

**UNIVERSIDAD DE VALLADOLID**

International Semester in Industrial Engineering

Academic Year 2022/2023

**The Environment and Renewable Energy**



**GRID CONNECTED PVSyst PROJECT REPORT**

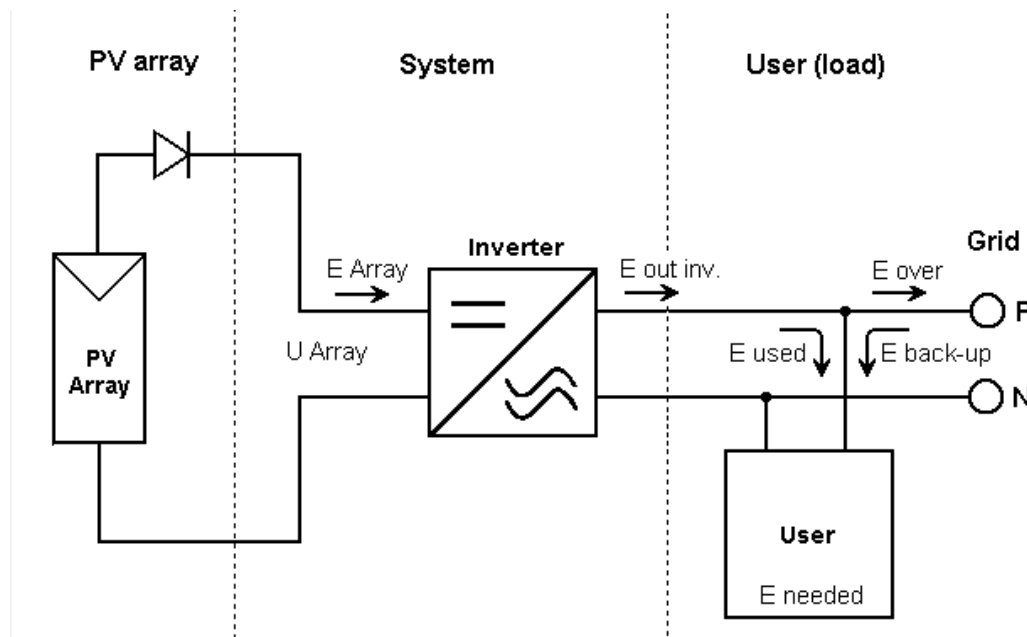
**Student:** BENIAMINO FRACCHIOLLA

## ABSTRACT

The main objective of this exercise is to design two grid connected photovoltaic systems using the PVSYST software. The first located in IndUva Building, Valladolid and the second located in our own country Bari, Italy.

The two projects will have a planned power of 55kWp and the orientation of the PV modules will be the best for the different location. To compare the performances of the two installation PV panel model and inverter model was already given. In addition will be taken in account losses to obtain more realistic results.

In the case of a grid connected system, of which scheme is shown following, it will be simpler than a grid connected one because it does not need batteries or charge controller:



The previous image will be the configuration used in these two projects.

This report is divided, as follows, in three parts:

1. **Inputs of first report**
2. **Procedure of first report**
3. **Inputs of second report**
4. **Procedure of second report**
5. **Outputs**

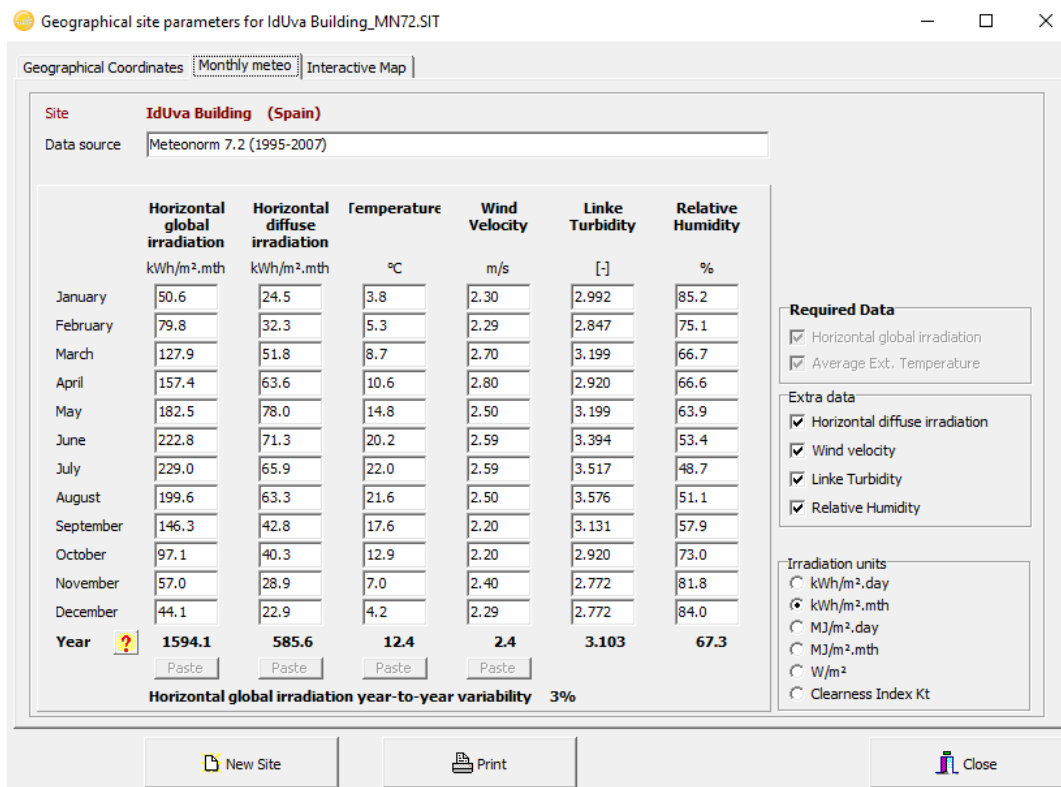
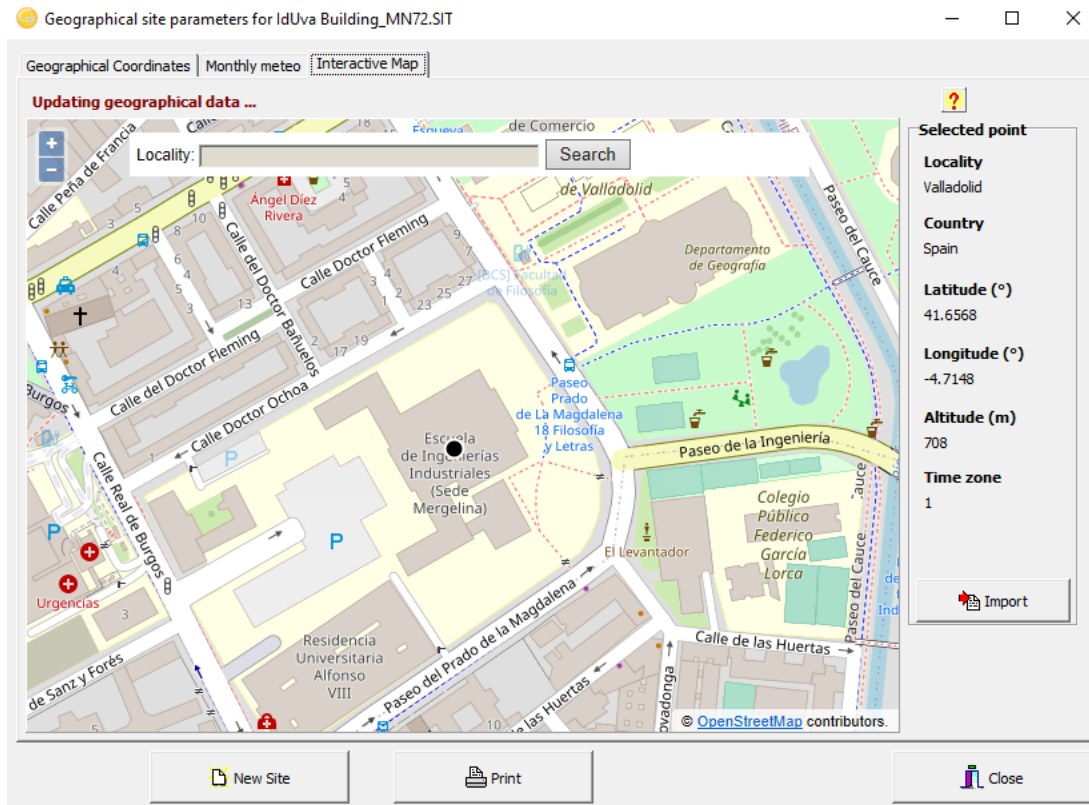
Every part shown will explored in the following report.

## INPUTS OF THE FIRST REPORT

1. **Location:** the location was set in IndUva Building, the university of Valladolid, and the meteorological values are already provided by the map of PVSyst.
2. **PV system components:** as an overview the system will include PV modules and inverter taken from database.
3. **User's needs:** a planned power of 55kWp.

## PROCEDURE OF THE FIRST REPORT

1. Set the project's destination (Name, Geographical location and weather file): in this case the building location was not already present into the database. So, it was added during the simulation as new site;



2. *Set the orientation of the PV module:* as specified before the tilt and azimuth angle will be taken as the optimal, as optimization method was chosen the one that take an average between winter and summer needs (called: *yearly irradiation yield*) this because a grid connected system aims to produce all the possible energy and feed the electrical grid and not perfectly satisfy a building demand;

Orientation, Variant "New simulation variant"

Field type: Fixed Tilted Plane

**Field parameters**

Plane Tilt: 34.8 [°]  
Azimuth: 0.0 [°]

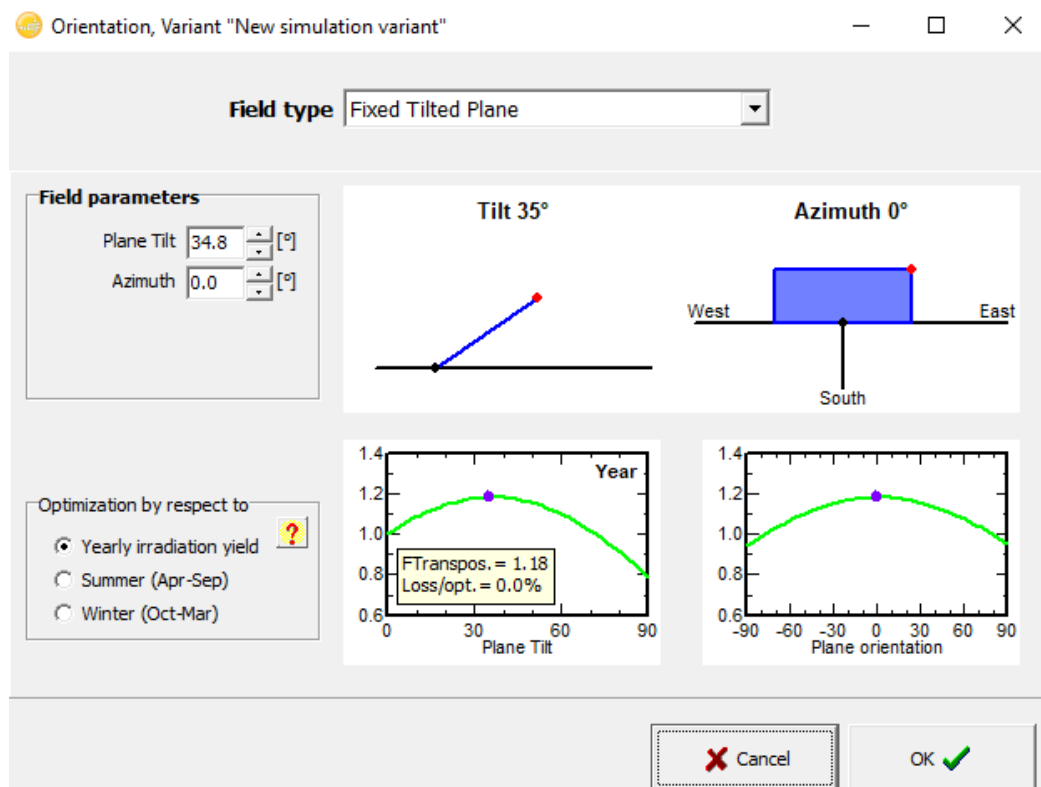
Optimization by respect to:  
☒ Yearly irradiation yield  
☐ Summer (Apr-Sep)  
☐ Winter (Oct-Mar)

**Yearly meteo yield**

Transposition Factor FT: 1.18  
Loss By Respect To Optimum: 0.0%  
Global on collector plane: 1883 kWh/m<sup>2</sup>

Show Optimization

Cancel OK



- Set the user's need: in this case a planned power of 55kWp.

Presizing Help

☐ No sizing      Enter planned power  kWp

☒  ... or available area(modules)  m²

Set the system in terms of: array and pre-sizing of inverter, define system components and define losses;

- Array and inverter pre-sizing:* typically, there is an oversizing of the PV panels' total power respect to inverter power about 10-20% because inverter allows overload. In the first time the inverter was selected as an intersection of its operative voltage with the voltage of an array of PV panels in serial connection ( $V_{mpp}$  20 Celsius degree).

After this, the minimum voltage of a single array dependent on the higher temperature of the location ( $V_{mpp}$  60 Celsius degree) and it has to be higher respect the minimum voltage of the inverter

The maximum voltage of a single array dependent on the minimum temperature of the location ( $V_{oc}$  -10 Celsius degree) and it has to be lower than input maximum voltage of the inverter;

- Define system component:*

Chosen inverter	It was given, this to have a low number of degrees of freedom in the problem
Chosen PV	It was given, this to have a low number of degrees of freedom in the problem

So, as follows:

Grid system definition, Variant "New simulation variant"

**Global System configuration**

1 Number of kinds of sub-arrays

**Global system summary**

Nb. of modules	165	Nominal PV Power	56.1 kWp
Module area	329 m²	Maximum PV Power	54.4 kWdc
Nb. of inverters	1	Nominal AC Power	50.0 kWac

**PV Array**

**Sub-array name and Orientation**

Name: PV Array

Orient: Fixed Tilted Plane

Tilt: 35°

Azimuth: 0°

**Select the PV module**

Available Now Filter: All PV modules

Approx. needed modules: 162

Hanwha Q Cells 340 Wp 32V Si-poly Q.PLUS L-G4.1 340 Since 2016 Manufacturer 2017

Sizing voltages:  $V_{mpp}$  (60°C) 32.5 V

$V_{oc}$  (-10°C) 52.2 V

**Select the inverter**

All inverters Output voltage 400 V Tr 50Hz

Ingeteam 50 kW 405 - 750 V LF Tr 50/60 Hz Ingecon Sun 50 Until 2013

Nb. of inverters: 1

Operating Voltage: 405-750 V

Input maximum voltage: 900 V

Global Inverter's power: 50.0 kWac

**Design the array**

**Number of modules and strings**

Mod. in series: 15 between 13 and 17

Nbre strings: 11 between 10 and 11

Overload loss: 0.0 %

$P_{nom}$  ratio: 1.12

Nb. modules: 165 Area: 329 m²

**Operating conditions**

$V_{mpp}$ (60°C)	487 V
$V_{mpp}$ (20°C)	578 V
$V_{oc}$ (-10°C)	782 V

Plane irradiance: 1000 W/m²

Imp (STC): 98.9 A

Isc (STC): 105 A

Isc (at STC): 105 A

Max. operating power at 1000 W/m² and 50°C: 50.5 kW

Array nom. Power (STC): 56.1 kWp

System overview

Cancel OK

6. Define losses: will be taken in account losses to obtain more realistic results, such as the following. They will be explained losses that were added on standard losses during simulation classroom:

PV field detailed losses parameter

Ageing	Unavailability		Spectral correction		
Thermal parameter	Ohmic Losses	Module quality - LID - Mismatch	Soiling Loss	IAM Losses	Auxiliaries
<p>You can define either the Field thermal Loss factor or the standard NOCT coefficient: the program gives the equivalence !</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><b>Field Thermal Loss Factor</b></p> <p>Thermal Loss factor <math>U = U_c + U_v \cdot \text{Wind vel}</math></p> <p>Constant loss factor <math>U_c</math> <input type="text" value="29.0"/> W/m²K <span>?</span></p> <p>Wind loss factor <math>U_v</math> <input type="text" value="0.0"/> W/m²K / m/s</p> <p><b>Default value acc. to mounting</b></p> <p><input checked="" type="checkbox"/> Free* mounted modules with air circulation</p> <p><input type="checkbox"/> Semi-integrated with air duct behind</p> <p><input type="checkbox"/> Integration with fully insulated back</p> </div> <div style="width: 45%;"> <p><b>NOCT equivalent factor</b></p> <p>NOCT (Nominal Operating Cell temperature) is often specified by manufacturers for the module itself. This is an alternative information to the U-value definition which doesn't make sense when applied to the operating array.</p> <p><b>Don't use the NOCT approach. This is quite confusing when applied to an array !</b></p> <p><span>See the NOCT anyway</span> <span>?</span></p> </div> </div>					
<p><span>Losses graph</span> <span>Cancel</span> <span>OK</span></p>					

*Thermal parameter:* to take in account the type of the installation. A “free mounted” installation means that there is enough space under the PV panel to allow air flow and the best dissipation of heat than others mounting system.

PV field detailed losses parameter

Ageing	Unavailability		Spectral correction		
Thermal parameter	Ohmic Losses	Module quality - LID - Mismatch	Soiling Loss	IAM Losses	Auxiliaries
<p><b>DC circuit: ohmic losses for the array</b></p> <p><b>Specified by</b></p> <p><input type="radio"/> Global wiring resistance <input type="text" value="85.8"/> mOhm <input type="checkbox"/> Calculated <span>Detailed computation</span></p> <p><input checked="" type="radio"/> Loss fraction at STC <input type="text" value="1.50"/> % <input checked="" type="checkbox"/> Default <span>?</span></p> <p>Voltage Drop across series diode <input type="text" value="0.7"/> V <input checked="" type="checkbox"/> Default</p>					
<p><b>AC losses after the inverter (Full system)</b></p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><b>AC circuit: inverter to injection point</b></p> <p><input type="checkbox"/> Significant length, to be accounted for</p> <p>Length Inverter to injection <input type="text" value="0.0"/> m <span>?</span></p> <p>Loss fraction at STC <input type="text" value="0.00"/> %</p> <p>Voltage drop at STC 5.2 V</p> </div> <div style="width: 45%;"> <p><b>External transformer</b></p> <p><input type="checkbox"/> External transformer present default</p> <p>Iron loss (constant value) <input type="text" value="0.00"/> % <input type="text" value="0.00"/> kW <input type="checkbox"/></p> <p>Resistive/Inductive losses <input type="text" value="0.00"/> % at STC <input type="checkbox"/></p> <p>(quadratic, <math>R \propto I^2</math>, <math>R = 0.0</math> mOhm <span>?</span>)</p> <p><input type="checkbox"/> Night disconnect</p> </div> </div>					
<p><span>Losses graph</span> <span>Cancel</span> <span>OK</span></p>					

*Voltage drops across series diode:* Each diode causes a voltage drop of almost 0.7 Volt. Diodes are typically used to transport electricity from one string to another.

PV field detailed losses parameter

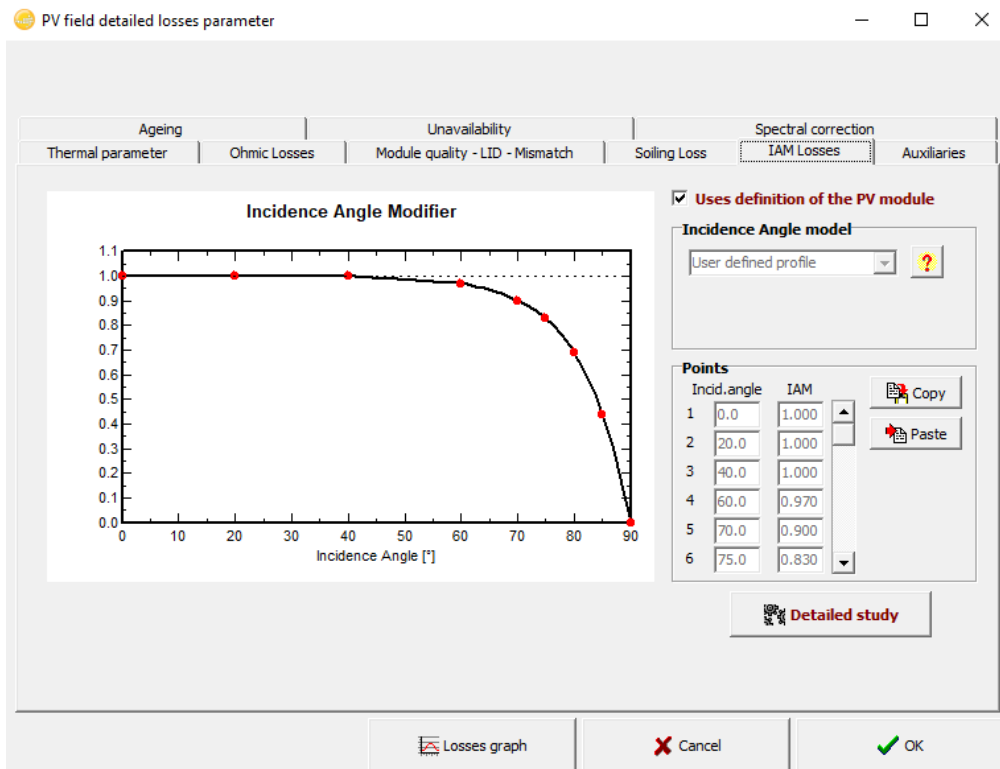
Ageing		Unavailability		Spectral correction	
Thermal parameter	Ohmic Losses	Module quality - LID - Mismatch	Soiling Loss	IAM Losses	Auxiliaries
<b>Module quality</b> default Module efficiency loss <input type="text" value="3.0"/> % <input checked="" type="checkbox"/> Deviation of the average effective module efficiency with respect to manufacturer specifications. ?		<b>Module Mismatch Losses</b> default Power Loss at MPP <input type="text" value="1.0"/> % <input checked="" type="checkbox"/> Loss when running at fixed voltage <input type="text" value="2.5"/> % <input checked="" type="checkbox"/> Not relevant when MPPT operation Detailed computation ?			
<b>LID - Light Induced Degradation</b> default LID loss factor <input type="text" value="2.0"/> % <input checked="" type="checkbox"/> Degradation of crystalline silicon modules, in the first operating hours by respect to the manufacturing flash test STC values. ?		<b>Strings voltage mismatch</b> Default Power Loss at MPP <input type="text" value="0.1"/> % <input checked="" type="checkbox"/> Detailed study ?			
		<input type="button" value="Losses graph"/> <input type="button" value="Cancel"/> <input type="button" value="OK"/>			

*Light Induced Degradation:* as is already shown from the software, take in account the degradation of crystalline silicon modules in the first operating hours by respect to manufacturing test in standard test condition.

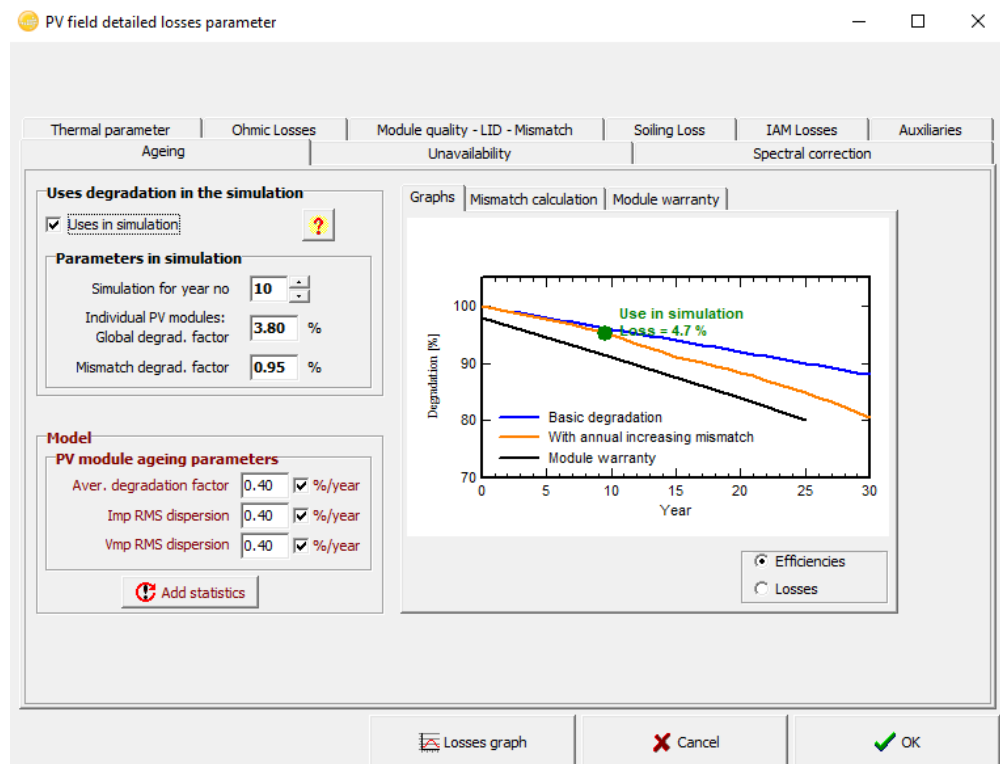
PV field detailed losses parameter

Ageing		Unavailability		Spectral correction	
Thermal parameter	Ohmic Losses	Module quality - LID - Mismatch	Soiling Loss	IAM Losses	Auxiliaries
<b>Yearly soiling loss factor</b> Default Yearly loss factor <input type="text" value="3.0"/> % <input checked="" type="checkbox"/> <input type="checkbox"/> Define monthly values ?					
		<input type="button" value="Losses graph"/> <input type="button" value="Cancel"/> <input type="button" value="OK"/>			

*Yearly soiling loss factor:* to take in account accumulation of dirt and its effect on the system performance of the PV panel.



*Incidence Angle Modifier*: to take in account the incidence effect corresponds to the decrease of the irradiance really reaching the PV cells' surface, with respect to irradiance under normal incidence. This decrease is mainly due to reflections on the glass cover, which increases with the incidence angle.



*Ageing*: to take in account the lost of the performance of the PV panel as time goes by. The simulation will be performed after 10 years of usage of the panel.



PV field detailed losses parameter

Thermal parameter | Ohmic Losses | Module quality - LID - Mismatch | Soiling Loss | IAM Losses | Auxiliaries



Ageing | Unavailability | Spectral correction

**Unavailability of the system** default

Unavailability time fraction  % ☒ default




Unavailability duration  days/yr

Number of periods

 Set Random 

**Unavailability periods**

Beginning Date / Hour	duration
29/04/1990 20:00	58 hour
19/08/1990 17:00	58 hour
28/11/1990 19:00	58 hour


 Losses graph  Cancel  OK

*Unavailability of the system:* to take in account the time while panels will be turned off for maintenance operations.

PV field detailed losses parameter

Thermal parameter | Ohmic Losses | Module quality - LID - Mismatch | Soiling Loss | IAM Losses | Auxiliaries

Ageing | Unavailability | Spectral correction

☒ Use spectral correction in simulation 

**FirstSolar model**




☒ According to PV module technology

Coefficient	Value
C0:	0.8409000
C1:	-0.0275390
C2:	-0.0079224
C3:	0.1357000
C4:	0.0380240
C5:	-0.0021218

Coefficient Set  Default ☒

**Meteo input** Relative humidity is available in the Meteo variables. It will be used to estimate the precipitable water column

**PV modules** PV module model: Q.PLUS L-G4.1 340

 Losses graph  Cancel  OK

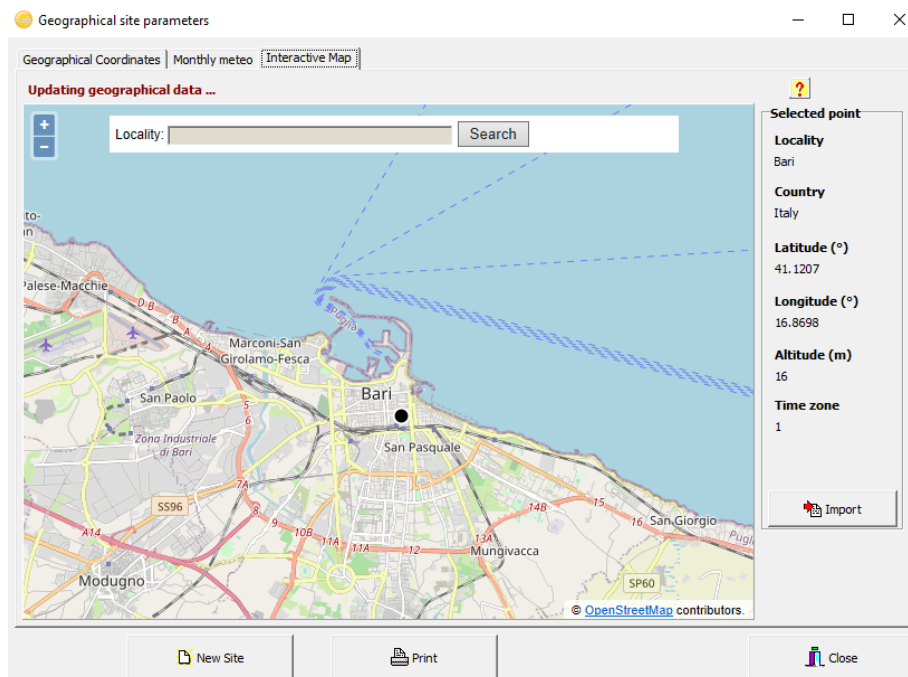
*Spectral correction:* to take in account changes in the solar spectrum due to scattering and absorption in the atmosphere that changes its characteristics.

## INPUTS OF THE SECOND REPORT

1. Location: the location was set in Bari, the bigger country in the South of the Italy, and the meteorological values are already provided by the map of PVSyst.
2. PV system components: as an overview the system will include PV modules and inverter taken from database.
3. User's needs: a planned power of 55kWp.

## PROCEDURE OF THE SECOND REPORT

1. *Set the project's destination (Name, Geographical location and weather file):* in this case country was not already present into the database. So, it was added during the simulation as new site;



	Horizontal global irradiation kWh/m².mth	Horizontal diffuse irradiation kWh/m².mth	Temperature °C	Wind Velocity m/s	Linke Turbidity [-]	Relative Humidity %
January	61.2	27.4	8.0	3.29	2.645	73.0
February	72.7	31.7	8.0	3.49	2.866	69.5
March	122.6	54.1	11.1	3.40	3.008	67.2
April	161.1	62.2	13.6	3.20	3.209	70.8
May	209.5	74.7	18.9	3.10	3.399	66.2
June	219.4	81.7	22.7	3.09	3.399	64.4
July	236.0	62.4	25.7	3.50	3.399	59.1
August	201.8	60.8	25.2	3.10	3.459	63.1
September	148.8	50.4	20.4	3.20	3.143	70.2
October	109.2	38.9	17.0	2.90	3.008	74.1
November	68.9	29.2	12.5	3.10	2.866	74.3
December	53.0	22.7	9.3	3.19	2.720	75.4
Year	1664.2	596.2	16.0	3.2	3.093	68.9

Horizontal global irradiation year-to-year variability 4.7%

2. Set the orientation of the PV module: as specified before the tilt and azimuth angle will be taken as the optimal, as optimization method was chosen the one that take an average between winter and summer needs (called: *yearly irradiation yield*) this because a grid connected system aims to produce all the possible energy and feed the electrical grid and not perfectly satisfy a building demand;

Orientation, Variant "New simulation with losses"

Field type: Fixed Tilted Plane

**Field parameters**

Plane Tilt: 38.0 [°]  
Azimuth: 0.0 [°]

**Optimization by respect to**

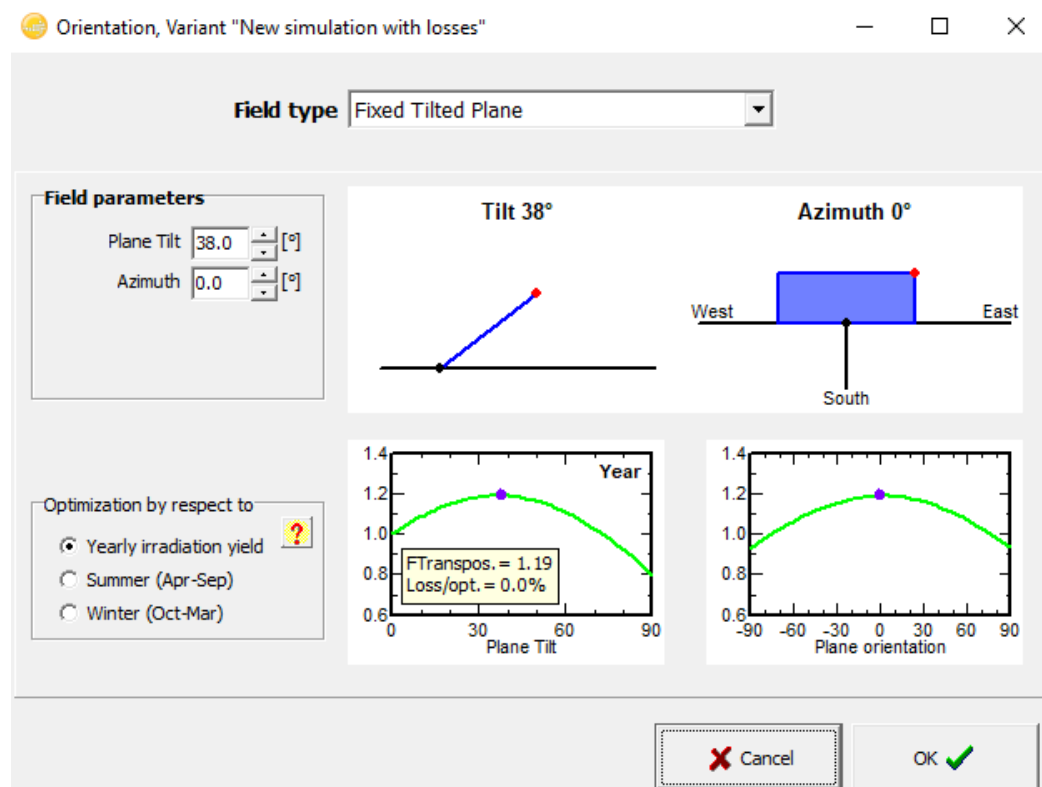
☒ Yearly irradiation yield ?  
☐ Summer (Apr-Sep)  
☐ Winter (Oct-Mar)

**Yearly meteo yield**

Transposition Factor FT: 1.19  
Loss By Respect To Optimum: 0.0%  
Global on collector plane: 1979 kWh/m<sup>2</sup>

Show Optimization

Cancel OK



- Set the user's need: in this case a planned power of 55kWp.

Presizing Help

☐ No sizing      Enter planned power  kWp

☒  ... or available area(modules)  m²

Set the system in terms of: array and pre-sizing of inverter, define system components and define losses;

- Array and inverter pre-sizing:* typically, there is an oversizing of the PV panels' total power respect to inverter power about 10-20% because inverter allows overload. In the first time the inverter was selected as an intersection of its operative voltage with the voltage of an array of PV panels in serial connection ( $V_{mpp}$  20 Celsius degree).

After this, the minimum voltage of a single array dependent on the higher temperature of the location ( $V_{mpp}$  60 Celsius degree) and it has to be higher respect the minimum voltage of the inverter

The maximum voltage of a single array dependent on the minimum temperature of the location ( $V_{oc}$  -10 Celsius degree) and it has to be lower than input maximum voltage of the inverter;

- Define system component:*

Chosen inverter	It was given, this to have a low number of degrees of freedom in the problem
Chosen PV	It was given, this to have a low number of degrees of freedom in the problem

So, as follows:

Grid system definition, Variant: "New simulation with losses"

**Global System configuration**

1 Number of kinds of sub-arrays

**Global system summary**

Nb. of modules	165	Nominal PV Power	56.1 kWp
Module area	329 m²	Maximum PV Power	52.6 kWdc
Nb. of inverters	1	Nominal AC Power	50.0 kWac

**PV Array**

**Sub-array name and Orientation**

Name: PV Array

Orient: Fixed Tilted Plane

Tilt: 38°

Azimuth: 0°

**Select the PV module**

Available Now: Filter: All PV modules

Approx. needed modules: 162

Selected: Hanwha Q Cells, 340 Wp 32V, Si-poly, Q.PLUS L-G4.1 340, Since 2016, Manufacturer 2017

Sizing voltages:  $V_{mpp}$  (60°C) 32.5 V,  $V_{oc}$  (-10°C) 52.2 V

**Select the inverter**

All inverters: Output voltage 400 V Tri 50Hz

Selected: Ingeteam, 50 kW, 405 - 750 V, LF Tr, 50/60 Hz, Ingecon Sun 50, Until 2013

Nb. of inverters: 1

Operating Voltage: 405-750 V, Global Inverter's power: 50.0 kWac

Input maximum voltage: 900 V

**Design the array**

**Number of modules and strings**

Mod. in series: 15, between 13 and 17

Nbre strings: 11, between 10 and 11

Overload loss: 0.0 %

$P_{nom}$  ratio: 1.12

Nb. modules: 165, Area: 329 m²

**Operating conditions**

$V_{mpp}$ (60°C)	487 V
$V_{mpp}$ (20°C)	578 V
$V_{oc}$ (-10°C)	782 V

Plane irradiance: 1000 W/m²

Imp (STC): 98.9 A

Isc (STC): 105 A

Isc (at STC): 105 A

Max. operating power at 1000 W/m² and 50°C: 50.5 kW

Array nom. Power (STC): 56.1 kWp

System overview

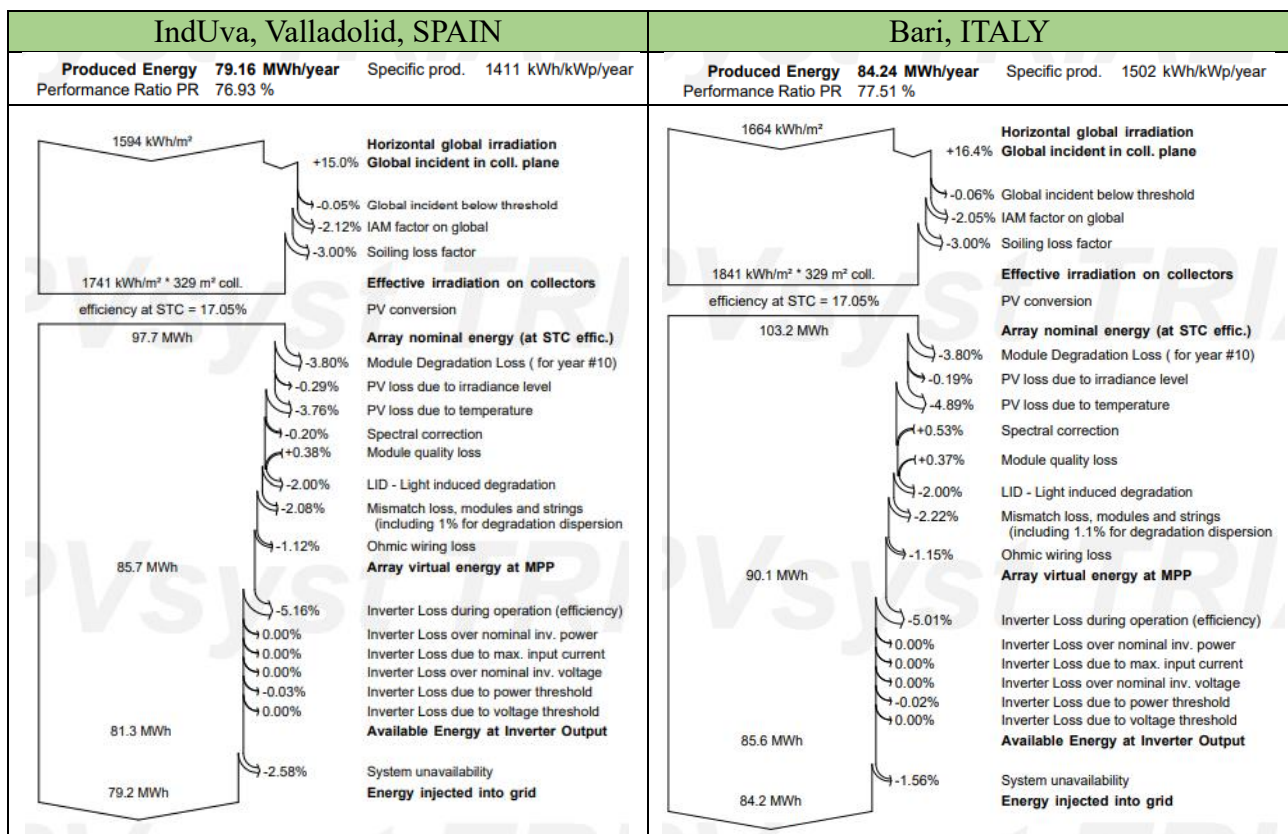
Cancel OK

- Define losses: will be taken in account losses to obtain more realistic results, such as: *Thermal parameter, Voltage drops across series diode, Light Induced Degradation, Yearly soiling loss factor, Yearly soiling loss factor, Incidence Angle Modifier, Ageing, Unavailability of the system and Spectral correction*. They will be the same as the losses of the first project.

## OUTPUTS

The main important results are:

- Produced energy;
- Specific production: The produced energy divided by the Nominal power of the array ( $P_{nom}$  at STC). This is an indicator of the potential of the system, taking into account irradiance conditions (orientation, site location, meteorological conditions).
- Performance Ratio: is the ratio of the energy effectively produced (used), with respect to the energy which would be produced if the system was continuously working at its nominal STC efficiency. Unlike the "Specific energy production" indicator, expressed in [kWh/kWp/year], this indicator is not directly dependent on the meteo input or plane orientation. This allows the comparison of the system quality between installations in different locations and orientations;
- Loss diagram over the whole year: that allow us to recognize the most affecting losses on our systems.



Comparing the two locations only by the higher value of specific energy production, Bari is the best location for this type of system because of higher value higher values of horizontal global and horizontal diffuse irradiation. Taking into the account the performance ratio: Bari is also the best location because of a higher value of performance ratio independently of meteo input or plane orientation. But, looking for losses, Bari has the higher losses due to the temperature. This is maybe because the colder temperature reached in Valladolid morning allows the PV modules to work better instead higher average temperature in the south of the Italy.