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Design of a PV power plant connected to the network: case study of the power plant 20MW Ain El melh

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We dedicate this work to the mother of student Khadraoui Mohammed, May Allah have mercy on her, and do not forget her support in reaching this level and supporting the continuation of the research..

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CHAPTER 01

Chapter 01 : Introduction

1.1. Object

The objective of this project is to carry out a complete study of the design, financing, installation, activation and maintenance of a photovoltaic power plant with an estimated production capacity of 20 megawatts. Connected to the national electricity grid (medium voltage) the energy produced is sold to the National Electricity Transmission and Distribution Company. Seeking through this project to invest in renewable energies in order to prove the high economic profitability of this project

The area has been selected as non-residential and does not contain obstacles to avoid its impact on production, and this choice does not affect the nature of the area, and this contributes to investment returns in economic profit, technological development and existing infrastructure (electricity distribution networks) methods of storing equipment and availability of qualified employment

Installation and connection of all necessary equipment for the plant the investment in this project is inexpensive and its expected high profitability

The importance of the project for investors and the prospects for working on it reach a more than acceptable level of investment risk

Regardless of the profitable investment, this project mainly aims to promote the use of renewable resources in the country to produce clean energy, which helps to avoid the risk of pollution resulting from traditional energy sources.

1.2. Baseline data and customer requirements

For this particular project, the client imposes a series of technical and economic measures

and commercial requirements. These requirements include:

- The nominal power of the solar field must be 20 MW
- The location of the facility must be in the municipal environment of Ain Elmelh, M’sila (Algeria).
- The type of panel to be used is Model YL250P-29b model, Yingli Solar.
- The inverters type from the manufacturer SUNGROW.
- Among the requests or conditions of the client are that the design of the installation is carriedout seeking cost reduction and high profitability of the installation.

1.3. Description of the technology to be used: the effect photovoltaic

The photovoltaic effect is known as the physical process by which photovoltaic cells convert sunlight into electricity. When a photovoltaic cell is exposed to sunlight, the amount of light it absorbs generates electricity, while the rest of the sunlight can be reflected or transmitted. Electrons in the atoms of PV cells are excited by the energy of the absorbed light. Using this energy, these electrons move from their normal positions in the semiconducting PV material and generate an electrical current, a current, through an external circuit connected to the PV cell terminals. The built-in electric field is a specific electrical characteristic of photovoltaic cells that provides the voltage potential difference that drives current through an external load. Two layers of different semiconductor materials are brought into contact with each other to create a built-in electric field inside the photovoltaic cell. The first layer is n-type, electron-rich and negatively charged. The other layer is p-type with lots of holes and is positively charged. Since n-type silicon has excess electrons and p-type silicon has excess holes, contacting the layers together creates a P/N junction at their interface, creating an electric field. With this contact, excess electrons move from the n-side to the p-side. This builds up a positive charge along the n-type side of the interface and a negative charge along the p-type side. Therefore, an electric field is created at the surface where the layers meet, known as a P/N junction. This electric field is created by the flow of electrons and holes. This electric field moves electrons from the semiconductor to the negative surface to conduct electricity. At the same time, the holes move in the opposite direction of the positive surface, where they wait for incoming electrons **[**1**].** The basic structure of a p-n junction in a PV cell is illustrated in Fig.1.1

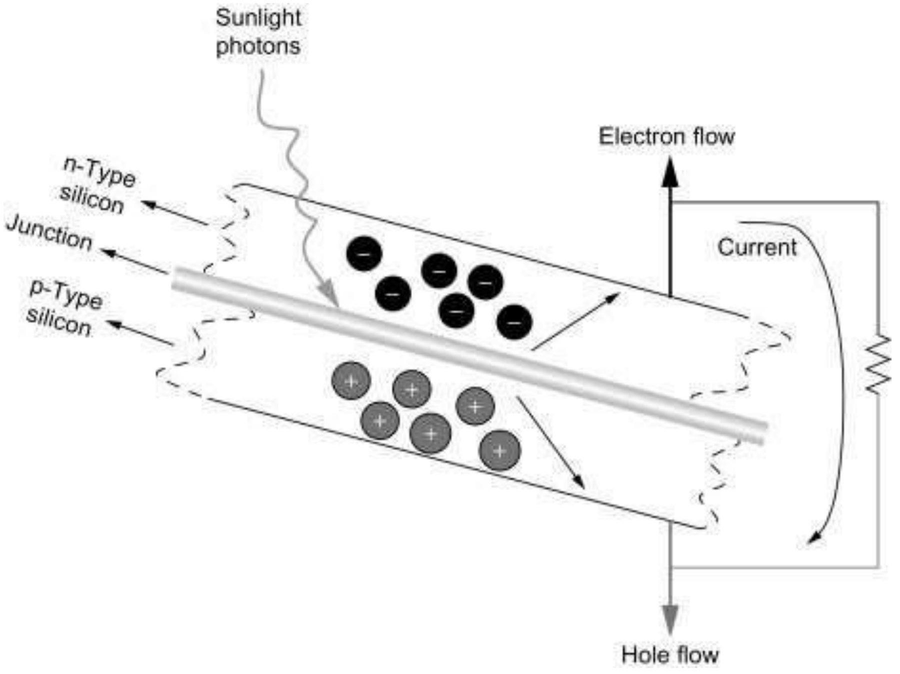


Figure 1.1 P/N junction structure and current flow in a PV cell.

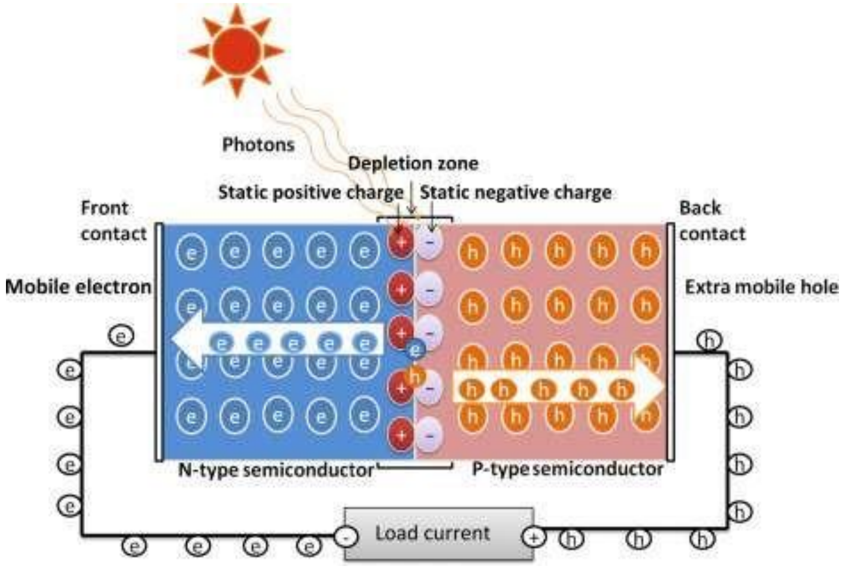


Figure 1.2 Schematic representation of a simple photovoltaic cell.**[**2**]**

1.3.1. Grid-connected power plant:

The particularity of photovoltaic energy connected to the grid in most cases, the photovoltaic plant can be installed close to the place of consumption, thus avoiding online losses that can reach 15% on large electricity grids when hundreds of kilometers separate the places of production and consumption. This energy responds well to the concept of decentralization. A photovoltaic power plant connected to the grid operates "over the course of the day" in a completely transparent way for the user and without intervention on his part. Its operation is particularly optimized. Since energy is normally stored in the grid itself, batteries are not needed unless we wanted a self-contained form of energy during power outage. Grid-connected photovoltaic energy is particularly well suited for integration in most buildings regardless of their type (homes, offices, businesses, shopping centers...). It is also particularly flexible in its use.

1.4. Description of the elements of the installation with network connection

1.4.1. Photovoltaic modules

The photovoltaic module is a unit that provides support for a number of cells electrically connected photovoltaic. The correct choice of them will condition largely the final production of the facility. Therefore, a small introduction to them:

Photovoltaic cells: The photovoltaic (PV) effect is the process by which photovoltaic cells convert the energy they absorb from sunlight into electricity. The photovoltaic system does not emit carbon dioxide when working, which is conducive to environmental safety. The photon energy absorbed by the nanomaterial is transferred to the electrons in the atoms. When two different PN-type semiconductor layers come into contact, a potential is created between the n-type and p-type semiconductor layers. Electrons migrate across the junction and jump to the p-type semiconductor, leaving behind a static positive charge. At the same time, holes migrate across the junction, leaving behind a static negative charge. These free electrons and holes combine and disappear. Above a certain level, a depletion region forms at the PN junction, where charge carrier migration is no longer possible. These separate static positive and negative charges create an electric field in the depletion region. This built-in electric field provides the force or voltage required to drive current through the external circuit. When the sun's photon energy is absorbed by the semiconductor layer, it is transferred to the material's electrons. The electron gains enough energy to move to the conduction band, leaving a "hole" in the valence band. Valence electrons escape from their normal positions in the atoms of the semiconductor material and become part of an electric current or current. This voltage causes electrons to move towards the negative terminal and holes to move towards the positive terminal. If there is enough solar energy, I. H. When the absorbed photon energy is greater than the bandgap energy of the materials used in photovoltaic cells, the atoms collide and free electrons begin to migrate, creating an electrical current.

A. By type of material used:

to. Of simple material: mainly Silicon, but also Germanium and Selenium. Germanium has a lower bandwidth than Silicon, making it suitable for absorbing longer wavelengths, such as infrared light. In the case that the semiconductor material is Silicon, one of the regions (called n-type), is doped with phosphorus (which has 5 valence electrons, one more than silicon). This region will have a much higher concentration of electrons than that of holes. The other region (p-type), is doped with boron, which has 3 valence electrons (one less than silicon). Converting this region into an area with a greater number of holes than electrons. This difference between holes and electrons is whatcreates the electric field responsible for separating the extra electrons and holes that are produced when thecell is illuminated.

a. Of binary compounds: CdTe, GaAs, InP, CdS, Cu2S (materials of the periodic table of groups III andIV)

b. Of ternary compounds: AlGaAs, and compounds with a chalcopyrite structure based on Cu such as CuInSe2, CuInS2 and CuInTe2. Highlight the first for its practical utility and good performance.

B. By the internal structure of the material:

a. **Monocrystalline** Solar Panels (Mono-SI) This type of solar panels (made of monocrystalline silicon) is **the purest one**. You can easily recognise them from the **uniform dark look** and the **rounded edges**. The silicon's high purity causes this type of solar panel has one of the highest **efficiency rates**, with the newest ones **reaching above 20%**.

b. **Multicrystalline:** lower performance than monocrystalline but lower manufacturing cost, because heterojunctions in the material cause efficiency losses. The internal structure is made up of a multitude of randomly oriented large grains or monocrystals.

c. **Polycrystalline:** grains or single crystals but smaller in size than in the case of Multicrystalline (below 1mm). Yield 11-13%. Comparable to monocrystalline in construction, electrical characteristics and durability. It allows toreduce costs by lowering the manufacturing cost of wafers, but it is very similar to that of Si-monocrystalline cells.

d. **Hybrid devices:** Less expensive, you may want to consider thin films. Thin-film solar panels are manufactured by placing a film of one or more photovoltaic materials (such as silicon, cadmium, or copper) on a substrate. These types of solar panels are the easiest to produce and the economies of scale make them cheaper than the alternatives due to the fewer materials needed to produce them.

They are also flexible which opens a lot of opportunities for alternative application and is less affected by high temperatures. The main issue is that they take up a lot of space, generally making them unsuitable for residential installations. Moreover, they carry the shortest warranties because their lifespan is shorter than the mono- and polycrystalline types of solar panels. However, they can be a good option to choose among the different types of solar panels where a lot of space is available.

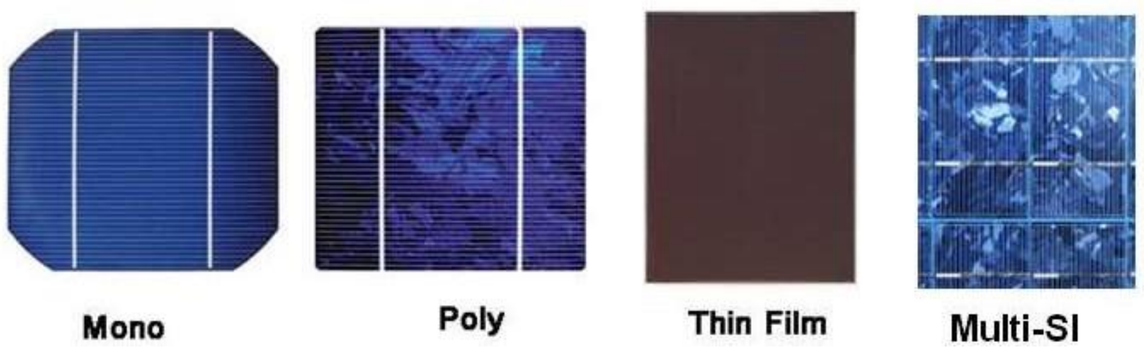


Figure 1.3 Silicon Cells

In **Figure 1.3** four commercial Silicon cells with different types of base material can be observed: Monocrystalline Si cell; polycrystalline silicon cell; Multicrystalline silicon cell (APEX); its amorphous Si modulus

A. By the structure of the device

a. Homojunctions: the **PN** union is created on a single material bydiffusion ofdopants from opposite sides of the cell

b. Heterojunctions: The materials on both sides of the pn junction aredifferent.

c. According to the number of pn junctions:

    i. Simple junction devices - single junction
    ii. Multi-junction devices

d. According to the number of devices used in the same cell:
    i. Single cell devices
    ii. Tandem or cascade devices: combination of two or more cells in the same structure in order to take advantage of the widest possible rangeof the solar spectrum. Yields superior to monocells, but they have not started to be commercialized.

B. By the type of application

a. Cells for terrestrial applications withoutconcentration: or also calledflat panel
b. For integration in buildings
c. For low concentration land applications: in search of the highest possible conversion performance. More expensive when adding hubs.
   Many models need heat sinks or cooling. For high power installations
d. For special applications

Photovoltaic modules

The photovoltaic module consists of photovoltaic cells, an envelope, bypass diodes, connectors, junction box, cable, and protective glass on the front face of the module, and glass or polymer film (generally Tedlar) on the back side of the module. The assembly of these components can protect cells from various contacts and “against environmental conditions such as moisture”. **[**3**]**

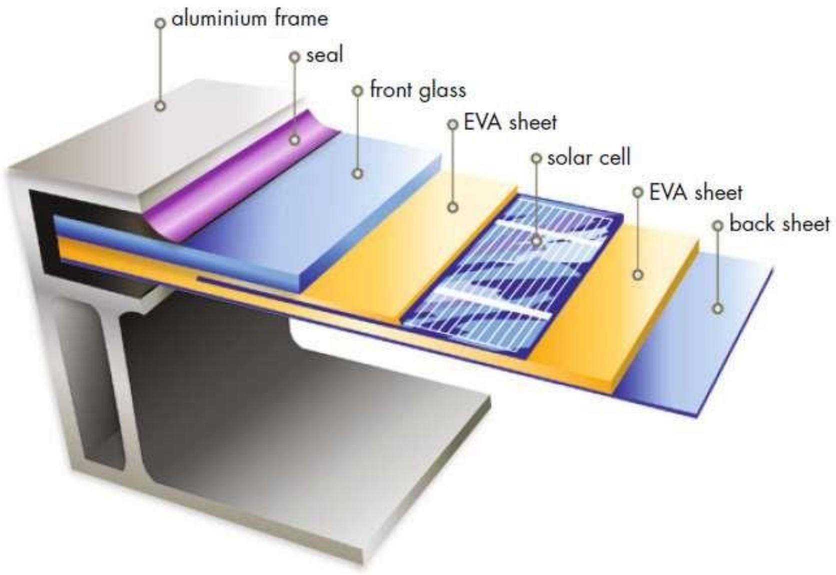


Figure 1.4 Structure of photovoltaic modules

- **Front shell:** It should have high transmission in the wavelength range and low reflection the front roof to make the most of the incoming solar energy. In addition, the material should be waterproof, have good impact resistance, low thermal resistance and be stable to prolonged exposure to UV rays. This front cover also has its main function, to give the unit rigidity and mechanical rigidity. The most commonly used materials are acrylic, polymers and glass. The most commonly used glass is usually low-e tempered glass iron content, which has low cost, high transparency, impermeability and good self-cleaning properties.

- **Encapsulant:** in charge of giving adhesion between the cells, the front surface and the rear of the module. The most used is EVA (ethylene-vilin-acetate).

- **Back cover:** it must be waterproof and with low thermal resistance. Usually a layer of Tedlar, or Tedlar and a second glass should be used.

Solar cells and their connectors: these are usually made of aluminum or stainless steel.

- The edges of the block are protected with a neoprene cover and the whole assembly is embedded in an aluminum frame, adhered with silicone, which provides mechanical

Resistance. At the rear of the module is the connection box with two terminals (positiveand negative), to allow the connection of the modules.

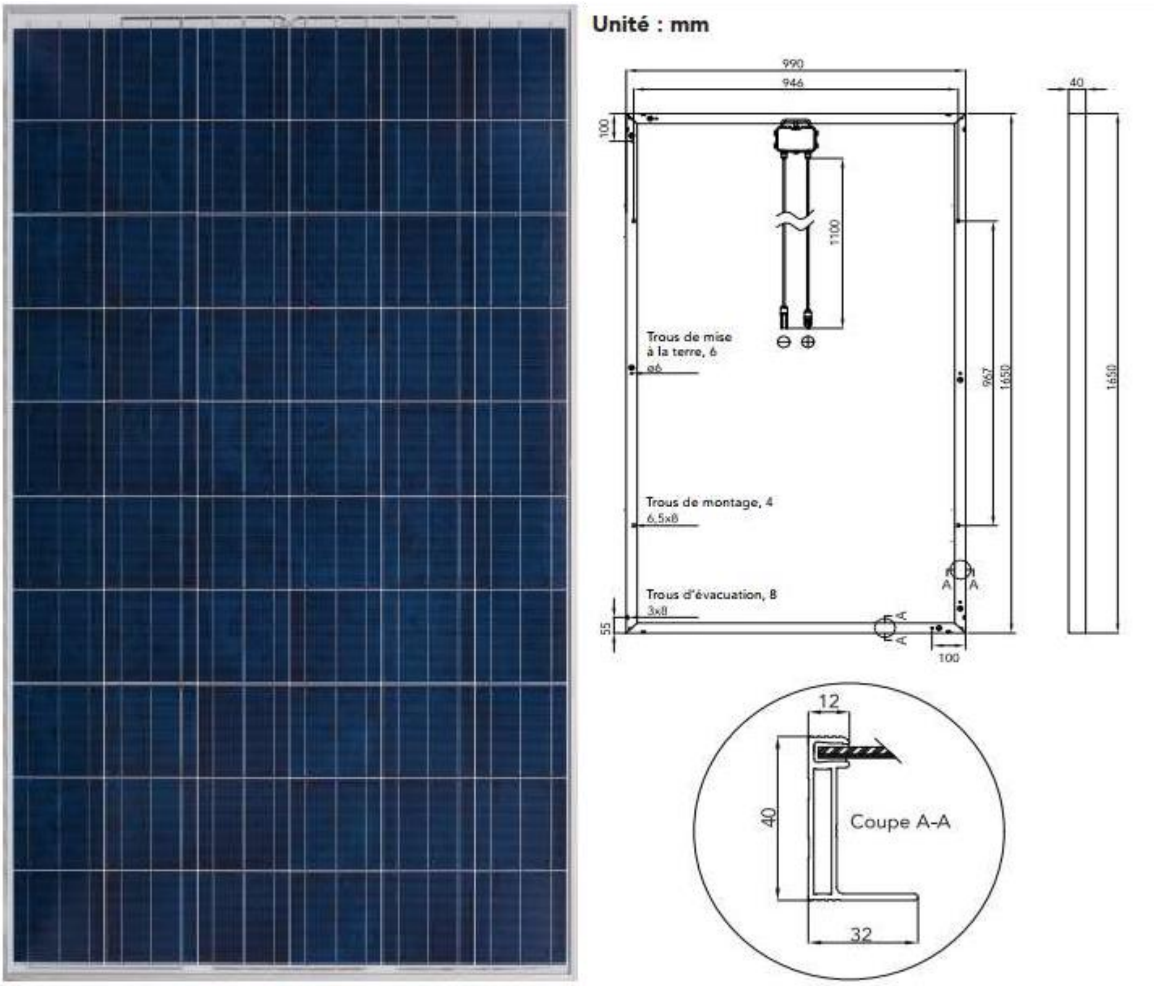


Figure 1.5 Photovoltaic module rear view (Yingli Solar Catalog).

Photovoltaic module used

The type of module to be used will be the YL250P-29b (Yingli solar) model, as defined in section 1.2. It is a module with polycrystalline silicon photovoltaic cells.

1.4.2. Panel support structure

The metallic structure on which the photovoltaic modules will be placed is established to support four (4) modules horizontally, at three (3) heights. The use of an adequate structure facilitates installation and maintenance tasks, minimizes the length of the wiring, avoids corrosion problems and improves the aesthetics of the plant as a whole. The chosen structure will be made of hot-dip galvanized steel, a material resistant to corrosion and with a good price-quality compromise (stronger than stainless steel and cheaper).

It must withstand winds of 100 to 150 km / h, it will place the modules at a height of more than 0.5 m from the ground, it must be electrically connected to an earth connection, and it will ensure good electrical contact between the module frame and the earth. To allow the protection of people against possible insulation losses in the generator. You must comply with the regulations:

Figure 1.6 Panel support structure

1.4.3. DC-AC inverter

It is a device intended to convert the direct current generated by the PV generator in alternating current. It uses power transistors or thyristors. The output wave presents, in the simplest of cases, a square shape which can be adapted to a few types of loads, considerable no-load losses especially for low powers.

Most inverters are bridge structures consisting most often electronic switches such as IGBTs (Insulated Gate Bipolar Transistor) The choice of this type of component is, on the one hand, its particularity in being able to switch from very large current and voltage values at switching frequencies of several tens of kHz and on the other hand, because it allows the suppression of all the circuits of aid to the switching of thyristor circuits. **[**4**]**

Figure 1.7 Inverter Appearance real photo

1.4.4. LV-MV transformers

The evacuation of energy to the distribution network is carried out at a voltage of 31 kV. This requires the use of step-up power transformers, which transform the output voltage of the inverters to the voltage of the distribution network.

The plant will have twenty (20) power transformers that perform this function. The transformer chosen for this project will be a Pad-Mount oil transformer, specific for outdoor use, nominal power 1250 kVA, transformation ratio 315 V / 31 kV, *(Cooper Industries).* This transformer meets the established requirements to be installed in areas with medium seismic activity, such as the place where the plant will be located. These transformers have all the necessary protection switchgear.

Figure 1.8 Transformer room power plant photovoltaic

1.4.5. Medium voltage cells

PV Fuses are a range of fuse package designed specifically for the protection and isolation of photovoltaic strings in solar panel applications. (Bussmann / Eaton PV Fuse) links are capable of interrupting low over currents associated with faulted PV (reverse current, multi-array fault) string arrays. These PV Fuses feature $1000V_{DC}$ rated voltage and rated breaking capacity of $33kA_{DC}$. These fuses also feature an amp range of 1A to 6A, 8A, 10A, 12A, and 15A. **[**5**]**

A group of bladed fuse links in the NH sizes that are specifically designed to safeguard and isolate photovoltaic array combiners and disconnects. Low overrated currents associated with faulty PV systems (reverse rated current, multi-array fault) might be interrupted by these fuse linkages.

Medium voltage (MV) cells have to respect standards (for example IEC ones (**IEC TC 17C 2003 IEC 62271-200 [**6**]** High Voltage Switchgear and Control gear—Part 200 1st edn)) that define security levels against internal arc faults such as an accidental electrical arc occurring in the apparatus. New protection filters based on porous materials are developed to provide better energy absorption properties and a higher protection level for people. To study the filter behaviour during a major electrical accident, a two-dimensional model is proposed. The main point is the use of a dedicated numerical scheme for a non-conservative hyperbolic problem. We present a numerical simulation of the process during the first 0.2 s when the safety valve bursts and we compare the numerical results with tests carried out in a high power test laboratory on real electrical apparatus. (Some figures in this article are in colour only in the electronic version)

Forty (40) 500kW inverters will be used in this installation, two (2) for each 1MW block. The inverter chosen for this project has been the one manufactured by Sungrow (customer requirement), model Sungrow SG500MX-M. This inverter meets the requirements established by the regulations.

1.4.6. Advantages and disadvantages of a PV installation

A. Advantages:

High reliability. has no moving parts that make it particularly suitable for remote areas. This is the reason for its use on spacecraft. Then modular nature of the photovoltaic panels allows a simple assembly and adaptable to various energy needs. Systems can be sized for power applications ranging from milliwatt to megawatt. The operating cost is very low due to the reduced maintenance and does not require fuel, transport or highly specialized personnel. Photovoltaic technology has ecological qualities because the finished product is non-polluting, silent and does not cause any disturbance of the environment, it is not by the occupation of space for large installations.

B. Disavantage [7]

The manufacture of the photovoltaic module is high-tech and requires high-cost investments. The actual conversion efficiency of a module is low, of the order of 10-15% (i.e. between 10 and 15 MW/km? per year for the BENELUX) with a theoretical limit for a cell of 28%. Photovoltaic generators are not competitive with diesel generators only for low energy demands in remote areas. Dependent on weather conditions. When the storage of electrical energy in chemical form (battery) is required, the cost of the generator is increased. The storage of electrical energy still poses many problems. The low efficiency of photovoltaic panels is explained by the very functioning of the cells. To be able to move an electron, the energy of the radiation must be at least equal to 1 EV. All incident rays with a lower energy will therefore not be transformed into electricity. Similarly, light rays whose energy is greater than 1 eV will lose this energy, the rest will be dissipated as heat.

CHAPTER 02

2. Chapter 2: Installation

2.1. Installation site. Justification

The photovoltaic installation will be in north-central Algeria, on a plot of land near the city of Ain El Melh (M'Sila). The facility's coordinates are 34° 50′ 54″ Nord, 4° 09′ 40″ Est The plant will be located at an altitude of 931 m above sea level.

2.2. Geological conditions:

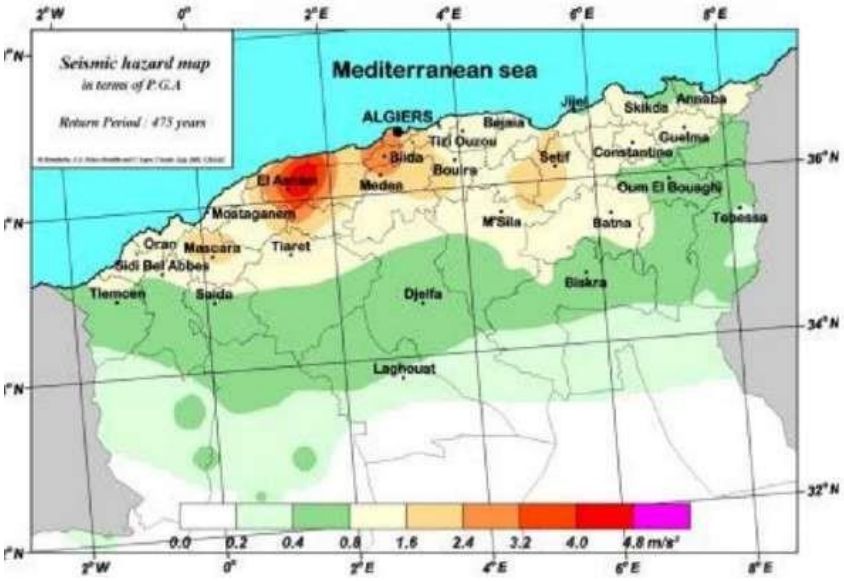


Figure 2.1 Seismis hazard for northern Algeria

Algerian geology is linked to neigh bouring countries (Tunisia and Morocco), Algeria is located in the north of the African plate near the European plate, making it with a large seismic activity in the north that gradually decreases as we head south. The selected area is characterized by a relatively weak seismic activity.**[**8**]**

2.3. Weather reasons:

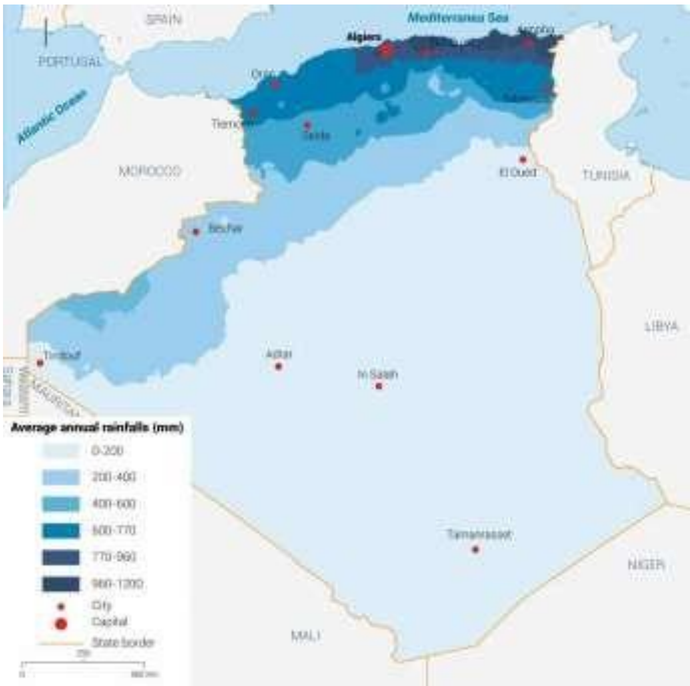


Figure 2.2 Average annual rainfalls (mm) **[**9**]**

The map shows the amount of annual rainfall in all Algerian territory, where the ratio varies from region to region.

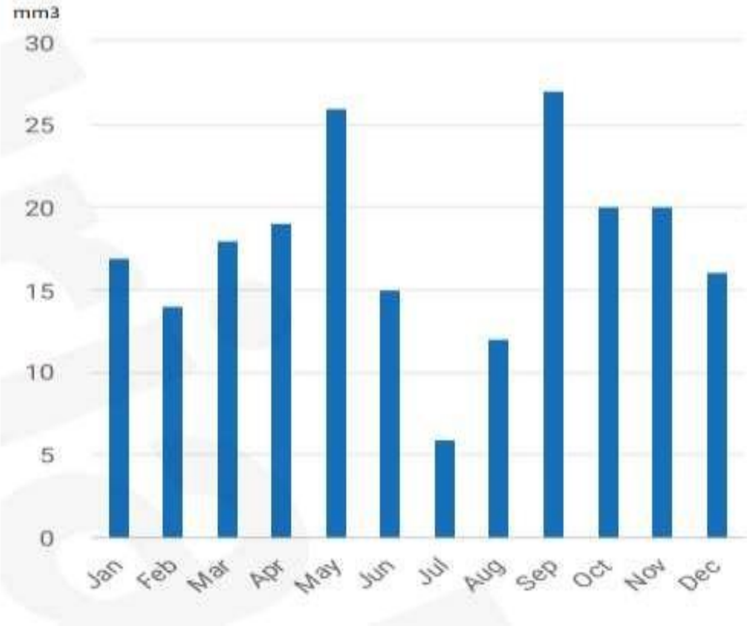


Figure 2.3 Precipitation (rainfall)

Figure 2.3 shows the amount of rain over a whole year.

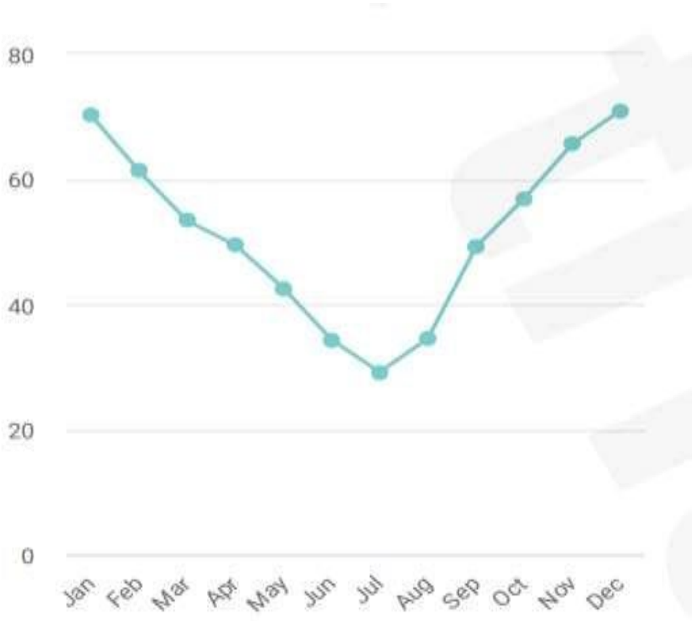


Figure 2.4 Relative humidity

The selected area has a medium precipitation continental climate, distinct climatic conditions and suitable area topography that positively affects production, leading to increased profits.

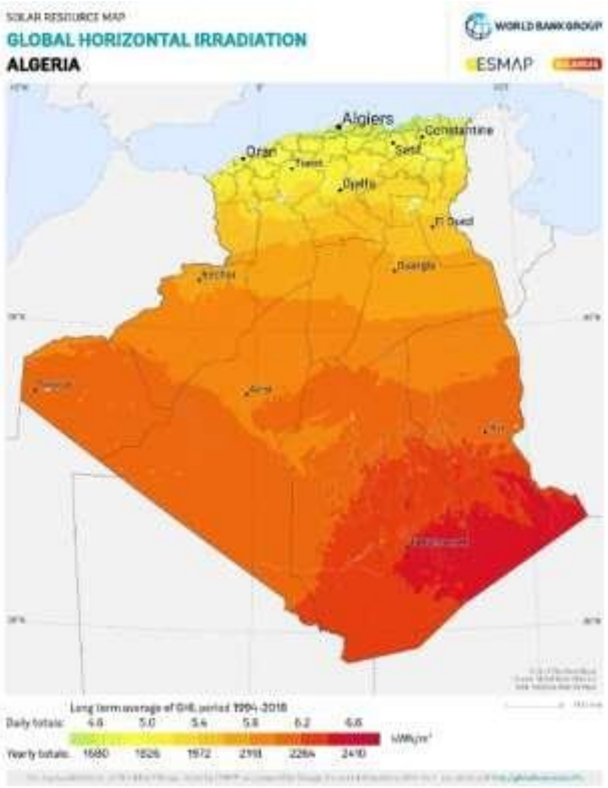


Figure 2.5 Global horizontal irradiation of Algeria

The purpose of the central is to exploit solar radiation to generate electricity and sell it to the distribution company **GRTE**.

2.4. 1MW modular blocks. Justification

The plant, with a capacity of 20 MW, is being built in 1 MW standard blocks In order to simplify the installation design due to various factors:

The choice of inverters: The market contains distinct brands in the manufacture of electrical inverters suitable for the energy of photovoltaic installations designed to produce and sell electricity to distribution companies

The choice of inverters with the maximum possible power will be beneficial to the customer who is responsible for the installation costs.

Investing in this equipment is necessary by reducing its number.

Among the products of the company (Sungrow). Manufactured inverters (according to customer requirements) Products of a variety of high power inverters for installations connected to a network.

The maximum voltage of the inverter must be 1000 volts (to work in the specified location - Ain El melh) and the because they have to provide UL certification. In this way, the reflectors have the highest strength The high we can reach is 500 kVA

The choice of BT-MT power transformers:

After selecting the 0.5 MW inverters, we can think and calculate the standard blocks of 0.5 MW, 1 MW, and 1.5 MW and beyond.

1) if 0.5 MW units are selected, there will be a need for power transformers.

To raise the voltage from LV to MV

Which means buying 40 power transformers with a big investment?

2) If you decide to work with 1.5MW modules, there would be several problems:

2.a. One option is to use two different transformer , one with a one-winding transformer and another with a double -winding transformer, and with the way we lose symmetry and equality, and there are more losses in one transformer than others.

Having to use different cables, this leads to a different purchase process for the manufacturer and the loss of reduction by purchasing by different equipment standards.

2.b 3-winding transformers are not standardized, and you would have to request the manufacturer to make them exclusively for this project, including a study of harmonics by the manufacturer to optimize the design. This last point has already been solved for transformers of two windings. Therefore this choice would mean a greater expense for thecustomer.

2.c Although the dimensions of the mass are increasing, they are therefore You need to spend less on transformers, and this reduction

The investment is not compensated by having higher expenses in wires at point 2.a.

- For these reasons, it is decided to use double winding transformers. In this way: reduce the harmonics that appear in three-phase transformers when cancelled

partially those generated in the first winding and in the second. On the other hand, the manufacturers of the inverters establish as a condition that the

investors, so there is only the possibility that each inverter goes to a windingindividually.

For all the above, it is decided to work with modular blocks of 1MW.

CHAPTER 03

Chapter 03: Design procedure

3.1. Energy study

In this section, the study of solar behavior and knowledge of the inexhaustible source will be conducted in order to increase the use and to exploit it more.

Evaluation of energy resources in the form of solar radiation

This is related to the movement of the earth and the sun, as well as the laws of physics and the presence of the atmosphere, which causes the random side to predict solar radiation.

3.2. Solar radiation:

3.2.1. The sun constant:

Solar radiation reaches the atmosphere after traveling about 150 million km. Total solar radiation (TSI), called the "solar constant" until a few years ago, was found to change about 0.1% in sunspot activity for an 11-year period. The most accurate current TSI values from the Total Radiation Monitor (TIM) in the NASA Solar Radiation and Climate Experiment (SORCE) are 1360.8 ± 0.5 W/m2 during the 2008 solar minimum compared to previous estimates of 1365.4 ± 1.3 W/m2 [10]

Less than 1% of these differences affects the design of PV systems and are mostly influenced by meteorological changes rather than solar cycles.

3.2.2. Sun-Earth Distance:

As already mentioned, the distance between the Sun and the Earth is variable throughout the year due to the elliptical orbit of the Earth. The eccentricity of this elliptic can be calculated as:

$$\varepsilon_0 = \mathbf{1} + 0.033\cos\frac{\mathbf{360\,.}dn}{\mathbf{365}}$$

Where dn is the day of the year (1≤dn≤365). This distance is important since when you have a light source that emits in all directions, the energy flux varies inversely with the square of the distance to the emitting source.

Note that:

If dn =365 days

$$\varepsilon_0 = 1 = 149597870.691 \text{ km}$$

3.2.3. Solar radiation:

In order for solar radiation emitted from the sun to reach the Earth, it must pass through the atmosphere, where it is exposed to many phenomena: reflection, diffusion and absorption that reduce its value. It can be classified into three types: direct, diffuse, and reflected.

- **Direct solar radiation:**

  It is the direct radiation from the sun that is focused on a specific point.

- **diffuse solar radiation:**

  It is the radiation that is absorbed by the atmosphere and diffuses before reaching the surface.

- **reflected radiation:**

  Radiation resulting from the reflection of solar radiation on the ground and other thingsIt depends on the characteristics and nature of the reflective surface.

- **global solar radiation:**

  It is the total solar radiation that includes: direct, diffuse and reflected

Measurement of Solar Irradiation:

The primary instrument used to measure global solar irradiance is the

Pyranometer, which measures the sun's energy coming from all directions in the hemisphere above the plane of the instrument directions in the hemisphere above the plane of the instrument the measurement is of the sum of the direct and the diffuse solar irradiance and is called the global solar irradiance. [11]

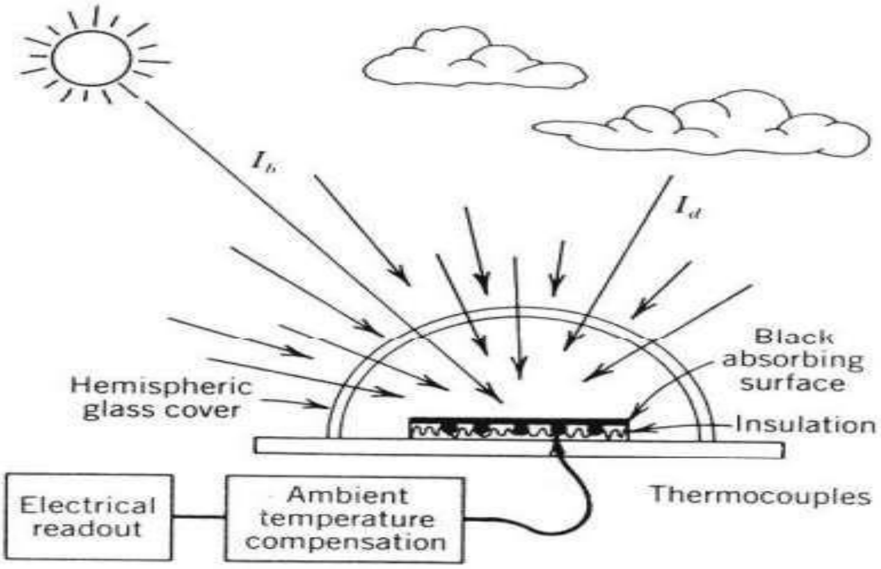


Figure 3.1 Measurement device diagram

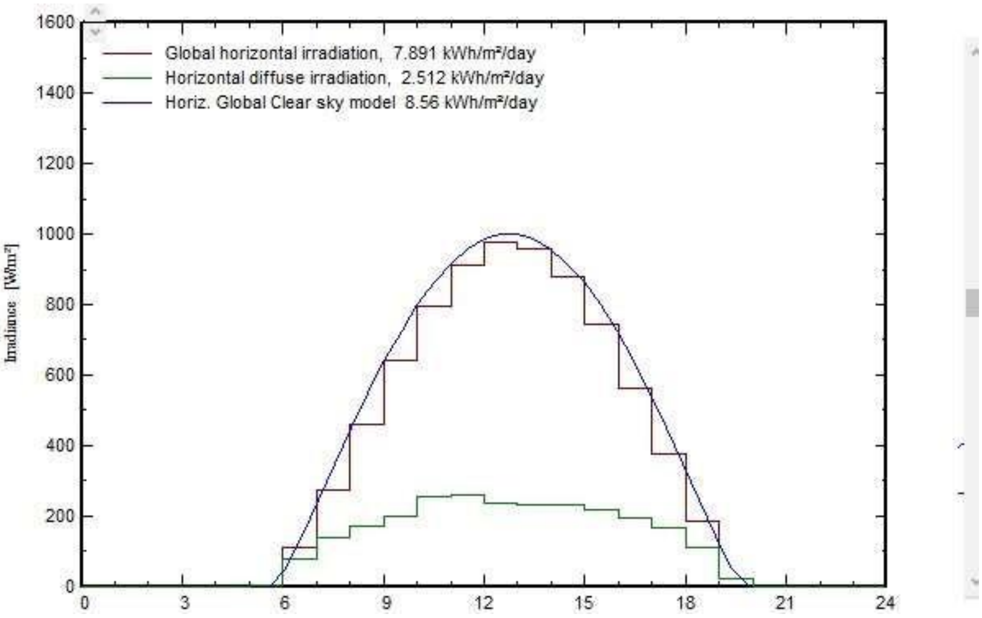


Figure 3.2 solr irradiance of locaition choise [12]

By working on the pv syst simulation system

Estimated data on the values of different solar radiation were obtained by selected area

Figure 3.3 global and diffuse horizontal irradiation.[13]

After working on the **PVGIS** site, which provides data, characteristics of solar radiation and daily values as well as even annual ones, data on the area studied were extracted.

MONTH	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Irradiance (Kwh/m2)	**165.85**	**168.75**	**199.14**	**203.28**	**210.55**	**208.36**	**218.02**	**212.85**	**190.96**	**188.46**	**161.56**	**156.63**
$Y_{r.}$ (h)	**5.53**	**5.625**	**6.638**	**6.77**	**7.01**	**6.94**	**7.26**	**7.09**	**6.36**	**6.28**	**5.38**	**5.22**

Table 01: Solar radiation and equivalent hours per day**.**

3.3 The production of the photovoltaic system:

3.3.1 Losses in a photovoltaic system (Performance Ratio PR):

When determining the size of the photovoltaic system, analysis of the various losses **[**14**]** in the same system must be done:

Temperature losses:

In photovoltaic modules, power losses of the order of 0.4-0.5% occur due to every 1°C of temperature increase that varies from the standard temperature of 25°C (for the modules Photovoltaic YL250P-29b. The value of this loss coefficient is -0.42% / °C data provided by the manufacturer).

Temperature causes less losses during winter than summer.

$$\mathbf{FT} = -0,\ 42\ \%\ /\ °\mathrm{C}$$

Losses due to non-compliance with the nominal power

solar cells, which are made by a synthetic process, are not all identical. Solar cells
The photovoltaic cells that make up the units differ from one another. This means that the energy that can be individually generated will vary from one tablet to another, ranging from ±3% to ±10% nominal. In our case
In particular, the manufacturer indicates that the photovoltaic units have a positive tolerance
Between margin 0/+5%.
The most negative value, 0%, means no board whose rated power is higher than that indicated by the manufacturer:

$$\mathbf{FP_{nom}} = 0\ \%$$

Connection losses (mismatch losses)

Communication losses are losses caused when connecting between units of different energy value. When you make a serial connection to modules, a panel that has less power than

All of this will limit the current going on through the series because it can't allow more trading. current of the maximum that he could give. As for parallel communication, a low-power unit will limit the maximum voltage of all. Losses per connection are usually in the range of 1% to 4%. In our case (see PVsyst chapter 04 simulation),

$$\mathbf{F_{con}} = 2,\ 1\%$$

Generator shading losses

Obstacles that cause the shading of photovoltaic generators directly affect the process of solar radiation capture, and the effects may be on the individual efficiency or a group of photovoltaic panels. In our case, there are no obstacles

Losses due to dust and dirt

Losses due to dust and dirt are related to the place of installation, the percentage of air pollution and the frequency of rain Typical annual values are less than 4% for surfaces with a high degree of dirt.

FS = 2 %

Angular losses:

It is the manufacturer who determines the nominal strength in relation to the standard conditions of measurement

(Irradiation de 1000 W / m2, temperature ambient de 25°C, AM = 1,5)

An angle corresponding to the radiation perpendicular to the unit and the fact that the radiation does not fall perpendicular to the plate means losses occur, which increase the further away the radiation falls on the vertical form.

Losses due to investor performance:

Inverters are one of the fundamental elements in the energy production of Grid-connected photovoltaic systems. The return of the investor is without a doubt the Most representative parameter of the investors.

The performance of the inverter is affected by the internal presence of a transformer, which causes this parameter to decrease. In this specific case, the 500HE-US inverter, SMA, lacks of internal transformer and its efficiency has a value of ŋ=98.80%

Finv = 1.20 %

Losses due to ohmic drops in the wiring

Losses in the continuous or alternating part are due to cable resistance, so you should make a good choice of connector sections.

The ohmic losses shall not exceed 2,5 % for continuous part and and 2 % for the alternating part.

Transformer losses

The transformer has a yield of 99.2%

$$\mathbf{F_{tr}} = 0.8\%$$

3.3.2 Equivalent Hours of Sunshine (HES) and Performance Ratio (PR)

To normalize the energy produced with respect to the nominal power of the installation in

STC standard conditions, it is necessary to define a relationship between the kWh produced

Annually for each kW peak installed.

This relationship is the “Equivalent Hours of Sunshine (HES)”, which is defined as the quotient of the energy injected into the electrical network divided by the total peak power installed.

$$\mathbf{ESH} = \frac{\mathbf{E_{inject}}}{\boldsymbol{P_P}} = \frac{\mathbf{1055000} * \boldsymbol{Fac} * \boldsymbol{Ftr}}{\mathbf{506000}} = \mathbf{1882.01}\ \boldsymbol{h}$$

Energy obtained from the simulation with the PVSyst program (Meteonorm 7.3 (1991-2000), Sat=100%). The energy that this program provides is at the point immediately after the

Inverter, so it must be multiplied by $\mathbf{F_{ac}}$ and by $\mathbf{F_{trf}}$ to obtain the value of the energy injected into the network. This value is:

$$\mathbf{E}_{\text{injected}} = 1050\text{Kwh}$$

Installed peak power according to section 2.3.1

The reference productivity (called YR) is defined as the ratio between the Incident annual solar irradiation in the plane of the photovoltaic modules (Annual in kWh/m2) andthe reference nominal radiation in standard conditions R=1000W/m2

$$\mathbf{Y}_{\boldsymbol{r}} = \frac{\boldsymbol{R}_{\underline{\boldsymbol{anual}}}}{\boldsymbol{R}} = \frac{\mathbf{2047}\boldsymbol{kWh/m}\mathbf{2}}{\mathbf{1000}\boldsymbol{W/m}\mathbf{2}} = \mathbf{2047\ h}$$

Ranual obtained from the simulation with the PVSyst program.

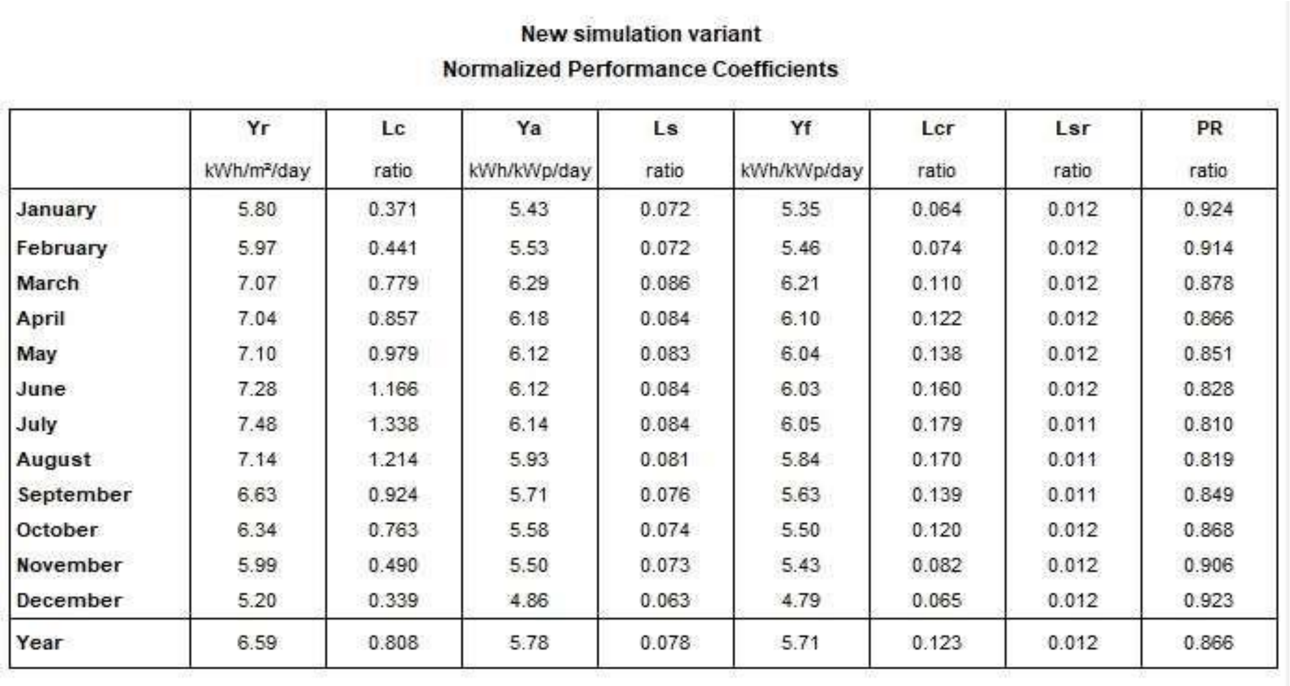
(Meteonorm 7.3 (1991-2000) Sat=100%).

The Performance Ratio or global performance factor of the system is calculated as the ratio

Between the Equivalent Hours of Sunshine and the reference productivity:

$$\mathbf{PR} = \frac{\boldsymbol{HSE}}{\boldsymbol{Yr}} = \frac{\mathbf{1882.01}}{\mathbf{2047}} = \mathbf{0.9194}.$$

Performance can also be calculated through losses in the system:



New simulation variant

Normalized Performance Coefficients

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	5.80	0.371	5.43	0.072	5.35	0.064	0.012	0.924
February	5.97	0.441	5.53	0.072	5.46	0.074	0.012	0.914
March	7.07	0.779	6.29	0.086	6.21	0.110	0.012	0.878
April	7.04	0.857	6.18	0.084	6.10	0.122	0.012	0.866
May	7.10	0.979	6.12	0.083	6.04	0.138	0.012	0.851
June	7.28	1.166	6.12	0.084	6.03	0.160	0.012	0.828
July	7.48	1.338	6.14	0.084	6.05	0.179	0.011	0.810
August	7.14	1.214	5.93	0.081	5.84	0.170	0.011	0.819
September	6.63	0.924	5.71	0.076	5.63	0.139	0.011	0.849
October	6.34	0.763	5.58	0.074	5.50	0.120	0.012	0.868
November	5.99	0.490	5.50	0.073	5.43	0.082	0.012	0.906
December	5.20	0.339	4.86	0.063	4.79	0.065	0.012	0.923
Year	6.59	0.808	5.78	0.078	5.71	0.123	0.012	0.866

Table 3.2 Calculation of the Performance Ratio

Yr: Reference incident energy in the collector plane

Lc: Normalized PV field losses

Ya: Normalized PV field production

Ls: Normalized system losses

Yf: Normalized system production

Lar: PV field loss / En. Plan Capt. Reference

Lsr: Loss of PV field / in. Plan Capt. Benchmark

PR: Performance index

CHAPTER 04

Chapter 04: Electrical calculations:

4.1. Orientation and inclination of modules:

Orientation

The production of solar panels is related to the direction according to the zemith angle, which is to the southeast or southwest. In order to capture the solar ash, it is the most appropriate guidance depending on the chosen location and the plan is repaired

ϒ The solar radiation incident angle on an arbitrarily oriented solar panel depends on the time of the day, the latitude of the location, **[**15**]**

And the orientation of the solar panel as illustrated in Figure 17:

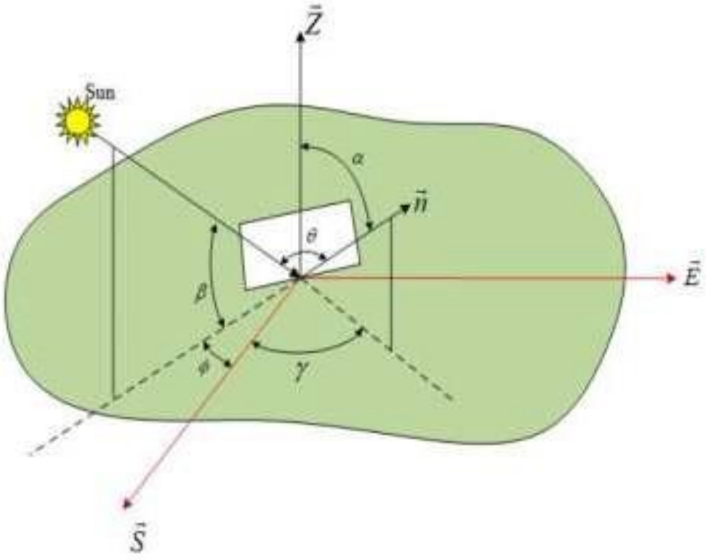


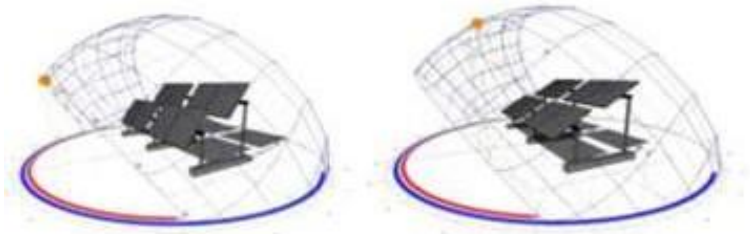
Figure 4.1 solar panel showing its orientation and solar angles.

The minimum distance between panels to avoid the shading of one row on the next is

Made from the following calculations:

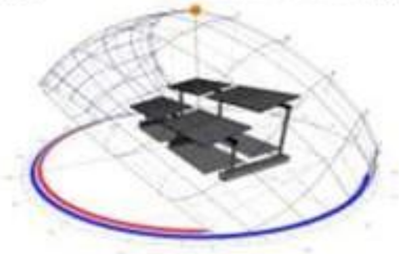
Declination solar:

$$\delta = 23.45 \sin (360/365(NJ+284))$$



21 Décembre

21 mars / 21 septembre



21 Juin

Figure 4.2 inclination relative to the sun

$\mathbf{H_0 = (90-\varphi) +\delta = ((90-34.84) -23.45) =31.71°}$

δ= -23.45° (value used for the northern hemisphere, since it is the value of the declination solar on the day when the solar altitude is minimum. The most inauspicious day, in which said declination is minimal, corresponds to the winter solstice in the northern hemisphere, on 21-22 December).

The inclination of the modules is calculated in order to maximize the annual uptake of Irradiation, instead of maximizing energy harvesting during the time of less radiation, by which a more homogeneous production curve would be obtained throughout the year.

To obtain the maximum annual production, a first approximation can be carried out, **[**16**]**

Whereby, to obtain the maximum annual production in a facility with

Fixed structure, the panels must have an inclination of**:**

Inclination = Latitude -10° = 34.84° – 10° = 24.84°

In this way we will carry out the simulations with the PVSyst program around this value Calculated. The simulation is carried out for different values of the inclination angle, and

Obtain the following annual production values for the 1MW module:

Inclination (degrees)	Production / MW (MWh / year)	Select
20	2050	No
23	2072	No
25	2084	No
27	2094	No
28	2098	No
29	2102	No
31	2106	No
32	2108	No
33	2110	Selected
34	2112	No
35	2112	No
36	2112	No
37	2110	No
38	2110	No

Table 4.1 Annual production as a function of the angle of inclination

- The optimum angle of inclination is 33°, for which an annual production of 2.110GWh/year for each 1MW modular block.

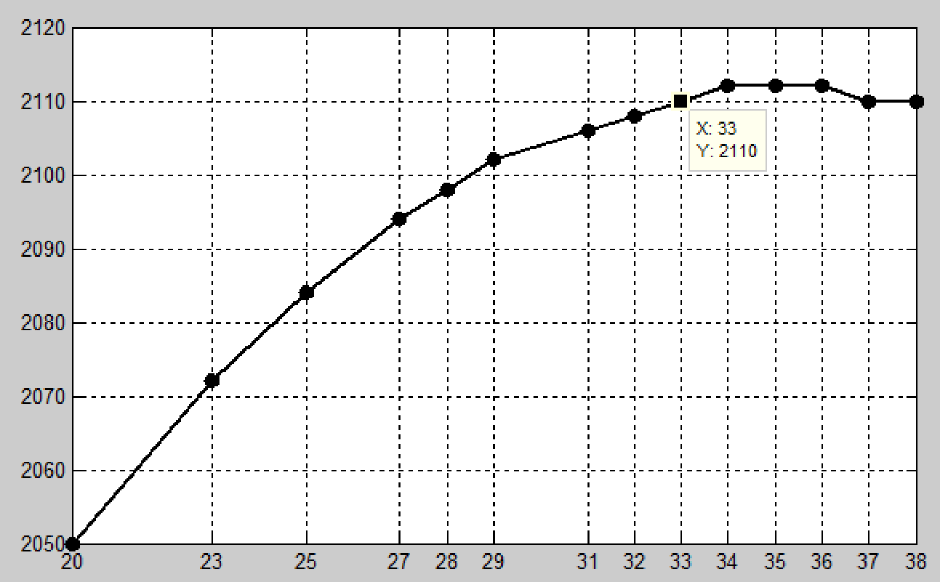


Figure 4.3 Production depending on the angle of inclination

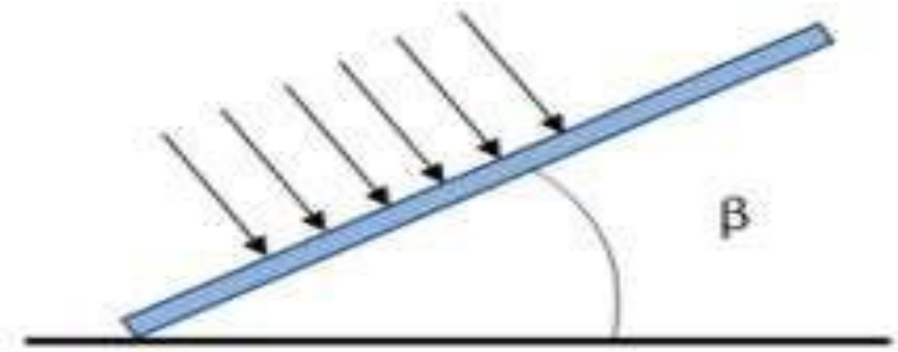


Figure 4.4 Panel inclination

4.2. Shadow calculation

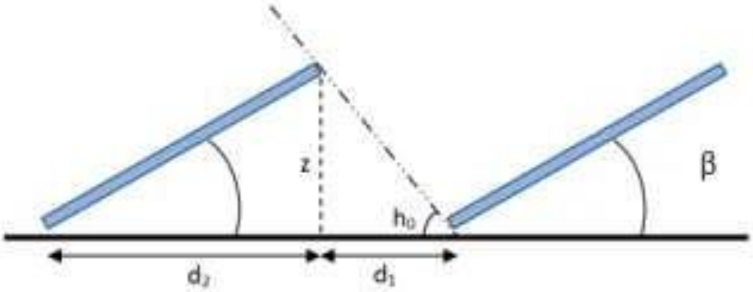


Figure 4.5 Distance between panels

Width of panel: 0.99 m

To used 4 panel

0.99*4 = 3.96 m

$$\cos(\beta) = d2/L \longrightarrow d2 = 3.96 \cdot \cos(\beta) = 3.32\text{m}$$

Z=d2tan (β) = 2.156

d1 = z/tan (h_0) = 2.156/tan(31.71)

d1=3.489 m

d_{min} = d1 + d2 = 3.32+3.489

d_{min} = 6.809 m

Then distance between the beginning of one table and the next will be **D**= 6.80 m

4.3 Installation sizing

• **Modules:**

VMP = **30.20v**: optimal operating voltage under STC standard conditions:

(Photovoltaic module temperature **25** ° C, **Irradiance 1000**W / m2, **AM** = **1.5**)

Module: YL250P-29b.

Power measurement: 250.0 w (0/+5w).

Voltage measurement: 29.8 v.

Courant measurement: 8.39 A.

Fusible series max: 15 A.

Open circuit voltage: 37.7 **V.**

Courant of court –circuit: 8.92 A.

Voltage Max of system: 1000 v.

- **α** = -0.42% / ℃ : VOC temperature coefficient of modules Photovoltaic YL250P-29b.
- **β** = 0.042% / ℃: ISC temperature coefficient of photovoltaic modules Yingli_YL250P-29b_2015.PAN

• **Inverter:**

- **ISC (Tmax) = 1064 A**

This value is maximum current allowed by the Sunny Central inverter

Sungrow_SG500MX_M.OND

Model: pmd-d125k

Power nominal: 125kw

Voltage maximum dc: 1000 v

Max.° of dc input: 4

Protection IP: IP 65

Ambient temperature: -25 c° to 60 c°

• Voltage range: VMPP **= 480 - 850 V**

• Maximum voltage in direct current: **850V**

Net weight: 110kg

The voltage and current in the photovoltaic modules is affected by temperature, as indicated in Figure 3.6:

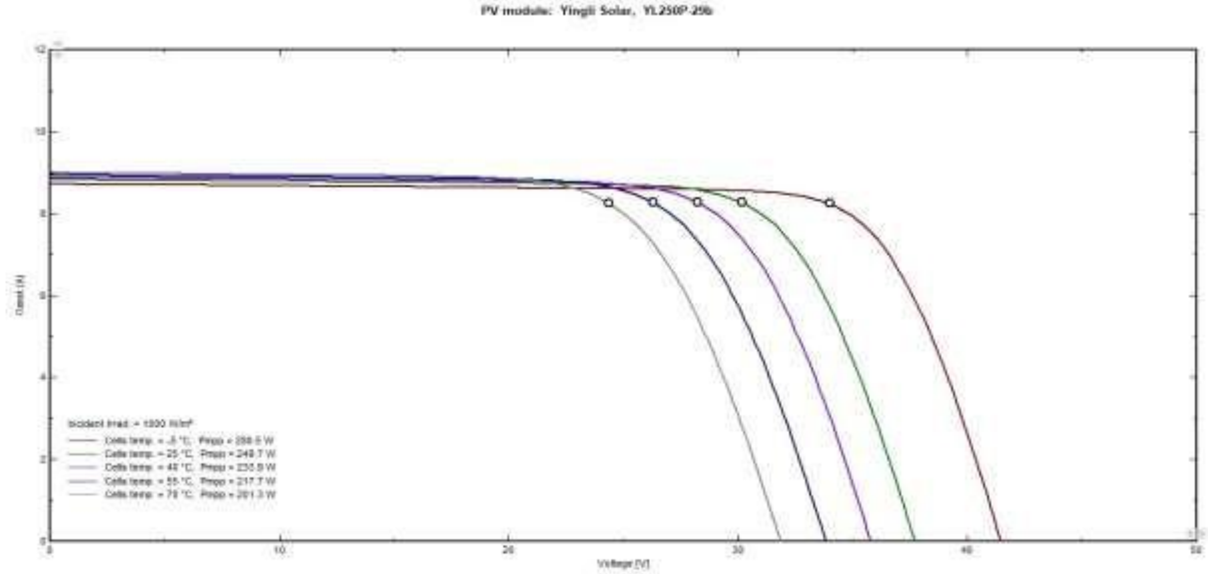


Figure 4.6 Effect of temperature on the voltage and current of the panels

As the temperature increases, the short circuit current (ISC) increases while the open circuit voltage decreases (VOC), according to the temperature coefficients specified by each manufacturer in the catalog of solar panels.V:voltage at cell terminals as defined in the book "Solar Electricity» **[**17**]**, the current supplied by a solar cell is defined by the Shockley equation:

$$I= I_L – I_D(V)=I_L-I_0[exp\frac{eV}{mKT} - 1]$$

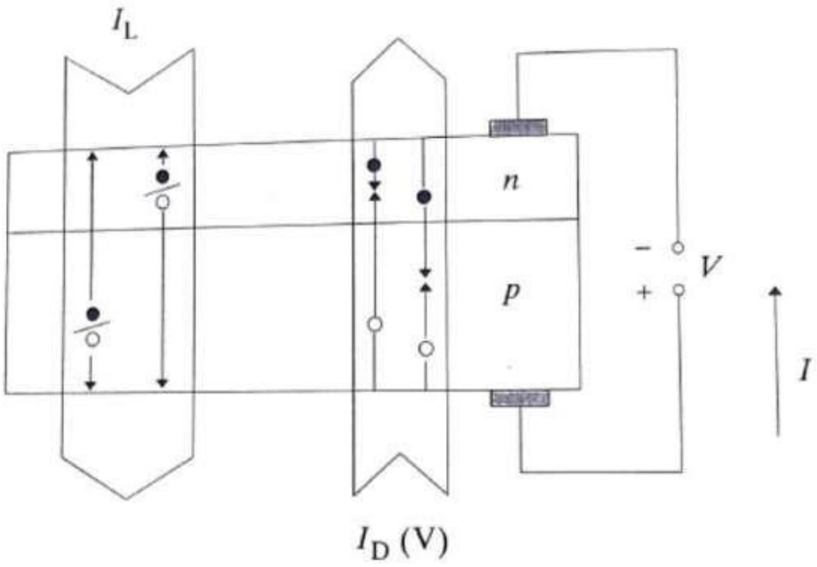


Figure 4.7 Photo generated current and diode current in a solar cell

The IL current defines the photo generated current due to the generation of carriers that causes the illumination of the cell. The current ID, called diode or dark current, is due to the recombination of the carriers, and therefore its sense is opposite to that of IL. The rest of the variables in the equation are:

- e = 1.602x10-19C: electron charge
- V: voltage at cell terminals
- m = 1 for low voltages (ÿ0.4V), m = 2 for high voltages (> 0.4V)
- k = 1.381x10-23 JK-1: Boltzmann constant
- T: absolute temperature

Photocurrent increases slightly with temperature due in part to increasing minority diffusion lengths and narrowing of the forbidden band (energy required to free an electron from its covalent bond into the conduction band where it can conduct a current) , shifting the absorption threshold towards photons of lower energy (photons that strike the cell with an energy greater than or equal to the width of the forbidden band are absorbed in the volume of the semiconductor and electron-hole pairs are generated that can act as current carriers, while photons with energy less than the width of the forbidden band passes through the semiconductor without being absorbed).
But the variation in the characteristics of the cell manifests itself most prominently in the termination of the diode current, which decreases with increasing temperature, increasing the current generated by the cell.

Regarding the open circuit voltage, it is defined by the equation:

$$Voc(T) = \frac{E_{GO}}{e} - \frac{KT}{e} ln \frac{KT^3}{IL}$$

K and EGO (0K bandwidth) being two constants approximately independent of temperature. Observing this equation it is found that the open circuit voltage decreases with increasing temperature.

Among the inverter's characteristics is the maximum power voltage range (VMPP = 480- 850 V), and the maximum direct current voltage (Max. DC voltage = 1000 V). The voltage generated by the modules in series must be within these ranges since the inverter keeps track of the maximum power point.

Therefore, to calculate the number of panels in series (Ns), it is necessary to perform three Checks:

- $V_{max} (T_{min}) = v_{mp}.N_s (1+\alpha (T_{min}-T_{amp}))$
- $V_{max} (T_{max}) = v_{mp}.N_s (1+\alpha (T_{max}-T_{amp}))$
- $V_{oc}(T_{min}) = v_{oc}.N_s (1+\alpha (T_{min}-T_{amp}))$

Tmin = -5 ° C: minimum temperature of the panels

Tmax = 70 ° C: maximum temperature of the panels

Tamb = 25 ° C: ambient temperature of the panels under STC conditions

For security reasons, more limited margins will be established, reducing the range of Voltages (480 - 850 V). The following table will be obtained depending on the number of modules in Series:

Ns	Vmax (Tmin)	Vmax (Tmax)	Voc (Tmin)	Validez
1	34	24.49	42.45	No
2	68	48.98	84.5	No
3	102	73.47	127.35	No
4	136	97.96	169.8	No
5	170	122.45	212.25	No
6	204	146.94	254.7	No
7	238	171.43	297.15	No
8	272	195.92	339.6	No
9	306	220.41	382.05	No
10	340	244.9	424.5	No
11	374	269.39	466.95	No
12	408	293.88	509.4	No
13	442	318.37	551.85	No
14	476	342.86	594.3	No
15	510	367.35	636.75	No
16	544	391.84	679.2	No
17	578	416.33	721.65	No
18	612	440.82	764.1	No
19	646	465.31	806.55	No
20	680	489.8	849	No
21	714	514.29	891	No
22	748	538.78	933.9	Selected
23	782	563.27	976.35	No
24	816	587.76	1018.8	No

Table 4.2 Finding the number of panels in series

It must be fulfilled that the three voltages calculated for each value of NS are found

Within the set range (480 - 850 V). Therefore, it follows that for said range

Defined, the only permissible number of modules in series is:

Ns = 22 modules

To calculate the maximum number of modules in parallel **(Np max)** it is also necessary to take into account the temperature. In this case the restriction is given by the maximum direct current permissible by the inverter (1064 A).

- $\mathbf{I_{sc}\,(T_{max}) = Isc.\,N_{p\,max}\,(1+\beta\,(T_{max} - T_{amp}))}$

For this method, the safety margin is established at 10 A **(so ISC (Tmax)** must be

Less than **1054** A). For that current value, the maximum number of modules in parallel is:

$$\mathbf{Np = \frac{1054}{8.84 * (1 - 3.7{*}10^{-3}(70 - 25)} = \quad 143}$$

$$\mathrm{Np} = 143$$

The oversizing (SD) supported by the Sungrow_SG500MX_M.OND

Inverter is calculated from the Maximum Power in Direct Current = 506 kWp

(For conditions below of the STC standard).

$$\mathbf{SD} = \frac{\mathbf{Pmax.cc - Pnom}}{\boldsymbol{Pnom}} = \frac{\mathbf{506 - 500}}{\mathbf{500}} = \mathbf{0.012}$$

The inverter admits up to 1.2% oversizing, which generates another restriction

for the calculation of the number of branches or strings in parallel:

$$\mathbf{Np} = \frac{\mathbf{Pmax\ cc}}{\boldsymbol{Ns.Pmodule}} = \frac{\mathbf{506(kw)}}{\mathbf{22 * 250}} = \mathbf{92}$$

With the values obtained so far (NS=21, NP<177 and NP=107 for SD=12%), we proceed to carry out a first dimensioning of the plant.

The arrangement of the solar modules on the structure is shown in Figure 3.8:

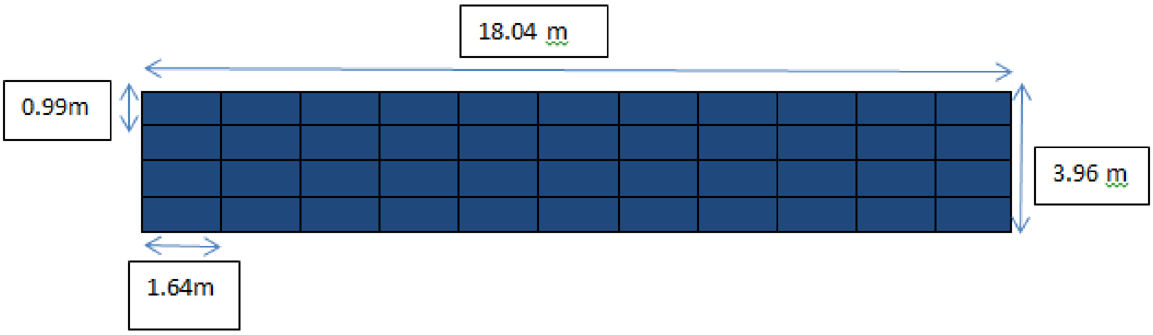


Figure 4.8 Arrangement of the panels on the support structure

- Number of photovoltaic modules connected in series per branch or string: 22 modules/string.
- In each Support 2 strings connected in parallel all carry the same characteristics and of the same type

  That is, we have 22*2=44

  44 photovoltaic module per Support.

In order to obtain a production capacity of 20 MW, the symmetry and balance between planning and organization must be achieved in the selection of supports and station elements; the balance is achieved according to the following:

Installation and leaving the necessary paths that allow access to all elements, leaving the distance between the supports to prevent misinformation and reduce obstacles, reduce the losses resulting from the transmission of energy through the cables created and all civil works and materials.

Based on the previous results obtained, we can form a design for a 1 MW block as follows:

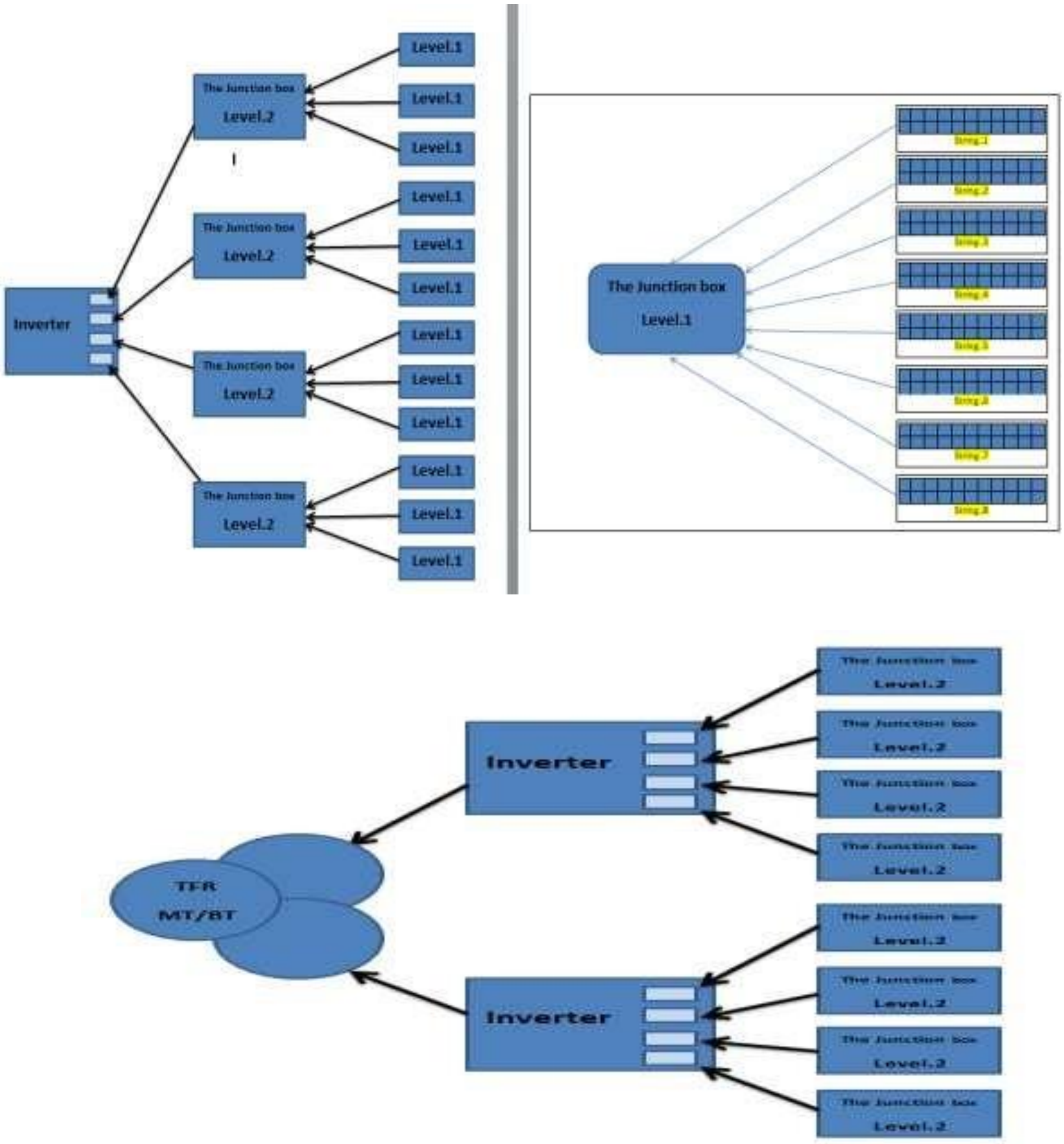


Figure 4.9 Modular block layout 1MW

In order to produce 20 MW, the megawatts must be so similar that each inverter receives the same amount of energy produced as well as produce the same value of losses in the system, this organization is obtained through 4048 panels photovoltaic units within 46 supports.

So that:

Ns =22 and **Np** = 92

That each inverter the energy produced will be 1012kwp

The excess size that each inverter will get (tow inverter per MW will be SD=12%).

Number of entries allowed by each inverter Sungrow_SG500MX_M.OND

Is 4 cables that are transported from the inverter are 3 which means that per MW 8 DC entrances and 6 ac exits in this way, all entrances are used without leaving any entrance vacant, depending on the design that has been put in place.

One of the reasons for raising the number of panels and increasing the size of the inverters is due to a decline in panel productivity over the years, as shown by the technical card for efficiency according to the years of operation in **Tableau 9**

Time in Years from Warranty Start Date	Programmed Performance value (PPV) minimum
0	100.00%
I	97.50%
2	96.80%
3	96.10%
4	95.40%
5	94.70%
6	94.00%
7	93.30%
8	92.60%
9	91.90%
10	91.20%
11	90.50%
12	89.80%
13	89.10%
14	88.40%
15	87.70%
16	87.00%
17	86.30%
18	85.60%
19	84.90%
20	84.20%
21	83.50%

22	82.80%
23	82.10%
24	81.40%
25	80.70

Table 4.3 Efficiency of the panels depending on the years of life.[18]

Part of the YGE 60 Cell Series, the YL250P-29b features high efficiency, polycrystalline solar cells with high-transmission textured glass delivering a module series efficiency of up to 15.3%, minimizing installation costs and maximizing the kWh output of your system per unit area.

Positive power tolerance of -0 / +5% minimizes PV system mismatch losses and ensures your power-per-watt Yingli solar panel system investment. **[**19**]**

In order to implement this project, it is necessary to verify that the limits of the power and the permissible density for each inverter are according to the temperature, so we study the values of the variables according to the chosen area for setting the solar field. The data can be obtained from the **PVsyst** simulation, the maximum power and the maximum current allowed by the inverter specified by its manufacturer in the values specified for the standard operating conditions **STC** ((25^{o}C, 1000W/m2, AM=1,5).

These maximum values decrease when a temperature is reached above 25°C and less than 1000w/m2.

Table 07: Maximum density values ranked from top to bottom inverter on days when the highest density reaches the highest values in a typical year

It should be noted that the current does not reach the inverter limit in the standard envelopes (the maximum direct current to enter into inverter in STC conditions: 1064 A)

In addition to the average temperatures on the days when these higher values are reached are below the standard temperature (TSTC =25°), this intensity can cause problems if the temperature is higher than TSTC due to the high temperature that would have been produced in the inverter components even if the 1064 A was not reached Referred to by the manufacturer.

Month	Hors	Courant (Ah/day)	Tension (V)	Power (KW)	Temperature (c °)
24 janury	**5.53**	**954.06**	**645.9**	**616.2**	**2.98**
06 December	**5.22**	**960**	**640.3**	**614.68**	**6.69**
16 februry	**5.625**	**973.68**	**637.8**	**598.05**	**7.19**
03 april	**6.77**	**907.17**	**635.6**	**576.6**	**8.34**
12 November	**5.38**	**920.57**	**623.8**	**574.25**	**13.29**
13 March	**6.638**	**918.3**	**614.9**	**564.6**	**10.31**
07 Otober	**6.28**	**905.04**	**600.4**	**543.4**	**21.1**
24 September	**6.36**	**921**	**587.1**	**540.7**	**25.08**
03 May	**7.01**	**833.03**	**605.7**	**504.56**	**20.23**
04 Jun	**6.94**	**817.6**	**614.1**	**502.08**	**17.95**
18 Augest	**7.09**	**801.08**	**570.7**	**475.7**	**32.16**
06 July	**7.26**	**769.2**	**592.7**	**455.92**	**25.49**

Table 4.4 Simulation data with PVsyst

4.3.1 Final sizing:

The final installation contains 2024 PV modules of 250 w_p up to each inverter 92 string Consists of 22 units connected in series A level 1 and level 2 junction box is used so that each inverter has 12 level 1 1and 4 level 2 junction boxes, to achieve the target rated power of 20 MW

We will have 40 inverters of 500 kilowatts in the station and thus 80,960 photovoltaic units in total with an installed power of 20,240 kilowatts and we will get an annual production of 42.2 megawatts.

4.4. LV-MV transformer sizing

The photovoltaic plant will have a total of twenty (20) power transformers, one for each 1MW modular block.

These transformers have the purpose of raising the Low Voltage to Medium Voltage to carry out the transport of energy through the plant, reducing losses as much as possible, and raising the voltage to the evacuation voltage defined by the **GRTE** distribution company (30kV). In this way it is possible not to resort to another step-up transformer that would be located next to the sectioning center to raise the voltage before evacuating to the distribution network

As a first approximation, the logical thing in this project seems to be to choose 1MVA transformers for each 1MW modular block. In this section, a study will be carried out to verify what overload the transformer allows, taking into account the temperature and being limited by the short and long-term effects it has on the transformer, and which are described later, without reducing the useful life of the same. The study will be carried out

Following the **ANSI / IEEE C57.92-1981 standard:** "Guide for loading mineral-oil-immersed power transformers up to and including 100 MVA with 55 ° C or 65 ° C average winding rise" **[**20**]**

The temperature takes on a remarkable importance in the operation of the transformers. There are several factors that affect the life span of a transformer. This duration is highly dependent on extraordinary events, such as power surges, short circuits in the network, and emergency overloads.

Normal life expectancy is defined for continuous uninterrupted service at reference ambient temperature and assigned operating conditions. If the applied load exceeds those defined on the nameplate and / or the ambient temperature is higher than the assigned value, this implies a risk and an acceleration of the aging of the transformer.

Overloading a transformer above the assigned values has several consequences, among which are:

- the temperatures of the windings, clamping pieces, connections, insulation and oil, increase and may reach unacceptable values
- the density of the leakage flux outside the magnetic circuit increases and causes an increase
  in heating by eddy currents in the metallic parts traversed by the flux
- the combination of the main flow and the dispersion flow limit the possibility of overdrive the magnetic circuit
- temperature variations imply changes in moisture content and gases, insulation and oil

- terminals, tap changers, cable terminals and current transformers will also be exposed to more severe conditions reducing their possibilities of use
- Based on the above and in anticipation of any changes related to increased loads or temperature leads to premature risk.

The effect on the transformer of temperature can be both short-term and long-term.

The short-term effects are: high temperatures cause a temporary

deterioration of the mechanical properties with the consequent reduction of the ability to withstand short-circuit stresses; If the insulation temperature exceeds the critical temperature, there may be accumulation of gases in the bushings or an expansion of the oil that causes an overflow of the same in the preservative tank

Long-term effects can be highlighted: there will be an acceleration of the cumulative thermal degradation of the insulation of the conductors, as well as of other insulating materials, structural parts and the conductors themselves; Transformer joints can become more brittle at high temperatures [UNE 20 110: 1995 Standard, "Loading guide for power transformers immersed in oil"]. **[**21**]**

The temperature effect on the adapter can be short or long-term. The performance of transformers is related to the temperature of geographical areas. Transformers that operate at low temperature have a higher carrying capacity,while high- temperature transformers are less durable.Transformers can operate under overload without reducing their productive life.

/	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Media anual
Maximum	11.17	13.35	19.17	22.42	27.59	32.17	34.3	32.75	28.77	25.2	17.6	12.3	23.06
Minimum	-0.83	1.43	3.36	7.11	11.9	17.95	24.6	23.75	15.82	11.86	4.66	0.89	10.22
Average	5.17	7.39	11.26	14.76	19.74	25.06	29.45	28.25	22.29	18.53	11.13	6.59	16.63

Table 4.5 Temperature data of the place where the plant will be located

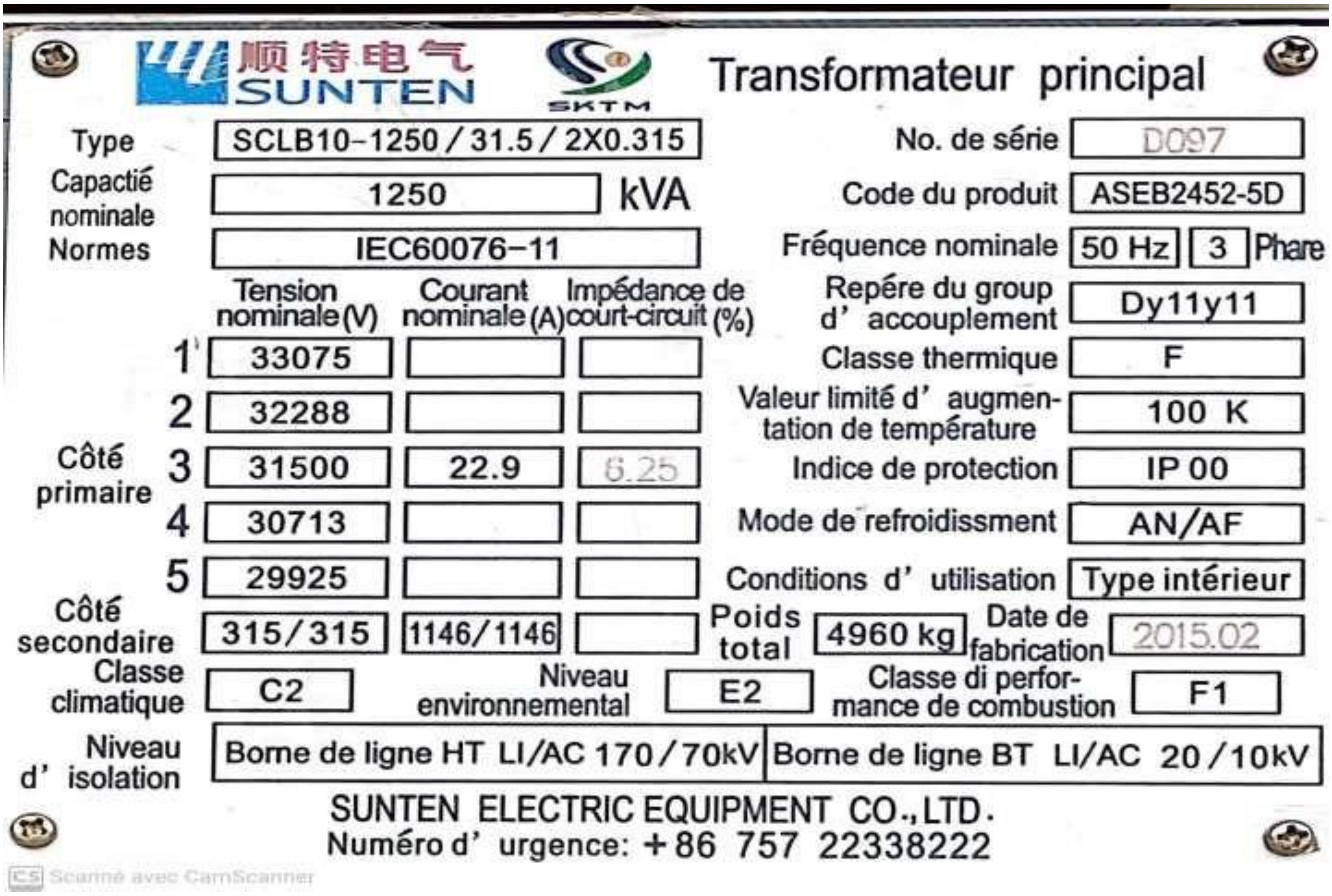
It is necessary to analyze the days in which the maximum amount of energy is produced compared to the rest of the year, and study the worst case, that is, the day in which the temperature is higher since the transformer will reduce its load capacity.

According to the hourly data provided by the PVSyst, the days in which production is highest (for each 1MW modular block) are those specified in table 9:

Month	**N HOURS**	**Courant (A)**	**Tension (V)**	**Power (KW)**	**Temperature (c°)**	**POW.2 INVERTER**	**Power * Red**	**APARENT POT TRAFO (kVa)**
24 janury	**5.53**	**954.06**	**645.9**	**616.2**	**2.98**	**1232.4**	**1217.6**	**1352.9**
06 December	**5.22**	**960**	**640.3**	**614.68**	**6.69**	**1229.36**	**1214.8**	**1349.7**
16 februry	**5.625**	**973.68**	**637.8**	**598.05**	**7.19**	**1196.1**	**1181.7**	**1313**
03 april	**6.77**	**907.17**	**635.6**	**576.6**	**8.34**	**1153.2**	**1139.36**	**1266**
12 November	**5.38**	**920.57**	**623.8**	**574.25**	**13.29**	**1148.5**	**1134.7**	**1260.7**
13 March	**6.638**	**918.3**	**614.9**	**564.6**	**10.31**	**1129.2**	**1115.6**	**1239.5**
07 Otober	**6.28**	**905.04**	**600.4**	**543.4**	**21.1**	**1086.8**	**1073.7**	**1193**
24 September	**6.36**	**921**	**587.1**	**540.7**	**25.08**	**1081.4**	**1068.4**	**1187.1**
03 May	**7.01**	**833.03**	**605.7**	**504.56**	**20.23**	**1009.12**	**997**	**1107.7**
04 Jun	**6.94**	**817.6**	**614.1**	**502.08**	**17.95**	**1004.16**	**992.11**	**1102.34**
18 Augest	**7.09**	**801.08**	**570.7**	**475.7**	**32.16**	**951.4**	**940**	**1044.4**
06 July	**7.26**	**769.2**	**592.7**	**455.92**	**25.49**	**911.84**	**901**	**1001.1**

Table 4.6 Simulation data with PVSyst.

The column "POWER" refers to the power (kW) received by each of the inverters. As the modular blocks are symmetrical and equivalent for the inverters, the active power that the transformer will receive will be twice the power of the inverters, and multiplied by their performance (98.8%). Finally, the apparent power that the transformer will see will be the previously calculated power (“POT * Rend”) divided by the most unfavorable power factor of the inverter (cos φ = 0.9 for SUNGROW 500HE-US).



顺特电气 SUNTEN

SKTM

Transformateur principal

Type	SCLB10-1250/31.5/2X0.315	No. de série	D097
Capactié nominale	1250 kVA	Code du produit	ASEB2452-5D
Normes	IEC60076-11	Fréquence nominale	50 Hz 3 Phare
		Repére du group d' accouplement	Dy11y11

		Tension nominale (V)	Courant nominale (A)	Impédance de court-circuit (%)
Côté primaire	1	33075		
	2	32288		
	3	31500	22.9	6.25
	4	30713		
	5	29925		
Côté secondaire		315/315	1146/1146	

Classe thermique	F
Valeur limité d' augmentation de température	100 K
Indice de protection	IP 00
Mode de refroidissment	AN/AF
Conditions d' utilisation	Type intérieur
Poids total	4960 kg
Date de fabrication	2015.02
Classe climatique	C2
Niveau environnemental	E2
Classe di performance de combustion	F1
Niveau d' isolation	Borne de ligne HT LI/AC 170/70kV Borne de ligne BT LI/AC 20/10kV

SUNTEN ELECTRIC EQUIPMENT CO., LTD.
Numéro d' urgence: +86 757 22338222

Figure 4.10 Characteristic of transformer.

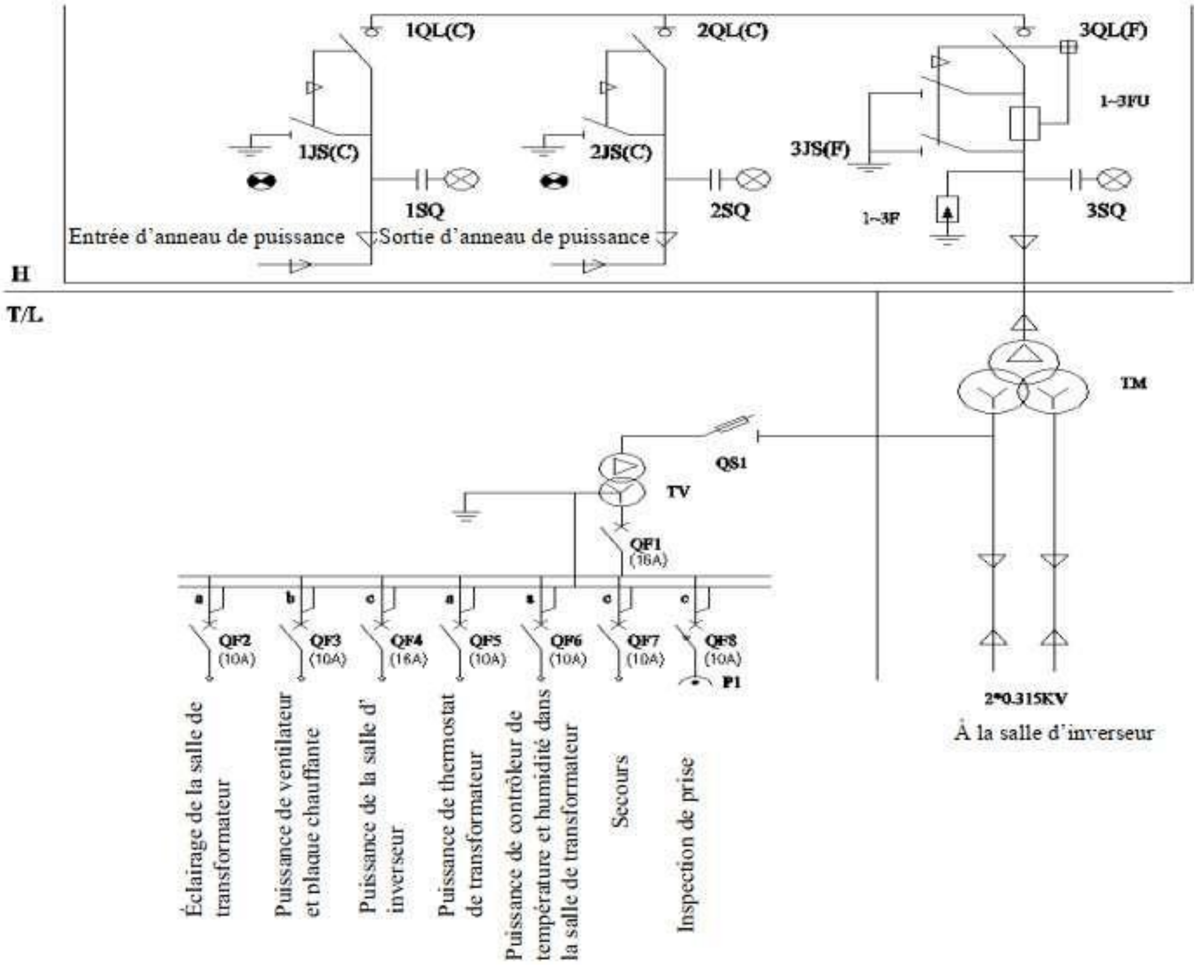


Figure 4.11 Device Equipment Primary System Diagram

4.4.1. Conclusion

According to the values in table N for power (kVa) and current, a 1 MW transformer is selected according to the characteristics and design of the station.

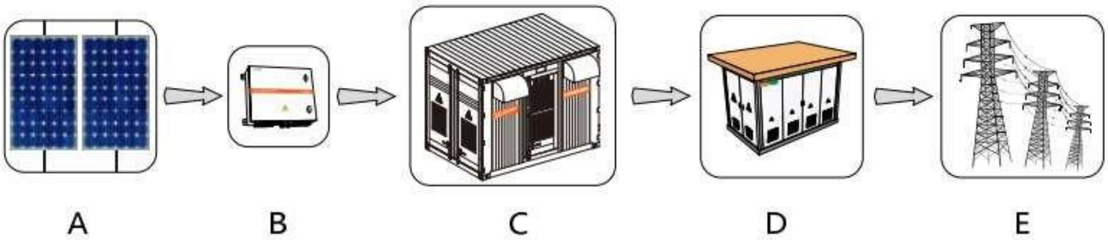


Figure 4.12 The photovoltaic system connected to the grid

	NAME
A	**Photovoltaic solar power**
B	**Solar photovoltaic power station combiner box**
C	**Inverter**
D	**Content-Type Transformer**
E	**Utility grid**

Table 4.7 Introducing items

4.4.2 The Digsin of block 1MW:

4.5. Calculation of DC and AC electrical wiring

4.5.1. Calculation of DC electrical wiring

In this part, wire sections will be calculated. The conductive cable is the indispensable component of its importance in transferring energy between the different elements of the photovoltaic system. Therefore, we should pay close attention to calculating cable sections and avoiding bad choice that leads to economic losses that could have been avoided by increasing cable sections in accordance with NEC regulations. Part (wire and material methods).

The standards that the conductors used in the installation must comply with are:

- Thermal Standard: The conductor must be able to dissipate the heat generated by The intensity that propagates through it during the permanent regime period, taking into account Calculation of correction factors for temperature, depth and resistance Terrain and assembly.
- Standard voltage drop: the voltage drop must be less than specified According to design terms
- Standard short circuit

Depending on many technical standards, cable sections are selected.

A. Calculation wiring panels – "combiner box"

At PV stations, there is a restriction on the use of conductors according to article nec-690.8 (b), the maximum current they can carry is 80%. of the maximum current capacity that could flow through them.

Thermal criterion

Working in accordance with article NEC-690.8(1), the maximum current must be the sum of the current of the strings connected in parallel multiplied by 125%.

$$\mathbf{I_{MAX} = 1.25 * I_{SC} = 1.25 * 8.84 = 11.05\ A}$$

ISC: the short circuit current of the photovoltaic modules.

The cable section satisfying this requirement, according to NEC-240.4 (D) (3) is (15 A), which is equivalent to 2.1 mm2. This section is too small to withstand the intensity of the current and maintain its performance for the longest period. In order to reduce the voltage drop, it was decided to raise the cable section to the standard 4 mm2.

Voltage drop criterion:

The low voltage of the PV panel beyond the inverter should be no more than 1.5 % To apply this standard it is necessary to calculate low voltage in cables

The maximum effort produced is :

$$\Delta u(\%)max = 0.265\%$$

The calculation method used:

$$\Delta u(v) = 2 * R * I = 2 * I * \rho * \frac{L}{S}$$

We have:

- I = IMPP =.827 A
- γ = 44 m/ohm.mm2: copper conductivity.
- L =25 m: Maximum length from the farthest PV unit to the “combiner- box”.
- S= 4mm2: The section of the cable.

$$\Delta u(\%) = \frac{\Delta u(v)}{U_{string}} * 100$$

We have:

U_{string} = 22 x 30,2V = 664.4 V: Voltage of the 22 modules in series that configure string.

B. Wired calculation "combiner-box"Level1 / "combiner-box" Level2:

Thermal criterion

Following the requirements set out in Article NEC-690.8(2), the permissible flow of Cables must support a current value equal to the sum of the currents for each of the Strings in parallel (8 strings per "combiner-box") plus 25%, according to article NEC- 7690.8(1).

$$I_{MAX} = 8*(1.25 * I_{sc}) = 8*(1.25 *8.84) = 88.4 \text{ A}$$

ISC: the short circuit current of the photovoltaic modules.

The overcurrent device must have a capacity of 125% of the current determined in the calculation above. This is to prevent devices from against Overcurrent's operating at more than 80% capacity. Therefore, the cables have to be sized to support that 125% of the calculated intensity, to ensure the correct operation of devices against connected overcurrent's.

So by this criterion a cable of a section (**70 mm2**) is chosen.

Voltage drop criterion

The low voltage of the PV panel beyond the inverter should be no more than 1.5 %.To apply this standard it is necessary to calculate low voltage in cables

The maximum effort produced is :

$$\Delta u(\%)max = 0.169\%$$

The calculation method used:

$$\Delta u(v) = 2* R *I = 2* I* \rho* \frac{L}{S}$$

We have:

- $I = I_{MPP} = 66.16$ A
- $\gamma = 44$ m/ohm.mm2: copper conductivity.
- L =35 m: Maximum length from the “combiner -box” level 1 to the “combiner -box” level 2.
- S= 70mm2: The section of the cable.

$$\Delta u(\%) = \frac{\Delta u(v)}{U_{string}} * 100$$

We have:

$U_{string} = 22 \times 30{,}2V = 664.4$ V: Voltage of the 22 modules in series that configure string.

C. Wired calculation "combiner-box «Level 2 / inverter

Thermal criterion

Following the requirements set out in Article NEC-690.8(2), the permissible flow of Cables must support a current value equal to the sum of the currents for each of the Strings in parallel (4 "combiner-box" level 2 per inverter) plus 25%, according to article NEC- 690.8(1).

$$I_{MAX} = 4 * I_{MAX} = 4 * 88.4 = 353.6 \text{ A}$$

ISC: the short circuit current of the photovoltaic modules.

The overcurrent device must have a capacity of 125% of the current determined in the calculation above. This is to prevent devices from against Overcurrent’s operating at more than 80% capacity. Therefore, the cables have to be sized to support that 125% of the calculated intensity, to ensure the correct operation of devices against connected overcurrent’s.

So by this criterion a cable of a section (**240 mm2**) is chosen.

Voltage drop criterion

The low voltage of the PV panel beyond the inverter should be no more than 1.5 % to apply this standard it is necessary to calculate low voltage in cables

The maximum effort produced is :

$$\Delta u(\%)_{max} = 0.677\%$$

The calculation method used:

$$\Delta u(v) = 2 * R * I = 2 * I * \rho * \frac{L}{S}$$

We have:

- $I = I_{MPP} = 264.64$ A
- $\gamma = 44$ m/ohm.mm2: copper conductivity.
- L =120 m: Maximum length from the “combiner -box” level 2 to the inverter.
- S= 240 mm2: The section of the cable.

$$\Delta u(\%) = \frac{\Delta u(v)}{U_{string}} * 100$$

We have:

U_{string} = 22 x 30,2V = 664.4 V: Voltage of the 22 modules in series that configure string.

$$\Delta u(\%)_{max} = \Delta u(\%)_{max\,1} + \Delta u(\%)_{max2} + \Delta u(\%)_{max3} = 0.265+0.169+0.677 = 1.11\ \%$$

4.6. Calculation of AC electrical wiring:

By intensity:

The intensity that driver will carry considering that investors are working

at its maximum power will be:

$$I = \frac{S}{\sqrt{3} * U} = \frac{P/COS(\varphi)}{\sqrt{3} * 315\ V} = 1030.47\ A$$

Voltage drop:

$$\Delta u(\%) = \frac{100}{U} \sqrt{3} * I * (r * L * \cos \phi + X * L * \sin \phi)$$

- r = 0.00035 ohm / m.
- x = 0.00072 ohm / m.
- L = 5 m: maximum cable length
- I = 264.4 A: (1018 A being the maximum current in AC for 315 V Of investor)
- U = 315 V
- Phi = 25.84
- S= 240 mm2

The voltage drop that occurs is ∆V (%) = 0.15%.

The fuses

Two types of fuses are used to maintain the integrity and good performance of the devices, (Where they are inside the Junction boxes). In order to prevent the current from exceeding the value of Imax.

Figure 4.13 fuse located in junction box level one

Figure 4.14 fuse located in level two junction box

Chapter 05

Chapiter 5 Station design through simulation program:

5.1 Introduction to PVsyst program

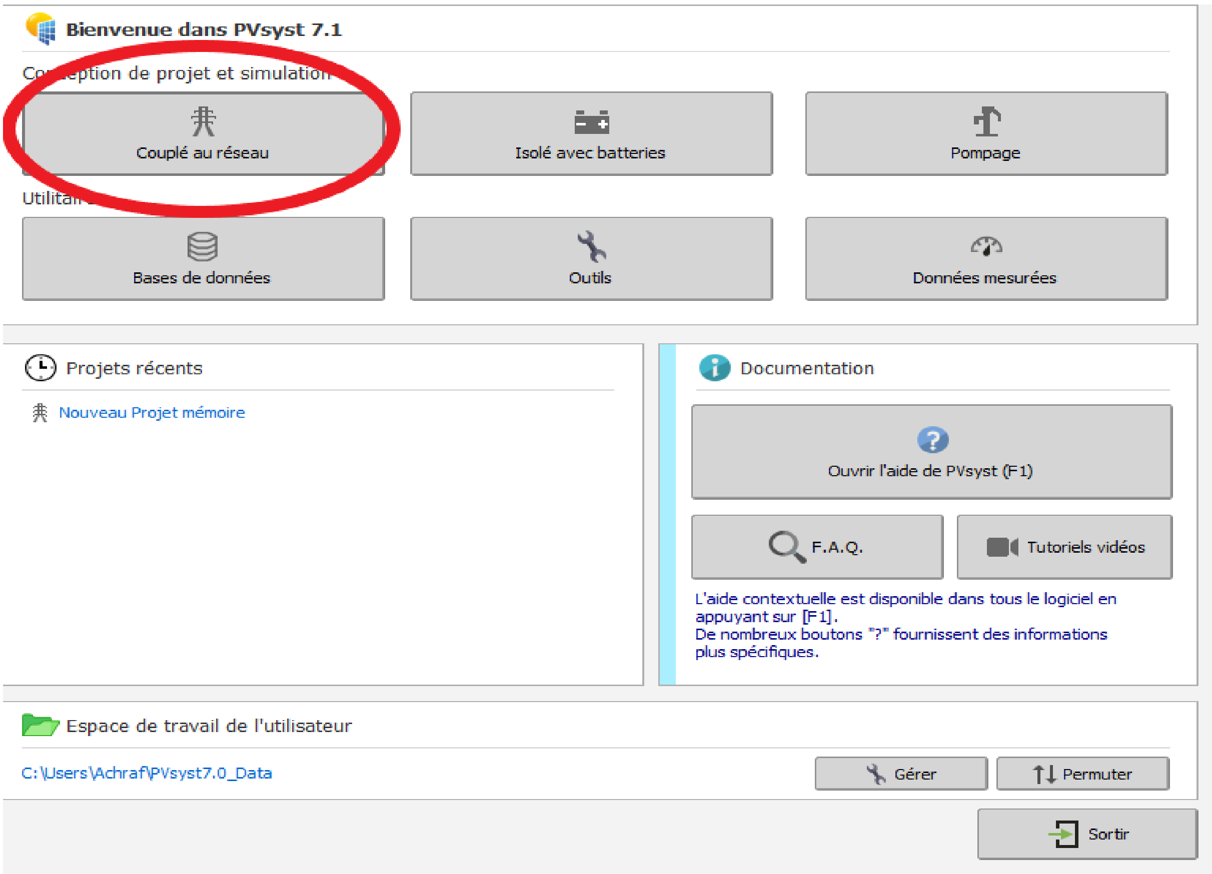
PVsyst is designed to be used by engineers, and researchers. It is also a very useful educative tool. It includes a detailed contextual Help menu that explains the procedures and models that are used, and offers a user-friendly approach with a guide to develop a project. PVsyst is able to import weather data, as well as personal data from many different sources. https://www.pvsyst.com/

The choice of design through the PVSyst simulation program is for the estimated design of the plant by taking the model 0.5 MW to facilitate the design of the plant so that the program has different types of photovoltaic panels and inverters after the design process is obtained the report of the simulations includes all the details of the station and various losses.
The design is intended for the Ain EL MELH - MSILA - Algeria, which was selected to develop the station to study the characteristics of the region in Chapter 2.
The simulation report contains details of the design, production capacity of the plant, performance and various reasons leading to losses in the system.

The detailed simulation of a photovoltaic system includes:

- The choice of components (photovoltaic panels, inverter).
- The detailed arrangement of the sensor field (orientation, mounting mode).
- Estimate of energy produced.

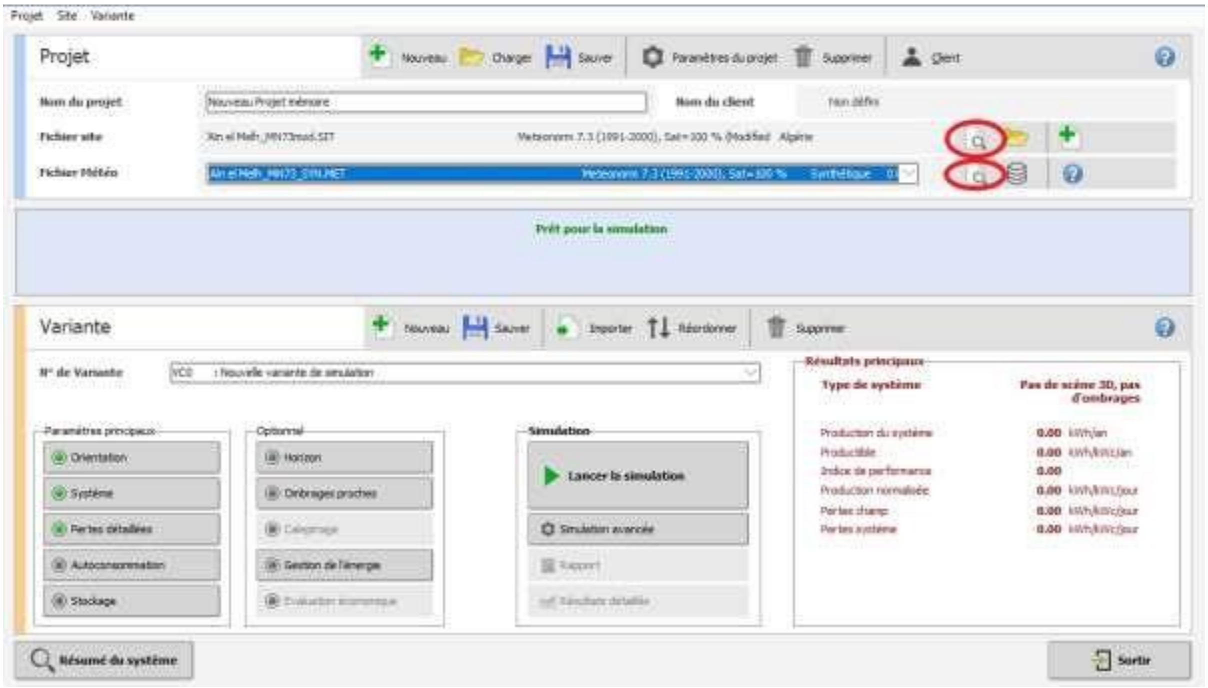
Stages of work on PVsyst program simulations represented by the steps arranged as shown in the following images



L'aide contextuelle est disponible dans tous le logiciel en appuyant sur [F1].
De nombreux boutons "?" fournissent des informations plus spécifiques.

C:\Users\Achraf\PVsyst7.0_Data

Figure 5.1 Choose the type of design



Nom du projet: Nouveau Projet mémoire
Nom du client: Non défini
Fichier site: Ain el Melh_MN73mod.SIT Meteonorm 7.3 (1991-2000), Sat=100 % (Modified Algérie
Fichier Météo: Ain el Melh_MN73_SYN.MET Meteonorm 7.3 (1991-2000), Sat=100 % Synthétique

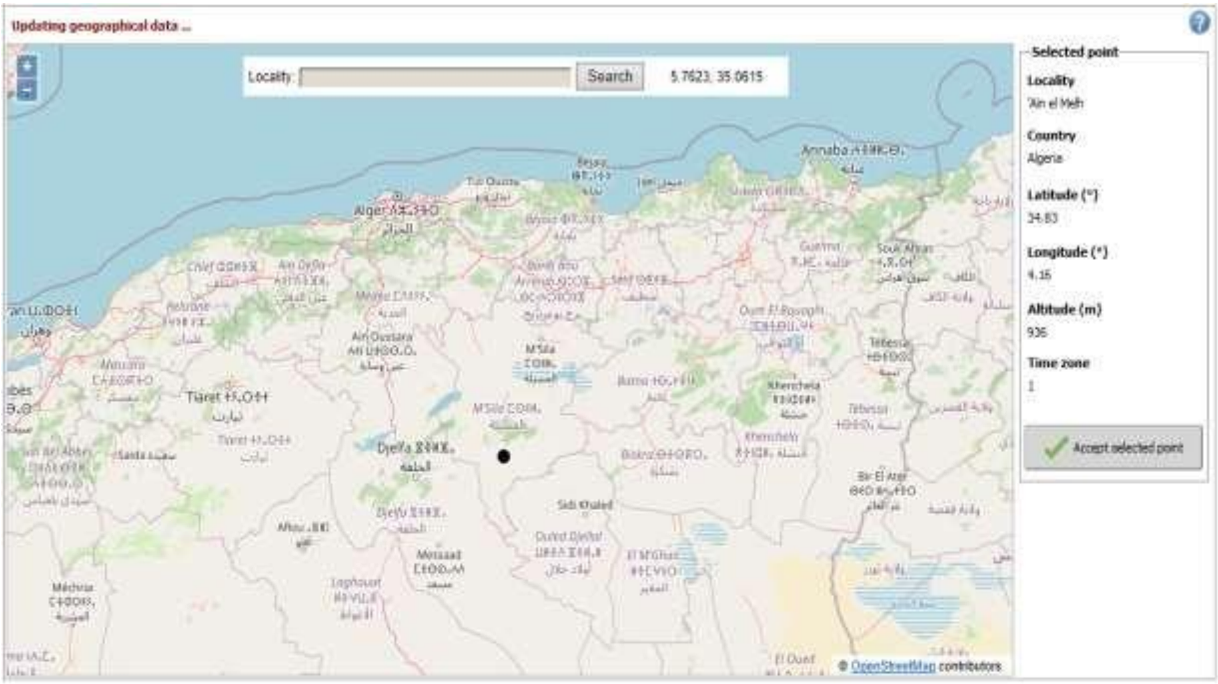
Prêt pour la simulation

N° de Variante: VC0 : Nouvelle variante de simulation

Résultats principaux

Type de système	Pas de scène 3D, pas d'ombrages
Production du système	0.00 kWh/an
Productible	0.00 kWh/kWc/an
Indice de performance	0.00
Production normalisée	0.00 kWh/kWc/jour
Pertes champ	0.00 kWh/kWc/jour
Pertes système	0.00 kWh/kWc/jour

Figure 5.2 Listing the site and file Weather



Selected point

Locality
'Ain el Melh

Country
Algeria

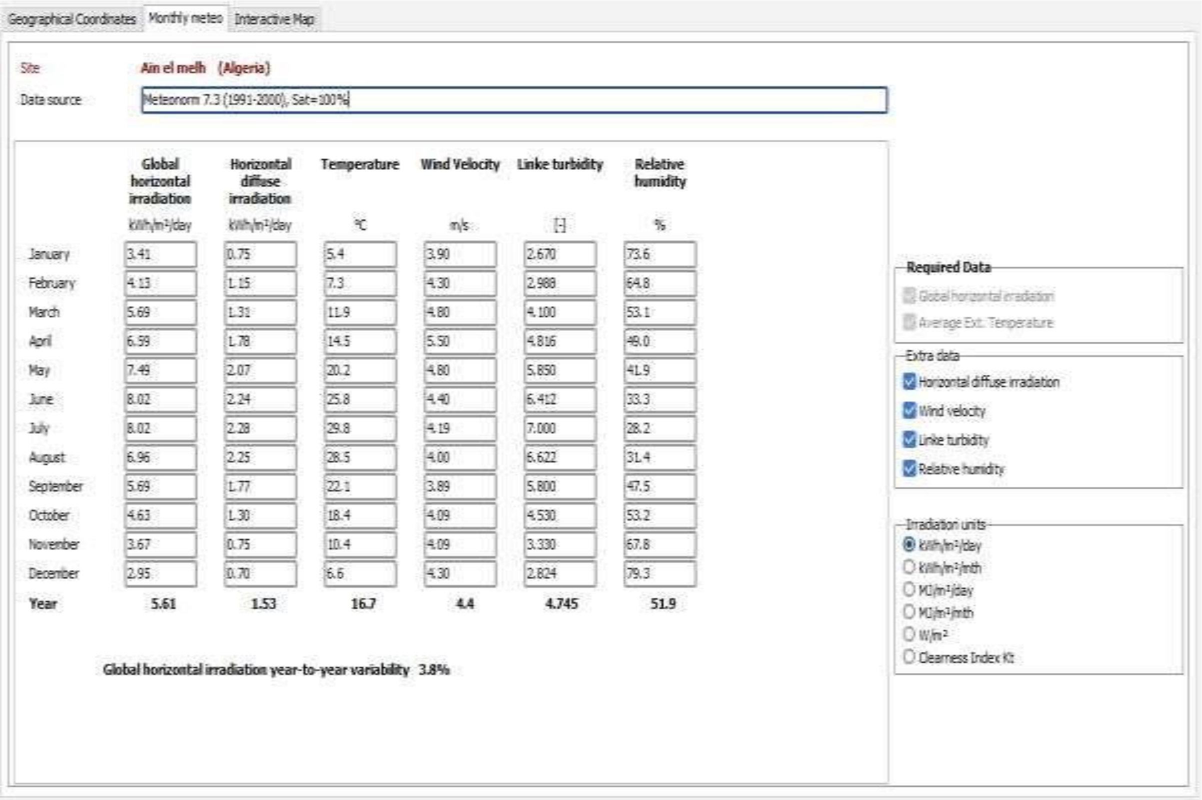
Latitude (°)
34.83

Longitude (°)
4.16

Altitude (m)
936

Time zone
1

Figure 5.3 Site and geographical map of Ain -El Melh area.



Site: Ain el melh (Algeria)

Data source: Meteonorm 7.3 (1991-2000), Sat=100%

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/day	kWh/m²/day	°C	m/s	[-]	%
January	3.41	0.75	5.4	3.90	2.670	73.6
February	4.13	1.15	7.3	4.30	2.988	64.8
March	5.69	1.31	11.9	4.80	4.100	53.1
April	6.59	1.78	14.5	5.50	4.816	49.0
May	7.49	2.07	20.2	4.80	5.850	41.9
June	8.02	2.24	25.8	4.40	6.412	33.3
July	8.02	2.28	29.8	4.19	7.000	28.2
August	6.96	2.25	28.5	4.00	6.622	31.4
September	5.69	1.77	22.1	3.89	5.800	47.5
October	4.63	1.30	18.4	4.09	4.530	53.2
November	3.67	0.75	10.4	4.09	3.330	67.8
December	2.95	0.70	6.6	4.30	2.824	79.3
Year	**5.61**	**1.53**	**16.7**	**4.4**	**4.745**	**51.9**

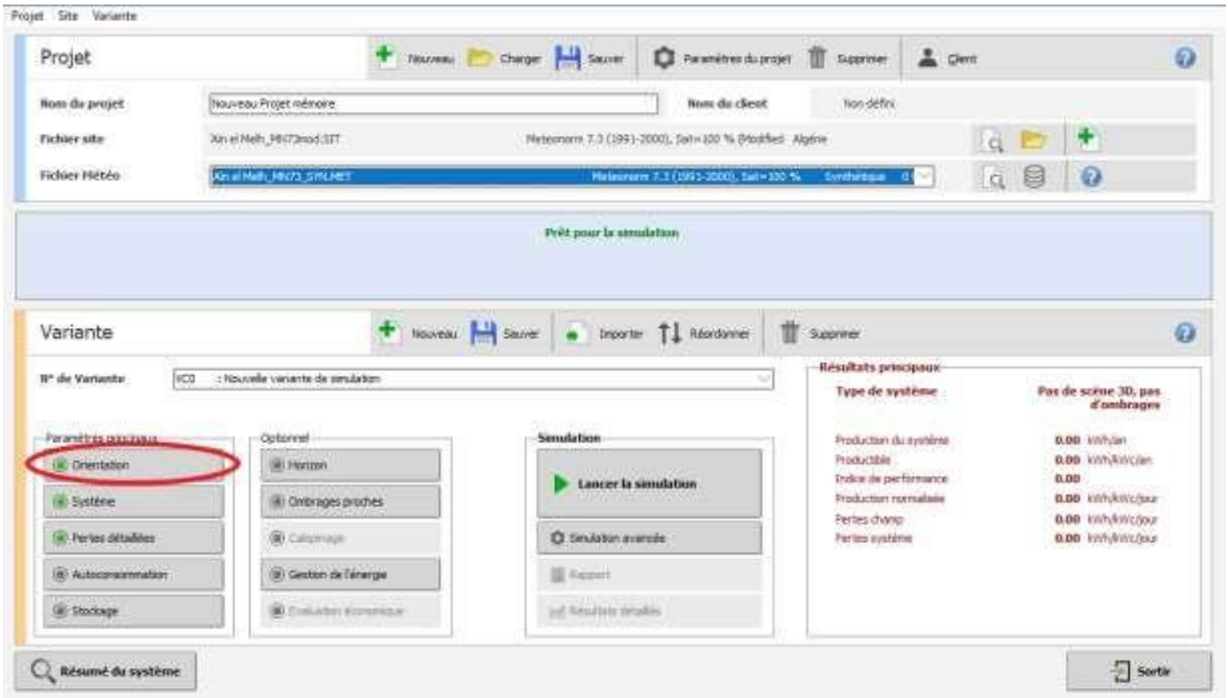
Global horizontal irradiation year-to-year variability 3.8%

Required Data
☑ Global horizontal irradiation
☑ Average Ext. Temperature

Extra data
☑ Horizontal diffuse irradiation
☑ Wind velocity
☑ Linke turbidity
☑ Relative humidity

Irradiation units
● kWh/m²/day
○ kWh/m²/mth
○ MJ/m²/day
○ MJ/m²/mth
○ W/m²
○ Clearness Index Kt

Figure 5.4 meteorological data of the site Ain El melh-Algeria**.**



Nom du projet: Nouveau Projet mémoire

Nom du client: Non défini

Fichier site: Ain el Melh_MN73mod.SIT — Meteonorm 7.3 (1991-2000), Sat=100 % (Modified) Algérie

Fichier Météo: Ain el Melh_MN73_SYN.MET — Meteonorm 7.3 (1991-2000), Sat=100 % — Synthétique 0

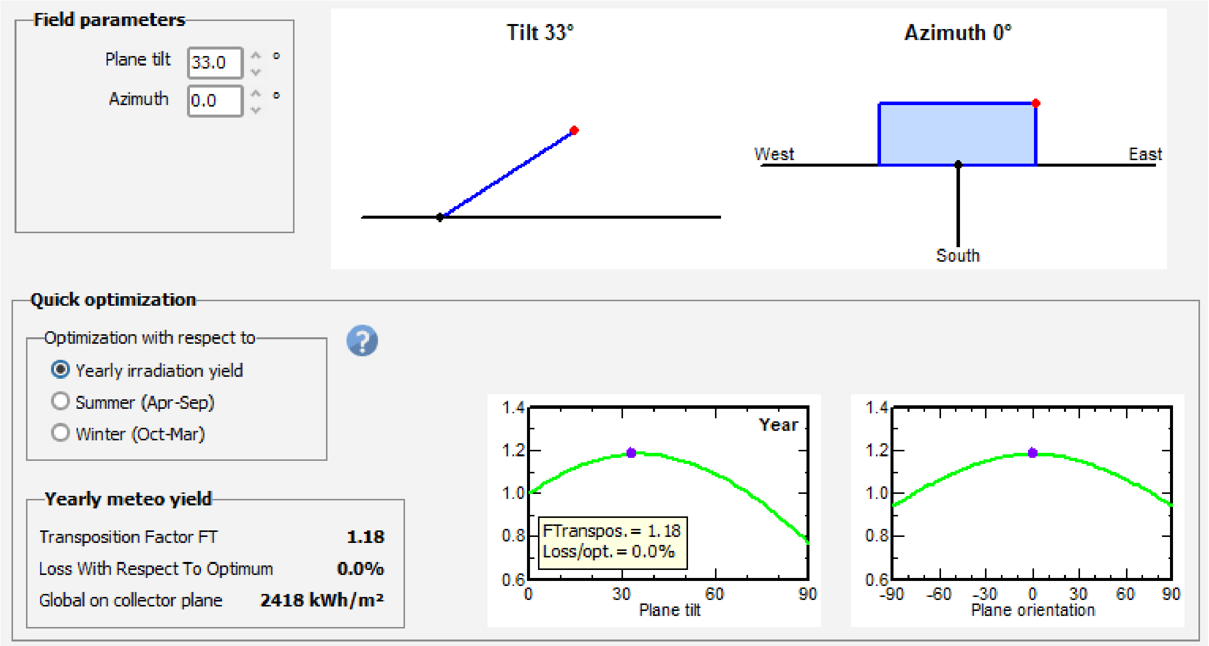
Prêt pour la simulation

N° de Variante: VC0 : Nouvelle variante de simulation

Résultats principaux

Type de système	Pas de scène 3D, pas d'ombrages
Production du système	0.00 kWh/an
Productible	0.00 kWh/kWc/an
Indice de performance	0.00
Production normalisée	0.00 kWh/kWc/jour
Pertes champ	0.00 kWh/kWc/jour
Pertes système	0.00 kWh/kWc/jour

Figure 5.5: Choosing to inclination and angle azimuth of panels



Field parameters

Plane tilt: 33.0 °

Azimuth: 0.0 °

Optimization with respect to

- ● Yearly irradiation yield
- ○ Summer (Apr-Sep)
- ○ Winter (Oct-Mar)

FTranspos. = 1.18
Loss/opt. = 0.0%

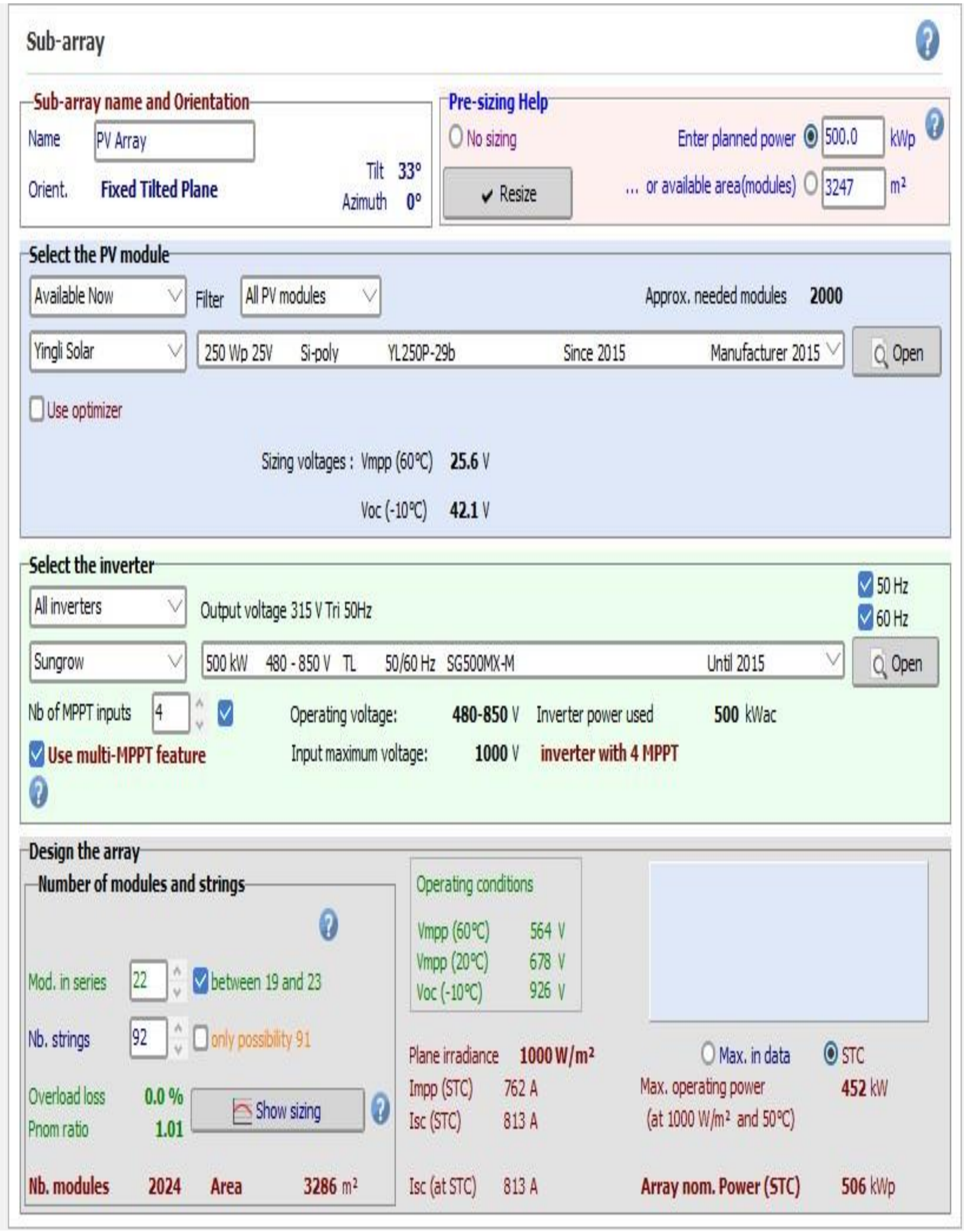
Yearly meteo yield

Transposition Factor FT	**1.18**
Loss With Respect To Optimum	**0.0%**
Global on collector plane	**2418 kWh/m²**

Figure 5.6 orientation of photovoltaic panels.

A good choice of orientation increases the production capacity of solar panels as well as the exploitation of a large percentage of solar radiation.

This increases economic profits.


Sub-array

Sub-array name and Orientation
Name: PV Array
Orient.: Fixed Tilted Plane
Tilt 33°
Azimuth 0°

Pre-sizing Help
○ No sizing
Enter planned power ● 500.0 kWp
... or available area(modules) ○ 3247 m²

Select the PV module
Available Now
Filter: All PV modules
Approx. needed modules 2000
Yingli Solar
250 Wp 25V Si-poly YL250P-29b Since 2015 Manufacturer 2015

☐ Use optimizer
Sizing voltages : Vmpp (60°C) 25.6 V
Voc (-10°C) 42.1 V

Select the inverter
All inverters
Output voltage 315 V Tri 50Hz
☑ 50 Hz
☑ 60 Hz
Sungrow
500 kW 480 - 850 V TL 50/60 Hz SG500MX-M Until 2015

Nb of MPPT inputs: 4 ☑
Operating voltage: 480-850 V
Inverter power used 500 kWac
☑ Use multi-MPPT feature
Input maximum voltage: 1000 V
inverter with 4 MPPT

Design the array
Number of modules and strings
Mod. in series: 22 ☑ between 19 and 23
Nb. strings: 92 ☐ only possibility 91
Overload loss 0.0 %
Pnom ratio 1.01

Nb. modules 2024 Area 3286 m²

Operating conditions
Vmpp (60°C) 564 V
Vmpp (20°C) 678 V
Voc (-10°C) 926 V

Plane irradiance 1000 W/m²
○ Max. in data ● STC
Impp (STC) 762 A
Max. operating power 452 kW
Isc (STC) 813 A
(at 1000 W/m² and 50°C)
Isc (at STC) 813 A
Array nom. Power (STC) 506 kWp

Figure 5.7 configuring the system in PVsyst.

5.2 Rapport of Simulation

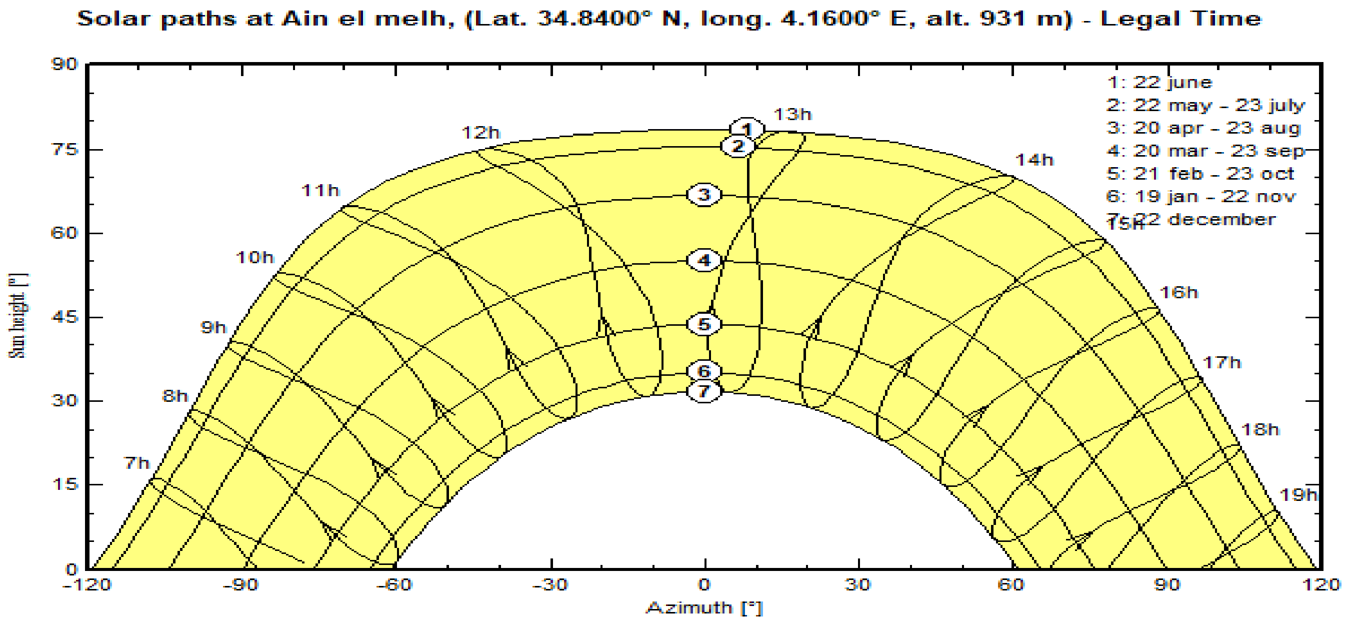


Figure 5.8 The path of the sun for the Region of Ain el melh Algeria.

- Characteristics I (v) and p (v) of the polycrystalline silicon panel photovoltaic:

a)

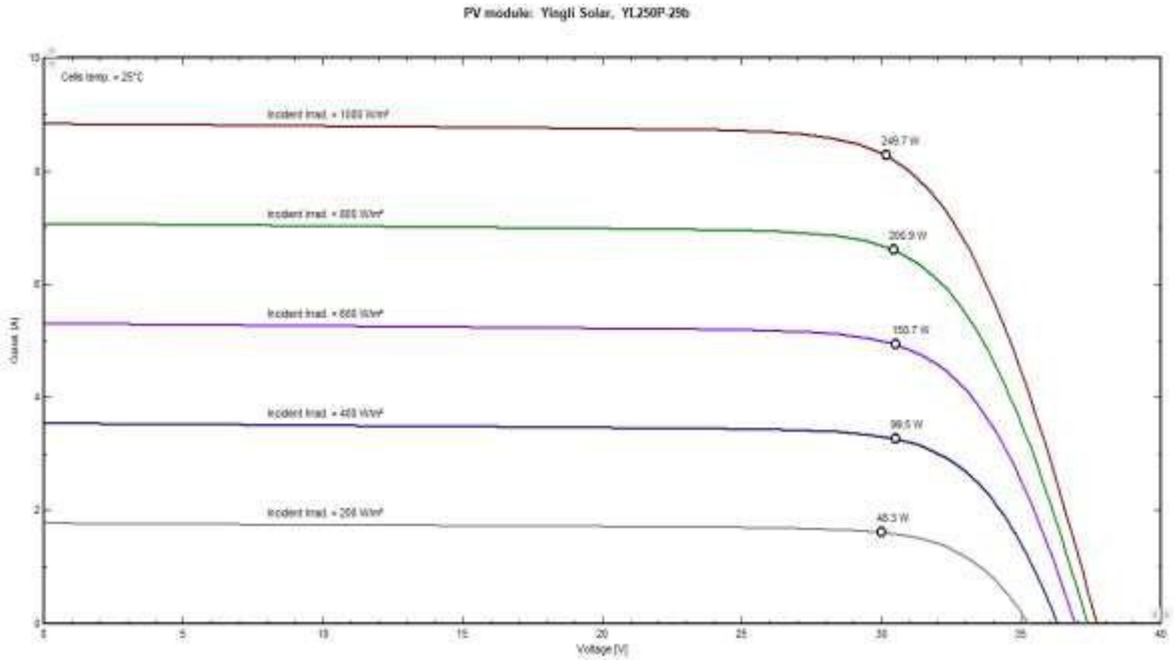


Figure 5.9 influence of temperature on characteristics I (v)

b)

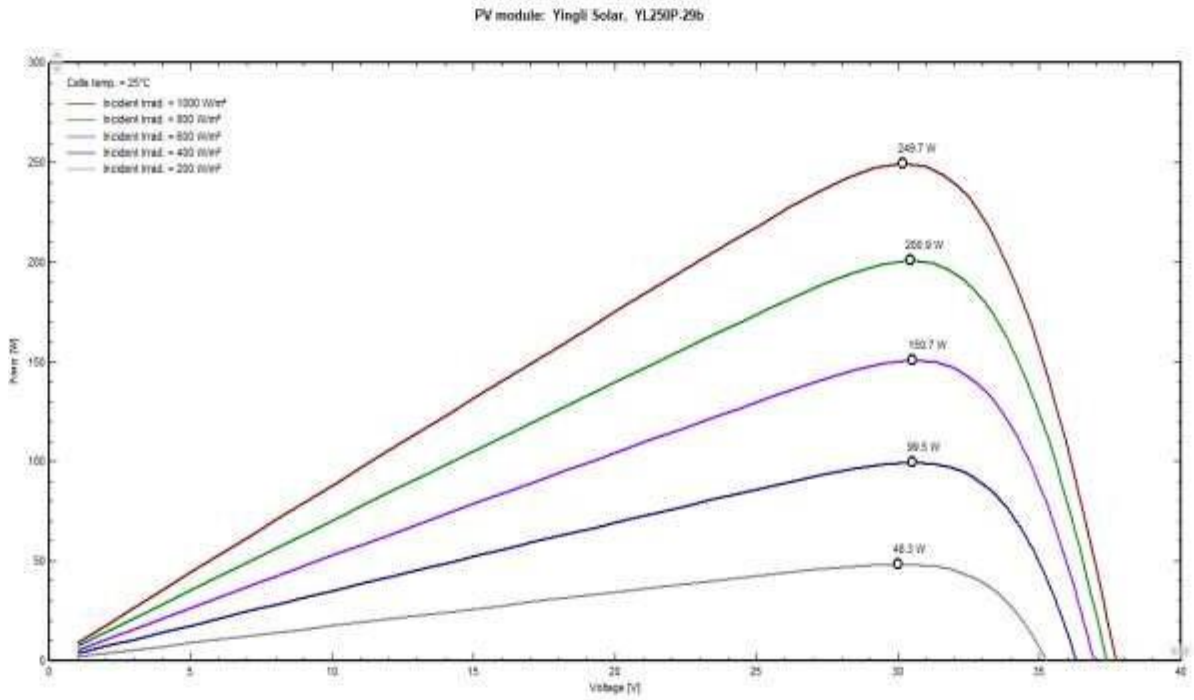


Figure 5.10 influence of temperature on characteristics p (v)

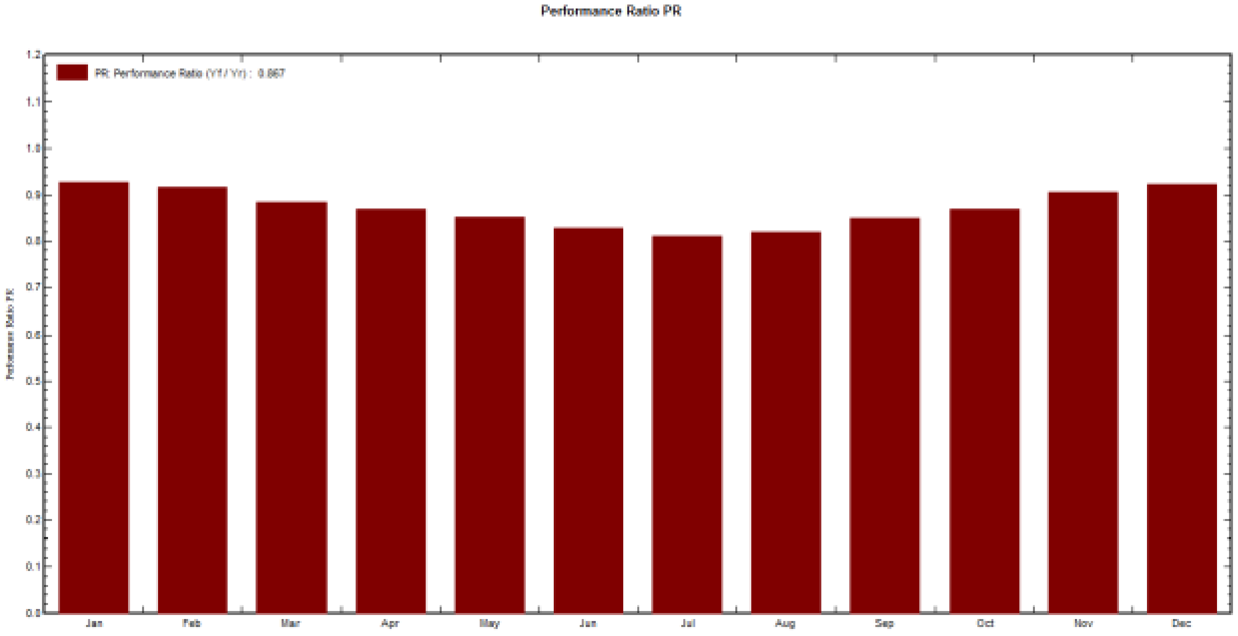


Figure 5.11 performance index of the photovoltaic central.

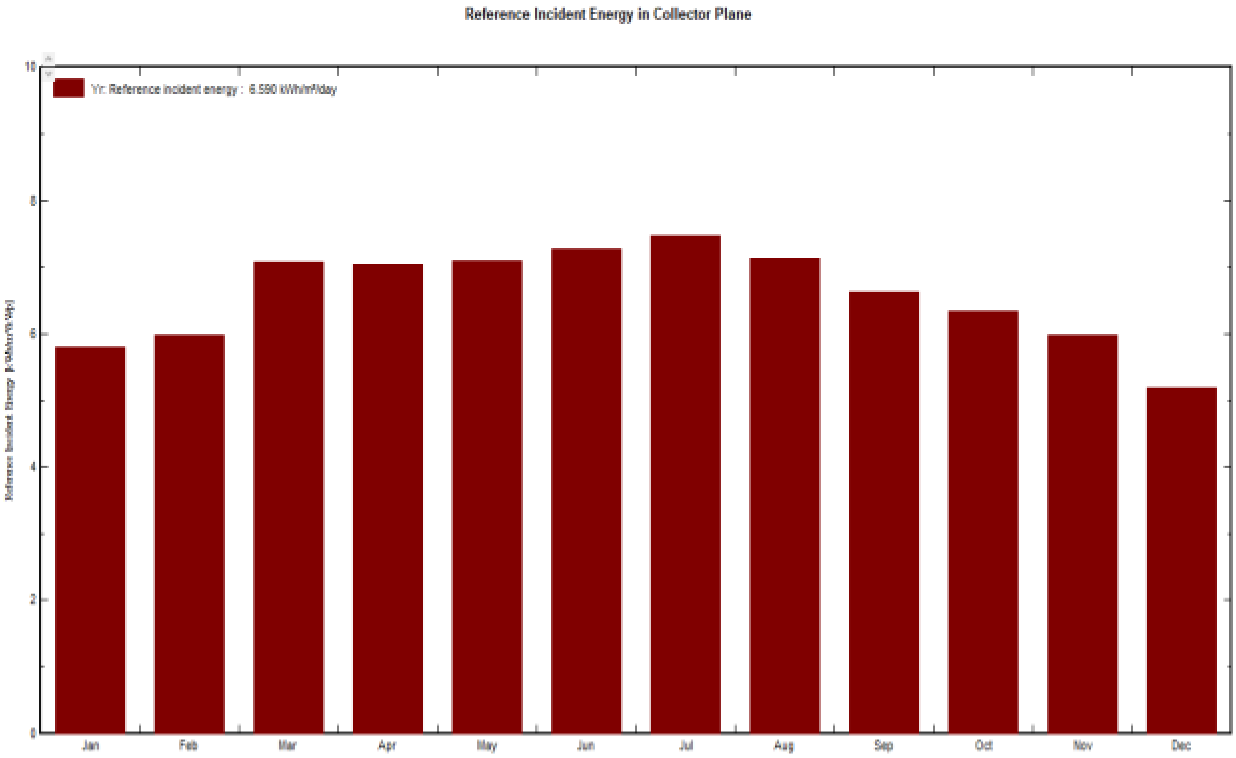
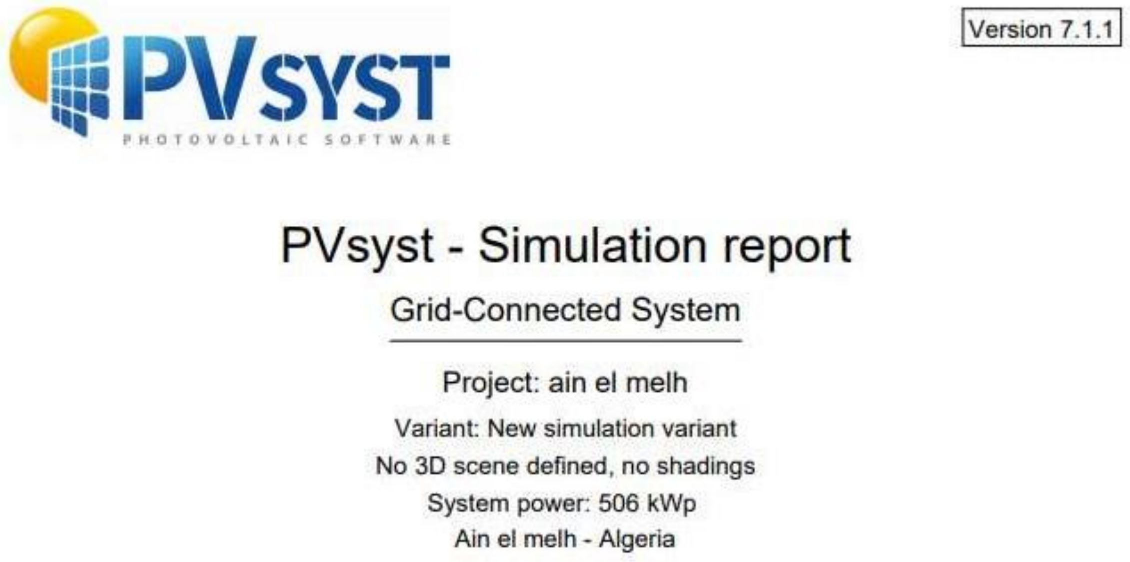


Figure 5.12 incident reference energy on the plane of the panels.



Version 7.1.1

PVsyst - Simulation report

Grid-Connected System

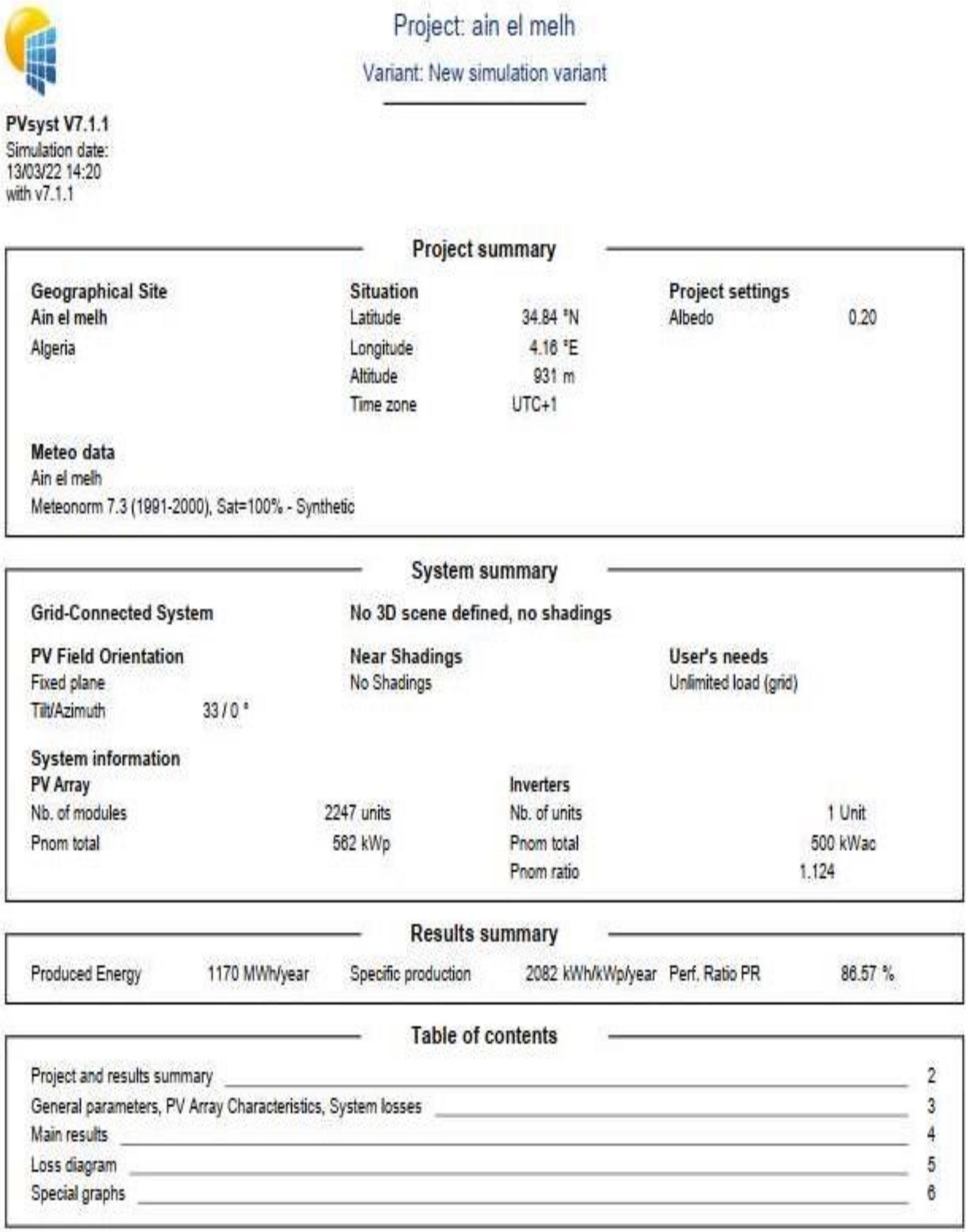
Project: ain el melh

Variant: New simulation variant

No 3D scene defined, no shadings

System power: 506 kWp

Ain el melh - Algeria



PVsyst V7.1.1
Simulation date:
13/03/22 14:20
with v7.1.1

Project: ain el melh

Variant: New simulation variant

Project summary

Geographical Site	Situation		Project settings	
Ain el melh	Latitude	34.84 °N	Albedo	0.20
Algeria	Longitude	4.16 °E		
	Altitude	931 m		
	Time zone	UTC+1		

Meteo data
Ain el melh
Meteonorm 7.3 (1991-2000), Sat=100% - Synthetic

System summary

Grid-Connected System | **No 3D scene defined, no shadings**

PV Field Orientation		Near Shadings	User's needs
Fixed plane		No Shadings	Unlimited load (grid)
Tilt/Azimuth	33 / 0 °		

System information

PV Array		Inverters	
Nb. of modules	2247 units	Nb. of units	1 Unit
Pnom total	562 kWp	Pnom total	500 kWac
		Pnom ratio	1.124

Results summary

Produced Energy	1170 MWh/year	Specific production	2082 kWh/kWp/year	Perf. Ratio PR	86.57 %

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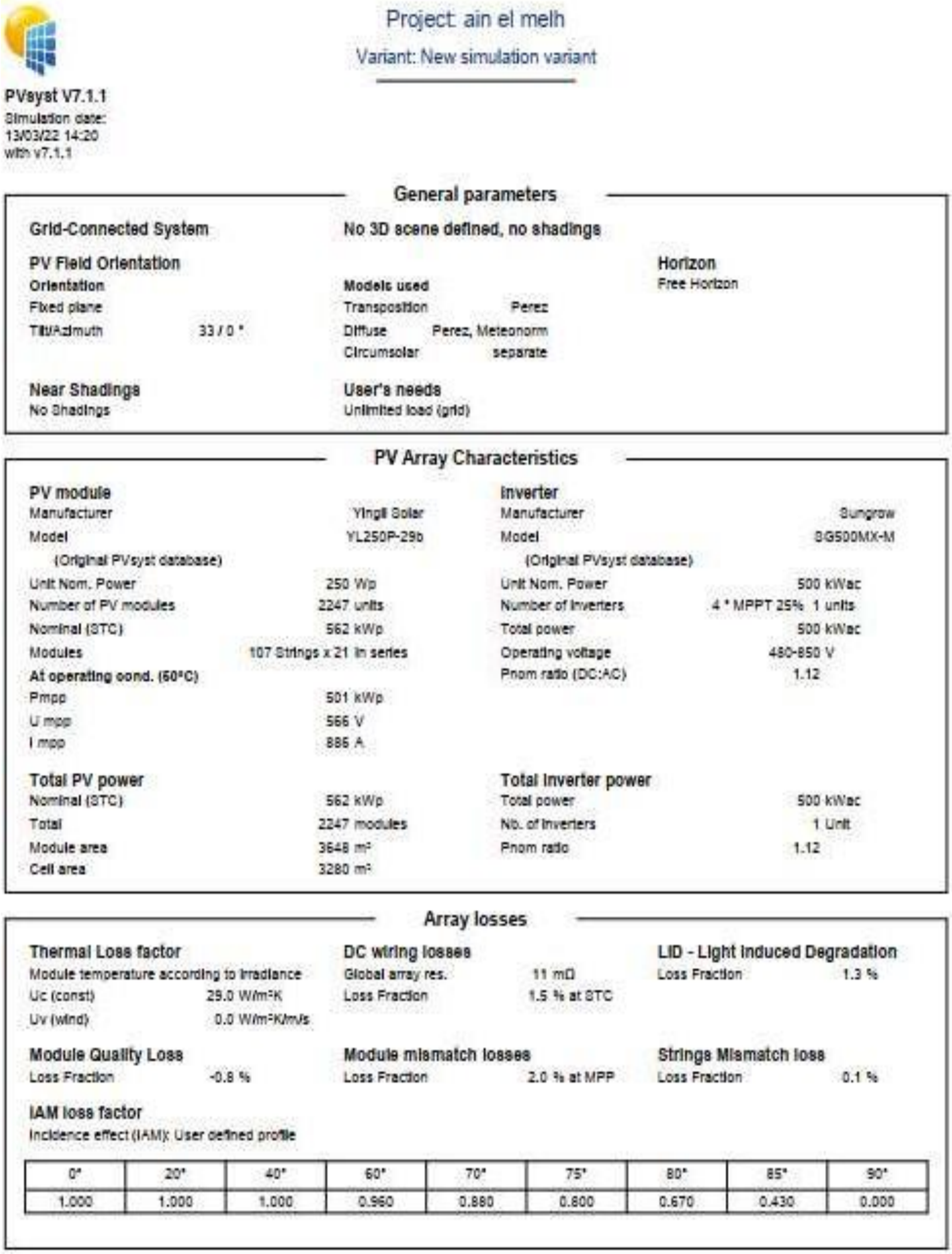


PVsyst V7.1.1
Simulation date:
13/03/22 14:20
with v7.1.1

Project: ain el melh

Variant: New simulation variant

General parameters

Grid-Connected System

No 3D scene defined, no shadings

PV Field Orientation

Orientation

Fixed plane	
Tilt/Azimuth	33 / 0 °

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Yingli Solar
Model	YL250P-29b
(Original PVsyst database)	
Unit Nom. Power	250 Wp
Number of PV modules	2247 units
Nominal (STC)	562 kWp
Modules	107 Strings x 21 In series
At operating cond. (50°C)	
Pmpp	501 kWp
U mpp	566 V
I mpp	886 A

Inverter

Manufacturer	Sungrow
Model	SG500MX-M
(Original PVsyst database)	
Unit Nom. Power	500 kWac
Number of inverters	4 * MPPT 25% 1 units
Total power	500 kWac
Operating voltage	460-850 V
Pnom ratio (DC:AC)	1.12

Total PV power

Nominal (STC)	562 kWp
Total	2247 modules
Module area	3648 m²
Cell area	3280 m²

Total inverter power

Total power	500 kWac
Nb. of inverters	1 Unit
Pnom ratio	1.12

Array losses

Thermal Loss factor
Module temperature according to irradiance

Uc (const)	29.0 W/m²K
Uv (wind)	0.0 W/m²K/m/s

DC wiring losses

Global array res.	11 mΩ
Loss Fraction	1.5 % at STC

LID - Light Induced Degradation

Loss Fraction	1.3 %

Module Quality Loss

Loss Fraction	-0.8 %

Module mismatch losses

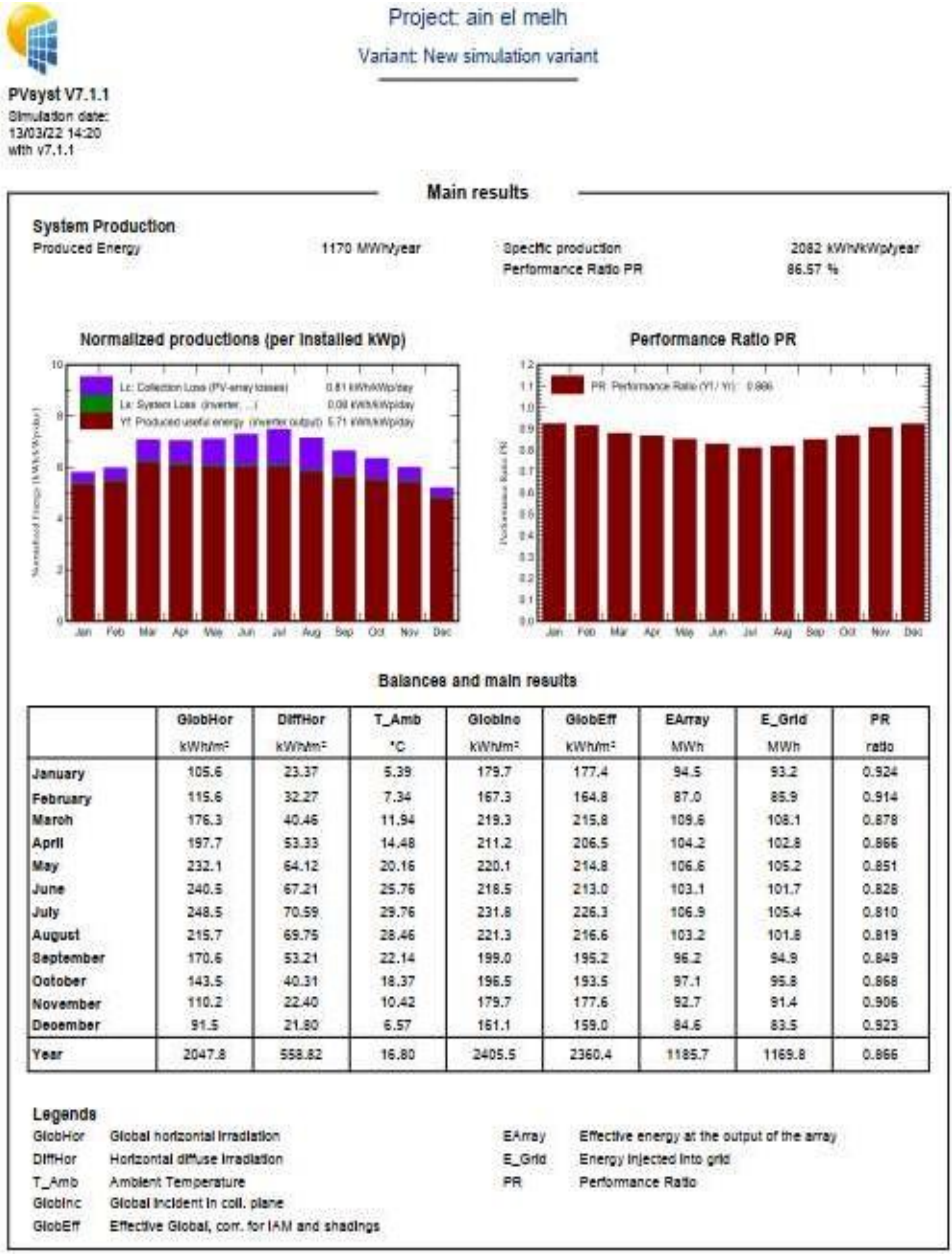
Loss Fraction	2.0 % at MPP

Strings Mismatch loss

Loss Fraction	0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000



Project: ain el melh

Variant: New simulation variant

PVsyst V7.1.1
Simulation date:
13/03/22 14:20
with v7.1.1

Main results

System Production

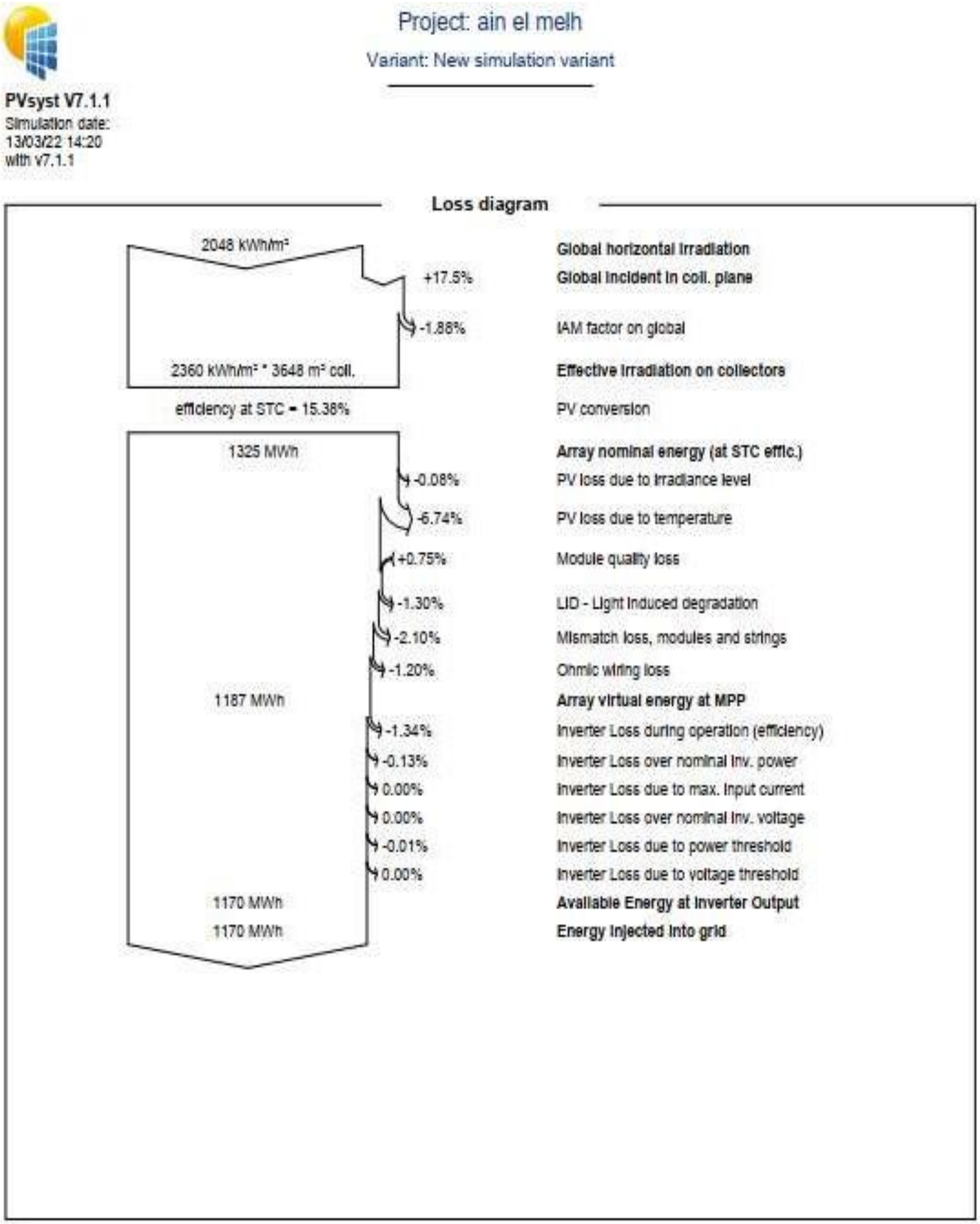
Produced Energy	1170 MWh/year	Specific production	2082 kWh/kWp/year
		Performance Ratio PR	86.57 %

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	105.6	23.37	5.39	179.7	177.4	94.5	93.2	0.924
February	115.6	32.27	7.34	167.3	164.8	87.0	85.9	0.914
March	176.3	40.46	11.94	219.3	215.8	109.6	108.1	0.878
April	197.7	53.33	14.48	211.2	206.5	104.2	102.8	0.866
May	232.1	64.12	20.16	220.1	214.8	106.6	105.2	0.851
June	240.5	67.21	25.76	218.5	213.0	103.1	101.7	0.828
July	248.5	70.59	29.76	231.8	226.3	106.9	105.4	0.810
August	215.7	69.75	28.46	221.3	216.6	103.2	101.8	0.819
September	170.6	53.21	22.14	199.0	195.2	96.2	94.9	0.849
October	143.5	40.31	18.37	196.5	193.5	97.1	95.8	0.868
November	110.2	22.40	10.42	179.7	177.6	92.7	91.4	0.906
December	91.5	21.80	6.57	161.1	159.0	84.6	83.5	0.923
Year	2047.8	558.82	16.80	2405.5	2360.4	1185.7	1169.8	0.866

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		



PVsyst V7.1.1
Simulation date:
13/03/22 14:20
with v7.1.1

Project: ain el melh

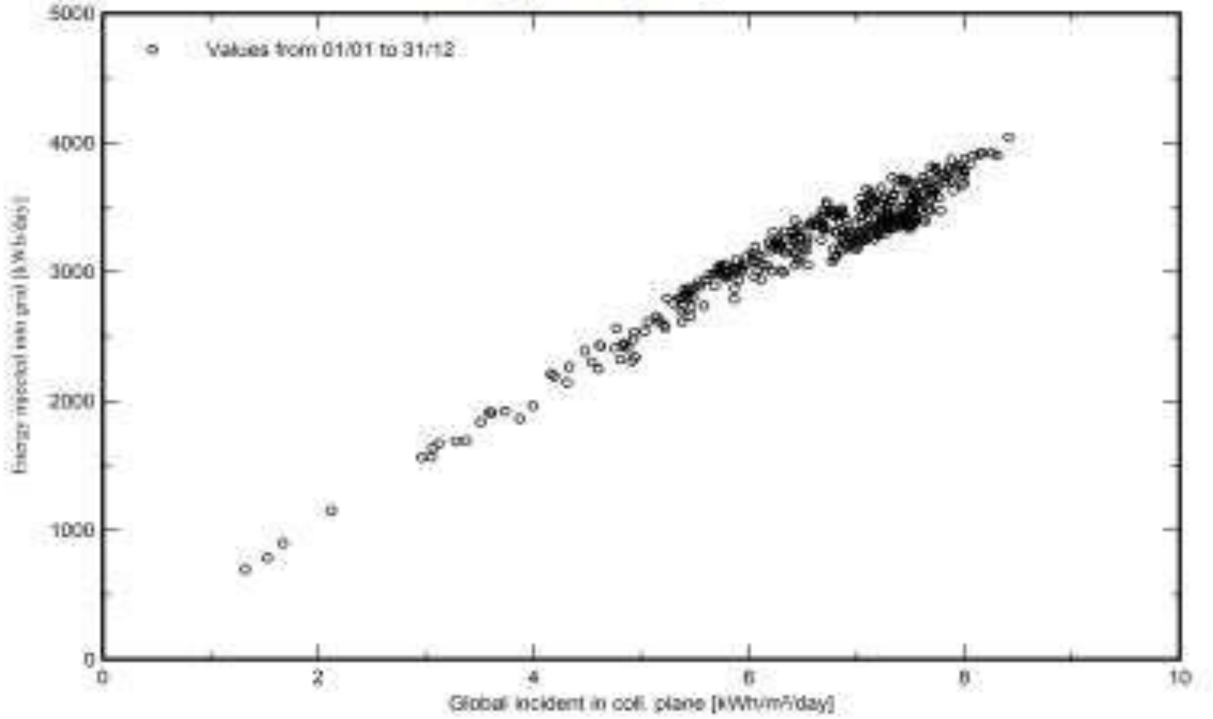
Variant: New simulation variant

Loss diagram

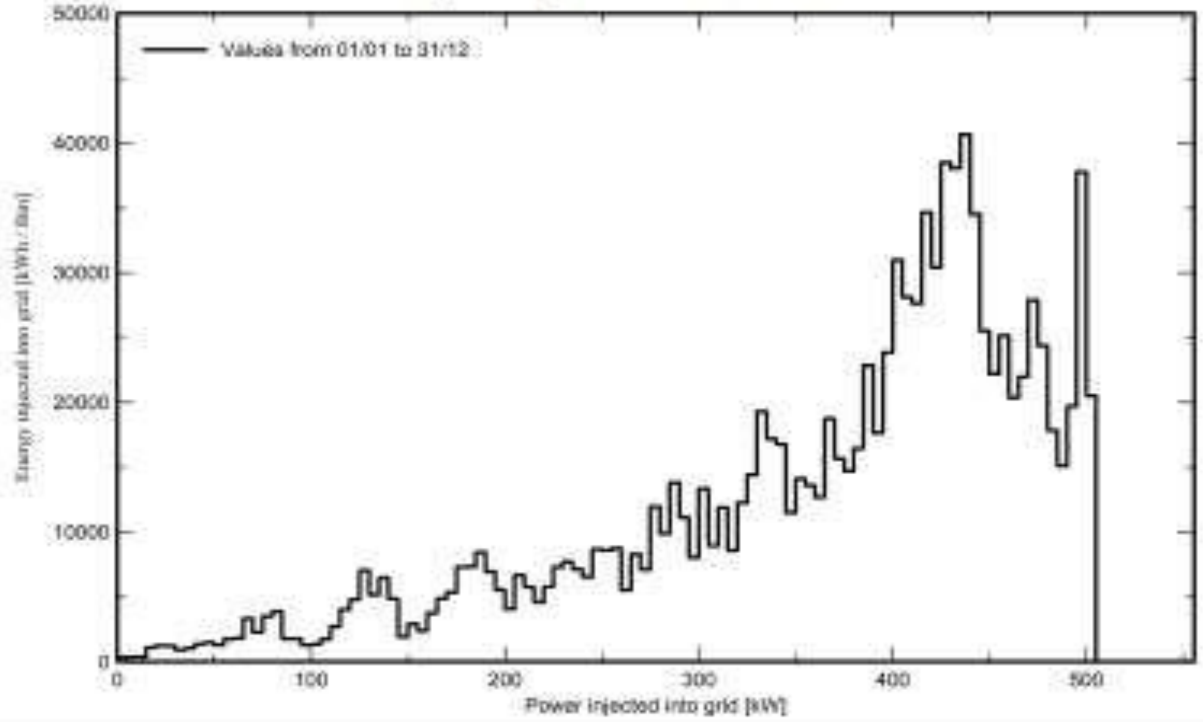
2048 kWh/m²		**Global horizontal irradiation**
	+17.5%	**Global incident in coll. plane**
	-1.88%	IAM factor on global
2360 kWh/m² * 3648 m² coll.		**Effective irradiation on collectors**
efficiency at STC = 15.38%		PV conversion
1325 MWh		**Array nominal energy (at STC effic.)**
	-0.08%	PV loss due to irradiance level
	-6.74%	PV loss due to temperature
	+0.75%	Module quality loss
	-1.30%	LID - Light induced degradation
	-2.10%	Mismatch loss, modules and strings
	-1.20%	Ohmic wiring loss
1187 MWh		**Array virtual energy at MPP**
	-1.34%	Inverter Loss during operation (efficiency)
	-0.13%	Inverter Loss over nominal inv. power
	0.00%	Inverter Loss due to max. input current
	0.00%	Inverter Loss over nominal inv. voltage
	-0.01%	Inverter Loss due to power threshold
	0.00%	Inverter Loss due to voltage threshold
1170 MWh		**Available Energy at Inverter Output**
1170 MWh		**Energy injected into grid**

Special graphs

Daily Input/Output diagram



System Output Power Distribution



5.3. Conclusion

Based on the results recorded in the simulation report on the program **PVsyst**
Turns out there are a lot of different losses in the system. However, the amount of production is considerable for the PV field, which is in the process of research and development. If the problem of losses is addressed, the production rate will rise further and the source will be better exploited. This makes the field of solar energy more important and the most successful in productivity.

6. Conclusion general

Through this project, we seek to learn the basics of designing a photovoltaic power plant connected to the public electricity transmission and distribution network. Through this project, we seek to create a balance between qualitative profitability and high productivity to achieve technical and economic feasibility.

In the first chapter, we conducted a theoretical study to define the devices and structures that make up the PV plant, as well as highlighting the requirements of the customer.

As for the second and third chapters, we conducted a climatic, geographical and geological study to calculate the maximum risks to determine the extent to which the climate affects the efficiency and productivity of the plant.

In the fourth chapter, we made a detailed study of the station, including the design, how to install each element, and the calculation of the wires needed for installation.

In the last chapter, we designed the plant using the simulation program PVsyst and through it we got a detailed report showing the characteristics of each element in the plant. The simulation study also allowed us to estimate the profitability of this plant (the photovoltaic power plant in Ain El Melh) from energy generation point of view, which contributes to encouraging investment in photovoltaic energy and renewable energies.

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