PVSYST 7

Stand Alone

INTRODUCTION

This document contains two different tutorials describing basic aspects of a simulation:

- Creation of a Stand-Alone project
- Study of the report

More tutorials are in preparation and will be added in the future. They will explain in more detail the different features of PVsyst. The complete reference manual of PVsyst is the online help, which is accessible from the program through the "Help" entry in the top menus, by pressing the F1 key or by clicking on the ⍰ help icons within windows and dialogs.

Contents

Part 1: Basic Approach - My First Project

1- First contact with PVsyst

Stand-alone systems are always organized around a battery storage:

- A PV array charges the battery or directly delivers its power to the user.
- The user's needs (consumption) should be well defined, with its daily profile (i.e. in hourly values).

On the hour, the simulation performs a balance between the PV production (depending on the irradiance) 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 reconnexion will be performed with a specified hysteresis, depending on the state of charge (SOC) of the battery.

Very little stand-alone systems (SHS: Solar Home Systems):
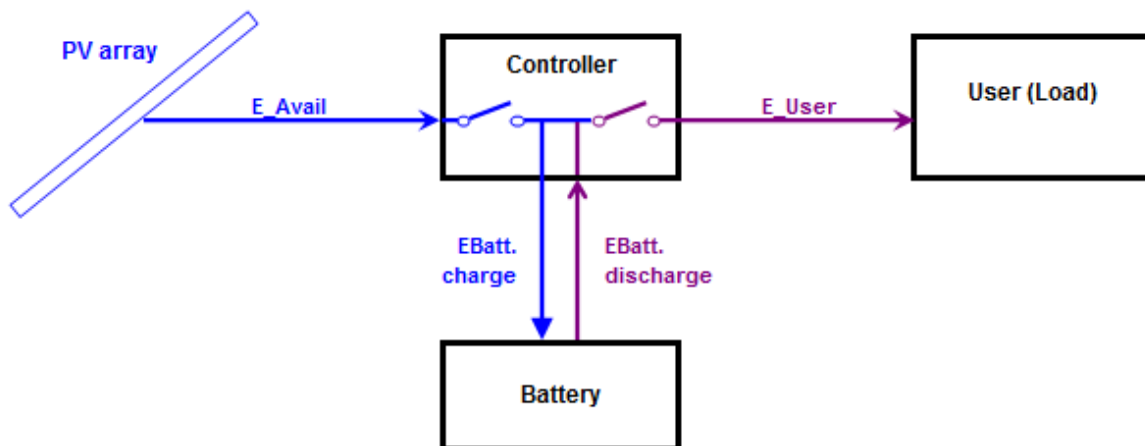

This concerns small systems (50 to 200 Wp) with a very limited consumption (some lights, radio-TV, computer, no fridge).

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 with 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 of controlling the load when the battery is empty.

Medium power systems (small household, communications):
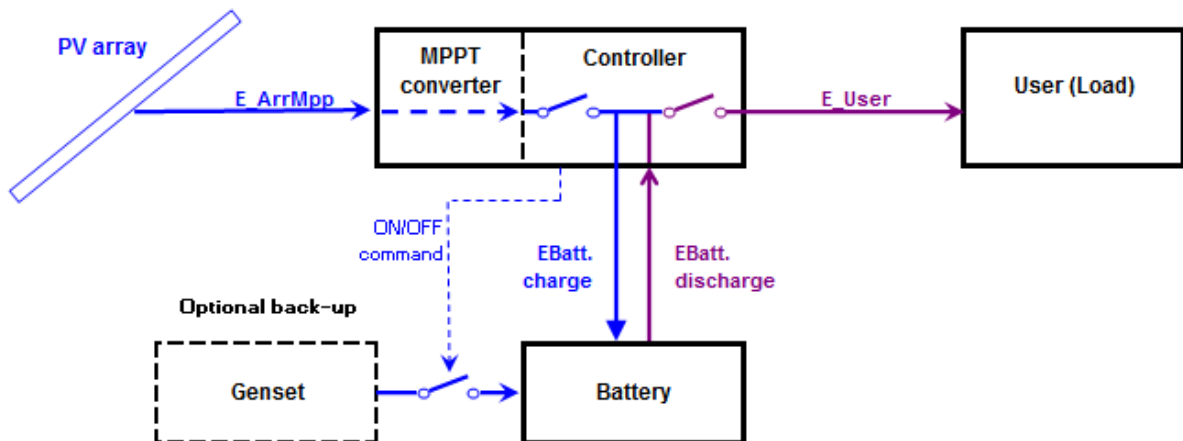
These systems usually range between 200 Wp and 2 kWp.

The controller includes a power conditioning unit, able to 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").

At present, PVsyst doesn't 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.

## High power systems (Household, communication relays, isolated little industry, etc)
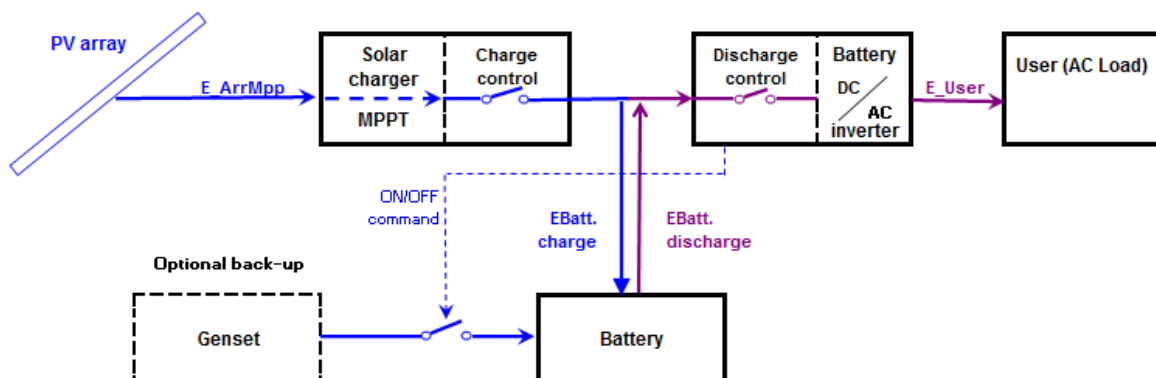
These may be stand-alone systems of 2 kWp to several dozens of kWp.

Such installations are using 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.
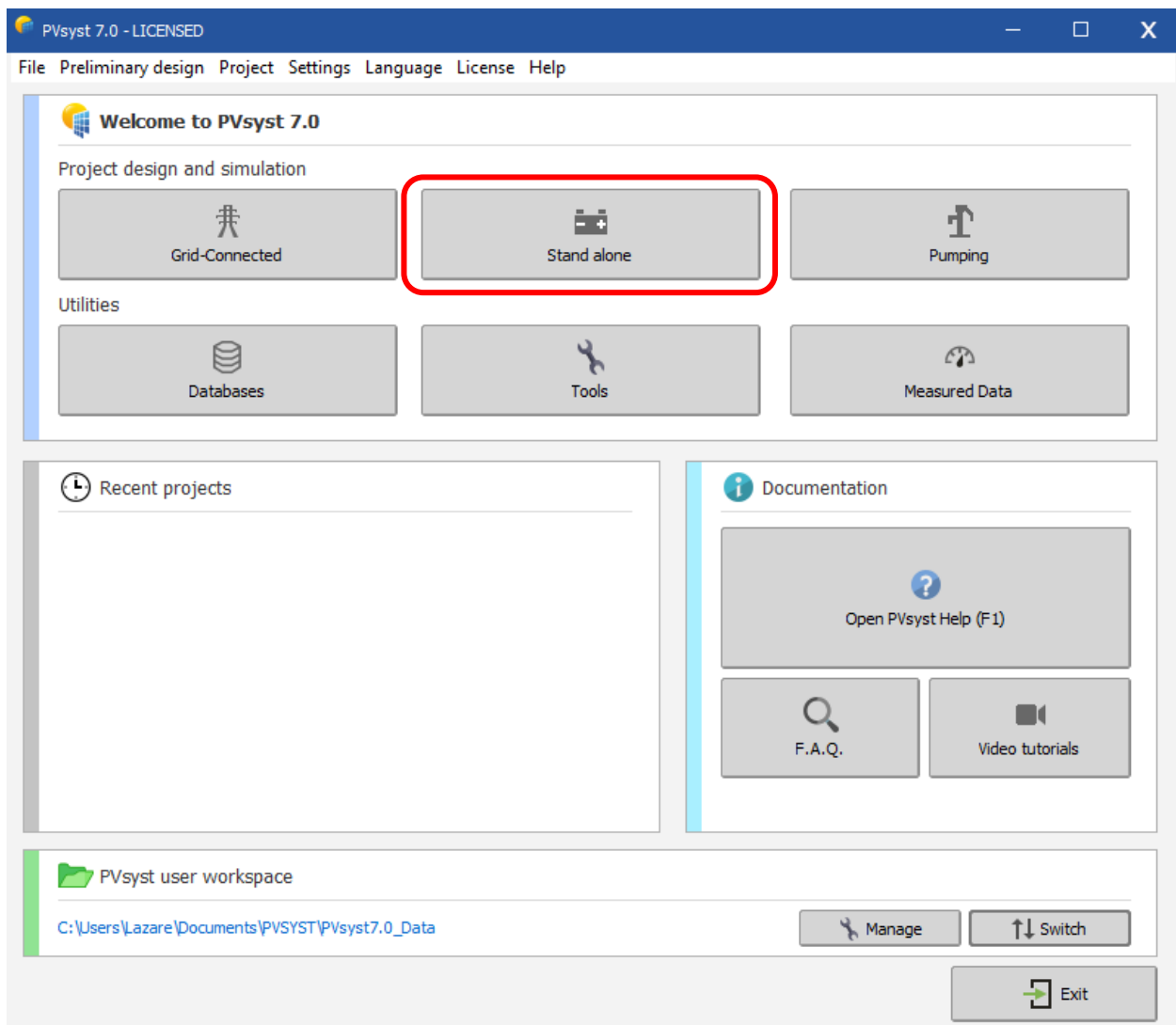
Stand-Alone system procedure:

This gives a step-by-step procedure when defining a stand-alone system in PVsyst.

First step:

As for any PVsyst system, you have to specify the orientation of the PV array.

Second step:

You are asked to define the user's needs.

By default for small systems, this is proposed as a list of domestic appliances and their consumption (may be seasonal or monthly).

For industrial or bigger systems, you have many possibilities of defining a load profile (including by a list of hourly values).

Third step:

The Pre-sizing tool (on top) gives advice about the required Battery bank and PV array power.

The calculation is based on your meteorological files and above definitions. You should define:
- the required autonomy (usually around 4 days),
- the acceptable probability that the needs are not covered by the system (PLOL for "probability of Loss of Load),
- the nominal voltage of the battery bank.

The program will then perform a system sizing, in a similar way as in the "Pre-sizing" section.

You also have a button for a more refined sizing study, for different meteorological distributions, or according to the PLOL parameter.

Fourth step:

Define the battery pack, by choosing a battery model ("Storage" page).

The program will propose the number of batteries in series and in parallel, according to the suggestions obtained in the previous pre-sizing tool.

You should also define the operating temperature conditions for the batteries, according to your system implementation.

Fifth step:

Define the array configuration and control strategy ("PV array" page)
- Acknowledge the pre-sizing propositions (planned power or available area),
- Choose a PV module model in the database,
- Choose the control strategy (direct coupling, MPPT or DCDC converter).

In a first step, you are advised to choose the "Universal controller", to get rid of the specific control conditions.

The program determines the number of modules in series and in parallel, according to the battery voltage or MPPT conditions and required PV power.

2- Define Orientation

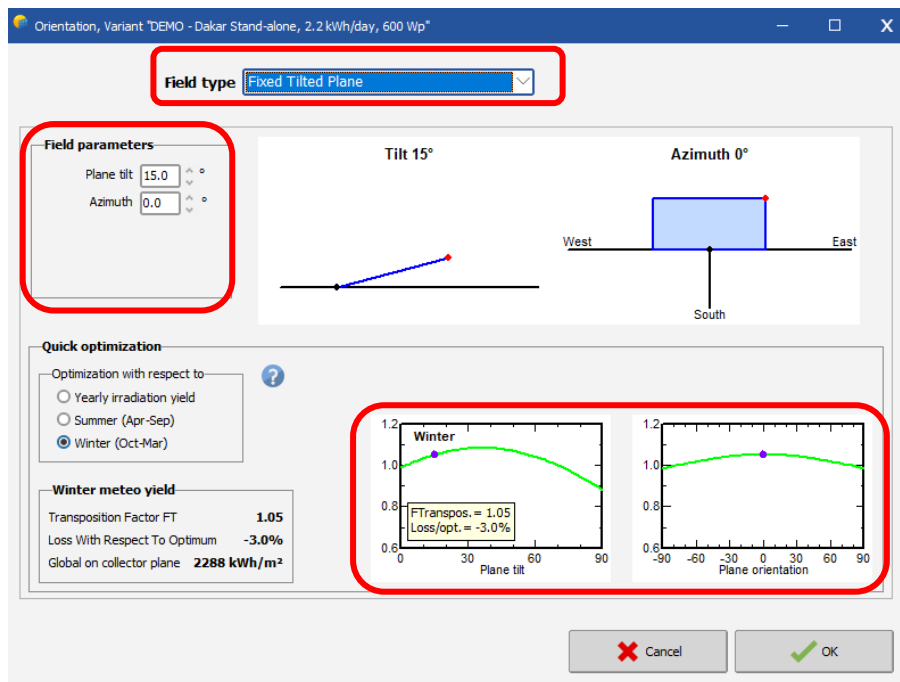### Creating the first (basic) variant for this project

After having defined 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 2 buttons marked in red: "Orientation" and "User's needs". The red color means that this variant of the project is not yet ready for simulation: additional input is required. Basic parameters that need to be defined for any of the variants, and not yet specified are the orientation of solar panels, User's needs, type and number of PV modules, type and number of batteries that will be used.

Firstly, you need to click on "Orientation Button":

This is a tool aiming at showing the best suited orientation for a PV system, or what you lose when not optimally oriented.

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.

Now please observe that the optimization of the orientation depends on the planned use for the PV energy.

- For Stand-Alone systems, the relevant solar yield for sizing the system may be, for example, the winter months for a house or industrial system, or some specific months for leisure appliances.

Therefore, this tool gives the possibility of choosing the optimization period: Year, Winter, Summer, or chosen months.

Moreover, the optimization may depend on specific far-shading conditions (mountains): you can define a horizon line, and this will usually result in an azimuth displacement.

Quick optimizing tool in the "Orientation" part:

When choosing the (fixed) plane orientation, an information panel indicates the corresponding Transposition Factor, the difference (loss) with respect to the optimum orientation, and the available irradiation on this tilted plane.

Clicking "Show optimization" button, you can see a graph of the Transposition Factor as a function of the plane tilt and azimuth. These graphs also indicate your actual choice by a violet dot on the curves, showing at once where you are positioned with respect to the optimum.

3- Basic definition of User's needs

Now, we need to define the User's needs.

Several options are available:

- Use of a consumption profile available in the database

- Import a consumption profile in CSV format

- Use the user needs definition interface

We will use the user requirements definition interface to give you keys to customize the definition of your energy needs.

To complete your energy needs, you must in any case click on the "User's needs" tab.

Once the "User's needs" menu is open, start by defining the frequency of your needs.

You can choose the distribution of your consumption between:

- Years

- Seasons

- Months

Also, you can choose the number of days regarding your consumption.

The next step is to complete the table of daily consumption.

To do this, you will need to define:

- Number of appliances corresponding to the designation

- Unit power in Watts

- The daily operating time

You can modify / customize the name of each device in the "Appliance" section.

Please note that we are not talking about unit power, but the energy consumed (in kWh / day).

Once the definition of your energy requirements is complete, you have a balance sheet of the total daily and monthly energy consumed by your devices.

You can see that we have added 24 Watts on 24 hours a day for the Stand-By consumers. In fact, when your devices are off, very often a standby or other lamps remains on.

It is therefore necessary to define this consumption in order to achieve a dimensioning closest to reality.

Several error messages in red indicate that you have not finished defining your "User's needs".

In fact, now that you have defined the devices and their power, you must enter the operating time slots for these devices.

It is important that these time slots are correctly completed because it is with these elements that the sizing of the photovoltaic field and the battery pack will be calculated by the "pre-sizing" tool.

When you click on the "hourly distribution" tab, the respective watch dials for your devices will be empty.

Only the dial for the refrigeration systems will be completed beforehand (obviously modifiable according to your project).
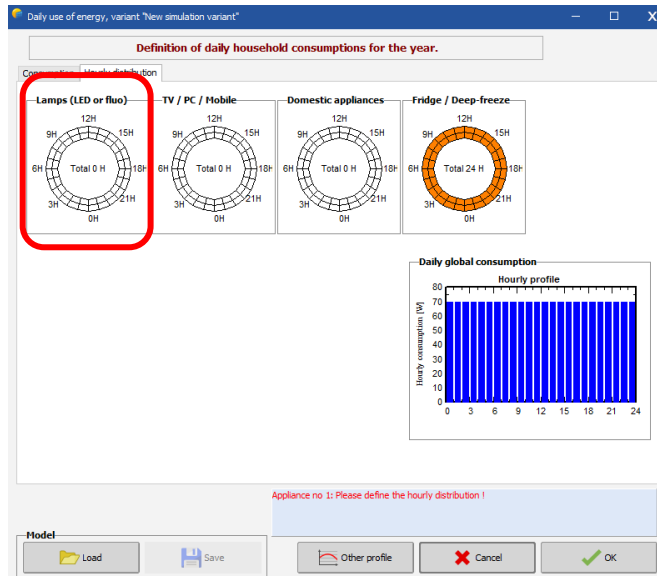
Each dial is made up of 48 sections. Each section represents 30 min of the day. To define a schedule or a time range you can do so using the left mouse button.

To delete a schedule or a time range you can do this by using the right click of your mouse.
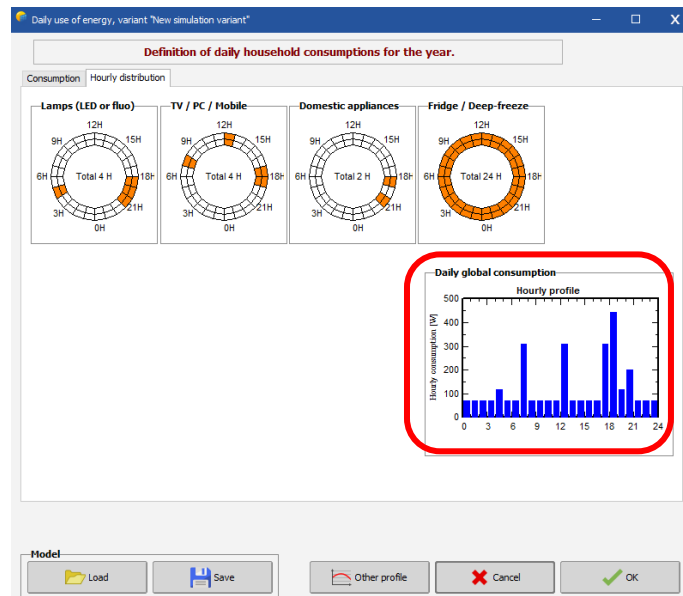
When you add a time slot, a graph corresponding to your daily consumption profile is automatically constructed.

Also, if the value of the operating hour positioned in the dials does not correspond to the daily use defined in the "Consumption" tab, the value defined in the dials in the "Hourly distribution" tab will be used for calculations.

Once the hourly distribution has been completed, you can return to the "Consumption" tab to check if a change in value has been made and if no error message appears.

When there is no longer a red message or an error message, you can validate this information by clicking OK.

All of these input parameters will be displayed in the final PDF report.

4- Define the System

Once you have finished defining the system orientation and your user needs, the "System" tab will turn red which means that you can click on it to define your electrical system.
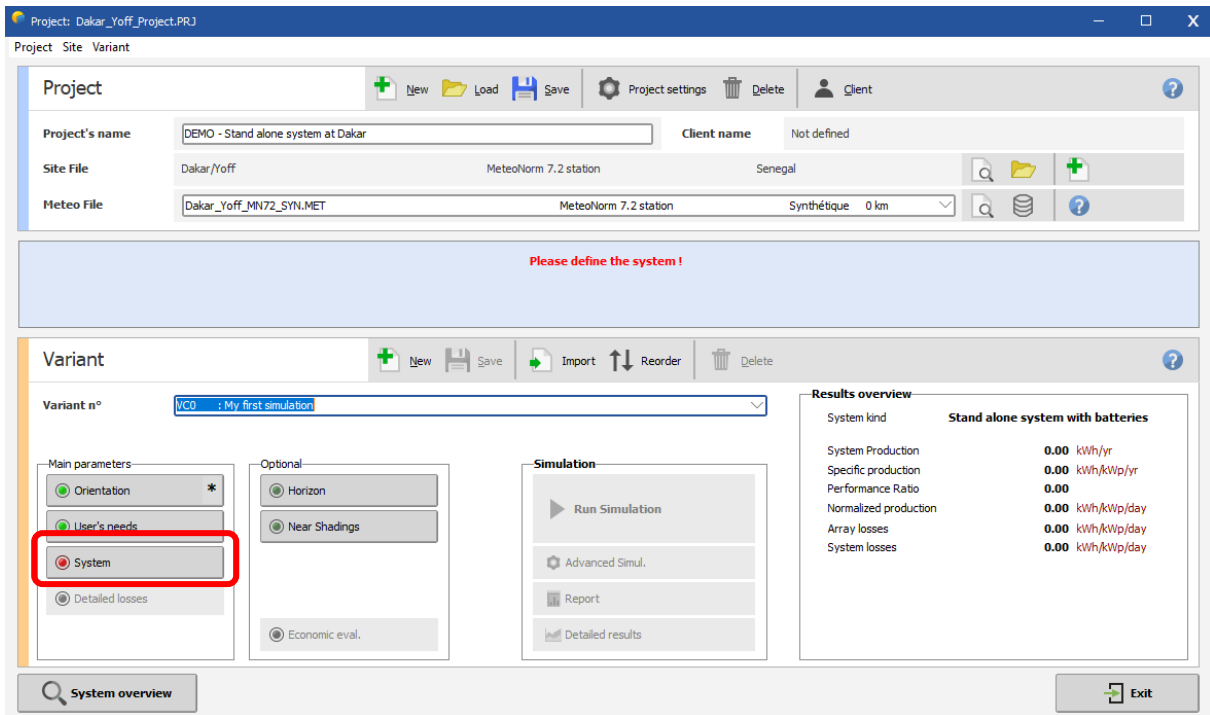
In the "system" tab, you must define:

- Characteristics of the battery pack
- Characteristics of the photovoltaic field
- Characteristics of the charge / discharge regulator

You can add optional generator system via the "Back-up" tab

In this first window several important information:

- Pre-Sizing
- Battery Set
- Operating battery temperature

The Pre-Sizing tool calculates two pieces of information:

- Suggested capacity (battery)
- Suggested PV Power

PLOL in % :

This value is the probability that the user's needs cannot be supplied (i.e. the time fraction when the battery is disconnected due to the "Low charge" regulator security).

It may be understood as the complement of the "Solar fraction" (although it is described in terms of time rather than energy).

During the sizing process, the LOL requirement allows for determining the PV array size needed, for a given battery capacity.

The LOL is calculated using a simplified and fast yearly simulation: the program splits the monthly meteorological values into a realistic random sequence of 365 days (according to Collares-Pereira

model), each day being divided into 3 periods: morning - day (with solar gains) - and evening. Then it performs a day-by-day balance, and reports the daily system state, in order to accumulate a realistic "LOL" yearly value.

This process is repeated with different PV-array sizes, in order to find the exact PV size matching the required "LOL".

Requested Autonomy in day(s :

In the Pre-sizing process, the proposed battery pack capacity is determined according to the required autonomy of the system, given in days.

The autonomy is defined as the time during which the load can be met with the battery alone, without any solar inputs, starting of course from a "full charged" battery state. With non-constant loads (seasonal or monthly definition, weekly use), this is accounted as the worst-case scenario over the year.

The calculation takes the minimum SOC disconnecting threshold, and the battery "energy efficiency" into account.
It also has to apply a capacity correction, as this mode of use usually occurs at a rather slow discharge rate (therefore corresponding about to the C100 capacity definition, i.e. with discharge in about 100 hours); when the nominal capacity of the batteries in the PVsyst database is defined as the C10 value. The C100/C10 ratio is usually in the order of 120% to 130%.

These 3 sizing parameters are adjustable in the "Hidden parameter".

NB: When defining a very large autonomy, the global system optimization process will choose the "minimum" PV size which just meets the required "LOL".

This may lead to a very low average State of Charge value over large periods of the year, which is quite damaging for the battery.

Battery (user) voltage:

In a stand-alone PV system with direct coupling to the user (without inverter), the battery voltage determines the distribution voltage. Nowadays many DC appliances can be found in 24V as as well as in 12V, this choice should be made according to the system and/or appliance's power, as well as the extension of the planned distribution grid to minimize the ohmic wiring losses.

This choice should be made at the early planning stage of an installation, since the existing appliance voltage usually cannot be changed, and voltage translators will be expensive and not 100% efficient.

The rated distribution values could be chosen according to the following criteria (inverter supposed directly connected on the battery pack):

- 12V: small systems for lighting and TV:
    o Appliance max power   < 300 W
    o Corresponding current   25 A
    o Inverter: about < 1 kW

- 24V: medium size, household with fridge and little appliances, or wiring extension to more than 10 m.
    o Appliance max power   < 1000 W
    o Corresponding current   42 A
    o Inverter: about   < 5 kW

- 48V: special industrial or agricultural use
    o Appliance max power   < 3 kW
    o Corresponding current   62 A
    o Inverter: about   < 15 kW

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

NB: In a battery pack, when a cell is weaker than the other ones, it will be empty earlier.

As all the cells are connected in series, i.e. with the same current, it may encounter deep discharges, or even reverse polarization (the forced current may reverse the polarity, like for the Hot-spot in a PV array).

This will still damage further this bad cell. In the same way, during charging, as the capacity is lowered, the overcharging conditions will produce gassing before the other cells, leading to loss of electrolyte.

Therefore, in high voltage battery packs, in absence of a careful maintenance or compensating strategies, the risk of failure is strongly increased.

Pre-sizing Help tool:

With this tool, you can define a maximum surface or power that you want to install.

When a value is defined in one of the two boxes, the software will make a wiring suggestion via the PV Array Design tool.

Universal controller:

During the early stage of a stand-alone system study, the main issues are the global system sizing, i.e. the determination of the Battery pack, the PV array power, as function of the user's needs and the meteorological conditions. After the quick pre-sizing evaluation, the results (PLOL, unused energy) must be assessed with a detailed hourly simulation.

The exact regulator strategy does not matter. To get rid of the control constraints, PVsyst introduces a general purpose "generic" universal controller, for the 3 different strategies: Direct coupling, MPPT converter or DCDC converter.

During the sizing process (specification of the battery pack and PV array), these special devices will adapt their parameters to the system, in order to always stay compatible with a normal behavior without control losses during the hourly simulation.

The main parameters to be adapted are:

- The control thresholds: their default values are specified in the "Hidden parameters" in terms of SOC. But you can change them for threshold's dependency studies, and eventually define them in terms of Battery voltage.
- Temperature corrections for the battery voltage thresholds
- With Power conditioning units, the input Voltages and Power according to the modules of the array, as well as the efficiency curve. The efficiency values (Euro and Max efficiencies) may be explicitly modified.
- The maximum Charging, Load and Back-up currents,
- Management of the back-up control if a Genset is specified

All these parameters are stored in your calculation variant, therefore also keeping your modifications.

If you want to keep a specific configuration for further use, you can always save this Universal converter with the present parameters. In this case please give it a significant name to the Manufacturer and Model parameters. You are advised to save it under a name like "Manufacturer_Model.RLT in your own database

5- Executing the first simulation

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

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

A progress bar will appear, indicating how much of the simulation is still to be performed. Upon completion, the "OK" button will get active. When you click on it, you will get directly to the "Results" dialog.
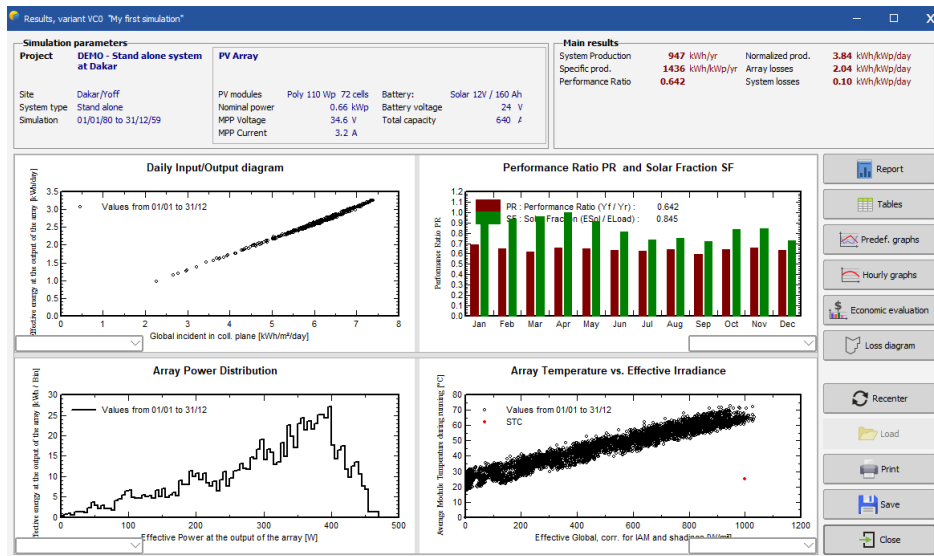
This dialog shows on the top a small summary of the simulation parameters that you should quickly check to make sure that you made no obvious mistake in the input parameters. Below is a frame with six values that summarize at one glance the main results of the simulation. They only give a very coarse picture 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.

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 [Report] you will get the complete report, which for this first simple variant consists of only three pages (for simulations with more detail you can get up to 11 pages of report). In this report you will find:

First page: All the parameters underlying this simulation: Geographical site and meteorological data used, plane orientation, general information about shadings (horizon and near shadings), components used and array configuration, loss parameters, etc.

Second page: A reminder of the main parameters, and the main results of the simulation, with a monthly table and graphs of normalized values and the definition of your User's needs.

Main simulation results

System Production	Available Energy	**947.5 kWh/year**	Specific prod.	1436 kWh/kWp/year
	Used Energy	924.0 kWh/year	Excess (unused)	0.0 kWh/year
	Performance Ratio PR	64.19 %	Solar Fraction SF	84.52 %
Loss of Load	Time Fraction	15.5 %	Missing Energy	169.3 kWh/year
Battery ageing (State of Wear)	Cycles SOW	97.1%	Static SOW	89.6%

Third page: The PVsyst arrow loss diagram, showing an energetic 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 any.

My first simulation

Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	159.5	179.3	81.07	0.000	8.98	83.87	92.85	0.903
February	164.7	177.4	80.20	0.000	5.43	78.43	83.87	0.935
March	207.0	210.7	95.56	0.000	3.76	89.09	92.85	0.959
April	209.7	200.9	91.37	0.000	0.00	89.86	89.86	1.000
May	209.2	190.6	85.69	0.000	8.15	84.70	92.85	0.912
June	188.0	168.9	75.69	0.000	16.76	73.10	89.86	0.813
July	176.4	160.1	71.34	0.000	24.30	68.55	92.85	0.738
August	168.7	158.8	70.69	0.000	23.03	69.82	92.85	0.752
September	161.7	159.5	70.84	0.000	25.24	64.62	89.86	0.719
October	170.8	178.2	79.16	0.000	14.76	78.09	92.85	0.841
November	153.1	169.3	75.43	0.000	13.69	76.17	89.86	0.848
December	137.9	156.7	70.45	0.000	25.16	67.70	92.85	0.729
Year	2106.7	2110.4	947.48	0.000	169.25	924.00	1093.25	0.845

The bottom of the third page contains a table with the main variables, given as monthly values and the overall yearly value. The yearly value can be an average like the temperature, or a sum, like the irradiation or energies. The meaning of the different variables is the following:

GlobHor: Global irradiation in the horizontal plane. This is our meteorological input value.
GlobEff: Ambient (dry-bulb) average temperature. This is also our meteorological input value.
E_Avail: Available Solar Energy
EUnused: Unused energy (battery full)
E_Miss: Missing energy
E_User: Energy supplied to the user
E_Load: Energy need of the user (Load)
SolFrac: Solar fraction (EUsed / ELoad)

Part 2: Define User's need – Other profile

1- PVsyst 's model

The software gives you the possibility of recording your consumption profile once it is fully defined (no error in red and the hourly distribution defined).

When you save your consumption profile, it will be reusable for your other projects in your workspace.

To record your "Daily consumptions", click on the "SAVE" button.

Once you have clicked on the "save" button, a personalization popup opens. From this window you can change:

- The name of "Description"
- The File name
- The Directory
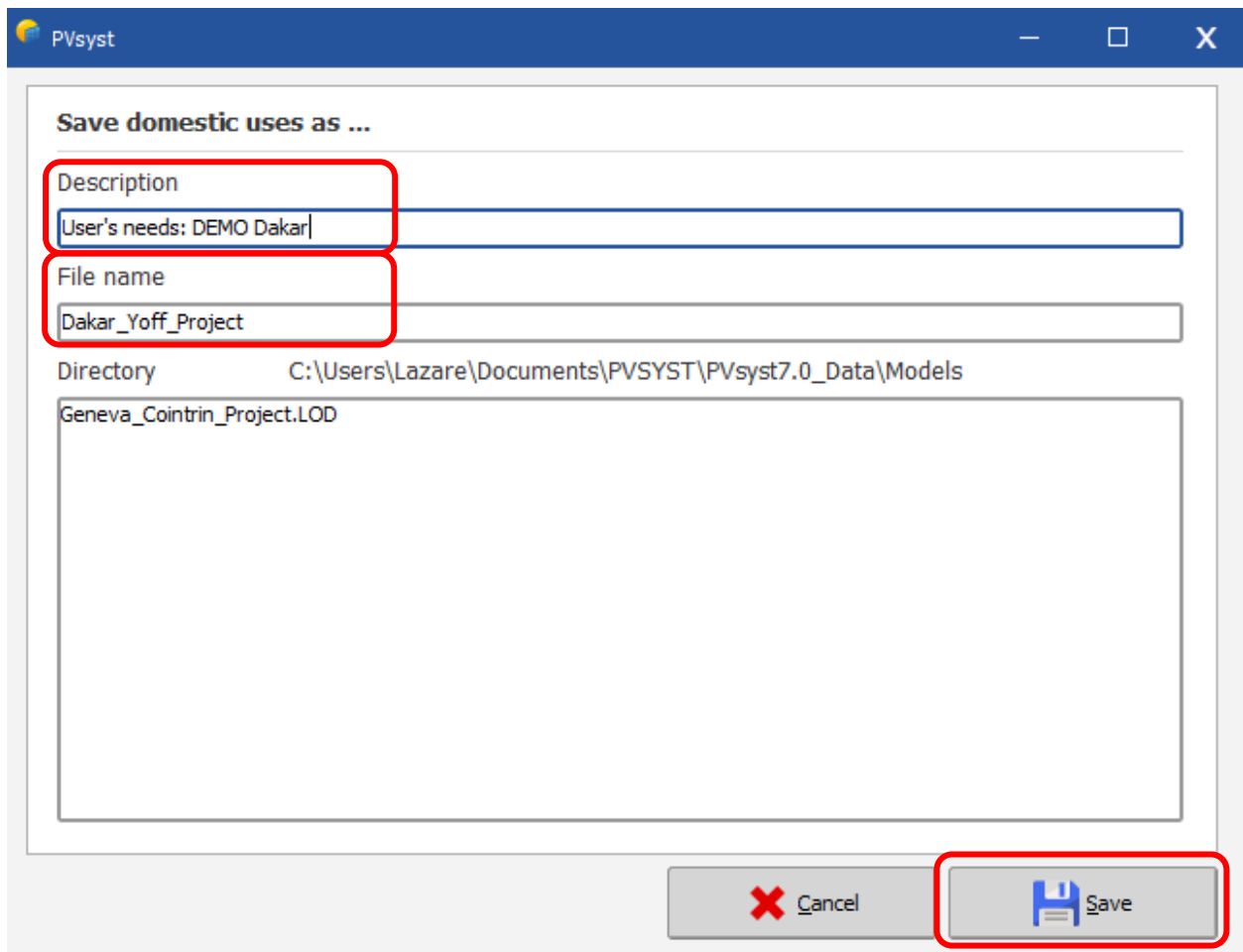
It is important to define the name of the recording so that you can easily find it in the list of records.

When you have finished naming your file, you must click on "Save" in order to save your file and exit this window.

Once the registration is complete, you can find your different models saved as well as the "DEMO Pvsyst" by clicking on the "Load" button.

Please note: You will only have your recordings if you have kept the same workspace during the recording.
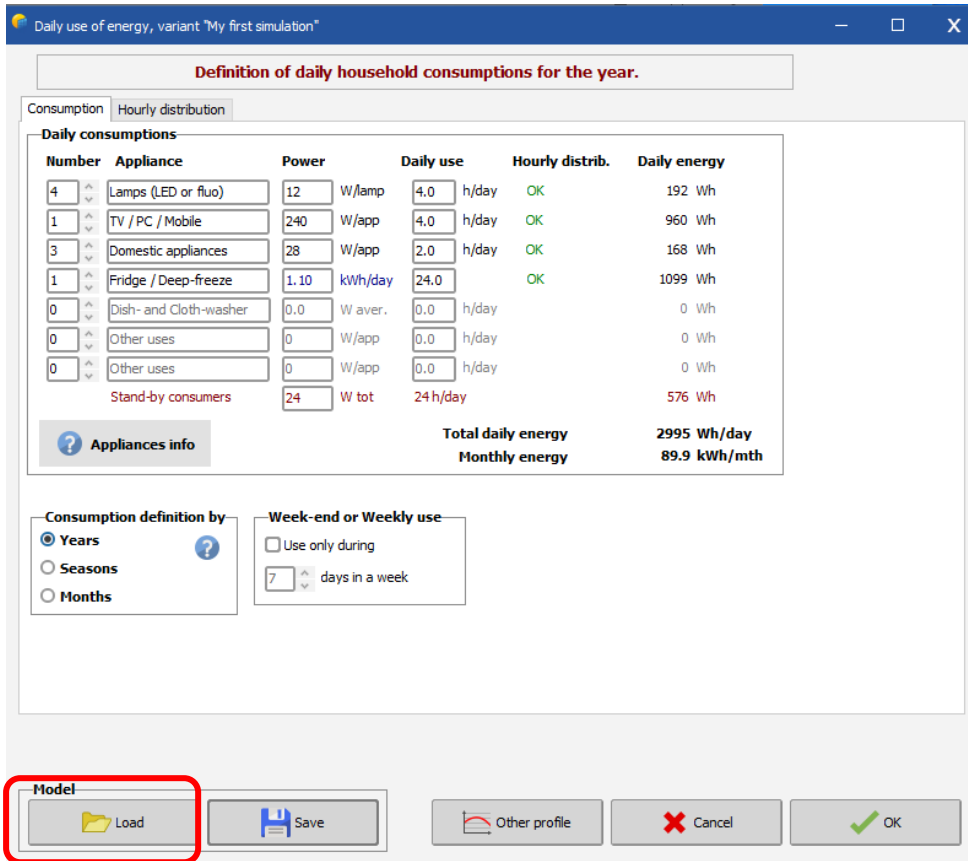
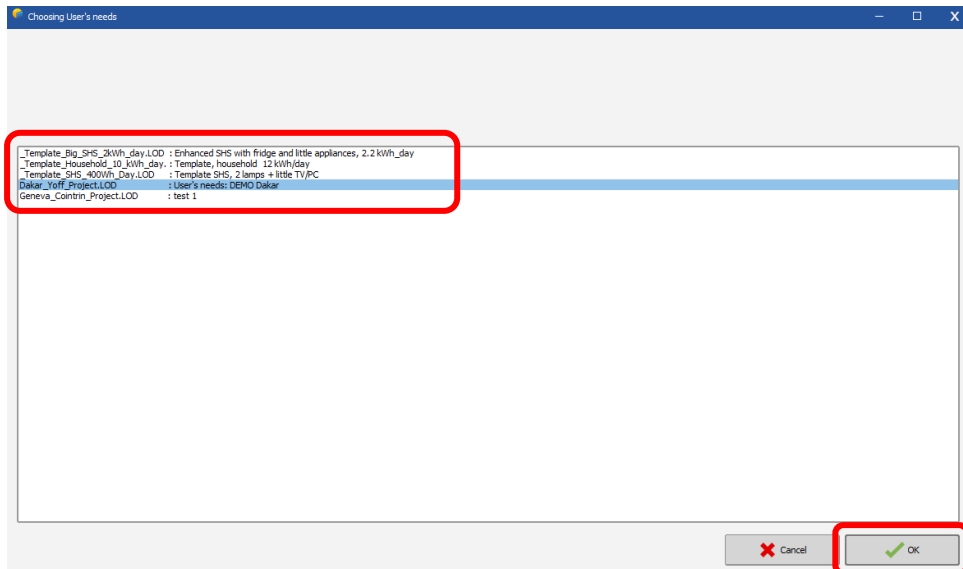In the window below you will find three Pvsyst DEMO from Daily Consumptions as well as your previously saved models. To load and use a defined Daily Consumption simply select it by clicking on it then click on the "OK" button.

2- Other Profile

Several other ways to define the consumption of your receivers are possible.

By clicking on the "Other profile" button, you access the tab below.
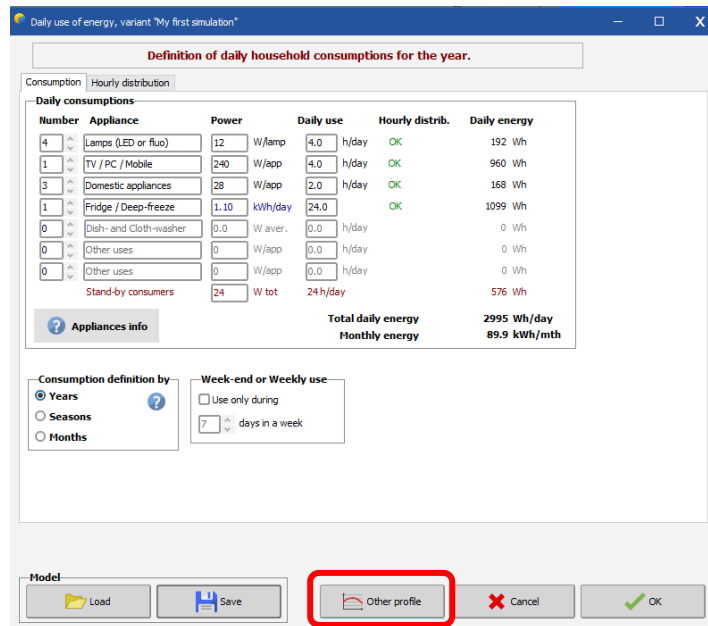
From this window you can define your consumption as follows:

- Load a model
- Fixed constant consumption
- Monthly values
- Daily profiles
- Household consumers
- Load values from a CSV hourly / daily file
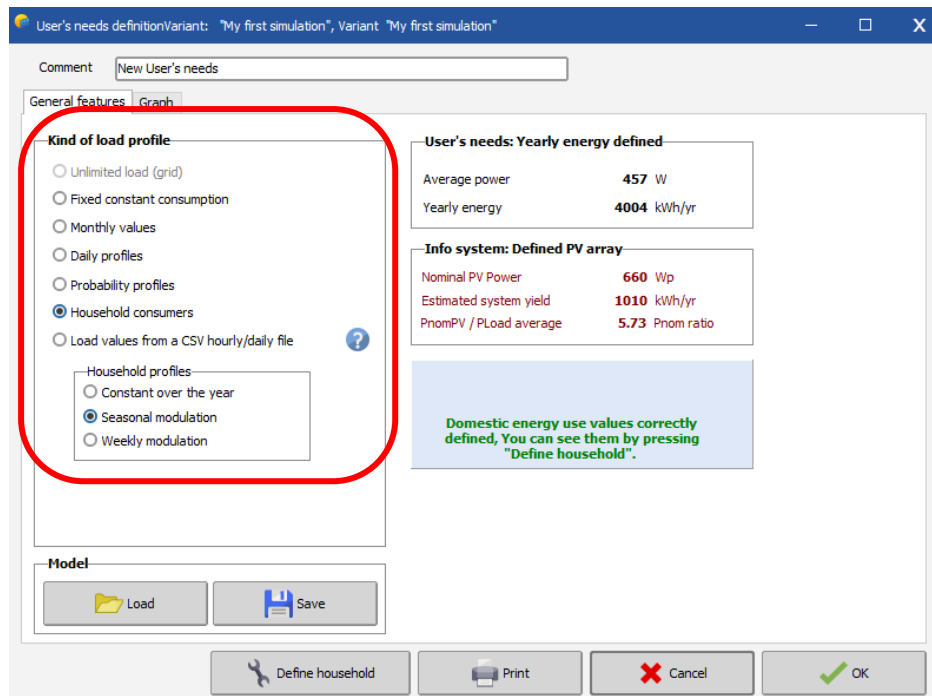
Load values from a CSV hourly / daily file:

The most flexible way for defining a custom load profile is to input it as an ASCII (CSV) hourly file.

Hourly Parameters file

The input source file should be prepared in a spreadsheet program (like MS-EXCEL), in the CSV-format (Comma Separated Values, separator may be semicolons or commas).

You can find a template named «PARAMS_Hourly_Template.CSV":

- Either in the program's location, usually   C:\ program files (x86) \ PVsyst7.x \ DataRO \ PVsyst7.0_Data \ Templates \

- Or in your workspace   C: \ users \ YourSession \ PVsyst7.0_Data \ Templates \

In the latter case you should update/reload this file using «Files > Workspace > reload templates» in the main menu.
When modified, you will put your data file in your workspace \"user"\ PVsyst7.0_Data \ user Hourly Params \

PVsyst standard format for hourly parameters
The required format for the import of hourly parameters in PVsyst is the following:
- Text file (CSV format with commas or semicolons) written in ANSI (not UTF8)
- All lines beginning by # are comments, ignored
- The blank lines are ignored
- The first line without # holds the column title. It should begin by "date", and "P Load" for an hourly load power (other keywords for other parameters will be defined in the future).
- Second line: units of the data in this column, will be read and interpreted by the program.
- In sub-hourly data, specifying [kW] will be interpreted as powers (values will be averaged within the hour step), and [kWh] will be energies (values will be added within the hour).
- First column of data and hour EXCEL format (both European DD/MM/YY hh:mm or US MM/DD/YY hh:mm formats are recognized).
- Other columns: values according to the column title and units
- The file should contain all hours of a generic year (from 01/01 at 0h00 to 31/12 at 23:00). The year is ignored.
- These dates/hours are not related to the real dates of your input meteorological file: they are for each hour of a generic year.
- Time label = beginning of the year

Use of the file
After carefully preparing this file, the «Hourly Parameter" dialog will ask to choose it in your workspace \ UserHourlyParams \, or anywhere else.

The file content will appear, so that you can check it.

The program will also check its validity, give some integrated values, and you can analyze it with plots.

The dialog will ask if you want to:

- Read the file at the time of the simulation (may be useful for batch mode),
- Read the file immediately and store it internally in your calculation version as input parameters for the simulation

Sub-hourly data
It is also possible to read sub-hourly data (for example Load profiles in 15-minutes steps).

Once the type of profile and the load are defined you can click on "graph" to view the profile of your load.
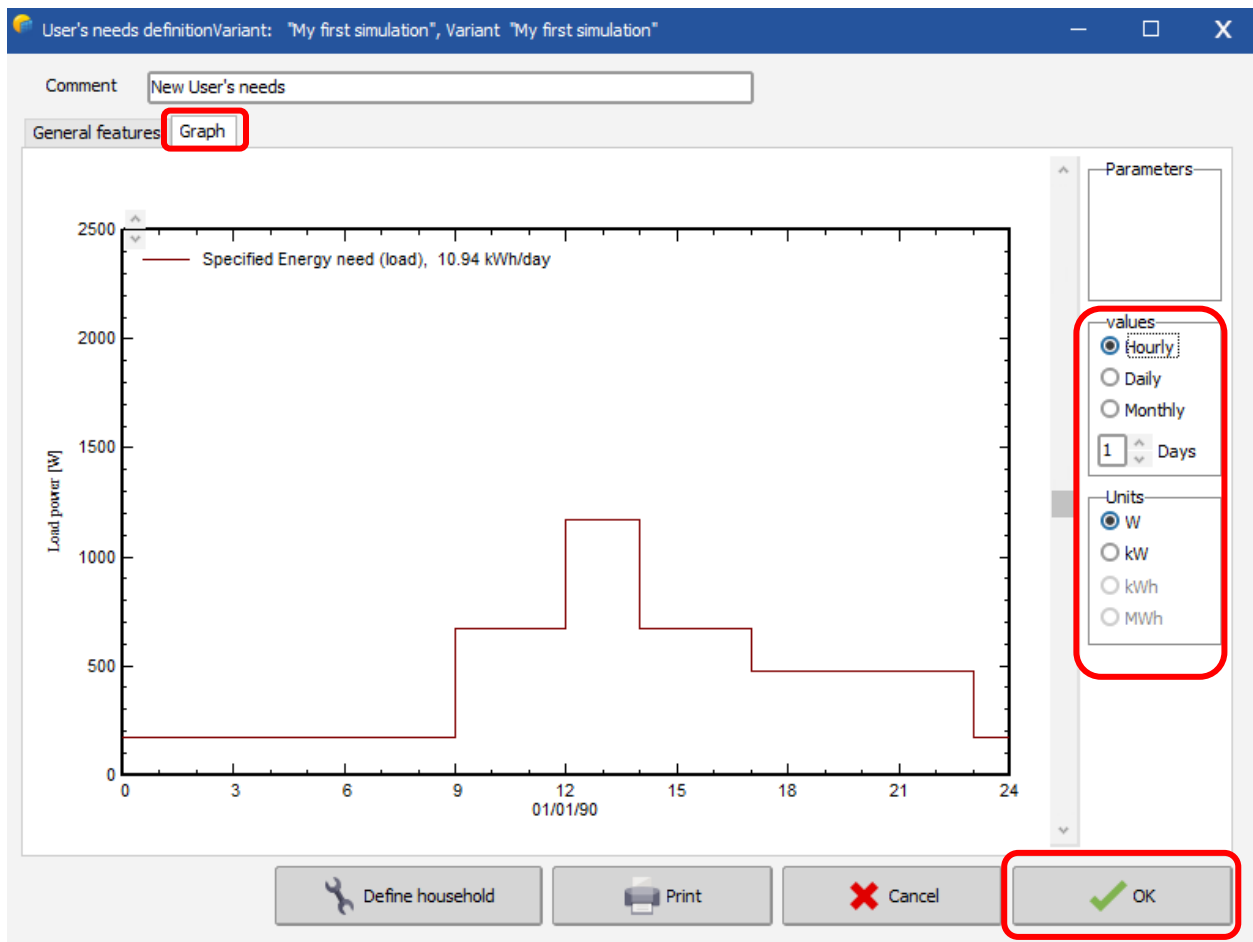
On the abscissa axis you will find the hours of operation per day by default.

On the ordinate axis you will find the power of the load (previously defined).

You can change some display settings for the graph above:

- Values

- Units

- Number of Day

Once all the data entered is set up and verified, you can validate it and continue your project by clicking on the "OK" button.