DESIGN REPORT

PV Plant Webinar Amperecloud
2024/10/29

Prepared for: Amperecloud

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1. INTRODUCTION

The objective of this report, produced by RatedPower, is to describe the specifications and design of the solar photovoltaic plant Webinar Amperecloud. The current description of the project could be subject to changes in the next stages of the project development.

The rated power of the PV Plant is 30.0 MWac and the peak power is 36.4 MWdc resulting in a DC/AC ratio of 1.21. The main characteristics of the project are shown in Table 1, Table 2 and Table 3.

Table 1. Project Characteristics

Webinar Amperecloud Project	
Main characteristics	
Location	Spain, Andalucía
Rated power (AC)	30.0 MWac
Peak power (DC)	36.4 MWdc
Ratio DC/AC	1.21
General Equipment	
One-axis tracker	1369
PV Modules (610.0 Wp)	59650
Power station (up to 4620.0 kW)	7
Number of inverters (up to 2310.0 kVA)	13

Table 2. Civil Characteristics

Area Name	Pitch	Clearance	GCR	Distance between consecutive rows	Azimuth angle	Tilt angle
Area 2	6.2 m	3.74 m	39.76%	0.5 m	0.0 °	[-]
Area 4	6.2 m	3.74 m	39.76%	0.5 m	0.0 °	[-]
Area 3	6.2 m	3.74 m	39.76%	0.5 m	0.0 °	[-]
Area 1	6.2 m	3.74 m	39.76%	0.5 m	0.0 °	[-]

Table 3. Areas

Area Name	Area	Suitable Area	Fence Area
Area 2	12.03 ha	12.03 ha	11.16 ha
Area 4	9.68 ha	9.68 ha	9.12 ha
Area 3	27.12 ha	26.84 ha	25.65 ha

Area 1	5.59 ha	5.59 ha	5.03 ha
Total	**54.43 ha**	**54.15 ha**	**50.96 ha**

The general layout of the PV plant is shown in Figure 1.

Figure 1. General layout

2. SITE

2.1. Location

The PV Plant location has the characteristics shown in Table 4

Table 4. Location characteristics

PV Plant location characteristics	
City / Town	Carboneras
Region	Andalucía
Country	Spain
Latitude	+36.99 °
Longitude	-2.04 °
Altitude	204.79 m a.m.s.l.
Timezone	UTC +1

The project location is shown in Figure 2. A closer view of the region is shown in Figure 3.

Figure 2. Location of PV Plant in the region of Andalucía, in Spain

Figure 3. Closer view of the PV plant in the region of Andalucía

2.2. Plot Areas

The area where the PV plant is to be built consists of 4 available areas, with a total surface area of 54.15 ha.

The size of each area and the total suitable area for installation purposes is shown in Table 5.

Table 5. Size of plot areas of the project.

Area name	Surface
Available areas	
Area 1	5.59 ha
Area 2	12.03 ha
Area 3	27.12 ha
Area 4	9.68 ha
Interconnection facility areas	
ST	
Area 1	0.28 ha
Total available area	**54.15 ha**

The substation(s), the plot area(s) and, if any, the restricted area(s) are shown in Figure 4.

Figure 4. Plot Areas of the Webinar Amperecloud PV Plant

2.3. Topography

A preliminary terrain topography analysis was performed to study the suitability of the terrain for the construction of a photovoltaic plant. The North-South and East-West slopes were calculated and are shown in Figure 5.

The elevation data was uploaded by the user in CSV (XYZ) format.

The analysis of the terrain slopes results in three differentiated areas:

- Zones where the slope is lower than 5.00 %.
- Zones where the slope is between 5.00 % and 10.00 %.
- Zones where the slope is greater than 15.00 %.

NOTE: The slopes measured on site when performing a detailed topographical analysis could be greater than the slopes obtained using this analysis.

The map shown in the Figure 5 represents the slopes of the terrain, with the following colors representing:

- Slopes <5.00 %
- Slopes >5.00 % and <10.00 %
- Slopes >10.00 % and <15.00 %
- Slopes >15.00 %

Using the previously mentioned elevation data, the position of the mounting structures in the terrain was calculated. The slope of the terrain in the North-South and East-West directions under the structures was calculated. The position of the structure posts was also calculated, including ground elevation and post height.

For some structures, earthworks were performed to adequate the terrain to the limits set by the mounting structure manufacturer. The conditions required to perform earthworks were as follows:

- The slope in the North-South direction is between 15.00 % and 25.00 %.
- The slope in the East-West direction is between 10.00 % and 20.00 %.

The earthworks analysis resulted in a total fill volume of 240.18 m3 and cut volume of 241.78 m3.

The structures which did not meet the following requirements were removed from the layout:

- The structure must be within the bounds of the Digital Elevation Model (DEM).
- The slope of the structure in the North-South direction must be lower than 15.00 %.
- The slope of the structure in the East-West direction must be lower than 10.00 %.

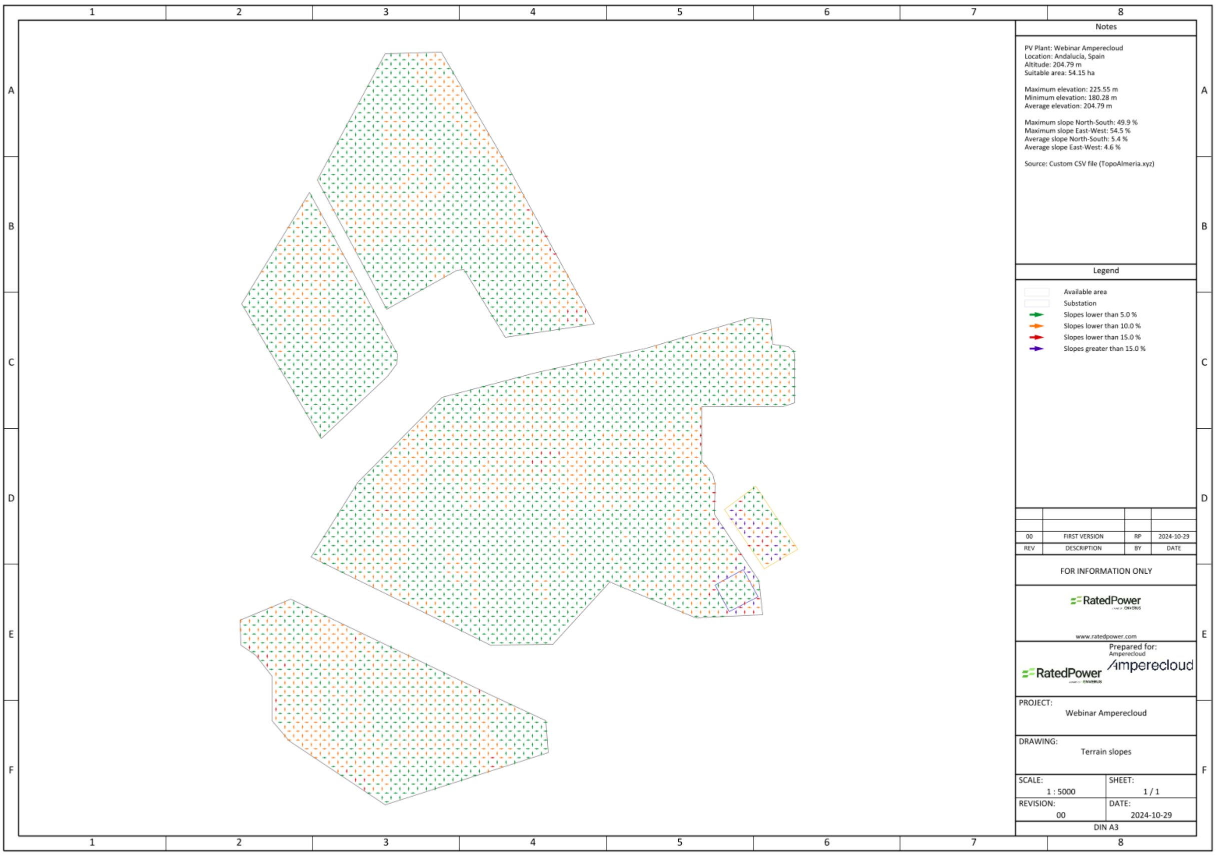

Figure 5. Slopes of the plot areas

The north-south direction is considered to be the direction parallel to the axis of the structure (row slope). The east-west direction is considered to be the direction perpendicular to the axis of the structure (pitch slope). Rotating the layout may have an impact in the topography analysis, due to the rotation of the axis of the structure.

2.4. Horizon profile

The solar irradiance reaching the photovoltaic modules will change if there are hills or mountains on the horizon. These physical obstructions will block the beam component of the irradiance during some periods of the day and will have an impact on the diffuse component as well. Therefore, the horizon profile directly impacts the energy yield of the photovoltaic plant.

The horizon line has an average elevation of 1.9° and a maximum elevation of 3.4°. Throughout the year, the Sun will be blocked by the horizon line for a total of 126 hours. The data source for the horizon line was PVGIS 5.2.

The blocked elevations over the complete azimuth range are shown in Figure 6.

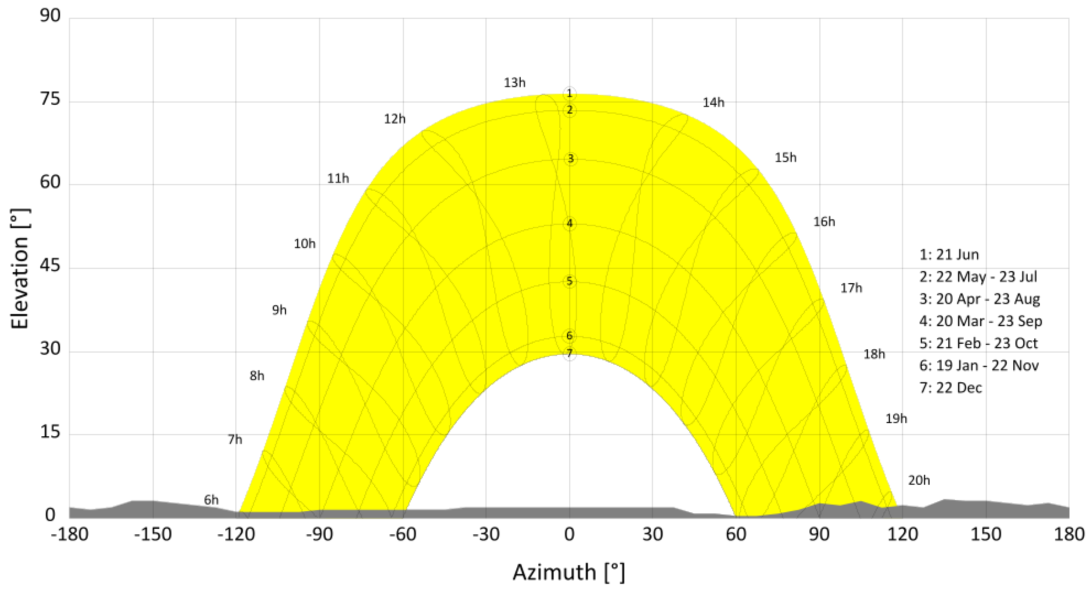

Figure 6. Horizon profile (data source: PVGIS 5.2)

3. SOLAR RESOURCE

The aim of the solar resource analysis is to provide an estimation of the solar energy the photovoltaic plant would receive throughout a typical year.

The solar resource is usually given as a series of hourly values for the irradiance and temperature, for a period of one year. This series is called the Typical Meteorological Year (TMY).

The source used to generate the TMY was the PVGIS database. It includes meteorological data ranging from 2005 to the present (the actual period used may vary depending on the location) and has a spatial resolution of 4 km by 4km. The uncertainty of the PVGIS data varies between ±3% to ±10%, depending on the location.

The hourly temperature values found in the TMY yield the following aggregates:

- Minimum temperature: 5.49 °C.
- Maximum temperature: 35.22 °C.
- Average temperature: 18.13 °C.

The results of the solar resource analysis are shown in Table 6. A chart representing these results is shown in Figure 7.

Table 6. Solar resource monthly values

Month	GHI [kWh/m2]	DHI [kWh/m2]	Temperature
1	90.3	28.3	11.95 °C
2	96.2	36.4	13.29 °C
3	159.5	50.2	14.15 °C
4	160.8	66.1	14.6 °C
5	227.7	64.3	20.68 °C
6	236.6	64.3	23.01 °C
7	248.9	62.8	25.5 °C
8	210.1	62.6	25.29 °C
9	166.4	53.5	23.29 °C
10	117.0	46.3	18.51 °C
11	94.9	30.4	15.58 °C
12	79.9	25.0	11.36 °C
Year	**1888.4**	**590.1**	**18.1 °C**

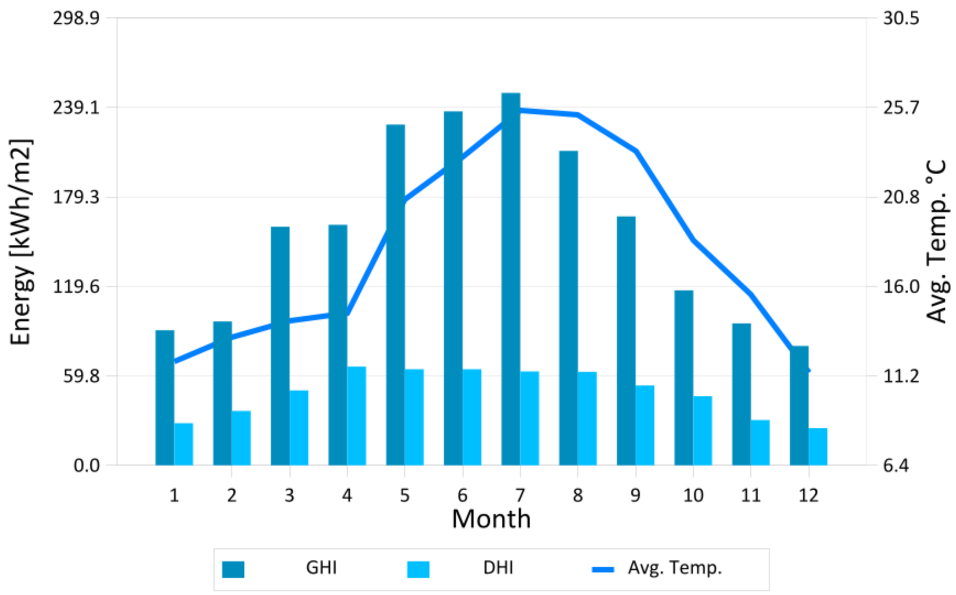

Figure 7. Solar resource chart

4. MAIN EQUIPMENT

The main equipment used to convert the solar energy to electricity is:

- Photovoltaic modules, which convert the solar radiation into direct current.
- The single-axis tracker, which supports and orients the PV modules to minimize the angle of incidence between the incoming sun rays and the PV modules surface during the day.
- The string combiner boxes, which consolidate the output of the strings of photovoltaic modules before reaching the inverter.
- Central inverters, which convert DC from solar field to AC.
- Power Transformers, which raise the voltage level from low to medium.
- Power Stations, which hold the necessary equipment to convert the DC power to AC.

The electrical configuration of the PV plant can be seen in Figure 8.

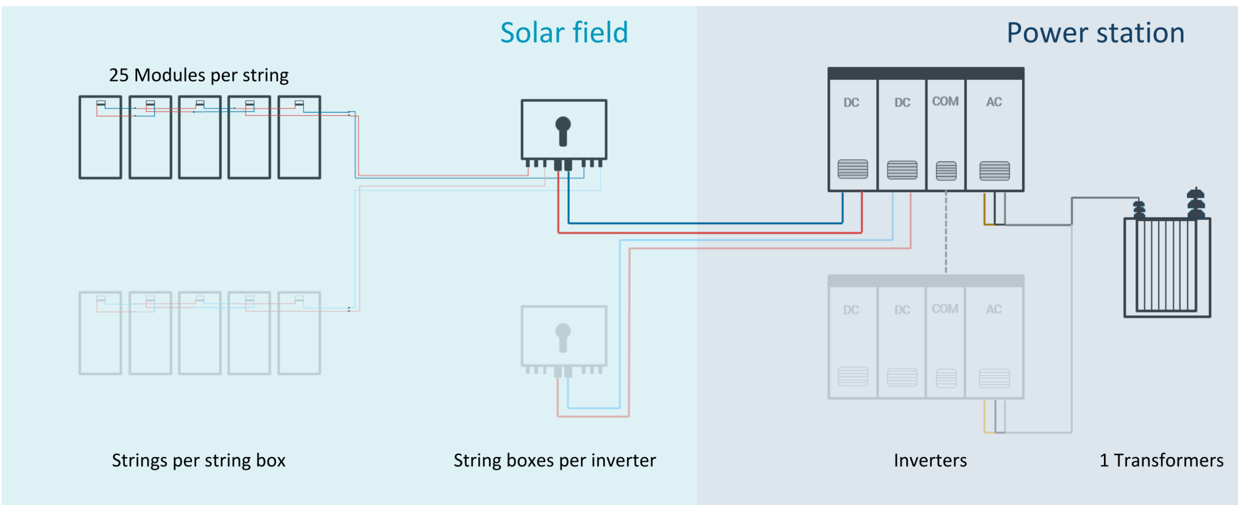

Figure 8. Simplified electrical configuration diagram

4.1. Photovoltaic module

The selected photovoltaic module is the General610 Bifacial model, manufactured by Generic (default). It has a peak power of 610.0 W, and the technology of the cells is Si-mono.

The features of the photovoltaic module are shown in Table 7.

The module has a bifaciality factor of 80.00 %.

Table 7. Photovoltaic module characteristics

Photovoltaic module characteristics	
Main characteristics	
Module model	General610
Manufacturer	Generic (default)
Technology	Si-mono
Type of module	Bifacial
Maximum voltage	1500 V
Standard test conditions (STC)	
Peak power	610.0 W
Efficiency	21.85 %
MPP voltage	45.7 V
MPP current	13.37 A
Open circuit voltage	55.3 V
Short circuit current	14.03 A
Temperature coefficients	
Power coefficient	-0.300 %/°C
Voltage coefficient	-0.278 %/°C
Current coefficient	0.046 %/°C
Mechanical characteristics	
Length	2465.0 mm
Width	1134.0 mm
Thickness	30.0 mm
Weight	34.6 kg

An example picture of a Bifacial Si-mono module is shown in Figure 9.

Figure 9. Example of a Bifacial Si-mono photovoltaic module

4.2. Single axis N-S tracker

The PV solar modules will be mounted on North-South oriented one-axis solar trackers, integrated on metallic structures combining galvanized steel and aluminum parts, forming a structure fixed to the ground. An example of a single-axis tracker is shown in Figure 10.

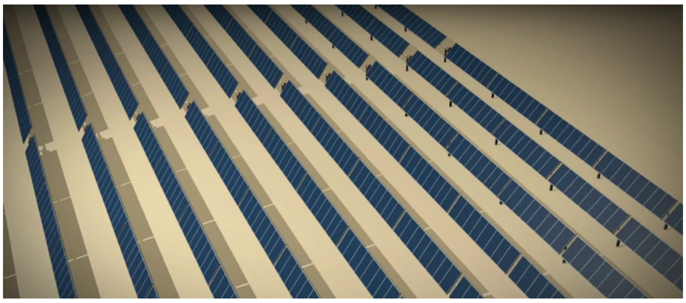

Figure 10. Example of single-axis tracker

Single-axis trackers are designed to minimize the angle of incidence between the incoming sun rays and the photovoltaic panel plane of array. The tracking system consists of an electronic device capable of following the sun through the day.

The main features of the tracking system are summarized in Table 8.

Table 8. Main characteristics of the single-axis trackers

Single-axis tracker characteristics	
Model	Generic tracker
Manufacturer	Generic (default)
Technology	Single-row
Configuration	1P (Portrait)
Tracking angle limits	+60 / -60 °
Minimum ground clearance	0.5 m
Designed for	MONOFACIAL modules
Motor gap	0.0 mm

Torque beam gap	0.0 mm
Gap between modules in the axis direction	20.0 mm
Gap between modules in the pitch direction	0.0 mm

The number of single-axis trackers installed are summarized in Table 9.

Table 9. Number of single-axis trackers installed

Strings per structure	Modules per structure	Length	Quantity
2	50	57.68 m	1017
1	25	28.83 m	352

4.3. String combiner box

The string boxes collect the power generated by the DC array, connect the strings in parallel to the inverter, and provide electrical protection to the PV field. To match the number of inputs of the inverters, several parallel strings will be concentrated to function as a single circuit. Junction boxes shall be installed with a fuse per string to protect each array. Overvoltage DC dischargers will be installed, and one DC switch will be situated in the output line. Additionally, a communication system may be installed to monitor the string current and voltage.

An example of a string box is shown in Figure 11.

Figure 11. Example string box (Schneider Electric)

The string boxes will be installed in a shaded area and shall be easily accessible to facilitate maintenance. They will be placed behind the PV modules and use existing structure poles if possible, so that they remain shaded and to prevent damage caused by rainwater or other meteorological phenomena.

The main features of the string box are shown in Table 10.

Table 10. Main string box characteristics

String box	Quantity	Inputs	Power	Fuse	Switch	Overvoltage

				Current	current	Arrester
1	116	16 string	244.0 kW	25 A	315 A	Yes
2	19	8 string	122.0 kW	25 A	315 A	Yes
3	13	15 string	228.8 kW	25 A	315 A	Yes
4	9	10 string	152.5 kW	25 A	315 A	Yes
5	7	9 string	137.3 kW	25 A	315 A	Yes
6	1	7 string	106.8 kW	25 A	315 A	Yes
7	1	12 string	183.0 kW	25 A	315 A	Yes
8	1	11 string	167.8 kW	25 A	315 A	Yes

4.4. Central inverter

The inverter converts the direct current produced by the photovoltaic modules to alternating current. It is composed of the following elements:

- One or several DC-to-AC power conversion stages, each equipped with a maximum power point tracking system (MPPT). The MPPT will vary the voltage of the DC array to maximize the production depending on the operating conditions.
- Protection components against high working temperatures, over or under voltage, over or under-frequencies, minimum operating current, mains failure of transformer, anti-islanding protection, protection against voltage gaps, etc. In addition to the protections for the safety of the staff personnel.
- A monitoring system, which has the function of relaying data regarding the inverter operation to the owner (current, voltage, power, etc.) and external data from monitoring of the strings in the DC array (if a string monitoring system is present).

In Figure 12 a commonly used photovoltaic inverter for utility-scale PV plants is shown.

Figure 12. Example of central photovoltaic inverter

The main characteristics of the selected inverter are shown in Table 11.

Table 11. Inverter characteristics

Inverter characteristics

Main characteristics	
Inverter model	Generic 2310
Inverter type	CENTRAL
Manufacturer	Generic (default)
Maximum DC to AC conversion efficiency	98.72 %
Input side (DC)	
MPPT search range	891 - 1310 V
Maximum input voltage	1500 V
Output side (AC)	
Rated power	2310.0 kVA
Maximum Power (datasheet)	2310.0 kVA
Nominal Power (datasheet)	2310.0 kVA
Output voltage	630 V
Output frequency	50 Hz

Table 12. Inverters

Inverter	Quantity	DC inputs	Power DC	DC/AC ratio
Generic 2310 (2310 kWac)	2	1 String Box of 15 string 1 String Box of 10 string 3 String Box of 8 string 8 String Box of 16 string	2699 kW	1.169
Generic 2310 (2310 kWac)	2	1 String Box of 9 string 1 String Box of 8 string 1 String Box of 15 string 9 String Box of 16 string	2684 kW	1.162
Generic 2310 (2310 kWac)	1	1 String Box of 8 string 1 String Box of 10 string 1 String Box of 12 string 10 String Box of 16 string 1 String Box of 15 string	3126 kW	1.353
Generic 2310 (2310 kWac)	1	1 String Box of 11 string 12 String Box of 16 string	3096 kW	1.340
Generic 2310 (2310 kWac)	1	1 String Box of 8 string 2 String Box of 9 string 10 String Box of 16 string	2837 kW	1.228
Generic 2310 (2310 kWac)	1	1 String Box of 15 string 1 String Box of 9 string 1 String Box of 8 string 1 String Box of 10 string 9 String Box of 16 string	2837 kW	1.228

Generic 2310 (2310 kWac)	1	2 String Box of 10 string 7 String Box of 16 string 1 String Box of 8 string 3 String Box of 15 string	2821 kW	1.221
Generic 2310 (2310 kWac)	1	1 String Box of 9 string 1 String Box of 10 string 1 String Box of 8 string 2 String Box of 15 string 8 String Box of 16 string	2821 kW	1.221
Generic 2310 (2310 kWac)	1	1 String Box of 9 string 2 String Box of 8 string 1 String Box of 10 string 1 String Box of 15 string 8 String Box of 16 string	2715 kW	1.175
Generic 2310 (2310 kWac)	1	1 String Box of 10 string 2 String Box of 8 string 1 String Box of 7 string 9 String Box of 16 string	2699 kW	1.169
Generic 2310 (2310 kWac)	1	1 String Box of 15 string 2 String Box of 8 string 9 String Box of 16 string	2669 kW	1.155

4.5. Power transformer

The power transformer raises the voltage of the inverter AC output to achieve a higher efficiency transmission in the power lines of the photovoltaic plant. An example of a power transformer is shown in Figure 13.

Figure 13. Example of power transformer

4.6. Power Station

The power stations or transformer stations are indoor buildings or containers. The voltage of the energy collected from the solar field is increased to a higher level to facilitate the evacuation of the generated energy.

The inverters and power transformers will be housed in the power station.

An example of an Indoors power station is shown in Figure 14.

Figure 14. Example of an Indoors power station

The power station shall be supplied with medium voltage switchgears that include one transformer protection unit, one direct incoming feeder unit, one direct outcoming feeder unit and electrical boards. Particularly, for the first power station of each MV line, a direct incoming unit will not be installed.

The common features of the power stations are shown in Table 13.

Table 13. Power station common characteristics

Power station characteristics	
Voltage ratio	0.63/20.0kV
Transformers cooling system	ONAN
Transformers tap changer	2.5%, 5%, 7.5%, 10%
Service	Indoors

The characteristics of the different power stations according to their AC configuration are shown in Table 14.

Table 14. Power stations according to the AC configuration

Power stations	Quantity	Num Inverters	Transformers configuration	Short circuit (Zcc)
1	6	2(4.62 MVA)	1 two-winding transformer of 4.62 MVA	0.080
2	1	1(2.31 MVA)	1 two-winding transformer of 2.31 MVA	0.080

The different types of power stations according to the DC field associated to them are shown in Table 15.

Table 15. Power stations according to the DC field

Power stations	Quantity	Num Inverters	Power AC	Power DC	DC/AC ratio
1	1	2	4.62 MW	6.222 MW	1.347

2	1	2	4.62 MW	5.658 MW	1.225
3	1	2	4.62 MW	5.658 MW	1.225
4	1	2	4.62 MW	5.383 MW	1.165
5	1	2	4.62 MW	5.383 MW	1.165
6	1	2	4.62 MW	5.368 MW	1.162
7	1	1	2.31 MW	2.714 MW	1.175

5. PV PLANT SIZING

5.1. Electrical configuration

The photovoltaic generator array consists of photovoltaic modules connected in serial and parallel associations. This configuration is defined by the module and inverter technical features, the power system requirements, and the meteorological conditions of the specific location in Spain.

The methodology used to define the electrical configuration consists of sizing the strings of modules, electrical junction boxes (if present), wiring and inverters to find an electrical configuration that satisfies the DC/AC ratio goal. Some of the design criteria considered were:

- Reaching the maximum DC voltage possible, staying below the maximum rated voltage of the photovoltaic modules, 1500 V. This is done to minimize the DC power transmission losses.
- The photovoltaic generator array (DC field) is oversized with respect to the rated power of the AC system, to maximize the energy yield.

The main features of the electrical configuration globally and by areas are shown in Table 16 and Table 17 respectively.

Table 16. Electrical configuration global characteristics

Electrical configuration global characteristics	
Plant rated power	30.0 MWac
Plant peak power	36.4 MWdc
DC/AC Ratio	1.21
Modules per string	25

Table 17. Electrical configuration characteristics per group of areas

Group of Areas	Rated Power	Peak Power	DC/AC Ratio
Area4	4620.0 kWac	6222.0 kWdc	1.35
Area3	16.2 MWac	18.8 MWdc	1.17

Area2, Area1	9240.0 kWac	11.3 MWdc	1.22

The medium voltage network connecting the power stations to the substation operates at 20.0 kV. It is composed of 4 medium voltage branches.

5.2. Electrical Cabling Design

The goal when calculating the characteristics of the electrical wiring is to minimize the cable lengths and sections. The sections are selected according to the IEC 60364-5-52 and IEC 60502-2 standards.

When selecting a cable cross section, the current carrying capacity, the voltage drop, and the short circuit current were considered. The maximum allowed voltage drop was 1.5% for the DC side, and 0.5% for the AC cables of the MV network.

A 35 mm2 earthing cable is used for the low voltage and medium voltage trenches, while a 50 mm2 earthing cable is used in the case of the power stations.

A summary of the selected cable sections and their installation method is shown in Table 18.

Table 18. Summary of the selected cable sections

Section	Conducting material	Insulating material	Installation type
Strings to string box			
10 mm2	Cu	XLPE	Fastened to structure
6 mm2	Cu	XLPE	Fastened to structure
String box to Inv.			
500 mm2	Al	XLPE	Buried in trench
300 mm2	Al	XLPE	Buried in trench
PS to MV switchgears			
240 mm2	Al	XLPE	Buried in trench
150 mm2	Al	XLPE	Buried in trench

5.3. Civil works

Some of the parameters considered for the civil works required to build the photovoltaic plant are shown in Table 19 and Table 20.

Table 19. Civil works

Civil works	
Pitch distance	6.2 m
Distance between consecutive rows	0.5 m
Road width	4.0 m

LV trench maximum section	0.8 m2
MV trench maximum section	1.2 m2

Table 20. Roads by area

Area name	Layout	Width	Length
Area 1	Perimeter	4.0 m	284.44 m
Area 2	Perimeter	4.0 m	733.26 m
Area 3	Vertical	4.0 m	1162.71 m
Area 4	Perimeter	4.0 m	399.5 m
Total			**2579.92 m**

For the design of the PV plant under study, roads of 4.0 m have been used. These roads run a total distance of 2579.92 m.

Road ditches used for drainage and for channeling water are placed on one side of the roads.

A total perimeter of 5957.34 m of chain link fence surrounds the different areas of the PV plant. The fence has at least 2.0 m of height and 3.0 m between posts. For every 50.0 m of fence, a light post of 4.0 m of height and a microwave barrier system are installed. For every 100.0 m of fence, a video camera post of 6.0 m of height is installed.

Low voltage cables from string boxes to the Power Stations have been directly buried in trenches. Various rows of cables may be included inside the same trench. Low voltage and medium voltage trenches are separated.

The minimum depth at which the low voltage cables are placed is 600.0 mm. These cables are horizontally in touch. The vertical separation between the low voltage cables is 50.0 mm.

A simplified trench cross section of the LV trenches is shown in Figure 15.

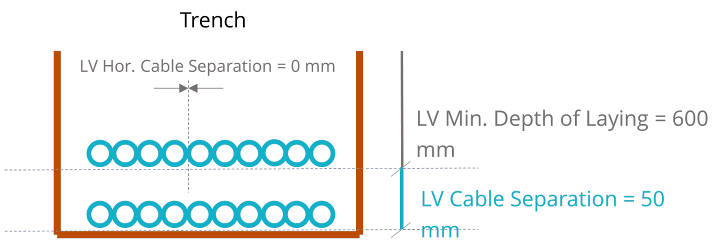

Figure 15. Simplified LV trench cross section

The minimum depth at which medium voltage cables are placed is 700.0 mm. These cables are separated horizontally by 200.0 mm. The vertical separation between them is 200.0 mm.

A simplified trench cross section of the MV trenches is shown in Figure 16.

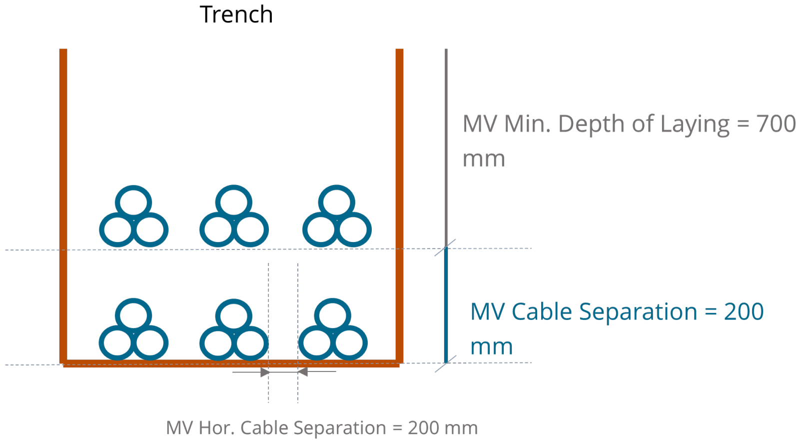

Figure 16. Simplified MV trench cross section

The offset horizontal space between the cable rows and the trench boundaries is 50.0 mm.

The section of the trenches used in the design are shown in Table 21, along with the total trench length and volume for each type.

Table 21. Trench cross sections

Trench type	Cross section	Length	Volume
Low voltage trench	400.0 x 1000.0 mm	9312.63 m	3725.05 m3
Low voltage trench	800.0 x 1000.0 mm	320.49 m	256.4 m3
Medium voltage trench	800.0 x 1500.0 mm	1633.22 m	1959.86 m3
Medium voltage trench	800.0 x 1000.0 mm	1420.0 m	1136.0 m3

5.4. Battery Energy Storage System

In addition to the PV Plant, an AC coupling BESS has been defined, for which an area in the plant has been defined. This battery system includes a set of 6 battery containers and 1 power conversion systems with a total apparent power of 5500.0 kVA and a total rated power of 5500.0 kW at a power factor of 1.000 and an energy capacity of 12.0 MWh, resulting in a storage capacity of 2.2 hours of discharge.