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Electric Vehicles Management for carbon neutrality in Europe

Deliverable D 1.6
Real-scale prototype of V2X management station

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[1] https://ev4eu.eu/

Executive Summary

This is a project task led by Smart Energy Lab, involving participants such as INESC ID, DTU, NEW, and ABB. The primary objective is to address the technological challenges associated with V2X (Vehicle-to-Everything) charging systems, adhering to international standards (IEC61851 and OCPP 1.6/2.0).

The project aims to develop cost-effective V2X stations suitable for shared parking spaces and mass deployment in mode 2 and mode 3 configurations. These stations will also integrate with the Open V2X Management Platform (O-V2X-MP) project (mainly in Work Package 5).

Key aspects of T1.6 include testing prototypes in Portuguese demos, exploring Sharing Charging services, assessing operational and economic trade-offs, quantifying EV battery degradation due to V2X services, and developing cost-effective V2X solutions for parking lots.

The goal is to promote EV adoption, address grid connection challenges in parking lots, and reduce infrastructure costs while complying with international standards.

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Keywords, Acronym

ABB	Asea Brown Boveri
CB	Circuit Breaker
CPU	Central Processing Unit
DI/DO	Digital Input / Digital Output
DIN	Deutsches Institut für Normung (German Institute for Standardization)
EDA	Energia dos Açores
EV	Electric Vehicle
IEC	International Electrotechnical Commission
LTE	Long-Term Evolution
Modbus	Communication protocol widely used in industrial automation for transmitting information between electronic devices over a serial connection.
NEW	EDP NEW
OCPP	Open Charge Point Protocol
RCD	Residual Current Device
RTU	Remote Terminal Unit
Schucko	Derived from the German word "Schutzkontakt," which means protective contact (domestic power outlet)
SEL	Smart Energy Lab
TCP	Transmission Control Protocol
UVR	Under Voltage Relay
V2X	Vehicle to Everything
Wind-curtailment	Excess eolic energy production that leads to the need of increasing consumption
WP	Work Package

1 Introduction

A global shift in the energy sector is happening right now, we are moving away from fossil-based systems to embrace renewable energy sources (RES) in a concerted effort to achieve necessary decarbonization. The consequent energy transition is accelerating the global adoption of electric vehicles (EVs) and micro-renewable resources, presenting challenges in adapting existing electrical infrastructures. For EV adoption to thrive, a crucial element is the availability and user-friendliness of charging points, necessitating a rapidly deployable charging infrastructure. Significantly, a substantial number of EVs are parked in shared spaces, such as condominiums and workplaces, lacking individual charging solutions despite a clear demand. The limited number of charging points in these environments stems from challenges in adapting shared parking electrical infrastructures to meet the required power capacity — a major hindrance to widespread EV adoption.

The recent introduction of bidirectional charging to the suite of options available results in a different way of thinking. Sharing power is now a possibility, meaning that it is necessary to explore the emerging decentralisation of the energy sector to mitigate capacity limitations either from the grid or from existing installations.

In summary, five levels of capacity limitation impede the broad adoption of individual EV charging systems: 1) Limited hosting capacity in distribution grids; 2) inadequately designed internal grid infrastructure in shared spaces for required EV charging capacity; 3) insufficient telecommunication infrastructure to support EV management systems; 4) a persistent shortage of skilled labour for deploying existing charging systems; 5) saturation of cloud infrastructure, necessitating efficient management through emerging edge computing capabilities.

1.1 Scope and Objectives

1.1.1 Scope

Task 1.6 (T1.6) centres around the comprehensive evaluation of technological challenges pertaining to Vehicle-to-Everything (V2X) charging systems. The primary scope of this task is to develop a V2X station that aligns with international standards, specifically IEC61851 and OCPP 1.6/2.0. This station is designed to enable V2X in shared parking spaces and support its mass deployment, providing a cost-effective, open solution for V2X charging in both mode 2 and mode 3 configurations. Additionally, the system is engineered to have the capability to interact with the Open V2X Management Platform (O-V2X-MP) (WP5). Various versions of the V2X station will be conceptualized and at least one will be implemented and deployed for real-world testing. Furthermore, T1.6 explores the requirements for a solution that accommodates integrating Photovoltaic (PV) systems and/or Energy Storage Systems (ESS).

1.1.2 Objectives

Development of Cost-Effective V2X Stations: Develop V2X stations that are not only cost-effective but also well-suited for shared parking spaces, addressing the needs of various Use Cases (UCs).

Mass Deployment in Mode 2 and Mode 3: Enable the mass deployment of V2X charging systems in both mode 2 and mode 3 configurations, ensuring accessibility and practicality.

Compliance with International Standards: Ensure that the developed V2X stations adhere to international standards, particularly IEC61851 and OCPP 1.6/2.0, for compatibility and interoperability.

Integration with O-V2X-MP (WP5): Establish the capability of the V2X station to seamlessly interact with the O-V2X-MP project in Work Package 5 (WP5) for comprehensive functionality.

Promotion of Electric Vehicle Adoption: Promote the adoption of electric vehicles by making V2X charging systems accessible, practical, and cost-effective for users.
Address Grid Connection Challenges: Address the challenges associated with grid connection in parking lots, particularly in cases where the limited number of EV chargers prevents EVs from connecting to the grid.
Reduction in Infrastructure Costs: Develop solutions that reduce infrastructure costs, encompassing both electric and communication infrastructure.

1.2 Relationship with other deliverables

- D1.7: Patent of V2X management station
- D2.1: Control strategies for V2X integration in houses (submitted) [1]
- D2.2: Control strategies for V2X integration in WP2 buildings (submitted) [2]
- D2.3: Optimal management of V2X in parking lots
- D2.4: Optimal management of EV fleets in companies
- D3.7: EV users' Needs and Concerns - Demonstrators' experience report
- D6.1: Implementation plan for the Azores demo (submitted) [3]
- D6.3: Implementation, operation and monitoring of the Azores demo
- D6.4: Evaluation and lessons learn of the Azores demo

2 Development

It is important to state once again that the focus of this task is the Hardware development of the equipment that will be installed in EDA facilities. The document is heavily focused on the physical equipment development and, at the time of writing this document, the control algorithms are being developed separately in Task 2.4 -EV Fleet Management in SMEs so they can be later integrated in the developed modular firmware structure.

2.1 Challenges, considerations and needs

In the development of the Demonstrator for installation in Azores, with a focus on the headquarters of Energia dos Açores (EDA), SEL encountered several challenges and considerations:

Diverse User Needs: EDA has a variety of users, including fleet vehicles, visitors, and administrators, each with unique charging requirements. This necessitates a flexible solution to accommodate different user needs.

Limited Available Power: In most utilization scenarios, the available power is not sufficient to charge multiple vehicles simultaneously. To address this limitation, it is necessary to have an installation-wide meter feeding data to a power balancing algorithm. Individual charging session power metrics are also supplied to the algorithm, allowing the system to leverage on its capabilities. This ensures that all of the cars charging at a given moment plus the power draw of the building or condominium don't exceed the installation maximum power limit.

Communications: Locally, the system needs to establish robust communication with internal meters within the modules and an overarching installation-wide meter, to ensure proper data collection. Simultaneously, it also needs to an external platform housing control algorithms from Task 2.4, enabling efficient remote control and optimization of the charging process. This dual communication capability makes the HUB an essential solution for managing electric vehicle charging, both at the local level and in coordination with external control systems that enable the possibility of performing grid services such as **wind-curtailment** and **frequency regulation**.

Modularity and Scalability: Not everyone owns a vehicle that needs to be charged, this means that we are still in an adoption phase and shared parking lots nowadays have a lower number of electric and plug-in vehicles parked when compared to internal combustion engine vehicles. That number is very likely to increase given the rising popularity and benefits associated with owning and using electric and plug-in vehicles it is important to prepare our solution to the future. To achieve this, a modular approach is the path to follow, allowing for easy integration or removal of users and charging equipments, as well as easy charging infrastructure expansion to cater to the needs of the ever-crescent user numbers.

Energy Literacy and EV Usage: Recognizing the lack of knowledge in energy literacy and electric vehicle usage, the project aims to provide a platform that simplifies the charging process and offers insights into the energy consumption and management of the charging infrastructure.

Cost-Effectiveness: Cost-effectiveness is a primary objective for the Demonstrator. Using off-the-shelf products and minimizing the usage of custom components helps keep the project within budget while ensuring compatibility and reliability.

Complexity of the installation: The equipment needs to be designed for easy installation in parking lots and condominiums, focusing on minimal weight, user-friendly connectors, and a cable-free module design to simplify the setup process and ensure broad adoption.

In summary, the development of the Demonstrator for EDA in Azores focuses on addressing the diverse needs of users, managing limited available power, ensuring modularity and expandability, proper communication with local devices as well as cloud servers, improving energy literacy, and maintaining cost-effectiveness. This approach aims to provide a flexible and affordable solution for electric vehicle charging in the context of the transition to electric vehicles.

2.2 Requirements

To address all the topics flagged in sub-chapter 2.1 a requirements table (Table 1) was put together.

Table 1 – Requirement outcomes from challenges, considerations and needs

Challenge / Consideration / Need	Requirement
Limited installation power	Power balancing algorithm
Communication with several metering equipments	Support for Modbus (RTU and/or TCP) communication
Cloud communication	Main control and processing equipment (gateway) needs to have mobile communication capabilities (SIM card support)
Communication and control of several different charging equipments	Support for OCPP communication
Scalability	Firmware and hardware developed to allow for easy integration of charging control equipment
Modularity	Scalable design architectures need modular approaches such as modules to control charging equipment and separated areas for installation and operation of the equipment
Ease of installation	Integrated in the design, areas for specific users (namely installers) as well as good documentation and a well-thought-out installation process
Low-cost	Limited custom components, leaning more onto "off-the-Shelf" to lower production and development costs
Energy literacy	Dedicated platform to engage with users
Grid-services	Integration of dedicated frequency monitoring equipment and leverage of the cloud communication capabilities to receive external signals to enable or disable those services
Diverse user needs	Merit-based algorithm that encompasses different users and slots them in different charging priority categories

2.3 Concept evolution

Once all the requirements were defined, the process of devising the demonstrator's construction was started. The initial ideas and concepts began to take shape, and to facilitate this creative process, an online diagramming tool, Miro[2], was employed. These digital tools provided an interactive platform for brainstorming and visualizing the evolving ideas, allowing for continuous refinement and improvement of the demonstrator's design. This collaborative approach, facilitated by digital diagramming, enabled the team to translate their initial thoughts into a more refined and well-structured plan for the demonstrator (Figure 2-A).

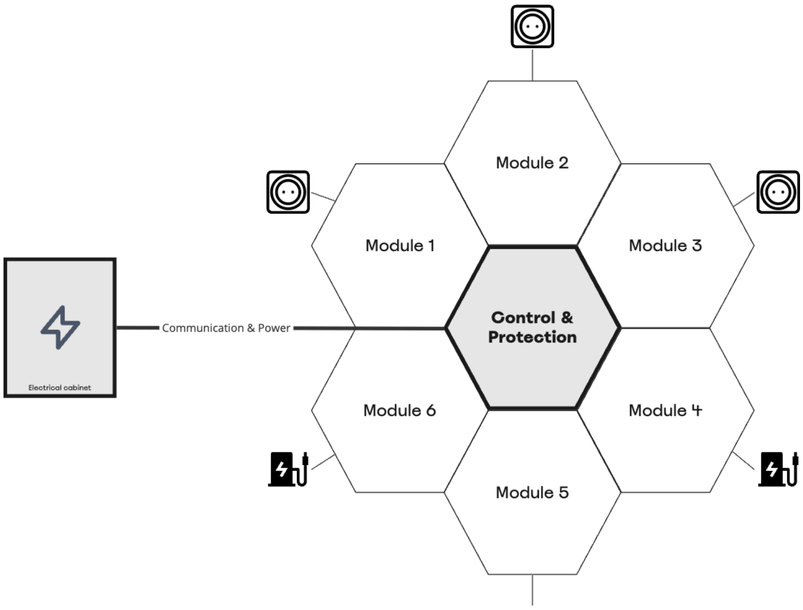

Figure 2-A – Initial concept "The Flower"

With this first schematization of the demonstrator, some specifications were defined right away:

- Focus on **modularity** means that each module that controls the power supply of the charging equipment, should be able to be connected without the need to use any tools or the need to mess with any wiring.
- **Agnosticism** is the key, since the market is already filled with multiple suppliers of charging equipment for electric vehicles, by directly controlling the power supply to sockets and leverage on the large number of AC charging points that support communication via OCPP, a significant portion of the charging equipment market is already viable to work with this solution.
- Data collection of important metrics (voltage, current, frequency…) to supply needed data for a **power balancing algorithm** that ensures a time-based distribution of power to each vehicle connected. This algorithm will be developed in T2.4.
- Electrical installations in parking lots depend on several factors such as wire gauge, age of installation and presence/absence of electrical protections. In case of being a parking lot of a condominium, electrical equipment that needs a lot of power to work (elevators, smoke extractors and water pumps are some examples) will affect how much available power is still

[2] https://miro.com/

left to charge electric vehicles. Bearing this in mind, total building/installation power consumptions needs to be measured and data fed directly (via Modbus RTU/TCP) to the HUB, again allowing for a **dynamic** power balancing algorithm to manage all the charging sessions.

- **Simplicity:** Simple to install, simple to assemble, meaning that is also simple disassemble, simple to use and simple to modify.
- **Competitively priced** since the major factor for mass adoption is cost. Dedicated electric vehicle chargers, accessories and even the electric installations are costly, positioning them in a limited scope of potential customers.

After the initial bloom of ideas, it was necessary to ensure if it is possible to build a device capable of complying with all the needs. The initial concept had some problems since it is focused on being a fully modular approach. To achieve such a product, several enclosures are needed that meet IP and IK needs, a way to connect those enclosures or modules together also raises some issues, namely finding cheap and simple to use plugs that are also water and dust resistant while being rated to support up to 32 A of current flowing through them. A shift in the focus was needed so we leaned more onto on simplicity and cost. The thinking here is that if all of the components are surrounded by a single enclosure that meets IP and IK needs, the internals then don't need to be subjected to tests to evaluate if they comply with these standards. The whole product is tested as a single unit, allowing us to use more readily available and less costly components inside the enclosure. It was now obvious that the device needed to fit inside a "off-the-shelf" electrical cabinet, with enough size for the components to be efficiently packaged, thus being as small and lightweight as possible.

After looking at some electrical cabinets and insulated electrical boxes, the challenge was to list and visualize components and parts that can be assembled in the best way possible to allow for easy operability, usage, and maintenance. If all these criteria are met, we have a product that is good to work on and to work with.

The results of this effort to satisfy every need are a custom metal plate modified to accommodate everything separately, while hiding cables and connections in an organised manner for user safety. Several dedicated areas were created to limit access to different types of users. There are areas specific to knowledgeable technicians with skills in communications and electricity, where they can perform some troubleshooting or repairs if needed. There is also dedicated areas for installers, with well laid-out and easy to use components for a hassle-free installation (power to the device, power to the charging points, communication with charging points, mobile communication antennas…) and finally an area to the E.V. owner / user, where it is possible to install a module without the need of messing around with cables or complicated procedures. This structure also doubles as a safety measure, avoiding unnecessary exposure of less-qualified users to complicated components and procedures.

In the next page it is possible to see a detailed description of each component and dedicated area with a visual representation of the next concept that was developed (Figure 2-B and Figure 2-C).

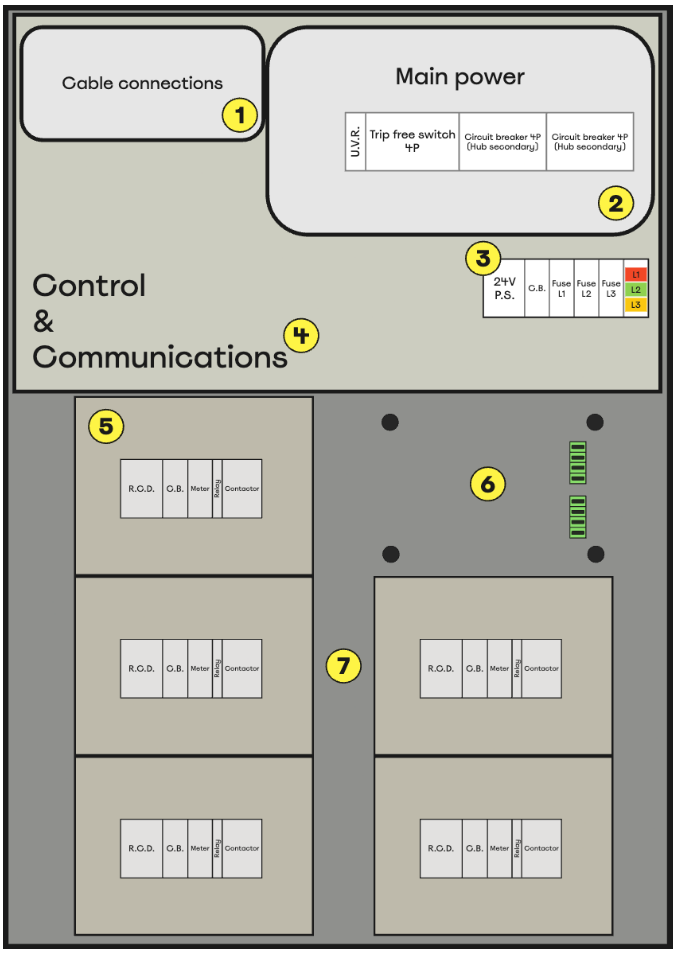

Figure 2-B – New concept “Six-pack”

1- **Cable connections:**
Cover that hides and protects the push-in connectors for power distribution to the different chargers/sockets that will charge the different EV’s. Behind these connectors a network switch will also allow to establish communications with OCPP compliant chargers.

2- **Main power connections:**
This cover protects the wiring that supplies all power to the equipment, along with the devices that supply power to secondary Hubs.

3- **Control & Connections power supply and phase status indicators:**
A 24V power supply and a circuit breaker for over current protection is necessary for the selected control equipment. LED phase indicators along with fuses to protect them are also installed in this area.

4- **Control & Communications main cover:**
This is one of the main covers that isolates the control equipment and wiring from the user. Behind this cover we encounter the main control equipment, a fan-less Linux-based computer, along with the busbar for power distribution, ground cable connectors, and dedicated communication and control cable connectors.

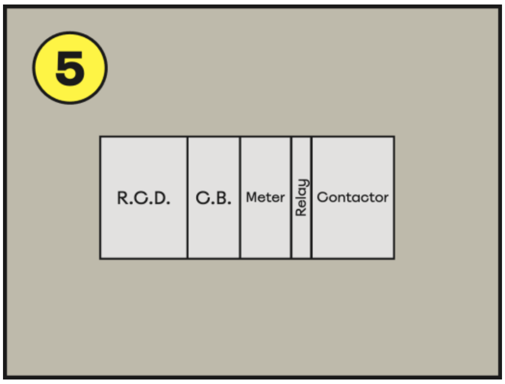

Figure 2-C – Module in detail

5- **Module:**
Each module is the piece responsible for collecting essential data and protect the user and the charging equipment, it is composed by several electrical equipment’s and will have two versions, depending on the maximum output current:

- A 16A version that targets domestic sockets and lower powered charging points.
- 32A version pointed at most of the single phase 7,4 kW chargers that exist in the market.

Both versions have the same hardware topology, starting from left to right, R.C.D. (Residual Current Device), C.B. (Circuit Breaker), single phase meter with Modbus RTU communication, interface relay to control the Contactor which in turn starts or stops the charging session.

6- Module landing zone
To be able to fit the module in position, 4 holes are in each landing zone, along with the plugs to establish communication and supply power to the module. The 4 holes will allow the studs (snap-fits) to be fed through the holes, fixing the module in place, discarding the need of additional supports and cables.

7- Main structural plate
To fit the whole assembly in place a custom designed metal backplate ensures structural rigidity, cable-management passages for internal cabling, holes for assembly, module fixation, connectors and components displacement.

2.4 Control & communications

As a major part of the development of this solution, controlling the several devices and being able to communicate not only with the connected devices but also with cloud servers and remote databases is fundamental. To help understand the backbone of both, two diagrams were conceived (Figure 2-D and Figure 2-E). Please refer to the inscription below that associates the numbers in the diagrams to the component represented:

1. Cloud platform / server
2. LTE antenna
3. Gateway
4. Installation-wide meter
5. Module
6. Schucko socket /plug
7. Dedicated E.V. charger

Note that different types of connection line also play a role when interpreting the diagrams:
- Continuous lines: show important connections between components.
- Dotted lines: represent wireless connections.
- Interrupted lines: demonstrate connections that are less relevant for the context of the diagram.

It is very important to read the connection type key below each diagram.

2.4.1 Control

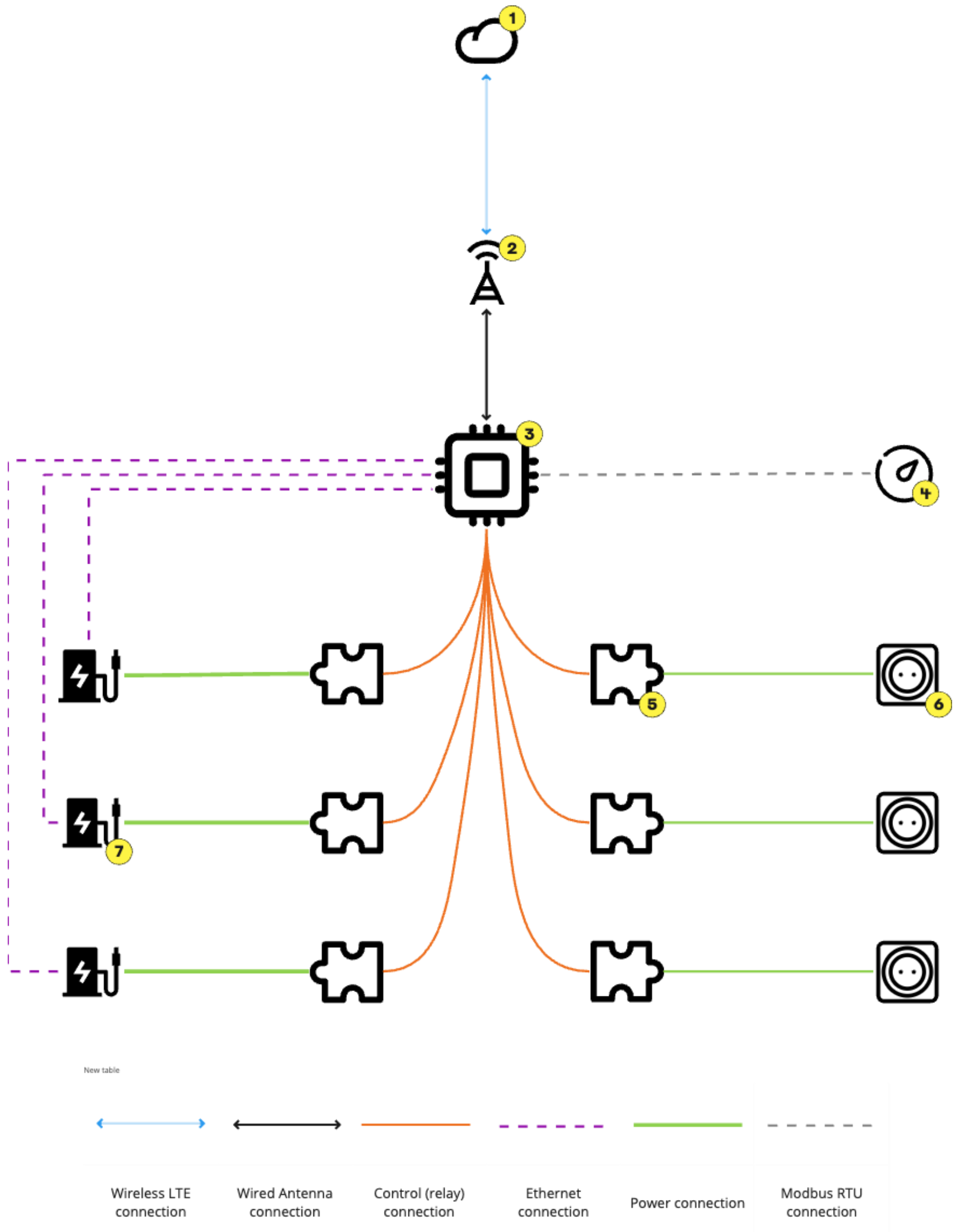

Figure 2-D – Control diagram

This diagram represents how it is possible to control the flow of power to each charger (6)/socket (7). At the same time, OCPP-compliant chargers (7) connect to the gateway (3) to allow for a finer adjustment of output/input current if it is inside the allowed values.

The flow of power from the module (5) to the charger (7) or socket (6) can be interrupted by opening or closing the relay in the module (5), this in turn controls the contactor (also installed in the module). The contactor has the necessary specification to support the currents that flow through the component.

The gateway (3) manages each charging session based on the installation power draw, measured by the installation meter (4) and based on the algorithms that are in the cloud server (1), by establishing mobile communications through an LTE antenna (2), avoiding connections to local networks.

2.4.2 Communication

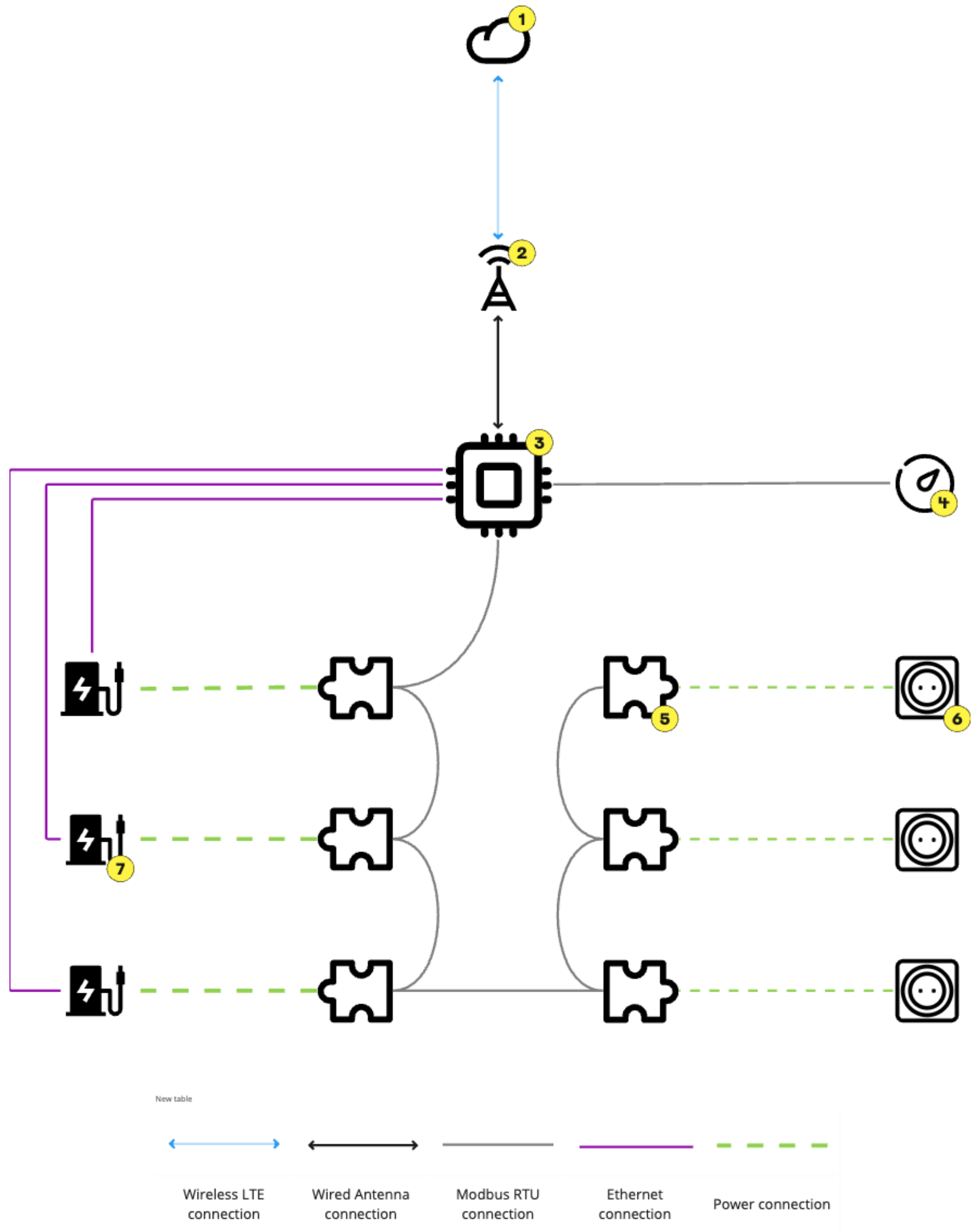

Figure 2-E – Communication diagram

Starting from the top, it is possible to visualize that the cloud server (1) can communicate with the gateway (3) through mobile network, possible using the LTE antenna (2) in the device.
Locally, the gateway (3) collects energy metrics such as voltage (V), current (A) and frequency from meters located in each module (5) and an installation-wide meter (4) to supply data to the control algorithm that will decide how much power is available to charge all connected vehicles, while monitoring the actual power draw and energy consumption of each session. These meters are all connected using RS-485 following the wiring scheme represented above.
There are also certain E.V. charging equipments (7) that allow for OCPP communication, these can be controlled individually. Controlling the chargers (7) directly increases the load balancing resolution, extracting the maximum from the available power in that moment, while charging equipments that don't support this, and regular sockets (6) are controlled normally (on/off).

2.5 Development takeaways

These concepts clearly show, especially from the last one, the focus on using "off-the-shelf" products is evident, this allows for a quick prototype to be developed while retaining all the functionality while maintaining the cost down. Most equipment used fit in the DIN form factor, allowing for quick replacement if they ever have a problem or if there are more suitable options available in the market.

To accommodate everything some customized parts still needed to be thought out since our modular approach doesn't fit well with the intended use of most electrical cabinets found in the market.

Defining from an early stage the main focuses of the development portion of the project kept the team focused on what is important, developing a simple and easy to use solution that meets all the defined criteria.

The "brain" of this whole product is the gateway, a powerful Linux-based computer that possesses all the features needed to allow this whole system to work properly. This device combines a powerful CPU with several expansions such as a mobile communications card and several DI/DO's to, in our specific case, supply or interrupt the power to the charging points. Goes to show how much devices such as this help when pursuing new ideas and concepts.

The complete system still has some focus points that need to be carefully investigated. These points raise additional challenges in the assembly stage of the actual device:

- Tolerances and actual dimensions of the main structural plate.
- Fixation system for the modules
- Plugs to be used in both the module and the main plate, these need to be rated to at least 32A.
- Wire routing for the whole solution, taking in consideration separating as much as possible communications from power cables.
- Control and Communications cover needs to have appropriately sized cut-outs for easy access to several equipments as well as screw holes for easy assembly/disassembly.
- Network switch needs to be supplied with 12V, since our power supply works with 24V a different way to power the device needs to be implemented, can be as simple as using the transformer included in the box.
- Decide on fasteners and screws, some are more appropriate than others for the intended use.

3 The solution

3.1 Main cabinet (HUB)

The implemented solution is a low-voltage electrical panel that allows for intelligent distribution of energy for charging 6 electric vehicles in the same parking facility. To expand the system, new HUBs should be added to the same electrical installation. The HUB provides the necessary protection to power other Secondary HUBs and thus facilitates installation. The HUB is compatible with both Wall Box and socket-type charging points.

The HUB Master (HM) is the version that should be initially installed in a condominium parking facility. This device runs a load balancing algorithm, managing the available power at each moment, and distributing it among all active charging stations. In doing so, it optimizes the use of available power for charging electric vehicles in the facility.
The Hub Master (HM) also has equipped a high accuracy frequency meter, enabling the capacity to perform grid services such as frequency regulation, either through just stopping or limiting vehicle charging or by leveraging the bidirectional charging capabilities of the installed charger (Wallbox Quasar).

The HUB Secondary (HS) is the version of the HUB to be installed in a location where the system is already in place (Figure 3-A). This version of the HUB allows for adding 6 new charging points connected to the system and provides for general floor disconnection when necessary.

Figure 3-A – The HUB

3.2 Modules

At the core of the HUB's design lies a fundamental component: the integrated module. This module serves as the central building block, encompassing the critical functionalities of metering, control, and protection for the charging point / charging socket. It forms the backbone of the HUB's modularity, offering adaptability and configurability to meet diverse user requirements (Figure 3-B).

Each integrated module seamlessly combines the roles of metering, control, and protection. This integrated approach simplifies the hardware configuration while retaining all essential functionalities. These modules can be easily inserted or removed from the system, granting users a high degree of customization and scalability.

The integrated module design ensures users can customize their charging infrastructure by selecting the integrated module that aligns with their specific needs. This modularity facilitates tailored solutions for diverse charging environments. Additionally, the HUB's scalability allows for the addition of more integrated modules in the future, accommodating evolving conditions and additional users.

Figure 3-B – The Module

3.3 Testing & Certification

Part of the process for developing and building a solution that meets the requirements stated in sub-chapter 2.3 is to ensure proper testing and validation.

CE Testing

So, starting off with CE testing, or Conformité Européene testing, is a process aimed at ensuring that products comply with European Union (EU) safety, health, and environmental protection requirements. In a nutshell, CE testing involves assessing and verifying that a product meets the relevant EU directives and standards. The process typically includes thorough testing, documentation review, and, in some cases, third-party involvement. Once a product successfully passes CE testing, it is eligible to bear the CE marking, indicating its conformity with EU regulations and enabling its free movement within the European Economic Area (EEA). The CE marking signifies that the product is in compliance with essential requirements, contributing to consumer safety and facilitating trade across EU member states. In our specific case, the products were submitted to testing specific for "Electric and electronic engineering" [4 to 8].

IP and IK testing

IK testing, also known as Impact Protection testing, assesses the resistance of an electrical enclosure or mechanical casing to impact from external mechanical forces. The testing involves striking the enclosure with a defined amount of energy at a specified impact level, and the enclosure's ability to withstand the impact is rated on an IK scale. The IK rating, ranging from IK00 (no protection) to IK10 (high protection), provides information about the enclosure's durability and its ability to protect internal components.

IP testing, or Ingress Protection testing, evaluates the degree of protection provided by an electrical enclosure against the intrusion of solid objects and liquids. The IP rating consists of two digits: the first indicates protection against solids, and the second against liquids. For example, an IP65-rated enclosure offers a high level of protection against dust (6) and is protected against low-pressure water jets (5). IP testing ensures that the enclosure meets specific environmental protection standards, helping users understand the extent to which it safeguards against foreign objects and moisture.

It is also foreseen the submission of a patent for the V2X management station (D1.7). Currently the product's patent is pending meaning that a provisional patent has been submitted. A provisional patent, in a nutshell, is a simplified and expedited way for inventors to establish an early filing date for their invention with a patent office. It provides a placeholder for up to 12 months, allowing the inventor to use the term "patent pending" and explore the market potential of their invention. Unlike a regular patent application, a provisional patent requires fewer formalities and details. It serves as a cost-effective option for securing a priority date while the inventor further develops and refines their invention. However, a provisional patent does not grant patent rights on its own; within the 12-month period, the inventor must file a regular patent application to maintain protection.

The result of this testing and certification process is resumed below:

- CE testing for electric and electronic engineering: Passed
- IP rating: 55
- IK rating: 10
- Provisional Patent: 118600 "Charging system for electric vehicles"

More safety specifications can be found in the Appendix.

3.4 Installation

Since the whole product also must attend to several installation needs, namely ease of installation, the whole installation process and eligible conditions were thoroughly thought out.
A dedicated document just for the installation was already issued, this chapter only focuses on the key areas regarding this topic.

3.4.1 Equipment dimensions and mounting

The designated place to mount the HUB should comply with some requirements [9] some of which are listed below:

- **Protected from the elements** (preferably indoor or shielded with a dedicated structure);
- At least **50 cm of clearance above** the Demonstrator.
- Due to the weight of the equipment and mounting characteristics, **a solidly built wall to mount the Station is needed** (wood or sheet metal walls are not eligible);
- The mounting location should be **clear of any obstacles**.
- Avoid cars/equipment maneuvering zones.
- Avoid nearby water sources;
- Ideally the equipment should be **installed in the same floor level** as the parking spaces.
- Avoid dirty/dusty places;
- The mounting location should be **leveled**.
- No objects (wiring, tubing ...) are allowed to pass between the equipment and the wall.

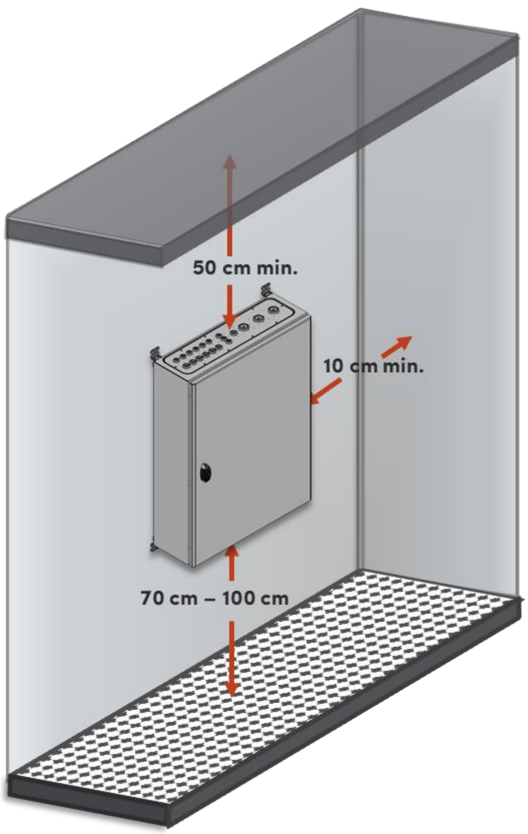

Figure 3-C - Surrounding clearance

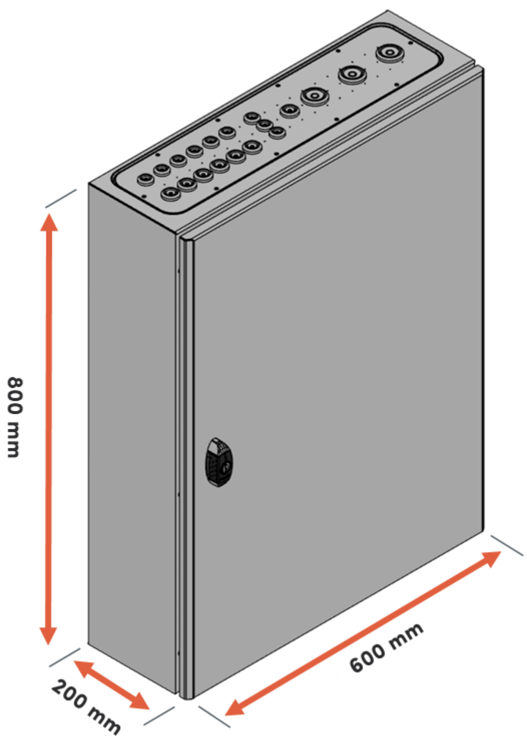

Figure 3-D - Equipment dimensions

3.4.2 HUB power supply

The estimated maximum distance between the Demonstrator and the source of its power is around 50 meters, meaning that the main power source can be located anywhere inside the yellow area (Figure 3-E).

In some cases, due to constraints specific to the installation location, these 50 meters can increase to 75 or even 100 meters if the wire gauge is adapted accordingly [10]. The maximum wire gauge supported by the HUB (for main power supply) is 20 mm^2.

The origin of the power supply needs to have as much power available as possible, as well as space to install additional equipment:

- Residual Current device
- Circuit Breaker
- Ground terminals
- Three-phase meter

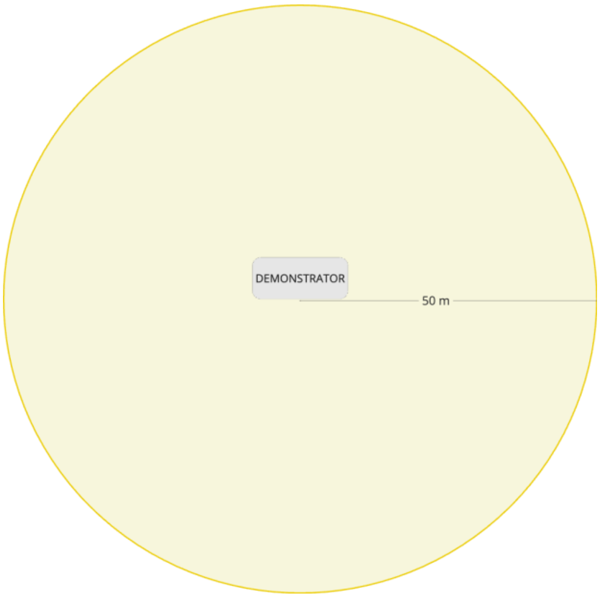

Figure 3-E – Power supply eligible area

These components grant proper protection to the HUB, and supply data regarding the whole installation, though the three-phase meter. Ideally this meter should be indirect to ease the installation process.
In scenarios where installation of these components inside the already existing switchboard isn't possible due to free space constraints, a separate board with all the components can also be installed externally.

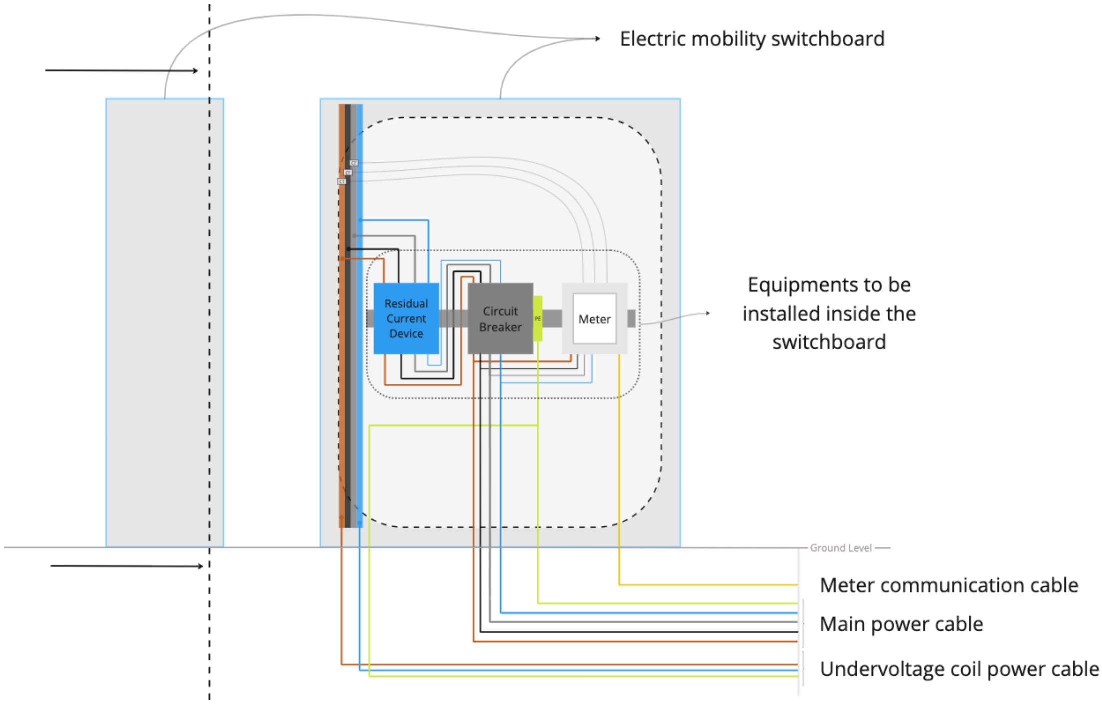

Figure 3-F – Necessary installation for power supply

The main power supply once connected should look like the figure below (Figure 3-G). It is worth pointing out that all the connections are done from above, assuming that most of these devices will be installed in underground parking spaces, facilitating the wiring process of the HUB in those scenarios and avoid tangled cables. When installing this device in open spaces, cables need to be routed around the device and properly protected from elements. A solid wall (brick, concreate) is also mandatory for proper HUB mounting, due to the weight (35 kg) of the equipment.

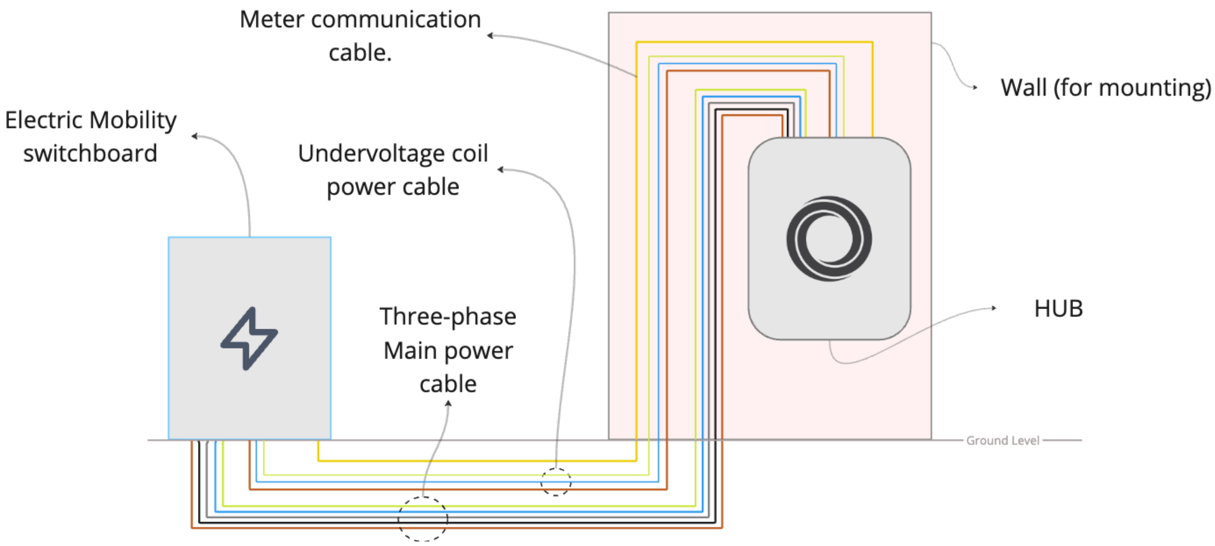

Figure 3-G – Main power supply diagram

3.4.3 Charging points power supply

The position of the HUB needs to be inside the green area around the parking spots (Figure 3-H). This 30-meter limitation is in place because it was considered 6 mm^2 wire gauge for the connections, it can be more than 30 meters if the wire gauge is increased accordingly [10]. The maximum wire gauge supported to supply the power to the charging points is 10 mm^2.

Figure 3-H – Charging points power supply eligible area

All the parking spots can operate up to a maximum power of 7,4 kW.

Depending on the type of charger and power rating different charging plugs/ports are used:

- V2X: CHAdeMo.
- AC: Mennekes Type 2.
- AC (domestic, 16A): Schucko female Plug.
- AC (domestic, 32A): CEE female Plug.

To establish communications with OCPP-compliant charging points (V2X and standard EV charging points) an additional CAT-6 cable (Ethernet) is routed to the charging point and the connected to the switch inside the HUB.

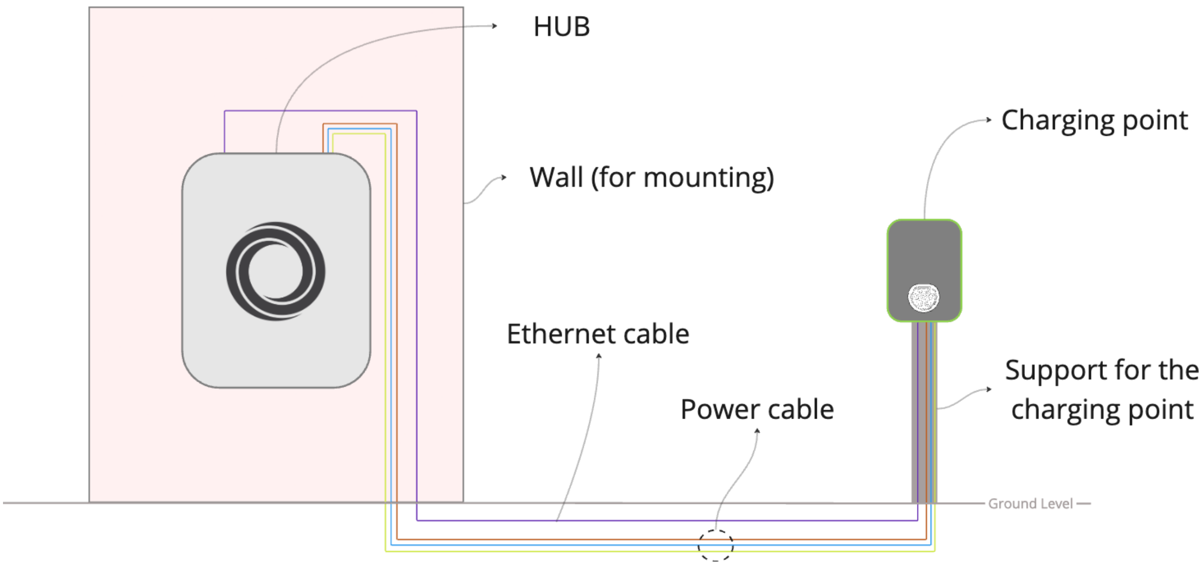

Figure 3-I – AC charging point wiring scheme

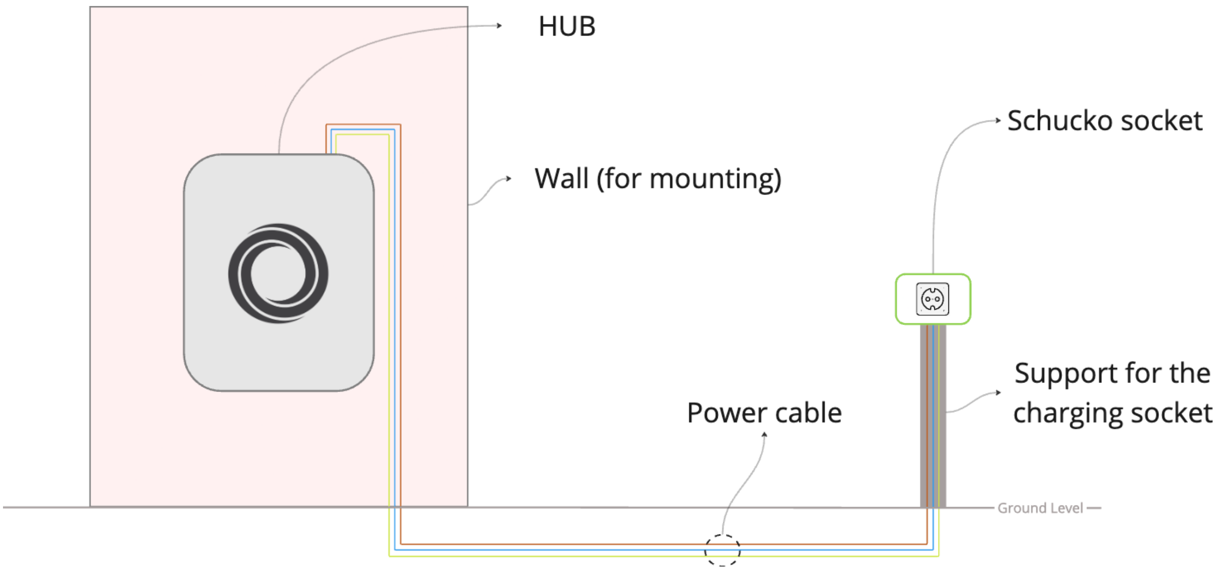

Figure 3-J – Schucko plug wiring scheme

The examples above (Figure 3-I and Figure 3-J) represent a topology where the cable passes through an underground path. It is important to mention that is just one of many ways to route power and communications cables, the important takeaway here is to grant proper protection to each cable and separate power cables from communication cables.

3.4.4 Communications

Regarding communication, some verifications need to be executed to ensure proper working of the HUB (Figure 3-K).

Network coverage:

- The device communicates with the cloud through a LTE network, so it is necessary to ensure good coverage at the desired installation location.

Charging points communications:

- Using one ethernet cable for each charging point through wired communications uses the OCPP protocol to send commands and receive data.

Equipment's devices communications:

- All the internal communications between devices needed for the correct operation of the Demonstrator use the Modbus protocol.

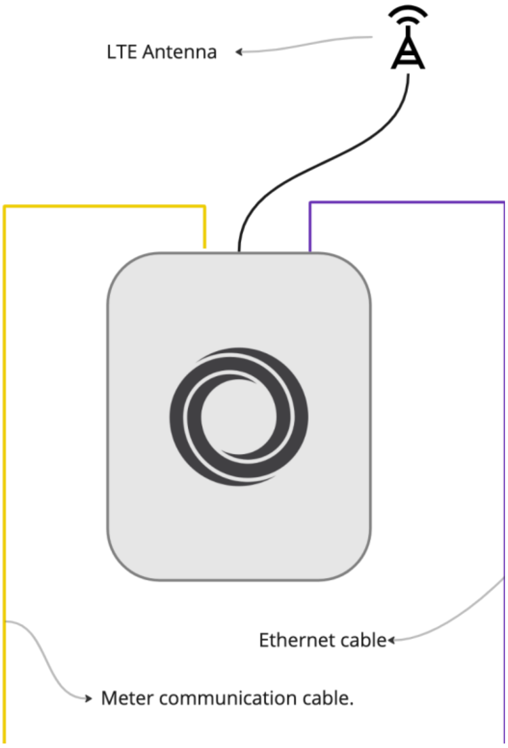

Figure 3-K – General communications topology

4 Conclusions

4.1 Summary

In the pursuit of developing an efficient and user-friendly electric vehicle (EV) charging infrastructure, the project has successfully navigated the complexities of design and prototyping. The emphasis on utilizing "off-the-shelf" products has proven instrumental in achieving a swift prototype development while maintaining crucial functionality and cost-effectiveness. The modular approach, although requiring some customized components, aligns with the project's goals.

Throughout the development process, the team has remained focused on simplicity and ease of use, ensuring that the solution meets defined criteria for wide-scale adoption in parking lots and condominiums. The integration of a powerful gateway, as the central component highlights the forward-thinking approach to incorporating advanced technology to drive the system.

As the project advanced, key challenges in the assembly stage have been identified, ranging from fine-tuning tolerances and dimensions to addressing specific requirements for plugs, wire routing, cover designs, and power supply considerations. These challenges underscore the commitment to refining and optimizing the system.

The prototype is now fully assembled and electrically tested. And the platform for the control algorithms and grid services to work is being tested so it can be implemented in our solution.

In conclusion, the project has laid a strong foundation to produce an accessible and efficient EV charging solution. The collaboration between "off-the-shelf" components and customized elements showcases a thoughtful balance between innovation and practicality. The result is an elegant and simple solution that will now be integrated with the control algorithms resultant from Task 2.4, so it can be ready to be installed at EDA in the 24^{th} month of the EV4EU project.

4.2 Next deliverables

The most important future deliverables that are related with Task 1.6 are the following:

- D1.7: Patent of V2X management station – due on month 21 of the project
- D2.4: Optimal management of EV fleets in companies – due on month 22 of the project

5 References

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APPENDIX A: Equipment datasheet

SMART EV CHARGING STATION

Electrical switchboard for smart charging of Electric Vehicles

Main specifications

Product Name	HUB
Cable communication types	Ethernet RS485
Wireless communication types	4G LTE / 3G / 2G Wi-Fi 2.4Ghz
Communication Protocols	OCPP 1.6 OCPP 2.0 ModBus RTU Modbus TCP

Electrical specifications

[Un] Rated voltage	230 V ~ 50 Hz 400 V ~ 50 Hz
[Ue] Rated operational voltage	415 V ~ 50 Hz
[Uimp] Rated impulse withstand voltage	4 kV
[In] Rated current	63 A
Breaking capacity	6 kA
Rated nominal outgoing power – Module Plug 16A	3.7 kW, 16 A, 230 V~ 50 Hz
Rated nominal outgoing power – Module AC Charger 32A	7.4 kW, 32 A, 230 V~ 50 Hz
[Fn] Rated frequency	50 Hz

Environment specifications

Mounting location	Indoor
Earthing system	TT or TNS
Pollution degree	2
Ambient air temperature for operation	-5….40 ˚C
Ambient air temperature for storage	-20…60 ˚C
Humidity conditions	0…95 %
Operating altitude	≤ 2000 m

Enclosure specifications

Mounting support supplied	4 Wall mounting supports
Mounting type	Wall mounting
Number of charging points	6
IP Degree of protection	IP55
IK degree of protection	IK10
Mandatory upstream protections	CB with Icc 6kA + RCD 300mA Type AC
Protection against electric shock	Class 1
Design type	Enclosed assembly
Accessibility for operation	Front
Cable entries	Top
Dimensions (Height x Width x Depth)	800 x 600 x 200 mm
Weight	35 Kg
Colour	RAL7035

Conformity

Standards	IEC 61439-1 | IEC 61439-3
Product certifications	CE
EU RoHS Directive	Compliant

ANNEX

SEL protype testing installation

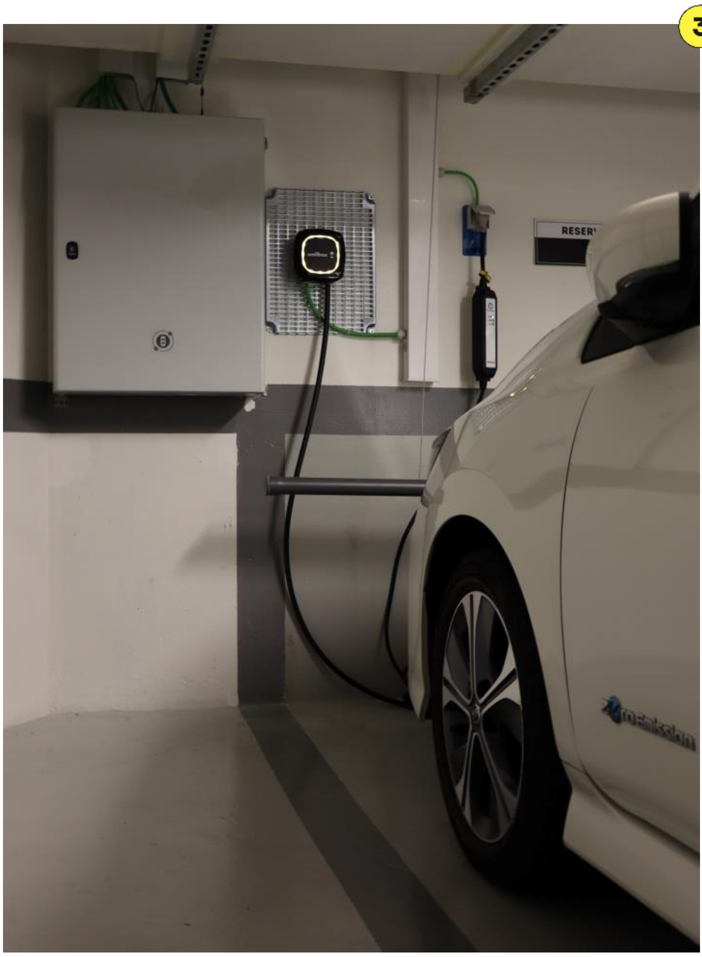
Below it is possible to find some images of the test installation done in SEL's parking lot.

1 → Main cabinet (HUB) and charging points
2 → Wallbox Quasar (V2X) and Copper SB
3 → Nissan Leaf connected to Wallbox Pulsar
4 → Mercedes E300de plugged to Schucko socket

1

2

3



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