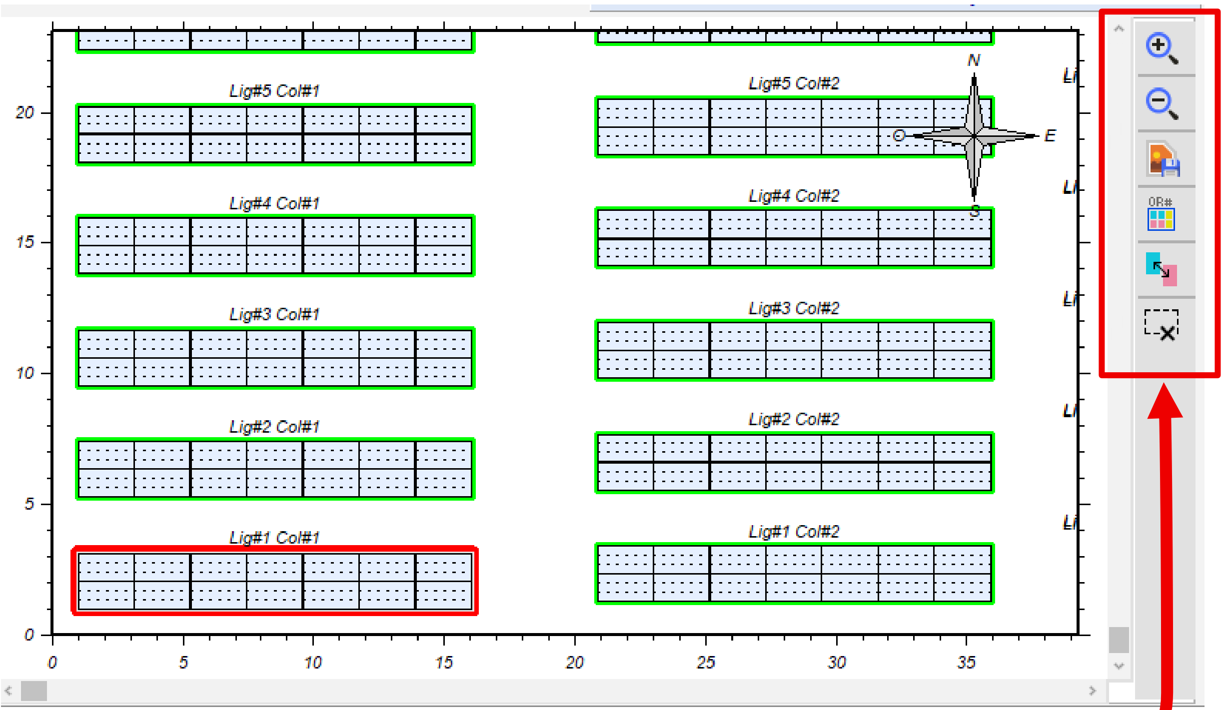


Table selection

- Click on a table to select it (red outline).
- Multiple selection: **Ctrl + left-click**.
- Deselect: **Ctrl + right-click** (orange outline).

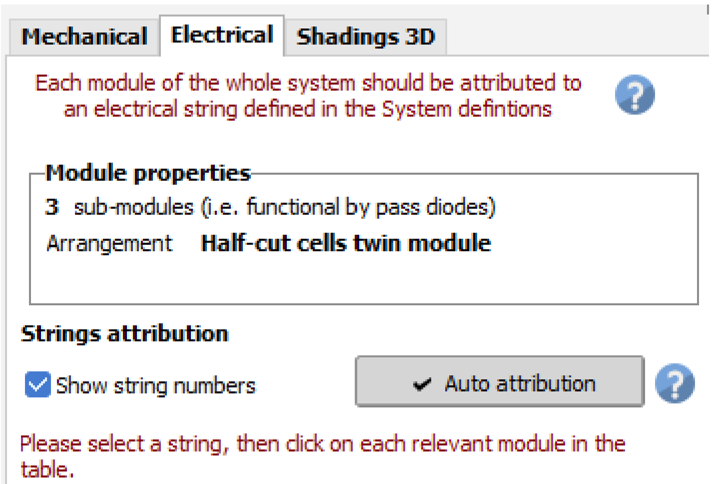
Available tools (icons on the right):

- Zoom IN / OUT (also using the mouse wheel).
- Save the table image as a *.BMP file.
- Select table labels (3D Name, **"Orient#, Row#, Col#"** or condensed version).
- Swap string assignment (see section 10.7.3 Toolbar).
- Deselect all selected tables.

11.6 Electrical definition

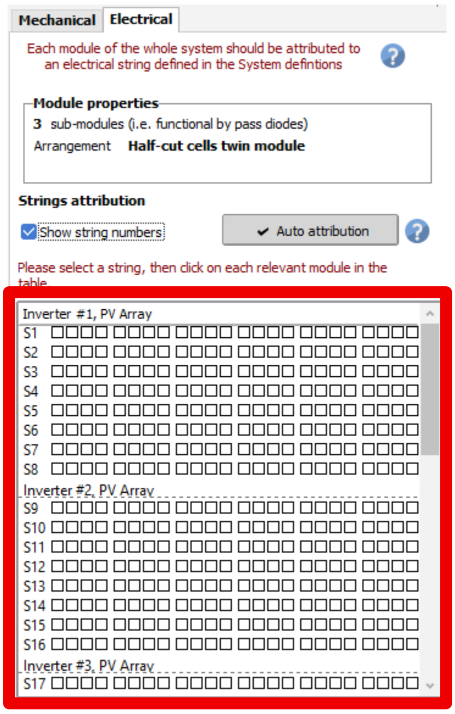
The purpose of this tool is to assign a string (defined in the sub-arrays of the **"System"** section) to each module placed on the tables.

This step can only be performed after a **correct definition of the mechanical parameters.**



11.6.1 String list

The left panel displays the list of all inverter inputs (or MPPTs) defined in the sub-arrays.

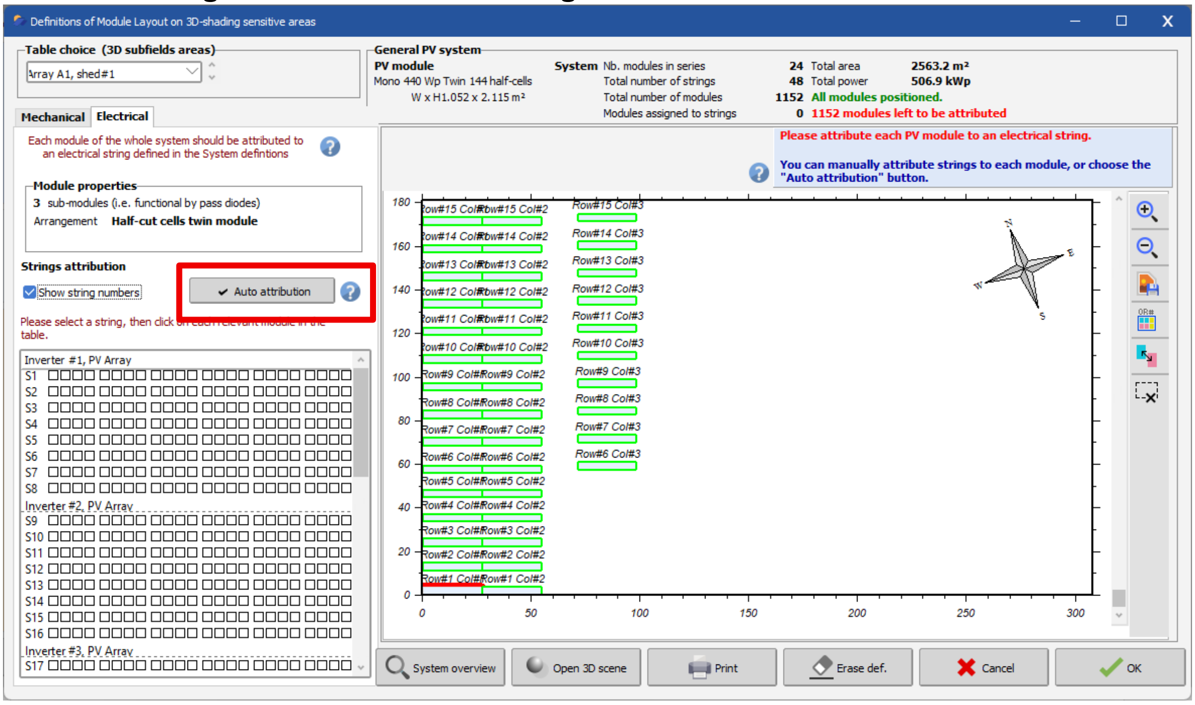


- Each string is represented by a set of PV modules, with a different color depending on its number (colors 1 to 10).
- *Example:* 5 strings per inverter, 16 modules per string.

11.6.2 Automatic string assignment

For large systems, the **"Automatic assignment"** button opens a dedicated window.

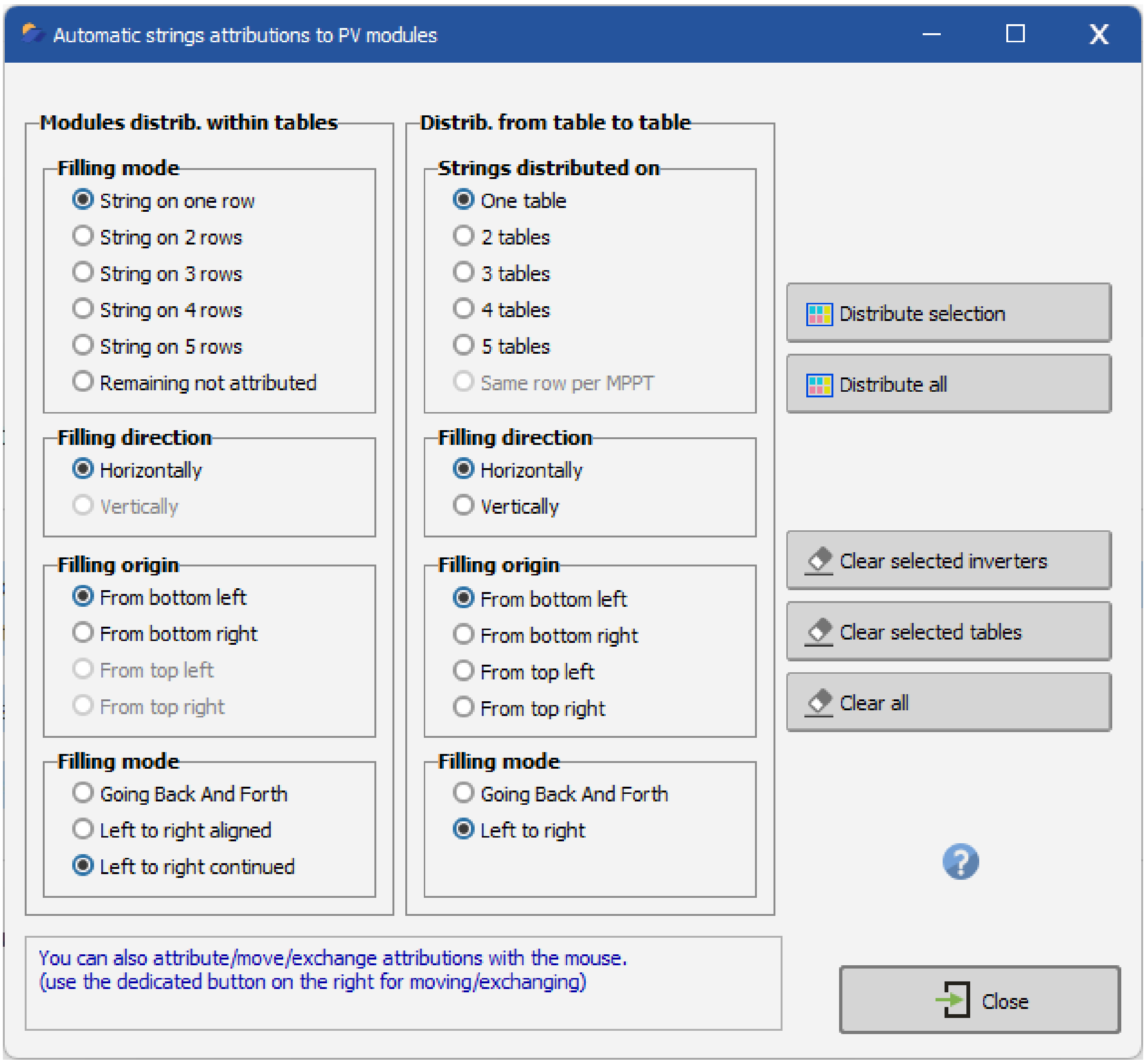
Automatic assignment of modules to strings



The assignment of each PV module to a string can be done manually using the mouse, but this approach becomes impractical for large systems.

PVsyst provides several automatic string assignment strategies, based on different approaches.

This feature is accessible via the **“Automatic assignment”** button, which opens a dedicated window.



11.6.3 Trials and adjustments

Assigning strings in a real installation is a complex task, depending on several parameters:

- table size,
- distribution of modules across multiple tables,
- grouping of modules from the same string within the same row,
- wiring constraints and distances between modules of the same string,
- matching the number of modules to the table width.

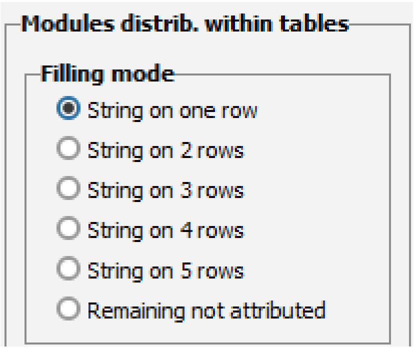
PVsyst provides several strategies, but they may not cover all specific cases.

The tool allows you to:

- apply a strategy to a selected set of tables or a group of selected inverters,
- test a strategy and selectively remove it if it is not suitable,
- manually adjust assignments by swapping modules using the mouse.

11.6.4 String assignment on "large" tables

When a table contains several complete strings, the **"Module distribution in tables"** tool offers several configurations:



a. **All modules of a string in the same row**

   This is the usual configuration in sheds, when the goal is to minimize shading effects: all modules of a string are grouped in the same row so that they are shaded uniformly.

b. **Strings distributed over two rows**

   This is also a common choice in some applications, often referred to as **"U-shaped wiring"**. Although it can simplify wiring, it is not optimal with respect to mutual shading.

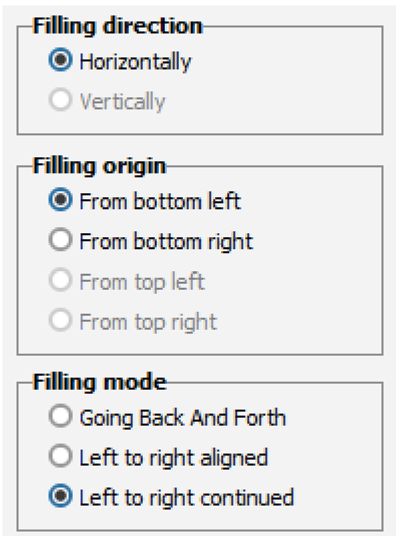
c. **Strings distributed over 3, 4, or 5 rows**

   This is not a common configuration.

d. **Remaining unassigned modules**

   If the table is not fully filled, the **"Remaining unassigned"** option allows automatic assignment of "free" modules without specific positioning constraints

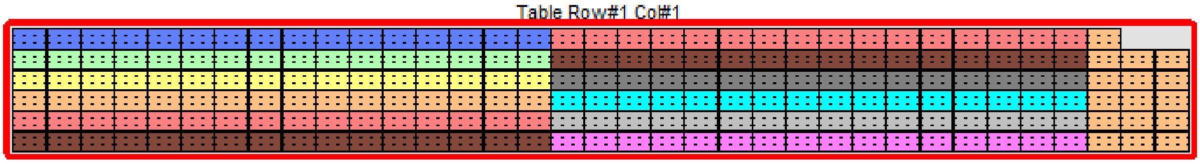
Filling mode



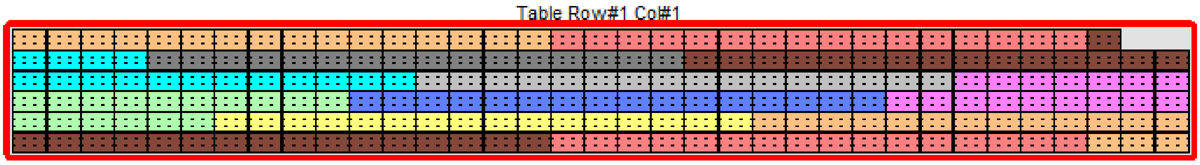
- **Filling direction:**
  - Horizontally (common in rows),

- Vertically (specific cases).

- **Filling origin:** all options are possible.
- **Filling mode:** useful when the number of modules does not exactly match the table width.
    - **Left to right:** strings start from the left, and remaining modules are placed on the right with an additional string (even distribution).



- **Back-and-forth:** filling row by row, alternating the direction on each new row. This avoids connections spanning the entire table, but may distribute a string across multiple rows, which is not optimal.



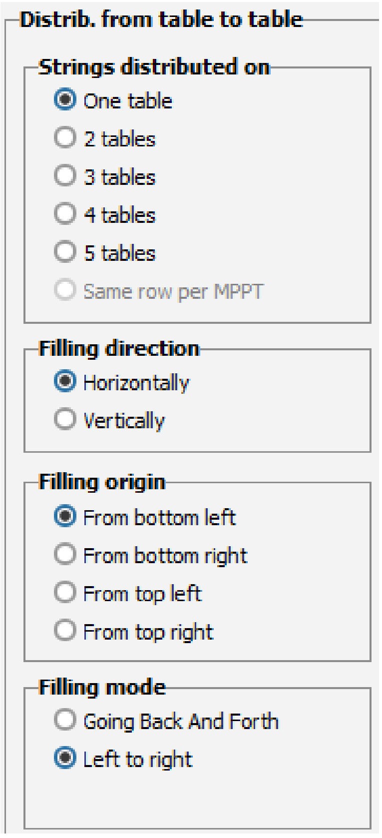
Note: Some strategy configurations may leave certain modules unassigned. In this case, the "Remaining unassigned" option can always be used to fill the gaps.

11.6.5 String assignment on "small" tables

More and more ground-mounted systems are made up of **small independent tables** (only a few modules wide), typically to better follow the terrain slope.

To **minimize mutual shading effects**, all modules of the same string should be placed in identical shading conditions (for example, all positioned at the bottom of each table).

Distribution parameters



The right-hand side of the **"Strings distributed over XX tables"** dialog allows you to define the sequence of tables when distributing a string. Depending on the number of modules in a string, you can choose:

- **Strings distributed over a single table**

  The next table is filled only when the previous one is fully assigned. → A string may still extend over two adjacent tables if the number of modules exceeds the capacity of a single table.

- **Strings distributed over two, three, four, or five tables**

  This setting depends on the system configuration (number of modules per table in width versus the number of modules in a string).

  Example: if you define 4 tables with 4 modules each, they perfectly accommodate the 16 modules of one string. This is an "ideal" case, but it is not always achievable.

  When distributing a string over multiple tables, careful consideration must be given to the wiring design.

- **Table filling mode**

  Tables can be filled in rows (side by side) or in columns (one behind another).

- **Filling origin**

  The starting corner in the table matrix can be defined.

- **Filling direction**

- **Left to right:** each string starts on the left and continues toward the right.
- **Back-and-forth:** one row is filled in sequence, then the next row is filled in the opposite direction.

Note

The **"Same row per MPPT"** option corresponds to a very specific case:
→ it allows all strings connected to the same MPPT input to be placed on the same row across all tables.

This is an optimal configuration for minimizing electrical losses, but in practice it is only applicable to string inverters (typically 2–3 strings per MPPT input).

11.6.6 Selection of filling zones

In complex systems, a single strategy is not always suitable for all parts of the system. The tool allows you to:

- select a group of tables (**Ctrl + left-click**) and apply a specific strategy,
- selectively clear existing assignments,
- select a group of inverters for partial assignment.

Once all modules are assigned to strings, the system is ready for simulation.

It is also possible to proceed to the next step: **"3D Shading" (10.8)**, for a visual understanding of electrical behavior under shading conditions.

11.6.7 Manual assignment of modules to strings

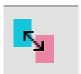
Simple method:

- Select a string in the left panel.
- Click on the modules to assign them (dragging the mouse across multiple modules is possible).
- Unassign a module with a right-click.

The colored boxes on the left indicate the number of modules already assigned. The white boxes indicate the number of modules remaining to be assigned.

Limitation: This method becomes tedious for large systems.

11.6.8 Manual modification and swapping of assignments

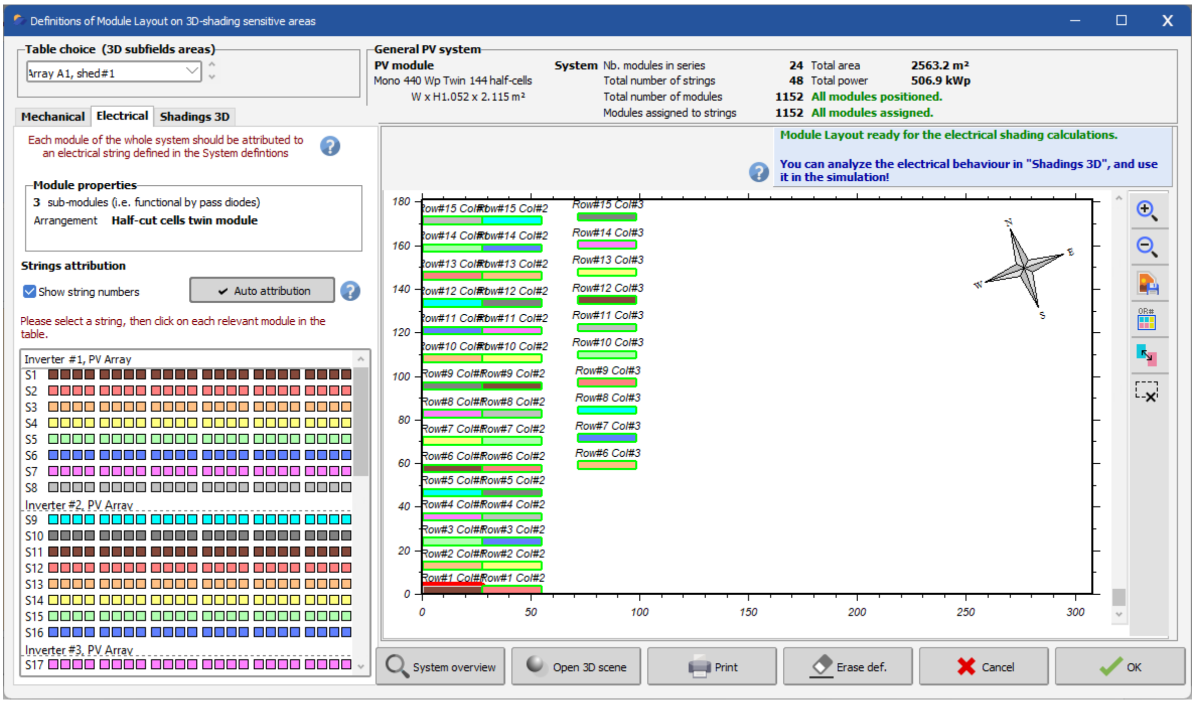
An optional mode (button on the right)  allows you to:

- move the assignment of a string to an unassigned module,
- swap two modules with each other.

This option is useful after an automatic assignment, to fine-tune the distribution.

11.6.9 Objective of string assignment

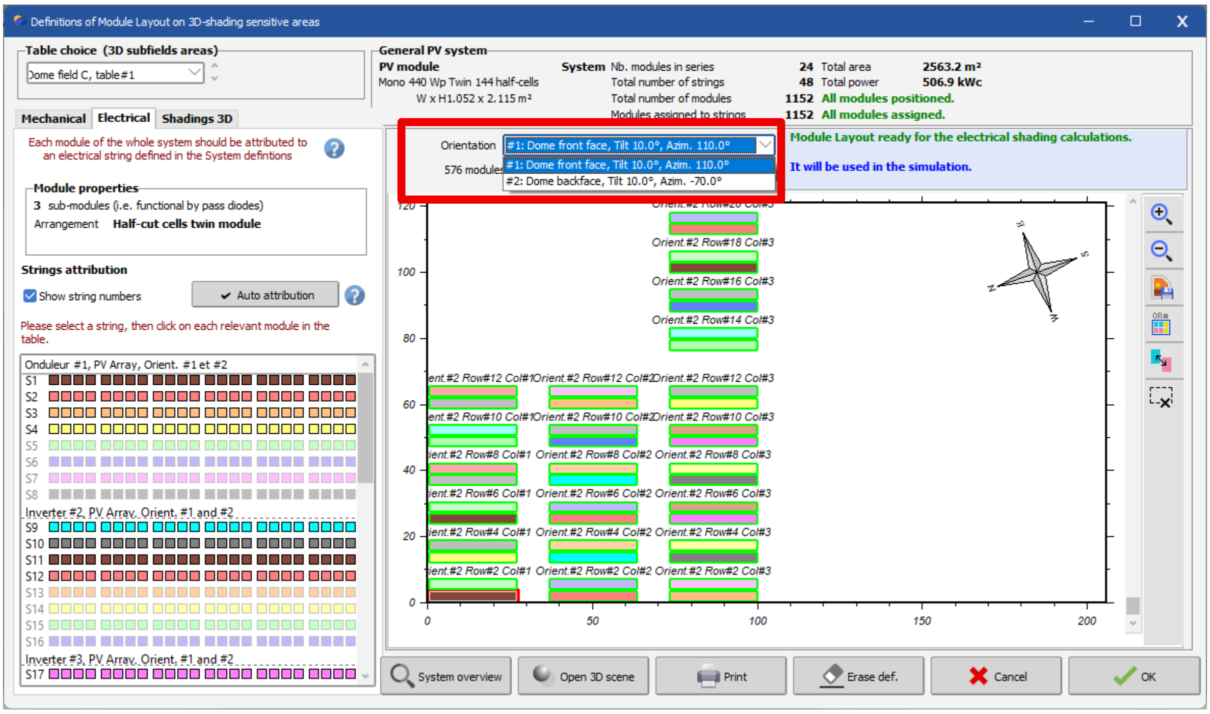
For row-based layouts (sheds) or tracker systems, it is recommended to assign all modules of the same string to a single row.



- **Advantage:** All modules in the string will experience identical shading conditions, which is optimal for minimizing inter-row shading losses.
- **Standard modules** (3 sub-modules in length) → Landscape orientation.
- **Half-cut cell modules** (twin half-cut cells) → Portrait orientation.

11.6.10 Orientation management

If the system has multiple orientations, they must be managed independently.



- Select the working orientation using the dropdown list.
- The right panel displays only the tables of the selected orientation.
- The orientation of each table is clearly defined in the 3D scene.
- The left panel displays all system inverters.
  - Each inverter input is associated with a sub-array orientation.
  - If an inverter does not match the selected orientation, it will be disabled.
  - If a sub-array uses mixed orientations, only the strings corresponding to the selected orientation will be activated.

Case of domes:

- Both tables of the dome are displayed in the right view.
- The active table (front or rear) depends on the selected orientation.

11.7 Module Layout dialog interface

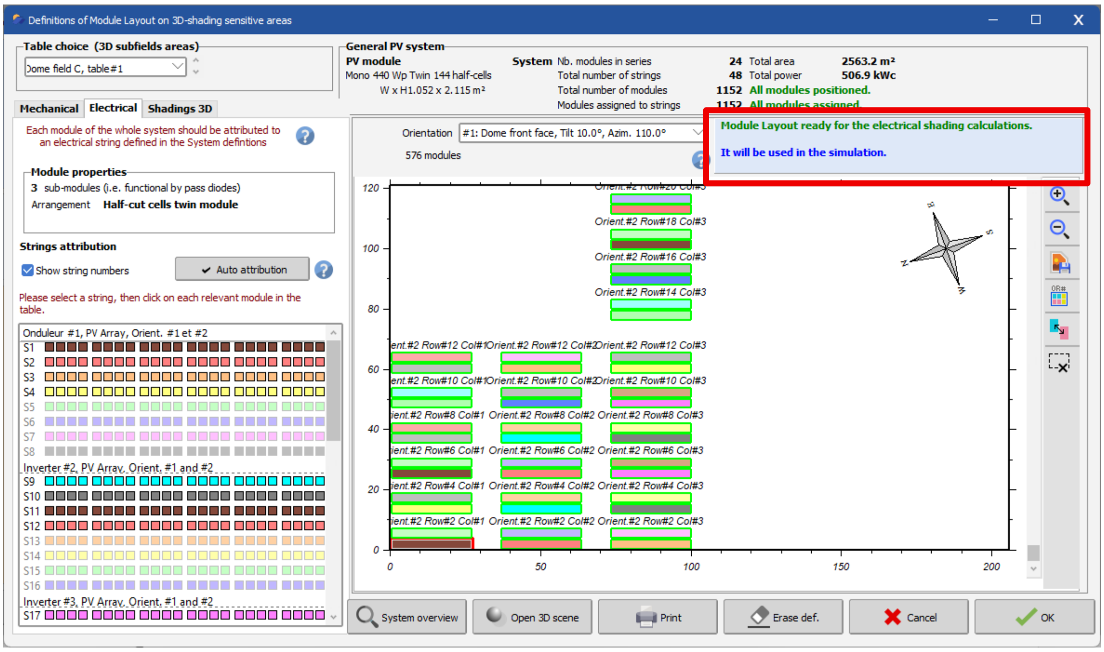
This section describes the features available in the Module Layout interface.

11.7.1 Orientation (appears only if multiple orientations are defined)

- If multiple orientations are defined in the system, the view displays all tables for one orientation at a time.
- The orientation is selected using the dedicated dropdown list.
- The compass serves as a reference for table orientation.

- The number of modules defined in the **"System"** section must match the number of modules assigned in the Module Layout, for each orientation.
- Each MPPT input corresponds to a given sub-array, and therefore to a specific orientation.
- When assigning modules to strings, only the strings corresponding to the selected orientation are active.

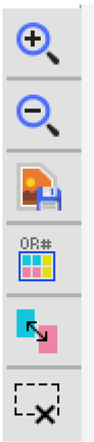
11.7.2 Blue information panel



- The blue panel on the right continuously provides information about the status of the Module Layout and the actions to be performed.
- If some modules are in excess, they can be removed with a right-click.
- If modules defined in the System do not find a match in the Module Layout, it is possible to add a column or a row to the existing tables.
- Warning: If a table belongs to a group, all tables in the group will be modified in the same way.

11.7.3 Toolbar

A set of tools is available on the right side of the image:

<table>
<tr>
<td></td>
<td>
1st and 2nd buttons: Zoom (also available using the mouse wheel).
3rd button: Creates an image of the current view in *.BMP format.
→ There is also a Print button at the bottom of the dialog, allowing you to generate various printouts and include them in the simulation report. These outputs can serve as reference wiring diagrams for the site.
4th button: Selection of table labels in the diagram (table name, or Orient#xx, Row#yy, Line#zz).
⚠️ All tables within an orientation are automatically numbered as a matrix. These indices cannot be modified.
5th button: Activates the mode for moving a module assignment (via drag-and-drop) or swapping two modules.
Last button: Deselects all tables that were multi-selected using Shift + click.
</td>
</tr>
</table>

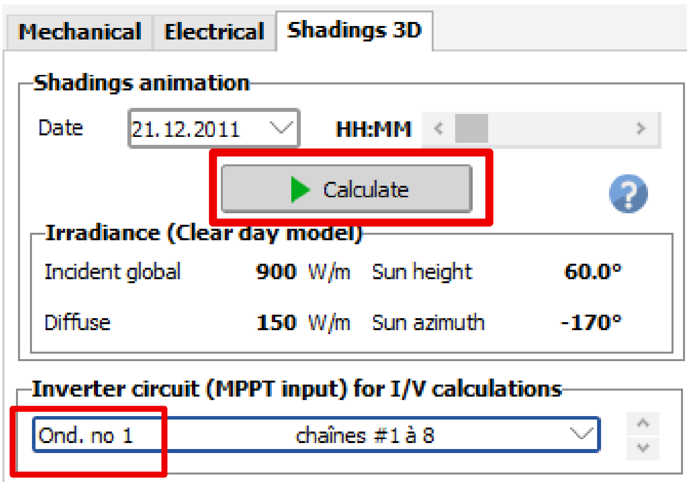
11.8 3D shading calculation

This tool is educational and allows visualization of shading animation on the PV system over a selected day (under clear-sky conditions).

⚠️ **This tool is for informational purposes only and is not required to run the simulation.**

11.8.1 Using the shading animation tool

Once the module layout is fully defined and ready for simulation, this page can be opened.

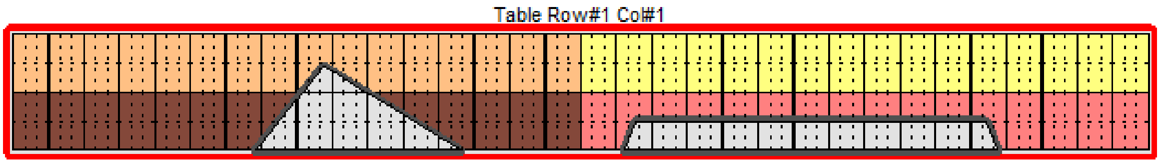


1. Click on **"Calculate"**

   → Starts the shading animation on the system tables for the selected inverter.

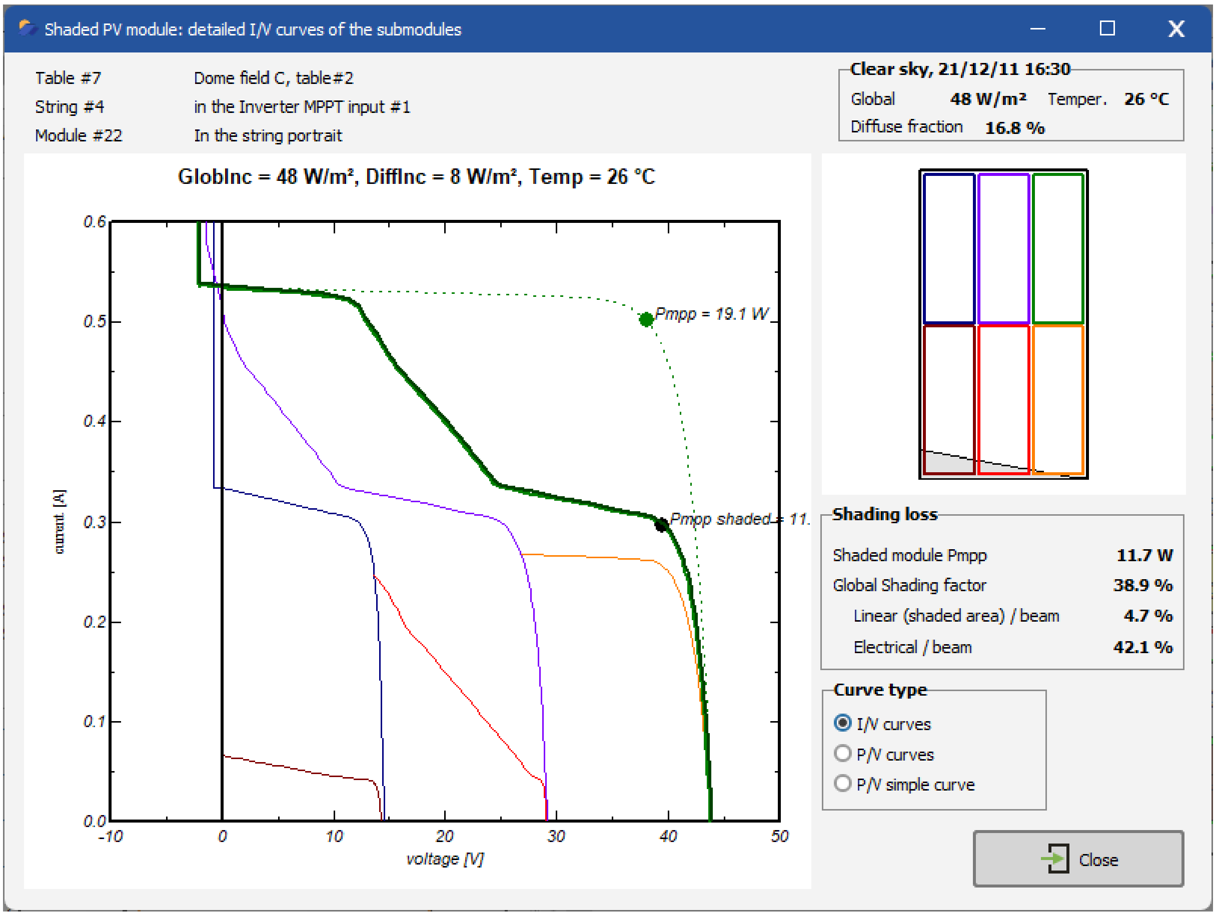
2. Use the slider → Allows you to observe the evolution of shading at 15-minute intervals.

Example: A table equipped with half-cut modules in portrait orientation shows partial shading.



11.8.2 Effect of shading on a module (or optimizer)

Right-clicking on a partially shaded module (or any module) allows you to display its electrical behavior through its I/V curve.



Behavior of a twin half-cut cell module

- **First sub-module** (bottom left, red): partially shaded → its I/V curve corresponds only to the diffuse component.
- **Second sub-module** (top left, blue): not shaded → its full current is added to that of the first.
- **Central sub-modules** (brown and purple): same situation, their currents are added → resulting in the same I/V curve.
- The voltages of these curves (identical here) must be summed (brown and purple curves).
- Finally, the **right sub-modules** (orange and green): not shaded, their I/V curve is a normal full-current curve. By adding their voltages to the previous sub-modules, the resulting curve is obtained (green/black).

➡️ For each current value, the resulting voltage corresponds to the sum of the voltages of the previous curves plus that of the "normal" curve.

⚠️ You can also visualize these behaviors using P/V curves, but their interpretation is less straightforward.

Calculation of electrical losses due to shading

The resulting curve corresponds to the actual I/V curve of the module.

- Here, **Pmpp (shaded)** = 78.5 W
- **Pmpp (unshaded module)** = 125.1 W
- The total shading loss is therefore:78.5 / 125.1 × 100 = **37.2%**

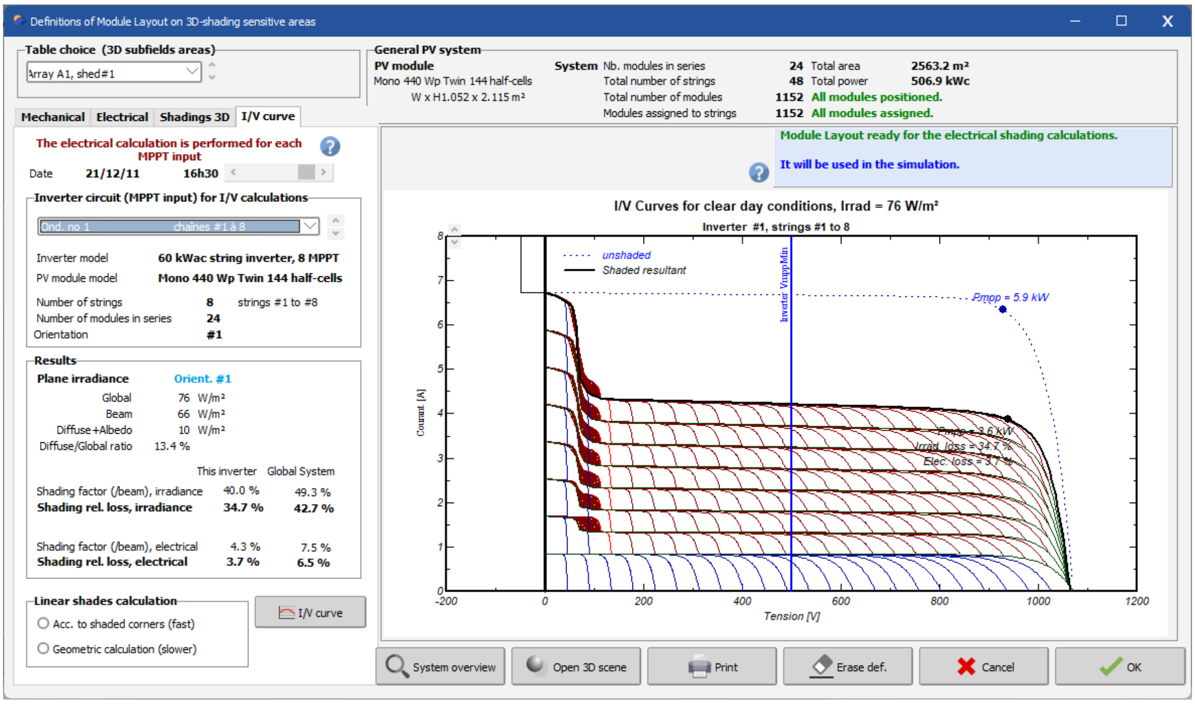
In this case:

- The **linear shading loss** (ratio of shaded area applied to the direct irradiance component, i.e., irradiance deficit) is **7%**.
- The **electrical loss factor** (I/V mismatch) is therefore:

  37.2% – 7.0% = **30.2%**

11.9 I/V curves of an MPPT input

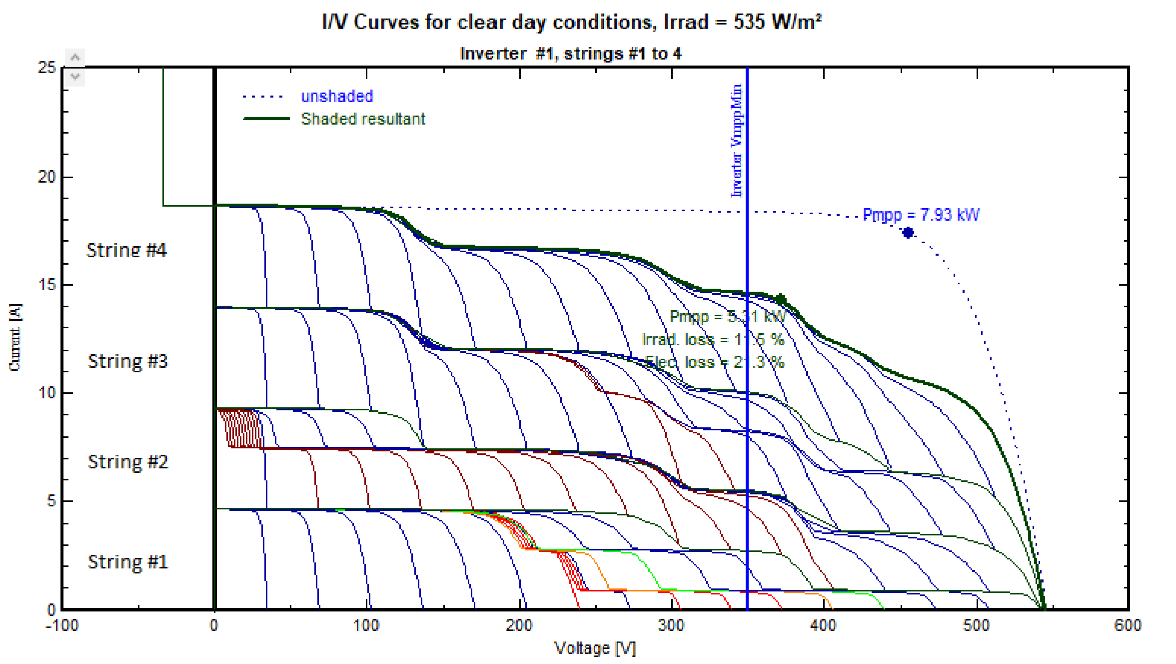
This is an educational tool that displays the complete I/V curves of a sub-array connected to an MPPT input.



After running the shading animation, it is possible to analyze the combination of I/V curves for a specific time and MPPT input.

11.9.1 Analysis of MPPT I/V curves

The example presented here is based on the previous case, with twin half-cut modules and 4 strings on one table.



Construction of I/V curves

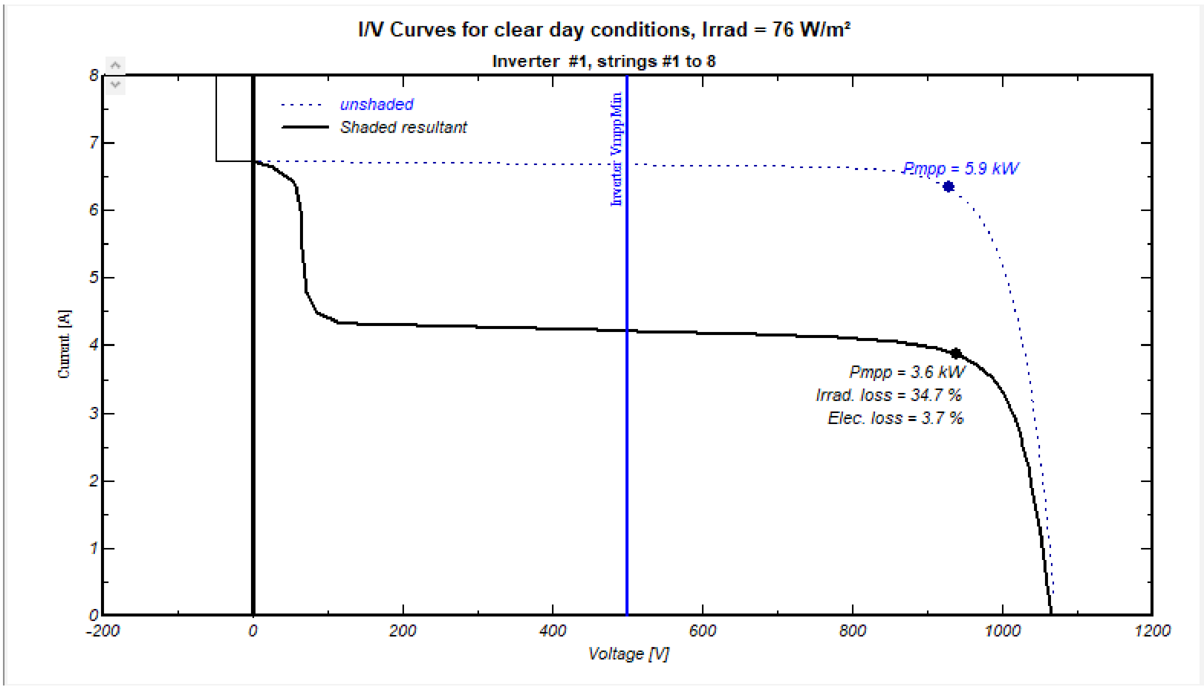
- Each string I/V curve is obtained by summing the voltages of each module.
- The 4 strings are connected in parallel → the total current is obtained by summing the currents.
- Strings #1 and #2 are split due to the use of twin half-cut modules.

Effect of shading on I/V curves

- **Roof shading on the first string**
    - The red sub-modules are shaded and inactive for direct irradiance.
    - These sub-modules go into reverse bias → activation of bypass diodes.
- **Shading from a rectangular object on the second string**
    - The brown sub-modules (on the left) are affected.
    - Same behavior: bypass diodes activate to prevent current blocking.
- **Low-current sub-modules on the first string**
    - The higher voltages correspond to the effect of the remaining diffuse irradiance.
    - Since the voltage has been reduced by the activation of bypass diodes (due to shading of direct irradiance), the module operates only under diffuse irradiance.

11.9.1 Calculation of the shading factor

The objective of this construction is to obtain the resulting I/V curve of the PV array.



The inverter will select the maximum power point (MPP) on this curve.

⚠️ If the MPP voltage is lower than the inverter's minimum MPPT tracking voltage, the operating point will be limited to this value (or set to a possible secondary MPP, depending on which provides the highest power).

11.10 Effect of bypass diodes and shading

11.10.1.1 Context

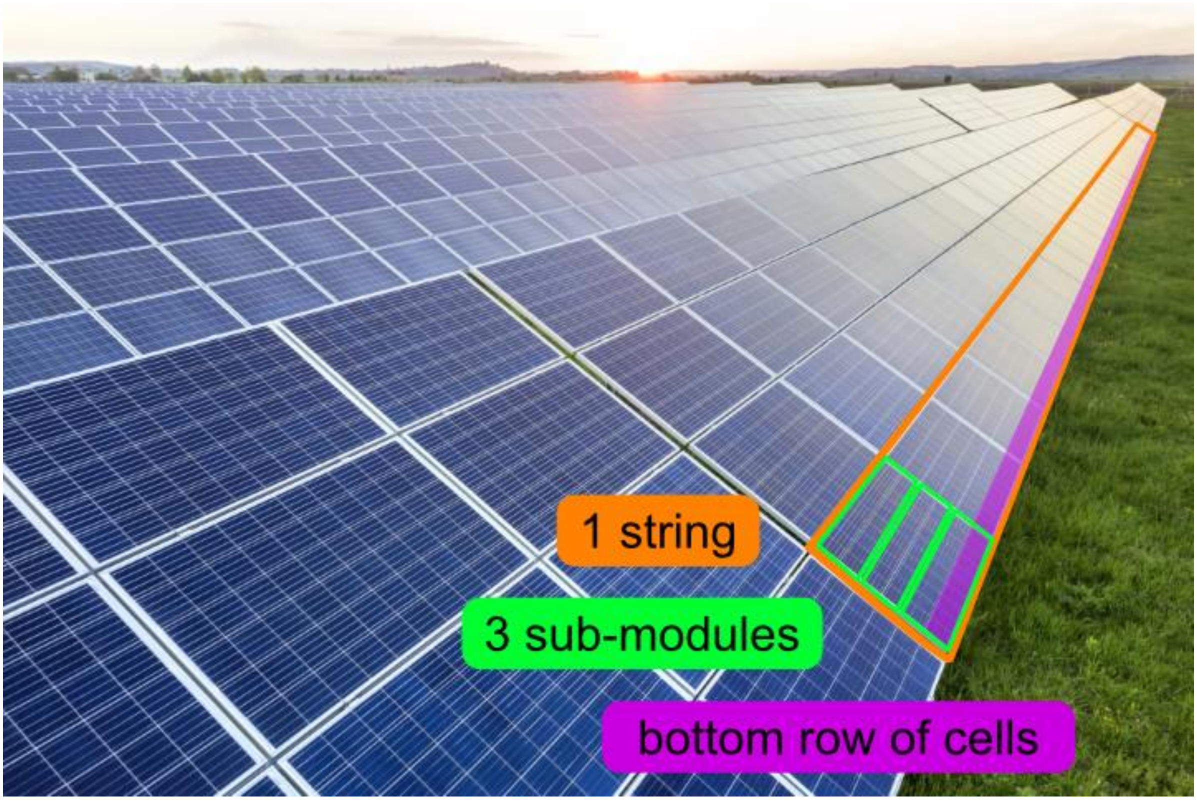
Consider a layout with rows of PV tables (fixed or on trackers).

In this case, when one row casts a shadow on the next, it is mainly the lower sub-modules—particularly the bottom row of cells in partially shaded modules—that are affected.

A sub-module corresponds to a group of cells protected by a bypass diode.

In most modules (60 or 72 cells), there are 3 bypass diodes, hence 3 sub-modules, usually arranged along the length of the module.

Assume that the modules are installed in landscape orientation, and that all modules in the bottom row belong to the same string.



It is often assumed that, in the case of mutual shading, if only the lower sub-module (or only the bottom row of cells) is shaded, the bypass diodes will limit the electrical loss to that sub-module. In other words, the string's electrical output would remain at about two-thirds of its normal production.

This is not necessarily true!

When the bottom row is shaded, depending on the interconnections of the system, the entire contribution of direct irradiance to the whole string may be affected—not just one-third.

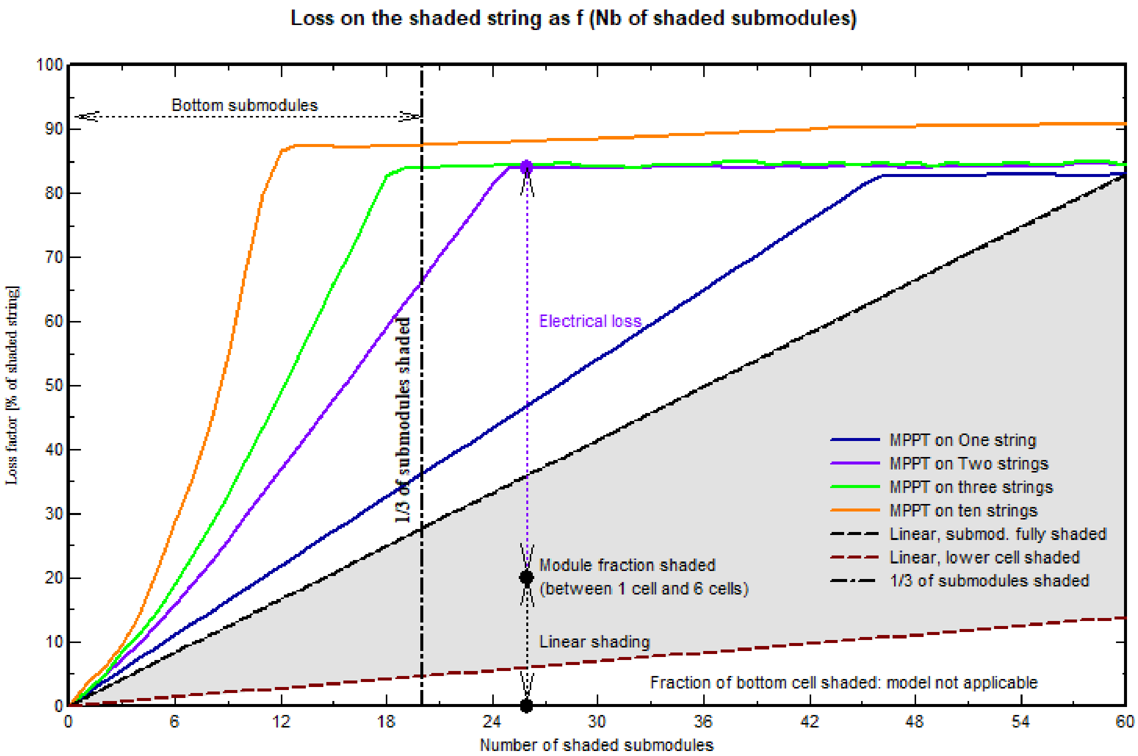
To understand this, let's look at the shading losses on a graph.

11.10.2 Shading losses as a function of the number of shaded sub-modules

The following graph shows the percentage of shading losses, normalized to the output of an unshaded string under clear-sky conditions, as a function of the number of shaded sub-modules.

This calculation includes both:

- irradiance loss,
- and electrical mismatch losses.



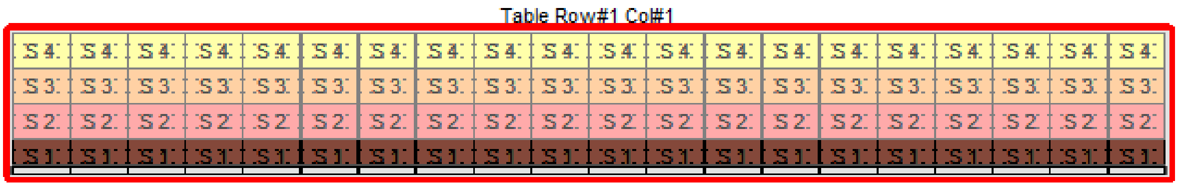
The solid curves represent shading losses as a function of the number of strings connected to one MPPT input (different colors).

- With only **one string per MPPT** (blue curve), electrical losses due to shading remain relatively limited.
- However, when several unshaded strings are connected in parallel, total losses increase significantly.

For example, with **3 strings** (2 unshaded + 1 shaded, green curve), if **1/3 of the sub-modules is shaded** (vertical dashed line), the loss reaches approximately **85%**.

In other words, the contribution of direct irradiance is completely lost in the shaded string: only the diffuse component remains (here ~15%).

Schematically, this corresponds to a situation where only the lower sub-modules are shaded (example with 4 strings).



Note: This graph was obtained under clear-sky conditions. Under predominantly diffuse conditions, these conclusions may differ.

In the following sections, we will examine this from another perspective by observing the corresponding I/V curves, as calculated by the **“Module Layout”** tool in PVsyst.

11.10.3Case 1 – Single string on an MPPT

When there is only one string connected to the inverter input (or when all strings on that input are shaded in the same way), the maximum power roughly corresponds to the Pmpp of the unshaded sub-modules, based on their I/V curves.

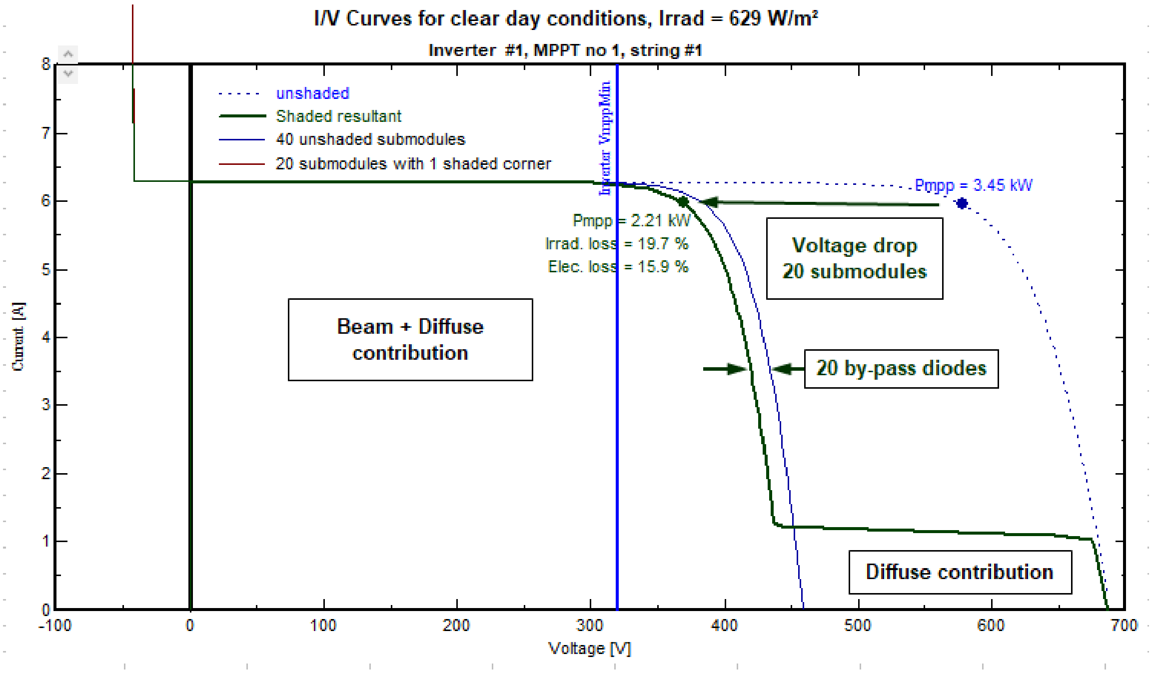
This means that if 1/3 of the sub-modules are shaded, the shaded Pmpp will be approximately equal to 1/3 of the unshaded Pmpp.

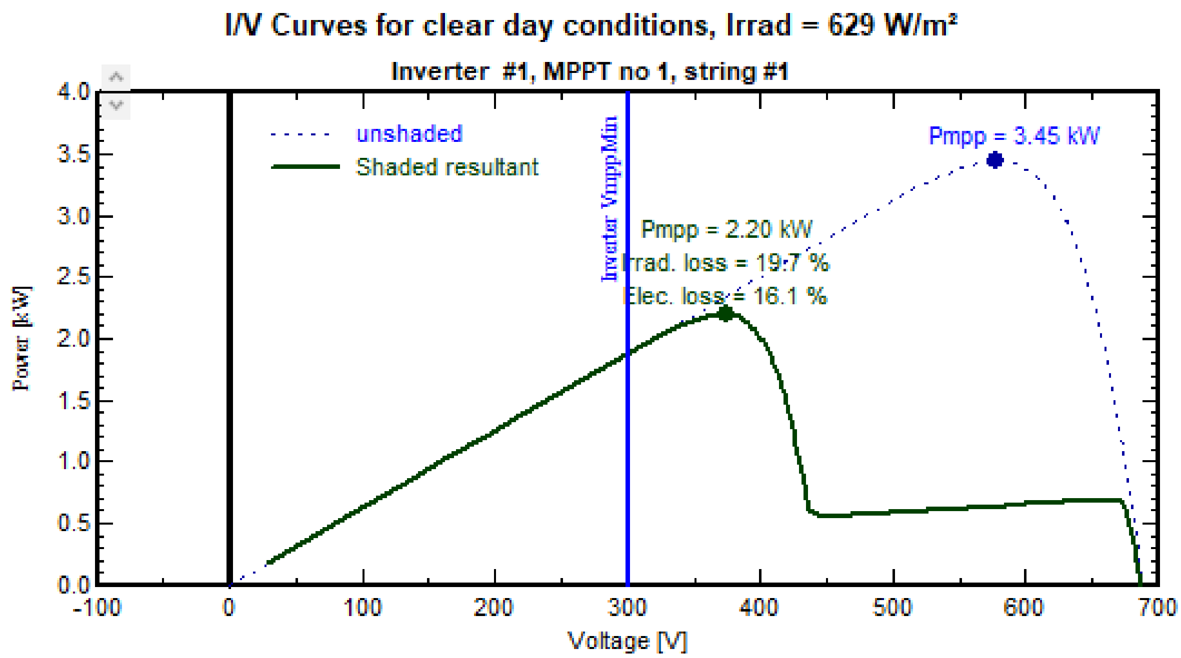
However, this is not entirely accurate: for each shaded sub-module, the bypass diode is activated, causing a voltage drop and therefore an additional power loss.

In the graph above, this loss due to bypass diodes explains the difference between:

- the blue curve (actual loss factor),
- and the black dashed line representing the theoretical proportion of shaded sub-modules.

In the graph below, the blue I/V curve corresponds to the 40 unshaded sub-modules, and the resulting green curve shows the voltage drop.





Note 1:

If the voltage at the shaded MPP (**Vmpp**) is lower than the inverter's minimum voltage (**Vmpp,min**, blue vertical line), then the operating point is located at the intersection of this voltage line and the I/V curve.

This shifts the operating point toward higher voltages, where the power drops rapidly, down to the part of the I/V curve corresponding to the diffuse contribution.

➡️ The advantage of the **"1 string per MPPT"** configuration may therefore be limited by the inverter voltage range.

To fully benefit from this configuration, the inverter must support a wide voltage range.

Note 2:

This reasoning also applies when several strings connected to the same MPPT input experience identical shading.

In the corresponding graph, this is equivalent to summing several identical I/V curves in current.

It may therefore be beneficial to connect all strings of the same inverter to the same row (uniformly shaded), distributed across different tables.

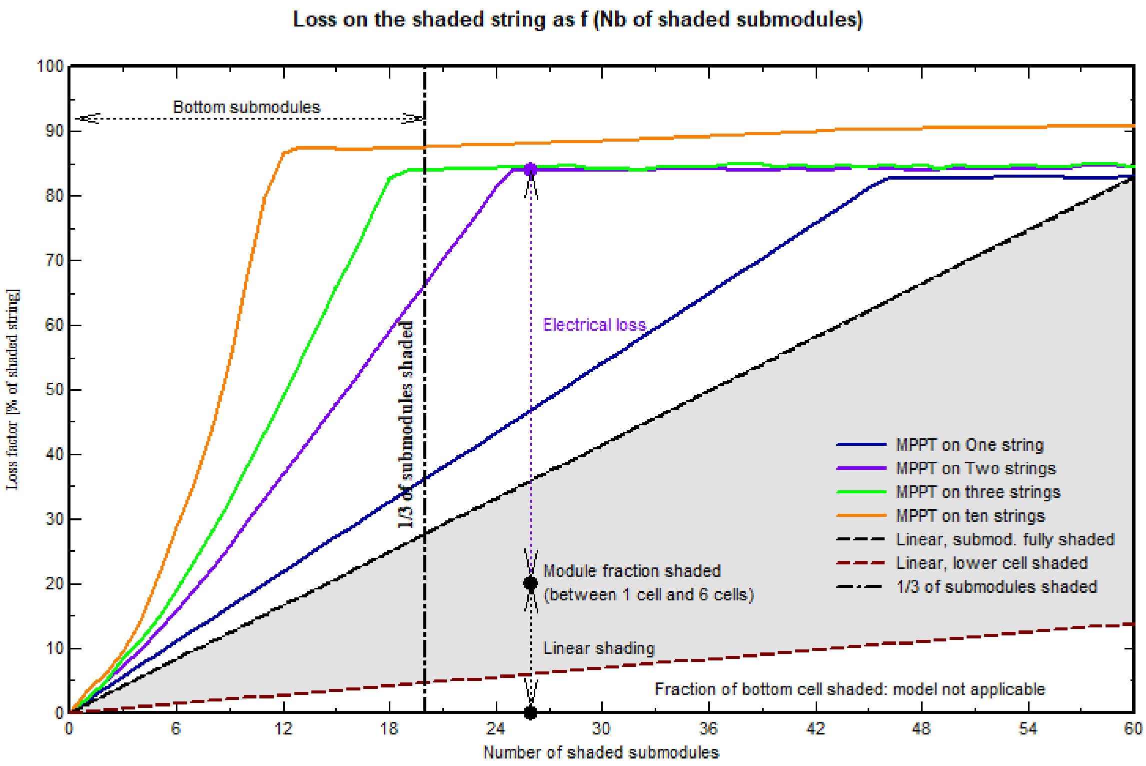
➡️ This makes it possible to concentrate shading losses on a single MPPT, leaving the others unaffected.

This configuration is only feasible with string inverters having 2 or 3 strings per MPPT. Otherwise, string cable lengths would become too large.

In the **Module Layout** tool, the automatic feature **"Automatic assignment of strings to modules"** allows this configuration: it corresponds to the **"Same row per MPPT"** option.

11.10.3.1 *Three strings on a single MPPT*

In the graph *shading losses as a function of the number of shaded sub-modules*, shown below:



It can be observed that with **3 strings** (green curve), shading losses are already maximal when only **1/3 of the sub-modules is partially shaded**.

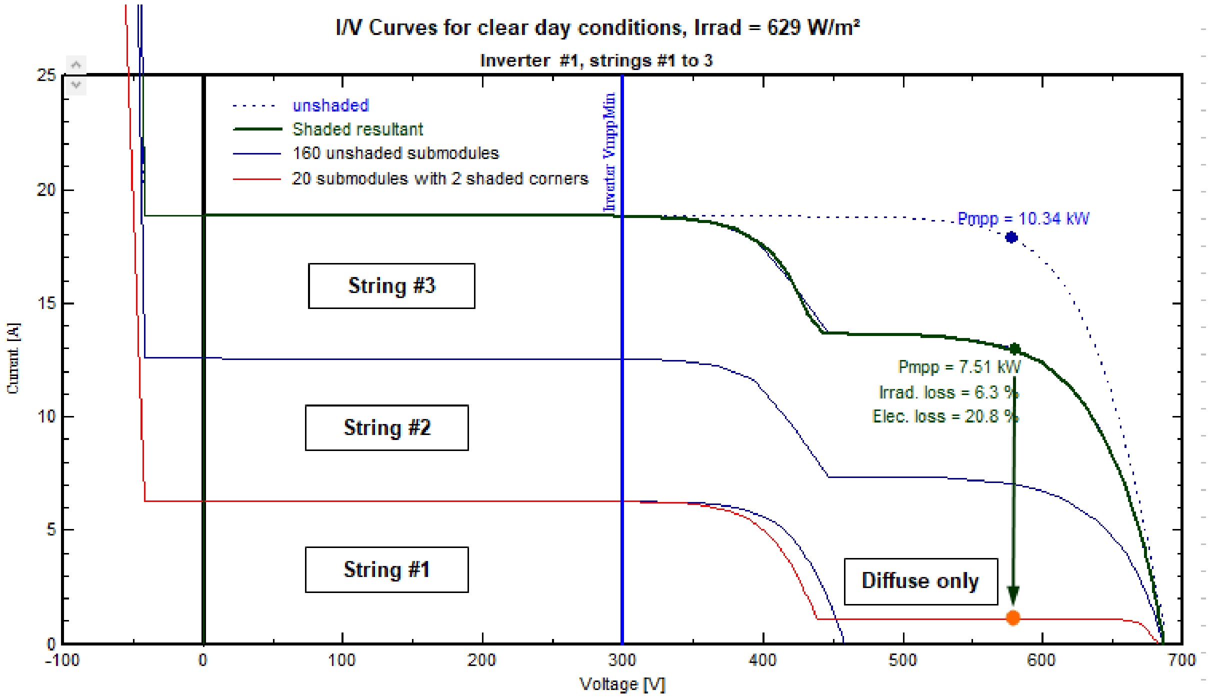
This corresponds to the following I/V curves:

- the first partially shaded string is identical to the previous case,
- but the **2 unshaded strings**, connected in parallel, modify the resulting curve, and in particular the maximum power point (MPP).

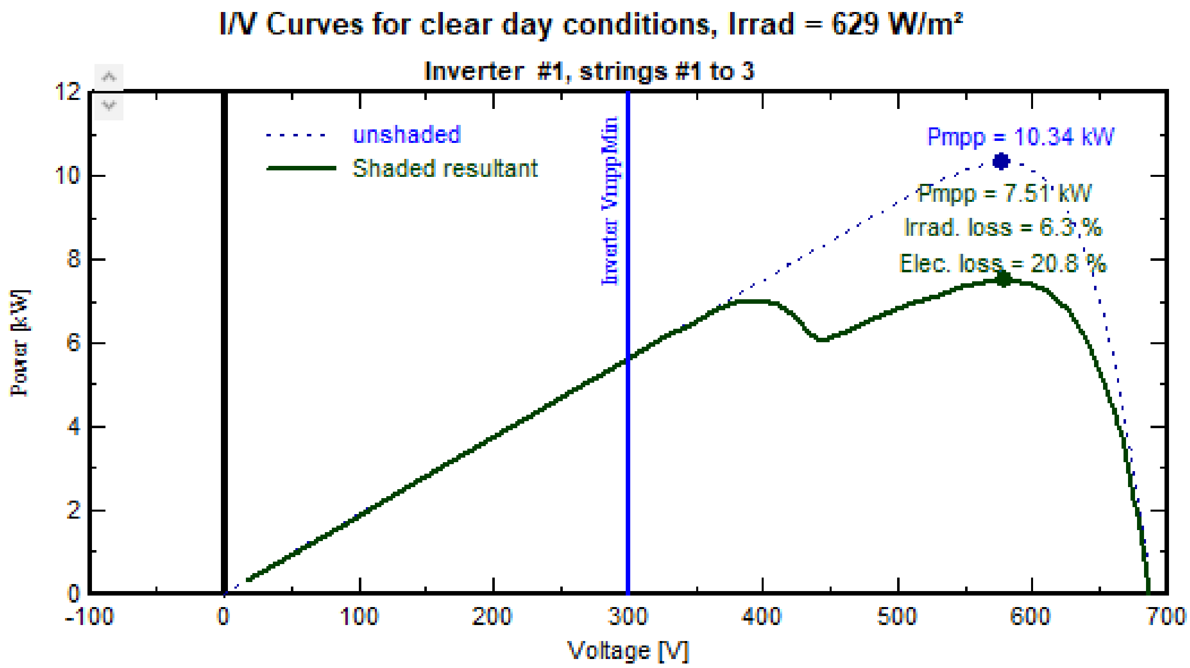
➡️ The MPP now imposes the voltage on all strings connected in parallel, and the operating point of the shaded string corresponds only to the remaining diffuse contribution.

This explains the previous statement: the contribution of direct irradiance from the partially shaded string is effectively zero.

Note: In this situation, the MPP is not very sensitive to inverter limitation by **Vmpp,min**.



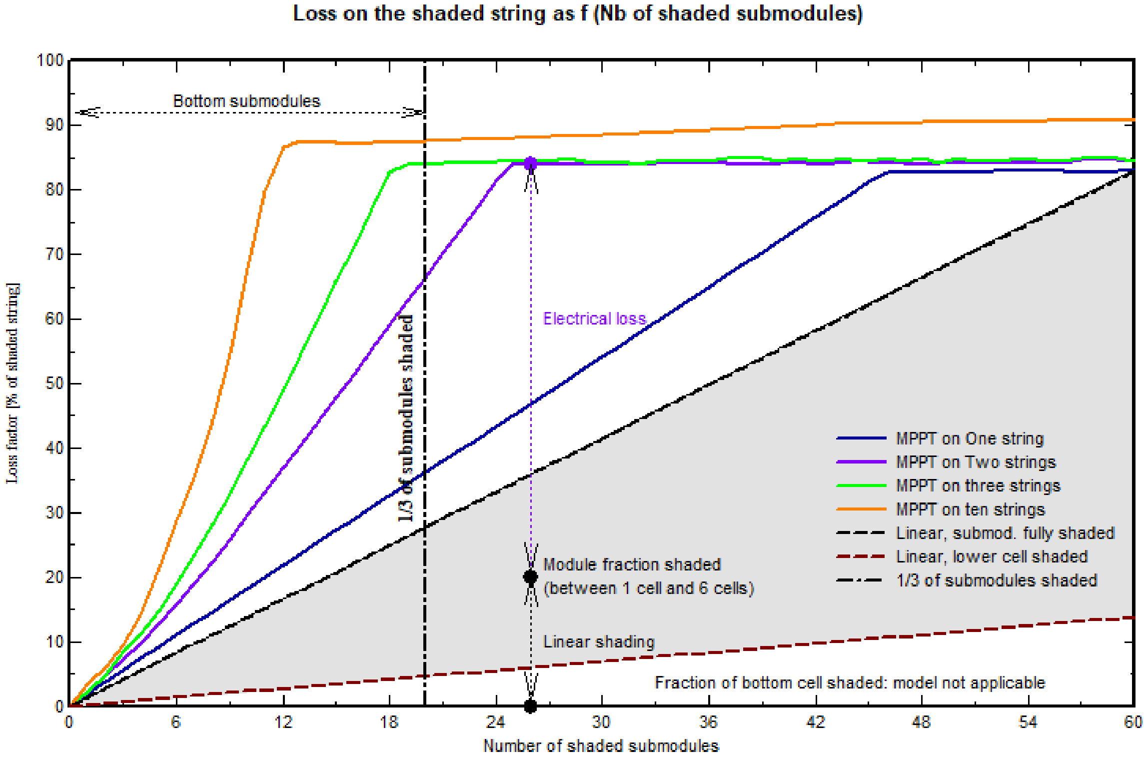
I/V Curves for clear day conditions, Irrad = 629 W/m²
Inverter #1, strings #1 to 3
unshaded
Shaded resultant
160 unshaded submodules
20 submodules with 2 shaded corners
Inverter VmppMin
Pmpp = 10.34 kW
String #3
String #2
String #1
Pmpp = 7.51 kW
Irrad. loss = 6.3 %
Elec. loss = 20.8 %
Diffuse only
Current [A]
Voltage [V]



I/V Curves for clear day conditions, Irrad = 629 W/m²
Inverter #1, strings #1 to 3
unshaded
Shaded resultant
Inverter VmppMin
Pmpp = 10.34 kW
Pmpp = 7.51 kW
Irrad. loss = 6.3 %
Elec. loss = 20.8 %
Power [kW]
Voltage [V]

11.10.3.2 Interpretation of the shading loss vs. number of shaded sub-modules graph

On this graph (**shading loss as a function of the number of shaded sub-modules**):



- **the increasing parts** of the curves correspond to the situation where the **first MPP** is higher than the secondary MPP related to the diffuse contribution;
- the **plateau** begins when the maximum lies on the diffuse part (see previous graph).

In this situation, it can be observed that with the **2-string configuration** (purple curve), part of the direct irradiance contribution still remains.

This graph was established with a **15% diffuse contribution**.

When the direct contribution decreases:

- the diffuse plateau is reached more quickly,
- normalized losses (relative to the direct contribution, which itself is decreasing) increase,
- but the **total loss factor** may actually decrease.

The **grey area** of the graph corresponds to the **linearly shaded fraction**:

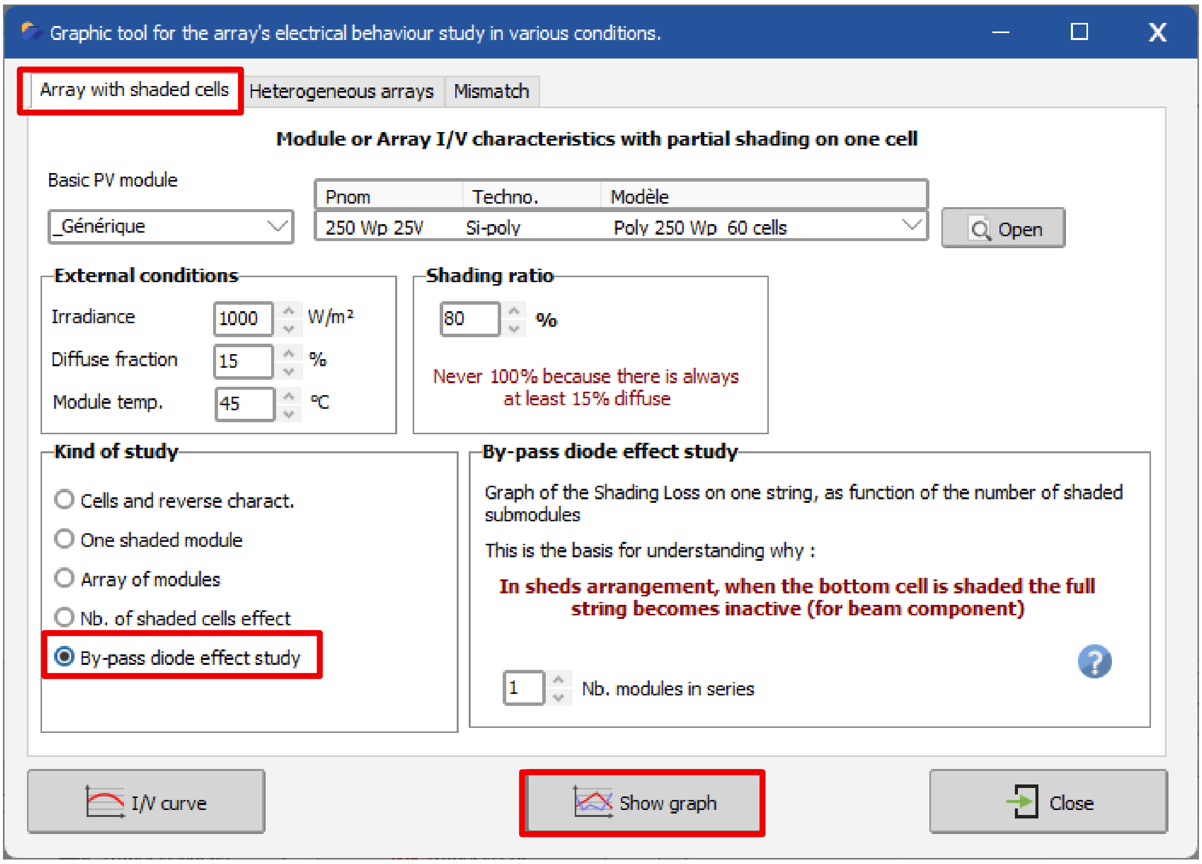
- the **lower line** represents the case where only the bottom cell is shaded (≈ 1/6 of the full module),
- the **upper dashed line** corresponds to the case where each affected module is fully shaded.

The shading loss—calculated from the I/V curves—therefore corresponds to the sum of:

- the **linear loss** (actual shaded fraction of each sub-module),
- and the **electrical loss**, which constitutes the remaining part.

The electrical loss is maximal when only the bottom cell is shaded.

In PVsyst, this diagram can be obtained via the menu: **Tools > PV module electrical behavior > Array with shaded cells > Study of bypass diode effect**



The calculation of electrical losses is performed accurately by taking sub-modules into account.

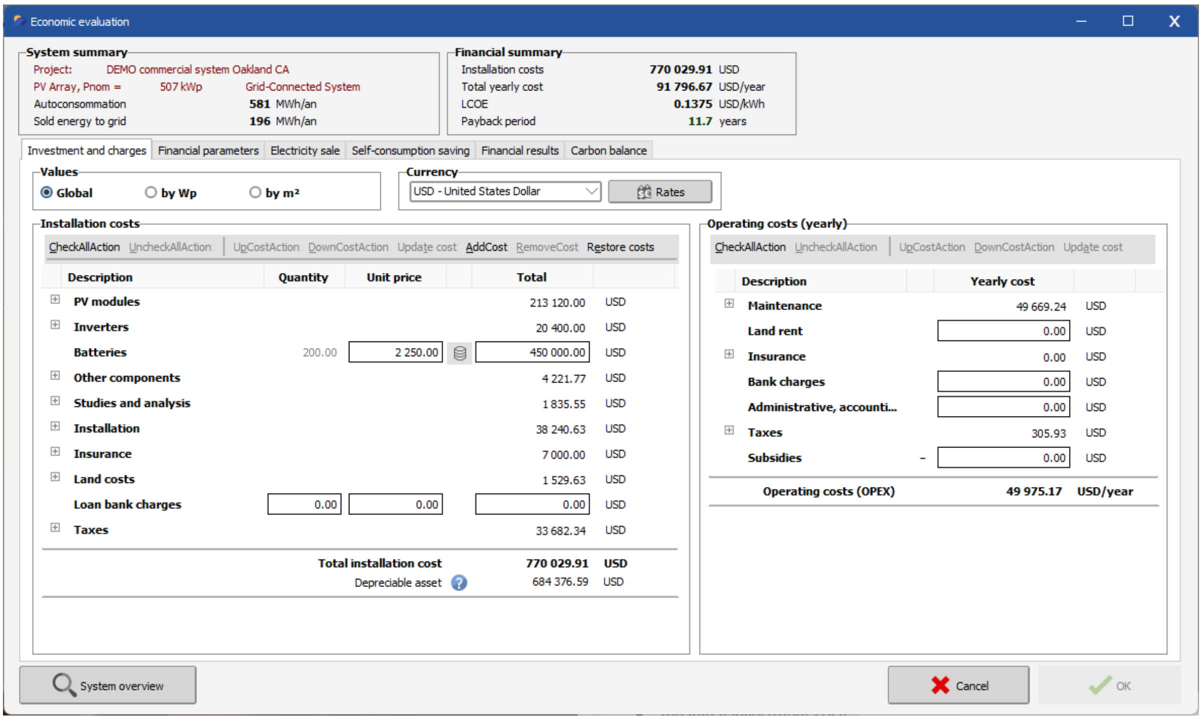
12 Economic evaluation

After the simulation, you can perform an economic evaluation of the system based on the defined parameters and the obtained results. This economic tool is accessible from the **“Project”** dialog. It allows you to define:

- the initial investment costs,
- the annual operating costs,
- and thus calculate the **Levelized Cost of Energy (LCOE)**.

By combining this data with financial parameters and tariffs, the tool can estimate long-term profitability. It also provides detailed financial indicators:

- **ROI (Return on Investment)**,
- **Payback period**,
- **NPV (Net Present Value)**.



12.1 Installation and operating costs

The **Cost** dialog, within the economic evaluation, allows you to define all **initial expenses** (installation) as well as the **annual operating costs** of the system. The objective is to calculate the total investment, the average annual cost, and the cost of the produced energy (LCOE).

Costs can be specified globally, per unit, per installed power (Wp), or per surface area (m^2). You can use any currency; it is possible to switch between different currencies using a dropdown list. The **“Rates”** button allows you to adjust exchange rates: you can choose a reference currency, manually modify rates or download them from the Internet, and even add new currencies.

12.1.1 Installation costs

This section includes both direct and indirect costs related to the system installation, such as:

- components (modules, inverters, batteries, pumps, controllers, generator),
- engineering and study costs,
- administrative expenses (grid connection, banking fees, permits, taxes),
- insurance, land, replacement credits, and subsidies.

The number and type of PV components involved are automatically updated based on the simulation parameters.

Installation costs

Description	Quantity	Unit price	Total	
PV modules			213 120.00	USD
Mono 440 Wp Twin 144 half-...	1152.00	140.00	161 280.00	USD
Supports for modules	1152.00	45.00	51 840.00	USD
Inverters			20 400.00	USD
60 kWac string inverter, 8 M...	6.00	3 400.00	20 400.00	USD
Batteries	200.00	2 250.00	450 000.00	USD
Other components			4 221.77	USD
Accessories, fasteners	1.00	856.59	856.59	USD
Wiring	1.00	1 713.18	1 713.18	USD
Combiner box	1.00	978.96	978.96	USD
Monitoring system, display s...	1.00	673.04	673.04	USD
Measurement system, pyra...	0.00	0.00	0.00	USD
Surge arrester	0.00	0.00	0.00	USD
Studies and analysis			1 835.55	USD
Engineering	1.00	1 223.70	1 223.70	USD
Permitting and other admin. ...	1.00	305.93	305.93	USD
Environmental studies	1.00	244.74	244.74	USD
Economic analysis	1.00	61.19	61.19	USD
Installation			38 240.63	USD
Global installation cost per ...	1152.00	30.59	35 242.56	USD
Global installation cost per i...	6.00	367.11	2 202.66	USD
Transport	1.00	305.93	305.93	USD
Settings	1.00	244.74	244.74	USD
Grid connection	1.00	244.74	244.74	USD
Insurance			7 000.00	USD
Building insurance	1.00	5 000.00	5 000.00	USD
Transport insurance	1.00	2 000.00	2 000.00	USD
Liability insurance	0.00	0.00	0.00	USD
Delay in start-up insurance	0.00	0.00	0.00	USD
Land costs			1 529.63	USD
Loan bank charges	0.00	0.00	0.00	USD
Taxes			33 682.34	USD
VAT (%)	18.00%	of 183 555.00	33 039.90	USD
Federal taxes (%)	0.00%	of 0.00	0.00	USD
State taxes (%)	0.00%	of 0.00	0.00	USD
Local taxes (%)	0.00%	of 0.00	0.00	USD
Other taxes (%)	1.50%	of 42 829.50	642.44	USD
		Total installation cost	**770 029.91**	**USD**
		Depreciable asset	684 376.59	USD

12.1.2 Depreciable asset

Depreciation is an accounting method that spreads the cost of a tangible asset over its useful lifetime, thereby reducing the taxable base each year.

Three methods are available:

- **None:** depreciation is not taken into account in the financial results.
- **Straight-line:** the asset value decreases uniformly each year down to its residual value.
  - Formula:

$$\textbf{Annual depreciation} = \frac{\textbf{\textit{Depreciable asset}} - \textbf{\textit{Residual value}}}{\textbf{\textit{Depreciation period}}}$$

  - *Example:* an asset of $120,000 with a residual value of $20,000 over 10 years results in $10,000 annual depreciation.
- **Declining balance:** accelerated depreciation, with higher amounts at the beginning, then decreasing over time. It is based on a coefficient applied to the straight-line rate; when it becomes lower than the straight-line depreciation:

  Straight-line depreciation rate = 1 / Project lifetime

  Declining balance rate = Straight-line rate × Depreciation coefficient

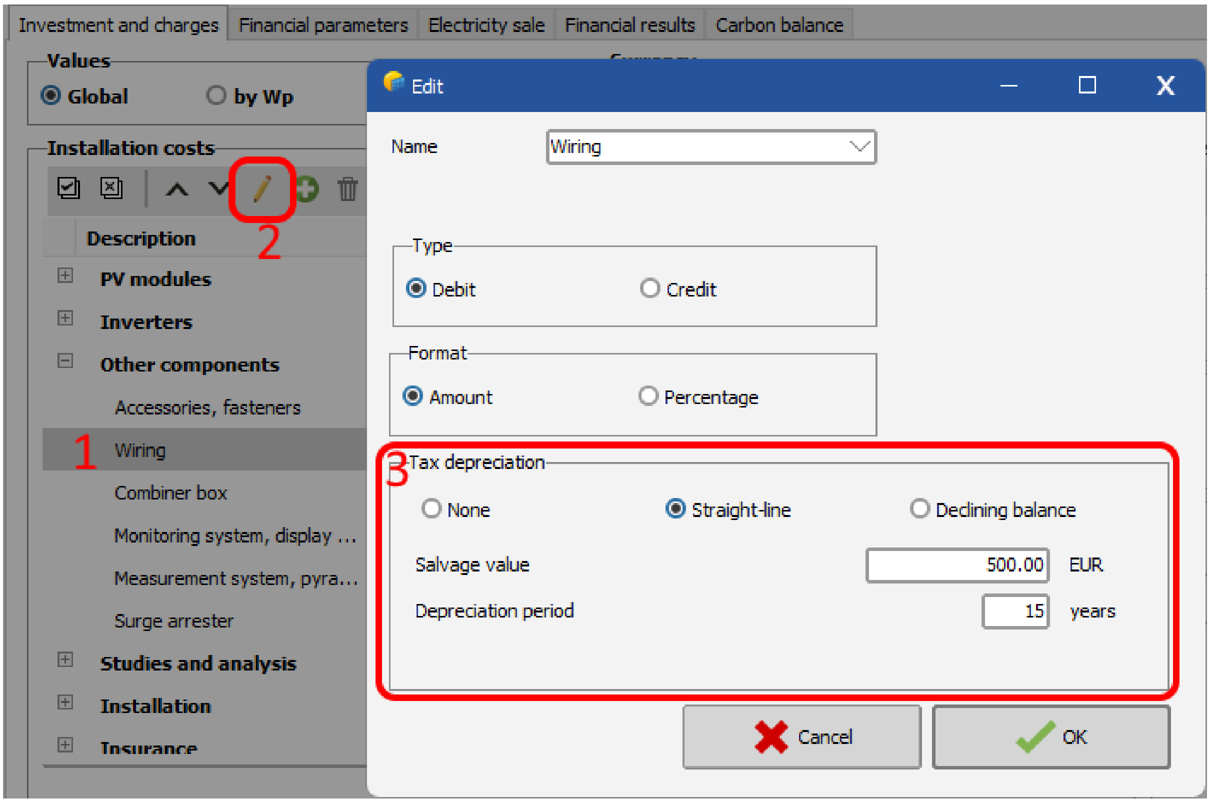
  Annual depreciation expense in year *t* = Residual asset value in year *t* × Declining rate

When the depreciation calculated using the declining method becomes lower than that obtained using the straight-line method, the straight-line method is applied for the remaining years of the project.

In PVsyst, the costs of components and accessories are considered depreciable by default.

To define the depreciation parameters for each asset:

1. Click on a **cost** item to select it.
2. Click on the **Edit** button (pencil icon).
3. In the window that opens, choose a **depreciation method** (straight-line or declining balance), according to your country's tax regulations.
4. Enter the **residual value** (estimated value of the asset at the end of the project).
5. Define the **depreciation period** (the time during which the asset is considered useful). Each asset has a specific duration defined by your tax system.
6. Click **OK** to confirm.



12.1.3 Add / Remove / Update costs

The predefined list of costs is **fully customizable** to include any system-specific costs that may not appear in the default list.

You can **add, delete, reorganize, or rename** costs.

You can also save the defined list as a **template** for reuse in another project.

Available buttons

☑ **Select all**

Selects all investment costs for deletion, editing, or moving.

☒ **Deselect all**

Deselects all selected costs. Button is inactive if no cost is selected.

^ **Move up**

Moves the selected costs up.

👉 The displayed order in the list is the one used in the printed report.

Button is inactive if no cost is selected.

∨ **Move down**

Moves the selected costs down.

👉 The displayed order in the list is the one used in the printed report.

Button is inactive if no cost is selected.

Update cost

Opens the installation cost editing window to modify the properties (name, section, type) of a selected cost.

Button is inactive if no cost is selected or if multiple costs are selected at the same time.

New cost

Opens the installation cost editing window to add a custom cost that does not exist in the predefined list.

Delete cost

Removes the selected installation costs from the list.

Button is inactive if no cost is selected.

Restore list

Restores the default PVsyst installation cost list.

Load from template

Loads a cost list from a previously saved template file.

Save as template

Saves the defined installation cost list as a template file for later reuse or for another project.

Component form

Allows you to define prices for each component.

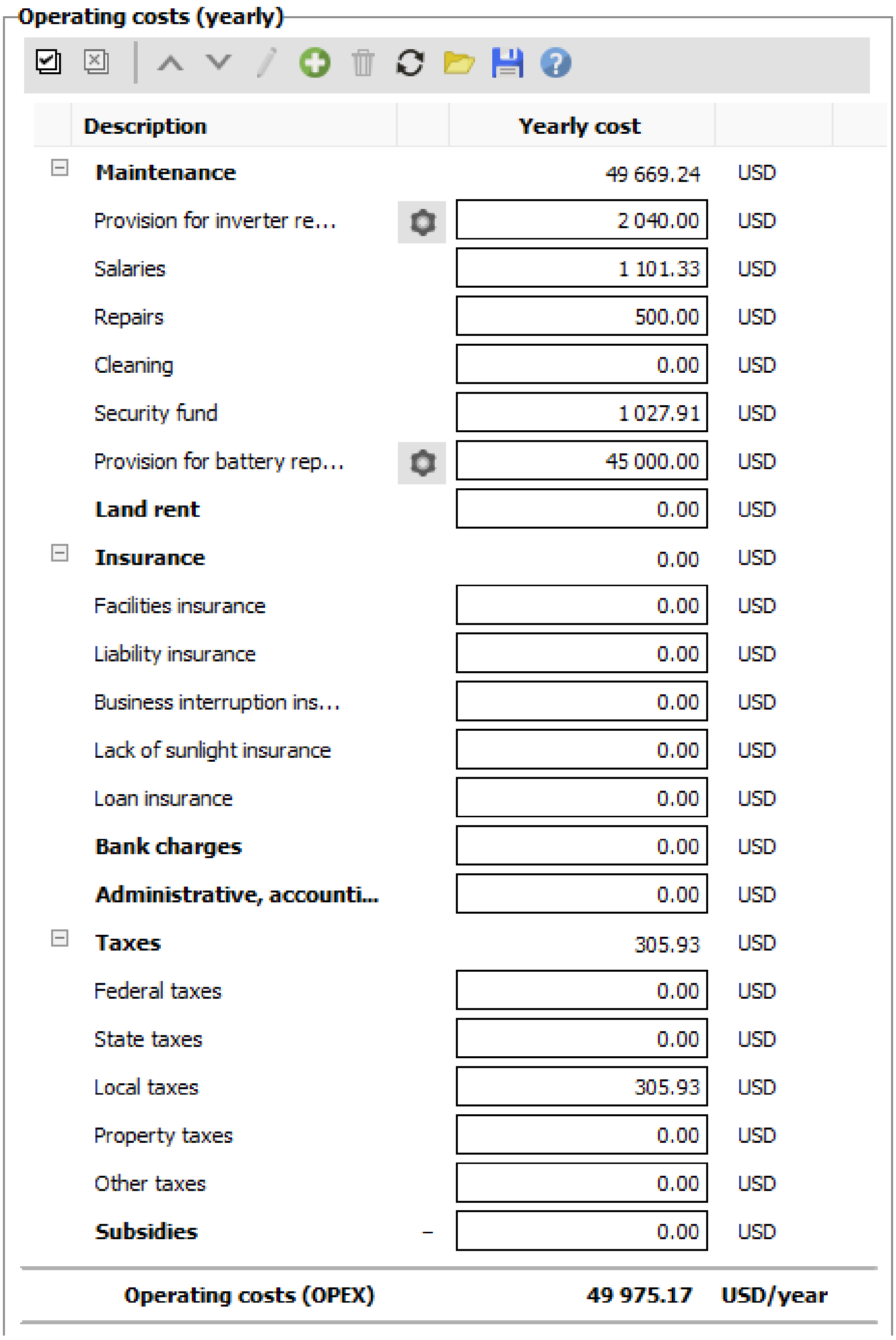
→ By clicking, you can enter your own prices for the components used (unit price or quantity-based pricing).

→ These prices can be saved in your component library or kept only for the current session (without modifying the database).

→ Prices can also be defined globally in the component database **price list** dialog.

12.1.3.1 Operating costs (annual)

This section defines the annual operating expenses of the system.



Operating costs (yearly)

Description		Yearly cost	
Maintenance		49 669.24	USD
Provision for inverter re...		2 040.00	USD
Salaries		1 101.33	USD
Repairs		500.00	USD
Cleaning		0.00	USD
Security fund		1 027.91	USD
Provision for battery rep...		45 000.00	USD
Land rent		0.00	USD
Insurance		0.00	USD
Facilities insurance		0.00	USD
Liability insurance		0.00	USD
Business interruption ins...		0.00	USD
Lack of sunlight insurance		0.00	USD
Loan insurance		0.00	USD
Bank charges		0.00	USD
Administrative, accounti...		0.00	USD
Taxes		305.93	USD
Federal taxes		0.00	USD
State taxes		0.00	USD
Local taxes		305.93	USD
Property taxes		0.00	USD
Other taxes		0.00	USD
Subsidies	–	0.00	USD
Operating costs (OPEX)		**49 975.17**	**USD/year**

The predefined list of costs depends on the type of system:

- **Grid-connected system**

  Generally very reliable, costs are limited to annual inspection, possible module cleaning, and insurance expenses. Some inverter suppliers offer extended warranties (including replacement), which can be considered similar to insurance.

- **Off-grid system**

  Maintenance and periodic replacement of batteries must be considered. This contribution is calculated by the program based on the expected lifetime of the battery pack (from the simulation).

  In addition, when an auxiliary generator is used, the program also calculates the cost of consumed fuel.

- **Pumping systems**

  Pump replacement must be considered (their lifetime is typically a few years), as well as batteries if they are part of the system.

➡️ As with installation costs, operating costs are fully customizable to suit the specific needs of your system.

The total sum of operating costs is referred to as **OPEX (Operational Expenditure)**.

Available buttons

Select all

Selects all operating costs for deletion, editing, or moving.

Deselect all

Deselects all selected costs. Button is inactive if no cost is selected.

Move up

Moves the selected costs up.

👉 The order displayed in the list is the one used in the printed report.

Button is inactive if no cost is selected.

Move down

Moves the selected costs down.

👉 The order displayed in the list is the one used in the printed report.

Button is inactive if no cost is selected.

Update cost

Opens the operating cost editing window to modify the properties (name, section, type) of a selected cost.

Button is inactive if no cost is selected or if multiple costs are selected at the same time.

New cost

Opens the operating cost editing window to add a custom cost that does not exist in the predefined list.

Delete cost

Removes the selected operating costs from the list.

Button is inactive if no cost is selected.

Restore list

Restores the default operating cost list in PVsyst.

Load from template

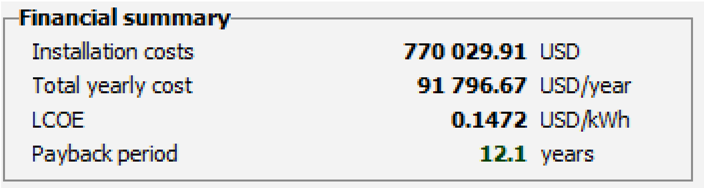
Loads an operating cost list from a previously saved template file.

Save as template

Saves the defined operating cost list as a template file for later reuse or for another project.

12.1.4 Financial summary

The total annual cost is the sum of operating costs and loan repayments (defined in the financial parameters).



It is an **average annual value** calculated over the entire project lifetime, taking inflation into account if defined.

The **LCOE (Levelized Cost of Energy)** is the **cost per kWh produced**.

It accounts for the **present value of future cash flows** by applying a **discount rate**.

Formula used in PVsyst to calculate LCOE:

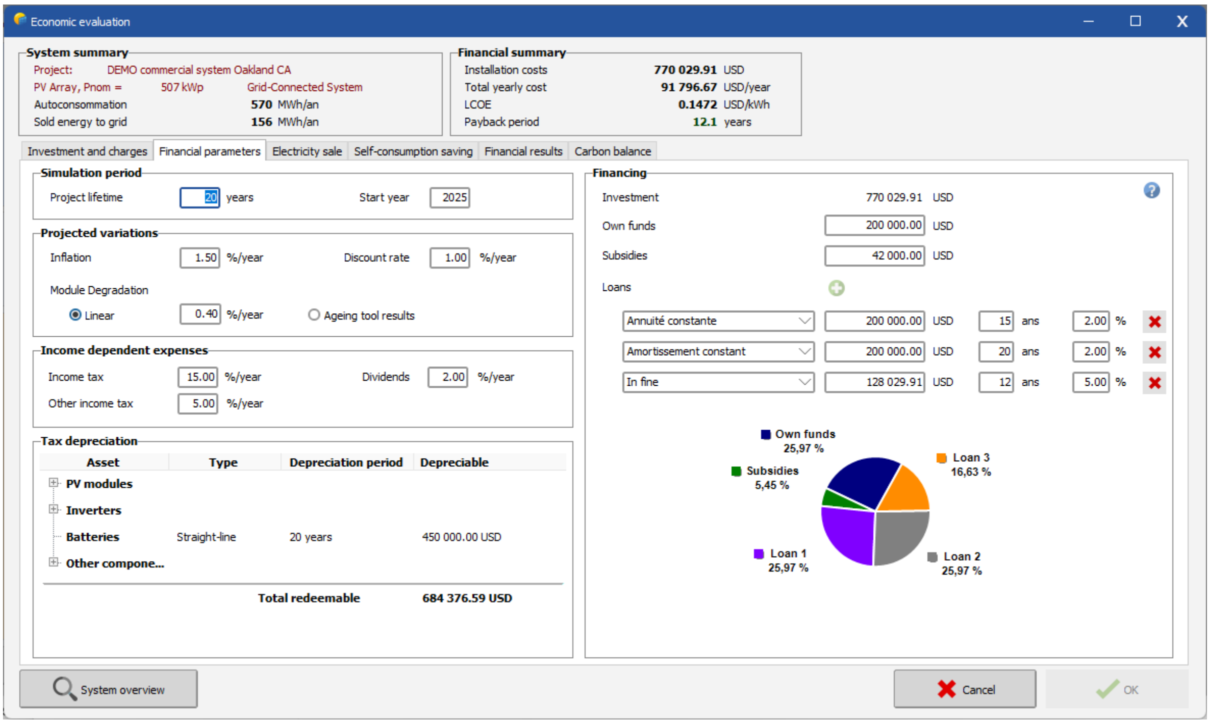
$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

- I_t= Investments and expenditures in year *t*
- M_t= Operation and maintenance costs in year *t*
- E_t= Electrical production in year *t*
- r= Discount rate (return that could be obtained from alternative investments)
- n= System lifetime

The **payback period** is the time required to recover the initial investment.

12.2 Financial parameters



12.2.1 Simulation period

Project start and lifetime

Define when the project starts and its total lifetime.

12.2.2 Cost variation over time

- **Inflation**
  Annual rate applied to operating costs (OPEX) over time. It can increase costs or, if negative, decrease them (deflation).
- **Discount rate**

  Used to discount future cash flows (revenues or expenses) in order to estimate their present value. It is used in particular for calculating the **LCOE (Levelized Cost of Energy)** and **NPV (Net Present Value)**.
- **Module degradation**

  Accounts for the performance degradation of PV modules over time. You can choose a fixed linear rate or use results from the **aging tool**, if such a simulation has been performed beforehand.

12.2.3 Revenue-dependent charges

- **Corporate income tax**

  Percentage applied to the taxable profit each year.
- **Additional income tax**

  Allows handling systems with multiple levels of taxation (e.g., federal + local).

- **Dividends**
  Percentage of net profits distributed to shareholders each year. If the result is negative, no dividends are paid.

12.2.4 Depreciation expenses

This section lists the depreciable installation costs and their total depreciable value over the entire project lifetime.

You can find the procedure for defining the depreciation of each asset in the **Investment and costs** section.

12.2.5 Financing

You can define the project's financing sources, divided into three categories. The total must match the installation cost:

- **Equity:** own funds or external investment.
- **Subsidies:** funds provided by the government or a public institution.
- **Loans:** up to three different loans can be defined, according to the following terms:

1. **Constant annuity**

$$Annuity = \frac{\text{loan amount x interest rate}}{1 - (1 + \text{interest rate})^{-year}}$$

The annuity (annual payment) remains constant, but the share of interest decreases over time.

2. **Constant amortization**

$$Annuity_{t\ year} = \frac{\text{loan amount}}{\text{loan duration}} \cdot [1 + (\text{loan duration} - year) \cdot \text{interest rate}]$$

The principal repaid each year is constant. The annual payments decrease over time.

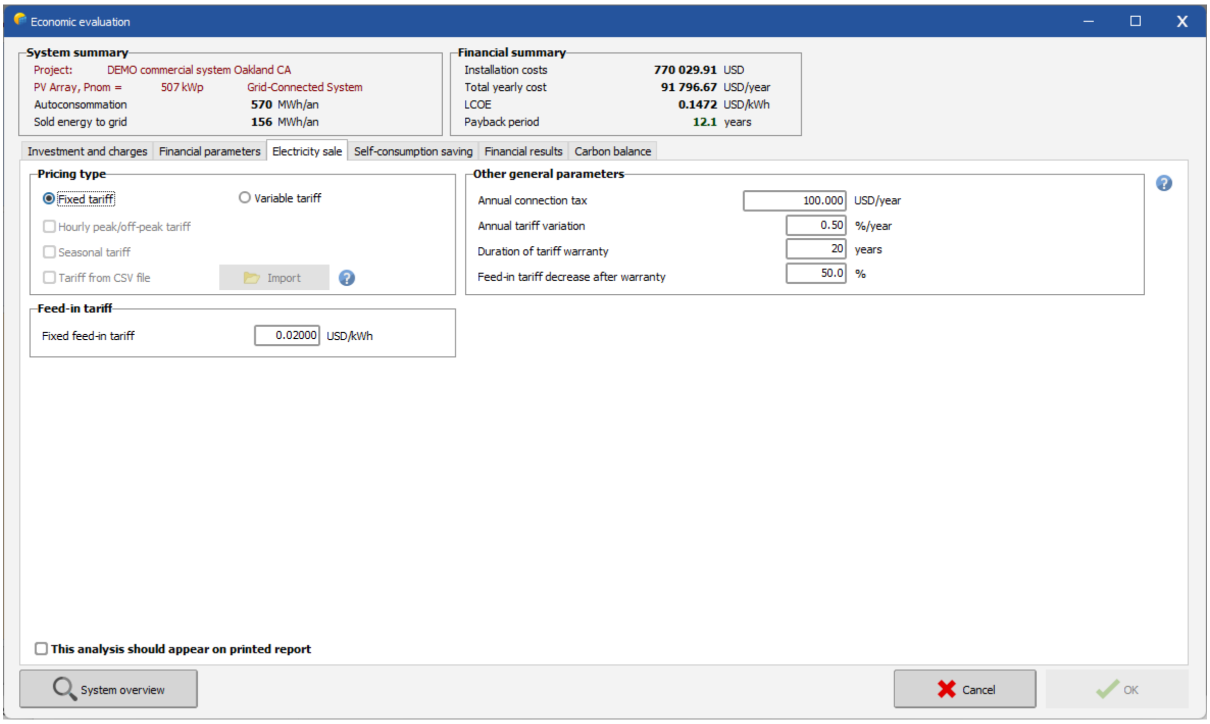
3. **Bullet loan (interest-only / in fine)**

$$Annuity = \text{loan amount} \cdot \text{interest rate}$$

Only interest is paid each year, and the principal is repaid in a single payment at the end.

12.3 Feed-in tariffs and self-consumption

This section allows you to define the **tariff strategy for electricity sales**. It is used to calculate financial **revenues over the project lifetime** and to assess its profitability.



12.3.1 Fixed feed-in tariff

This practice, common in several European countries, is based on the purchase by the grid operator of all the energy produced. The feed-in tariff is defined by a long-term contract (typically 20 years), established at the system commissioning and **fixed for the entire contract duration.**

In PVsyst, the simplest option allows you to define a single fixed feed-in tariff over a specified contractual period. It is also possible to include:

- an annual grid connection fee,
- a progressive tariff variation each year,
- a modified selling price after the end of the contractual period.

Since this period often corresponds to the loan repayment duration, **the annual balance after this period (even with a reduced tariff) will increase significantly until the end of the system lifetime.**

12.3.2 Time-of-use / seasonal tariffs — peak and off-peak hours

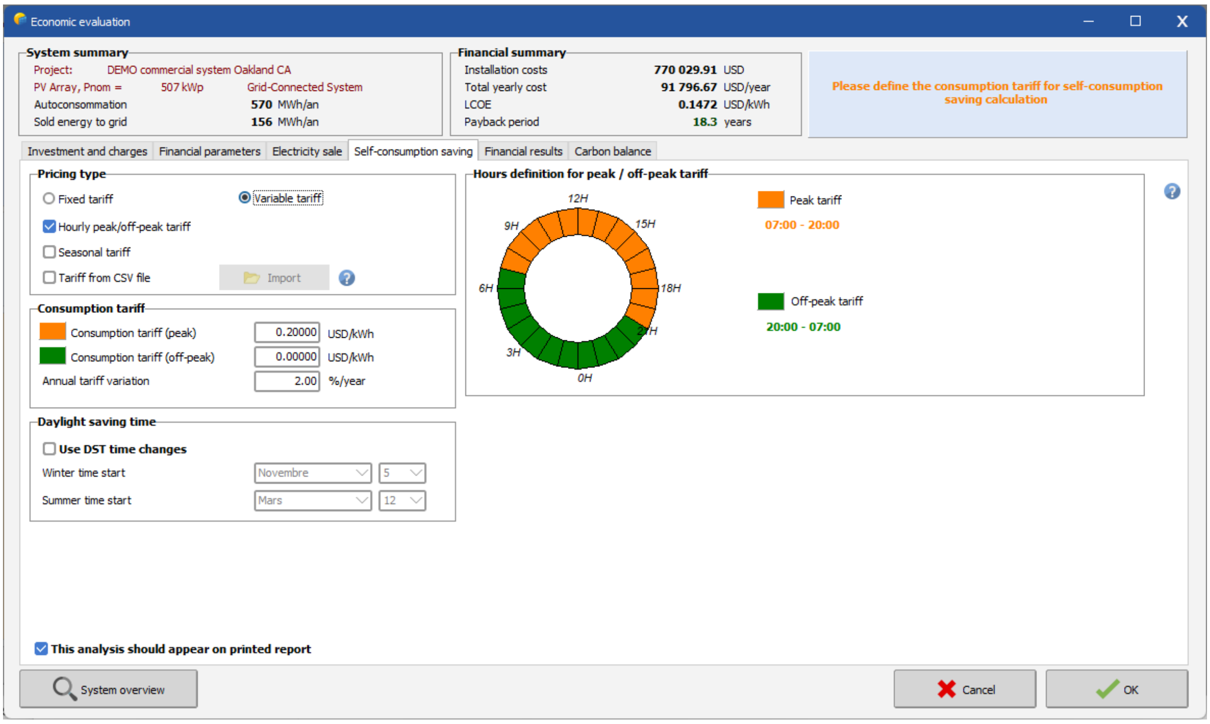
In some countries, the tariff depends on the time of day or the season. PVsyst allows you to define **peak** and **off-peak** tariff levels for specific time periods. These tariffs can differ between **summer** and **winter** (with specified months).

Once the preferential contract period ends, all final tariffs are reduced using the **same coefficient.**

12.3.3 Hourly/daily tariff defined via a CSV file

For more complex tariff strategies, where the selling price varies throughout the year without a simple pattern, you can define an hourly tariff for the entire year using a CSV file. PVsyst provides a dedicated section to guide you in preparing this file.

12.4 Self-consumption saving



Self-consumption allows the user to directly **consume their own production**, thereby reducing their electricity bill. It requires defining:

- an **internal consumption tariff** (what would have been paid to the grid),
- a **selling tariff** for the surplus energy injected into the grid.

This calculation requires that the **consumer's load profile** be defined and computed on an hourly basis, with data stored over the entire period. These tariffs may also vary depending on the time of day, and an **annual tariff evolution** can be included (e.g., an increase in the internal consumption tariff).

12.4.1 Summer time / Winter time (Daylight Saving Time – DST)

This information is only required for **feed-in tariff strategies**. All PVsyst simulations are based on the site's **standard time (winter time)**.

For countries using daylight saving time, the user must provide the **summer/winter transition dates** so that the system can determine whether a simulated hour falls within peak or off-peak periods.

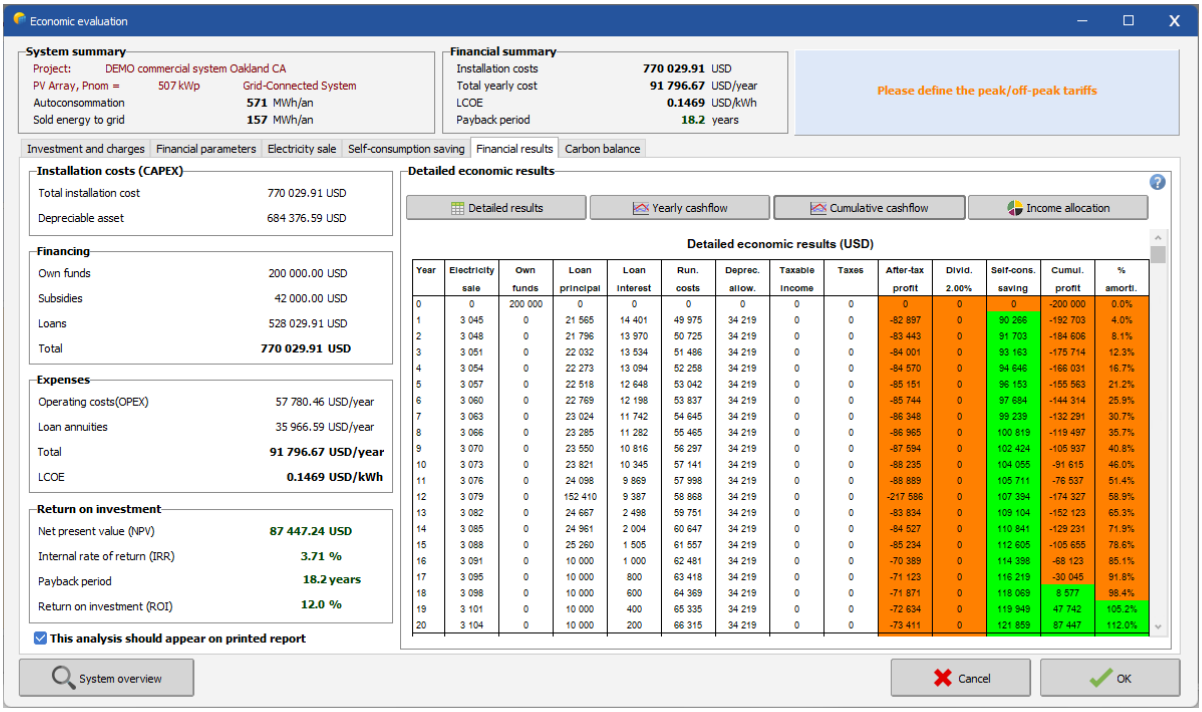
12.5 Financial results

12.5.1 Overview

This section summarizes the profitability of the system. The main indicators presented are:

- **Net Present Value (NPV),**
- **Payback period,**
- **Internal Rate of Return (IRR)** *(often referred to as ROI in PVsyst)*.

It also provides a breakdown of annual balances between costs (defined in **"Installation and operating costs"**) and revenues (determined according to the selected tariff strategy).



12.5.2 Detailed results and calculation methods

- **Depreciation:**
  Transfer of part of the installation cost from the balance sheet to the income statement each year over the system lifetime.

  The depreciable portion of the installation is defined in the **Installation and operating costs** section.

  The depreciation calculation depends on the selected method (straight-line or declining balance), defined in the **Financial parameters** section.

- **Taxable income:**

  Annual amount on which the tax rate is applied.

  There are many tax systems worldwide, often complex.

  In most cases, loan interest and equipment depreciation are tax-deductible.

  The tax calculation in PVsyst is based on this principle.

Taxable income = Energy sales revenue – Operating costs – Loan interest – Depreciation

- **Net result after tax:**

  This is the net income after deducting expenses and taxes. It is used as the basis for calculating potential dividends.

Net result = Energy sales revenue – Operating costs – Loan annuity – (Taxable income × Tax rate)

- **Self-consumption savings**

  These represent the value saved on the electricity bill by directly consuming part of the PV production.

  Self-consumption savings$_t$ = Self-consumed energy$_t$ × Consumption tariff

- **Payback period:**

  The number of years required to recover the net investment cost defined in the **Installation and operating costs** section.

  If the system is not profitable (expenses exceed revenues), the payback period is not defined.

  The amount recovered each year is calculated as:

Recovered amount$_t$ = Net balance$_t$ + Self-consumption savings$_t$ + Capital repayment$_t$

  - **Net annual balance:** corresponds to the profit after tax, minus any dividends paid.
  - **Loan repayment share:** corresponds to the repayment of the borrowed capital (annuity excluding interest).

Net Present Value (NPV): Difference between the present value of incoming cash flows and the present value of outgoing cash flows over a given period.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

where:

- R_t= Net balance (revenues − expenses) in year *t*
- i= Discount rate (return from an alternative investment)
- n= System lifetime

Internal Rate of Return (IRR): The value of the discount rate that makes the Net Present Value equal to zero (**NPV = 0**) for all cash flows.

Return on Investment (ROI): Ratio of net profit to the initial investment, measuring system profitability.

A negative ROI indicates that the system is not profitable.

$$ROI = \frac{Net\ profit\ at\ end\ of\ lifetime}{Initial\ investment}$$

12.5.3 Calculations performed by PVsyst

PVsyst generates:

- the **annual balance** as well as the **cumulative balance** over the expected system lifetime, based on simulated production and all selected economic strategies,
- a detailed **annual summary table**.

Warning: small variations in actual production or simulated costs can significantly impact the final profitability indicators. This is especially true in cases of real solar variability or system failures during the system lifetime.

12.6 Carbon balance

12.6.1 Introduction

The **Carbon Balance** tool allows estimating the expected CO_2 savings of a photovoltaic installation. It is based on **life cycle emissions (LCE)**, i.e., the amount of CO_2 associated with a component or a quantity of energy, including manufacturing, operation, maintenance, end-of-life, etc.

The principle is that the electricity produced by the PV system replaces an equivalent amount of electricity from the grid. If the carbon footprint of PV (per kWh) is lower than that of grid electricity, there is a net reduction in CO_2 emissions.

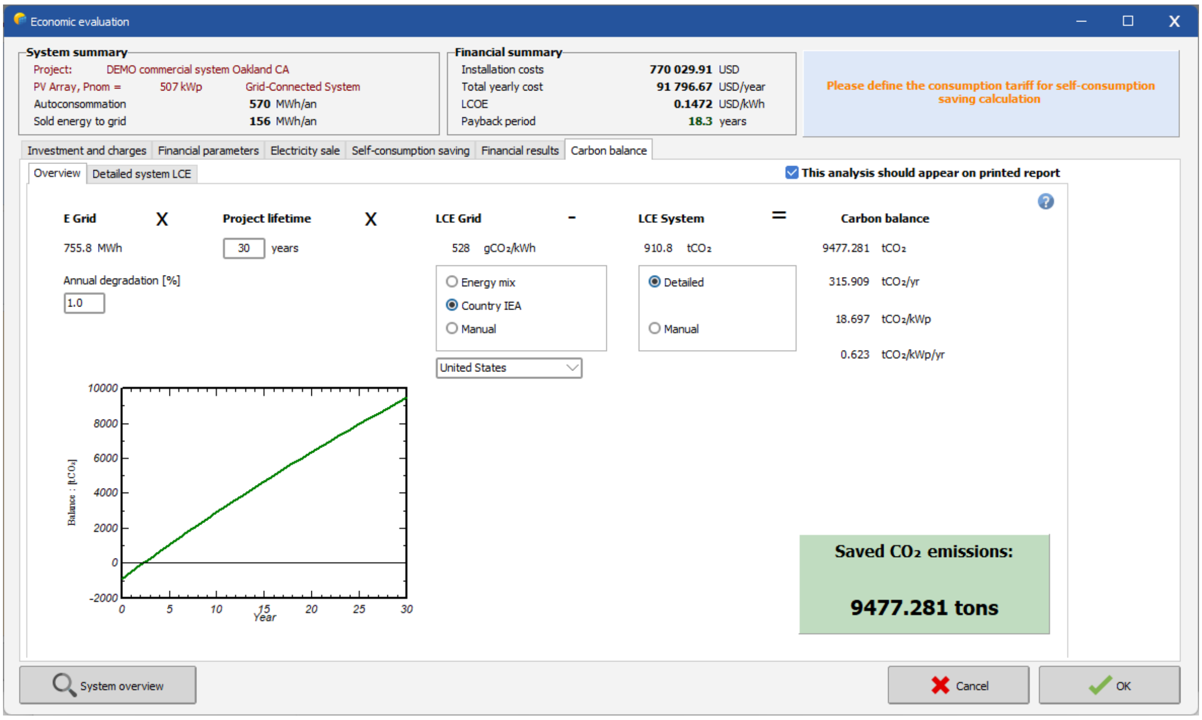
The total carbon balance is therefore the difference between the **avoided CO_2 emissions** (thanks to PV production) and the emissions related to the production and operation of the PV system.

This balance depends on four key parameters:

- **E_Grid:** annual system production (energy yield simulated by PVsyst).
→ An annual degradation can also be defined (default: 1%), representing the decrease in production due to module aging.
- **System lifetime:** number of years of expected operation.
→ Together with E_Grid, it determines the total energy replaced by PV over its lifetime.
- **Grid LCE:** average CO_2 emissions of the grid (in gCO_2/kWh).
- **PV System LCE:** total emissions (in tons of CO_2) related to manufacturing, installation, and operation of the PV system.

Estimating these emissions often requires uncertain data, depending on technologies, manufacturing processes, etc. PVsyst provides predefined values for **Grid LCE**, based on publicly available data, but the user must supply the **PV System LCE** (from manufacturers or databases such as ECOINVENT or Carbon Trust). Default values may be provided in the future.

12.6.2 Overview tab



This tab provides a **summary view** of the carbon balance parameters and results:

User-defined parameters:

- Grid LCE
- System lifetime
- Annual degradation
- PV System LCE

Calculated parameters (from PVsyst simulation):

- System production (E_Grid)
- Carbon balance results, including:
  - **Total CO_2 savings (tCO_2) over the entire lifetime,**
  - **Average annual CO_2 savings (tCO_2/year),**
  - **CO_2 savings per installed capacity (tCO_2/kWp),**
  - **Annual CO_2 savings per installed capacity (tCO_2/kWp/year).** Annual values are **weighted averages over the system lifetime**, taking degradation into account.

12.6.3 Grid LCE customization

Three modes are available:

1. **Manual:** you enter a value and can add a note explaining its source (displayed in the report).

2. **Country (IEA):** predefined value according to the International Energy Agency, based on average CO_2 emissions per country/region (2010 data).
3. **Energy mix (Grid Energy Mix):** provides access to a dedicated tab where you can detail the electricity mix sources and their specific emissions.

12.6.4 PV System LCE customization

Three options are available:

1. **Manual:** you directly enter a value and can specify the source in a comment.
2. **Default value:** an estimate based on international scope (IPCC), with an average value of **46 gCO_2/kWh** (based on 26 analyzed publications).
3. **Detailed:** opens a **"Detailed System LCE"** tab where you can enter data by component (modules, structures, inverters, etc.) to calculate the impact more precisely.

12.6.5 Grid Energy Mix

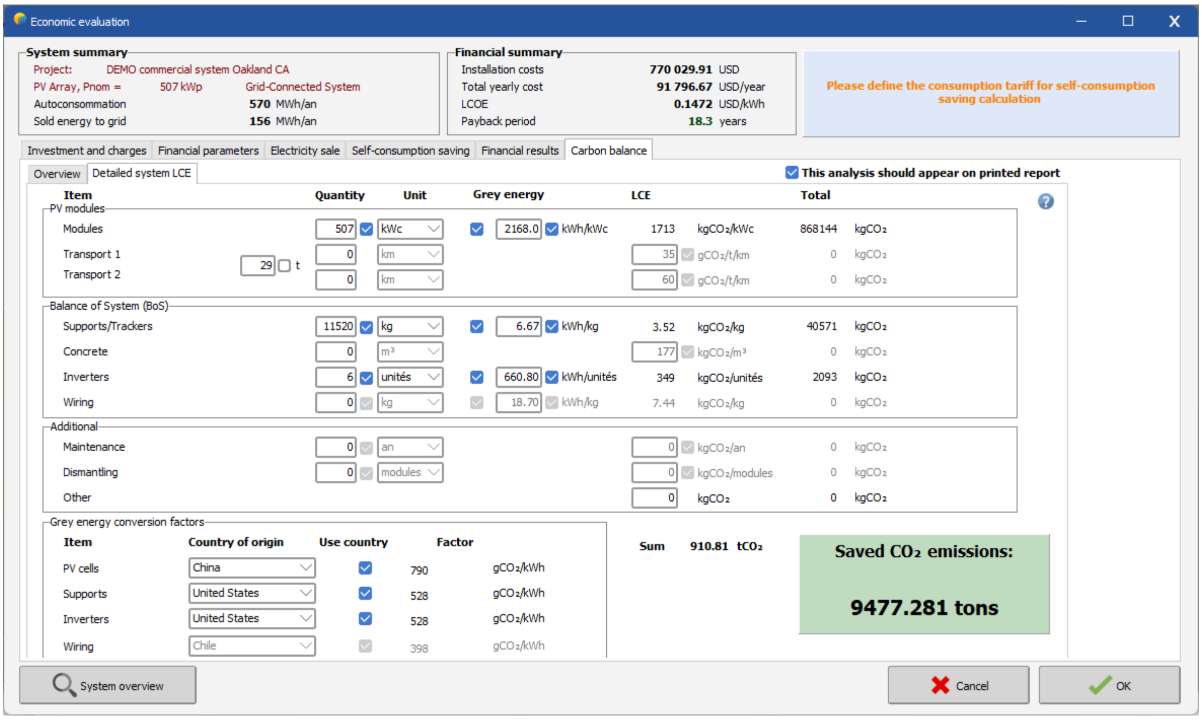
The grid energy mix represents the distribution of different electricity generation sources within a given grid.

- In the left column of the tab, eleven different types of electricity production are listed.
- The second column shows the CO_2 emissions per kWh associated with each source.
  → By default, these values come from an IPCC publication and correspond to the 50th percentile of a meta-study based on 296 publications.
  → You can also enter custom values using the dropdown menu at the top of the column. In this case, it is important to rely on a reliable source reflecting the grid you are studying.
- The third column specifies the share of each production type in the grid.
  → Default values are available for several European countries, based on a study by the Paul Scherrer Institute (PSI) in Switzerland.
  → If your country is not listed, or if you have more accurate data, you can select the **"Custom"** option and enter your own values.

The resulting **Grid LCE value** is automatically calculated as you make your selections and is displayed on the right side of the tab.

12.7 Detailed System LCE

In this tab, you can define a detailed breakdown of CO_2 emissions associated with the different components of a photovoltaic system.



Potential sources of CO_2 emissions are grouped into three main categories, each further divided into several sub-components.

- If reliable data on **life cycle emissions (LCE)** for a component are available (provided by a manufacturer or a specialized database), they should be used as a priority.
- If such data are not available, some components allow estimation of LCE based on **embodied energy** (the amount of energy required to manufacture the component). In this case, a conversion factor is needed to translate this embodied energy into an equivalent LCE value.

LCE values are expressed in **kgCO_2 per unit**, with the unit depending on the category and the user's choice. For each category, the corresponding quantity must also be specified.

Whenever possible, PVsyst automatically inserts values derived from the simulated variant.

For each category, the contribution to total emissions is calculated and displayed in the last column. The total (in tons of CO_2) appears at the bottom of the column and is automatically updated. This value is immediately reflected in the **Overview** tab.

12.7.1 Categories and sub-components

PV modules

- **Module manufacturing:** this is generally the main source of emissions in a PV system. LCE and embodied energy values can vary significantly. PVsyst provides default values based on publications for **monocrystalline silicon** modules.
  By default, the estimate is based on **embodied energy**, using a conversion factor corresponding to electricity emissions in China (IEA data).
- **Transport 1 / 2:** two separate contributions to distinguish different transport modes (e.g., maritime freight + road transport).
  The transported load is calculated based on the total module weight defined in the

project.
Distances must be provided by the user.

Default values proposed:

- 35 gCO_2/t/km → long-distance maritime transport
- 60 gCO_2/t/km → road transport by truck

System components (BoS – Balance of System)

Includes all other components required for the installation, without a dedicated transport category (less significant than for modules).

- **Mounting structures / Trackers:** PVsyst estimates the amount of steel based on the number of modules or trackers. Default values are based on 1 kg of steel. By default, the estimation is based on **embodied energy**, with a conversion factor corresponding to electricity emissions in the country of installation.
- **Concrete:** often a significant source of emissions. Default values are provided for massive foundations or trenches.
- **Inverters:** values vary depending on technology and manufacturer. By default, PVsyst estimates LCE based on embodied energy (default value: 2.5 kW inverters).
  Conversion factor = emissions from electricity in the country (IEA data).
- **Cabling:** default values are based on copper.

  LCE estimation is based on embodied energy.

  Conversion factor = emissions from electricity in Chile, the world's leading copper producer.

Additional

- **Maintenance:** includes inspections, repairs, panel cleaning, vegetation management, etc. Highly project-specific → no default value. Contribution is usually low.
- **Decommissioning:** includes all end-of-life operations (dismantling, recycling, disposal, site restoration, etc.). Highly specific → no default value.
- **Other:** allows adding a contribution that does not fall into the above categories. This is a fixed value directly added to the total.