PVsyst 7

Pumping Systems
My first project

INTRODUCTION

This document consists of tutorials for the simulation of pumping systems. As a sequel to the first chapter, we will be describing the basic aspects on creating your first project for pumping system.

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.

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2.1 First contact with PVsyst

2.1.1 Isolated pumping systems

The "Pumping Systems" in PVsyst only concern "isolated" pumping systems that work according to the sun's availability. Such a system has neither electrical storage nor a grid, and consists of a (or several) pump, a PV array and a controller/power conditioning unit (very exceptionally a booster battery).

The implementation of such system involves a detailed definition of the hydraulic circuit (type of system like deep well, pumping from a lake or equivalent, or pressurization system) and water needs, the pressure gauge height (as function of the flowrate and possible other parameters), the water needs, and a tank storage. Some other constraints may be taken into account (maximum drawdown in a deep well, tank full, etc).

The running mode according to the sun's availability implies that the pump will operate at a power imposed by the maximum power of the PV array at a given time. As the head is imposed by external conditions (level difference, head loss in the pipes, drawdown in a deep well, etc.), the resulting flow rate will be directly related to the instantaneous power availability.

Therefore, the simulation needs a complete model of the pump behavior, giving the resulting flowrate in any conditions of power and head. The Operating point, depending on the Total Head variations according to the flowrate (pipes head losses, drawdown level) will be evaluated by successive approximations.

The main advantage of isolated pumping systems is the absence of a battery. Consequently, the associated maintenance costs (replacement, etc.) is lower. The storage is indeed performed by the accumulation of water in the tank. However, this requires a pump that is able to operate in a wide range of powers.

2.1.2 Conventional pumping systems

The conventional pumping systems fed by a grid electrical system (or eventually a big stand-alone system like a village mini grid) will operate at the specified voltage of the grid. The operating power will be fixed, it is supposed to be available at any time. The system will operate in "ON/OFF" mode, according to the water needs and control system. An intelligent strategy of energy management may favor the pumping during the daylight hours, when the sun is available.

Such systems are not implemented explicitly in PVsyst. The pumping system should be considered as a load in the same way as any other load.

Therefore, a pumping system as defined in PVsyst cannot be associated to any other PV system, even a stand-alone system. It should really stay independent of any other power system.
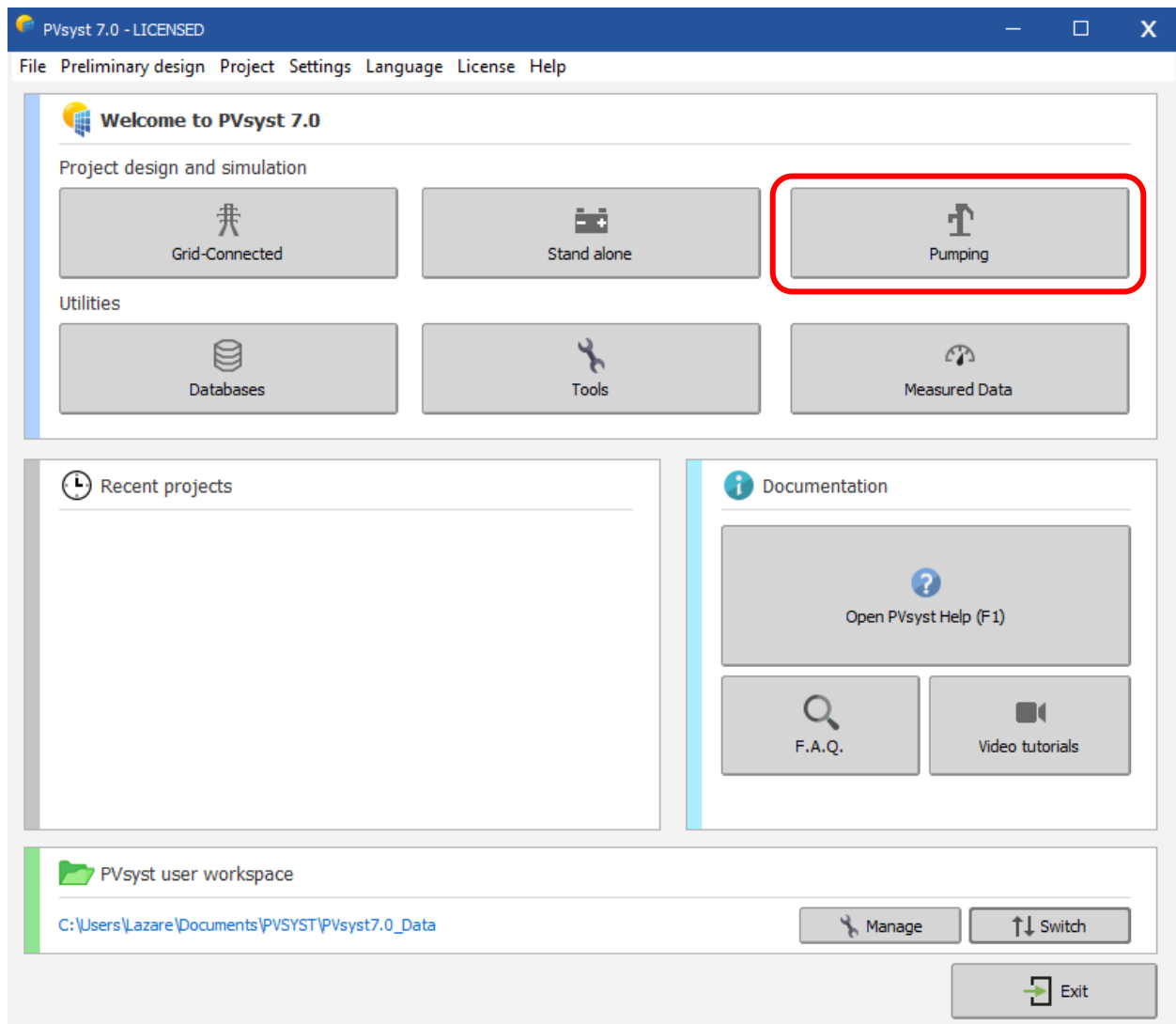
Figure 1: Pumping button in the main dialog.

This page gives the full procedure for the development of a Pumping system in PVsyst.

First step:
As for any variant calculation in PVsyst, you should begin by defining the collector array orientation.

Second step:
You must define the pumping circuit, i.e., choose among one of the three available systems:

- Pumping from a deep well, to a tank storage,
- Pumping from a lake or river, to a tank storage,
- Pumping into a pressurized tank, for water distribution.

and define the Hydraulic Circuit configuration (Storage Tank and Pipes).

Third step:
Go to the "Water needs and head definitions" page.

Define the water needs in m3/day (may be yearly, seasonal or in monthly values).

Define the pumping static depth if it varies along the year (may be seasonal or monthly). The value defined here corresponds to the "Level depth" or "Static depth" level specified on the previous page.

Fourth step:
Choose the "System" button, observe and play with the "Pre-sizing suggestions".

The pre-sizing suggestions on the top of the dialog pre-evaluates some parameters (tank volume, pump and PV array power) required for meeting your pre-defined water needs requirements. See also "Pumping sizing" for the principle. You can play with the parameters for getting orders of magnitude. However, this pre-evaluation is difficult and may be inaccurate, as performances are very different from one to another pump.

NB: This evaluation is independent from the parameters you define yourself for the simulation.

Fifth step:
In the "System" dialog at the "Pump definition" page.

Choose a pump model, taking the nominal Head into account (pumps are colored in green for suitable, orange for not optimal, or red for not suited devices).

You have a summary of the pump capabilities, as well as the set of pumps if you choose several ones.

This dialog also provides a little tool for the calculation of the Hydraulic Power corresponding to a given Head x FlowRate product.

Sixth step:
In the "System" dialog at the "Sub Array design" page.

Choose a PV module (also Green/Orange/Red) and a suitable PV array configuration (proposed by PVsyst).

Seventh step:
Here you have to choose the control mode.

Again, the Green/Orange/Red colors indicate the suitability of the choices, according to the System type, Pump model and Pumps number chosen previously. A collection of specific Warning messages explains the reasons of incompatibilities or poor design.

The chosen Regulation strategy fixes the available set of control devices.

Eighth step:
You can open the Controller Device and check its parameters.

All system running specificities are defined in the Controller/Regulation device. This includes namely the boundary operating conditions (Tank full, dry running, Power, Voltage, Current limits, etc.)

Nineth step:
PV array design, number of modules in series/parallel.

For MPPT converter devices, the procedure is analogous to the design of grid connected systems: you can specify a planned power and PVsyst will propose a configuration (use the button "Resize" for a complete resizing). You have to choose a number of modules in series for which the Voc(Tmin) doesn't exceed the VmaxAbs of the converter, and the Vmpp(TOper) should not be under the VmppMin of the converter.

The number of strings is to adjust according to the power requirement of the pump in operating conditions. This is not always easy to obtain, due to constraints on the MPPT inputs of the real controllers.

Tenth step:
If no error appears in red, you are ready for the first simulation of your system.

2.2 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 2 buttons marked in red: "Orientation" and "Water needs". The red color means 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, Water needs, type and number of PV modules, type and number of pumps that will be used.
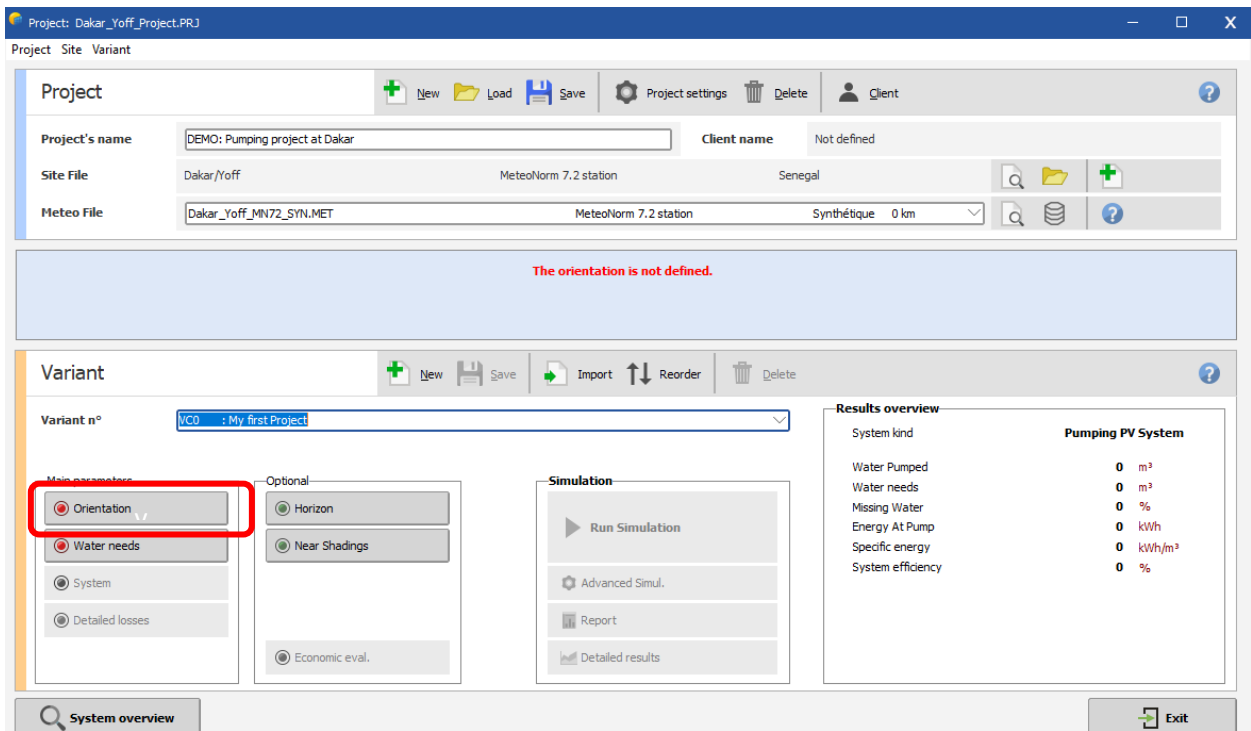

Figure 2: Variants to be defined

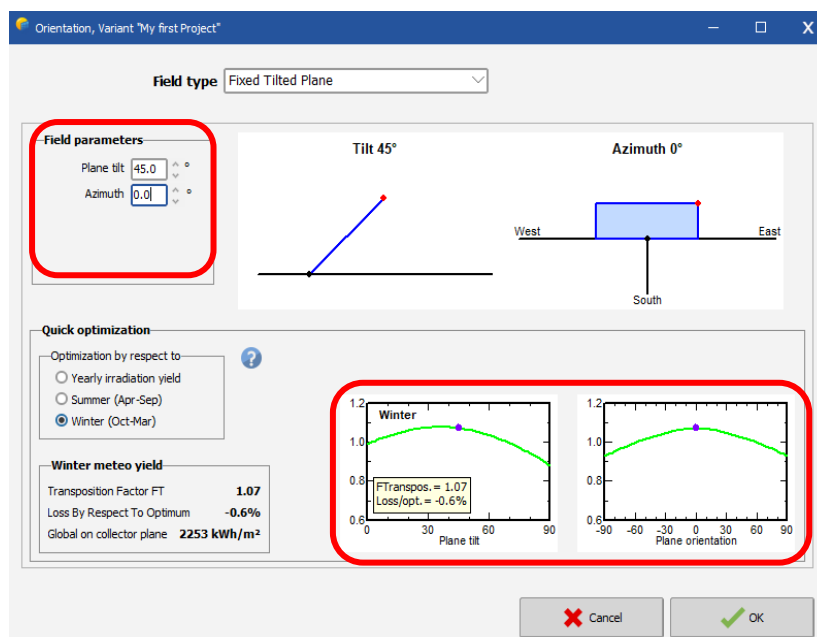Firstly, click on the "Orientation Button":

Figure 3: Orientation dialog.

This tool aims 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. Therefore, this tool gives the possibility to the optimizing 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 the "Show optimization" button, you can see a graph of the Transposition Factor in terms 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

2.3 Basic definition of Water needs

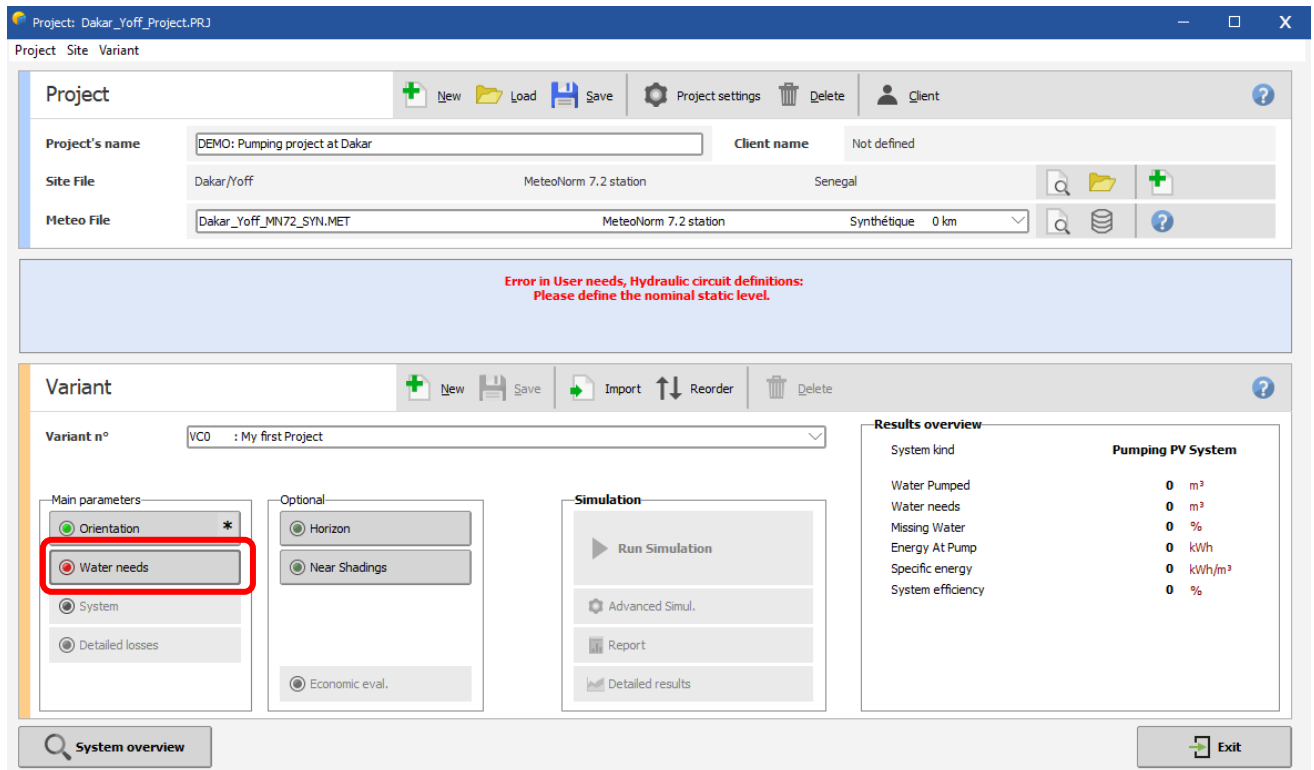To complete the Water needs, click on the "Water needs" tab.

Figure 4: Water needs button in the main dialog.

Once the "Water needs" menu is open, you must define:

- Pumping System Type:
  - Deep Well to Storage,
  - Lake or River to Storage,
  - Pressurization.
- Characteristics of well.
- Storage tank.
- Hydraulic circuit.
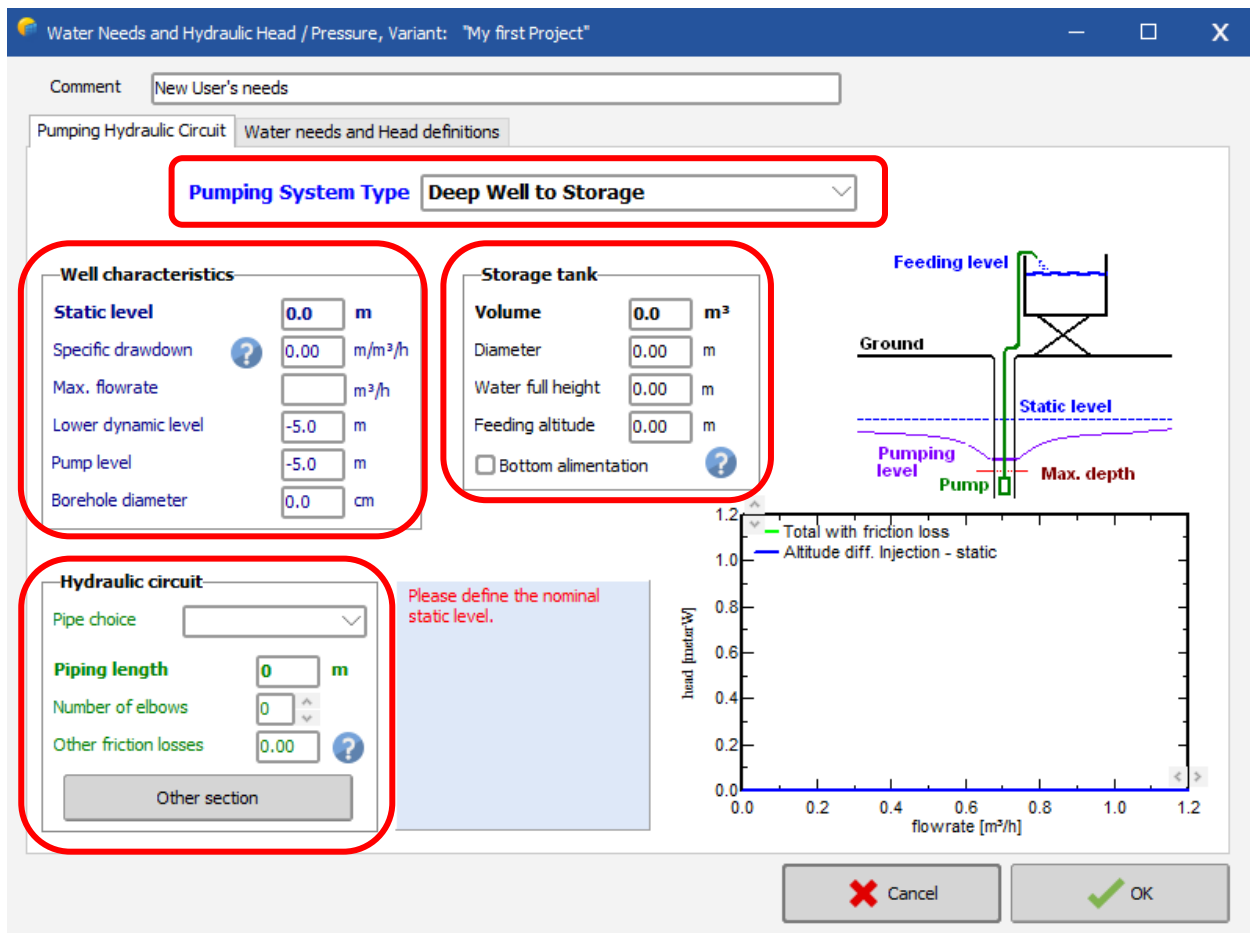- Water needs (next window).

Figure 5: List of parameters to be completed.

Here is the list of elements that you must fill in to continue the simulation.

- **Well Characteristics:**
  - Static Level
  - Drawdown or Max Flowrate

One of the two values will suffice, the other value will be automatically calculated by the software according to the following formula: Drawdown = (Lower Dynamic Level – Static Level) / Max. Flowrate

  - Lower dynamic level (will be calculated by software, if you modify the value, this will modify the value of Drawdown or Max Flowrate. The value of the lower dynamic level must always be greater than the value of the static level.
  - Pump Level
  - Borehole Diameter (not used in calculation or simulation)

Levels or distances in PVSYST are always relative to natural ground (TG).

- **Storage Tank:**
  - Volume
  - Diameter
  - Water full height (This value has for reference the bottom of the tank and not the natural ground)
  - Feeding Altitude (The injection height is important, especially if your tank is high. This will allow more pressure at the outlet of the tank)

- Hydraulic circuit
  - Pipe choice.
  - Piping length.
  - Number of elbows (can stay at "0" for the simulation).
  - Other friction losses (can stay at "0" for the simulation.

Now, you need to define the water needs. To do so, click on the "Water needs and Head definitions" tab.
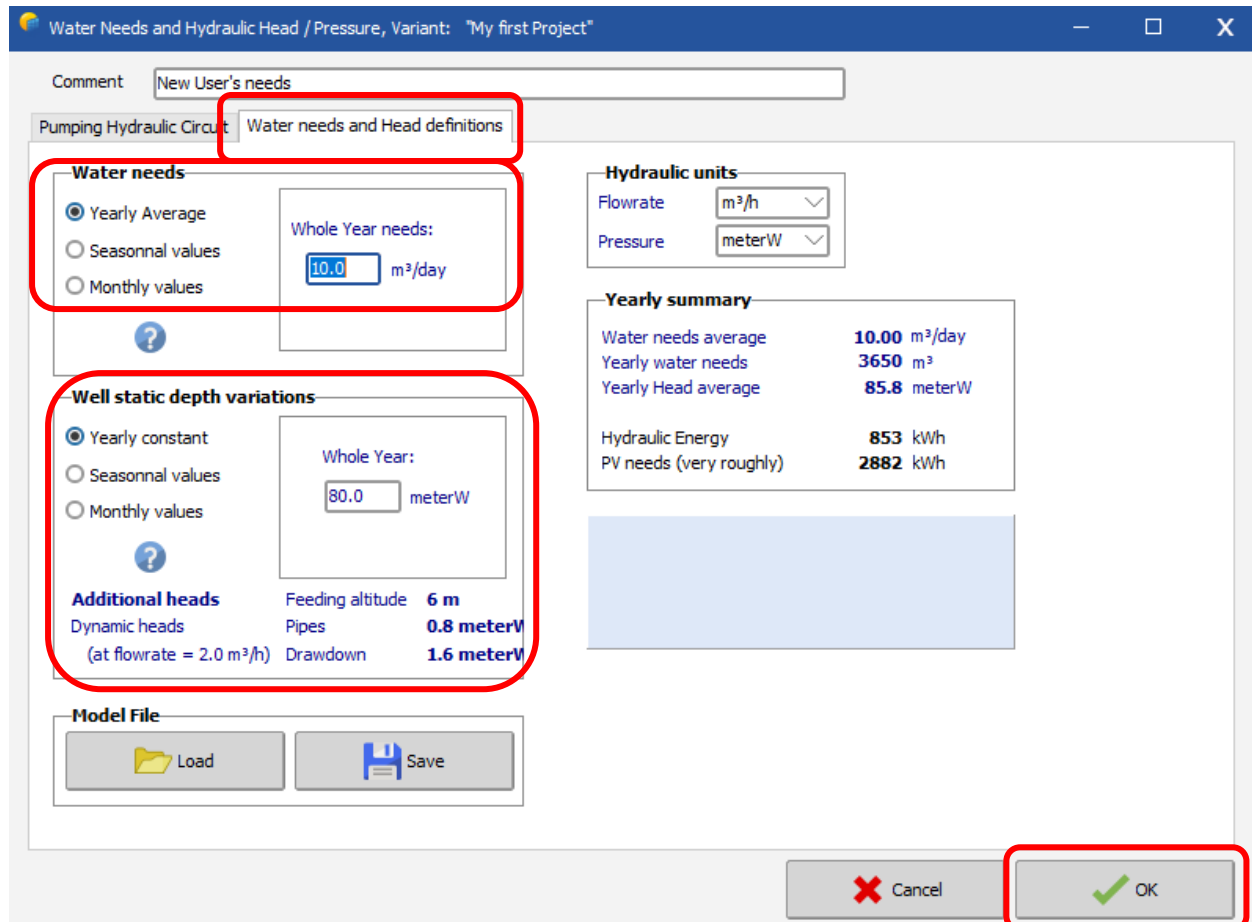

Figure 6: Water needs and hydraulic head parameters.

The water needs (volume of pumped water) may be specified yearly (constant value), or in monthly / seasonal values.

Specifying needs in terms of hourly values (daily distribution) does not make sense, as most of the time the pumping system includes a storage for at least one day of consumption.

NB: The pre-sizing part cannot take these variations into account and will be established using the yearly average.

Of course, the detailed simulation will rely on these specified values (monthly or seasonal) at each time step. You do not need to change the value of "well static depth variations", this value is the same as the static level in the "Pumping Hydraulic Circuit" tab.

2.4 Definition of system

We can now click on "System" to define:

- Pump technology / brand and reference.
- Technology / brand and reference of the photovoltaic field.
- Technology / brand and reference of the pumping regulation system.
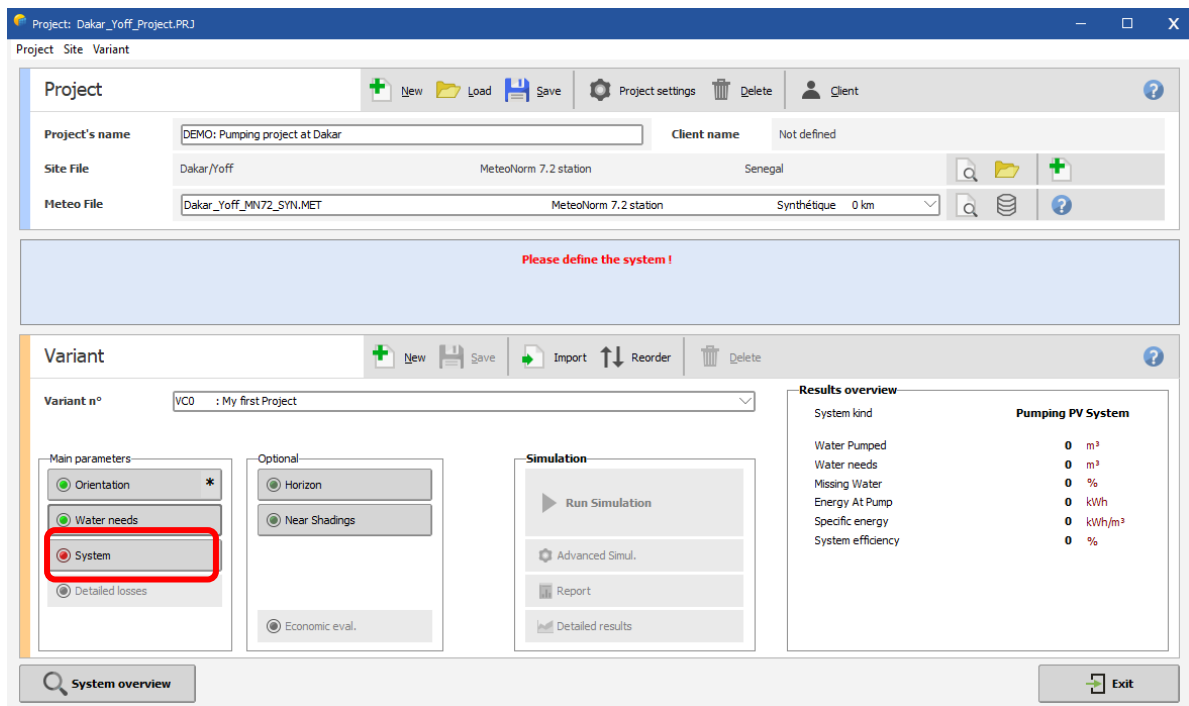

Figure 7: System definition.

In this first window, you will have to define the model and the number of pumps in your circuit.

You have the choice between several pump manufacturers, where you can choose between:

- Surface pump,
- Immersed pump,
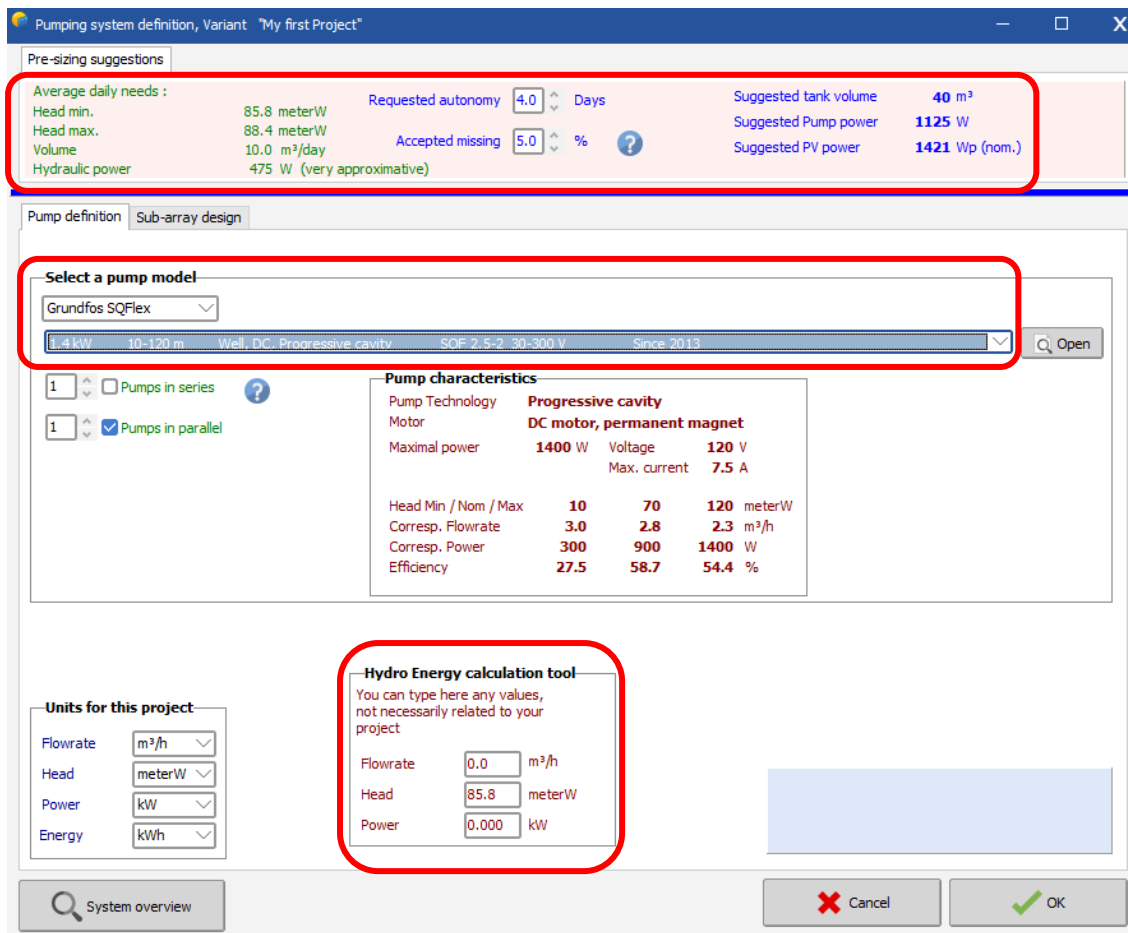- AC pump,
- DC pump,
- Etc….

Figure 8: Pre-sizing a pump.

The pre-sizing tool gives you advice based on your choices. Its results are not passed on to your system definition. You can play with it without interfering your system.

The Pre-Sizing tool calculates three pieces of information:

- suggested tank volume (calculated with the expected consumption and the requested range),
- suggested Pump power,
- suggested PV Power.

The "Accepted shortage" is the time during which the user accepts not to be satisfied (empty tank).

You can modify the autonomy and the "Accepted shortage" values according to the needs of your simulation. The modification of these values will automatically recalculate the three values suggested by the software.

Select a pump model:

To choose the most suitable pump for the characteristics of your system, the software will make a Pre-Selection. This selection is made according to the following characteristics:

- Total HMT (minimum and maximum),
- Flowrate,
- Drawdown.

The pumps in red are not compatible with your needs, the pumps in orange are compatible but do not fully meet your needs, the pumps in green are compatible and optimum.

Pumps in parallel and in series:

Either on the electric side or on the hydraulic side, you are advised to connect all the pumps in parallel.

For noy, PVsyst accepts electrical connections in series only for centrifugal pumps with DC motor. Other configurations do not make sense. The reasons are:

- On the electric side, connecting two positive displacement pumps in series will prevent good starting conditions; after one pump has started, overcoming its peak starting current, the current will suddenly drop to the operating value; therefore, the total current will be limited so that the second pump may never reach its own thresholds current.
- On the hydraulic side, it is probably not a good practice to connect two pumps in cascade for obtaining a higher head in the same flow, as non-linearities in the pump behavior, or electric feeding differences, may lead to very unbalanced heads. This is especially true for positive displacement pumps.

It is way better to choose a pump model that undertakes the nominal foreseen head.

Hydro Energy calculation tool:

This tool allows you to simulate the characteristics of a borehole (not necessarily related to your project).

In the second windows, you will have to define the model and the number of PV module and controller.
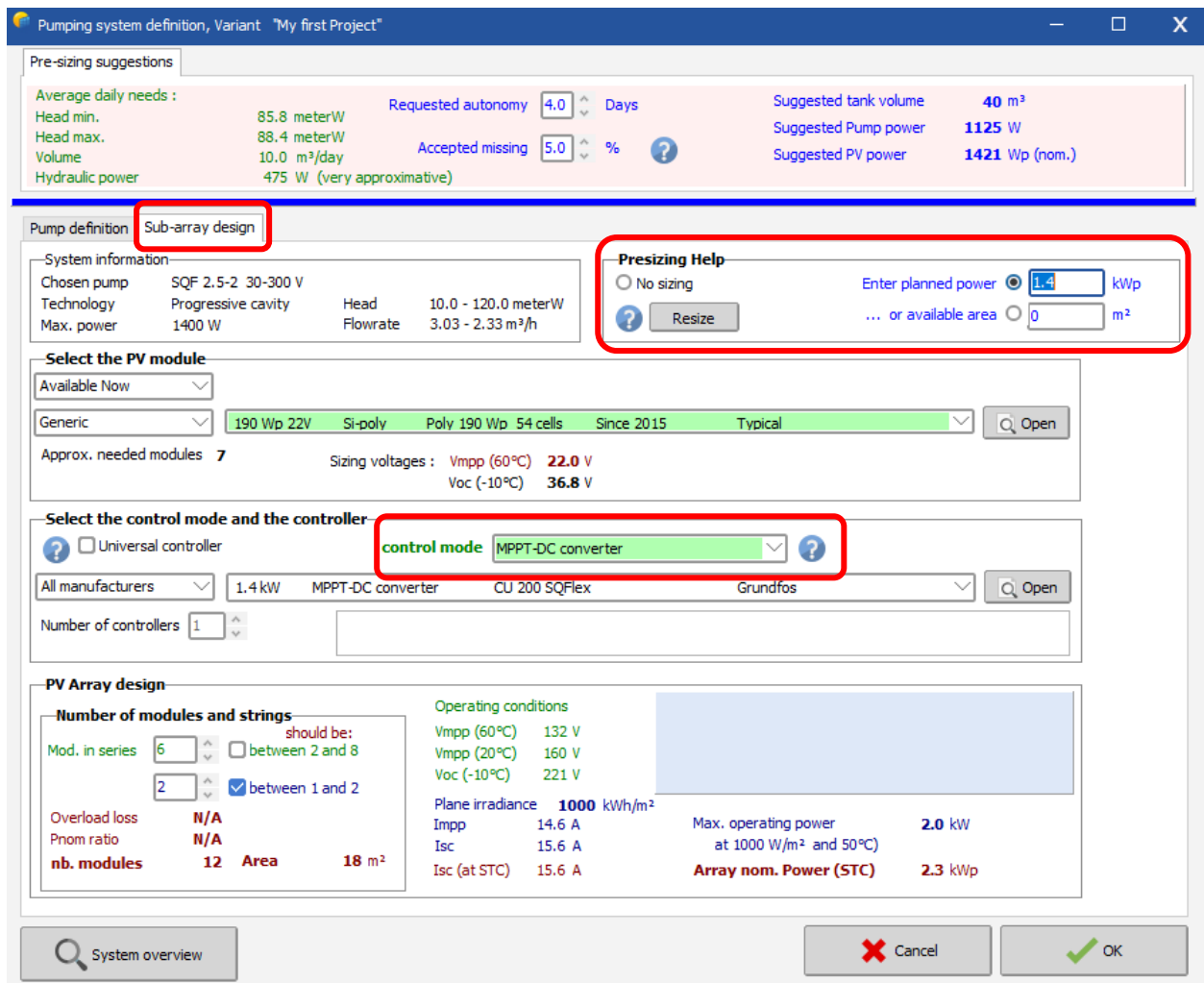
Figure 9: Sub-array design in pumping system definition.

PV array sizing 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.

Several system layouts and coupling strategies are possible:

- Direct coupling between the PV array and the pump(s), without power conversion unit.

    This is of course only possible with DC motor pump(s). Although sometimes used owing to its simplicity, this layout requires a very careful electrical optimization, and cannot yield a good efficiency in any operating conditions.

- Power conditioning: Device to adapt the PV Voltage/Current characteristics to the specific electrical needs of the pumps (the behavior of DC motors is mainly current driven) using modern electronic components. Such a device is of course necessary with AC pumps (inverter)

The direct coupling mode may be improved by several special regulation modes (very rarely used):

- Booster device, electronic device for overcoming high starting current due to friction losses
- Cascading when using several pumps.
- PV field reconfiguration, not common but rather simple technique involving simple controlling device with relays.
- Battery buffered systems, where a battery is used to regulate the pump running in time. The PV Battery behaves like a standard standalone system, and the pump is always running in optimal conditions at the nominal battery voltage.

You can have a look at the simulation Results to compare the performances of these operating strategies.

In modern practice, the direct coupling mode is no longer used. There is always an electronic device to adapt the power supplied by the collector field to the power needed by the pump (AC or DC).

Controller + Power Conditioning

In fact, even the simplest configurations (direct coupling) require the presence of a control device, which should at least assume the following functions:

- Manual Power ON/OFF,

- Pump OFF when tank is full,

- Pump OFF when aspiration level is below the pump inlet (preventing dry running),

- Eventually motor temperature protection,

- Protection against powers, currents or voltages which overcome the maxima specified for the pump(s).

The sizing constraints depend substantially on the system layout.

2.5 Executing the first simulation

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

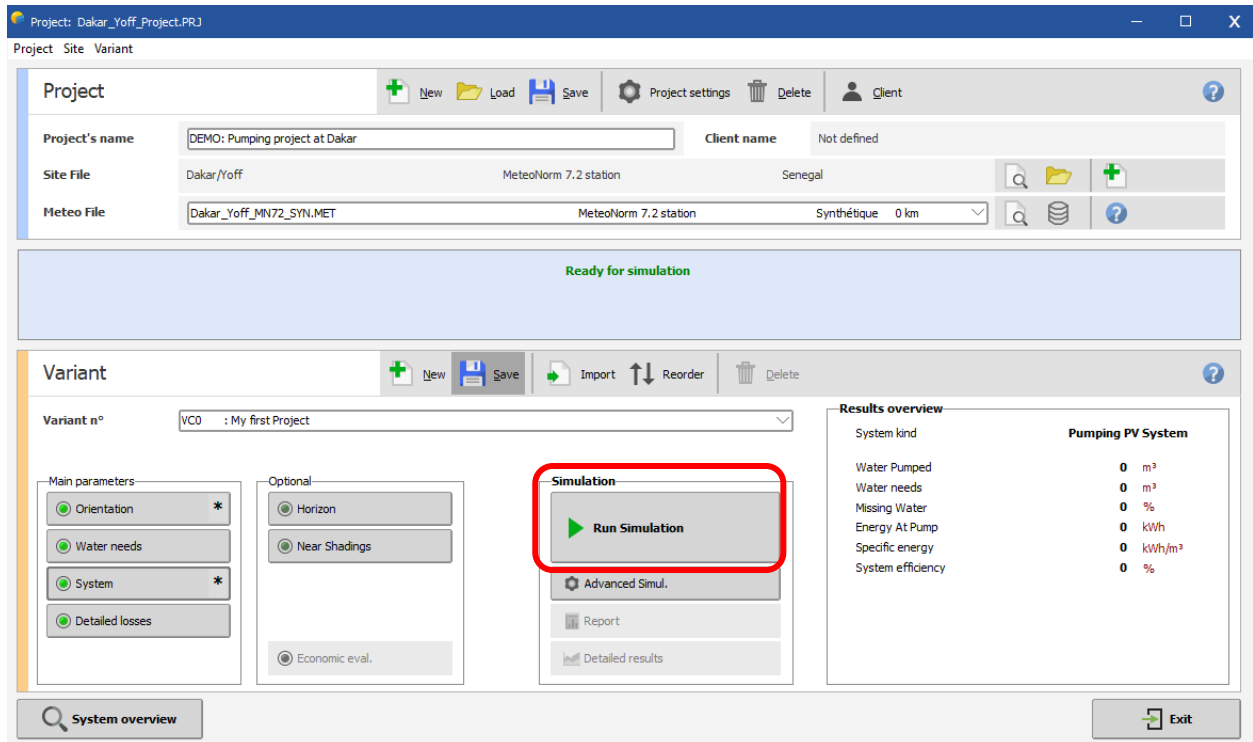The "Simulation" button is activated, and we can click on it.

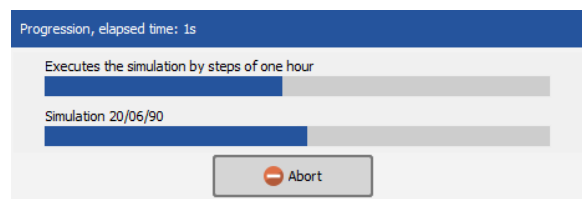*Figure 10: Project page when ready to run simulation.*

Figure 11: 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 active. When you click on it, you will get directly to the "Results" dialog
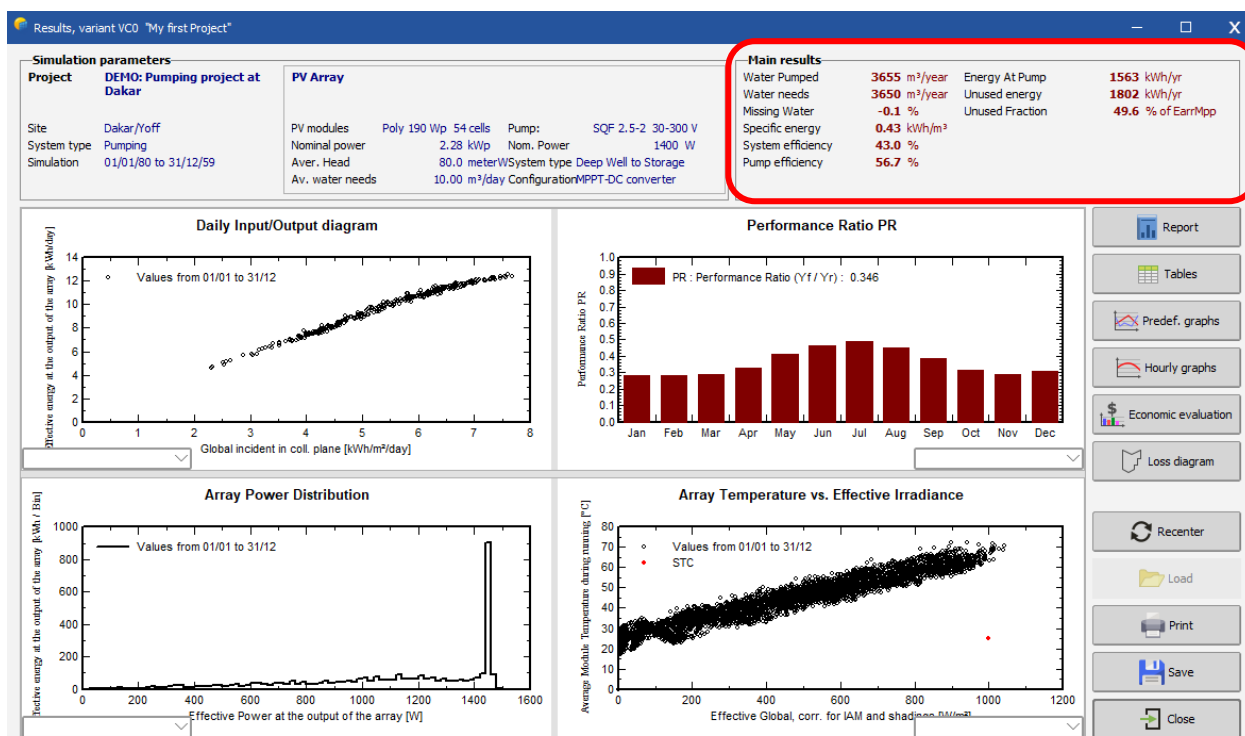
Figure 12: Results dialog.

This dialog shows a small summary of the simulation parameters on the top. Check quickly to make sure that you made no obvious mistake in the input parameters.

On the bottom is a frame with nine values that summarizes the main results of the simulation at one glance. This only gives a very rough picture of the results and is there to quickly spot obvious mistakes or to get a first impression of a change or a comparison between variants of the project.

The simulation report will give a complete description of your system, with all the parameters used and the results.

The "loss diagram" at the end of the report allows a detailed analysis of the actual operation of the system throughout the year and a thorough check of its sizing. Here are some examples of loss diagrams:

Example 1:

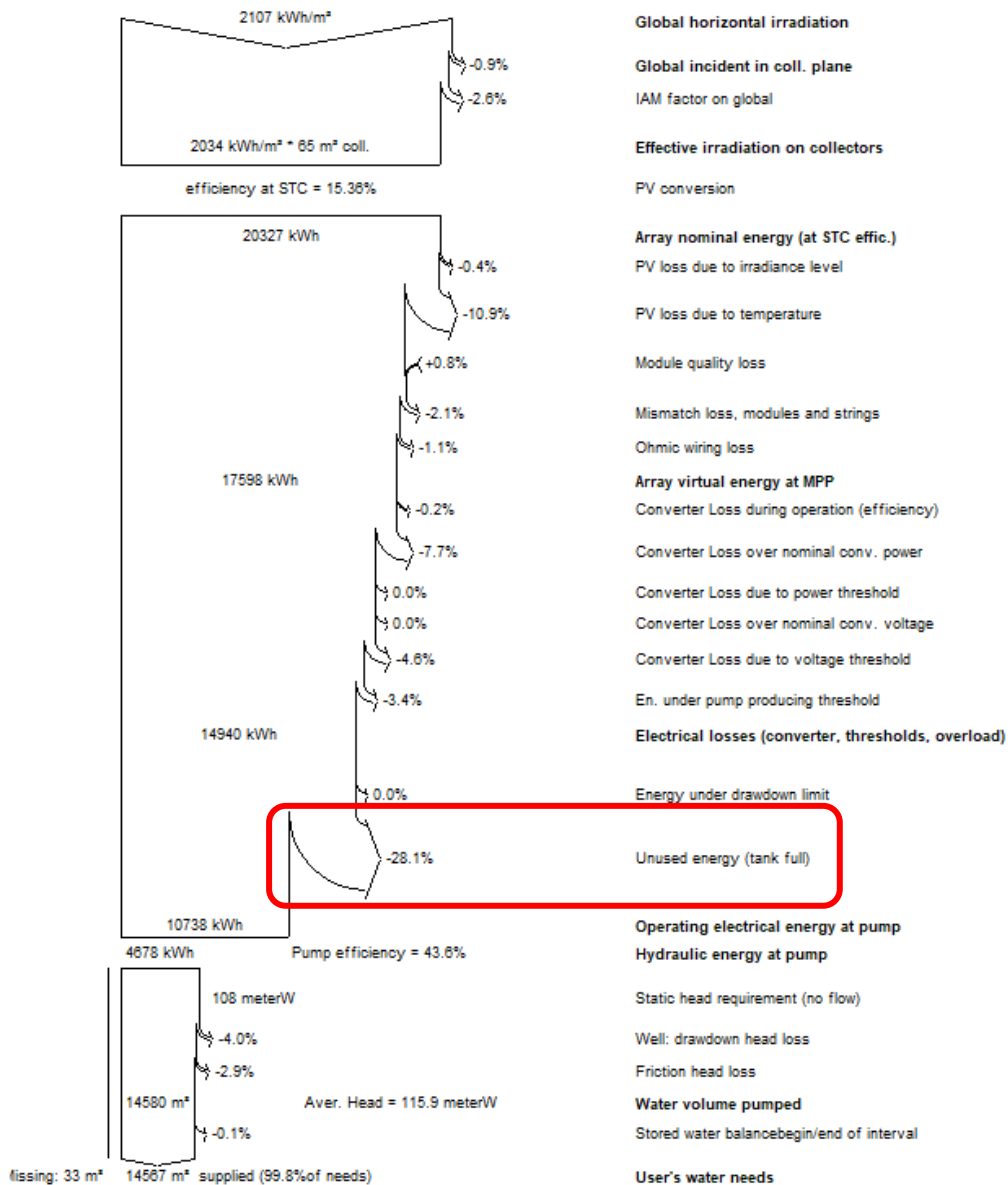|	
2107 kWh/m²	**Global horizontal irradiation**
-0.9%	**Global incident in coll. plane**
-2.6%	IAM factor on global
2034 kWh/m² * 65 m² coll.	**Effective irradiation on collectors**
efficiency at STC = 15.36%	PV conversion
20327 kWh	**Array nominal energy (at STC effic.)**
-0.4%	PV loss due to irradiance level
-10.9%	PV loss due to temperature
+0.8%	Module quality loss
-2.1%	Mismatch loss, modules and strings
-1.1%	Ohmic wiring loss
17598 kWh	**Array virtual energy at MPP**
-0.2%	Converter Loss during operation (efficiency)
-7.7%	Converter Loss over nominal conv. power
0.0%	Converter Loss due to power threshold
0.0%	Converter Loss over nominal conv. voltage
-4.6%	Converter Loss due to voltage threshold
-3.4%	En. under pump producing threshold
14940 kWh	**Electrical losses (converter, thresholds, overload)**
0.0%	Energy under drawdown limit
-28.1%	Unused energy (tank full)
10738 kWh	**Operating electrical energy at pump**
4678 kWh Pump efficiency = 43.6%	**Hydraulic energy at pump**
108 meterW	Static head requirement (no flow)
-4.0%	Well: drawdown head loss
-2.9%	Friction head loss
14580 m³ Aver. Head = 115.9 meterW	**Water volume pumped**
-0.1%	Stored water balance begin/end of interval
Missing: 33 m³ 14567 m³ supplied (99.8% of needs)	**User's water needs**

Figure 13: Loss diagram example 1.

In this loss diagram, we see an energy loss of 28.1% with the label "Unused energy (tank full)".

This loss is present when:

- The water tank is undersized,
- or the PV field is oversized,
- or the water demand is low compared to the simulated system.

This loss is normal. Sunshine conditions and water requirements can change throughout the year. In order to satisfy the user, it is necessary to size the system with conditions less favorable than a full sun. There will inevitably be times during the year when the production will be more than sufficient.
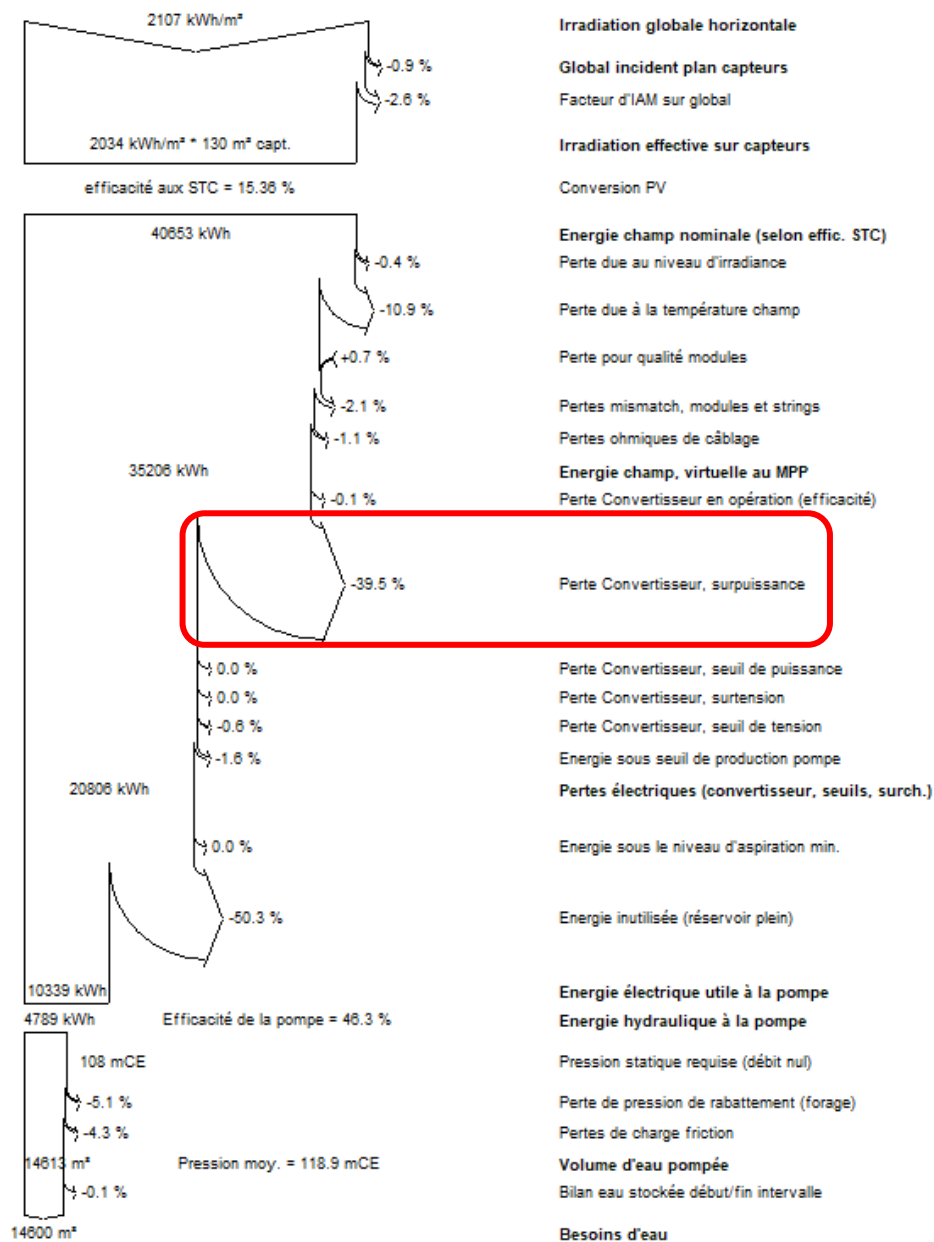
Example 2:

Figure 14: Loss diagram example 2.

In this loss diagram, we see an energy loss of 39.5% with the name "Converter loss, overpower".

This loss is present when:

- The power of the PV array at certain times of the day is higher than the max power of the pump controller (characteristic of an oversized PV array).
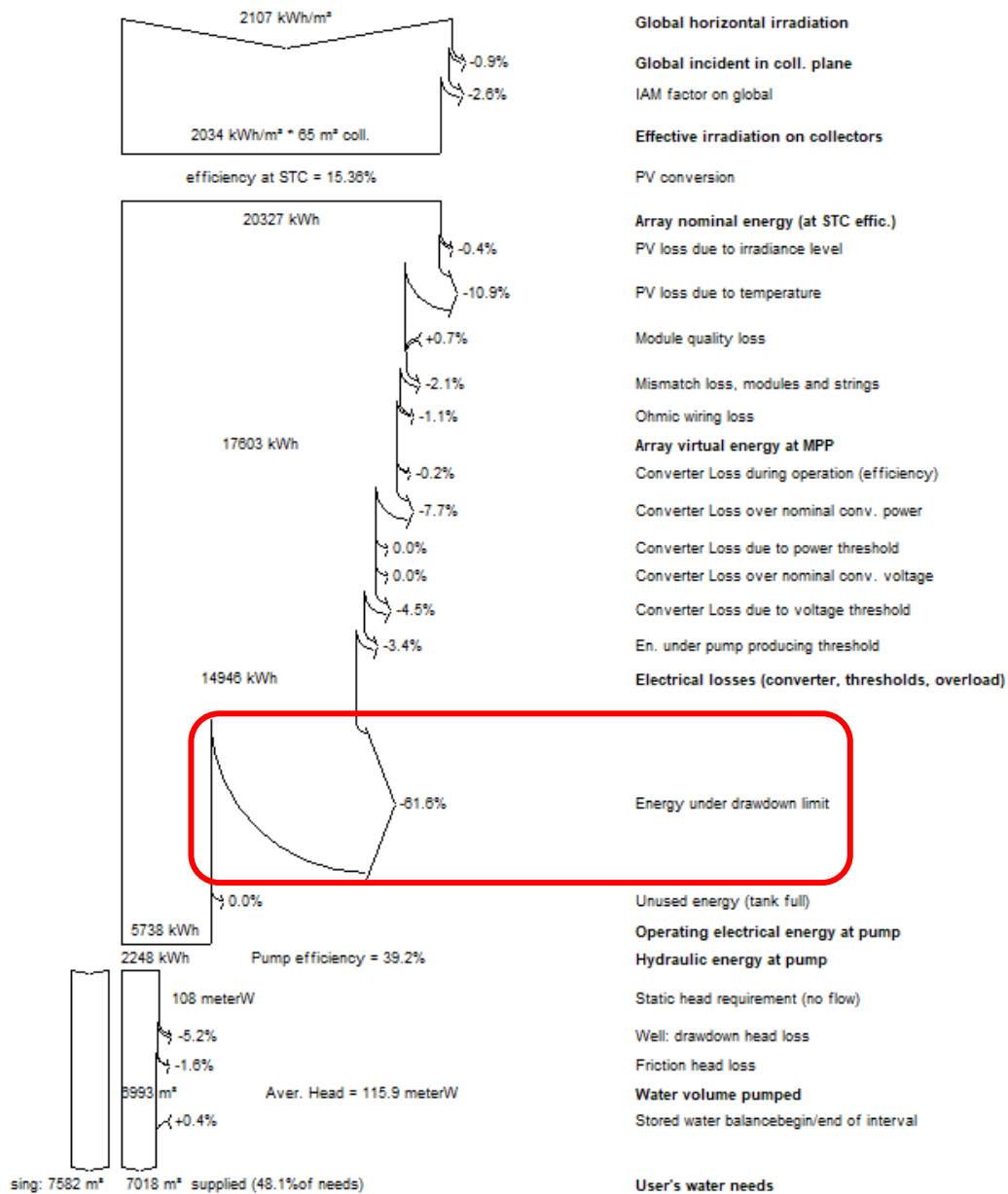
Example 3:

Figure 15: Loss diagram example 3

In this loss diagram, we see an energy loss of 61.6% with the label "Energy below min. suction level".

This loss is present when:

- The pump has a flow rate that is too high compared to the drawdown of your well. The dynamic level is therefore below the suction strainer. The pump stops for safety thanks to the lack of water sensor in the well

To analyze the loss diagrams in more detail, you can view them in monthly values.

2.6 Conclusion

In this document, we demonstrated how to create your first project on pumping systems starting by describing the isolate and conventional pumping systems, followed by a step-by-step guide on creating variants to the project, defining the water needs and the system, executing the simulation and rounding it up with analyzing the results with a few examples given.