D4.13 Madeira Lighthouse UC-6 report

INSULAE – Maximizing the impact of innovative energy approaches in the EU islands

Grant agreement: 824433
From 01/04/2019 to 31/03/2023

Prepared by: CIRCE

Date: 30/11/2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 824433

DELIVERABLE FACTSHEET

Document Name: Madeira Lighthouse UC-6 report

Responsible Partner: CIRCE

WP: 4

Task: 4.4

Deliverable nº: 4.13

Version: FINAL

Dissemination level	
X	PU = Public
	PP = Restricted to other programme participants (including the EC)
	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

Version Date: 30/11/2022

Approvals

	Company
Author/s	CIRCE
Task Leader	EEM
WP Leader	CIRCE

Documents history

Revision	Date	Main modification	Author
1	01/06/2021	ToC	CIRCE
2	01/09/2021	Partner contributions	All
3	22/04/2022	Check and restart	CIRCE
4	01/07/2022	Partner contributions	All
FINAL	30/11/2022	Finalisation	CIRCE

DISCLAIMER OF WARRANTIES

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 824433".

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Following initial inputs presented in D4.16 (Confidential Report), this deliverable will collect the main conclusions reached after finalizing the modelling, basic and detail engineering and equipment development activities previous to the deployment of UC-6: Electrification of the islands' transport looking to grid frequency and voltage regulation at Madeira island.

Madeira is a Portuguese archipelago located in the Atlantic Ocean, Figure 1. It is formed by 4 islands (2 inhabited: Madeira with an area of 741 km2, and Porto Santo with 42,5 km2. Madeira is the biggest island in the group and has about 270.000 inhabitants). Most of the population (75%) live on only 35% of the territory due to mountainous terrain. The capital city of Madeira is Funchal with a population of 130.000 inhabitants. There are several ports in Madeira, but the most important is the Port of Funchal (International Maritime Passenger Terminal) where a lot of people arrive on cruise ships, especially in summer. Madeira island also has an airport for commercial and private flights.

Figure 1.- Location of Madeira

In UC-6, the use of the EV charging infrastructure as part of a methodology to enhance grid stability and optimal use will be explored. In order to test and validate this concept, the project scope includes, the installation of two (2) 50 kW smart fast-chargers, four (4) 10 kW V2G (Vehicle-to-Grid) chargers and one (1) 50 kW Fully SiC V2G charger. The main objective is to demonstrate how the operation of these assets can be used in favour of the electrical grid, particularly by providing services to the grid such as participating in the frequency control (reacting to variations in the grid frequency) and voltage regulation.

This deliverable D4.13 is divided into 2 parts. The first part describes the specifications as an outcome from the design and engineering process and all other prior considerations (such as location of installation, required user engagement or permissions etc.) The information is presented for the specific equipment to be installed and commissioned in Madeira under Use Case 6.

Section 3 follows with the digital infrastructure required for proper control and management of Use Case 6, especially considering that central control is required as the core of the Use Case.

1 UC-6: Electrification of the Islands' Transport Looking to Grid Frequency and Voltage Regulation

1.1 Smart chargers installation

1.1.1 Main technical specifications

The smart chargers that were considered for the project allow the EV fast charging of almost all vehicles in the market. By other words, they can perform a.c. charging and d.c. charging, using the CHAdeMO or CCS interface.

Moreover, two different models were used in the project. One is rated for 45 kW and a second one is rated for 60 kW. Both pieces of equipment have advanced smart charging and load sharing capabilities. The detailed specification of these fast chargers can be found in Table 1 and Table 2.

Table 1. QC45 Smart Charger main specifications.

Description	**Specification**
Input	
Rated voltage/range	400 V / 360 V – 440 V
Rated frequency/range	50 Hz / 45 Hz – 55 Hz
Rated power	75 kVA
Rated current	110 A
Neutral regime	TT, TN-S
Efficiency	>93,5 %
Output (CHAdeMO)	
Voltage range	150 V - 500 V
Maximum current	125 A
Maximum power	50 kW
Output (CCS)	
Voltage range	150 V - 500 V
Maximum current	200 A
Maximum power	50 kW
Output (a.c.)	
Rated voltage	400 V
Maximum current	32 A
Maximum power	22 kW
General	
Dimmensions (WxHxD)	600x600x1800 mm (without cable supports)
Weight	600 kg
Protection Class	IP54
Temperature range	-35 ºC .. +50 ºC
Designed according	Safety: IEC 61851-1, IEC 61851-23 EMC: EN 61000-6-2, EN 61000-6-4
EV interface	CHAdeMO 0.9 / CCS (Combo T2) / IEC 61851-1
Communication	OCPP 1.6
User interface	Color display / RFID card

Table 2. QC60 Smart Charger specifications.

Description	Specification
Input	
Rated voltage/range	400 V / 360 V – 440 V
Rated frequency/range	50 Hz / 45 Hz – 55 Hz
Rated power	85 kVA
Rated current	123 A
Neutral regime	TT, TN-S
THD	<5 %
Efficiency	>95 %
Output (CHAdeMO)	
Voltage range	150 V - 500 V
Maximum current	125 A
Maximum power	50 kW
Output (CCS)	
Voltage range	150 V - 1000 V
Maximum current	200 A
Maximum power	60 kW
Output (a.c.)	
Rated voltage	400 V
Maximum current	32 A
Maximum power	22 kW
General	
Dimmensions (WxHxD)	786x510x1978 mm (without cable supports)
Weight	378 kg
Protection Class	IP54
Temperature range	-35 ºC .. +50 ºC
Designed according	Safety: IEC 61851-1, IEC 61851-23 EMC: EN 61000-6-2, EN 61000-6-4
EV interface	CHAdeMO 0.9 / CCS (Combo T2) / IEC 61851-1
Communication	OCPP 1.6
User interface	Color display / RFID card

These chargers support simultaneous charging sessions with advanced load balancing features, which is important for the project. The user interface is very agile and after user identification (if authentication is required), by simply choosing the charging standard compatible to your vehicle and coupling the charger's output plug to the EV, it is possible to have a fast, secured and stable charging process. The QC60 includes an advanced power electronics stage, higher efficiency and flexibility in the charging power management between outputs, resulting in top specifications for DC and AC fast charging.

These chargers are able to communicate with the CMS, using the OCPP 1.6 protocol, in order to make the authentication/authorization process, status update and receive operational profiles.

1.1.2 System location

The two smart-chargers of UC6 intervention are located next to each other, creating a charging hub capable of charging simultaneously at least four EVs. The location of this smart-charging hub is in downtown Funchal in a public site, close to EEM headquarters, which is where it is the secondary substation (6,6/0,4 kV) that supplies electricity to the chargers. By the time of this report both of the smart-chargers (Efacec's QC45) and (Efacec's QC60) are deployed, though there is ongoing troubleshooting in the communication platforms.

Figure 2. – Madeira INSULAE's smart-charging hub.

In terms of location, the charging hub is approximately 120 m from the nearest secondary substation , Figure 3.

Figure 3. - Satellite view of the smart-charging hub location.

In terms of cable path, red line of Figure 3, the electrical supply of the two chargers have an approximate length of 315 m, of which 185 m already existed, while the remainder of the path was added with the preparation of the charging-hub. The new cable path implied the construction of two underground concrete boxes and the installation of three distribution cabinets. The electrical supply of the chargers comes directly from the secondary substation, through an aluminium cable with a section of 185 mm^2 (LXV 3x185+95), with capacity for the combined power of the chargers, 160 kVA (233 A). Then this cable enters in a distribution cabinet, and is divided into two separated copper cables with a section of 35 mm^2 (XV 5G35), protected by fuses of 125 A. Each of these cables then enter a separated cabinet that supplies independently each charger. These cabins, upstream the chargers have a dedicated energy-meter for the counting of the energy, an AC differential protection of 300 mA and a circuit breaker of 125 A, Figure 4.

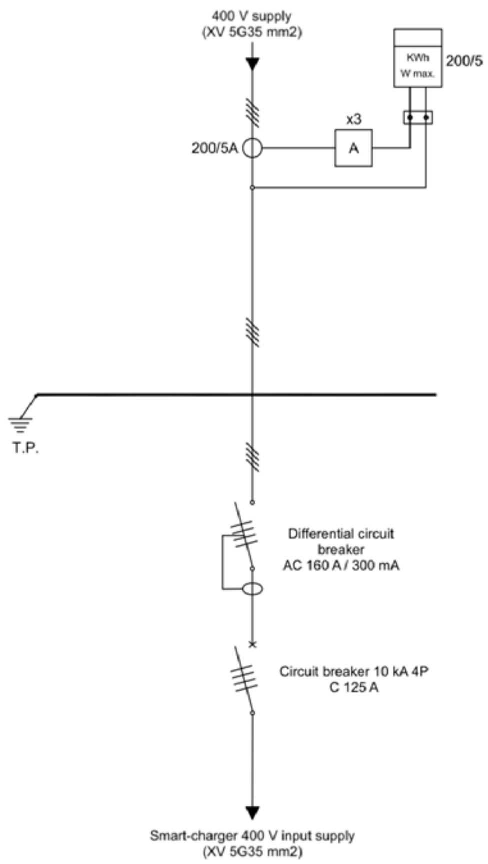

Figure 4. - Schematic of the supply cabinet of the smart-charger.

In addition to the electrical supply, a fibre optic infrastructure was established in parallel to the electrical cable (through a separate underground conduct), connecting the smart-chargers to EEM's data centre, that is located in the headquarters building. This telecom link enables the connection of the smart-chargers to the CMS (Charging Management System).

1.1.3 User-engagement for the smart-charging demonstration

As the smart-charging pilot will be tested by real users, an online user-engagement campaign was deployed in Madeira between the 13th of May to the 15th of June of 2021, organized by the local partners, ACIF and EEM. The goal was to gather a minimum of 25 participants for the smart-charging demonstration. In total,72 EV users residents in Madeira island, submitted their interest to participate in this demonstration. These smart-chargers are compatible with both DC (CCS Combo and CHAdeMO) and AC norms of charging, and due to this, it was established that of the 25 participants, 10 will be assigned for the CCS Combo charging, other 10 for the CHAdeMO charging and 5 for the AC charging. In Table 1 is presented, by charging norm, the number of participation submissions for this demonstration.

Table 1. Number of EVs enrolled by compatible charging norm.

DC		AC
CCS	CHAdeMO	
28	21	23

A selection criteria was defined by EEM and published in the project's Portuguese landing page (https://eeminov.eem.pt/insulae/):

1. The vehicle must be 100% battery electric (BEV);
2. The user must have a smartphone with internet access: necessary to use the associated app for the charges scheduling and monitoring;
3. Compatibility with one of the charging norms (CCS Combo, CHAdeMO or AC);
4. Order of arrival of the request to participate.

Based on the criteria exposed above, 25 participants were selected from the 72 submissions received until the 15th of June 2021. In Table 2 is presented the number of participants in the smart-charging by EV manufacturer and model.

Table 2. - EVs model and brand of the smart-charging participants.

Brand	Model	Number of EVs enrolled
Nissan	Leaf	8
Renault	Zoe	4
MINI	Cooper SE	2
Hyundai	Kauai Electric	2
Kia	e-Soul	2
VW	e-Golf	1
Smart	EQ fortwo coupe	1
Tesla	Model 3	1
Peugeot	e-208	1
Peugeot	Ion	1
Mercedes	EQC	1
Mitsubishi	I-Miev	1

Based on the profile use of the chargers by these initial participants, EEM will decide or not to increase the number of participants, in order to maximize the usability of the chargers and potentiate the impact of the smart-charging. The remaining requests that were not selected, were integrated in a stand-by list, ordered by the same selection criteria mentioned above. Participants must commit to the success of the demonstration by agreeing and respecting two duties established in the demo regulation:

1. Respect the orderly use of the charging stations, namely by using them in accordance with the schedule of charging sessions, which can be programmed and viewed on the demonstration's smartphone app (under final trouble shooting by CIRCE);
2. Carry out at least two weekly charges of at least 30 minutes each at these stations, or a minimum weekly energy consumption at these stations equivalent to 1,5x the energy capacity of the EV battery.

Participants that don't comply and commit to these duties, can be excluded from the demonstration, and be replaced by other users from the reservation list.

1.2 Fully SiC V2G fast charger installation

1.2.1 Main technical specifications

The fully SiC 50 kW EV Fast Charger is designed to charge Electric Vehicles through CHAdeMO or CCS protocol, for Madeira 1 Chademo cable with full V2G capability and 1 CCS with a future potential for V2G will be provided. One of the most remarkable features of the equipment is the bidirectional operation working as Vehicle-to-Grid V2G converter or inverter. Furthermore, thanks to the use of Silicon Carbide (SiC) semiconductors, a high frequency switching is possible, reducing the noise generation and improving the converter efficiency. The equipment has very low harmonic current and an accurate operation thanks to the 4-Leg AC/DC converter, and adds galvanic isolation in the DC/DC converter.

The main functionalities are the variable power factor in function of the needs, the reactive power balance, phase balancing and the DC current source, for EV recharging with CHAdeMO (bidirectional Vehicle-to-Grid V2G) or CCS (unidirectional) charge. The power electronics could be used as a stationary battery charger with a communication interface modification.

The next figures show the general block diagram and how it has been divided internally in two 25 kW AC/DC converters and four 12,5 kW DC/DC converters, adding new possibilities to the system connection between modules, and the capability to increase the output voltage or current.

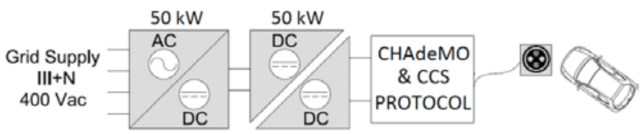

Figure 5 – Fully SiC 50 kW Fast Charger. General block diagram.

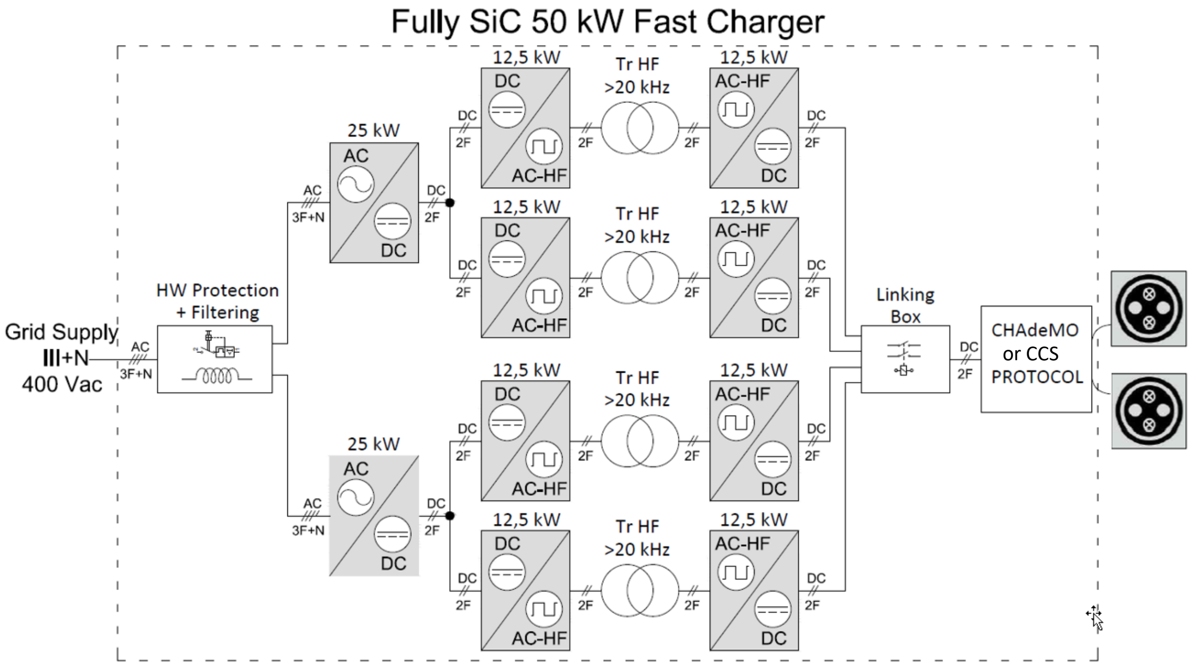

Figure 6 – Fully SiC 50 kW Fast Charger. Power electronics converters block diagram.

The main specifications are shown in the next table:

Table 3 - Fully SiC 50 kW Fast Charger. Main specifications.

Specification	Description
Connection type	3-Phase System x Neutral (III+N)
Rated AC power Input	400 Vac / 50 Hz / 100 Arms / 55 kVA

Rated DC Voltage Output	50-500 Vdc
Rated DC Current Output	0-60 A
Auxiliar power supply	230 Vac / 16 A / 50 Hz
Communication interfaces	CAN Bus / ModBUS RS485 Possibility to monitor data through WiFi
Cooling system	Forced air cooling
Dimensions and weight	(1,900 x 800 x 650) mm (height x width x depth) 200 kg (Approx.)
Protection grade	IP 54, IK9
CHAdeMO or CCS hose (For Madeira 1 each).	  Plastic material, for saline and subtropical environment

Each 25 kW AC/DC converter is a fully SiC, bidirectional, low harmonic current, high frequency switching, 4-leg converter, with an accurate operation, reactive power balance, variable power factor in function of needs and phase balancing.

While each 12.5 kW DC/DC converter consists of two bridge converters: DC/HF converter and HF/DC converter, fully SiC, bidirectional, with galvanic isolation and high frequency switching between 80 and 120 kHz. It can operate as current source, voltage source only for insulation test, vehicle-to-Grid or battery charger.

The equipment has many hardware and software protections, such as grid under and over voltage, grid under and over frequency, anti-islanding, grid over current, differential current protections, over temperature, isolation protection, microcontroller watchdog, hardware safety chain, and the necessary protections in CHAdeMO and CCS protocols(designed).

The next figures show the 3D design of the cabinet, and the dihedral views:

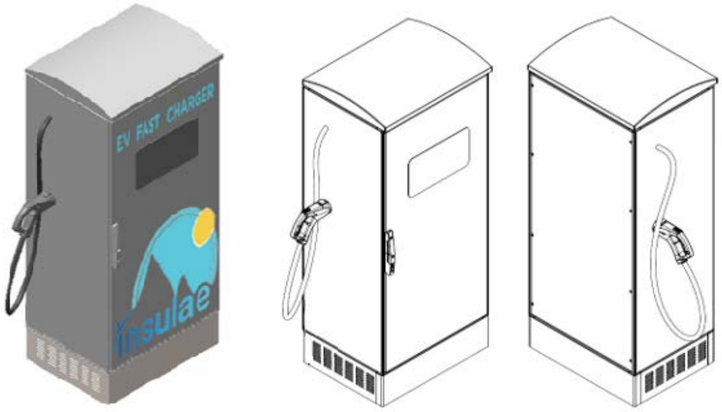

Figure 7 – Fully SiC 50 kW Fast Charger. Cabinet views.

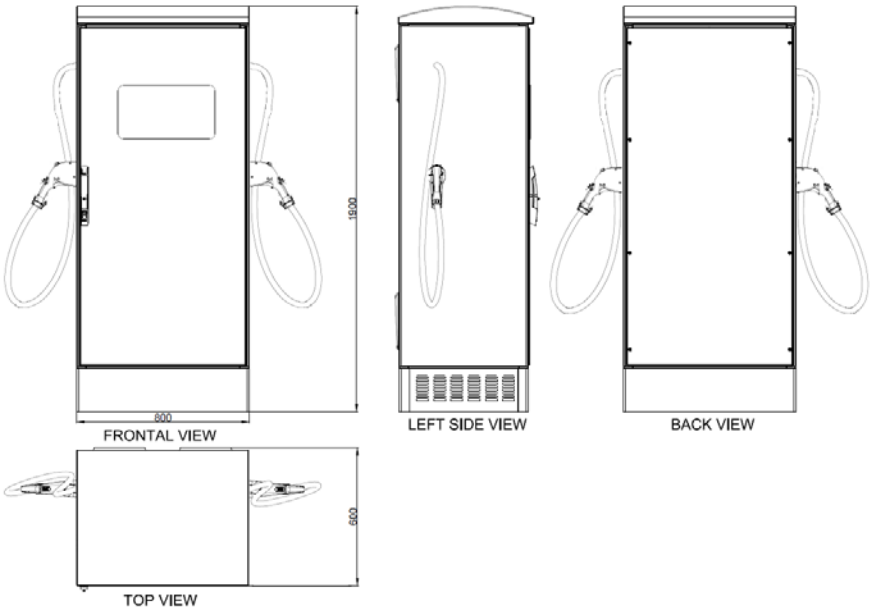

Figure 8 – Fully SiC 50 kW Fast Charger. Dihedral views.

1.2.2 System location

Due to the prototype nature of this Fully SiC based V2G fast charger, which may require technical support and system mionitoring, it was proposed and decided by the Regional consortium, that this equipment will be installed in EEM's headquarters garage. This site is controlled, with restricted access, and the company has a fleet of NISSAN Leafs (3) compatible with the bidirectional charging. In Figure 9 is presented a photomontage of the Fully SiC V2G fast charger installation site (the design of the real charger cabinet differs slightly from that depicted in the figure).

Figure 9. - Photomontage of the Fully SiC fast charger installation in EEM's headquarters garage.

Due to the input power of the equipment (55 kVA) (79 A), the electrical supply will come directly from a secondary substation with an installed capacity of 630 kVA . This way, a low voltage feeder from the substation will be reserved for this charger, and consequently equipped with an energy meter and a circuit breaker (4P, 100 A, C curve, 25 kA). The electrical cable that will be used for the electrical supply of the charger (approximate length of 30 m) will be rubber flexible cable with 4 copper conductors, each one with a section of 25 mm^2 (H07RN-F FBBN 5x25).

Upstream of the charger will be installed the equipment protections and a power analyzer for the V2L (Vehicle-to-Load) feature, Figure 10.

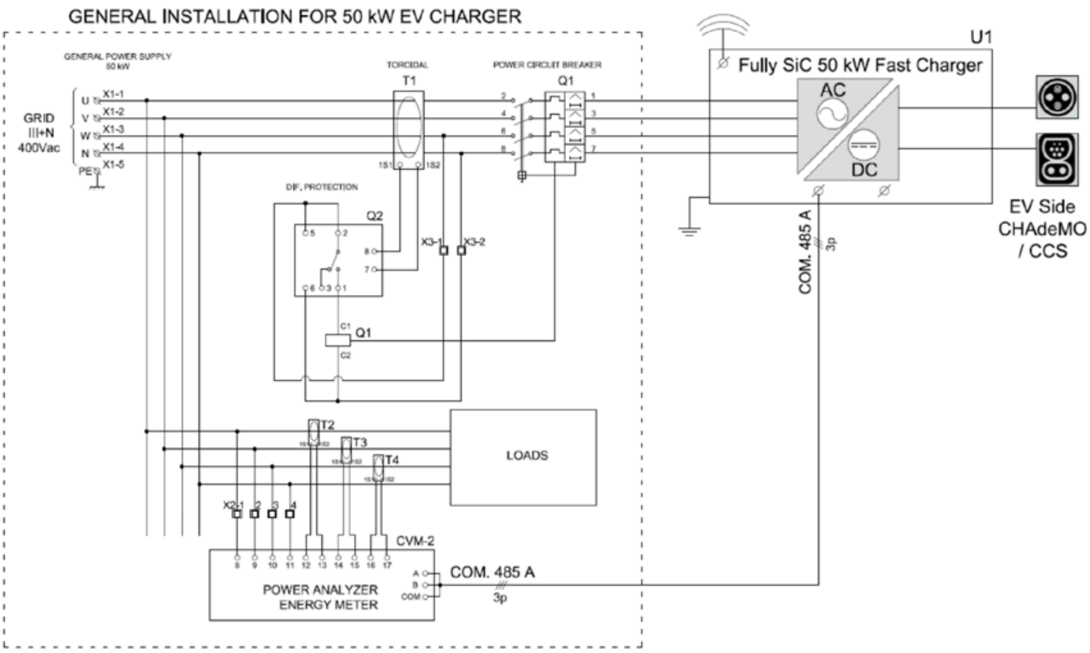

Figure 10. - Fully SiC 50 kW V2G fast-charger input connections diagram.

The circuit protections of the charger consists in a 100 A, C curve, 10 kA circuit breaker with a shunt release that can be triggered by the differential breaker. The differential protection is superimmunized, with a rated current of 100 A and a residual current of 30 mA. The power analyzer will monitor the loads from the secondary substation that supplies the charger, so that the charger can compensate and balance the local grid with its bidirectional power flux capability. The power analyzer will communicate through ModBUS RS485 with CIRCE's energy box, then this device will command the charger based on the analyzer measurements. Besides this local load management, the charger will be connected to the Charging Management System (CMS) and controlled by EEM's Dispatch Center power setpoints.

1.3 10 kW V2G chargers installation

1.3.1 Main technical specifications

In the demo the installation of four units of a V2G charger are planned, with a rated power of 10 kW, equipped with a CHAdeMO output to support the V2G functionality and grid support functionalities. The main characteristics of the charger are represented in Table 3.

Table 3. - Smart V2G charger (10 kW) main specifications.

Description	**Specification**
Input	
Rated voltage/range	400 V / 360 V – 440 V
Rated frequency/range	50 Hz / 45 Hz – 55 Hz
Rated current	15 A
Neutral regime	TT, TN-S
THD	<5 %
Efficiency	>95,2 %
Output	
Voltage range (charging)	150 V - 500 V
Voltage range (discharging)	250 V - 500 V
Maximum current	30 A
Maximum power	10 kW
General	
Dimmensions (WxHxD)	740x646x415 mm (without cable supports)
Weight	55 kg
Protection Class	IP44
Temperature range	-5 ºC .. +45 ºC
Designed according	Safety: IEC 61851-1, IEC 61851-23 EMC: EN 61000-6-2, EN 61000-6-4
EV interface	CHAdeMO V2H
Communication	OCPP 1.6
User interface	Color display / RFID card

The charger is a wall mounted type with the external layout as represented in Figure 7. The unit is equipped with a user interface based on a color display and a set of led indicators for the signaling the charging status.

Figure 7. - 10 kW V2G fast-charger layout.

The charger is compliant with the relevant standards in terms of Safety, namely the requirements stated on the IEC 61851-1 and IEC61851-23.

To support the specific functionalities related with the grid support for the island grid, the charger incorporates specific control layers, namely voltage and frequency control loops for the regulation objectives proposed in the project. These advanced features will reveal the potential and flexibility of this EV charger concept as a smart asset on the grid.

The voltage control loop is embedded in the charger and will actuate according to a configurable profile of voltage variation. In the case of a grid voltage being too low, below a certain limit, the charging rate will be limited or, worst case, it will stop. In the opposite condition, the discharging of the battery can also be considered as a method to contribute to the increase of the grid voltage.

The frequency control block implements a precise calculation of the grid frequency, in order to react to the deviations, by adjusting the charging, or discharging power respecting a configurable curve with an optional dead band, and a power reference based on the frequency rate of change.

The Figure 8 presents the charger internal diagram, where the main blocks, their interfaces, and safety devices, are represented.

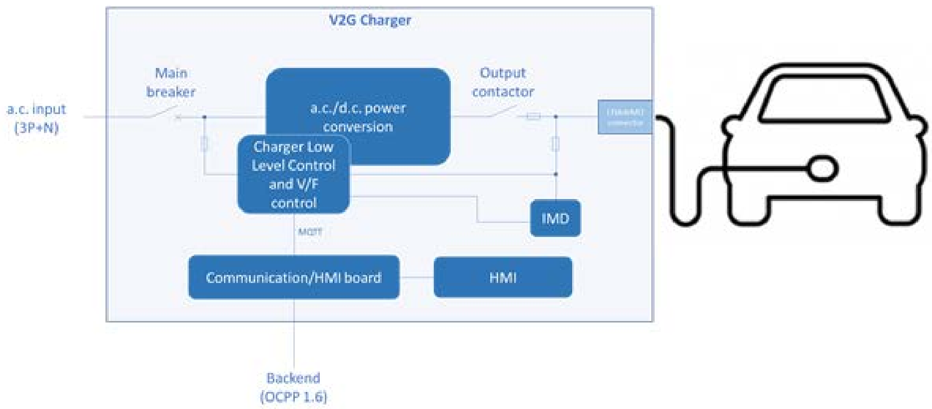

Figure 8. - V2G internal architecture.

Moreover, the charger integrates an interface with the CMS for the exchange information related with the charging session and to receive the necessary operational profile and setpoints.

1.3.2 System location

At the time of this report the installation location of the 10 kW V2G chargers is not defined, since the assessment of the installation is still in process (households/work facilities) technical conditions of the registered EV users. Technical visits were made to all household/work facilities of the EV users interested in participating in this demo. In total 10 technical visits were performed. Due to the multiple delays of the equipment shipment to Madeira, EEM decided to only select the 4 participants and perform the necessary electrical and civil works for the installation closer to the date given for the shipment of the chargers (L 2022). The main concerns of the site assessment are:

- Local LV distribution grid with capacity for a new three -phase load/gen of 10 kW;
- Location with space for the charger and of private access;
- Availability for a new LV distribution line exclusive for the 10 kW V2G charger;

The objective is to connect directly the charger to the grid, in a parallel connection to the electrical installation of the household. This way the V2G will not be constrained by the local load, since it will have a dedicated electrical connection to the electrical public grid. This solution is viable, but in the case the chargers are installed in indoor environments, the main circuit breaker of the local electrical installation, for safety reasons, when turned off, must also open the power supply of the V2G charging station.

1.3.3 User engagement for the V2G demonstration

User engagement activities were also developed in the scope of gathering EV user to participate and test the 10 kW V2G chargers. It ran parallel to the smart-charging user engagement, from the 13th of May to the 15th of June 2021. The main goal of this campaign was to gather four different EV users to use the V2G chargers. During this phase, sixteen different EV owners (some of them also applied to participate in the smart-charging), residents in the island, submitted their interest to participate in the INSULAE V2G demonstration. As far as we know, since the ISO15118 it's not yet fully implemented on CCS vehicles, only owners of NISSAN Leafs or NISSAN e-NV200 can participate in this pilot (the V2G chargers only comes with the CHAdeMO norm). Table 4 presents the number of submissions by EV model compatible with V2G and by charging type selection.

Table 4. - Distribution of V2G compatible EVs submissions by charging type.

	Number of submissions by charging type	
EV model	V2G	Smart-charging & V2G
Leaf	3	12
e-NV200	1	0

All the submissions received for the V2G demonstration will be subject to a technical evaluation by a technical team of EEM, which will include site visits for a deeper analysis.

The first four submissions (by order of arrival) which comply with all the technical conditions for the proper installation of the 10 kW V2G chargers, will be selected to participate in this demonstration. Similarly of what was done on the smart-charging, a stand-by list will be created, for whom still gather the technical conditions. Those who accept to participate have the responsibility to commit to the success of the demonstration by, when always possible, connecting its EV to the bidirectional charging point. In this sense specific terms and conditions were created and has to be acknowledge upon participation. If it is verified a poor use of the equipment, without proper justification, the charger can be removed and given to other user that is in the reservation list.

One of the benefits that the participants will have by letting their EV batteries available for V2G, is free energy for the charging of the vehicles, although this is still under analysis by the National regulator.

1.4 Operational dispatch assumptions

All chargers involved in the Madeira's UC6 intervention will be aggregated to a common platform, the Charging Management System (CMS). This platform will continuously interface with EEM's Dispatch Centre, receiving power setpoints for both the smart-charging and V2G sides of the chargers connected to the CMS. Thus, two setpoint generation logics were developed for smart-chargers and V2G chargers.

1.4.1 Control logics

1.4.1.1 Smart-charging

The charging power setpoints of the smart-chargers will be continuously defined based on the RES availability in Madeira's energy mix. The goal is to decrease the energy curtailment from RES by increasing the EVs charging. In Figure 11 is presented the logic for the smart-charging control by EEM's Dispatch Centre. The power setpoints generated, will be sent to the CMS and then this platform will distribute the assigned power by the available chargers.

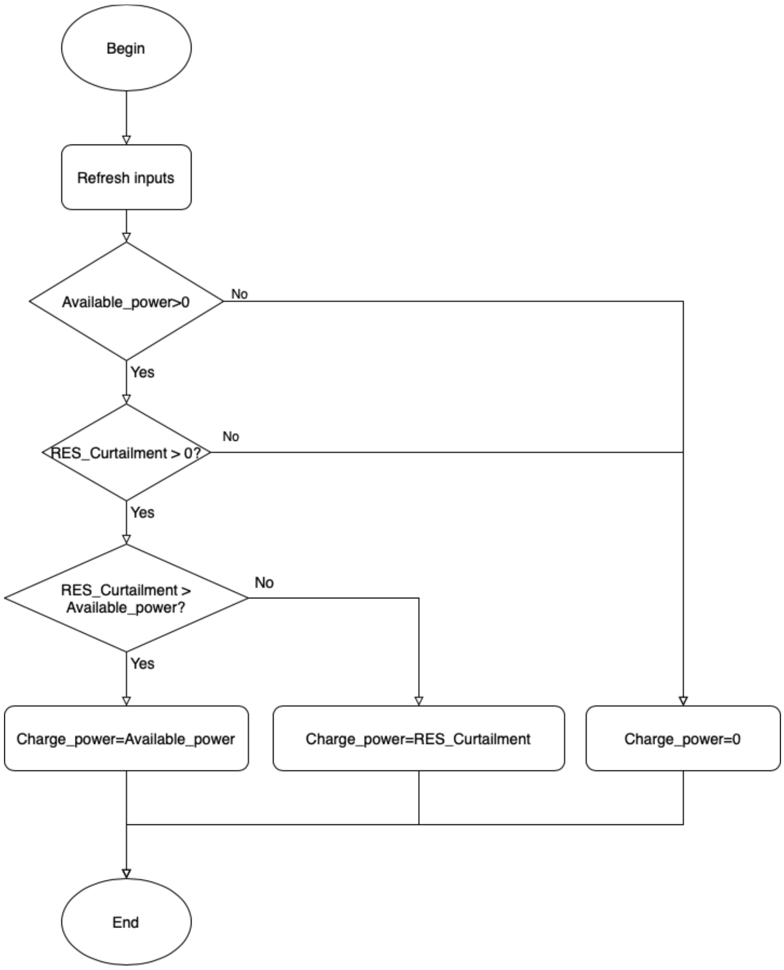

Figure 11. - Smart-charging control logic that will be implemented by the Dispatch Center.

The involved variables in the smart-charging logic are the following:

- **Available_power (input)**: Sum of the power of the available smart-chargers plus the V2G chargers;
- **RES_Curtailment (input):** Real time RES power curtail;
- **Charge_power (output):** Charging power setpoints to be divided between the active smart-chargers.

1.4.1.2 V2G

The V2G chargers (Also smart but focused on V2G) charging/discharging setpoints will have a similar control to the one applied for the smart-chargers. The charging control is similar and has the same objective as the smart-chargers, decrease RES curtailment with the increase of EVs . Regarding the discharging part of the V2G, the objective is to contribute to the spinning reserve of Madeira's energy system with the EVs' stored energy. Figure 12 presents the control logic for the V2G chargers that will be implemented by EEM's Dispatch Centre.

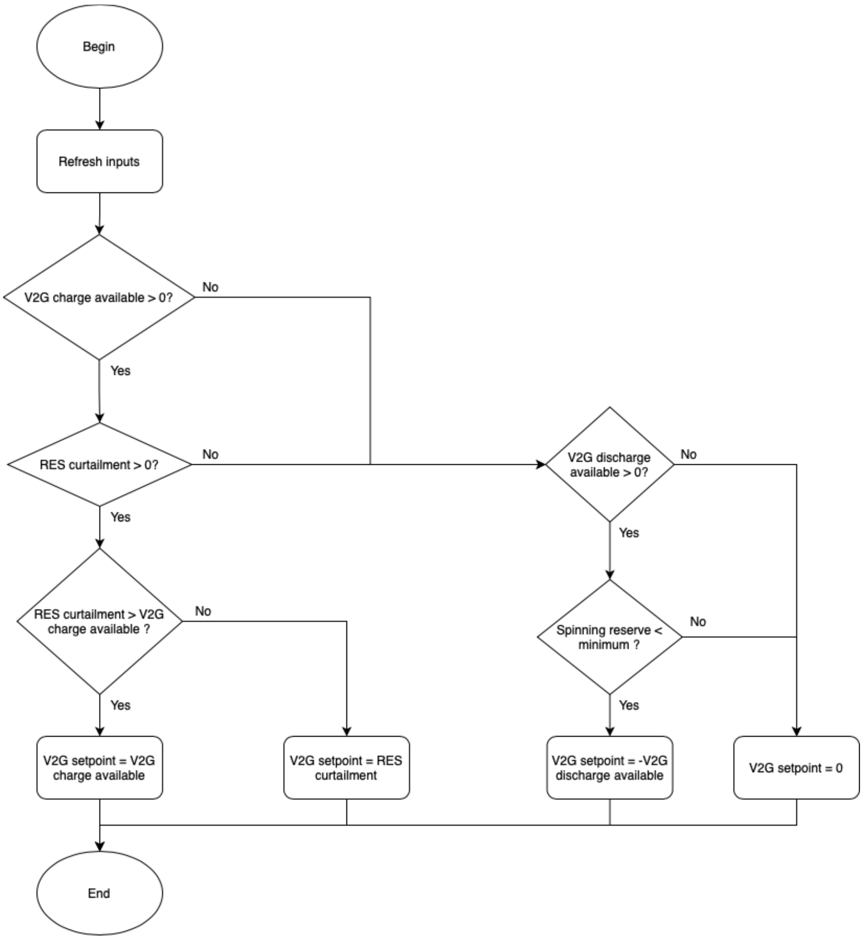

Figure 12. – V2G control logic to be implemented by the Dispatch Center.

The variables involved in the V2G control by part of the Dispatch Centre are the following:

- **V2G charge available (input)**: sum of the V2G chargers power available for charge;
- **V2G discharge available (input)**: sum of the V2G chargers power available for discharge;
- **RES curtailment (input):** power of the RES being curtailed;
- **Spinning reserve (input):** spinning reserve of Madeira's power system;
- **V2G setpoint (output):** power setpoint for the V2G chargers, can be positive or negative depending on the charging/discharging scenario.

1.4.1.3 Must-charge function

Despite the objectives of the smart-charging and V2G control are to increase the RES penetration and system stability, not always are compatible with users' mobility needs. This way it will be implemented by the CMS a must-charge function, that can be changed through a web-app accessed by the participants, that can assure the energy for the users' mobility needs despite the existence or not of enough RES for the charging:

$$SoC_{Request} \geq SoC(t) + \frac{P_c}{E_b} \times (t_{departure} - t) \quad (1)$$

where:

- $SoC_{Request}$ is the battery level requested at the end of the charging session (%);
- $SoC(t)$ is the current battery level of the EV (%);
- P_c is the charger power (kW);
- E_b is the battery capacity of the EV (kWh);
- $t_{departure}$ is the departure time (timestamp);
- t is the current time (timestamp).

The condition in (1) allows the users to have the requested state of charge at the end of the charging session despite the lack of RES generation during the charging time window. When this condition is verified, the management system should bypass the setpoints from EEM's Dispatch Centre, and set the charging power to the maximum.

1.4.2 Simulation scenarios

The smart-charging and V2G expected operation and impact on the grid can be assessed by visualizing the historical load diagrams and identifying the periods with excess RES generation and low spinning reserve.

1.4.2.1 Smart-charging example

Currently in Madeira, the only RES that is subject to curtail is wind generation, mainly due to its high installed power and volatility. To represent this effect, in Figure 13 is presented a load diagram (load and generation values in each minute) from the 28th of June 2021, where it is possible to identify periods of the day where the wind energy is curtailed. All energy sources are represented in the diagram, and regarding the wind contribution are drawn two lines, one for the wind energy injected to the grid (in dark green) and one for the total wind power available in each minute (in light green). When these two lines do not overlap each other, it means that part of the wind power is being curtailed and it is equal to the difference between these two lines.

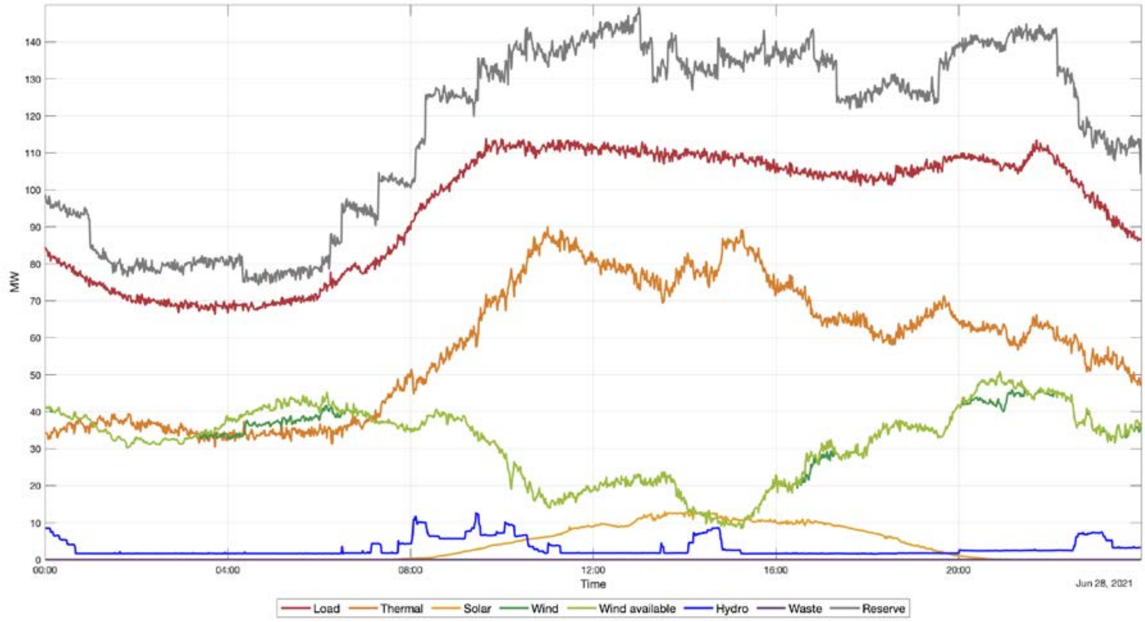

Figure 13. – 28th of June 2021 Madeira Island load diagram.

By analyzing Figure 13, it is possible to identify three periods where wind power is being curtailed: from 03h17 to 06h32, from 16h33 to 17h21 and 20h08 to 22h06. Assuming that an EV with a battery of 64 kWh and a SoC (state-of-charge) of 20%, will charge between 16h00 and 18h00 in a 60 kW smart-charger, with a target SoC of 95%. By applying the smart-charging logic of Figure 11, it was obtained the following SoC evolution of Figure 14.

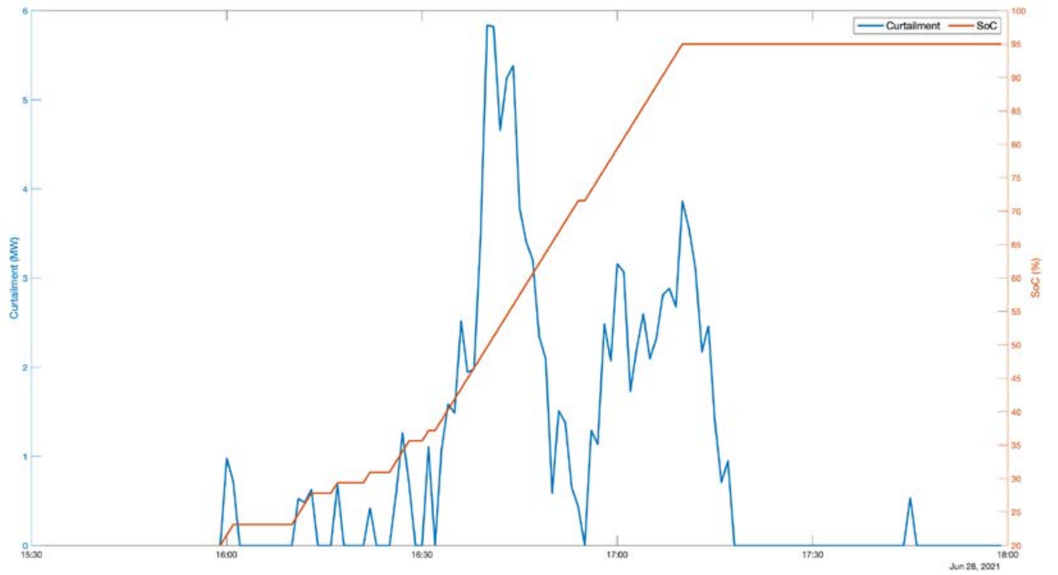

Figure 14. - SoC evolution during a smart-charging session simulation.

In this simulation, it was simplified the charging process of the EV with assuming that the charging power is not limited by the battery's SoC. The results in Figure 14 shows that the EV only charges in the presence of curtailed power. The must-charge function was not triggered, since the curtailed energy was more than enough for the target SoC.

The flexibility of this charging solution combined with a large deployment, has a high potential for increasing the RES penetration in the energy mix. In this assumption scenario, the EV charged in that time frame 48 kWh, while the curtailed wind energy in the same period was 1,995 MWh. The charging of this EV in this period contributed with a reduction of 2,4% of the verified curtailment.

1.4.2.2 V2G example

For the V2G simulation, it was used the load diagram from the 30th of June to the 1st of July of 2021, Figure 15.

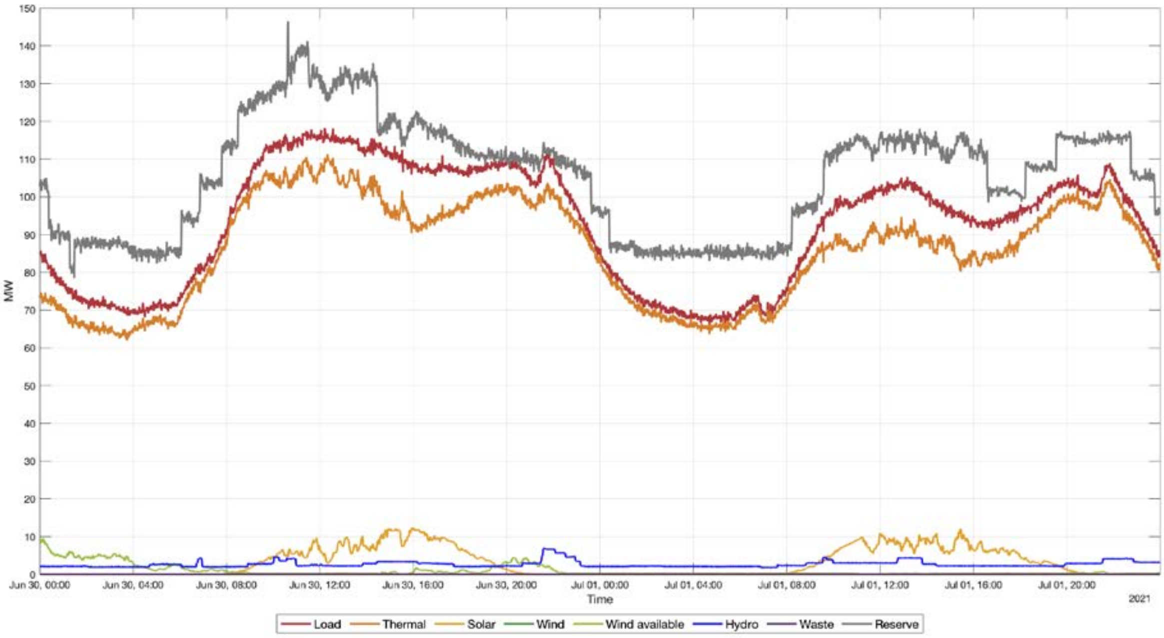

Figure 15. - Madeira load diagram from 30th of June to the 1st of July 2021.

As mentioned in section 2.4.1.2, the charge part of the V2G has the same philosophy as the smart-charging, the main difference it's the fact that this asset can discharge and therefore, contribute to the spinning reserve of the energy mix. This technology allows the EV to inject power to the grid, when the spinning reserve is zero. These chargers will also absorb/inject power from/to the grid in response to the voltage and frequency variations that can occur while operating.

By assuming the load and generation scenario of Figure 15 an EV with 50% SoC and with a target SoC by the end of the charge of 95%, connected to the V2G charger, from 18h00 of 30th of June to the 7h00 of the following day, it was obtained the results bellow (Figure 16).

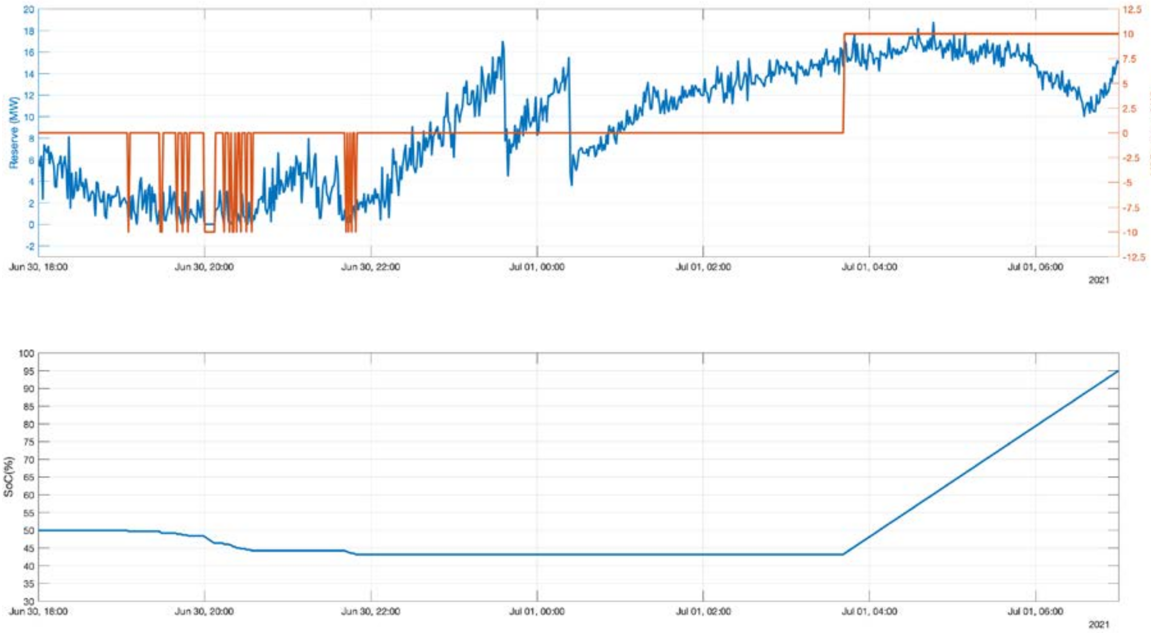

Figure 16. - V2G charging session simulation: time-series plots of the spinning reserve, V2G power and EV SoC.

In this scenario the V2G injected to the grid when the spinning reserve was zero, and due to the lack excess RES generation, the EV was only charged when the must-charge function was triggered later in the charging session, guaranteeing the mobility needs from the users.

With higher deployment of V2G solutions, in the order of the MW, the V2G can be seen has grid storage asset, that can contribute to the grid stability, by allowing the reduction of the thermal minimum, without compromising the safety of supply. Figure 17 presents of the expected outcome of the mass deployment of V2G chargers in Madeira island.

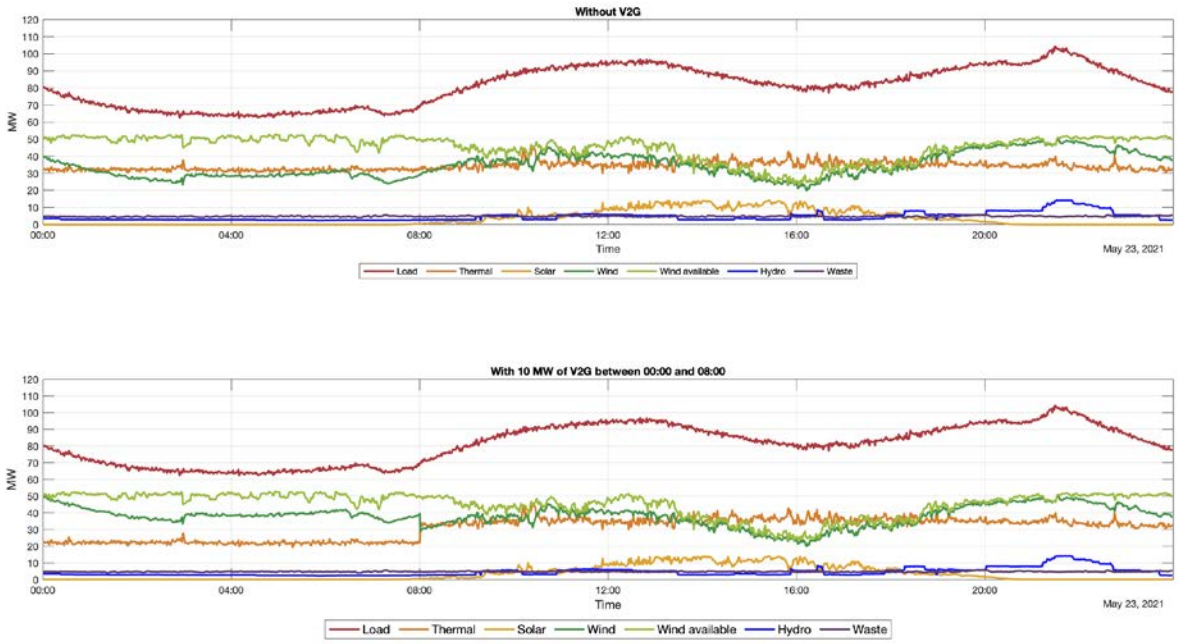

Figure 17. - Plot of generation and demand with and without the availability of 10 MW of V2G power.

The scenario of Figure 17 assumes that 10 MW of V2G power are connected and available to charge / inject to the grid at any moment from 00h00 to 08h00. This availability allows the reduction of thermal generation and the increment of the RES penetration. In the scenario without V2G (current scenario), curtailment of wind energy correspondent to 22,8% of total wind energy (1,08 GWh), while in the V2G scenario the wind curtailment decreased to 15,40%, allowing the penetration of more 80,17 MWh of wind energy and the reduction of the same amount of thermal energy.

2 Electric Vehicle Chargers Management Approach Proposed in INSULAE

In the framework of UC-6 developed in Madeira lighthouse island, CIRCE is deploying their Charge Management System (CMS) as a solution to optimally manage the electric vehicle chargers that are being demonstrated in Madeira Island.

As explained in D4.16, CIRCE has developed a fully functional web control centre for remote management of EV chargers based on the OCPP standards. It is a full stack solution based on open-source tools. As Figure 18 shows, the CMS is a complete solution that can be then virtualized or set up in any server, so it is compatible with both SaaS and on-premises approaches, allowing multiple instantiations for scalability.

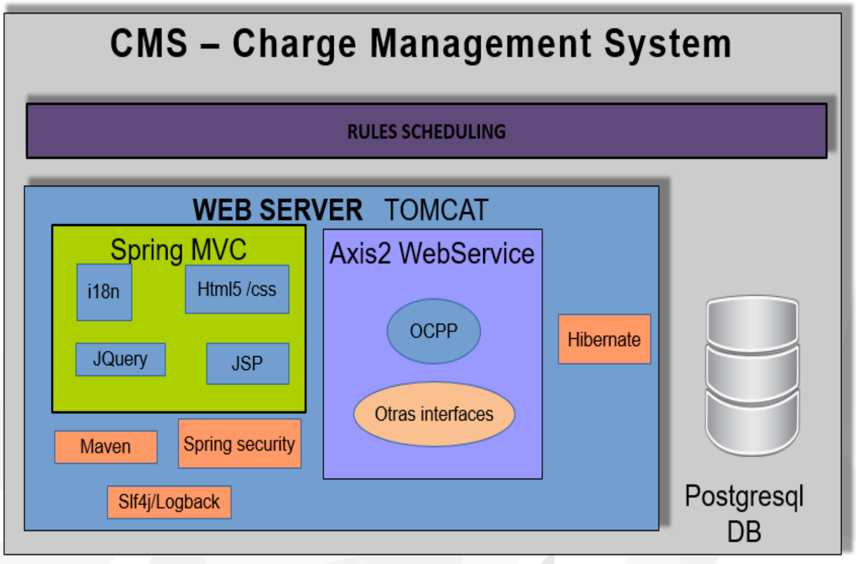

Figure 18.- CMS software architecture and main screen

As mentioned before, the functional features of the CMS are based on the OCPP standard, which defines request-response sets of messages to code the actions that can be started either by the charger or the management system (e.g. charge start, user validation, status update, etc.). These functions are already available in the current implementation.

OCPP functionalities

The current version of OCPP developed is the 1.6, that includes the Smart Charging concept. The basic functionalities and messages included in the development are:

- **Charger-started operations:**
  - Authorize: request to the CMS for authorizing a charge operation based on the user ID captured by the charger (RFID or similar, vendor-dependent).
  - Heartbeat: periodical signal for connection check.
  - Meter values: upload of measurements of a given charging process.
  - Start / stop transaction: notification of the beginning or ending of a charge operation.

  - Status notification: transmission of a set of signals related to the charger status and general operation.
  - Data transfer: message to send general-purpose, customizable information to the remote system.

- **CMS-started operations:**
  - Change configuration: modification of configuration parameters in the charger.
  - Reserve now / cancel reservation: time-scheduled reservation of a charger for its use for a given user.
  - Get / send local list: query or update of the authorized user list stored in the charger.
  - Update firmware: remote download of a new firmware version on the charger.
  - Remote start / stop transaction: command for beginning or ending a charge operation remotely sent from the CMS.
  - Data transfer: message to send general-purpose, customizable information to the charger.

Roles and user management

Taking advantage of the web application approach and the capabilities of the OCPP protocol, several user roles have been defined in CIRCE's CMS:

- **Corporate**: owner or manager of a charger or charging facility. Main functions: resource monitoring, retrieval of usage reports, etc.
- **Maintenance**: functions related to the charger status and the service provided (configuration, update, security, etc.).
- **User**: EV driver, fleet owner or agent who represents the user of the chargers. GIS representation of the chargers, usage reports, reservations, etc.
- **Admin**: complete access rights over the CMS functions.

The CMS makes it possible to manage separate chargers or facilities, from different owners, in the same system. In addition, several user groups can be defined so that they can be assigned to different chargers or assets. That way, the application guarantees that each member only has access to the proper chargers.

Smart Charging

In addition to the general management capabilities described above, CIRCE has developed an implementation of OCPP 1.6 Smart Charging, server side. It is based on the JSON version of the standard and includes functionalities of all the profiles defined by the protocol: *core, firmware management, local auth list management, reservation, smart charging and remote trigger*. The four first ones were already available in OCPP 1.5, with some minor changes, while the two last profiles have been added in 1.6.

Remote trigger functions enable active information requests from the CMS to the charging point, and Smart Charging is designed to implement power management systems from the CMS. For example, the power and current of a charging operation can be controlled, as well as the maximum allowed energy consumption in an individual charging point or in a charging station. These functions can be combined with external measurements, as expected in the e-Bus project, to design combined energy optimization schemes.

Apart from the implementation of the associated OCPP 1.6 messages, CIRCE's has developed a smart charging logic workflow that has been arranged in collaboration with EEM.

Mobile application

CIRCE has developed an app version of the CMS, that allows visualisation of most functionalities of the CMS in a suitable format for mobiles and tablets. In Figure 19 some examples of the screens are shown. Note that this has been adapted to Portuguese for use in Madeira.

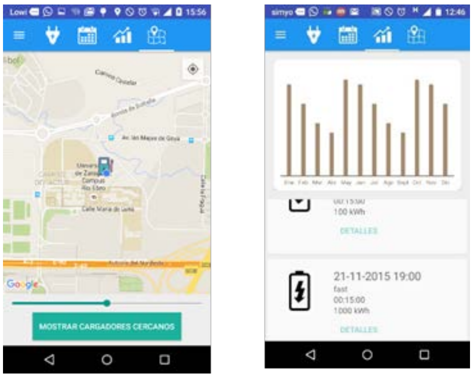

Figure 19.- Example of screen of app, beta version.

Testing of complete system in Madeira.

Internal testing of the systems in CIRCE has been carried out and the system is functional. Testing of the CMS and application on the actual Use Case infrastructure in Madeira are ongoing. It will run on EEM supplied infrastructure and connect to the QC45 and QC60 in the first instance prior to installation of the other equipment.

3 Conclusion

This deliverable D4.13 is a summary of the finalisation of the design, procurement, assembly and in house testing activities for UC6 in Madeira, as well as the simulation of their impact on Madeira grid using historical data to perform simulations.

In particular the equipment comprises the 2 fast chargers QC60 and QC45, and the 4 V2G chargers supplied by EFACEC; and the Fully SiC vehicle charger provided by CIRCE.

Although final assembly for some equipment is not complete the functional testing of the equipment prototypes and/or components or simulations are complete pending final assembly, sending, installation and commissioning in Madeira.

Apart from the challenges of design and development of the charging equipment the main problem faced by partners EFACEC and CIRCE has been timely procurement of components in the face of global shortages in supply, and specific supply issues for EFACEC related to organisational and higher level strategic business issues affecting operations.

Despite these challenges shipping and installation of equipment are now imminent.