SUBSTATION REPORT

PV Plant Webinar Amperecloud
2024/10/29

Prepared for: Amperecloud

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1. INTRODUCTION

The objective of this report compiled by RatedPower is to describe the specifications and design for the substation of the project, Webinar Amperecloud.

The sizing and calculations introduced in this report are performed according to the IEC standard.

The current specifications of the project can be subject to change in the next stages of project development. The main characteristics of the project are shown in Table 1.

Table 1. A summary of the characteristics of the project

Webinar Amperecloud project	
Location	Spain, Andalucía
Substation capacity	35.53 MVA
High voltage level	132.0 kV
Medium voltage level	20.0 kV
Lightning impulse withstand voltage	650.0 kV
Rated frequency	50 Hz
Installation	Outdoor
Type of switchgear	Air-insulated switchgear
Circuit arrangement	line to Transformer
Step-up power transformers	1

2. SITE

2.1. Location

The 132.0/20.0 kV air-insulated substation will evacuate 35.53 MVA and it is in Andalucía. Additional information about the location of the substation is shown in Table 2.

Table 2. The location characteristics of the project

Substation location characteristics	
City / Town	Carboneras
Region	Andalucía
Country	Carboneras
Latitude	37.0
Longitude	-2.0
Altitude	204.79 m a.m.s.l.

The project location is shown in Figure 1. A closer view of the region is shown in Figure 2.

Figure 1. Location of the substation in the region of Andalucía, in Carboneras

Figure 2. Closer view of the substation in the region of Andalucía

2.2. Topography

A preliminary terrain topography analysis was performed to study the suitability of the terrain for the construction of the substation.

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

Using the previously mentioned elevation data, earthworks were performed to level the terrain. The ground within the boundaries defined by the ST area in the KML file was leveled for the installation of the interconnection facility. The earthworks analysis resulted in a total fill volume of 49.45 m3 and cut volume of 93.5 m3.

3. DESCRIPTION OF THE SUBSTATION

The characteristics of the 132.0 kV high voltage system are shown in Table 3:

Table 3. The high voltage system characteristics

High voltage system 132.0 kV	
Nominal system voltage	132.0 kV
System highest voltage	145.0 kV
Short-circuit level	40.0 kA
Installation	Outdoor
Insulation material	Air
Circuit arrangement	line to Transformer
High-voltage equipment transformer bays	1
Output circuit levels	1

Regarding the power transformers that will raise the voltage, further characterization is given in Table 4:

Table 4. The transformer's characteristics

Transformers	Voltage ratio	Rated power	Short-circuit impedance	Vector group
Num 1	132.0 / 20.0 kV	40.0 MVA	10.0 %	Ynd11

In total, 1 medium voltage cubicle/s will connect the PV solar plant to the electrical substation. The 20.0 kV medium voltage system´s features are delineated in Table 5:

Table 5. The medium voltage system characteristics

Medium voltage system	
Nominal system voltage	20.0 kV
System highest voltage	24.0 kV
Short-circuit level	25.0 kA
Installation	Indoor
Insulation material	SF6
Circuit arrangement for the cubicles	Single busbar
Medium voltage cubicles	1
Output feeder lines (to transformer bays)	1
Input feeder lines	5
Auxiliary cubicle	1
Metering lines	1 per cubicle

4. GENERAL CONSIDERATIONS OF THE SUBSTATION

4.1. Environmental conditions

Environmental conditions are shown in Table 6. They have been used to calculate some of the substation´s key features such as the type of insulators, the size of the buses or the value of the loads.

Table 6. The environmental conditions of the site

Environmental conditions	
Altitude	204.79 m a.m.s.l.
Maximum temperature	35.22 °C
Average temperature	18.13 °C
Minimum temperature	5.49 °C
Pollution level	Medium
Specific creepage distance	30 mm/kV
Maximum wind speed	120 km/h
Air pressure	70 daN/m^2

4.2. Short-circuit current

The short-circuit levels that have been considered in the design of the electrical substation are shown in Table 7.

Table 7. The short-circuit levels

Nominal system voltages	Short-circuit levels
132.0 kV	40.0 kA
20.0 kV	25.0 kA

4.3. Insulation coordination

The values of the insulation coordination that have been adopted to select the electrical equipment and calculate the clearance distances are presented in Table 8.

Table 8. The primary insulation coordination values

Insulation coordination	
Lightning impulse withstand voltage	650 kV
Short-duration power-frequency withstand voltage (phase-to-earth)	275 kV
Short-duration power-frequency withstand voltage (phase-to-phase)	275 kV

4.4. Minimum safety distances

The safety distances are the minimum distances that should be maintained in the placement of different devices located within the perimeter of the substation field. The safety distances are made up of two values:

- The basic value which is related to the impulse withstand voltages of the substation.
- A safety zone to protect the staff during maintenance. This zone considers the likely area that would be regularly traversed by staff.

Figure 3 shows the relationship between the basic value and the safety zone for staff.

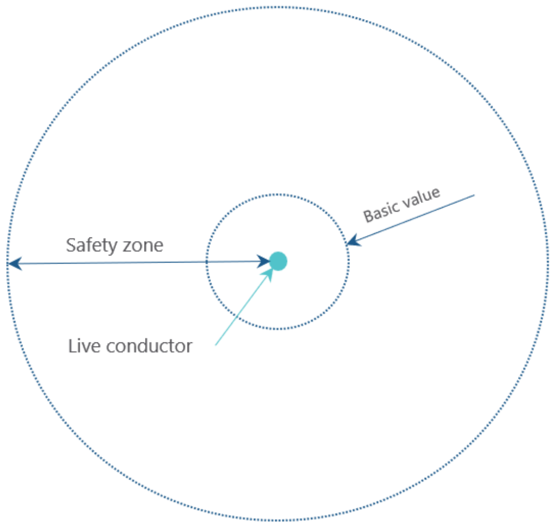

Figure 3. The safety distance is the sum of a basic value plus a safety zone

<u>Basic values</u>

After the calculation of the impulse withstand voltages, the following electrical clearances are obtained:

- Phase to earth distance for 132.0 kV: 1.3 m.
- Phase to phase distance for 132.0 kV: 1.3 m.

For these distances, the effect of the altitude over the sea level has been considered.

<u>Safety zone for staff</u>

The safety distances shall be delineated in way that facilitates the maintenance efforts of staff in the substation field. The following criteria have been adopted for all voltage levels within the facility:

- The height of a worker with the arms raised is 2.25 m.
- The height of a worker with the arms outstretched passing above the working plane is 1.25 m.
- The length of a worker with the arms outstretched is 1.75 m.

<u>Minimum safety distances</u>

The conductors will be arranged to meet the following heights in the 132.0 kV side:

- The connection between the devices installed at the substation field will be at a height of 3.68 m above the floor.

- The outgoing lines will leave the substation at a height of 9.68 m.

The minimum safety heights of the substation are shown in Figure 4.

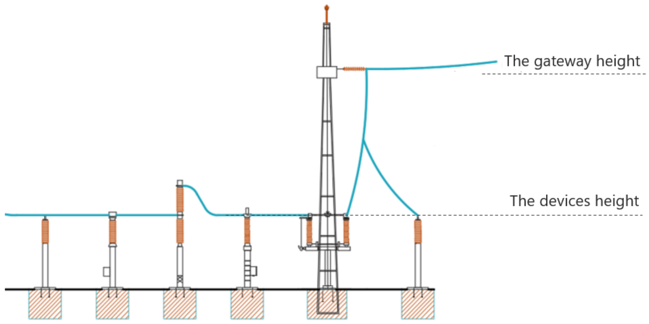

Figure 4. The minimum safety heights

The following separation parameters will be maintained in determining the location of the switchgear in the 132.0 kV side:

- Among the three phases of the conductor, each is separated by 3.18 m from the others.
- The bay width is 12.72 m. This is also the span of the busbar/gateway.
- An electrical device or switchgear shall keep a minimum distance of 3.18 m with an existing device in the bay direction.

The minimum safety heights of the substation are shown in Figure 5.

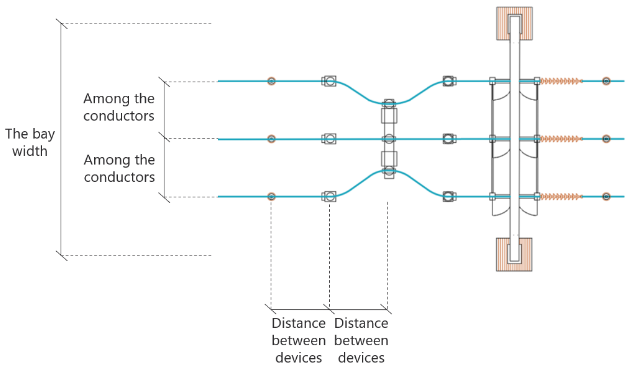

Figure 5. The minimum safety distances

Following, a summary of the distances that have been considered is presented in Table 9, Table 10, Table 11 and Table 12.

Table 9. The basic values in 132.0 kV side.

Basic values 132.0 kV	
Phase-to-earth distance	1.3 m
Phase-to-phase distance	1.3 m

Table 10. The additional distances for staff.

Safety zone for staff	
The height of a worker with the arms raised	2.25 m
The height of a worker with the arms outstretched passing above the working plane	1.25 m
The length of a worker with the arms outstretched	1.75 m

Table 11. The minimum safety distances in 132.0 kV side.

Minimum safety distances 132.0 kV	
Among the three phases of the conductor	3.18 m
The width of the bay	12.72 m
Distances between electrical devices	3.18 m

Table 12. The minimum safety heights in 132.0 kV side.

Substation element	Minimum safety heights
The devices´ height	3.68 m
The gateway´s height	9.68 m

5. HIGH VOLTAGE SYSTEM

The 132.0/20.0 kV line to Transformer substation consists of 1 transformer bay/s, 1 overhead line/s and a 20.0 kV system that is made of 1 medium voltage cubicle/s to connect the PV plant to the substation.

The main equipment used to step up the voltage are:

- **Circuit breakers** that are mechanical switching devices which connect and break current circuits.

Figure 6. An example of a circuit breaker (source: ABB)

- **Disconnectors** that are used to isolate parts of the substation during maintenance. They are used to control the current that flows in the circuits. They operate when the circuit breakers are open.

Figure 7. An example of a disconnector (source: ABB)

- **Instrument transformers** that are either current or voltage transformers. They are used to reduce the current and voltage to levels that are measurable. These devices are key in enabling the protection measures that react to fault currents.

Figure 8. An example of instrument trasnformers (source: ABB)

- **Power transformers** which raise the voltage level from medium to high voltage.

Figure 9. An example of a power transformer (source: GE)

- **Grounding devices** that limit the fault currents that would flow by the neutral point of a transformer. They consist of a zig-zag transformer followed by a resistance to protect the personnel against uncommon voltage values, especially during fault conditions.

- **Surge arresters** that limit overvoltages on a system to protect the power transformer. They are placed at the end of the outgoing lines of the substation.

Figure 10. An example of a surge arrester (source: ABB)

- Medium voltage cubicles, which hold the necessary equipment connecting the PV outgoing medium voltage lines to the electrical substation.

Figure 11. An example of medium voltage cubicles (source: Ormazabal)

5.1. High-voltage equipment level - Output circuit bays

The output bay is equipped with the following devices:

- Three (3) surge arresters.
- Three (3) inductive voltage transformers.
- One (1) earthing disconnector.
- One set of three current transformers.
- One (1) circuit breaker.
- Three (3) surge arresters to protect the primary winding of the power transformer.

6. HIGH VOLTAGE EQUIPMENT - OUTPUT CIRCUIT BAYS

The output circuit bays connect the substation to the grid. They are the overhead lines that leave the substation to the distribution or transmission networks.

6.1. Disconnectors

The principal characteristics of the disconnectors that are located at the output circuit are given in Table 13.

Table 13. The main characteristics of the disconnectors

Disconnector characteristics	
Type	Outdoor three-pole disconnector
Rated frequency	50 Hz
Nominal voltage	132.0 kV
Maximum voltage	145.0 kV
Rated normal current	1600.0 A
Rated short-circuit withstand current	40.0 kA
Rated short-circuit peak withstand current	100.0 kA

6.2. Circuit breakers

The main characteristics of these circuit breakers that are located at the output circuit are given in Table 14.

Table 14. The main characteristics of the circuit breakers

Circuit breaker characteristics	
Type	Outdoor three-pole on-load circuit breaker
Interrupting medium	Air
Rated frequency	50 Hz
Nominal voltage	132.0 kV
Maximum voltage	145.0 kV
Rated normal current	1600.0 A
Rated short-circuit breaking current	40.0 kA
Rated short-circuit making current	100.0 kA

6.3. Current transformers

The secondary windings current transformers are equipped with one winding for metering purposes and two windings for protection purposes. The main characteristics of the current transformers that are located at the output circuit are presented in Table 15.

Table 15. The main characteristics of the current transformers

Current transformer characteristics	
Type	A current transformer with three secondary windings
Rated frequency	50 Hz
Nominal voltage	132.0 kV
Maximum voltage	145.0 kV
Rated primary to secondary current ratio	200.0/5.0-5.0-5.0 A
Rated continuous thermal current	40.0 A
Rated short time thermal current	100.0 kA
Number of secondary windings	3
Accuracy class at a standard burden (First core)	15.0 VA, Cl 0.2s
Accuracy class at a standard burden (Second core)	30.0 VA, Cl 5P
Accuracy class at a standard burden (Third core)	30.0 VA, Cl 5P

6.4. Voltage transformers

Outdoor inductive voltage transformers have been selected. The 3 secondary windings voltage transformers are equipped with one winding for metering purposes and two windings for protection purposes. They have the electrical characteristics given in Table 16.

Table 16. The main characteristics of the voltage transformers

Voltage transformer characteristics	
Type	A voltage transformer with three secondary windings
Rated frequency	50 Hz
Rated primary to secondary voltage ratio	132.0:√3 / 0.11 / 0.11 / 0.11 kV
Number of windings	3
Accuracy class at a standard burden (First core)	25.0 VA, Cl 0.2
Accuracy class at a standard burden (Second core)	100.0 VA, Cl 3P
Accuracy class at a standard burden (Third core)	100.0 VA, Cl 0.5-3P

6.5. Surge arresters

The principal characteristics of surge arresters at the beginning of the outgoing lines are shown in Table 17.

Table 17. The main characteristics of the surge arrester in the HV level

Surge arrester characteristics	
Maximum voltage for insulation	145.0 kV
Rated voltage	132.0 kV
Continuous operating voltage	92.0 kV

Temporary overvoltage (10s)	137.0 kV
Switching impulse protective level	272.0 kV
Lightning impulse protective level (10kA)	311.0 kV
Lightning impulse protective level (20kA)	342.0 kV
Nominal discharge current	10.0 kA

7. HIGH VOLTAGE/MEDIUM VOLTAGE SYSTEM - POWER TRANSFORMER LEVEL

7.1. Power transformers

The power transformer raises the voltage of the medium voltage lines of the PV plant to achieve a higher efficiency in transmission or distribution lines. The principal characteristics of the power transformers are presented in Table 18.

The installed power transformer is a two-winding transformer.

Table 18. The main parameters of the power transformers

Transformers	Voltage ratio	Rated power	Short-circuit impedance	Vector group
Num 1	132.0 / 20.0 kV	40.0 MVA	10.0 %	Ynd11

7.2. Earthing devices

The earthing device is made of a reactance and a resistance. The earthing reactance consists of a zig-zag transformer. Their characteristics are shown in Table 19.

Table 19. The components of the grounding device

Grounding reactance and resistance characteristics	
Reactance	
Earthing current	800.0 A
Earthing reactance per phase	4.6 Ω
Fault time	10.0 s
Resistance	
Earthing resistance	14.4 Ω
Disconnector	
Rated current	1600.0 A
Current transformer	
Rated primary current	1500.0 A
Rated secondary current	5.0 A

7.3. Surge arresters

The principal characteristics of surge arresters at the secondary voltage system are shown in Table 20.

Table 20. The main characteristics of the surge arrester in the MV level

Surge arrester characteristics

Maximum voltage for insulation	24.0 kV
Rated voltage	21.0 kV
Continuous operating voltage	16.8 kV
Temporary overvoltage (10s)	21.6 kV
Switching impulse protective level	47.0 kV
Lightning impulse protective level (10kA)	54.4 kV
Lightning impulse protective level (20kA)	61.0 kV
Nominal discharge current	10.0 kA

8. MEDIUM VOLTAGE SYSTEM

A 20.0 kV system of 1 medium voltage cubicles connects the PV plant to the substation. A single busbar arrangement has been selected for the gas insulated switchgear and its characteristics are shown in Table 21.

Table 21. The main parameters of the MV busbar

Busbar characteristics	
Rated voltage	20.0 kV
Rated current	1600.0 A
Short-circuit current	25.0 kA
Rated frequency	50 Hz

The system consists of a group of medium voltage cubicles which fulfils a variety of functions that are presented in this chapter.

8.1. Cubicles for incoming lines

The incoming feeder cubicles are equipped with:

- One (1) three position earthing disconnector.
- One (1) circuit breaker.
- One set of three current transformers.

The main features of the input cubicles are shown in Table 22.

Table 22. The main components of the input cubicles

Input cubicles	
Disconnector	
Rated current	630.0 A
Circuit Breaker	
Rated current	630.0 A
Current transformer	
Rated primary current	600.0 A
Rated secondary current	5.0 A
Number of secondary windings	1
Accuracy class at a standard burden (First core)	15.0 VA, Cl 0.2s

8.2. Cubicles for outgoing lines

The outgoing feeder panels are equipped with:

- One (1) three position earthing disconnector.
- One (1) circuit breaker.
- One set of three current transformers.

The main features of the output cubicles are shown in Table 23.

Table 23. The main components of the output cubicles

Output cubicles	
Disconnector	
Rated current	1600.0 A
Circuit Breaker	
Rated current	1600.0 A
Current transformer	
Rated primary current	1500.0 A
Rated secondary current	5.0 A
Number of secondary windings	1
Accuracy class at a standard burden (First core)	15.0 VA, Cl 0.2s

8.3. Metering cubicle

The metering panels are equipped with:

- One (1) three position earthing disconnector.
- One voltage transformer.

The main features of the metering cubicles are shown in Table 24.

Table 24. The main components of the metering cubicles

Metering cubicles	
Disconnector	
Rated current	630.0 A
Voltage transformer	
Voltage ratio	20.0:√3 / 0.11/ 0.11 kV
Number of secondary windings	2
Accuracy class at a standard burden (First core)	25.0 VA, Cl 0.2
Accuracy class at a standard burden (Second core)	100.0 VA, Cl 3P

8.4. Auxiliary services’ cubicle

The cubicles are designed to connect the auxiliary transformer to the system. They are equipped with:

- One (1) three position earthing disconnector.
- One (1) circuit breaker.

The main features of the cubicle for auxiliary services are shown in Table 25.

Table 25. The main components of the auxiliary services´cubicles

Auxiliary services´ cubicles	
Disconnector	
Rated current	630.0 A
Circuit Breaker	
Rated current	1600.0 A

Auxiliary transformer	
Rated primary voltage	20.0 kV
Rated secondary voltage	0.4 kV
Rated power	100.0 kW

8.5. Cables

The cables that connect the medium voltage cubicles to the substation are characterized as shown in Table 26.

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 criteria are considered.

Table 26. A summary of the cable sections

Section	Conducting material	Insulation material	Installation type
185 mm2	Al	XLPE	Directly buried