PVSYST 7

Grid Connected Systems
My first project

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INTRODUCTION

This document is a first step of a series of tutorials that demonstrates the use of PVsyst Version 7 and may be understood as a PVsyst user's manual. This first chapter describes the basic aspects of creating your first grid-connected project.

More tutorials on different features of PVsyst are in preparation and will be added in the future. The complete reference manual for PVsyst is the online help that is accessible from the program through the “Help” entry in the menu, by pressing the F1 key or by clicking on the help icons  inside the windows and dialogs.

Contents

Chapter 1: Basic Approach - My First Project

1.1 First contact with PVsyst

When opening PVsyst, you get to the main page:

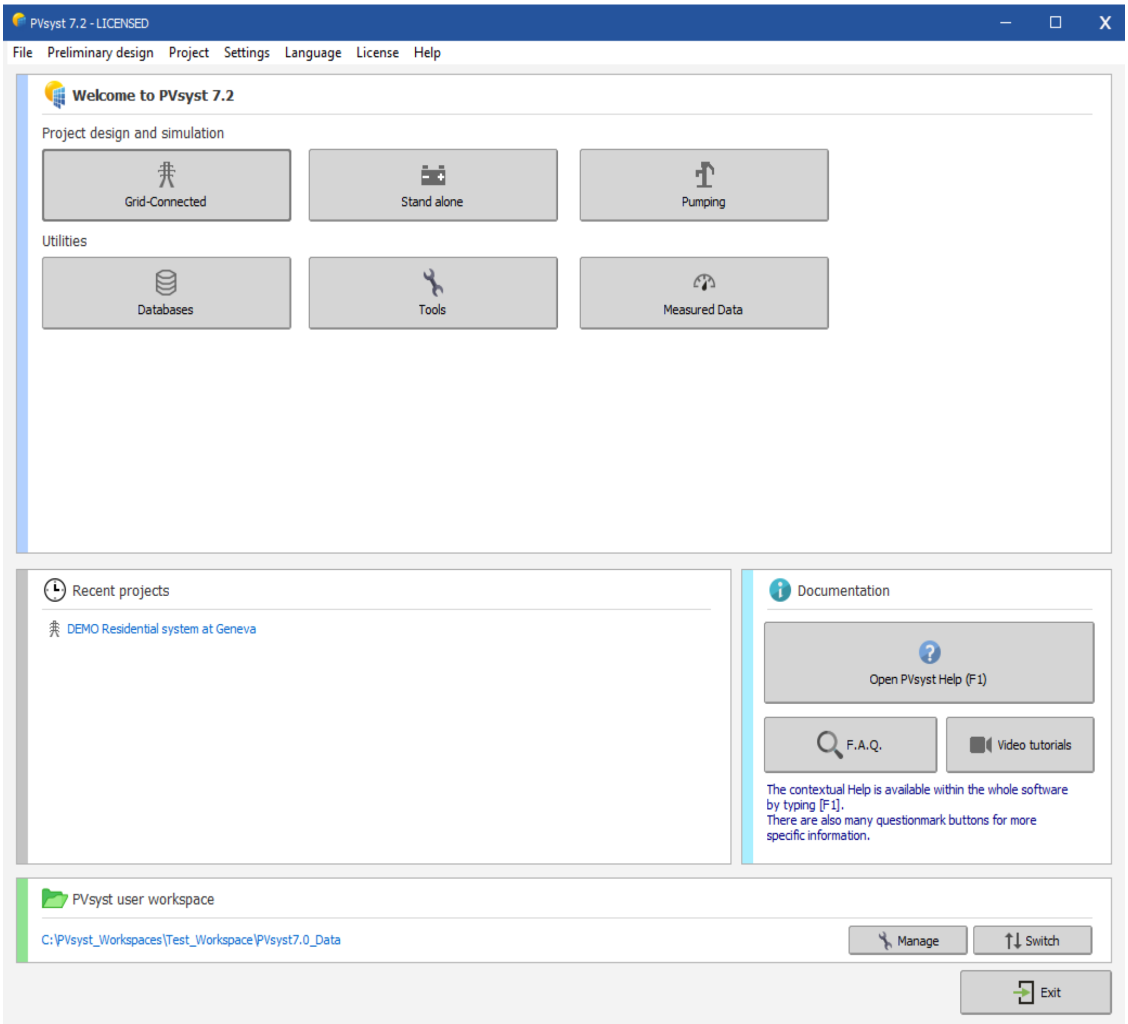


Figure 1: Main page of PVsyst 7.2.

This gives access to four main parts of the program:

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

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

3. "Documentation" will assist you in implementing different simulations with the help of PDF tutorials, videos and a FAQ.

4. "Pvsyst user Workspace" contains all data created by the user. The default place is C:\Users\<username>\Pvsyst7.0_Data but this can be changed by the user.

1.2 Full study of a sample project

1.2.1 Project specifications and general procedure

To introduce the development of a project design in PVsyst, we will walk through a full project step-by-step. As an example, we consider a farm located in Switzerland close to Geneva. The building in question is illustrated in Figure 2:

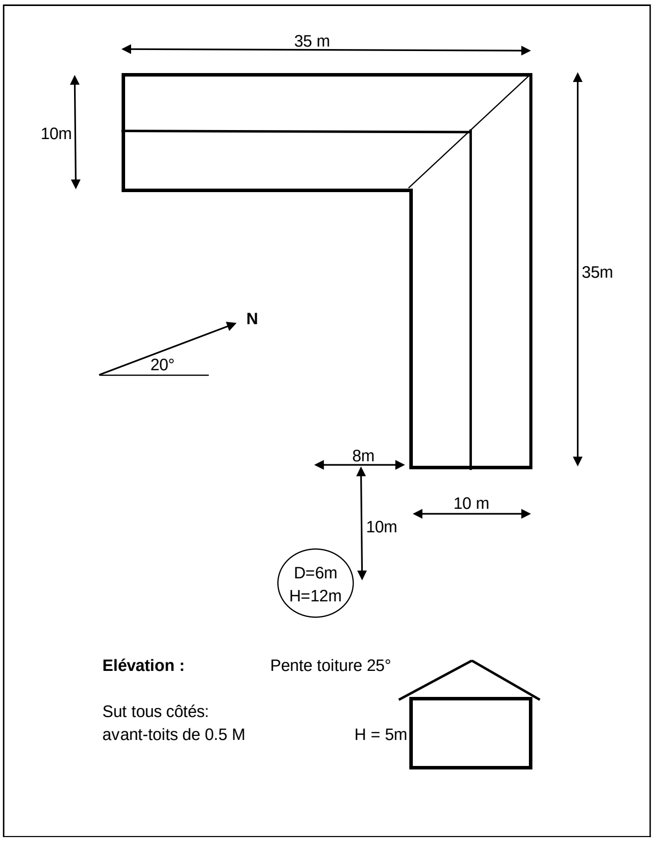


Figure 2: Project sketch.

The roof of the farm is facing south, a roof surface of 125 m^2 is available and we plan to cover 50 m^2 of the roof with mono-crystalline PV modules.

As explained before, we will not use the "Preliminary Design" for a grid-connected project, but rather start with a complete "Project design".

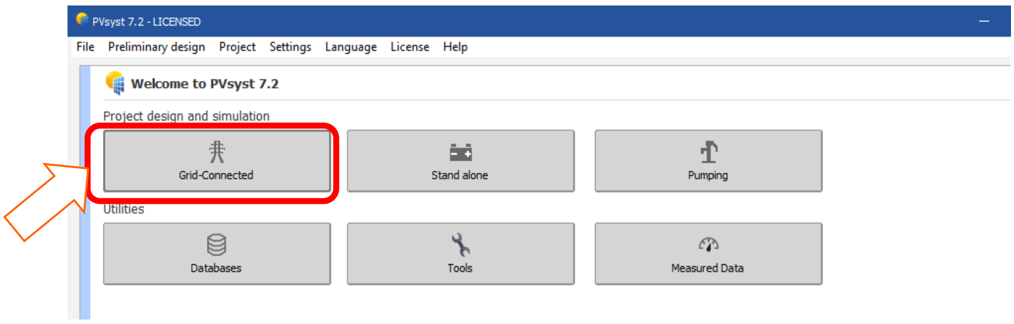


Figure 3: Starting a grid-connected project.

When you choose a "Grid connected" project, the following project management dashboard appears:

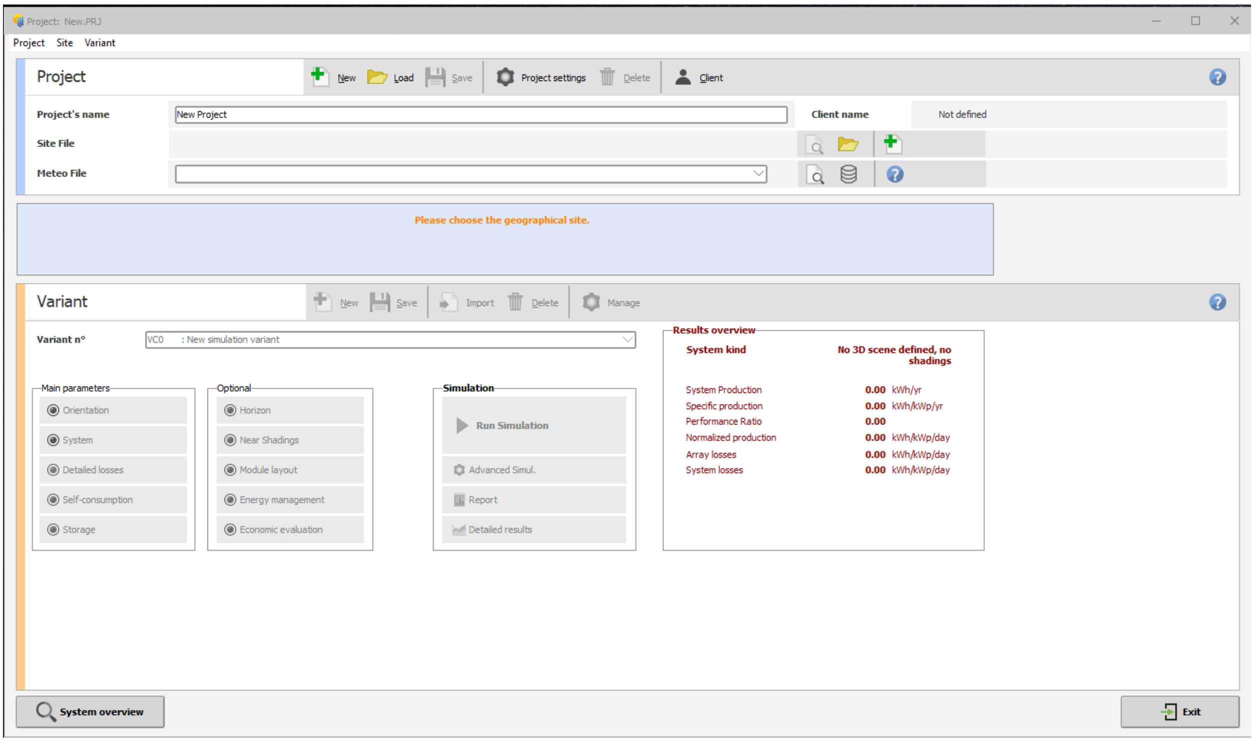


Figure 4: Project management dashboard.

The dashboard has two parts:

1. 'Project': The central object that allows the basic definition of your project in which you will construct different variants (also called system configurations or calculation variants) of your system. Project contains the geographical site of your system, the reference to a file with the meteorological data and some general parameters like the Albedo definition, some sizing conditions and parameters specific to this project. In the PVsyst workspace, it will get a filename with the extension *.PRJ.
2. 'Variant': Each system variant contains all the detailed definitions of your system, which will result in a simulation calculation. These definitions include the choice and number of solar panels and inverters, geometrical layout and possible shadings, electrical connections, different economic scenarios, etc. In the database, the files with the Variants of a project will have the Project's file name, with extensions such as VC0, VC1, VCA, etc. You can define up to 936 Variants per project.

Steps in the development of a project.

When developing a project in PVsyst, you are advised to proceed in small incremental steps:

- Create a project by specifying the geographical location and the meteorological data.
- Define a basic system variant, including only the orientation of the PV modules, the required power or available area and the type of PV modules and inverters that you would like to use. PVsyst will propose a basic configuration for this choice and set reasonable default values for all parameters that are required for a first calculation. Then you can simulate this variant and save it. It will be the first rough approximation that will be refined in successive iterations.
- Define successive variants by progressively adding perturbations to this first system, i.e., far shadings, near shadings, specific loss parameters, economic evaluation, etc. You should simulate and save each variant so that you can compare them and understand the impact of all the details you are adding to the simulation.

Tips - Help

In PVsyst, you can always get to the Help context by pressing F1. Sometimes you will also see a little blue question mark button . Clicking on the button will lead to more detailed information on the topic in the Help section.

When PVsyst displays messages in red, you are advised to read them carefully! They may be either warnings or error messages, or they can be procedures that should be followed to get a correct result.

1.2.2 Defining the Project

In the project dashboard, click on "New project" and define the project's name.

Then, click on "Site and Meteo".

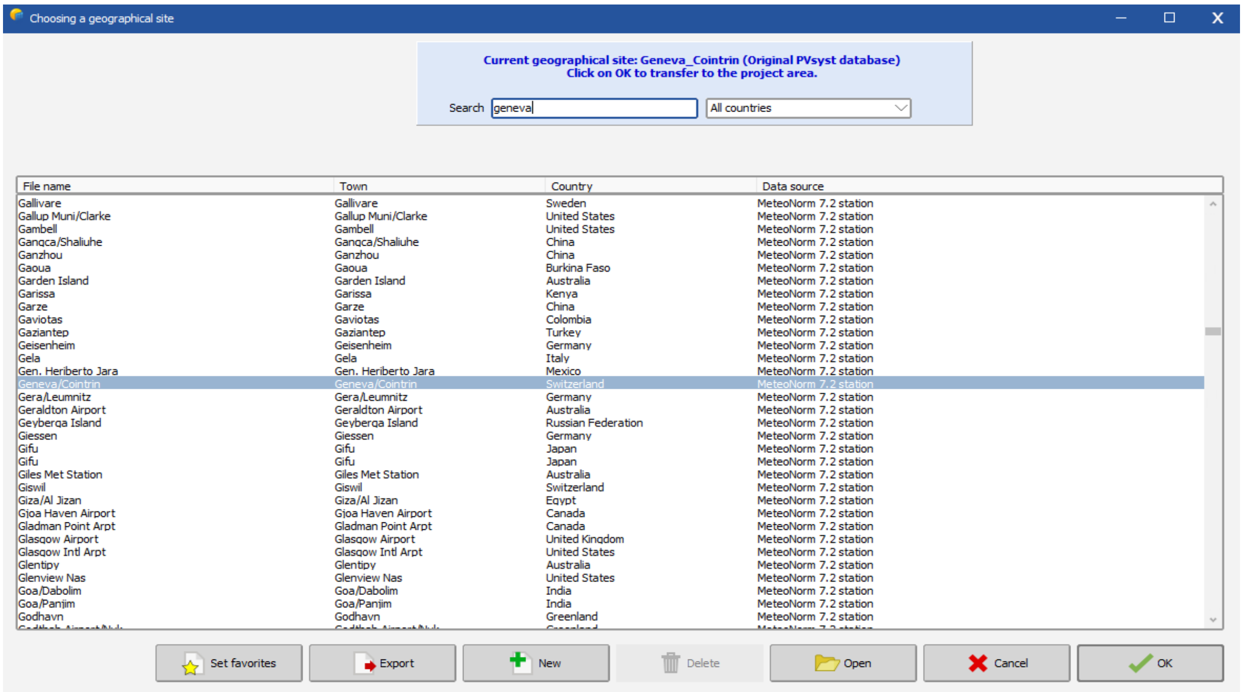


Figure 5: Dashboard to choose a geographical site.

You can either choose a site from the built-in database, which holds around 2,550 sites from Meteonorm, or you can define a new site that can be located anywhere on the globe. Please refer to the tutorial. “Meteorological Data management" if you want to create or import a site other than those available in the database.

The project’s site defines the coordinates (Latitude, Longitude, Altitude and Time zone) and contains monthly meteorological data.

The simulation will be based on a Meteo file with hourly data. If a near meteo file exists in the vicinity (less than 20 km), it will be proposed. Otherwise, PVsyst will create a synthetic hourly data set based on the monthly meteo values of your site. However, you can always choose another Meteo file in the database. A warning will be issued if it is too far from your site.

N.B.: If you start by choosing a meteo file, you have the possibility to copy the site associated to this file.

In the project dashboard, you can click on the button "Project settings" (Figure 6) that will give you access to the common project parameters, namely the Albedo values, the design conditions, design limitations and interface preferences.

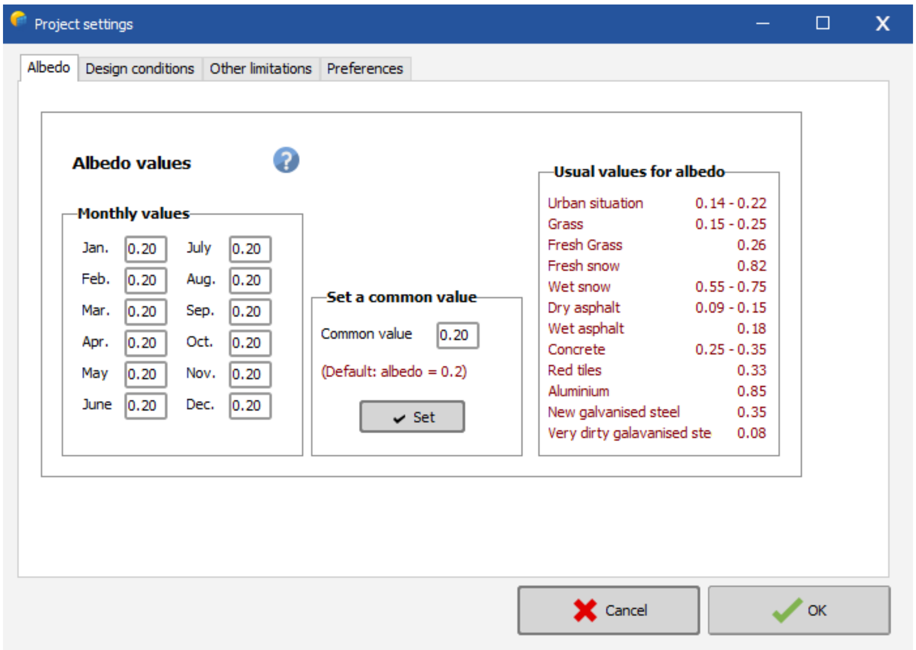


Figure 6: Project settings to access common project parameters.

In general, you will never modify the Albedo factor. The value of 0.2 is a standard value most commonly. Nevertheless, if for example your site is in the mountains, you can define a higher Albedo factor like 0.8 for the months with significant snow cover.

The second tab in the project parameters dialog contains the "Design Conditions" page, see Figure 7.

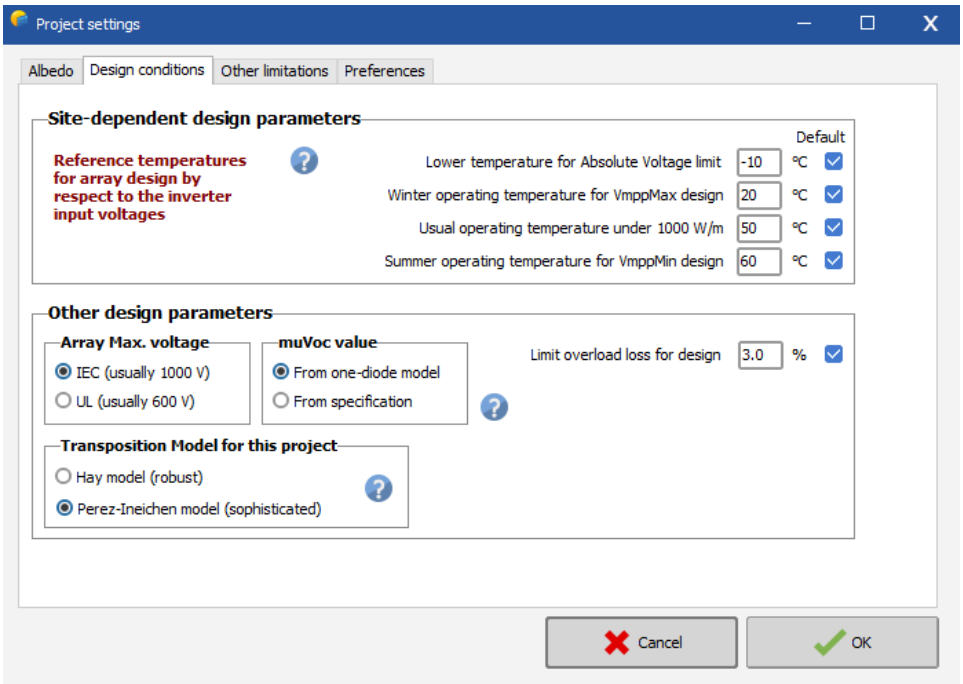


Figure 7: Design conditions for project settings.

This page defines sizing temperatures, which may be site dependent. These are only used during the sizing of your system, and they are not involved in the simulation. The "Lower temperature for Absolute Voltage Limit" in this tab is an important site-dependent value, as it is related to the safety of your system (it determines the maximum array voltage in any conditions). Ideally, it should be the minimum temperature ever measured during daylight at this location. In Central Europe, the common practice is to choose -10°C (lower in mountain climates).

1.3 Saving the Project

When you are finished (i.e., you have gone to the Variant choices), you will be prompted to save the project. The dialog that comes up (Figure 8) allows you to rename the project. We recommend that you use a simple filename, since it will be used as a label for all the Variants.

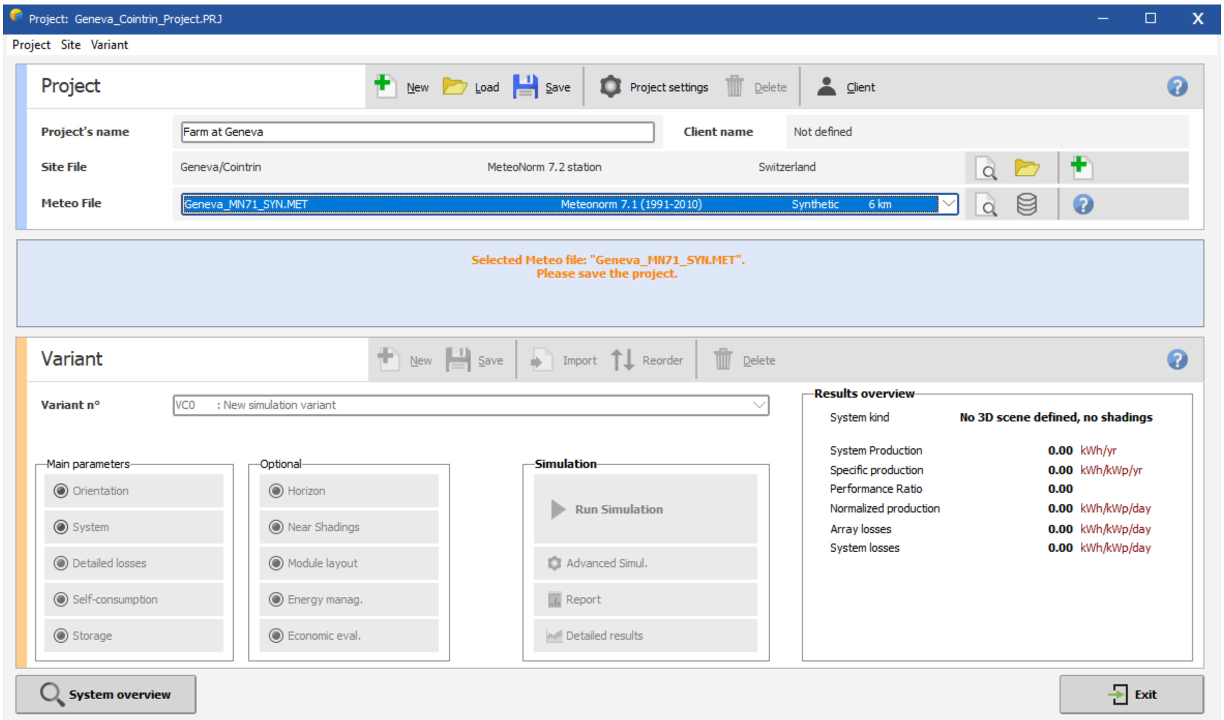


Figure 8: Saving the project.

1.3.1 Creating the first (basic) variant for this project

After defining the site and the meteorological input of the project, you can proceed to create the first Variant. You will notice that in the beginning, there are two buttons marked in red: “Orientation” and “System”, see Figure 9. The red color means that this variant of the project is not yet ready for the simulation, additional input is required. The basic parameters that must be defined for any variant, and that we have not specified yet, are the orientation of the solar panels, the type and number of PV modules and the type and number of inverters that will be used.

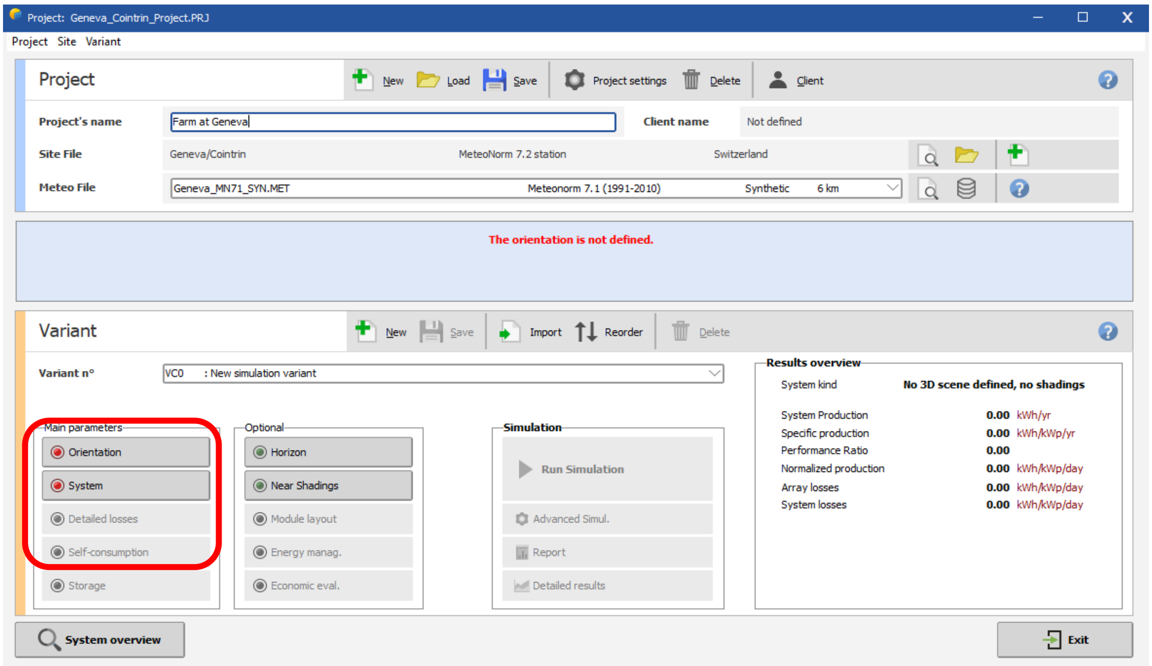


Figure 9: Two basic Variants -"Orientation" and "System".

First, click on "Orientation". You will get the orientation dialog where you will have to supply values for the type of field for the solar installation and tilt and azimuth angles, see Figure 10.

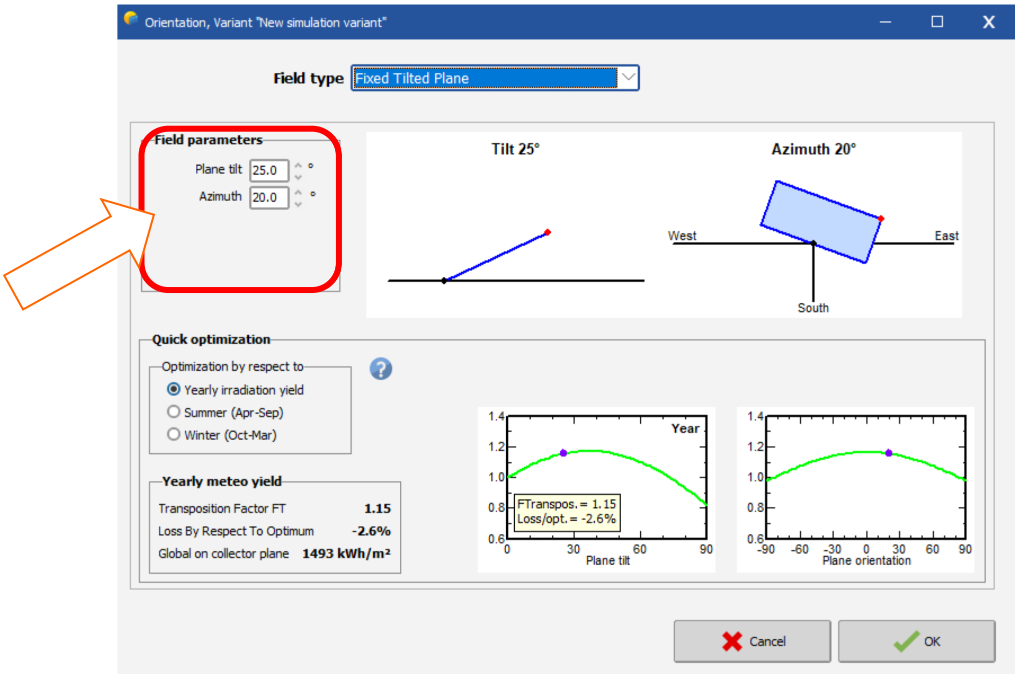


Figure 10: Orientation dialog.

The solar panels in our example will be installed on a fixed tilted plane. From the project's drawing in Figure 2, we get the plane tilt and azimuth angles (25° and 20° west respectively). The azimuth is defined by the angle between the South direction and the direction where the panels are facing. Angles to the west are considered positive, while angles to the east are considered negative.

After setting the correct values for tilt and azimuth, you click on "OK" and the “Orientation” button will turn green. Next click on "System".

Pre-sizing Help: From the system description, we recall that we have an available area of around 50 m². It is not mandatory to define a value here but doing so will simplify our first approach as it will allow PVsyst to propose a suitable configuration.

Select a PV module: Choose a PV module in the database. Among "All modules", select "Generic" as manufacturer and select the 300 W model. In the bottom right part of the dialog, PVsyst will display a hint for choosing the inverter: *"Please choose the Inverter model, the total power should be 7 kW or more."*

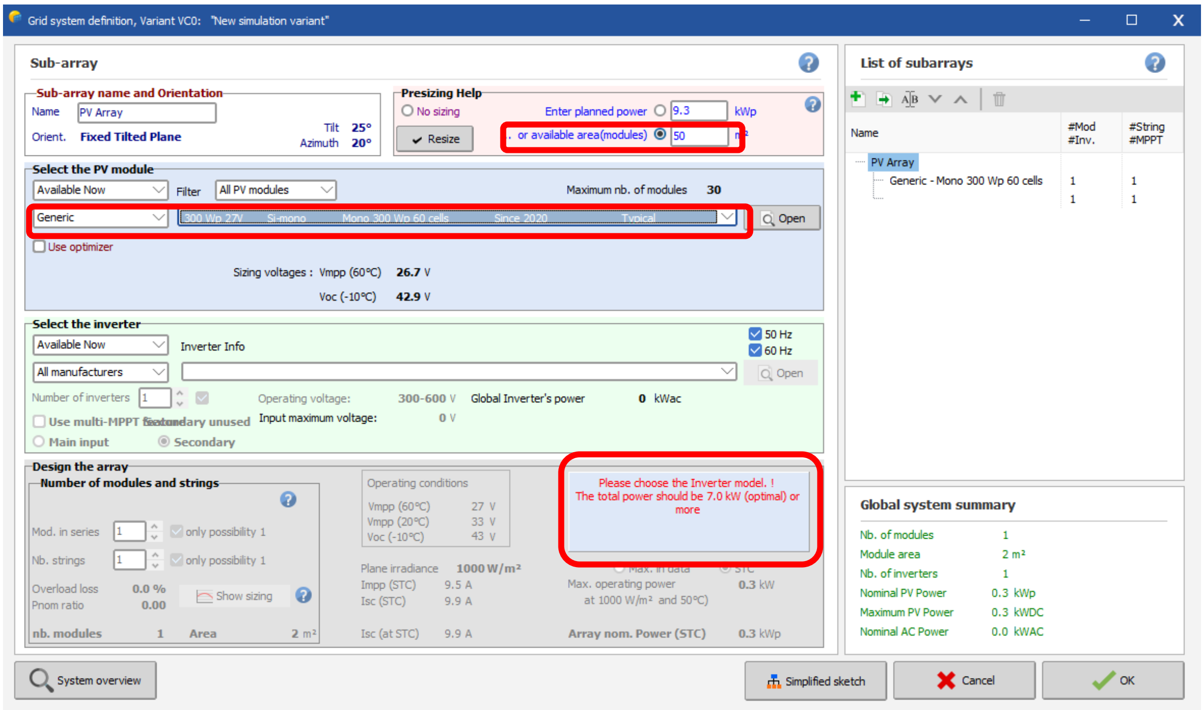


Figure 11: Grid system definition dialog on selecting the PV module.

Select the Inverter: For the installation in our example, we can choose a monophase inverter of around 7 kW. We choose the Generic 7.5 kW inverter, and PVsyst proposes a complete configuration for the system: 1 inverter, 2 strings, each with 15 modules connected in series.

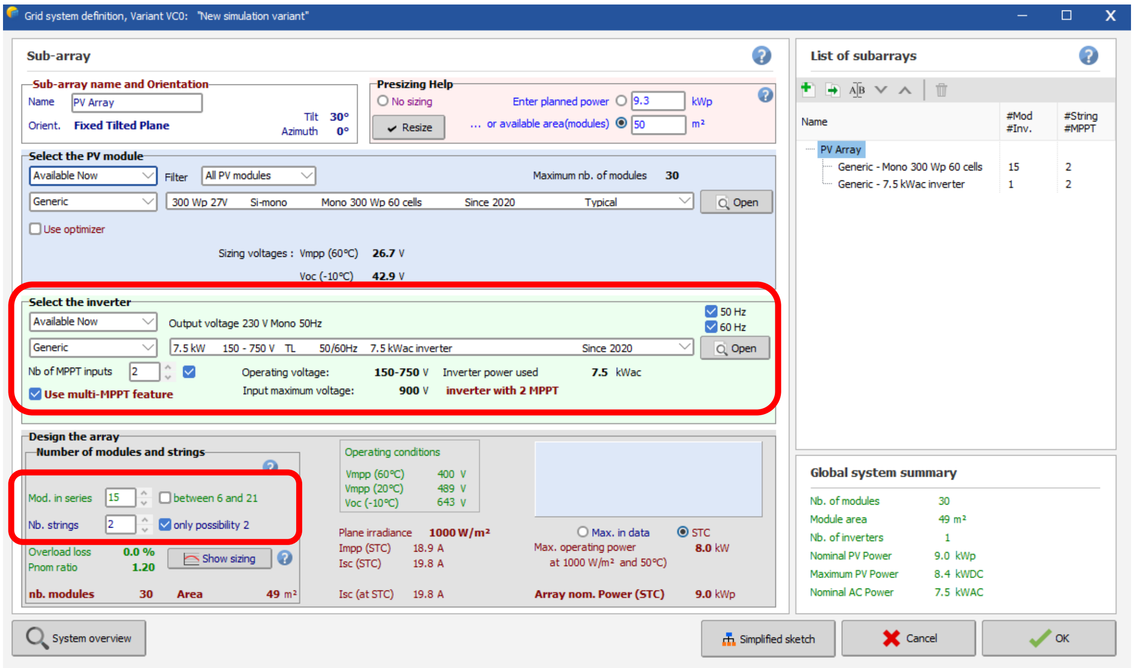


Figure 12: Grid system definition dialog on selecting the inverter.

After defining module type, the inverter and the design of the array, the blue panel in the bottom right part of the dialog should be either empty or orange. If you get a red error message, check all choices you made and correct them to the values described above (it may take a short moment for the message to adapt to the changes you make).

We have now defined all mandatory elements that are needed for a first simulation. We will go through more details of this very important dialog later in this tutorial. For now, you can click on "OK" to validate the choices. You will get a message box with the warning: “The inverter power is slightly undersized”. For the time being we will ignore it and just acknowledge with the OK button.

Message colors in PVsyst

In many of the PVsyst dialogs you will be prompted with messages that are meant to guide you through the different steps of the definition and execution of a simulation. The color of the text gives you a clue on how important the message is:

- Messages in black are additional information or instructions on how to proceed.
- Warnings in orange indicate design imperfections, but the system is still acceptable.
- Errors in red mean serious mistakes, which will prevent the execution of the simulation.

A similar color code is also valid for the buttons on the project's dashboard (in addition a greyed-out button means “has not been defined”).

1.4 Executing the first simulation

On the Project's dashboard, all buttons are now green (possibly orange) or off.

The "Run Simulation" button is activated, and we can click on it.

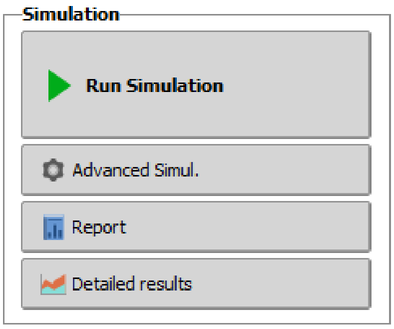


Figure 13: Run simulation button.

The simulation dates are those of the underlying meteo data file. Do not modify them (you cannot perform a simulation outside of the available meteo data).

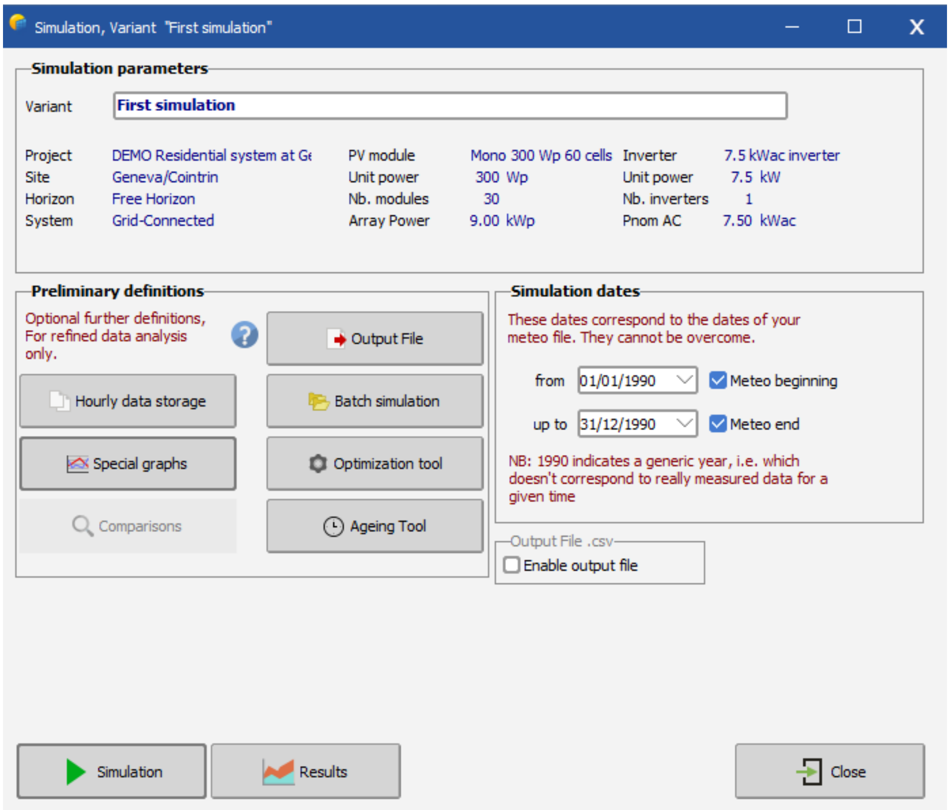


Figure 14: Simulation variant dialog.

The preliminary definitions are additional features that may be defined for advance purposes. We will skip them for now and click right away on “Simulation”.

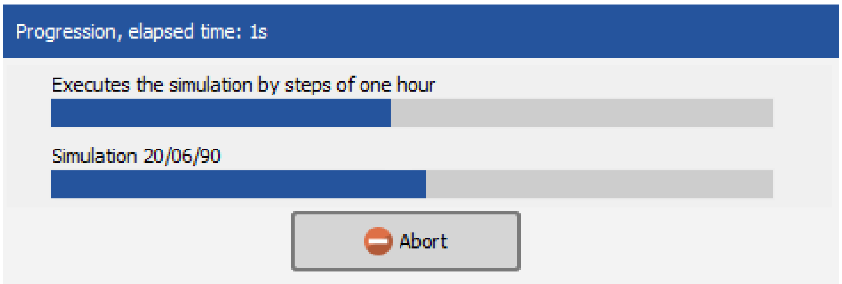


Figure 15: Progress bar.

A progress bar will appear, indicating how much of the simulation is still to be performed. Upon completion, the "OK" button will be activated. Clicking on it brings you directly to the "Results" dialog.

1.4.1 Analyzing the results

The "Results" dialog shows on the top a short summary of the simulation parameters that you should quickly check to make sure that you made no obvious mistakes in the input parameters. On the right is a frame with six values that summarize at one glance the main results of the simulation. They only give a very rough idea of the results and are there to quickly spot obvious mistakes or to get a first impression of a change or a comparison between variants of the project.

On the bottom part of the dialog, you will see several diagrams that provides detailed information about the general behavior of the system. The "Daily Input/Output diagram" displays the energy that was injected to the grid as a function of the global incident irradiation in the collector plane for a daily basis.

- For a well dimensioned grid-connected system, this should be roughly a straight line that slightly saturates for large irradiation values. This slight curvature is a temperature effect. If some points (days) deviate at high irradiances, this is an indication of overload conditions.
- For stand-alone systems, a plateau indicates overload (full battery) operation.

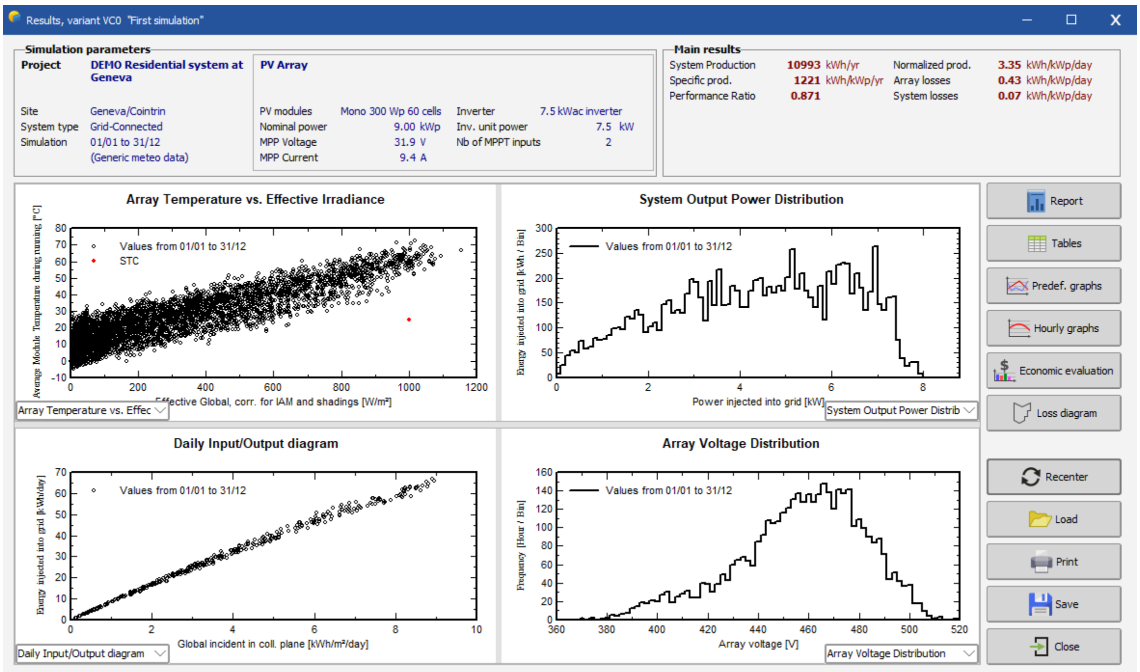
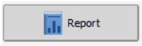


Figure 16: Results dialog.

The main information of the simulation results is gathered in the report. The other buttons give access to complementary tables and graphs for a deeper analysis of the simulation results. For now, we will ignore them. When you click on 

you will get the complete report consist of only six pages for this first simple variant (for simulations with more detail you can get up to 11 pages of report). In this report you will find the:

- **Cover page:** Various aspects of the simulation project and variant name including the PVsyst version number and information about the system kind, size and location.
- **Second page**: A high level summary of the project system and results of the simulation variant. A fully defined geographical site and meteo properties. Table of contents of the report is also provided.
- **Third page:** General underlying parameter of the simulation: the system kind plane orientation, general information about shadings (horizon and near shadings), components used and array configuration, loss parameters.
- **Fourth page**: The main results of the simulation: energy production, specific production and performance ratio.
- **Fifth page**: The PVsyst arrow loss diagram, showing an energy balance and all losses along the system. This is a powerful indicator of the quality of your system, and will immediately indicate the sizing errors, if they exist.
- **Sixth page**: Special graphs on the simulation. Daily input/output diagram and the distribution of power injected to the grid are shown.

1.4.2 Analyzing the report

Fourth page: main results

For our first system: three relevant quantities are defined:

1. Produced Energy: The basic result of our simulation.
2. Specific production: The produced energy divided by the Nominal power of the array (Pnom at STC). This is an indicator of the potential of the system, taking into account irradiance conditions (orientation, site location, meteorological conditions).
3. Performance ratio: An indicator of the quality of the system itself, independently of the incoming irradiance. We will give its definition below.

Main results

System Production			
Produced Energy	11.57 MWh/year	Specific production	1285 kWh/kWp/year
		Performance Ratio PR	87.79 %

Figure 17: Main results of the simulation from the report.

The bottom of this page contains a table (Figure 18: Table of main variables and its results., given as monthly values and the overall yearly value. The yearly value can be an average (i.e., for the temperature), or a sum (i.e., for the irradiation or energies). The definition of the different variables is the following:

- GlobHor: Global irradiation in the horizontal plane. This is our meteo input value.
- T_amb: Ambient (dry bulb) average temperature. This is also our meteo input value.
- GlobInc: Global irradiation in the collector plane, after transposition, but without any optical corrections (often named POA for Plane of Array).

- GlobEff: "Effective" global irradiation on the collectors, i.e., after optical losses (far and near shadings, IAM, soiling losses).
- EArray: Energy produced by the PV array (input of the inverters).
- E_Grid: Energy injected into the grid, after inverter and AC wiring losses.
- EffArrR: PV array efficiency EArray related to the irradiance on the collector's total area.
- EffSysR: System efficiency E_Grid related to the irradiance on the collector's total area.

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	33.4	20.36	1.85	50.8	49.0	0.442	0.431	0.944
February	56.1	31.33	2.59	76.6	74.2	0.664	0.650	0.943
March	105.7	44.56	6.67	131.4	127.7	1.093	1.072	0.906
April	138.8	63.42	10.57	154.0	149.5	1.257	1.233	0.890
May	168.3	73.80	14.58	171.7	166.9	1.368	1.341	0.868
June	187.7	85.93	19.11	184.5	179.1	1.446	1.419	0.854
July	187.2	74.13	21.34	188.0	182.7	1.448	1.420	0.839
August	160.5	62.96	20.35	174.7	169.9	1.355	1.329	0.845
September	119.0	55.25	15.68	141.3	137.3	1.127	1.106	0.869
October	72.0	39.11	11.43	92.8	89.8	0.764	0.749	0.897
November	38.5	21.86	5.96	56.8	54.8	0.481	0.470	0.919
December	26.7	15.70	2.73	41.7	40.2	0.359	0.349	0.930
Year	1293.9	588.41	11.12	1464.3	1421.1	11.804	11.569	0.878

Figure 18: Table of main variables and its results.

The monthly graphs on the fourth page of the report are given in units called "Normalized Performance Index". These variables have been specified by the "Joint Research Center" JRC (Ispra) for a standardized report of PV system performance and they are now defined in the international IEC61836 norm. The PVsyst online help contains a full explanation of these values (you can directly access this section of the online help by pressing F1 when you are on this page of the report). In these units, the values are expressed in [kW/kWp/day] and contain the following information:

- Yr, Reference Yield: Energy production if the system were always running at "nominal" efficiency, as defined by the array Pnom (nameplate value) at STC. This is numerically equivalent to the GlobInc value expressed in [kWh/m²/day].
- Ya, Array yield: Energy production of the array.
- Yf, Final System yield: Energy to the grid.
- Lc= Yr – Ya: Array capture losses.
- Ls= Ya – Yf: System losses.
- PR = Yf / Yr: Performance Ratio = E_Grid / (GlobInc Pnom(nameplate)).

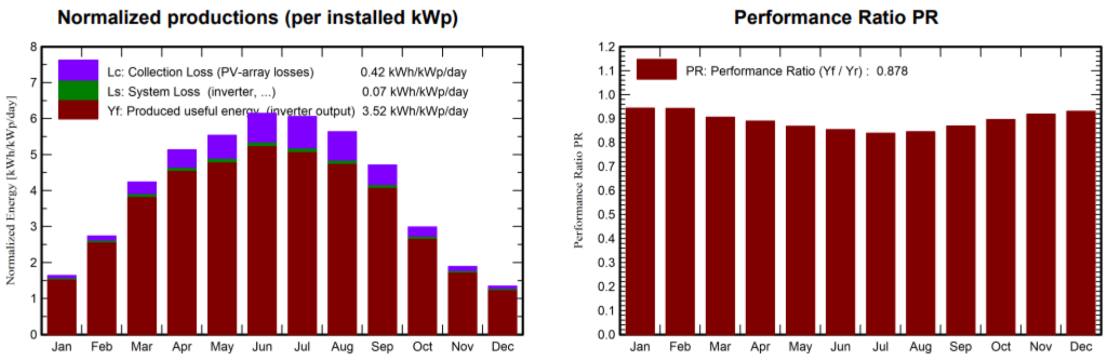


Figure 19: Normalized performance indexes.

Fifth page: arrow loss diagram

This is the PVsyst way of reporting the systems' behavior, with all detailed losses. This diagram is very useful for the analysis of the design choices and should be used when comparing systems or variants of the same project.

- GlobHor: Horizontal irradiation (starting point from meteo value).
- GlobInc: After transposition (reference for the calculation of PR, which includes the optical losses).
- IAM: The optical losses. When adding further details to a variant, there will be additional arrows for far and near shadings, soiling, etc.
- GlobEff · Coll. Area: Energy on the collectors.
- EArrNom: Array nominal energy at STC (= GlobEff Effic. nom).
- Array losses: Collection losses (irradiance, temperature, mismatch, module quality, wiring, etc.).
- EArrMPP: Array available energy at MPP.
- Inverter losses: Efficiency and eventual overload loss (all others are usually null).
- EOutInv: Available energy at the output of the inverter.
- AC losses: Eventual wiring, transformer losses between inverter and injection point, unavailability.
- EGrid: Energy injected into the grid.

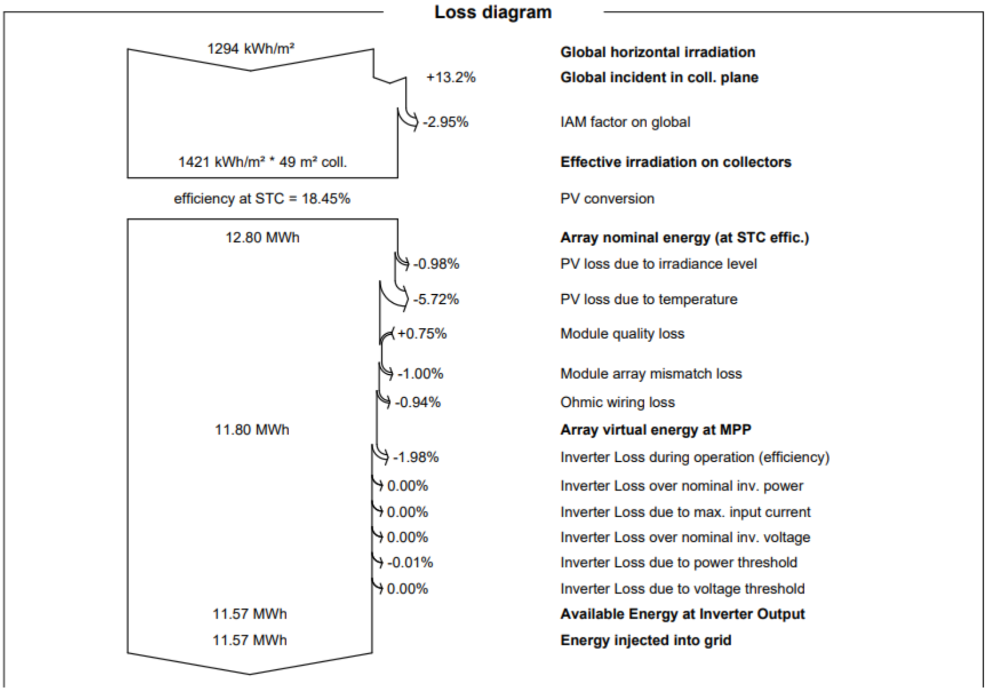


Figure 20: Loss diagram.

Note that there are different types of arrows on the diagram:

- The outward facing arrows represent losses of energy from the simulation. The size of the arrows is proportional to the loss amount of the system.
- The inward facing arrows represent energy gained of the system and the percentage are noted with a positive sign (+).

The report can be sent to a printer or copied to the clipboard. These options are accessible through the Print button 

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Here, you can select which part of the report should be printed or copied. You can also define comments that will show up in the header of the report. With the “Settings” button, you can customize even more details for the header comments and the clipboard copy resolution.

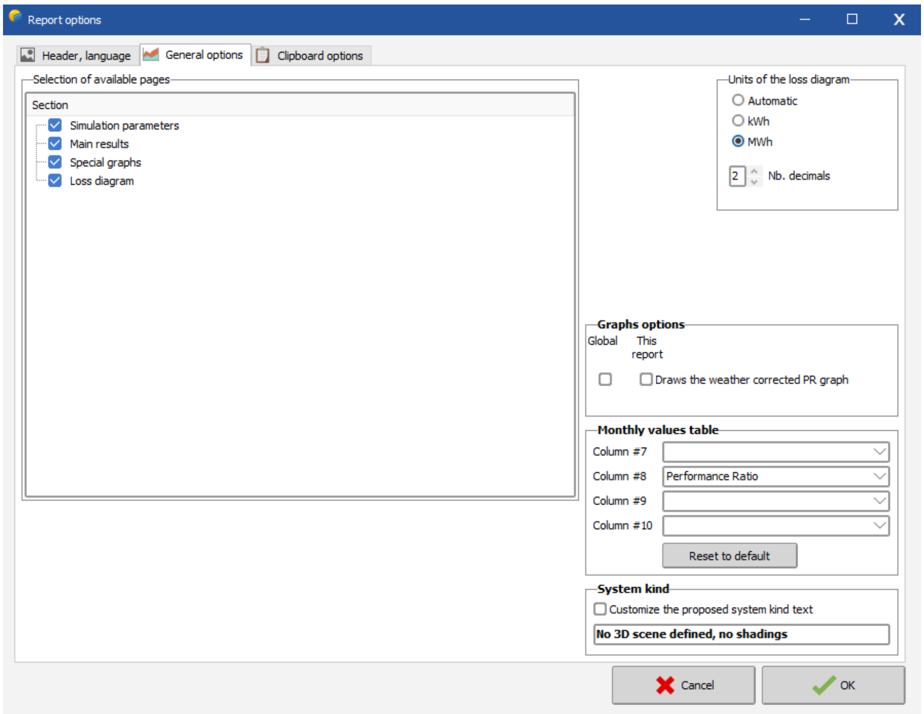

Figure 21: Report options.

Saving the simulation

Take the habit to "Save" your different variants for further comparisons. Choose a meaningful title to easily identify your variant in the future. This title will be mentioned on the report (it can also be defined in an earlier step, for example at the time of the simulation).

The first variant will be saved in the file "DEMO_Residential_Geneva_First Simulation.VC0". Later Variants will get the file endings VC1, VC2, etc. If you want to create a new Variant, make sure that you use "Save As" to avoid overwriting your previous variants. To open previous simulations of the project, you just have to select a variant in the drop-down list.

1.5 Adding further details to your variant

After this first "standard" simulation, you can progressively add more specific details to your project. You are advised to perform and save a new simulation for each step in order to check its effect and pertinence - especially to analyze the "Loss diagram".

1.5.1 Far shadings, Horizon profile

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

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

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

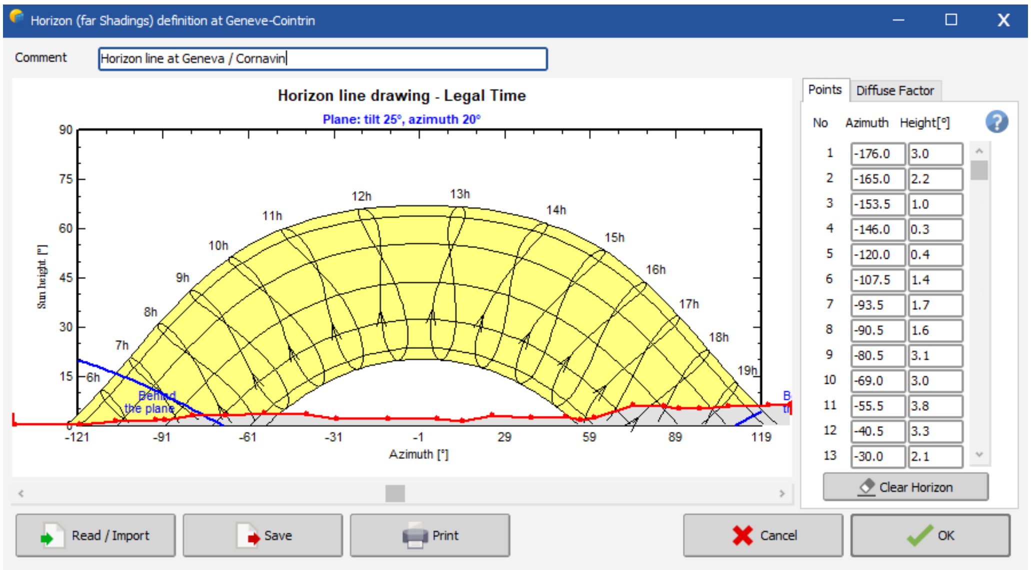

Figure 22: Horizon line drawing.

You can define the horizon line manually. For this, the values (Height, Azimuth set of points) have to be recorded on-site using a compass and a clinometer (measuring the height angles), a land surveyor or some specific instrument, photographs, etc. But you can also import a horizon line that has been generated with the “SunEye” device or some dedicated software as explained below.

Defining a horizon line by hand:

You can move any of the red points, by dragging it with the mouse or define accurately its values in the edit boxes on the right. To create a new point, right-click anywhere. To delete a point, right-click on the point. You can save this horizon as a file for further use in other PVsyst projects.

When you click on the “Read / Import” button 

, you will get the “Horizon profile reading / importation” dialog (Figure 23). You can either read a horizon line that you have previously saved in PVsyst, or you can import a predefined format from external sources.

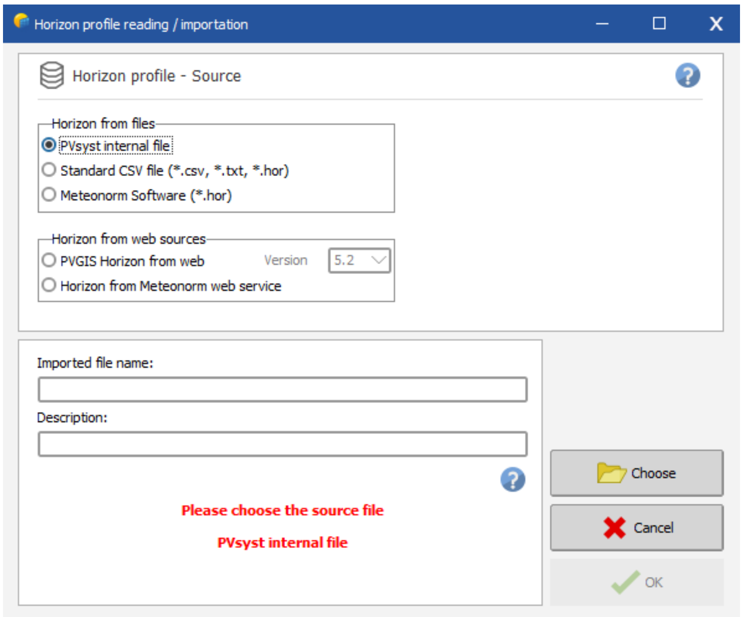

Figure 23: Horizon profile reading/importation dialog.

Importing Horizon from Solmetric "SunEye" instrument

The "SunEye" records the horizon line using a fisheye camera and provides the result in several files. You should choose the file called "ObstructionElevation.csv". Do not use the "Sky0x_PVsyst.hor" file! This is an obsolete format created by Solmetrics for the old versions 4.xx of PVsyst.

NB: If near objects are present on the pictures taken by the “SunEye”, you should remove them from the data by editing the horizon line after importing it.

Importing Horizon from the "Carnaval" software

"Carnaval" is a geo-referred free software (including altimetry data), that creates a horizon line starting from geographical coordinates - Latitude and Longitude – of a site. It works only for locations in France and its neighboring countries.

NB: You should not use the ‘near objects’ option in this software when creating the far shadings for PVsyst. Carnaval produces a file named “YourProject.masque.txt”. You will have to rename this file, removing the ".masque" characters, as PVsyst does not accept file names with 2 dots in them.

Importing Horizon from the “Horiz'ON" software

The "Camera Master" tool is a special support for photo cameras to take a series of pictures in precise horizontal rotation steps (every 20° in azimuth). The software "Horiz'ON" gathers these photographs in a single panorama picture on which you can draw the horizon line by using the mouse. The software will produce a file format of the horizon line that is directly readable in PVsyst.

NB: When you want to create a horizon line starting from a geographical location (like in Carnaval or Meteonorm), the exact coordinates of your PV system have to be carefully defined. You may determine them using GoogleEarth or with a GPS instrument. Keep in mind that a degree in latitude corresponds to

111 km, a minute to 1850 m and a second to 31 m. For the longitude, this is also valid for locations on the equator. These values decrease as you move away from the equator.

Using the horizon in the simulation

After defining a horizon line, the button in the project dashboard will turn from greyed-out to green. The shading of the horizon will be taken into account if we perform a simulation at this point. The report will

Horizon definition

Horizon from Carnaval, Lat=46.167°, Long=6.000°, Alt=431m

Average Height	3.2 °	Albedo Factor	0.88
Diffuse Factor	0.98	Albedo Fraction	100 %

Horizon profile

Azimuth [°]	-176	-165	-154	-146	-120	-108	-94	-91	-81	-69	-56	-41
Height [°]	3.0	2.2	1.0	0.3	0.4	1.4	1.7	1.6	3.1	3.0	3.8	3.3
Azimuth [°]	-30	-12	6	14	25	39	51	56	61	74	85	90
Height [°]	2.1	1.8	1.8	1.4	2.9	2.2	2.7	1.7	2.3	6.0	5.8	5.2
Azimuth [°]	98	108	122	133	143	150	160	171	179	180		
Height [°]	5.1	5.7	6.0	6.0	6.5	6.0	5.7	4.6	3.7	3.7		

Sun Paths (Height / Azimuth diagram)

Fixed plane, Tilts/azimuths: 25°/ 20°

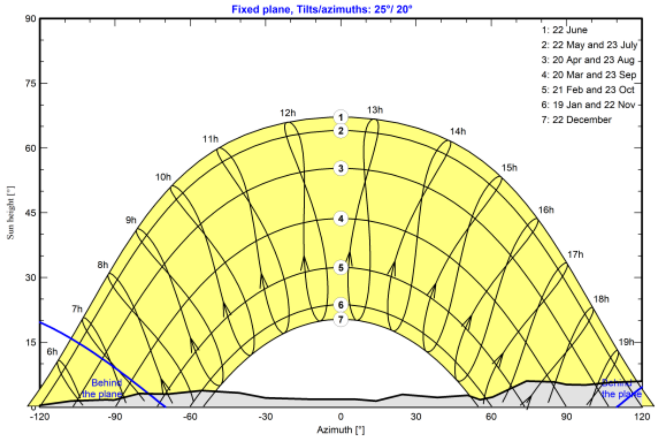

Figure 24: Horizon definition and sun graph.

now have an additional page. On the fourth page of the report, you will find the horizon definition and the sun graph that includes the far shading effect:

Also, the loss diagram on the last page of the report will now include the effect of the far shadings:

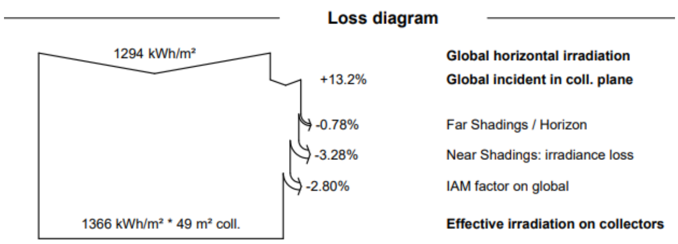

Figure 25: Far shadings effect on loss diagram.

1.5.2 Near shadings, 3D construction

The near shadings treatment (shading of near objects) requires a full 3D representation of the PV system. Details on the construction of the near shadings is described in the next chapter “3D Near Shadings Construction”.

1.5.3 Detailed losses

Finally, 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.

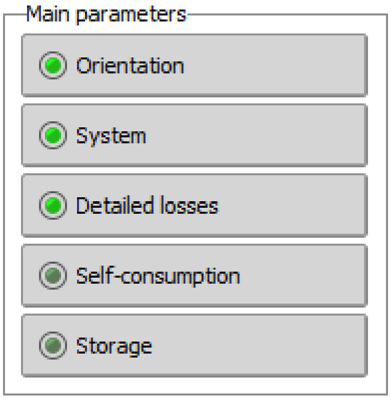

Figure 26: Main parameters for detailed loss.

The Dialog “PV field detailed losses parameter” will pop up. It contains the following nine tabs:

- Thermal Parameters.
- Ohmic Losses.
- Module Quality – LID – Mismatch.
- Soiling Loss.
- IAM Losses.
- Auxiliaries.
- Ageing.
- Unavailability.
- Spectral correction.

In what follows, we will go through all these tabs and give a brief explanation of the different parameters and options.

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" $U = U_c + U_v \cdot WindSpeed$ $[W/m^2 \cdot K]$. In practice, we advise not to use the wind dependency, as the wind speed is usually not well defined in the meteo data, and the parameter Uv is not well known. Therefore, we put $U_v = 0$ and include an average wind effect in the constant term.

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

- $U_c = 29\ W/m^2K$ for completely free air circulation around the collectors (free-standing collectors).
- $U_c = 20\ W/m^2K$ for semi-integrated modules with an air duct on the back.

- Uc = 15 W/m²K for integrated modules (back insulated), as only one surface participates to the convection/radiation cooling.

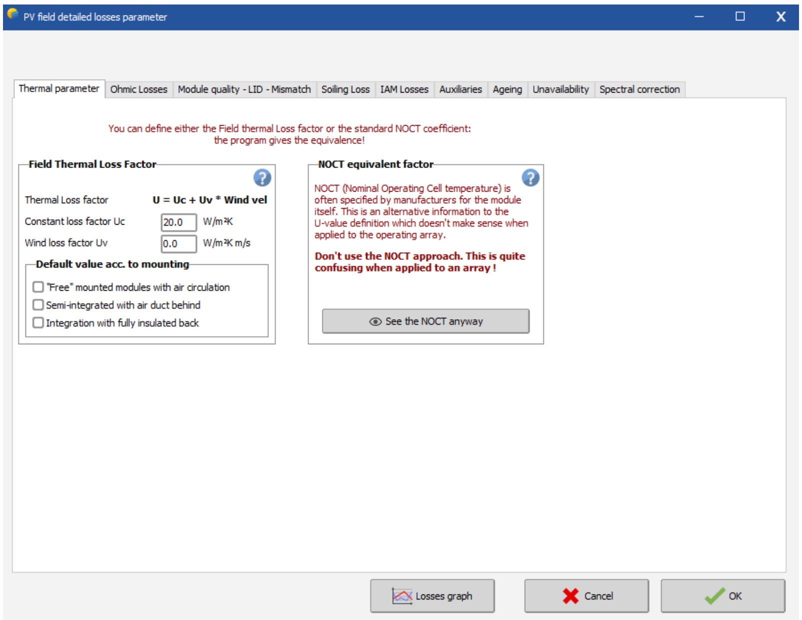

Figure 27: PV field detailed losses parameter dialog.

There are no well-established values for intermediate situations with back air circulation. Our measurement on quasi-horizontal modules on a steel roof, 8 cm spacing and not joint collectors, gave 18 W/m²K.

NB: up to PVsyst version 5.1, the default value for Uc was 29 W/m² (free standing). From version 6 onwards the default is set to 20 W/m² since nowadays, more and more installations are being built in an integrated way.

The thermal loss effect will show up on the array loss diagram in the final report.

The 'Standard NOCT factor' (Nominal Operating Cell Temperature) is the temperature that the module

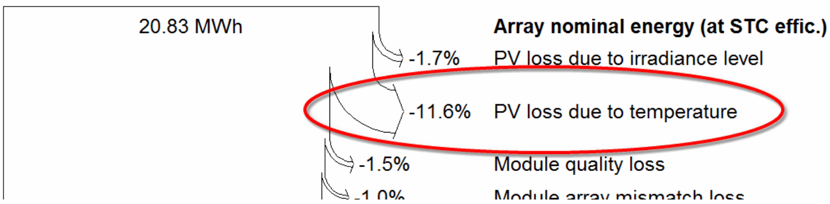

Figure 28: Thermal loss effect in the loss diagram.

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.

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.

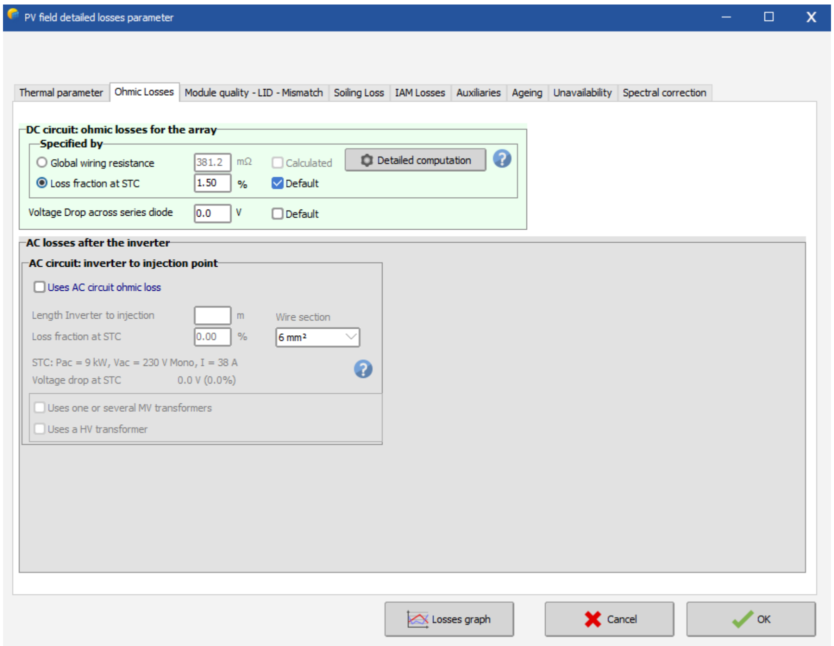

Figure 29: Ohmic loss parameter.

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 (click on the "Detailed Calculation" button). This tool asks for the average length of wires for the string loops and between the intermediate junction boxes and the inverter and helps the determination of the wire sections.

NB: remember that the wiring loss behaves as the square of the current. Therefore, operating at half power (500 W/m²) 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.

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.

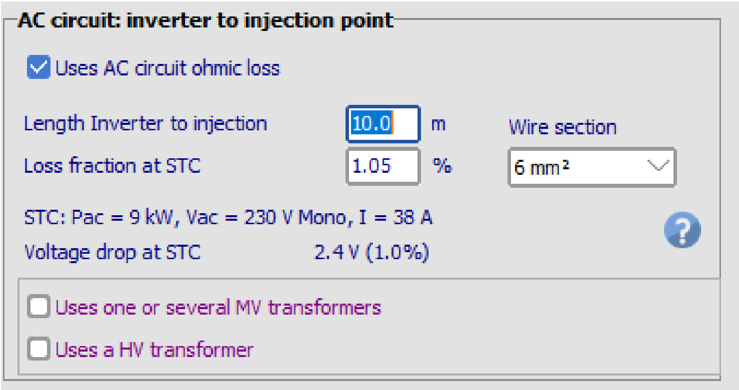

Figure 30: Losses between output of the inverter and the injection point.

In addition, there is an option to include the losses due to an external transformer. If you select this option, you will get two radio buttons in the "AC circuit" frame, where you select if the AC losses to be accounted for are between the inverter and the transformer, or between the transformer and the injection point.

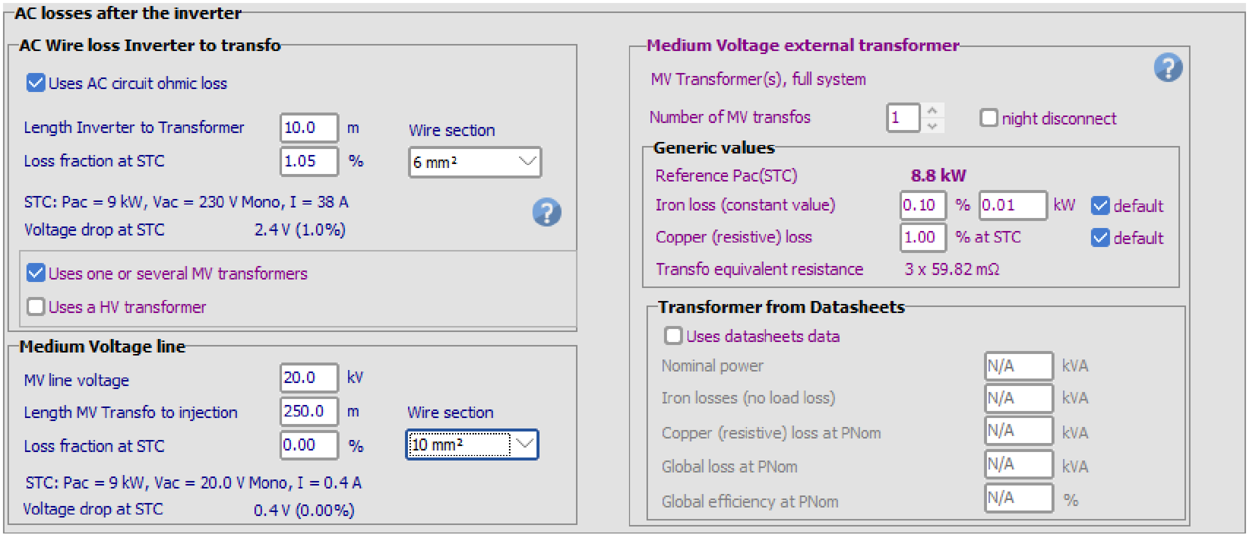

Figure 31:Losses due to external transformer.

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. The default PVsyst value is half the lower tolerance of the modules.

The value that is specified in this field might not be exactly the same as the one shown in the "Array loss

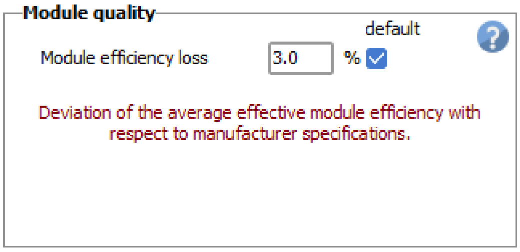

Figure 32: Module efficiency loss.

diagram". The reason for this is that this parameter is defined with respect to the Standard Test Conditions (STC) while the value in the diagram is given with respect to the previous energy.

LID – Light Induced Degradation

The light induced degradation happens in the first few hours of module operation. Typical values are around 2%, but you can define a different value in this field.

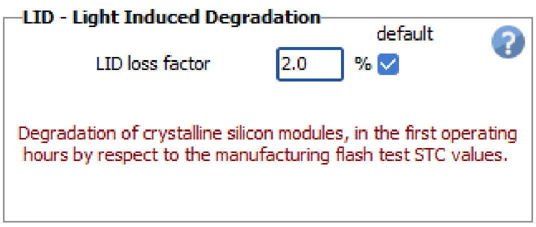

Figure 33: Light Induced Degradation.

Mismatch loss

Losses due to "mismatch" are related to the fact that the modules in an array do not have exactly the same I/V characteristics. In a string of PV modules, the worst module drives the string's current.

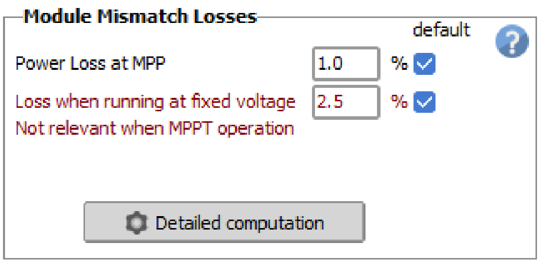

Figure 34: Module mismatch loss.

The "Detailed computation" button helps to understand this phenomenon and gives indications on the loss parameter to be set for the simulation, according to your estimation of the inhomogeneity of the set of modules.

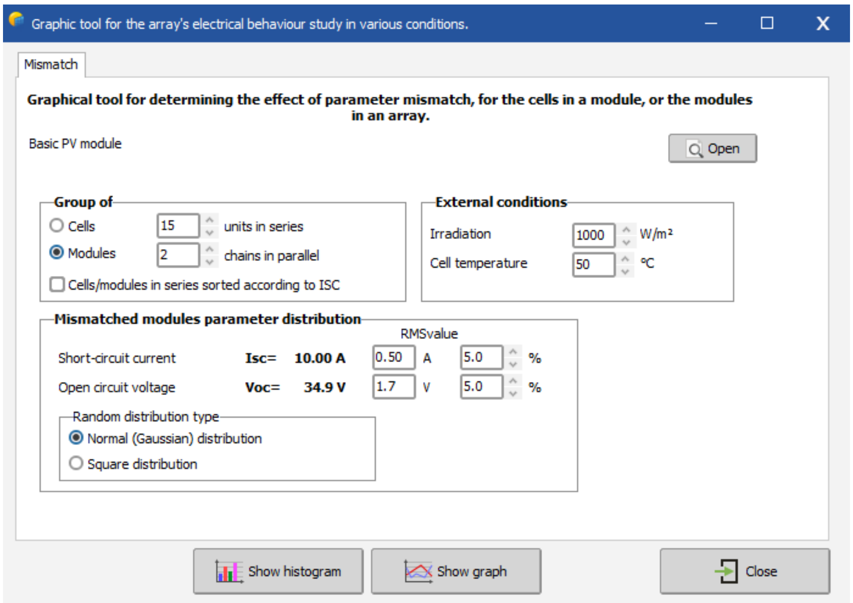

Figure 35: Detailed computation of mismatch loss.

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).

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

Soiling loss

According to our experience, the soiling effect is almost negligible in temperate-climate residential situations.

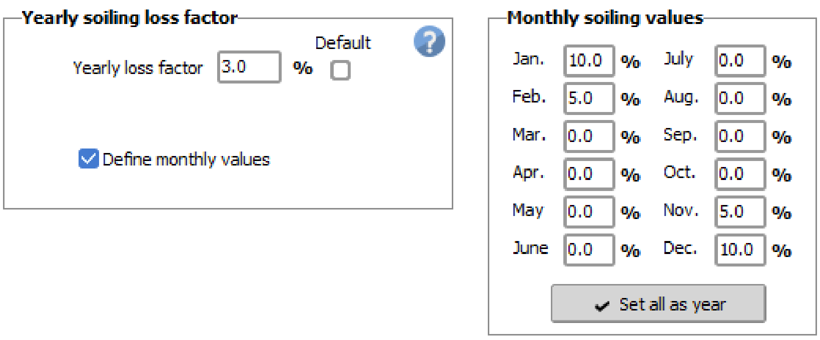

Figure 36: Soiling loss.

It may become significant in some industrial environments (for example near railway lines), or in desert climates. The soiling loss can be defined individually for each month to consider periodical cleaning or rainy periods.

This parameter may also be used for describing the effect of snow covering the panels (for example put 50% in winter months with 15 days of snow coverage).

Auxiliaries

The auxiliary consumption is the energy used to manage the system. This may be fans, air conditioning, electronic devices, lights, or any other energy consumption which must be deducted from the generated PV energy that is injected into the grid.

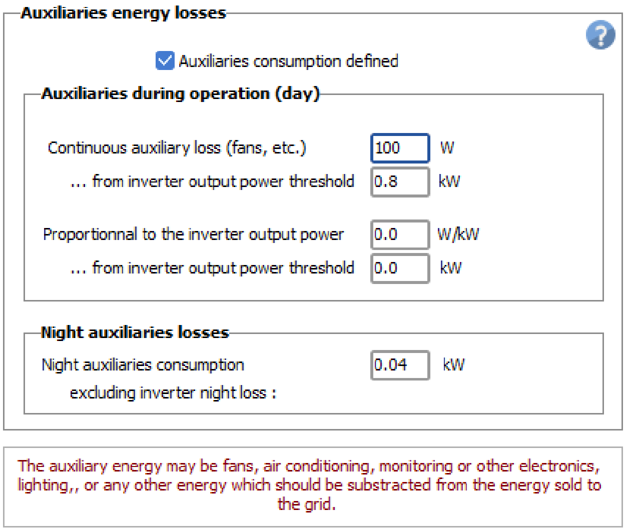

Figure 37: Auxiliary energy loss.

Aging

People often use the Manufacturer's warranty as loss reference when designing PV systems, which is usually a loss of efficiency of around 20% after 25 years. However, the Manufacturer's warranty should be understood as a lower limit for any individual PV module.

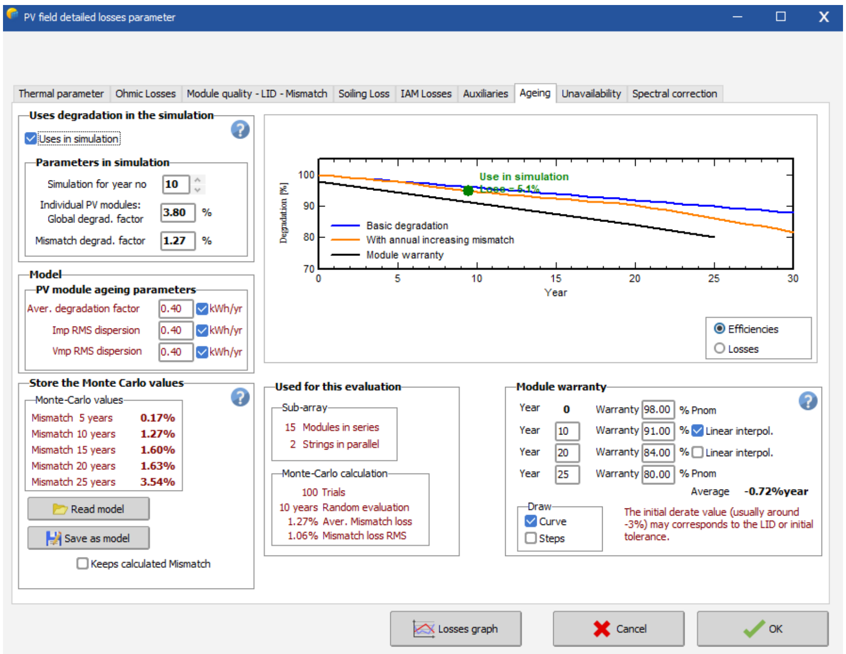

Figure 38: Aging loss.

In this tool, we define an average degradation rate (for a set of modules). This loss value may be much lower than this degradation 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 80-90´s, with old technologies). Long-term degradation rate measurements are relatively scarce.

Unavailability of the System

It is sometimes useful to foresee 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

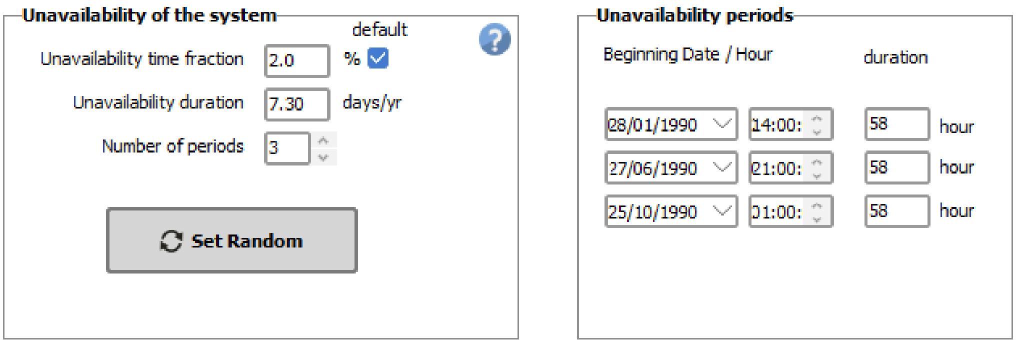

Figure 39: System unavailability.

Spectral correction

The spectral correction takes into account the changes in the solar spectrum due to scattering and absorption in the atmosphere. These changes depend on the water content in the atmosphere, the aerosols and the traveling distance of the light, expressed in Air Mass (AM). There are several models implemented in PVsyst to describe the spectral correction:

1. The CREST model that is used for amorphous silicon modules. This correction is applied automatically.
2. The spectral correction for PV modules in the Sandia database. This correction is applied automatically.
3. The FirstSolar spectral correction model that is disabled by default, and can be turned on by the user.

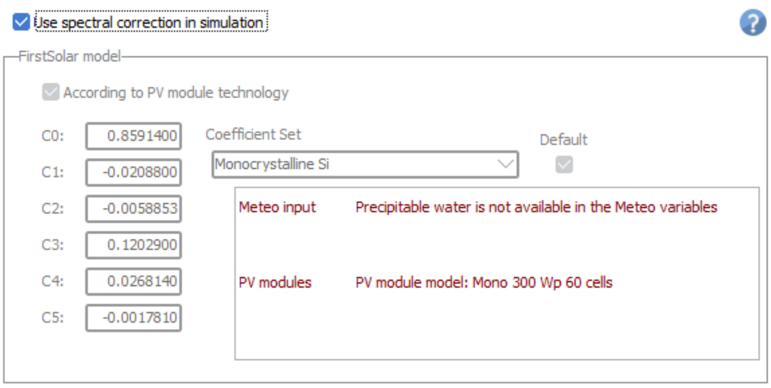

Figure 40: Spectral correction.

Losses graph

To visualize the impact that the losses have on the I/V-behavior of the array, you click on "Losses Graph" to get to the window "PV Array behavior for each loss effect".

In the top right field, you can define the running conditions of the array.

From the field below, you select the kind of loss you want to display.

The red curve gives the nominal conditions that represent the upper limit of the system performance. For each selected loss you will get a curve in a different color.

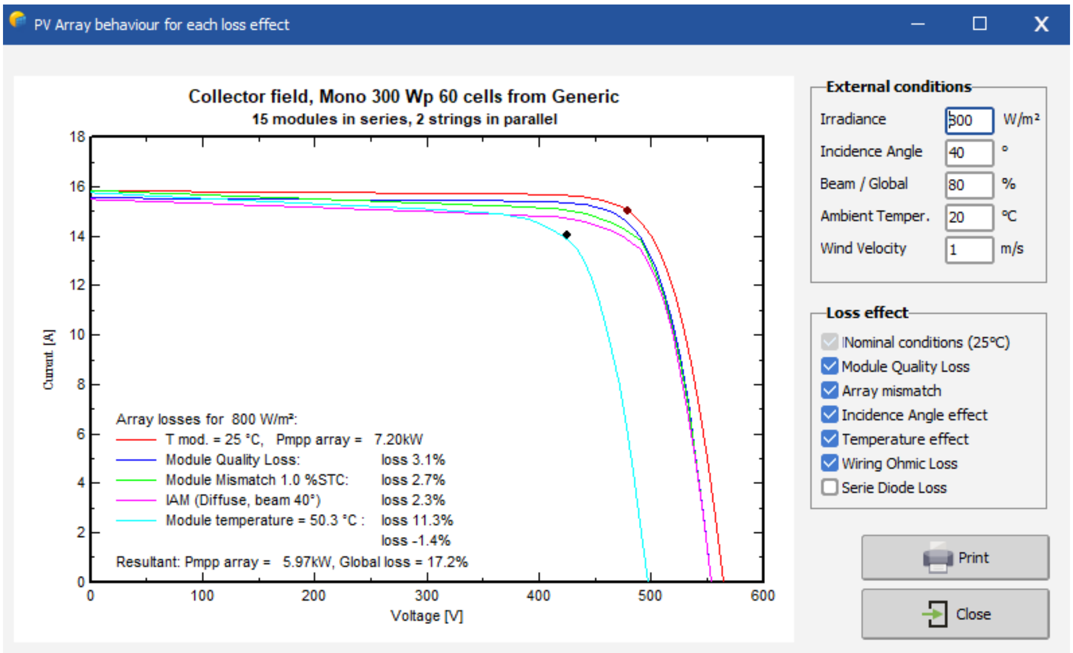

Figure 41: Losses graph.

1.5.4 Loss diagram examples

After running the simulation with different variants, it is possible to compare the results between different variants directly from the report. The differences between the reports are highlighted to give a direct overview of the differences. Figure 42 illustrates the loss diagram comparison between two different variants. The left diagram is the results with the horizon and linear shadings whereas the right diagram is the one of the first simulation without further details in the variant. Note that the report for the horizon and linear shadings now has 8 pages instead of 6. The additional pages include information on the horizon definition with the sun path diagram, which is now in page 4, and the near shadings parameter with its associated iso-shading diagram, which is now included in page 5.

Now, referring to the loss diagram in Figure 42, the differences between the losses are highlighted and can be spotted immediately. On the left, the loss diagram for the variant with horizon and linear shadings, the far shadings and near shadings losses are now incorporated and we observe changes on the effective irradiation on collectors and other energy that follows.

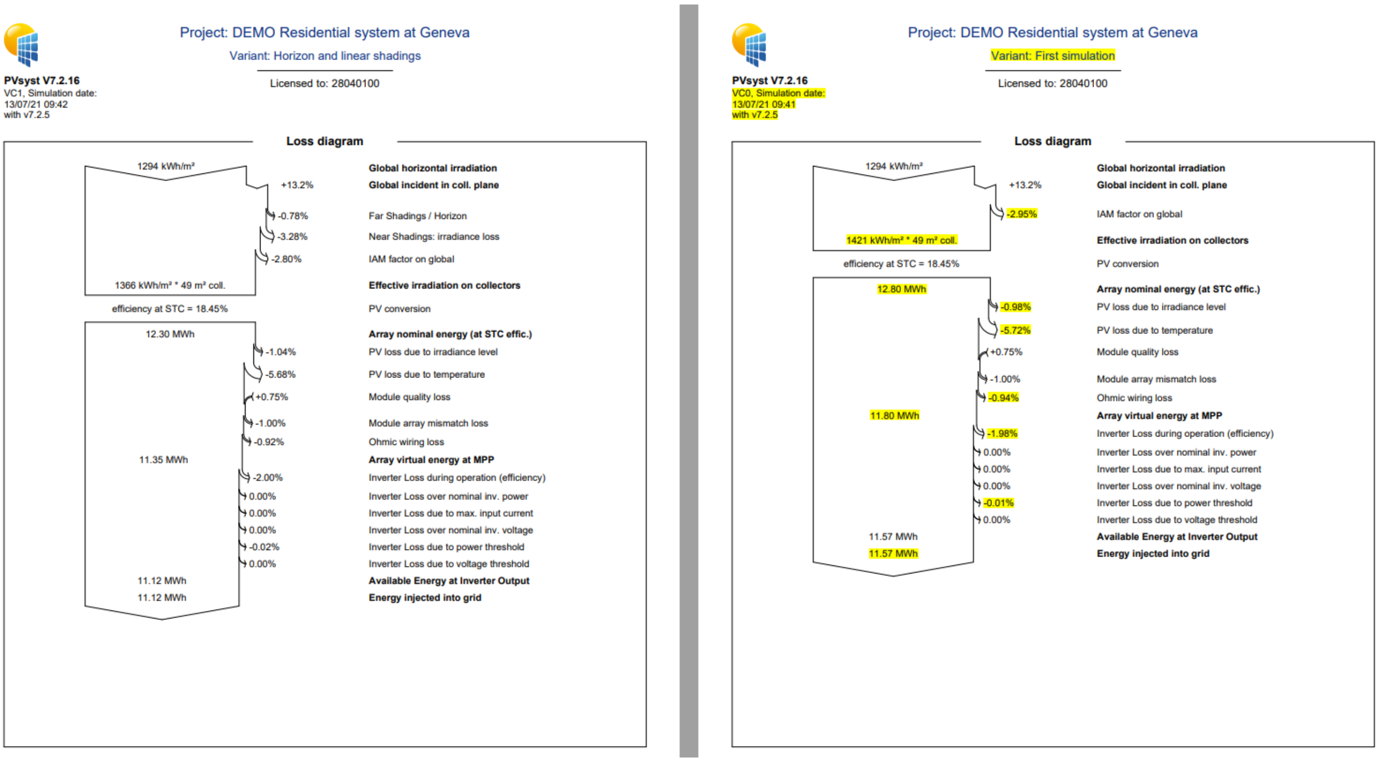

Figure 42: Loss diagram comparison between two different variants.

We illustrate some other eventual examples of losses.

<u>Example 1</u>:

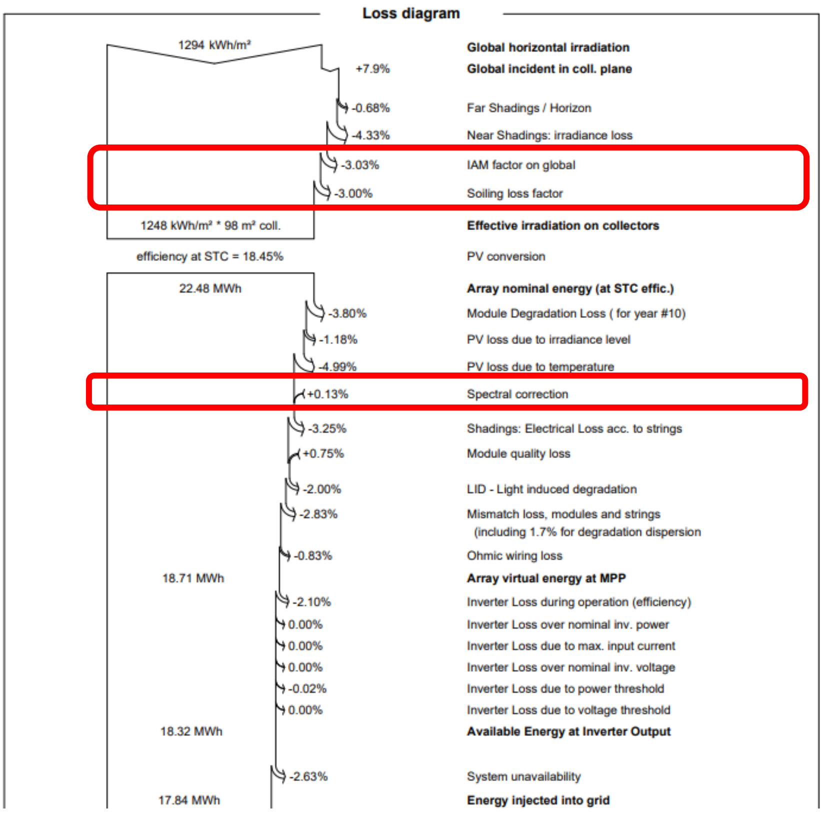

Figure 43: Loss diagram example 1.

In this example, we see a 3% loss in soiling factor. This is due to accumulation of dirt on the system that further affects the performance. The definition of soiling loss factors can be defined in PVsyst in monthly values.

We also observe a +0.13% of gain from spectral correction. The spectral correction considers the changes in the solar spectrum due to scattering and absorption in the atmosphere where a set of coefficients is defined by default when the spectral correction is enabled for a simulation.

Example 2:

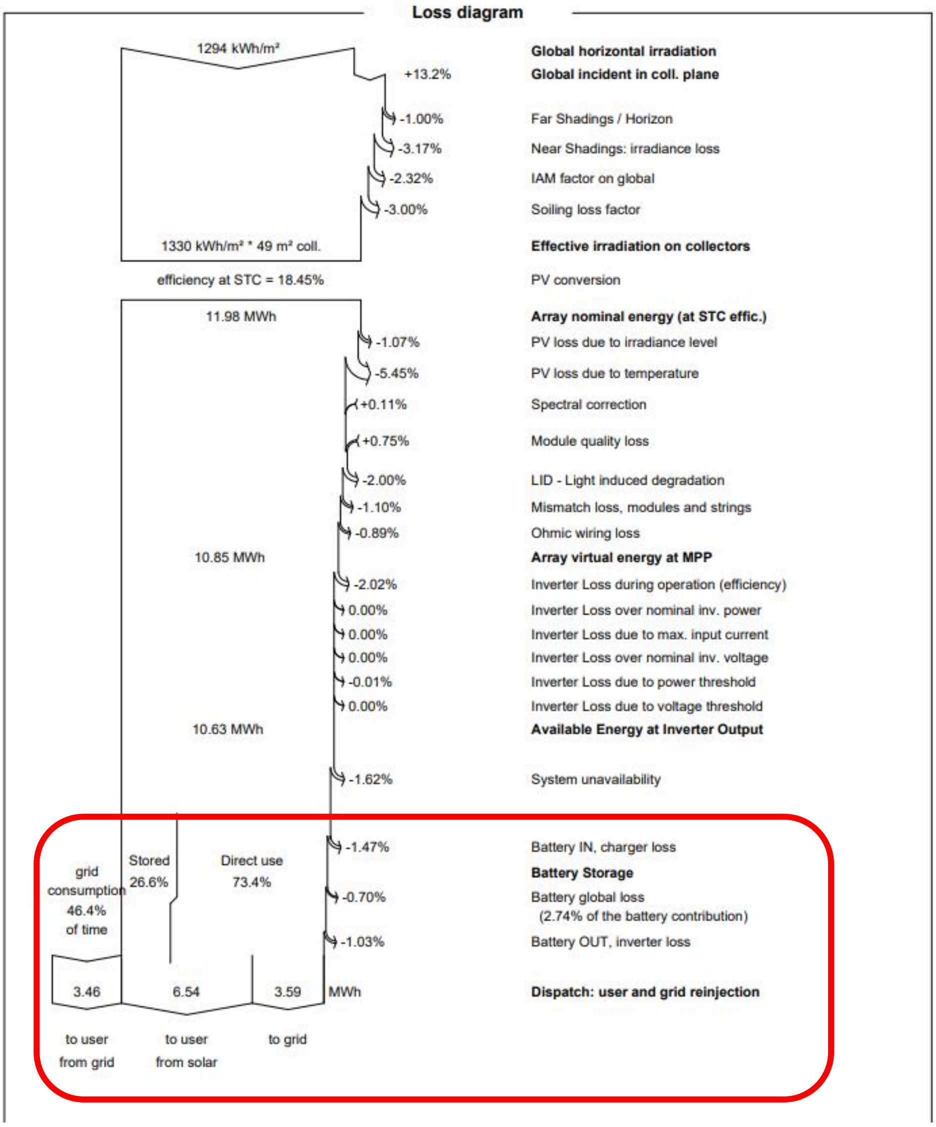

Figure 44: Loss diagram example 2.

In this second example, another branch of energy flux balance appears in the loss diagram, representing the loss in the self-consumption with storage strategy. This strategy consumes its own energy produced by the PV and draws minimum energy from the grid. The diagram gives information on the battery's lifetime and the cost of the stored energy that will be highly dependent on the sizing of the system.

1.6 Conclusion

In this document, we demonstrated the basic approach to run a first simulation project on PVsyst using an example, starting from the project specifications, saving the project, executing and analyzing the results on the report and adding further details to the project variant.

The next chapter demonstrates the basics of near shading construction for grid-connected systems.