PVSYST
PHOTOVOLTAIC SOFTWARE

Version 8

Stand Alone
My first project

PVsyst SA
www.pvsyst.com

Contents

1 Definition of a Stand alone system

A stand-alone system in PVsyst will be centered around battery storage. A solar array either charges the battery or provides energy directly to the user. As a result, it's important to have a clear understanding of the user's daily consumption pattern, ideally broken down into hourly values.

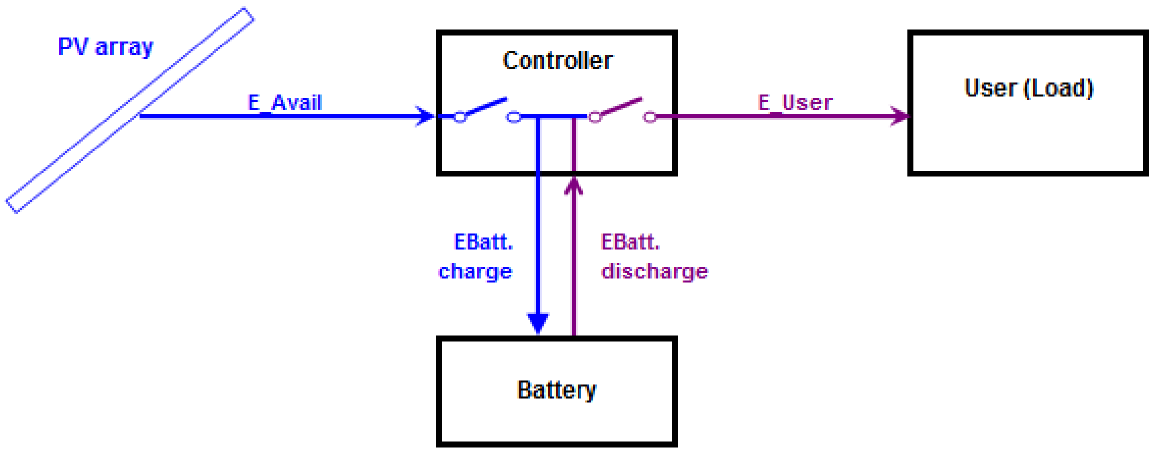
The simulation is done hourly and performs a balance between the PV production and the user's needs. The difference should be derived in the battery, either positively (charge) or negatively (discharge). This energy balance is controlled by a controller. The role of the controller is to handle the energy flow, mainly for the protection of the battery:

- When the battery is full, the PV array should be disconnected.
- When the battery is empty, the user should be disconnected.

Moreover, the controller may manage the starting of an eventual back-up generator (Genset), when the battery is empty, and the solar gain is not sufficient.

In any case, the reconnection will be performed with a specific hysteresis, depending on the state of charge (SOC) of the battery.

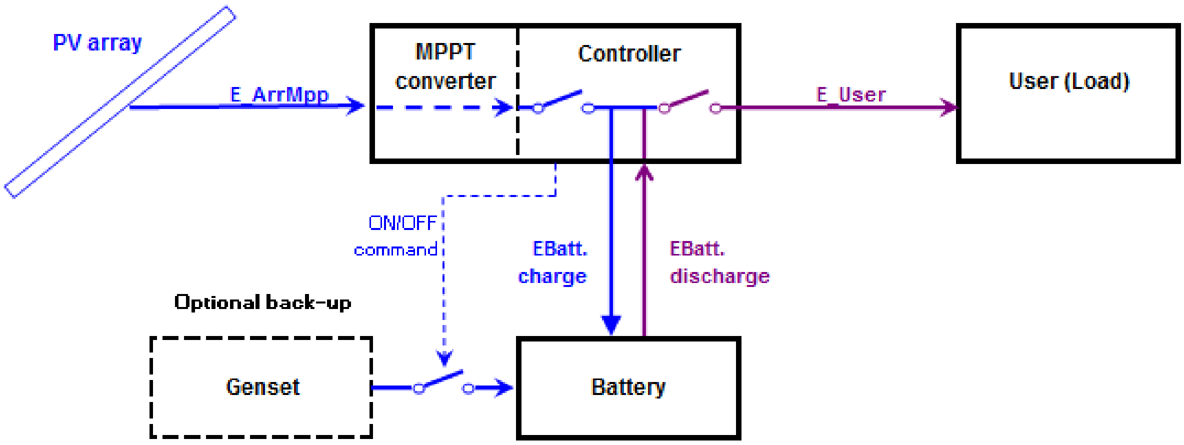
1.1 Small stand-alone systems (SHS: Solar Home Systems)



This concerns small systems (50 to 200 Wp) with a very limited consumption (some lights, radio-TV, computer, no fridge). With these simple systems, the PV array (one or few modules) is usually connected directly to the battery, without power conditioning. This implies that the PV modules should be "12V" or "24V" modules, i.e., with 36 or 72 cells.

This type of installation is managed by simple controllers, acting either by disconnecting the battery, or short-circuiting the PV modules when the battery is full. These controllers have always the ability to control the load when the battery is empty.

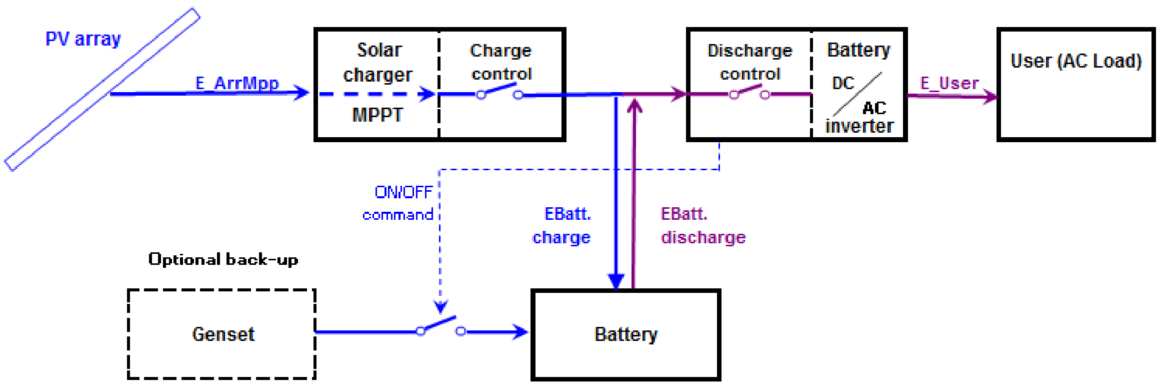
1.2 Medium power systems (small household, communications)



These systems usually ranged between 200 Wp and 2 kWp. The controller includes a power conditioning unit that can perform the maximum Power Tracking on the PV array. Therefore, the PV array voltage is no longer related to the Battery pack voltage. Most of the time, the controller is also able to ensure the load control, with a limited current capability (usually of the order of the charging current).

These installations may power lighting, fridges, washing machines, dishwashers, small electro-tools, etc. These may also be used in some small remote communication stations. The energy may be used as DC energy or fed as AC energy through an inverter ("Battery inverter"). Currently, PVsyst does not implement the inverter. The Load is specified as energy, whichever way it will be used. Such systems may - rarely - be supported by a back-up generator in case of lack of energy. If automatic, the Genset start/stop command should be managed by the controller.

1.3 High power systems



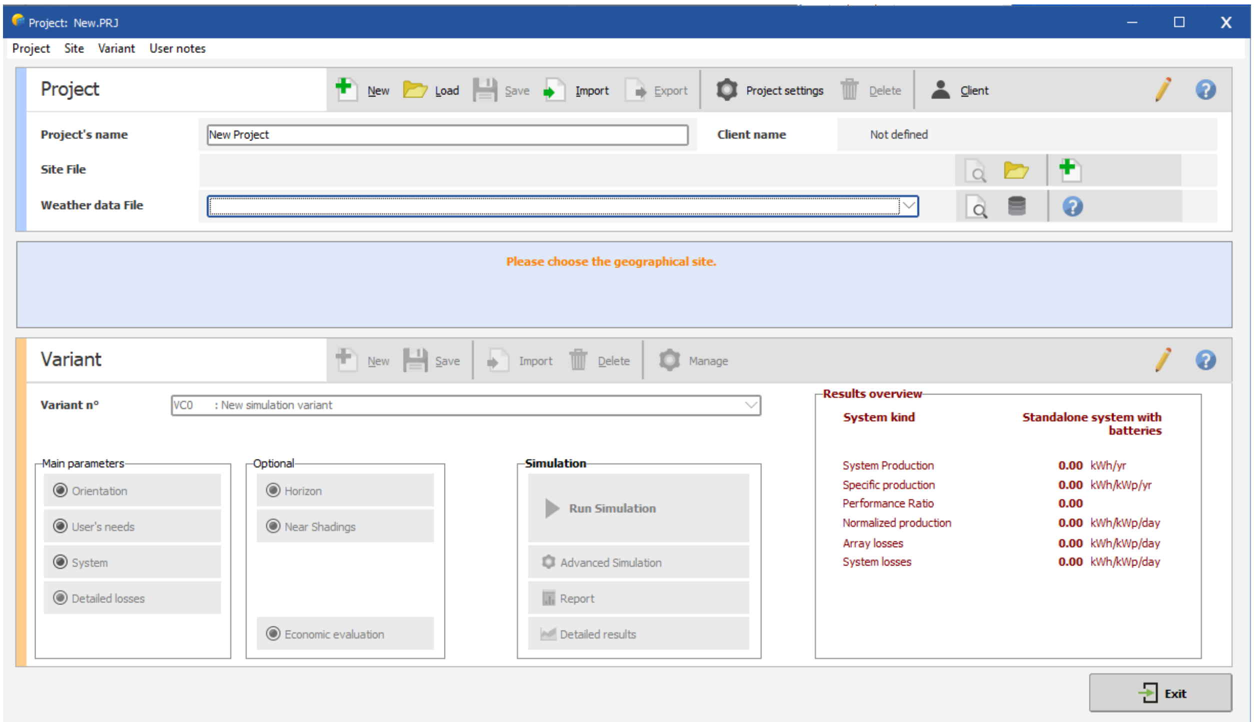
These may be stand-alone systems of 2 kWp to several dozens of kWp. Such installations use one (or several) “Solar chargers", equipped with MPPT converters, and DC/AC battery inverters.

The controller is not a single device anymore: the charging control is ensured by the Solar charger (sometimes several in parallel) and the discharge control by the inverter. The inverter should also manage the back-up generator if any.

In PVsyst, we consider the Solar Charger as the "Controller for Stand Alone" component. For historical reasons (and simplification), this PVsyst component has also to control the discharge and the back-up generator. But as the parameters for these functions are not defined within the "Solar charger" physical devices (data sheets), the internal parameters for these controls (maximum current, thresholds, etc) will remain in the dialog of this component, but their values will be defined within the system. Their initial values will be adapted from the system configuration and will be modifiable according to the real Inverter used, or other control device.

2 My first Stand alone project

Similarly to any PVsyst project, your work will be based on a Projects file containing geographical site of your system, the reference to a file with the meteorological data and some general parameters like the albedo definition and parameters specific to this project. The project will be the central object that allows the basic definitions in which you then will construct different variants of your system. The Project settings, site definition and weather data import are further described in the Users Manual for a Grid Connected system.

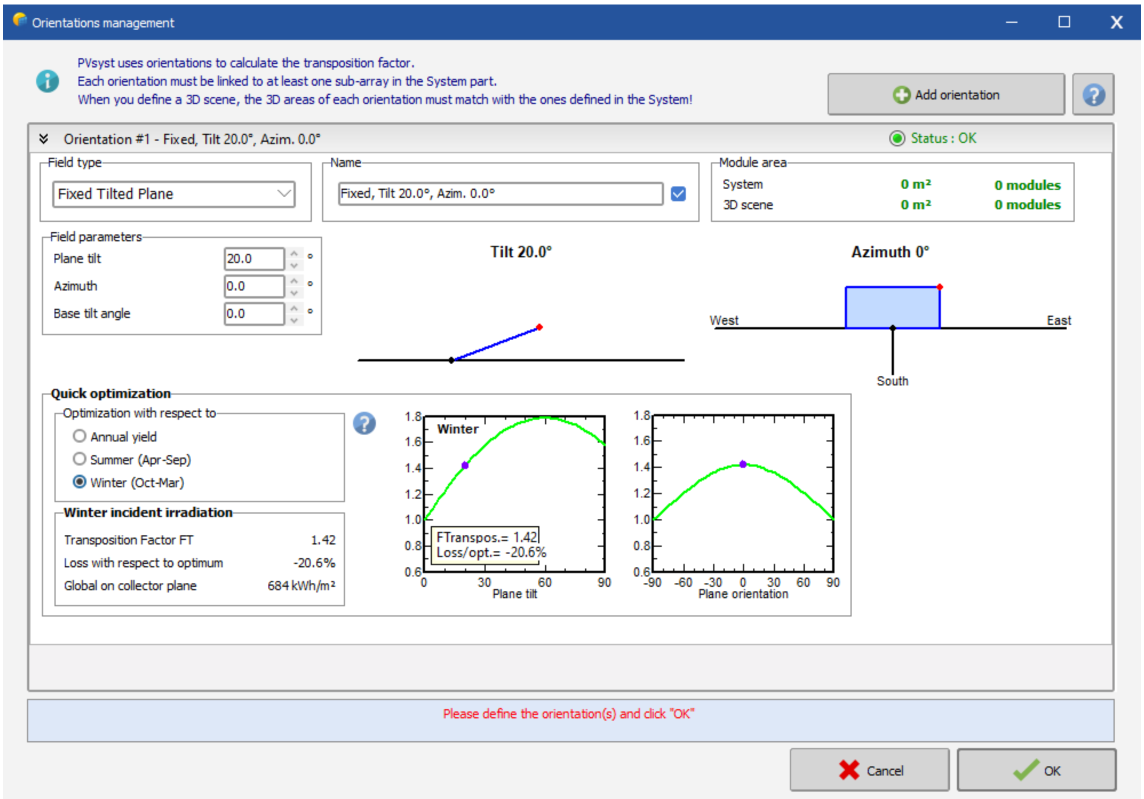


The system variant contains all the detailed definitions of your system, which will result in a simulation calculation. These definitions include the choice and number of solar panels, the users need, geometrical layout and possible shadings, electrical connections, different economic scenarios, etc.

3 Orientation

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

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

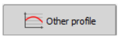


The field types have in common that you must define the *plane tilt* and *azimuth*. In general, the plane tilt is defined as the angle between the collector plane and the horizontal. The plane azimuth is the angle between the collector plane and the direction toward the equator. In the northern hemisphere,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

A fixed tilted plane is the simplest kind of orientation, it defines the plane tilt and the plane azimuth. 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. The Transposition Factor is the ratio of the incident irradiation on the plane to the horizontal irradiation, i.e., what you gain (or lose) when tilting the collector plane compared to the horizontal plane.

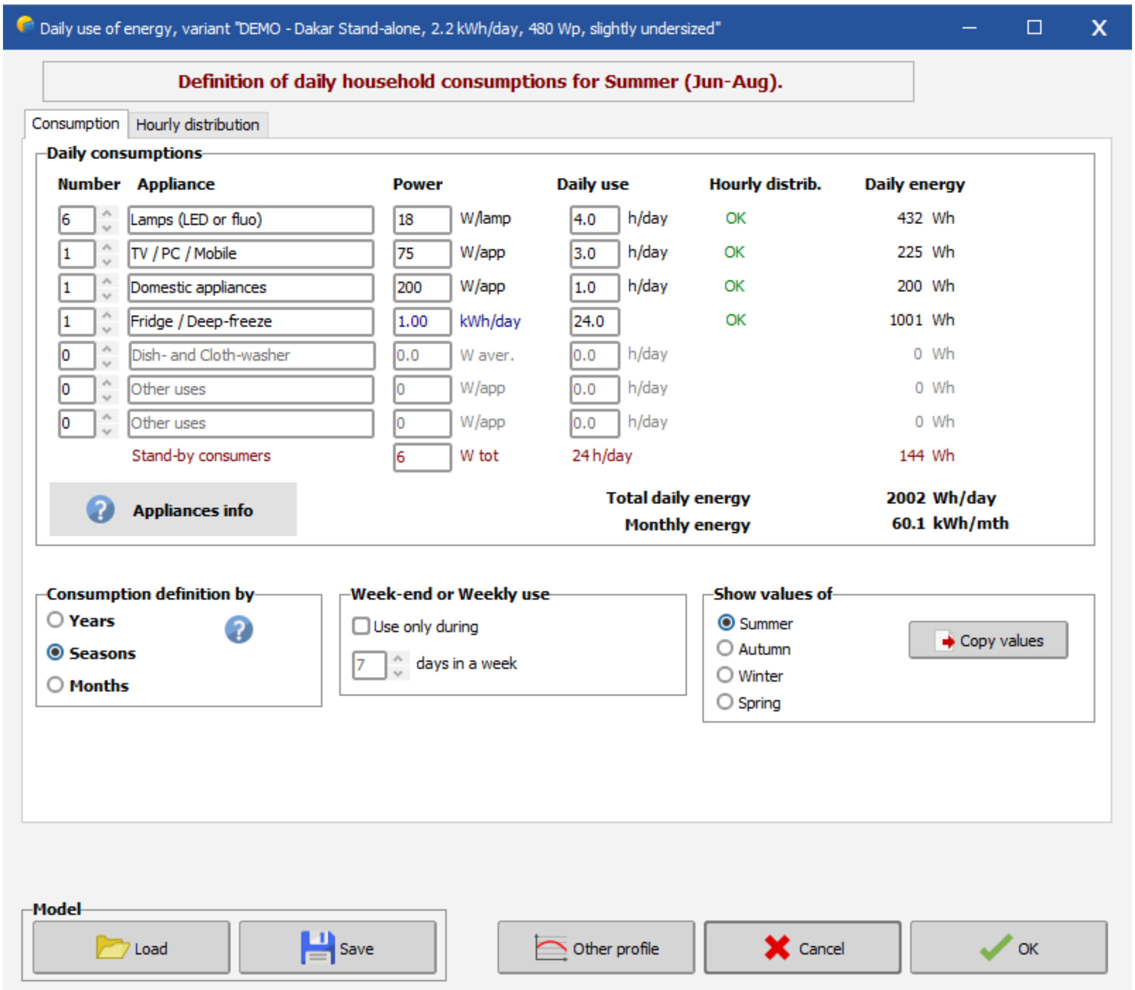
Each field type are further described in the Users Manual for a Grid Connected system.

4 User’s needs

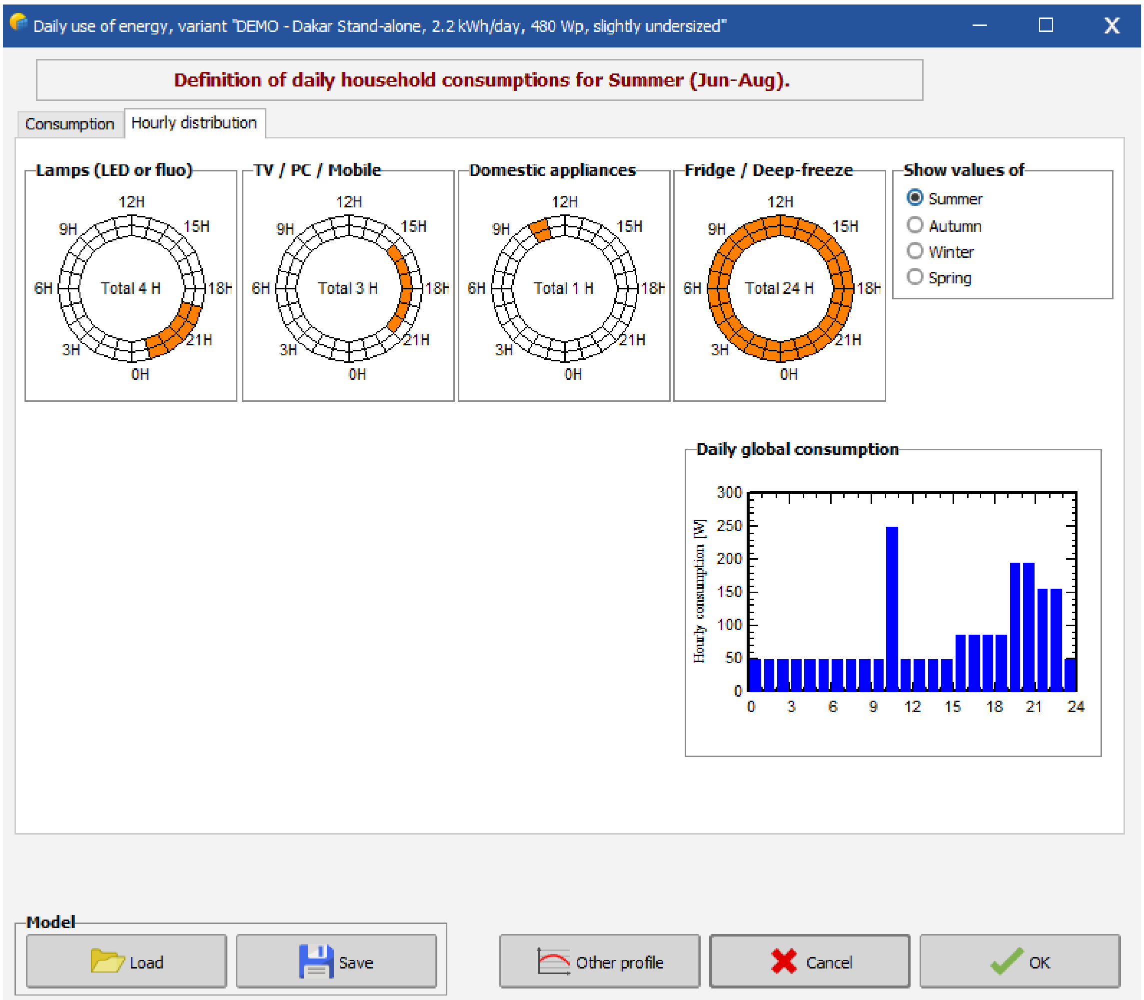
The User's needs menu offers great flexibility in defining the user's requirements. Daily Household Consumers is the default option for defining the user's energy needs in stand-alone systems. It is specifically designed to represent typical residential energy consumption by listing the most commonly used domestic appliances. Other Kinds of load profiles are available by clicking 

4.1 Daily Household Consumers

Each appliance comes with its unit power, which is the amount of power it consumes when in use, and its daily use duration, which refers to how long each appliance is used on an average day. The Hourly Distribution involves detailing how the daily energy consumption is spread out over the hours of the day. By providing these details, the system can accurately calculate and simulate your energy needs, helping to ensure that your system is properly sized and performs optimally.



In the Hourly distribution tab, each chart is made up of 48 sections and each section represents 30 min of the day. Left-click to define a schedule or a time range, and right-click to delete a schedule or a time range.



The system allows for flexible configurations of energy use, depending on how the household's energy consumption varies throughout the year. There are three main ways to define the load values for these appliances:

- **Constant over the year**: This option assumes that the daily energy consumption remains the same throughout the entire year, meaning there is no variation in the load profile from one season to the next. The same daily load value is applied consistently, making it ideal for homes with steady energy needs.
- **Seasonal modulation**: In this setting, the energy consumption is adjusted according to the seasons. You can define specific daily loads for each season (e.g., winter, summer), recognizing that appliance use may change during different times of the year, such as higher heating in the winter or more air conditioning in the summer.
- **Monthly definitions**: This option offers an even more granular approach, allowing users to define a specific distribution of appliance use for each month. This means you can adjust the energy consumption profile based on month-to-month variations in appliance use, accommodating more detailed seasonal changes or specific usage patterns during different parts of the year.

4.2 Fixed Constant Consumption

This method involves setting a constant power or yearly energy need.

4.3 Monthly Values

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

4.4 Daily Profiles

Daily profiles allow users to 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."

4.5 Probability Profiles

This method is used to describe how often different levels of energy consumption occur, especially in cases where the grid load is not unlimited. It involves creating probability distributions for various consumption levels.

4.6 Load Values from a CSV Hourly/Daily File

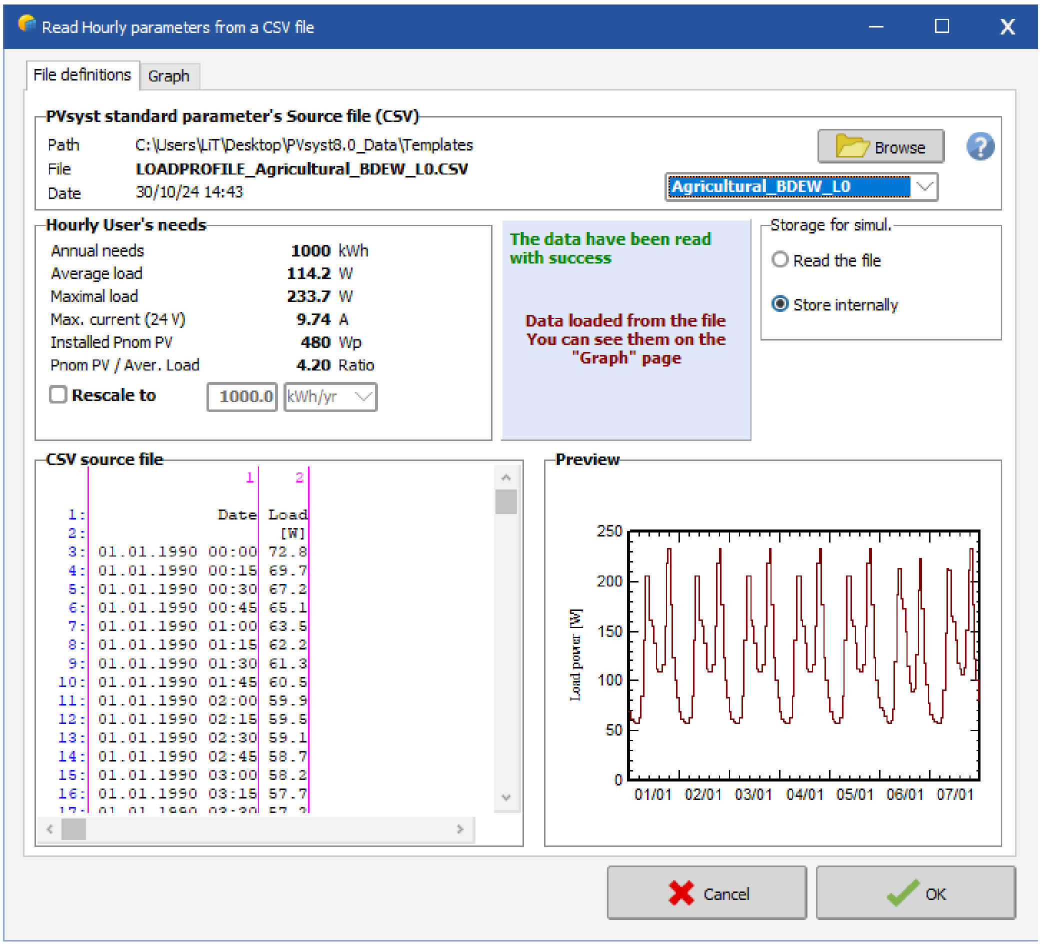
The most flexible way to define a custom load profile is to import an hourly file in CSV format. You can select a template from a predefined list, which can be rescaled to match your specific consumption needs or upload your own profile, following the required format.

- 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.

If the load profile file contains sub-hourly data (for example, values every 15 minutes), these will automatically be converted to hourly values upon import.

- Power units ([W], [kW], etc.) will be averaged over the hour.
- Energy units ([Wh], [kWh], etc.) will be summed over the hour.

Once the file is successfully imported, its raw content will be displayed in the bottom left corner of the window. Below the file name, you will see several summary values, such as average load, maximum load, and total annual consumption. You can resize the annual consumption to adapt it to a measured or expected consumption. In the Graph tab, you can visualize the imported profile as an hourly time series or as integrated daily or monthly values. A preview of this graph is also available in the first tab.



In the dialog box, you can specify how the values from the file will be used in the simulation:

- Store Internally (default option): The imported values, including any that have been resized, are stored in the variant. These values will be used in subsequent simulations, even if the original file changes (unless you re-import the data).
- Read the File at Each Simulation: PVsyst copies the file to the UserHourlyParams folder and reads it each time a simulation is launched. This allows for resizing to be applied if necessary. This mode is particularly useful when modifying the load profile in batch mode.

5 System

In the early stages of studying a stand-alone system, it is essential to focus on the overall system sizing. This involves determining the capacity of the battery pack and the power of the photovoltaic (PV) array based on the user's energy needs and the meteorological conditions.

In the System window, you need to configure the following:

- **Battery pack characteristics**: Define the capacity and specifications of the battery pack based on your energy needs.
- **Photovoltaic field specifications**: Set the parameters related to the solar modules (number of panels, power, orientation, etc.).

- **Charge and discharge controller settings**: Adjust the settings of the controller that manages the charging and discharging of the batteries for efficient energy management.

You can add optional generator system via the “back-up tab.

To the left in the window, you see the list of sub-array and in the top of the window with a pink background color you find the Pre-sizing. To define the suggested battery capacity and PV power, you need to define the desired PLOL (Probability of Loss of Load), the requested autonomy and the battery (user) voltage. PVsyst will then suggest a battery capacity and PV power.

The **PLOL** is expressed as a percentage and represents the probability that your energy needs cannot be met. It indicates how often the battery may be disconnected due to low charge levels. The PLOL can be considered the complement of the "Solar Fraction," which reflects the percentage of load satisfied by solar energy. However, PLOL is expressed in terms of time rather than energy. During the sizing process, PLOL helps determine the necessary size of the PV array in relation to the battery capacity.

The tool performs a simplified annual simulation, creating a realistic sequence of 365 days based on monthly weather data (using the Collares-Pereira model). Each day is divided into three periods: morning, day (with solar gains), and evening. The program balances the energy used day by day, allowing for a realistic annual LOL value. Different sizes of the PV array are tested to find the exact configuration that meets the required PLOL.

The **requested autonomy** refers to the number of days the system can operate solely on battery energy, without any solar input, starting from a fully charged battery state.

Autonomy is crucial for assessing the system's ability to manage variable energy demands, taking into account seasonal and monthly fluctuations in usage.

The calculation considers the minimum state of charge (SOC) disconnect threshold and the energy efficiency of the battery. It applies a capacity correction since the mode of use often involves slow discharge rates, corresponding to C100 capacity (discharge over about 100 hours). In contrast, the nominal capacity of batteries in the PVsyst database is defined as C10 (discharge over 10 hours), resulting in a C100/C10 ratio typically ranging from 120% to 130%.

In a stand-alone photovoltaic system directly coupled to the user (without inverter), the **battery voltage** determines the distribution voltage. Currently, many direct current (DC) appliances are available in both 12V and 24V. The choice of voltage should be made based on the power of the system and/or appliances, as well as the planned extension of the distribution network to minimize ohmic losses in the wiring.

It is crucial to make this choice during the early planning stage of an installation, as the voltage of existing appliances usually cannot be changed. Voltage converters can be expensive and are not always 100% efficient.

Criteria for selecting distribution values:

- 12V – Small systems for lighting and television:
    - Maximum appliance power: < 300 W
    - Corresponding current: 25 A

    - Inverter: about < 1 kW
- 24V – Medium-sized systems, household use with refrigerator and small appliances, or for wiring extensions over 10 m:
    - Maximum appliance power: < 1000 W
    - Corresponding current: 42 A
    - Inverter: about < 5 kW
- 48V – Specific industrial or agricultural use:
    - Maximum appliance power: < 3 kW
    - Corresponding current: 62 A
    - Inverter: about < 15 kW

Higher powers require either high DC voltages (for special appliances) or AC feeding through an inverter.

In a battery pack, if one cell is weaker than the others, it will discharge more quickly. Since all cells are connected in series and receive the same current, they can experience deep discharges or even reverse polarity (the forced current can reverse polarity, similar to hot spots in a photovoltaic array). This will further damage the faulty cell. Similarly, during charging, a reduction in capacity can lead to overcharging conditions that produce gassing before the other cells, resulting in electrolyte loss. Therefore, in high-voltage battery packs, the absence of careful maintenance or compensating strategies significantly increases the risk of failure.

These three sizing parameters can be adjusted in the "Hidden Parameters" section.

When setting a very high autonomy, the global system optimization process will select the "minimum" PV size necessary to meet the required Loss of Load (LOL). This approach may result in a very low average State of Charge (SOC) over extended periods throughout the year, which can be detrimental to the battery's health.

5.1 Storage

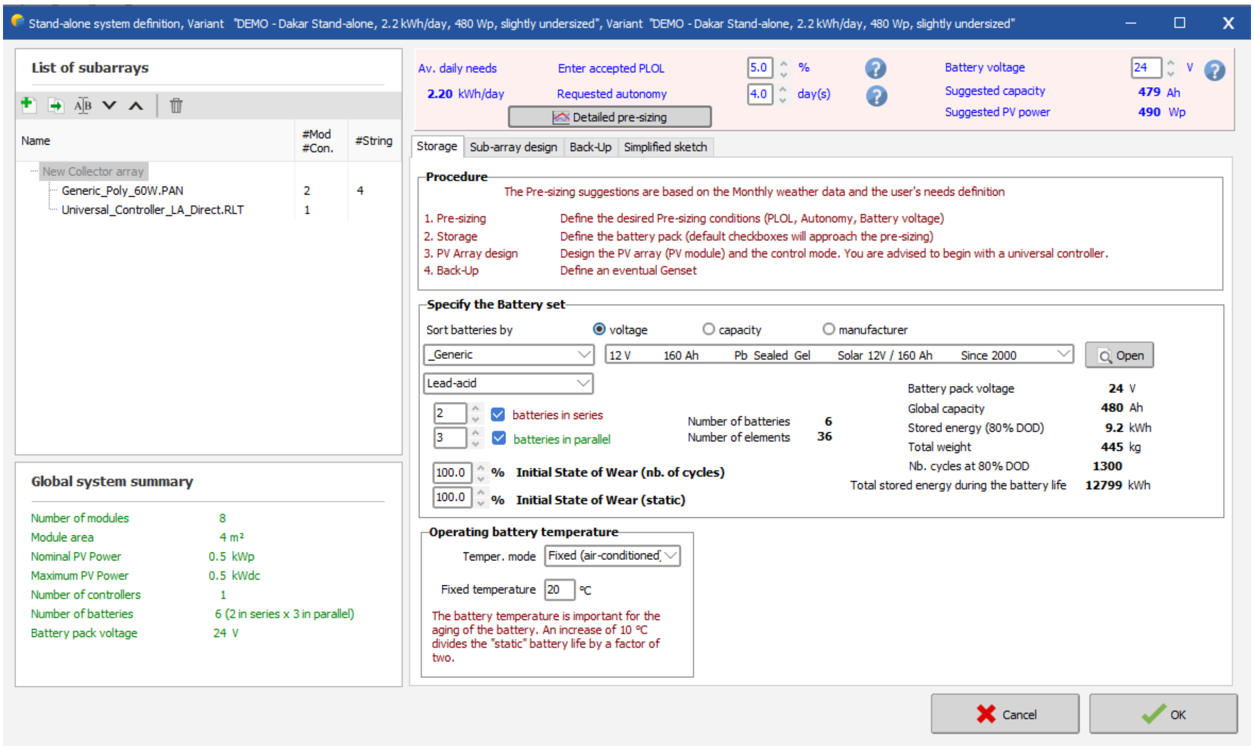
To specify the battery set, begin by choosing the battery technology, and selecting a specific battery from the database. Next, define the number of batteries in series and parallel to configure a battery pack with the characteristics required. The default checkboxes will guide you according to the pre-sizing conditions defined.

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 total weight is 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, an estimate of the total energy that can be stored over the battery lifetime.

In the bottom left box, you can choose the battery operating temperature that will be used in the simulation. The battery temperature is used in the aging model of the battery. An increase of 10°C in the operating temperature reduces the "static" battery life by a factor of two.



5.2 Sub-array design

With the pre-sizing Help, you can specify the maximum surface area or power you wish to install. Once a value is entered in either of the two fields, the software will provide wiring suggestions through the PV Array Design tool.

PV array design: Design the PV array by selecting the solar modules and configuring the control mode. It is recommended to start with a universal controller for greater flexibility.

In this version 8, you will also find a summary of the "List of Subarrays" and the "Global System Summary" providing a detailed view of the installed system.

In this version, it is also possible to define multiple orientations by selecting different PV fields. Each orientation is paired with its own dedicated regulator, ensuring optimal performance for each configuration. It's important to note that these regulators cannot be mixed; each must operate independently to maintain the integrity and efficiency of the system.

Universal Controller

The chosen regulation strategy is not crucial. To simplify control, PVsyst offers a "generic universal controller" suitable for three types of strategies:

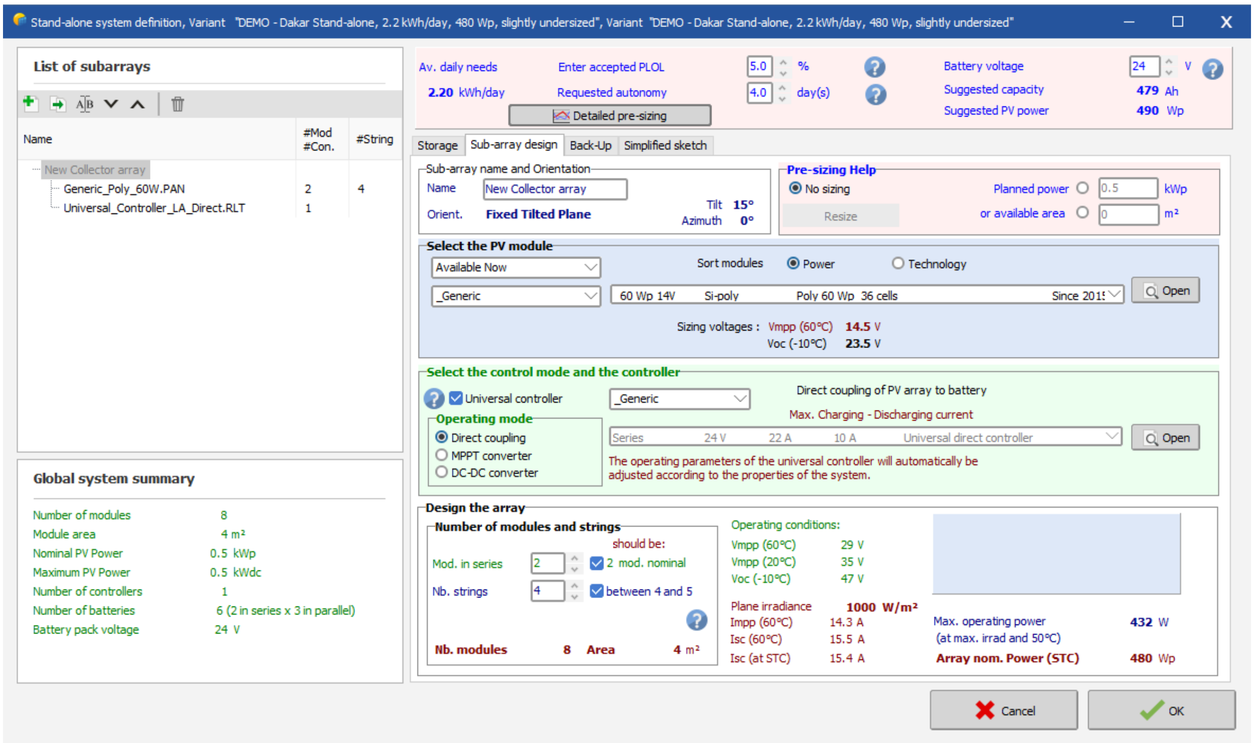
- **Direct Coupling**: In this mode, solar panels are directly connected to appliances or batteries, allowing for simple use of the produced energy. However, this system does not always optimize energy production.
- **MPPT Converter (Maximum Power Point Tracking)**: This device adjusts the load on the panels in real-time to maximize the energy captured based on sunlight conditions. It is particularly useful in more complex systems where energy production varies.
- **DCDC Converter**: This device adapts the voltage of a direct current to another level, allowing the output of the panels or batteries to meet the specific requirements of the appliances.

During the sizing process (specifying the battery pack and the PV array), these devices will adjust their parameters to the system to ensure normal operation without control losses during the hourly simulation.

Key Parameters to Adapt:

- **Control Thresholds**: Default values are specified in the "Hidden parameters" based on the state of charge (SOC). These values can be modified for threshold dependency studies or defined according to battery voltage.
- **Temperature Corrections**: These adjustments are necessary for battery voltage thresholds to ensure accuracy under various climatic conditions.
- **Power Conditioning Units**: This includes adjusting input voltages and power based on the modules in the array, as well as the efficiency curve. Efficiency values (Euro and maximum) can be modified as needed.
- **Maximum Currents**: Settings for charging, discharging, and backup are crucial to protect the system from overloads.
- **Backup Control Management**: If a genset is specified, the system can automatically adjust parameters to integrate this energy source.

All these parameters are stored in your calculation variant, allowing you to keep your modifications. If you want to maintain a specific configuration for future use, you can save this universal converter with the current parameters. It is advisable to give it a meaningful name for the Manufacturer and Model parameters and save it as "Manufacturer_Model.RLT" in your personal database.



5.3 Backup

You also have the possibility to define an optional auxiliary generator (genset) if needed.