





Deliverable administrative information

| Deliverable number | D1.4 | |
|---------------------|---|--|
| Deliverable title | Multi-actor Smart Charging & V2X System Architecture | |
| Dissemination level | Public Public | |
| Version number | Final 1.0 | |
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SCALE introduction

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed.

The project will test and validate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Greater Munich Area (GER), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders. SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

SCALE's consortium comprises 29 cutting-edge European e-mobility actors covering the entire smart charging and V2X value chain (equipment and charging manufacturers, flexibility service providers, research and knowledge partners, public authorities, consumer associations, etc.).

List of abbreviations and acronyms

| Acronym | Meaning | |
|-------------|--|--|
| AC | Alternating Current | |
| ACD | Automated Connection Device | |
| ВРТ | Bidirectional Power Transfer | |
| ccs | Combined Charging System | |
| СРО | Charge Point Operator | |
| CSMS | Charging Station Management System | |
| DC | Direct Current | |
| DSO | Distribution Grid Operator | |
| EAN code | European Article Numbering – Unique identification number for grid connections | |
| EM | Energy Manager, 'outside' of EMS | |
| EMS | Energy Management System | |
| EMSP (eMSP) | E-Mobility Service Provider /e-Mobility Service Provider | |
| EN | European Norm (European Standard) | |



| EV | Electric Vehicle | | |
|---------|---|--|--|
| EVSE | Electric Vehicle Supply Equipment | | |
| GUI | Graphical User Interface | | |
| HEMS | Home Enegy Management System, specific EMS for at home. | | |
| IEC | International Electrotechnical Commission | | |
| ISO | International Organisation for Standardization | | |
| OEM | Vehicle Original Equipment Manufacturer | | |
| ОСРІ | Open Charge Point Interface protocol | | |
| ОСРР | Open Charge Point Protocol | | |
| OpenADR | Open Automated Demand Response protocol | | |
| OSCP | Open Smart Charge Protocol | | |
| РКІ | Public Key Infrastructure | | |
| SCALE | Smart Charging Alignment for Europe | | |
| SCSP | Smart Charging Service Provider | | |
| SoC | State-of-Charge | | |
| CSO | Charging Station Operator – alternative name for CPO | | |
| TDP | Trusted Data Platform | | |
| ToU | Time-of-Use | | |
| TSO | Transmission System Operator | | |
| V1G | (Unidirectional) smart charging | | |
| V2B | Vehicle-2-Building | | |
| V2G | Vehicle-to-Grid | | |
| V2H | Vehicle-to-Home | | |
| V2X | Vehicle-to-Anything | | |
| VDP | Validation Data Provider | | |



Report executive summary

1.1 Key words

Electric vehicles, smart charging, bidirectional charging, V2X, ISO 15118, OCPP, OCPI, OpenADR, interoperability, congestion management, behind-the-meter, before-the-meter, balancing responsible, system balancing.

1.2 Summary

This document defines the general outcomes of a system architecture for smart and bidirectional charging. In order to ensure both widespread adoption of electric vehicles and a stable energy system, smart charging strategies and use cases are needed that provide both prospective profit and systemic benefits. The system architecture should enable the provision of use cases that are not only socially acceptable and provide a clear benefit, but can also be used with the lowest possible barriers. Architecture principles are created to provide the general rules and guidelines for how the system architecture is created. The following principles focus on what the system architecture should enable. These principles are user involvement, open and fair market, protection of the electricity system, interoperability and data integrity. In addition, the principles concerning how the system architecture should work are: Scalability & Extensibility, Universality & Flexibility, and Comprehensiveness & Consistency.

The rise of electric vehicles is bringing the electricity and mobility sectors closer together. As the number of electric vehicles increases, the demand for capacity on the local distribution network of the DSO continues

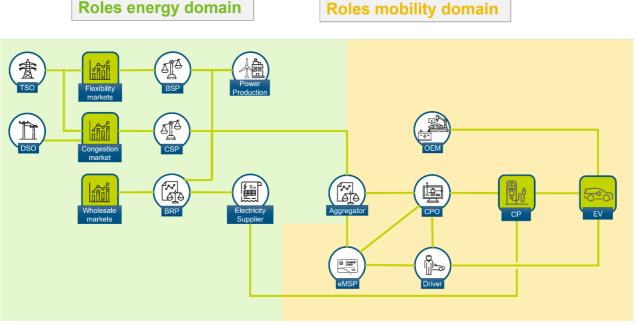


Figure 0.1 System architecture (Market Roles)

to rise. As a result, the power quality and reliability of the existing network is declining. Although electric vehicles cause some of the problems, the use of smart charging can reduce the impact and help prevent problems. With smart charging, electric vehicles can adjust their charging behaviour, for example by reducing their charge rate at certain times of the day. V2X charging offers an additional option by allowing electric vehicles to not only consume but also supply electricity. The intelligent charging services that



electric vehicles can provide are based on four optimisation clusters: local optimisation, congestion management, portfolio management and balancing services. The congestion management and balancing services optimisation clusters focus on solving problems in the electricity grid. Congestion management is about preventing the grid from becoming overloaded. Balancing services is about frequency regulation and keeping supply and demand on the grid in balance.

In order to enable the application of smart charging services in the current electricity system, the current market roles in the sectors have been examined. The defined market roles are derived from the stakeholders identified in "Deliverable 1.2. Stakeholder Analysis Report". Figure 0.1 shows the market roles from the two domains and their administrative links. The figure shows that the aggregator plays a central role between the two domains. The aggregator takes over the smart charging services and thus fulfils the role of the smart charging service provider in the electric vehicle domain. Smart charging is thus decoupled from the charging point operator. This is because the role of the aggregator is already defined in Directive 2019/944 on common rules for the internal electricity market. The aggregator thus bridges the gap between the regulated electricity sector and the open e-mobility market.

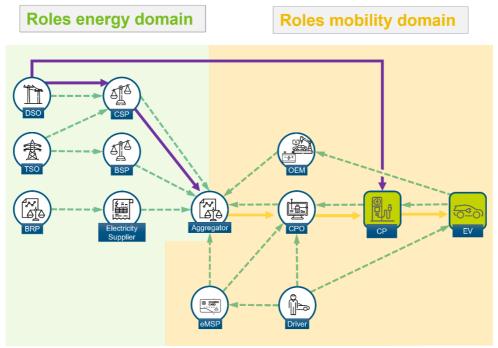


Figure 0.2 Control topology

To enable smart charging services, it is essential that data is available and can be exchanged effectively between different roles. A control topology provides insight into how data circulates between different roles in the market, and it also reveals the current protocols and standards used for data exchange. Figure 0.2 shows the control topology, again highlighting the central role of the aggregator. This aggregator acts as a node between the electricity sector and the electric mobility sector. Figure 0.2 shows the data flow needed between the different roles in the market to enable smart charging.

Within the e-mobility sector, data may be routed by different parties. Placing the responsibility for smart charging on the aggregator simplifies the data flow. The control topology shows not only a control signal for smart charging, but also a signal coming from the DSO. This DSO signal acts as an absolute control signal to prevent overloading the grid as a last resort in extreme cases and has two possible routes: directly to the charging station or via the different market roles. Both signals have advantages and disadvantages, which are discussed in Chapter 5.



As a logical consequence, the market roles responsible for transmitting control signals to the charging stations must meet certain quality standards. In addition, it is essential that all charging stations are suitable for smart charging, similar to the situation in the UK (1).

Based on the control topology, the available protocols for the displayed data streams can be considered. Standard protocols are essential to enable seamless data exchange and to realize the full potential of smart charging services. Currently, there is no standard data protocol that facilitates data exchange with the aggregator. The OpenADR and OCPI protocols have the potential to fill this gap, and in some cases are already being used for this purpose. However, these protocols are not yet widely used. Beyond communication with the aggregator, there is a considerable amount of European standardisation in the mobility domain in terms of data protocols. However, the ability to exchange data between the charging station and the electric vehicle battery is lacking, which hampers the adoption of V2X. The ISO15118-20 protocol offers a solution, but adoption is still low and will take several more years.

It is concluded that, in addition to the lack of protocols, there is no European legal framework for smart charging and DSOs. While TSOs, BRPs, BSPs and energy suppliers have a legal basis to promote smart charging for the benefit of the grid, this is lacking for DSOs. This results in separate additional legislation in individual Member States to fill this gap, which is not desirable for the promotion of smart charging at European level.

Recommendations

Based on the above findings, the following recommendations can be made to stimulate the uptake of smart charging. Firstly, it is important to promote a standard protocol to the aggregator, with a single standard applied across different Member States. In addition, given the slow uptake of ISO15118, alternative data streams for obtaining battery data should be explored. This is not intended to be an alternative protocol to ISO15118, but rather an interim solution that could include proprietary OEM protocols in conjunction with legislation regarding their reliability. Since this is an interim solution, effort should be put into promoting ISO15118 since this is an open standard and therefore preferred.

A second recommendation is to create a legal basis for DSOs to incentivise EVs to steer in favour of the grid in terms of capacity demand. This could be achieved by adapting the legal framework to introduce a non-firm connection and transport contract by DSOs. Under such a contract, it should be economically attractive to use available capacity. In a non-firm variant of the current agreement, the connected party pays for the bandwidth of the capacity used on the electricity system, which can be significantly cheaper compared to a firm connection and transport agreement. The details of such an agreement may vary from Member State to Member State and from DSO to DSO, but the key is to create a legal basis to enable such non-firm agreements. Section 6.4 gives more insight into the creation of a legal framework.

Finally, it can be concluded from the system architecture that data exchange currently has a good basis, but there is still a lack of standardisation in the data exchange between the aggregator and the availability of battery data for V2X. In addition, it was found that there is no legal basis for DSOs to control power capacity.



Purpose of the deliverable

1.3 Attainment of the objectives and explanation of deviations

The objectives related to this deliverable have been achieved in full and as scheduled

1.4 Intended audience

| Role | Who | |
|--|--|--|
| SCALE consortium partners | Everyone with interest. | |
| Regulators (all kind from EU, national, to regional/local level) | Smart and bidirectional charging can contribute significantly to the deep decarbonisation of our electricity system while minimising the capital investment needed to increase the capacity of our grid infrastructure to accommodate these electricity flows. Those interested in how these companies can broaden their offerings with enhanced charging service offerings that meet customer needs to Increase independence, have financial value, or reduce in emissions | |
| E-Mobility actors (vehicle manufacturers, EMSP, CPO and SCSP). | | |
| Energy Market actors (DSO, TSO, energy suppliers, BRP, CSP/BSP) | Those who want to understand how smart charging can prevent or resolve congestion, and those who are interested in how EVs fit into balancing services. | |
| Standardization bodies | Those who wants to understand the usage of protocols in the smart & bidirectional charging ecosystem. | |

Table 0.1: Label of the first table

1.5 Structure of the deliverable and links with other work packages/deliverables

This deliverable begins with the goals of the system architecture. To streamline the process, the second chapter presents architecture principles that must be considered when making design decisions. After that, the basics of technology and infrastructure are explained. In the fourth chapter, a stakeholder analysis is conducted. The stakeholder analysis is based on the deliverable 1.2 Stakeholder analysis report. This analysis is used to indicate the different market roles in the system. In chapter five, we examine the flow of data between market roles when smart charging an EV. In chapter six, we present the data necessary for smart charging. Additionally, we examine the protocols between market roles. In chapter seven, we discuss potential security considerations when dealing with V2X smart charging. In chapter eight, we apply the market roles system architecture to different use cases. Finally, in the last chapter, we present a conclusion and recommendations.



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1 Goals of a Multi-actor Smart Charging & V2X System Architecture

The goal of this document is to provide a reference system architecture for a multi-actor 'smart charging and V2X system'. The reference architecture provides a common vocabulary and industry best practices used as a constraint for more concrete architectures. Typically, reference architecture includes common architecture principles, patterns, building blocks, and standards. They are not solution architectures (i.e., they are not implemented directly).

A multi-actor system combines two or more systems (actors) that act and intercommunicate in a shared task environment. Multi-actor systems are systems in which the stakes, efforts, and perspectives of multiple actors in or outside this system are considered. A system architecture is the conceptual model that defines the structure, behaviour and other views of a system. An architectural description is a formal description and representation of a system, organised in a way that supports reasoning about the structures and behaviours of the system.

Researchers 30 years ago already emphasised the importance of a more social perspective on the design and implementation of systems. If we apply that to charging, then there is a distinguish between acceptance and use of smart charging & V2X. Social acceptance of smart charging is a function of attitudes, behaviours, opinions, and activities resulting from interactions between public and private stakeholders, providers and the general public or society at large and the proposed smart charging technologies. By placing decision-making in the hands of the user and harnessing the potential of financial incentives, any barriers to public participation and support for Smart Charging & V2X can be identified and addressed.

1.1 Why Smart Charging & V2X

Smart charging and bidirectional charging (V2X) provide a range of advantages. Firstly, they address challenges encountered in the widespread adoption of electric vehicles, particularly the strain placed on the electricity grid due to their increasing numbers. This strain leads to diminished power quality and reliability. However, the implementation of smart charging mitigates this strain, reducing the burden on the grid and enhancing stability. Moreover, smart charging contributes to grid stabilization by offering balancing services.

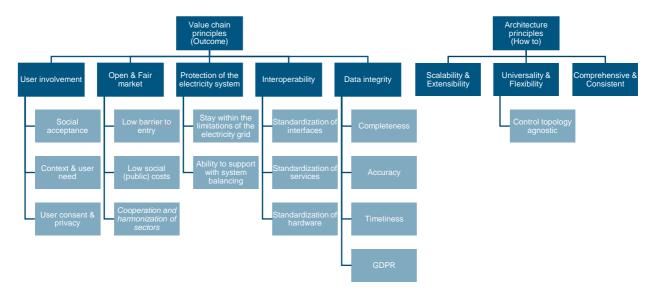
Secondly, these technologies facilitate the optimal utilization of renewable energy sources. Electric vehicles equipped with bidirectional charging capabilities can store surplus renewable energy during periods of high generation and release it during times of high demand or low renewable energy production. This effectively transforms them into distributed energy storage systems.

From a financial perspective, smart charging presents cost-saving opportunities for consumers. It enables them to take advantage of lower electricity prices by charging their vehicles during off-peak hours. Additionally, V2X charging allows consumers to sell excess electricity back to the grid when prices are higher than the initial charging cost. These financial incentives promote the adoption of electric vehicles. By encouraging their uptake and optimizing their integration with the grid, smart charging contributes to a more sustainable and efficient transportation system.



2 Architecture principles and references

Architecture guiding principles establish the general rules and guidelines for defining reference architecture, promoting structure and the standardisation of processes. There are two categories of architecture principles; the first comprises value chain principles, which apply to the decision-making process. The value chain principles shape the outcome of the reference architecture. The second category comprises the architecture principles, which establish the criteria for how the reference architecture is to be designed. The figure below gives an overview of the eight main principles and their subprinciples.



2.1 Value chain principles

The value chain principles provide guidance for the decision-making and give insight into how the value chain will set out to fulfil its mission of enabling smart charging and V2X.

The value chain principles provides guidance for the decision-making process.

2.1.1 User involvement

The user is involved in smart charging and V2X and is therefore considered accordingly throughout the value chain. Without the users consent and continued engagement, the potential of smart and bidirectional charging will not be able to be fully exploited. It is therefore important the user is involved in the process of smart charging and V2X. This principle can be measured similarly as in the deliverable 1.1 Report on consumer behaviour.

Social acceptance is distinct from the use of smart charging and V2X. Social acceptance is achieved when the general public has a positive attitude towards smart charging and V2X.

Context & User need is to understand the (potential) users' desires and how and when they will interact with assets, solutions, and services.

User consent & privacy means that collecting, sharing, and processing of data is of data is not allowed unless users consent to this. Data is considered to be a valuable asset and handled accordingly from the perspective of the user.



2.1.2 Open & Fair market

The market should be a 'level playing field' so that every competitor can compete freely. This will help to prevent the abuse of monopoly-type powers. An open and fair market provides users with a variety of choices. In addition, it helps with incentivising efficiency and innovation.

Low barrier to entry helps new business to participate on the market, enabling an open market.

Low social costs for smart charging services. Striving towards efficiency with the lowest social cost.

Cooperation and harmonization of sectors focusses on the combination of a regulated electricity sector and the free EV sector. The combination of both sectors needs to be balanced.

2.1.3 Protection of the electricity system

The boundaries of the electricity system need to be respected when implementing smart charging and V2X. The potential scale of smart charging and V2X solutions has the potential to contribute positively to the electricity system. Without smart charging or proper application of it, charging electric vehicles could have a negative impact on the electricity system.

Stay within the limitations of the electricity grid ensures the functioning of the grid will not be hindered by the application of smart charging and V2X

Ability to support system balancing focusses on the potential of smart charging and V2X to positively impact the balance between demand and supply in the electricity system. To help restore balance between supply and demand, the electricity system can be supported by adjusting the charging speeds of a group of EVs.

2.1.4 Interoperability

The essential elements of smart charging and V2X should be interoperable. To avoid a high degree of customization in smart charging, interoperability is needed to accelerate connectivity and information exchange between parties.

Standardization of interfaces promoting interoperability for data, applications, and technology. The connection between the different components, like charge stations and operator systems, also needs to be standardized to facilitate an open market.

Standardization of services promoting interoperability for data, applications, and technology. The standardization focuses on what is provided in the interaction between different roles.

Standardization of hardware promoting interoperability for data, applications, and technology. Minimum hardware requirements ensure smart charging and V2X implementation meets a basic standard of quality.

2.1.5 Data integrity

Integrity of all data must be safe-guarded during the exchange and storage of data. Implementing smart charging and V2X requires a lot of data to be exchanged between all actors active in the smart charging ecosystem. It is therefore important that the data is reliable.



Completeness means that the relevant parties have access to the requisite data for smart charging and V2X implementation. Furthermore, in order to establish reliability, it is imperative to ensure no data is absent.

Accuracy means the available data can be relied upon. It is crucial that the measured data aligns with reality.

Timeliness means the requisite data can be accessed with minimal delay. Minimal delay helps to increase the potential of smart charging and V2X.

GDPR helps to ensure data is collected and only used for smart charging and V2X. Appropriate levels of confidentiality and compliance with GDPR must be maintained during the collection, use, transmission, storage, and destruction of all data.

2.2 Architecture principles

The architecture principles provide guidance for the decision-making and gives insight into how the reference architecture is created.

2.2.1 Scalability & extensibility

The reference architecture must support the possibility of scaling and extending into additional entities or even new domains and zones of smart charging and V2X. The charging market and energy markets are evolving constantly. To ensure that the reference architecture is able to stay relevant, scalability and extensibility are essential.

2.2.2 Universality & flexibility

The reference architecture must be universally applicable and flexible to use. The reference architecture is to provide a common and neutral view on smart charging and V2X. Maintaining flexibility at all layers supports additional use cases and system designs.

Control topology agnostic ensures that different control topologies (for smart charging and V2X) are supported. Enabling a wide range of possible implementations of the reference architecture.

2.2.3 Comprehensive & consistent

The reference architecture must provide an appropriate mapping of all relevant entities and structures. Ensuring the architecture is comprehensive and consistent with the smart charging and V2X system it is representing.



3 Technology and infrastructure

This chapter provides an overview of the relevant hardware components for smart charging and V2X. It begins with the electricity infrastructure and then focuses on the hardware elements within the EV domain.

3.1 The electricity system

The following sections discuss different aspects of the electricity system. This will provide the background knowledge to understand the reference architecture. Firstly, the front-of-the-meter electricity system and the relevant power quality standards are discussed. Finally, the behind-the-meter electricity system is explained.

3.1.1 Energy network structure

In the electricity network, there are three distinct types of networks. Each with its own role in the electricity network. The three types are interconnection, transmission and distribution networks.

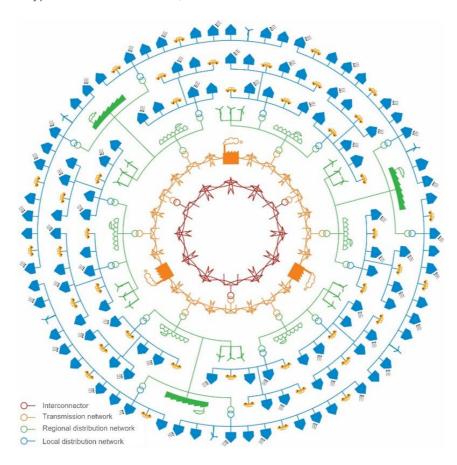


Figure 3.1 Schematic view of the electricity system (2).

Within the electricity network, there are three types of network, each with its own function: interconnection, transmission and distribution. The function of the first type of network is international interconnection with neighbouring countries and, at national level, the transmission of electricity from large power plants (>500 MW). Shown in red. From the national level, electricity travels to the provincial level, the transmission grid (TSO level). The function of the transmission grid is to act as a link between the interconnected and the

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distribution grid (DSO level). At this level are power plants and industrial connections above 10 MW. The transmission network is shown in orange. Below the transmission network is the distribution network. The distribution network can be thought of as the 'capillaries' of the electricity network and contains all the branches. Within the distribution network there are two further subdivisions. The regional level is responsible for connecting large decentralized generators and industrial customers with a capacity of more than 0.3 MW. The regional distribution network is green. At the bottom is the local distribution network, which connects consumers with a capacity of less than 0.3 MW. Charging stations are connected to this type of network.

In addition to the functional subdivision, the network can be further subdivided into high, medium and low voltage levels. The high voltage level covers the voltage from 50 kV to 380 kV and concerns the coupling and transmission network. The management of the 110 to 380 kV cable is the responsibility of the TSO. The medium voltage level is from 3 to 25 kV. The medium voltage cables together form the regional distribution network. The lowest level is the local distribution network with a low voltage of 0.4 kV with a phase voltage of 0.23 kV. Responsibility for the medium and low-voltage networks is divided among several DSOs. The different DSOs have a geographical area for which they are responsible.

In the electricity network, the quality of the mains voltage is essential for maintaining the system. The maintenance of quality has been defined throughout Europe in the EN 50160 standard. The standard defines the minimum requirements for monitoring power quality in Europe. At national level, more stringent requirements for maintaining power quality may apply in some cases.

3.1.2 Power quality of the electricity system

Power quality is a complex topic which can be divided in many different subcategories. Electric vehicle charging impacts many of these subcategories, yet not every category can be influenced by smart charging. For instance the introduction of higher harmonics in the power system by electric vehicles is something that can be prevented by choosing the right electrical components in the AC/DC convertors in the vehicle, but it cannot be influenced by applying smart charging techniques. Below there is a selection of power quality requirements that can be influenced by applying smart charging.

Frequency The European electricity system uses a frequency of 50Hz. When there is a difference between supply and demand, the frequency goes up or down. The FCR services on the grid ensure that the frequency returns to 50Hz in the event of a deviation. EN 50160 states that within a week the frequency must be within ±1% deviation 99.5% of the time and within -6%/+4% deviation 100% of the time.

Voltage deviations The European electricity network consists of several voltage levels. Changes in the use of the electricity network result in deviations in voltages. To ensure the quality of electricity, the EN 50160 standard states that low and medium voltage must be within ±10% for 95% of the time over a week.

Supply voltage unbalance As the electricity network consists of three phases, it is essential that the phases are balanced. If the consumption of these phases is not evenly distributed, this can lead to uneven voltage between the phases. The difference between the phases should not exceed 2% for 95% of the time during a week.



3.1.3 Behind-the-meter local network

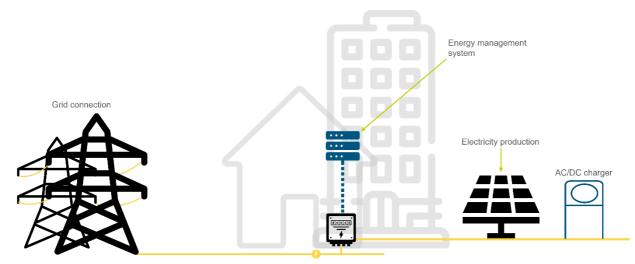


Figure 3.2 Schematic overview of a local electricity network.

The behind-the-meter network refers to the part of the electricity network on the side of a household or business that is connected to the electricity meter. The electricity meter marks the boundary between the public electricity network (in front of the meter) and the private electricity network of an individual household or business (behind the meter).

Several components can be connected behind-the-meter.

Electricity meter Tracks the electricity usage behind the meter and production to the grid.

Electricity production As well as consuming electricity, some buildings also produce electricity. For households, this most often includes PV production.

AC/DC charger The point of connection at which an electric vehicle recharges its battery.

Energy management system As the number of electrical devices and the demand for electricity behind the meter increased, so did the need to control electrical devices. An energy management system helps to control electrical equipment.



3.2 The EV sector

This section provides an explanation of concepts in the EV sector. Firstly, the different definitions of smart charging are described. Secondly, the relevant components for smart charging are explained. Finally, a brief explanation of what smart charging means from the perspective of an EV is given.

3.2.1 Different definitions of the smart charging

An upcoming technology in EV charging is bidirectional charging: the battery in an electric vehicle can not only be charged but also discharged via the charge point. This way the vehicle supplies energy from the battery to the charge point.

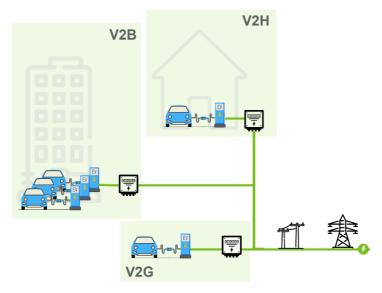


Figure 3.3 Overview of the V2X categories.

Depending on where the charge station is connected to, bidirectional charging may be categorised differently:

- In case of a home charger, the term Vehicle to Home (V2H) is sometimes used.
- In case of an office charger, the term Vehicle to Building (V2B) is sometimes used.
- In case of a public charge station, the term Vehicle to Grid (V2G) is sometimes used. V2G is however also used to describe the previous two use cases.

However:

- the technology is the same in all use cases.
- no matter where the charge station is connected to, it is always taking part in and influencing the energy markets.
- no matter how the charge station is connected, it is always in some way connected to the public grid.

Therefore, in this report, the term V2X is used as an umbrella term for all forms of bidirectional charging.

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3.2.2 Electric Vehicle and Charging station

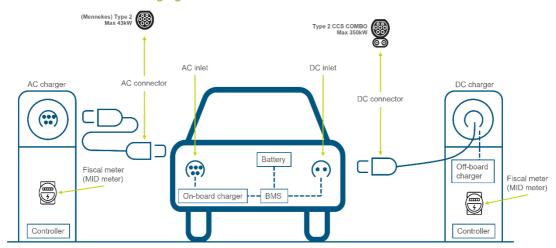


Figure 3.4 Essential EV parts for Smart Charging

An EV can be charged through two types of charging stations, alternating current (AC) or direct current (DC). The components used to charge an EV are similar for both types of charging stations. Where necessary, this document will name the differences.

Below are the various components and their respective functions when charging an electric vehicle:

AC & DC Connector The connector supplies either AC or DC power. The connector is also used for communication between the charger and the EV.

Fiscal meter (MID meter) The electricity used in the charging station is tracked by the fiscal meter. The meter is essential to track all components of smart charging. However, for DC chargers MID certified fiscal meters are not yet on the market.

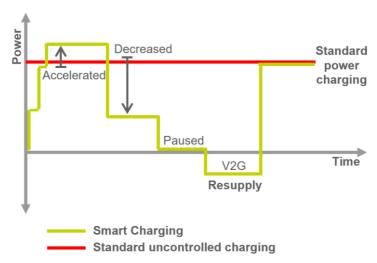
Controller Enables several functions within the charging station. The controller allows the charging station to start and stop the charging process, ensures electrical safety and manages communication between the EV and the charging station (3).

On- & Off-board charger Electricity from the grid is AC, but enters the battery as DC. The on-board charger converts the AC current into DC current (4). If you are using a DC charging station, the conversion takes place in the off-board charger before it enters the EV. In this case, the electricity bypasses the on-board charger in the EV. The on-board charger is used when AC power is used as the input. In addition, the on-board charger allows the EV to control the current and voltage at which the battery is charged to ensure safe charging. The on-board charger is also responsible for the communication between the EV and the AC charger.

Battery management system (BMS) DC power enters the BMS, where it controls various aspects of the charging process. The BMS is responsible for charging and communicating with the DC charger (5). It also determines aspects such as the state of charge and health of the battery.



3.2.3 Smart charging



Smart charging works on the principle that the charging profile of an EV is varied from the standard charging profile. It is called smart charging when the variations in the profile are based on an external variable with the aim of generating value, be it social value or financial value. It's important to note that while the value of a single EV's contribution might be modest, the impact of smart charging can be significant when applied to a large pool of EVs.



4 Smart charging and Bidirectional services

As previously mentioned, smart charging for electric transport offers numerous benefits. These benefits primarily stem from the various services that can be provided through smart charging.

Table 4.1 Smart charging and Bidirectional services

| Location | Optimization cluster | Optimization type | Primary objective |
|------------------------|--------------------------|--|--|
| Behind-the- | Local optimization | Load management | Increasing independency; Cost optimization |
| meter | | Emergency power supply (i.e. backup power) | Increasing security of supply |
| | Congestion | Long term | Preventing grid congestion |
| | Management | Short term | Preventing grid congestion; Financial benefit |
| Front-of- the-meter | Portofolio Management | Long term | Revenue/Cost optimization |
| | | Short term | Portofolio optimization; Revenu/Cost optimization |
| | Balancing Services | Operating reserve | Restoring grid frequency |



4.1.1 Local optimization

Local electricity optimisation involves acting on the individual's network (as discussed in 3.1.2). Behind-themeter optimisation is therefore concerned with meeting the needs of a building or household rather than the needs of the electricity system as a whole. There are two different types of behind-the-meter optimisation: load management and emergency power supply.

Local optimisation applies to a single EV or a fleet of EVs. Electricity consumption during charging can be varied, changing the charging profile. By doing this intelligently, the local network can be used more efficiently. If an EV can charge bidirectionally, it is also possible for the EV to act as an energy storage device. This, combined with local generation, can reduce reliance on electricity from the grid. Alternatively, costs can be reduced by storing electricity when prices are low and then using it at times when prices are more expensive.

Load management involves adjusting power consumption to prevent overloading the local grid connection. One strategy is to reduce peak consumption during the day, known as peak shaving, to avoid overloading the local grid. Furthermore, electric charging consumption can be shifted to align with solar panel production, a process commonly referred to as load shifting. Although load shifting typically pertains to electricity consumption, V2X-enabled EVs can also shift electricity over time. For example, the battery can be charged using self-generated solar energy, and the stored energy can be used later for consumption. This increases the consumer's independence and can potentially generate financial value.

Emergency power supply can be provided by an EV, with V2X capabilities, in the event of a local power failure, temporarily taking over the power grid and increasing security of supply.

4.1.2 Congestion management

Congestion management is employed when the power grid's capacity is insufficient to transport the full desired capacity between two points (6). It is important to distinguish between structural congestion, which requires long-term solutions, and temporary congestion, for which short-term solutions are sufficient to prevent an overload on the grid.

Congestion management involves a group or fleet of electric vehicles. As with local optimisation, power consumption is adjusted to avoid congestion.

Long term involves contractually limiting available capacity during specific timeframes. When requesting a new grid connection, a certain capacity is typically made available regardless of the time. However, the request will be rejected if it cannot be guaranteed that the grid will be able to handle the requested capacity at all times. In the Netherlands, a capacity limiting contract is now available in such cases. To prevent structural congestion, connected parties can be restricted from accessing the grid during specific time blocks each day. Implementing this contract ensures that new connections can be made without issue.

Short term involves limiting available capacity during specific timeframes to prevent imminent grid overload on relatively short notice. Short-term congestion management is carried out on an intraday basis. The day-ahead nomination has already taken place, which requires consideration of the balance between electricity supply and demand at the national level. To maintain balance, redispatching is applied. If capacity at location x is reduced, an increase will be required at another location where there is no congestion. In the Netherlands, market-based redispatching is used for this purpose (7). The parties provide a specific capacity, and then the TSO or DSO will seek a suitable match between the offered increase and decrease in capacity.



4.1.3 Portfolio management

Portfolio management involves optimising the price at which electricity is bought and sold. This is done on the various power exchanges. In addition to finding the best price, optimisation also involves matching the electricity actually produced and/or consumed during the day to what was sold or bought on the wholesale markets.

Long term A BRP trades on several wholesale markets, the long-term market and the day-ahead spot market. When a BRP buys or sells energy, it estimates the desired price based on its own assets and future weather forecasts.

Short term involves electricity trading on the intraday market. Traders may compensate potential mismatches between what is predicted before the day started and the predictions during the day.

4.1.4 Balancing services

Balancing services compensate for a mismatch between supply and demand on the electricity grid by restoring the grid frequency. When there is an imbalance, capacity is bought to restore the balance. This is done on the balancing markets, where the frequency is restored by increasing or decreasing capacity to compensate for the mismatch between demand and response. This involves recording the imbalance in real-time, which can be done by measuring the grid frequency (see section 3.1.2). Three services have been established for this purpose: Frequency Control Reserve (FCR), Automated Frequency Restoration Reserve (aFRR), and Manual Frequency Restoration Reserve (mFRR). These services will respond to frequency anomalies and will be activated in this order for as long as the imbalance persists. If a party participates in the imbalance market, it may receive an availability fee and/or compensation for the capacity provided. The costs incurred by the TSO for rectifying imbalance are the responsibility of the BRP that caused the discrepancy.

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5 Stakeholders analysis

5.1 Summary of the stakeholder's analysis

This chapter identifies the main stakeholders in the smart charging and V2X ecosystem. In "Deliverable 1.2. Stakeholder analysis report", for each stakeholder, three key aspects were analysed:

- (1) the main driving forces for the stakeholder's interest in electric mobility, smart charging, and V2X services:
- (2) the most vital needs for the stakeholder towards the acceleration of large-scale smart charging and V2X services; and
- (3) the most crucial barriers identified by the stakeholder towards the acceleration of large-scale smart charging and V2X services.

In this chapter, we limit the description of the stakeholders to their role and interest in electric mobility, smart charging and V2X services.

5.1.1 EV Driver

An EV driver is an individual that drives an electric car. EV Driver also means an individual who uses the Charging Equipment at a private or public Location to charge an Electric Vehicle. EV drivers have an EV available to them and want to know they can get to their destination conveniently and affordably.

Early EV adopters are used to plugging in their cars, and charging starts immediately. However, charging patterns are starting to change, either as a result of external influences such as regulation or standards, or as a result of intrinsic motivation. Smart charging is becoming the norm. With private charging infrastructure, the driver has more freedom of choice. However, with public infrastructure, decisions can be made centrally and rolled out on a larger scale, while still considering consumer (driver) preferences. Variations in consumer charging behaviour can be motivated by environmental ideology, economic incentives, or social reasons.

5.1.2 Fleet operators

An EV fleet operator is responsible for managing and controlling the charging of an EV fleet. Although this report focuses on logistics vehicles and shared cars, an EV Fleet Operator could also manage taxis, buses, boats, construction vehicles or other EVs. The main challenge is to ensure that sufficiently charged vehicles are available when needed, considering charging times, expected operating time and optimising charging costs. This may require changes to existing business processes.

EV fleets are a promising market for charging services, as they can help fleet operators reduce costs by procuring and managing energy more efficiently. In addition, the market size of EV fleets is expected to grow dramatically.

Most logistics EVs are used during the day and parked at a depot at night, typically between 8 p.m. and 6 a.m. Smart charging at the depot or charging hubs is essential because plugging in all the vehicles simultaneously in the evening would result in a massive spike in electricity demand. To fully optimise costs and revenues, a fleet operator needs to respond to electricity prices and grid costs and may participate in flexibility markets. By using smart charging and V2X whenever possible, electricity costs can be reduced, and costly grid upgrades avoided, with the added benefit of increased grid resilience. Another trend is to combine charging with energy storage and renewable generation, and time-of-use arbitrage.

A shared electric vehicle fleet has less predictable operating times and requires good algorithms and input data to make accurate predictions and optimal decisions. However, the same principles apply: smart



charging can reduce costs by charging at off-peak times, V2X can optimise savings, and running on (mainly) solar power is a USP.

5.1.3 Local and regional authorities

Investment in charging infrastructure is one of the key drivers for the transition to electric mobility. Local and regional authorities have a crucial role in supporting the deployment of publicly available charging infrastructure. They can help shape the market for charging infrastructure by controlling certain aspects of the planning, installation, and exploitation. They also impose certain requirements to make the charging infrastructure future-proof (upgrades to smart charging and V2X). Both national and European-wide guidelines have been adopted in recent years to provide guidance for public procurement procedures.

While the tendering requirements at the national and European levels are generally well established, there is still uncertainty regarding cybersecurity requirements and which communication protocols will become dominant. Ensuring that public charging infrastructure is future-proof in terms of data exchange is a significant barrier for local and regional authorities.

5.1.4 European and national regulators

European regulators are driven by the need to accelerate action on climate change. In recent years, regulations aimed at decarbonising the transport sector have become increasingly ambitious, with targets ranging from a 60% reduction in transport emissions by 2050 to a complete ban on new fossil-fuel cars by 2035. Specific legislation for e-mobility is supported by strict rules on data sharing, free market principles and fair competition to protect consumer choice, technology neutrality and consumer protection.

To optimise the potential of e-mobility in terms of flexibility services, the acceleration of the e-mobility market should go hand in hand with measures related to smart charging and V2X. To fully utilise smart charging and V2X, it would be advantageous to have political agreement among national regulators. The current fragmentation of grid codes is impeding the widespread adoption of smart charging and V2X across Europe.

Ideally, the necessary measures will be taken as much as possible at the European level, without violating the principle of subsidiarity, to allow for harmonising national rules on e-mobility. From the perspective of cross-border stakeholders, such as EV and charging point manufacturers, MSPs and energy suppliers, a European-wide policy framework will greatly improve the opportunities to penetrate the European market as a whole, thereby reducing costs for consumers.

Widespread awareness of smart charging and V2X must be developed to fully realise their potential. The adaptation of multi-level regulatory frameworks in smart charging and V2X perspective will be a major driver for the widespread deployment of EV flexibility, but this needs to be accompanied by the right measures at all regulatory levels: from public tendering at the local level to financial incentives at the national level, to the development of open standards at European level. Similarly, raising consumer awareness through public engagement, marketing strategies, and large-scale pilots is essential to bring EV flexibility into the public and, consequently, political debate.

5.1.5 Charge Point Operator

A charge point operator (CPO) installs and maintains charging stations from one or more manufacturers so that electric vehicles can charge. The CPO is responsible for operating the hardware.

CPOs buy may be the owner of the charging infrastructure (typically the case for public charge stations) but may also do the operations for charge stations owned by others (typically the case for home and office charge stations).



The CPO benefits from high charge station utilisation and wants to minimise costs and maximise revenues. Smart charging can account for this, optimising charging based on electricity prices, grid fees or grid capacity. For example, Lower grid fees can be achieved by (virtual) clustering of EVSEs or adjusting charging to the available grid capacity.

5.1.6 eMobility Service Provider

The contracting party and point of contact for EV drivers is their E-Mobility Service Provider (EMSP). EMSPs aim to make EV charging convenient for drivers by providing access to a large network of charging stations via a charge card or app - and in the future, via Plug & Charge using digital certificates. EMSPs bundle transactions for charging over a period into one invoice and often offer multiple payment methods. Through an EMSP app, EV drivers can find available charging stations, check rates, and sometimes even make reservations for a charging station.

The EMSP role can be fulfilled by various companies, including energy suppliers, charging station operators, leasing companies, fuel card issuers, and others.

EMSPs can play an important role in facilitating smart charging as they are often the single point of contact to the EV driver. The EMSP is therefore in many cases the only market-role that has access to important smart charging inputs like the desired state of charge, time of departure/arrival, charging preferences (e.g. to optimise on price/renewables), or sometimes even the current state of charge (where this cannot yet be retrieved via another way)..

To create optimal smart charging profiles and ensure transparency to customers, an EMSP needs to be well-connected to other market-players like a CPO, OEM and aggregator.

5.1.7 Distribution System Operator

According to the Electricity Market Directive, the role of the DSO is to 'operate, ensure the maintenance of and, where necessary, develop the distribution system in a given area and, where appropriate, its interconnections with other systems, and to ensure the long-term ability of the system to meet reasonable demands for the distribution of electricity (European Parliament and Council, 2019b)'.

Specifically, the DSO fulfils three roles within the electricity market:

- 1. Connecting distributed energy resources and many energy consumers to the grid
- 2. Physically transporting electricity flows through the distribution grid
- 3. Facilitating the market by managing the registration of grid connections and the exchange of messages with market participants such as energy suppliers, meter data companies and TSOs.

DSOs are responsible for ensuring the availability of electricity to all consumers and are held accountable for the frequency and average duration of system interruptions. The roles and responsibilities of DSOs have not changed significantly over time, but meeting system security objectives has become more challenging due to the energy transition. With the rapid electrification of the energy system, grid congestion and power quality problems on low-voltage grids are occurring more frequently than before. DSOs are currently unable to keep up with the pace of electrification. Still, they are now allowed and incentivised to procure flexible assets to maintain system security (European Parliament and Council, 2019b). Electric vehicles with smart charging capabilities are a potential flexible asset that could help maintain system integrity.

Ensuring coordination between system operators is another key objective for DSOs. DSOs need to work with TSOs, BSPs and CSPs to ensure that congestion management measures do not lead to system



balance problems for TSOs and, conversely, TSO actions to ensure system balance do not lead to system congestion in DSO areas.

5.1.8 Transmission System Operator

A Transmission System Operator (TSO) is an entity entrusted with the transport of electricity at the national or regional level using a fixed infrastructure. TSOs are responsible for the reliable and secure operation of the electricity transmission network. The security of the electricity supply depends on the TSO's ability to maintain the grid frequency within predefined limits and to ensure that the transmission system can transport all electricity demand.

The day-to-day tasks of a TSO are, therefore, both to resolve imbalances in the network by activating balancing reserves and to prevent the technical limits of the transmission network from being exceeded by applying constraint management (e.g., congestion management in the high-voltage network).

Increasing frequency instability due to the volatile production patterns of distributed energy resources, such as solar PV, is forcing TSOs to activate balancing reserves at higher total capacity and on a more regular basis. Historically, large power plants have provided frequency stability, but their slower response time, high marginal costs and high CO₂ emissions makes other sources of balancing reserves more economically viable. This leaves a lucrative market opportunity for smart charging and V2X, as frequency regulation requires both up- and down-regulation of balancing energy. On the balancing market, TSOs can procure or incentivise various balancing reserves (operating reserves) to restore grid frequency.

5.1.9 Energy Supplier

Energy suppliers are the primary intermediary party between a consumer and the electricity market. Suppliers purchase electricity on wholesale markets via a BRP or directly from plant owners and sell it to consumers. In many Member States, energy suppliers fulfil a crucial role in the energy transition by compensating small-scale energy prosumers (e.g. households owning solar panels, or, in the future, households that make use of bidirectional charging) via feed-in tariffs or net metering. Suppliers are key enablers of the liberalised energy market and their roles and responsibilities have therefore been extensively described in European legislation. Consumers are free to purchase electricity from a supplier of choice and should be given transparent information on prices and tariffs. In return, suppliers are free to determine retail prices of electricity according to market-based principles as to allow effective competition between suppliers.

The gradual transition from internal combustion engine vehicles to electric vehicles enable suppliers to tap into a new market. E-mobility is, first and foremost, a new business opportunity for suppliers as they will be able to sell more electricity and consequently generate higher profits. EV charging as a form of flexibility is another interesting prospect for suppliers with the use of dynamic pricing.

5.1.10 Balance Responsible Party

In principle, each market participant is responsible for the imbalance it causes in the electricity system as a result of a mismatch between electricity production and consumption. Small consumers, such as most EV owners, typically transfer this responsibility to a Balance Responsible Party (BRP). A BRP must balance its portfolio, which consists of a large number of consumers and producers. A BRP's business model involves optimising its portfolio as accurately as possible to avoid imbalance charges and receive compensation for mitigating system-wide imbalances.

Portfolio optimisation is becoming increasingly difficult due to the increasing electrification of the energy system. Deviations in forecast weather patterns and unreliable consumption patterns can lead to an imbalance in the BRP's portfolio, which is undesirable due to imbalance charges. To keep imbalance



charges as low as possible, deviations from planned production and consumption should be avoided. One solution is so-called demand-side management, where a BRP (sometimes via an aggregator) tries to influence the power consumption in order to match the power production in its portfolio. Smart Charging and V2X are an attractive source of demand-side management flexibility for the BRP, due to their ability to respond to short-term signals and, in the case of V2X, to adjust both consumption and production patterns.

5.1.11 Aggregator

The aggregator is a new market role created by European legislation to allow small prosumers to participate in flexibility markets. An aggregator bundles many small assets and offers the aggregated volume on one of the flexibility markets on behalf of its customers, with the aim of making a profit or reducing overall energy costs. An aggregator may offer its service to any party that requires flexibility, this could be the BSP, CSP, BRP, Energy Supplier, DSO or TSO (the last two only in case there is no CSP active). The aggregator role may be fulfilled by an independent party or may be fulfilled by a market party like an Energy Supplier, BSP, CPO, etc.

For some flexibility markets, a minimum bid size is required. In this case smart charging and V2X requires an aggregator to combine many charging sessions into a larger flexible power portfolio.

5.1.12 Electric Vehicle Manufacturer (OEM)

The business case for traditional car manufacturers to invest in e-mobility and for new pure EV manufacturers to enter the market has improved because of EU policies. The EV market has gradually moved from a business model based on luxury-EVs to one based on their economic and environmental characteristics, increasing market penetration.

From the perspective of the automotive market, the transition to smart charging and V2X readiness requires the adoption of an EU-wide policy framework in favour of EV manufacturers. Manufacturers are reluctant to invest in smart charging and V2X because of the investment costs, while not benefiting from the flexibility it provides. The current lack of demand from potential EV buyers for smart charging and V2X functionality makes it difficult to justify additional costs. A supportive regulatory framework for the automotive sector would, at a minimum, include measures to increase end-user awareness of smart charging and V2X, and financial incentives to stimulate demand, such as tax breaks for 'V2X-ready' EVs. In this way, manufacturers will be encouraged, but not obliged, to add more sophisticated functionality to their EVs.



5.2 Roles and Cooperation models

This section presents an overview of the market roles involved in smart charging, as depicted in Figure 4.1. The figure illustrates the economic and administrative relationships between these roles, indicated by green lines. The administrative relationships specifically reflect the interactions related to smart charging. For example, Power Production sells its electricity on the wholesale market. This results in an economic relationship between the Power Production role and the wholesale markets. However, this relationship is not shown in the figure as it is not relevant for smart charging. It is important to note the difference between market roles and stakeholders (market party's): a stakeholder can fulfil multiple market roles and multiple stakeholders can fulfil the same role. As an example: there are many examples of market parties that combine the role of bother Electricity Supplier, CPO, EMSP and Aggregator.

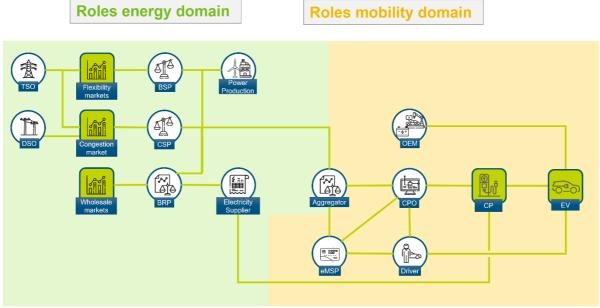


Figure 5.1 Roles and relationships in the energy and mobility domain

In Figure 4.1, the aggregator is positioned at the boundary between the two domains, with the aggregator playing the role known as the Smart Charging Service Provider (SCSP) in the EV domain.

The choice of the aggregator as the central role is driven by the fact that this position is regulated by the European Union. Directive 2019/944 on common rules for the internal electricity market sets guidelines that define how all electricity users can benefit from providing flexibility to the system, including the potential of EVs for flexibility. The Directive states that flexibility can be provided through aggregation.

Aggregation allows normally passive consumers to become active consumers. The Directive states that consumers should be fairly compensated for the value created by the provision of flexibility. The role of the aggregator is thus to act as an intermediary to give consumers access to all electricity markets through aggregation.

With aggregation, it encompasses all assets through which a consumer can add value to the system, not just smart EV charging. The role of the aggregator therefore spans both areas. In addition, a party's smart charging functionality may represent significant capacity, which may pose a potential risk to the system. Assigning responsibility for smart charging to the aggregator role will regulate it, removing the need for separate legislation for smart charging and creating a standardised framework for managing flexibility in the electricity system.



6 Software control solutions

The EV sector is currently experiencing strong growth, with a significant increase in the number of EVs on the road (8). While this is a positive development, it is notable that the EV sector appears to be developing largely in isolation from the electricity sector. This can be problematic, as problems within the electricity sector can inhibit the growth of the EV sector, while uncontrolled growth of EVs can exacerbate existing problems in the electricity grid (9) (10).

To minimise barriers within the electricity sector, the implementation of smart charging in the EV sector is an effective approach (11). It is essential that the control of smart charging is clear and straightforward. This chapter presents a control topology that clearly links the different market roles in smart charging.

This control topology provides insight into existing communication protocols and standards, identifies areas where improvements are needed and where protocols may be missing. It also allows for the identification of commonalities so that different smart charging applications can be mapped to the same control topology. This will provide direction for market organisation, protocol development and setting price signals for control within the EV sector.

6.1 Control topology

Figure 5.1 shows a control topology. In the control topology, the data flows are shown as dotted lines. These are flows that are relevant to smart charging. Next to the data flows, the yellow arrow shows how smart charging can be controlled.

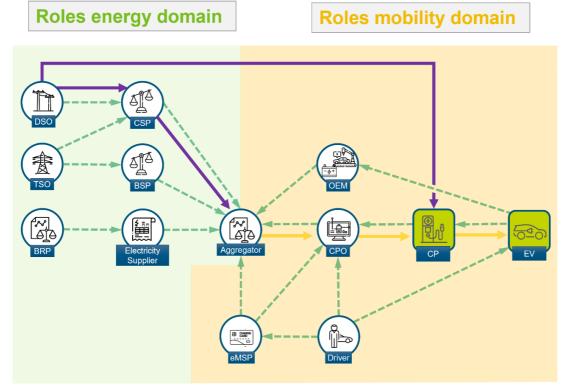


Figure 6.1 Overview of the data flow between roles

The displayed data streams exhibit varying degrees of maturity, and not every application of smart charging utilizes each data stream. Chapter 6.3 provides further insight into this.



Figure 5.1 again emphasises the central role of the aggregator. As data on electricity markets flows into the aggregator, it becomes clear that the flow of information between roles in the EV domain is less linear than in the electricity domain. Relevant data can take several paths. Establishing an aggregator as a central point helps to simplify the data streams for smart charging.

As data streams move towards the aggregator, it is considered desirable to allow the aggregator to control smart charging. It also provides consumers freedom of choice who they want as their aggregator. Consumers could choose an independent aggregator or allow their CPO/EMSP/Energy Supplier/OEM to fulfil the aggregator role. The freedom to choose an aggregator promotes competition and innovation in the smart charging market.

An important control signal that deserves attention is the signal sent from the DSO to the CP with which the DSO can send an absolute control signal. An absolute control signal may be necessary in situations where market-based congestion solutions fail to resolve congestion or in situations of acute congestion.

In Figure 5.1 this absolute signal is indicated in purple. The absolute control signal has two possible paths in the figure. The first signal goes directly to the charge station (or to the smart meter or home energy management system connected to the charge station), bypassing the ecosystem. Such a steering signal has the advantage of giving absolute control to the DSOs, making them independent of other market players in their efforts to prevent grid overload. In situations of acute congestion and risk of damage to the grid, this control may be necessary. The downside however is that such a control signal bypasses other roles in the ecosystem, which might other leave them unaware of these control actions.. This can result in higher costs for other parties, for instance higher costs for BRPs whose portfolio is impacted and were unable to correct for this because of a lack of information on the control actions by the DSO. It will for instance also be difficult for CPOs and EMSPs to inform their customers in such events. Another downside is that for the communication between the CPO and the charge station there is one single protocol (OCPP) that all charge stations in Europe support. An industry-wide accepted protocol for the local control of charge stations however doesn't exist, which might make direct control by DSOs hard to scale and more expensive than the alternative via the other purple arrow in Figure 5.1.

The second possible signal path is through the aggregator and the 'normal route' of a control signal. This route is advantageous because it allows market participants to choose the economically optimal way to resolve a potential problem. It prevents disproportionate loss of value and can reduce the costs imposed on other parties. In addition, the steering signal travels along existing paths, reducing the need for additional hardware

Regardless of *how* the DSO controls the power consumption of a charge station (via an aggregator or via a direct control signal), the DSO must be *allowed* to do so. This means the owner of the grid connection a charge station is connected to must have a contract with the DSO that describes how the DSO may manage the capacity of the grid connection in case of congestion. This is described in more detail in Section 6.5.

A logical consequence of the DSO managing grid congestion via (a CSP and) an aggregator is that additional certification is required. Since overload should under no circumstance be allowed to happen, both the Charge Stations, CPOs, Aggregator and CSP should meet certain quality standards. Also, it could be a requirement that, given the impact that charge stations have on the distribution grid, every charge station must (via an aggregator) be smart charging ready. As an example, the UK already has such legislation in place (1).



6.2 Smart charging segments

The charging infrastructure is spread across various segments, which are often categorised as at home, at work and road. The following sections highlight how the described control topology can be used for these segments. For each segment the possible smart charging and bidirectional services are discussed, described in Table 3.1. In addition, the possible incentives that can contribute to the adoption of smart charging are discussed.

6.2.1 At home

The first segment concerns home charging points. In most cases, the number of home charging points is limited to one. When the control topology is applied to a home charging point, the party implementing the energy management system will fulfil the roles of CPO and aggregator. Depending on the use case, the aggregator will control factors external to the home.

Smart charging use cases applied at home

Local optimisation:

Charging an EV at home usually does not exceed the available grid capacity of a household. However, if a household has uses a lot of power (e.g. because of electric heating and/or cooking) or has solar panels, smart charging may become attractive. This is mainly about local behind-the-meter optimisation, incentivised by the potential to prevent overloading the existing grid-connection and maximise self-consumption of the electricity generated.

Grid congestion:

Although charging a single EV has a minimal impact on the local grid front-of-the-meter, multiple EVs charging simultaneously can have consequences for the local electricity grid. In a street where many households charge simultaneously, the grid may become overloaded, especially when the charging is added to the evening peak. Additionally, the amount of charging points at home are growing across Europe (8). For this reason, it would be important to incentivise home charging points to also apply smart charging to prevent grid congestion, but due to a lack of incentives from DSOs and a lack of flexibility in the contracts between home-owners and DSOs, this is currently not happening.

In the Netherlands, GOPACS has been set up to create a market for congestion management, although the use of GOPACS for low-voltage networks is currently limited. Nevertheless, it has potential as an incentive for households through an aggregator.

Portfolio management & balancing services

The EU Directive 2019/944 on common rules for the internal electricity market states that households should being able to participate in and benefit from electricity markets is an essential incentive for households to manage their charging activities based on external factors. Several energy suppliers in the EU already provide Time of Use tariffs, where day ahead market prices are passed on to consumers, incentivising them to consume energy at cheap times (thus when there is a lot of energy available). The aggregator-role in this case is often fulfilled by the CPO or Energy supplier. Especially in case the Energy Supplier is also active as CPO and BRP, balancing services are also provided by the home charging points.



6.2.2 At work

The second segment concerns charging points at work. Note that this segment is sometimes also as defined as "semi-public". What is meant is that there is a cluster of charge stations connected to a single grid connection. So also a cluster of charge stations at e.g. a store or theme park could be categorised as 'work'-chargers. Just like with home charging locations, a party providing the energy management system will fulfil the roles of CPO and Aggregator.

Use cases

Local optimisation:

When it comes to charging points at the workplace, it is more often than not the case that charging all charging points at the same time results in the capacity of the grid connection being exceeded. Therefore, it is attractive for such locations to use smart charging in order to stay below the capacity limit of the grid connection. In addition, the use of the electricity generated with solar panels can be an incentive to implement smart charging or a potential cost saving. With the expected increase of charging points at workplaces, supported by the EU Directive 2010/31 on the energy performance of buildings (article 8), it is crucial to encourage building owners to adopt smart charging.

Grid congestion:

Just like the home charging case, when several office buildings connected to the same grid cable use smart charging to maximise their power consumption within their existing grid connection, the sum of the power consumption of these buildings is likely to overload this shared grid cable. Quite often, even though there are multiple charge stations in a single office building, there would be still enough flexibility left to now and then reduce the power consumption. Novel capacity contracts can be an attractive option to motivate building owners to apply smart charging with regards to grid congestion. These contracts can impose a capacity limit, but can also encourage participation in capacity markets such as GOPACS. There are currently some small scale initiatives with so-called non-form grid connection contracts but on a European level this is still very early stage, due to which smart charging with respect to grid congestion is not yet taking place (12) (13).

Portfolio management & balancing services:

Since most of the flexibility in the at work segment is used to prevent overloading the grid connection and still fully charge all EVs, there is less flexibility available for portfolio management and balancing services. There are some example though from work charging clusters that take dynamic energy prices into account, especially in countries where dynamic energy prices are widespread, like Portugal or the UK.

6.2.3 At road

The last segment is at road, sometimes also identified as public charging. This segment can be divided into two different categories: AC charging stations and DC charging stations. It is important to note that in this segment, the party that fulfils the role of the CPO is usually also the owner of the charging station(s).

AC Charging stations

These are AC charging stations that serve as public charging stations and are located on the street. These charging stations are often placed individually or in small groups in one location. With regards to the control topology, a number of variants are possible. The aggregator controlling a charge station can be integrated



with the party that plays the role of the CPO of the charge station, but the CPO may also outsource this responsibility to an external aggregator. The latter may be attractive if charge stations are located in neighbourhoods where several CPOs have charge stations.

Use cases

Local optimisation:

As a public AC charging point is directly connected, the application of behind-the-meter optimisation is not relevant as in the at home or at work situation. The only local optimisation that can occur is that the two charge points of a charge station together do not overload the grid connection.

Grid congestion:

The situation here is comparable to the at home charging case: several public AC charge stations in the same area could cause an overload of the local grid, yet due to a lack of incentives and suitable contracts smart charging with regards to grid congestion does not take place.

Portfolio management & balancing services:

Some CPOs operate networks of thousands of public AC charge stations. Since usually these charge stations all have the same energy supplier, there is value in doing both portfolio management and balancing services. Portfolio management is usually a bit less interesting, since the price-differences on day-ahead markets are usually limited while the impact on the EV-driver could be large, especially in countries where the settlement periods for day-ahead prices are hours (avoiding an expensive hour would mean curtailing an EV for a full hour).

Some CPOs agree with their energy supplier on a pass-through contract for imbalance costs (which means that instead of the energy supplier, the CPO is now responsible for balancing its power portfolio and also for the rewards or penalties that come with it). At certain times, imbalance prices can reach several hundred euros per MW. Curtailing the charge rate of thousands of charge stations for a short period of time in such cases can be quite beneficial for CPOs and is already applied by several of them.

DC Charging stations

DC charging stations are mainly located along motorways, quite often in clusters. DC charging stations are the electric alternative to conventional petrol stations. They provide fast charging and high power compared to AC charging stations. The control topology is the same as for public AC charging stations, with the party that fulfils the role of CPO usually also being the owner of the infrastructure.

It should be noted that smart charging utilises the flexibility of a charging sessions, and that this flexibility stems from the fact that EVs are typically connected to a charge station for a longer period of time than that they need to charge. This is not the case for DC charging, where EVs typically park for a short period of time and are charging during the entire parking time. Therefore there is significantly less flexibility in DC fast charging than in the other segments.



Use cases

Local optimisation:

This is the one use case for DC fast charging where smart charging is very relevant. Since usually not all charge stations are used at the same time and since not all EVs can actually charge at the charge station maximum capacity, CPOs usually contract a lower grid capacity then the sum of the maximum power of all charge stations combined (as this can save a significant amount of money). Only in the exceptional cases that all charge stations are occupied by very fast charging EVs, smart charging may briefly intervene in order to keep the maximum power consumption below the limit of the grid connection.

Grid congestion

There is usually not enough flexibility in EV charging at DC fast charging sites to allow to apply smart charging for grid congestion. There are some initiatives to combine DC fast charging sites with local storage, to allow for an even smaller grid connection and to be able to do grid congestion, but here again there is to date still a lack of incentives and suitable contracts from the DSO.

Portfolio management & balancing services

Portfolio management and balancing services are not applied at DC fast charging sites due to the lack of flexibility in EV charging at those locations.

6.3 Smart charging functionalities

In this section the functions of each role in the smart charging architecture are described. This is not a complete list of all the functions that these roles have, but only those functions relevant to smart charging and V2X. So for instance an EMSP also has a function in presenting EV drivers with a monthly invoice, but as this is not a smart charging specific functionality it is not included as a function of the EMSP-role in this section.

ΕV

- Draw power from a charge station
- Adjust charge rate based on a signal from the charge station (via IEC61851-1 or ISO 15118)
- In case of high level charging (ISO 15118 AC or DC, relatively new, see Section 7.2.2)
 - o Share State of Charge with charge station
 - o Share EV authentication ID with charge station
- In case of ISO15118 communication, the list of items above can be extended to:
 - o option to share desired time of departure with charge station
 - o option to share desired amount of kWh charged with charge station
 - o Receive and communicate EV driver charging preference to charge station
 - Determine and communicate EV battery status to charge station
- In case of ISO15118 combined with V2G capabilities, the list of items above can be extended to:
 - Deliver energy from the EV battery to the charge station
- Share vehicle information like State of Charge and (if available) State of Health, desired SoC, driver preferences, etc., with third parties via (custom) APIs.



Charging point

- Communicate maximum charge rate to the EV
- Change the maximum charge rate for the EV (=smart charging)
- Interrupt charging in case of unsafe situations (e.g. an EV charging at higher power than the maximum charge rate)
- Check and communicate real time charge rate of the EV
- Support autonomous smart charging in offline situations
- Support communication with a CPO (via OCPP)
- Support local communication, e.g. with a Home Energy Management System, Smart Meter or other nearby charge stations (no uniform standard available)
- Support absolute steering signal from DSO

CPO

- Receive smart charging input signals from the Aggregator
- Match information about local constraints (from site or charge station) with Aggregator control signals
- Send smart charging signals to Charge Stations
- Set up fallback smart charging scenarios for charge stations in case of loss of communications.
- Ensure secure communication to both Aggregator and CS
- Communicate with EV driver about charging preferences
- Communicate with EMSP about EV driver's charging preferences
- Communicate with Aggregator about EV driver's charging preferences
- Determine and communicate the impact of smart charging on the session price to the EV driver
- Determine and communicate the impact of smart charging on the session price to the EMSP
- Determine and communicate the impact of smart charging on the session price to the Aggregator
- Receive and communicate real time charge rate of the EV to aggregator
- Communicate smart charging behaviour of charge station to eMSP

EMSP

- Communicate local site constraints to EV driver
- Communicate current and expected smart charging behaviour of charge station to EV driver
- Communicate with EV driver about charging preferences
- Communicate with CPO about EV driver's charging preferences
- Communicate with Aggregator about EV driver's charging preferences
- Determine and communicate the impact of smart charging on the session price to the EV driver

EV driver

- Determine and communicate charging preference to CPO
- Determine and communicate charging preference to eMSP
- Determine and communicate charging preference to EV



Aggregator

- Support communication with local devices, e.g. with a Home Energy Management System
- Support EV OEM signal concerning EV data
- Support absolute steering signal from DSO
- Support receiving wholesale prices from the energy supplier
- Ensure secure communication to BSP, CSP, CPO, and energy supplier
- Notify the CSP about the grid connections for which the aggregator can provide demand management services per time interval
- Notify the CSP about the available flexibility (in MW) that is available for demand management per time interval
- Notify the CSP about the demand prognoses for the grid connections
- Notify the BSP about the grid connections for which the aggregator can provide frequency management per time interval
- Notify the BSP about the available flexibility (in MW) that is available for frequency management per time interval
- Notify the BSP and/or CSP about the actual flexibility (in MW) used per time interval

CSP

- Support absolute steering signal from DSO
- Receive data from the aggregator and notify the TSO/DSO about the grid connections the aggregator that are available for demand management per time interval
- Receive data from the aggregator and notify the TSO/DSO about the available flexibility (in MW) that is available for demand management per time interval
- Receive data from the aggregator and notify the TSO/DSO about the demand prognoses for the grid connections
- Receive data from the aggregator and notify the TSO/DSO about the actual flexibility (in MW) used per time interval
- Receive the steering signal as result of accepted flexibility for demand management from the TSO/DSO and notify the Aggregator

BSP

- Receive data from the aggregator and notify the TSO about the grid connections the aggregator that are available for frequency management per time interval
- Receive data from the aggregator and notify the TSO about the available flexibility (in MW) that is available for frequency management per time interval
- Receive data from the aggregator and notify the TSO about the actual flexibility (in MW) used per time interval
- Receive the steering signal as result of accepted flexibility for frequency management from the TSO/DSO and notify the Aggregator

BRP

- Communicate electricity price to electricity supplier
- Communicate grid connection forecast to aggregator



Electricity Supplier

• Communicate electricity price to aggregator

DSO

- Monitor and predict grid load and (expected) congestion
- Determine and communicate absolute steering signal to charge station
- Determine and communicate absolute steering signal to CSP
- Communicate steering signal as result of accepted flexibility for demand management to CSP

TSO

- Monitor and predict grid load and (expected) congestion
- Communicate steering signal as result of accepted flexibility for demand management to CSP
- Communicate steering signal as result of accepted flexibility for frequency management to BSP



7 Control of Data

This chapter examines the data related to smart charging. Smart charging depends on data availability at both local and system levels. Therefore, this chapter provides a clear overview of the required data and flows between the different roles in the system. Additionally, it examines the current protocols that enable data transfer to identify any deficiencies in the protocols.

As Figure 6.1 presents, data is an important part of the decision making process. More data helps in the decision making process to make smart charging more accurate.

Increased DATA creates SMARTER charging

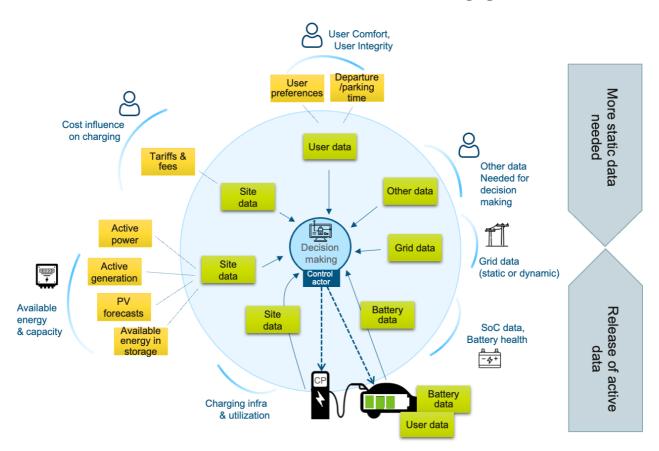


Figure 7.1 Smart charging data



7.1 Data requirements

The table below shows the data required for smart charging and clearly indicates who owns the data. It also indicates the degree of value added of the data for both V1X and V2X applications. The added value is determined by the numerical values in the table, where a lower value means a higher added value. Different applications of smart charging require different data sets for effective implementation. Not only are the data required for unidirectional charging identified, but it is also clear that bidirectional charging has a specific dependency on data related to battery status. Deliverable 2.2 Specifications and IT Use-Case definition for V2X services gives a more in depth analysis of the required data.

Table 7.1 Required data for Smart Charging. The higher the number the lower the importance of the data.

| Data | Importance for smart charging service | | | | | | | |
|-----------------------------|---------------------------------------|---|-----------------------|-----|-------------------------|---|--------------------|-----|
| | Local optimization | | Congestion management | | Portfolio management | | Balancing services | |
| | V1G | | - | V2G | V1G | _ | V1G | V2G |
| Location | 1 | 1 | 1 | 1 | 3 | 3 | | |
| Grid capacity | 1 | 1 | 1 | 1 | 3 | 3 | | 1 |
| CP capacity | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Charging preferences | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Electricity price | 1 | 1 | | | 1 | 1 | | |
| Imbalance prices | | | | | 1 | 1 | 1 | 1 |
| Congestion price | | | 1 | 1 | 1 | 1 | | |
| Charging profile | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| State of charge | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |
| Battery capacity | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |
| Battery Efficiency | | 2 | | 2 | | 2 | | 2 |
| Congestion areas | | | 1 | 1 | | | | |
| Connection groups | | | 1 | 1 | | | 1 | 1 |
| Regulation state | | | | | | | 1 | 1 |
| Connection demand prognosis | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |

Table legend:

- 1 = Data is necessary to implement the smart charging service
- 2 = Data is not necessary but will increase efficiency of the smart charging services
- 3 = Data is not necessary but will slightly increase efficiency of the smart charging services none = Data is not relevant for implementation of the smart charging services

Explanation data:

- <u>Location</u> refers to the EAN code which is used by the TSOs and DSOs to identify the connection on the electricity grid.
- Grid capacity refers to the available transport capacity on the grid connection.
- CP capacity refers to the maximum charging power available at the charging point.
- <u>Charging preferences</u> refers to the preference of the EV driver. For example, the EV driver could indicate the desire to opt-out of smart charging services.
- <u>Electricity price</u> refers to the electricity price. Depending on the contract with an electricity supplier the price could vary. For example, wholesale prices or a fixed price.
- <u>Imbalance prices</u> refers to the prices as result of the different balancing services. This price depends on mismatch in demand and supply volumes in a large geographical (TSO-)area.



- <u>Congestion price</u> refers to the price at which flexible capacity available for demand management will be used by the TSO/DSO. Of: refers to the price that TSOs/DSOs are willing to pay for a reduction in power consumption (in order to prevent grid congestion)
- <u>Charging profile</u> refers to the charging rate over time. The charging profile includes possible changes made as result of smart charging and is based on the current charging session.
- <u>State of charge</u> refers to the remaining capacity available in the battery at a given time, expressed as a percentage.
- <u>Battery efficiency</u> refers to the loss of energy when charging and discharging a battery.
- <u>Congestion area</u> refers to an area on the electricity network that is predicted to have, or does have, less transport capacity than required.
- <u>Connection groups</u> refers to a bundle of EAN codes, therefore containing multiple connections. Bundling connections into a group can increase the effectiveness of smart charging services. More on this in section 6.4.
- Regulation state refers to the current state of imbalance within periods of 15 minutes. The regulation state indicates whether imbalance is caused by a surplus of either demand or supply.
- Connection demand prognosis refers to the predicted supply or demand for a connection within
 periods of 15 minutes. This is used as a reference point to measure the effect of a smart charging
 event.

7.2 Interoperability (via protocols)

In order to promote and successfully implement smart charging across Europe, it is essential to enable effective exchange and communication between the different roles involved in the process. This means that the protocols used between these roles must meet interoperability standards. Interoperability ensures that different systems and entities can communicate and exchange information seamlessly.

The figure below summarizes the current protocols used to communicate between different roles. It also looks at the shortcomings of existing protocols and communications. This section then highlights different data flows.

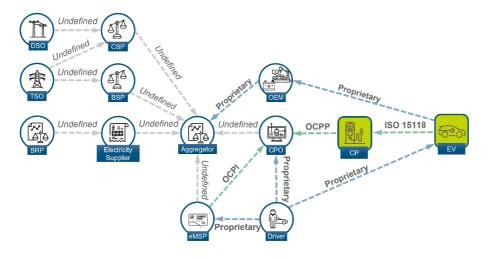


Figure 7.2 Overview of the data exchange protocols



7.2.1 User preferences

Gathering user input provides insight into user charging preferences. This input could contain time of arrival, time of departure, desired state of charge, current state of charge (if not obtained via the OEM), details around the energy contract (for home charging) and preferences regarding charging optimisation (e.g. optimising on price or CO₂ emissions). This data is mainly collected through applications developed by eMSPs or CPOs, but also directly through the operating system of the EV itself. The method by which users provide input varies greatly depending on the specific use case. In so-called closed user groups, which is the case if charge stations are used by a limited and static group of people, user data may be gathered by the CPO or aggregator. For instance in the home charging case, the closed user group typically consists of only a single EV and one or two drivers. (semi-)public charge stations are accessible to virtually every EV-driver in the world, in these situations the interface between the EV driver and the ecosystem is usually provided by the eMSP-app (although CPO-apps exist also for these cases).

It is important to note that , as identified in the previous section, smart charging can also be done without driver input. Nevertheless with an increasing number of charge sessions being smart charged and especially in case of V2G, user input being available is becoming increasingly important. The user input needed concerns one-off input of the user.

The role of the eMSP revolves around the user, as explained in an earlier chapter. The eMSP fulfils this role by providing ease of use to the EV driver. Direct communication between the CPO and the eMSP happens via the OCPI protocol (14). Communication could also take please indirectly via a roaming hub. Most roaming hubs use OCPI as well, yet Hubject uses a proprietry protocol called OICP. Hubject is currently however gradually moving to OCPI, making OCPI the only standard for communication between CPO and eMSP.

Just as the eMSP acts as a bridge between the CPO and the EV driver, it can also play this role between the aggregator and the EV driver. There is currently no established protocol for communication between the eMSP and the aggregator. However, the OCPI protocol seems a practical choice for this purpose.

7.2.2 EV data

In the EV ecosystem, communication between the vehicle and the charging infrastructure plays a crucial role. The protocol that is currently used is defined in the IEC61851 standard. This is a very old protocol which main purpose is to guarantee safety, but was never designed for advanced data-exchange. To overcome this challenge, the ISO15118 protocol was designed, which superimposes a high-frequence communication layer on top of the low-frequency IEC61851 communication.

In 2022, module 20 of the ISO15118 protocol was released (ISO15118-20). This module describes the communication necessary for bi-directional charging. Unfortunately, the large-scale adoption of ISO15118 and specifically of V2X charging is expected to still take quite some years (see below).

Given the long time required for large-scale adoption of ISO15118, there is an urgent need to develop alternative methods for communicating battery data relevant for smart charging applications. One logical alternative is to receive this information directly from the OEM. OEMs already have the capability to receive battery data through customised solutions. In addition, some customised solutions already exist between the OEM and aggregators. However, due to the importance of battery data and the need for interoperability, it is very important to define minimum standard requirements for the OEM connections through their own API.



Setting standard requirements in the communication protocol avoids the need to develop new protocols, while ensuring reliability and quality of data exchange. This allows a standardised approach to be maintained, which facilitates the integration of different systems and promotes the development of a robust V2X infrastructure.

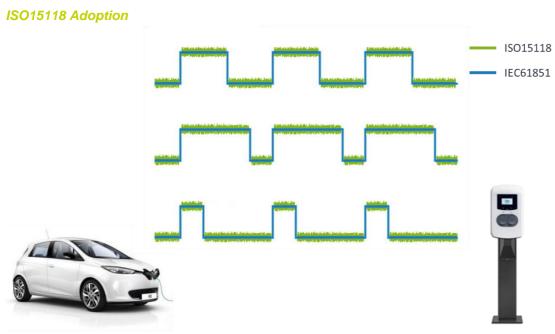


Figure 7.3 Communication protocols

Figure 6.1 shows the difference between the two communication protocols between an EV and a charge station. The standard communication between an EV and charge station, which is supported by every EV and every charge station in the world, is based on the IEC61851 protocol. This is a low bandwidth protocol (hence the slow variations between low and high) allowing only a minimal set of messages to be communicated between EV and charge station. These messages are based on PWM and voltage value.

ISO15118 is not a replacement of IEC61851, but forms an additional, high bandwidth communication layer on top of it. Where the IEC61851 operates at 1kHz, ISO15118 operates at 33MHz (33.000 times faster).

The main improvements that ISO15118 brings are plug & charge functionality (the EV can identify itself at a charge station, so no more need for charge cards, payment terminals or Apps), enhanced security and Vehicle to Grid charging.

There is little doubt that ISO15118 will ultimately be the dominant standard, yet there are several reasons why it might take quite some years before there is a significant amount of charging sessions using ISO15118:

When considering AC charging, as mentioned, ISO15118 operates at a clock frequency of 33MHz, which is 33.000 times faster than the clock frequency needed for IEC61851. 33MHz is not very hard at all to realize, most cheap chips can run at significantly higher frequencies. Yet if the hardware of a charge station or EV was designed for a low clock frequency it is usually not possible to suddenly



multiply the operating speed by a factor 33.000. This means that for all existing hardware, supporting ISO15118 cannot be supported.

The number of charge stations manufacturers and OEMs that support ISO15118 is growing, yet to date the majority of new EVs and chargers does not support ISO15118, meaning the incompatible installed base is still growing.

As mentioned, ISO15118 comes with improved security. This security is handled by so-called certificates. In order to be able to trust these certificates, somewhere in the ecosystem there needs to be a party that is trusted by all and hands out the certificates. Such a party is called the Root Certificate Authority (RCA). To date, there are only two RCAs in Europe: Hubject and Irdeto. Unfortunately, these parties are not yet compatible, meaning that an EV with a certificate of Hubject cannot charge at a charge station with a certificate of Irdeto. In time this will be solved, but to date there is no real solution in sight.

For technical reasons that go to deep for the scope of this report, V2X charging is only really feasible on DC charge sessions, which means that the application of ISO15118-20 (which covers V2X charging) is only done on DC charge stations. As a consequence, many AC charge station manufacturers currently don't focus on ISO15118.

7.2.3 Data flow towards Aggregator

The role of the aggregator is central to smart charging. These aggregators act as a crucial link between the electricity and the EV domains. However, within the EV domain, the role of the aggregator in smart charging has not yet been standardised, resulting in the lack of a common communication protocol at European level.

Given the central position of the aggregator and the need to connect the EV domain with the electricity domain, the development of a standard protocol is of great importance. However, there is currently no uniform solution for this protocol, which hinders the integration of EVs into the energy management system.

One promising option for such a protocol is the OpenADR standard. This protocol was originally designed for communication between grid operators and/or utilities and so-called distributed energy resources (DERs). An EV can be classified as a DER.

A case study conducted by the OpenADR Alliance has shown that the OpenADR protocol can be successfully implemented using the OCPP protocol, which facilitates communication between CPOs and the charge point (15). This successful implementation offers a promising perspective for the further development of standardised communication protocols in the EV domain.

The broad scope of the OpenADR protocol makes it attractive to aggregators. It can be applied not only to EVs, but also to other generation units such as solar panels or wind farms. This versatility contributes to the interoperability of the system and promotes the integration of different energy sources into the grid.

Despite the potential of the OpenADR protocol, widespread adoption is still lagging behind. It is therefore important to consider whether adoption should be encouraged through policy and standardisation initiatives, or whether the product is not yet mature enough for large-scale implementation. Promoting widespread adoption can improve the efficiency of smart charging and contribute to a more sustainable energy infrastructure.



7.3 Privacy

This report examines the use of smart charging technology. The collection and use of data is an important part of smart charging. Ensuring privacy in EV charging is therefore crucial. Regardless of whether charging is smart or not, the handling of data is no different.

In both normal and smart charging, data is collected about the user's charging behaviour. Managing this data is essential to protect privacy. In both cases, EV users need to be confident that their personal data is kept secure and only used for its intended purpose, as required by GDPR legislation.

Since the focus of this report is on smart charging, an in-depth examination of privacy issues is beyond the scope of this analysis. Nevertheless, it is important to note that privacy remains a critical consideration in the implementation of smart charging technologies.

7.4 Legal framework for DSO congestion management

In the preceding chapters, the report emphasized the importance of communication and data exchange to enable smart charging. Yet, while market roles are generally allowed to incentivize smart charging to support the electricity grid, a notable gap exists in the legal framework concerning DSOs in the context of smart charging. Although the TSOs, BRPs, BSPs, and energy suppliers possess legal bases to incentivize steering actions, the same cannot be said for DSOs throughout the European Union.

Presently, certain member states endeavour to address this gap by establishing legal bases within their national network code. However, this approach results in a plethora of member state-specific regulations. Such a fragmented landscape, contrary to the principles outlined in Chapter 2, is less than ideal. Ideally, a harmonized approach across member states would be preferred to enable the adoption of smart charging.

In the following sections, different DSO incentives are discussed and explored.

7.4.1 Variation in connection and transmission agreements

In some European countries, connection charges are still set based on the limit of the physical fuse in the meter cabinet. This practice dates back to a time when fuses were essential for enforcing contractual obligations and meters could not be read remotely. However, with the development of technologies such as smart meters, online charging stations and the Internet of Things, new possibilities are emerging. With smart meters, connection charges can now be based on the actual usage of the connection over time, rather than the theoretical maximum determined by the physical fuse or the total energy used in a year. This opens the door to more accurate and fairer pricing at the small consumer level and grid contracts that minimize or prevent grid congestion.

In other European countries, the connection tariff is based on the energy consumed instead of the capacity of the grid connection. Energy based tariffs may help to incentives consumers to reduce their total energy consumption and thus the overall impact on the grid, it doesn't yet incentivize the reduction of grid congestion during specific time intervals. There are some initiatives (e.g. in Belgium), where the DSO uses Time of Use energy based fees, meaning that the price per kWh for using the electricity grid is more expensive during the evening peak. The downside of such time-based incentives is that they might have an adverse effect when applied to large numbers of EVs: the incentive is successful in shifting EV charging away from the existing evening peak, but the consequence is that all EVs simultaneously start their charge session as soon as the kWh-price drops again. The new peak introduced this way may (and with sufficient



EVs will) be higher than the peak that would have occurred without grid control and could lead to higher instead of lower congestion. This effect was for instance demonstrated in the Flexpower3 project in Amsterdam (16).

The goal of a DSO with regards to EV charging is not to steer the power consumption to a specific optimum (which would require a very specific and complex set of price signals, like on energy markets), but to keep the power consumption between the minimum and maximum boundaries of what the grid can support. The grid operator is not concerned with the exact power consumption of EVs, as long as this power consumption stays between these boundaries. This goal should be reflected in novel types of contracts between the DSO and the owner of the grid connection.

In essence, the legal framework should be updated to allow a DSO to introduce <u>non-firm connection and transmission agreements</u>. This can be best understood by comparing this to an broadband internet subscription. Depending on the required speed, consumers can subscribe to different bandwidths (50Mbit, 100Mbit, 500 Mbit, 1 Gbit, etc.). The higher the bandwidth, the higher the monthly charge and the higher the <u>average</u> internet speed. The telecom provider does not guarantee that the chosen bandwidth is available 100% of the time, since this depends on the total load of the local network (so congestion management is applied).

Electricity is not the same as internet speed, since electricity consumption is not as flexible as data consumption. Yet, if a consumer has access to flexibility, for instance because this consumer charges an EV at home, has a stationary battery or has a controllable warm-water boiler, then a similar flexible contract could be used. Such a non-firm connection and transport agreement does not need to replace existing contracts, but it should be introduced as an alternative to firm connection and transport agreements and priced in a way that if a consumer has flexibility available, it would be the most financially attractive option.

An **example** of a non-firm connection and transport agreement that could be interesting for a household with an EV could **for instance** be:

- The minimum power that is available on the grid connection is 4 kW
- The maximum power that is available on the grid connection is 17 kW
- The average power that is available on the grid connection per day is at least 10 kW
- The average power that is available on the grid connection per 4-hour block is at least 6 kW
- The price of the grid connection is €150 per year

Another **example** of a non-firm connection and transport agreement that could be interesting for a connection to which several public AC charge stations are connected could **for instance** be:

- The minimum power that is available on the grid connection is 0 kW
- The maximum power that is available on the grid connection is 55 kW
- The average power that is available on the grid connection per day is at least 35 kW
- The average power that is available on the grid connection per 4-hour block is at least 12 kW
- The price of the grid connection is €450 per year

In the last example, a CPO could choose to go for a *firm* grid connection of 55kW costing (for instance) €3000 per year, or the much cheaper non-firm one, which allows a grid operator to apply -within certain limits- congestion management on this grid connection.



What the actual shape and form of the non-firm connection and transmission agreement should be can be determined per country and per DSO, but it would be important that there is a legal framework in all European Member States allowing such contracts to exist.

7.4.2 Clustering connections

The effectiveness of non-form connection and transport agreements could be even further increased if the DSO would have the option to allow the clustering of different grid connections into one virtual grid connection. By default, the connection and the available capacity at the connection apply to a single connection, but the congestion in grid area is not determined by the consumption of a single grid connection, but by the sum of the consumption of all grid connections in that area.

As an example, assume that in a certain grid are there are 20 grid connections with a non-firm connection and transport agreement. At a certain moment in time, the DSO limits the maximum power to those grid connections to 2kW. 2kW is not enough to charge a 3-phase charging EV, since it is lower than the technical minimum of 4.14kW. As a consequence, all EVs would stop charging. Yet for the DSO the impact of 20 grid connections all-consuming 2kW or 16 grid connections consuming 0kW and 4 connections consuming 10kW would be identical. In other words: if there are four consumers that *really* need to charge their EV that would be ok, as long as the rest of the EVs in the area are ok with postponing their charge session. Allowing such a clustering of grid connections into one virtual maximum, would allow commercial parties like CPOs and Aggregators to provide a much better service to EV drivers even in case of congestion management, since they have insight into which EV drivers need to be prioritized. As a consequence, DSO operators could have bigger reductions in power consumption to EV charging, without having too much impact on the customer satisfaction of the EV drivers.

A recommendation is that a legal framework is created in all European Member States allowing such a clustering. Note that clustering and non-form grid connection and transport agreements can be covered individually: clustering could also be applied to firm grid connections.



8 Security

This chapter presents the potential security risks associated with smart charging and V2X applications. The security risks associated with smart charging are important to consider. However, due to the scope of this project, the security risks will be limited to a brief summary and the potential impact of the proposed data architecture. In the deliverable 2.2 Specifications and IT Use-Case definition for V2X services gives a more detailed analysis of the cybersecurity.

8.1 Protection of Power system

The potential risks lie in the potential for EVs to create flexibility in their electricity consumption. This flexibility, if used properly, is beneficial to the electricity system. However, this flexibility can be used maliciously. The security risks are minimal when looking at the individual level of EV charging. However, the impact increases as the number of EVs charging increases. An important factor to consider is the increased impact of bidirectional charging. When considering unidirectional charging the charging amount can be altered between not charging and maximum charging. However, bidirectional charging can be altered between maximum discharging and maximum charging. Therefore, doubling the potential steering capacity. Given the increase in EV charging in recent years and the forecast that this will continue, it is important to consider the impact of the proposed architecture on the security and protection of the electricity system.

As described in chapter 5.1 control topology, there are currently two main steering signals. One signal directly from the DSO and another through the aggregator and the other roles. Having two different steering signals instead of one signal creates an additional security risk. The necessity for multiple routes for steering signals is a crucial consideration. Although having multiple steering signals does not inherently elevate risks, the degree of risk depends significantly on the effectiveness of implemented security measures. Opting for the aggregator as an intermediary for the steering signal between the DSO and charging point may heighten the likelihood of intercepting a malicious steering signal. However, with absence of verification and forwarding does not increase the likelihood of filtering potential risks.

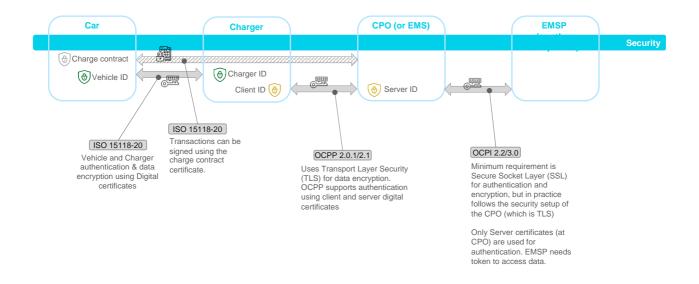
8.2 Protection of Data and Data exchange

With the introduction of V2X and the increase of EVs on the road the impact as a result of a breach asks for more considered implementation of data protection and data exchanges. At the moment there is no regulation on the security requirements of the data exchange protocols in the European Union.

Currently, the European Network for Cyber Security (ENCS) in collaboration with ELAAD has created a set of security requirements for charging stations to mitigate risks (17). However, these requirements are voluntary in most cases (18). It is important to have a harmonised set of requirements throughout Europe. The standard will help to ensure a more cost-effective implementation of charging station security (17).



Use of DIGITAL CERTIFICATES greatly enhances SECURITY





9 Application in use cases and pilots

This chapter will apply the proposed system architecture in different contexts. First, the system architecture is applied to some example cases. Then the ongoing SCALE pilots will be applied to the system architecture.

9.1 Example use cases

Some example use cases are developed to give an insight into the use of the system architecture. For each use case, the control topology is used to indicate which role is relevant for the given case. The data flow is also shown. The list below gives an overview of the data and their number that will be shown in the figures for each use case.

| 1 | Location |
|---|----------------------|
| 2 | Grid capacity |
| 3 | CP capacity |
| 4 | Charging preferences |
| 5 | Electricity price |
| 6 | Imbalance prices |
| 7 | Congestion price |
| 8 | Charging profile |
| 9 | State of charge |

| 10 | Battery capacity |
|----|-----------------------------|
| 11 | Battery Efficiency |
| 12 | Congestion areas |
| 13 | Connection groups |
| 14 | Regulation state |
| 15 | Connection demand prognosis |
| 16 | Weather data |
| 17 | Solar panel data |
| 18 | Wholesale price |



At Home charging

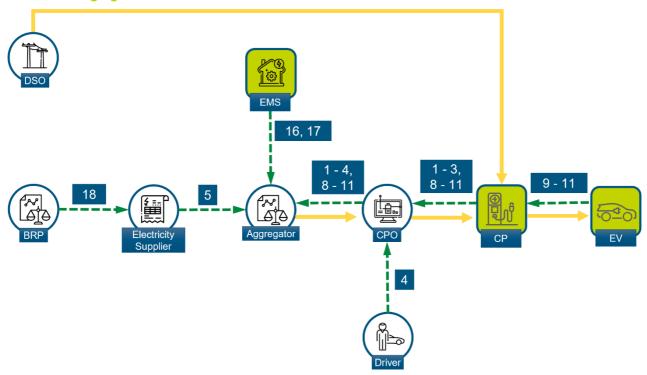


Figure 9.1 Use case, At home charging

Example characteristics:

- A home with a charging station connected to the household network
- The electric vehicle and charging station are V2G ready
- The electricity contract has dynamic prices
- Behind-the-meter local optimization is applied to also adapt the charge rate of the EV to the production of solar panels and other household electricity consumption (e.g. the induction stove)
- The DSO has the ability to send direct steering signals to the smart meter
- EV driver user preference is provided via a CPO app
- Firm connection and transmission agreements

With the described case above the smart charging services applied to the EV is behind-the-meter local optimization. The EV will be part of the home electricity system and apply smart charging to optimize the use of electricity generated from the solar panels. And additionally, ensuring the maximum limit of the grid capacity is not exceeded.

In this use case, it is important for the aggregator to be aware of electricity consumption and production behind-the-meter. For example, the aggregator must take into account the weather forecast, the number of solar panels on the house and their orientation. This is necessary to accurately predict what the output of the solar panels will be. This information must be carefully weighed against optimizing dynamic electricity prices. With the EV driver users preferences the optimalisation can be done with limited hinderance on the EV driver.



At Office charging

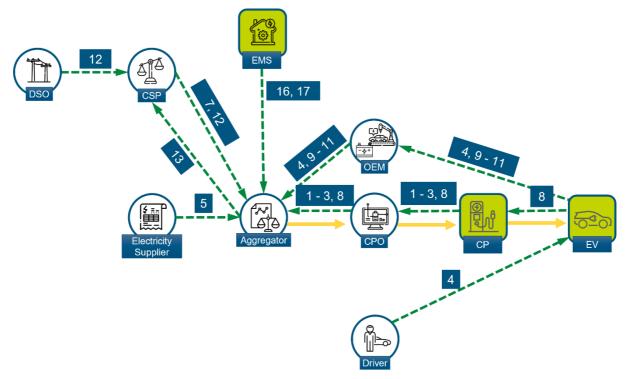


Figure 9.2 Use case, At office charging

Example characteristics:

- An office with multiple charging stations used for at work fleet charging. Charging stations are connected to the same network connection as the office building
- Fleet EVs are supplied by one OEM.
- Fleet EVs are V2G ready
- The electricity contract has a fixed price
- Office building has solar panels
- Non-Firm connection and transmission agreements
- Congestion management is possible for the charging fleet
- EV driver user preference is send through internal EV system

The use case described can implement behind-the-meter local optimization and front-of-the-meter congestion management. The office building has a fleet of EVs that are V2G smart charging ready. However, the charging stations are not V2G ready. As there is one OEM for the whole fleet, it is possible to collect battery data via a proprietary connection. Additionally, the EV driver may input the user preferences into the EV's system. For example, the time of departure could help to ensure that the EV is charged fully at the moment of departure. With the time of departure the aggregator can make optimal use of the V2G functionalities.

With an entire fleet, the aggregator can act on the basis of front-of-the-meter congestion management. With access to data such as departure time and solar panel data, the aggregator can make the most impact. For example, to complement a ramp down in a congested area, the office building could stop the EVs from charging from the solar panels and feed the electricity from the panels directly into the grid with additional capacity from the V2G ready EVs. In addition to creating more impact, the data is also needed to

4 5



accurately determine the connection demand prognosis. This prognosis is needed to participate in congestion management, as the DSO needs a forecast to calculate congestion areas.

A non-firm connection and transmission agreement incentivises local optimisation to reduce capacity peaks. For example, in a situation where the maximum fuse capacity might be sufficient to support all EVs charging at the same time, a non-firm agreement gives the authority a reason to reduce the capacity needed to reduce the grid tariff by implementing smart charging. Without a non-firm agreement, there would be no incentive to apply smart charging based on the capacity used.

At road AC charging

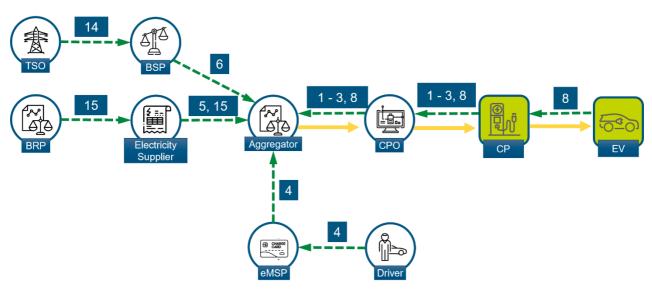


Figure 9.3 Use case, At road AC charging

Example characteristics:

- 10 000 public charging stations located throughout a larger geographic area
- The charging stations are clustered based on grid location and on different voltage levels (More explanation below)
- The electricity contract has a fixed price
- Balancing services are possible for the charging cluster
- Non-Firm group connection and transmission agreements
- EV driver user preference is provided via an eMSP app

The use case entails large collection of public charging stations. The charging stations are located within a large geographic area and will service a variety of EVs. In addition, the charging stations will not be uniform with some charging stations V2G ready but not all. This makes it difficult to optimize for V2G within the portfolio of all charging stations.

In order to participate in balancing services, the charging stations within the portfolio are strategically grouped together, forming clusters. This clustering is essential to ensure adequate capacity for participation, as there is a minimum requirement of 1 MW. Figure 8.4 illustrates the clustering of electric vehicles (EVs) at various voltage levels. Larger clusters of EVs offer increased flexibility for participating in balancing services. However, limitations in capacity may restrict participation with higher-level clusters. Therefore, it can be advantageous to establish clusters at different voltage levels to optimize participation opportunities.



To participate in balancing services it is necessary for the aggregator to know the connection demand prognosis. The prognosis is needed since it is used as reference point for the TSO to determine the degree of participation in balancing services.

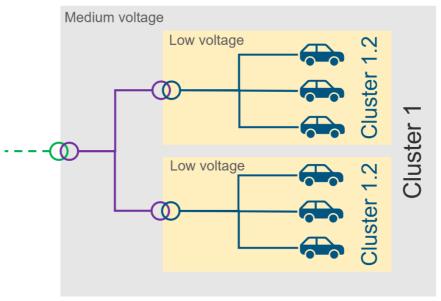


Figure 9.4 Schematic representation of EV clusters

By default, individual grid connections are assessed for connection and available capacity separately. However, congestion within a grid area is not solely determined by the consumption of a single connection; it's influenced by the total consumption of all connections within that area. Given the complexity of grouping connection and transmission agreements, especially when dealing with firm combined capacities, DSOs may find it challenging. A non-firm agreement, coupled with a group agreement, facilitates the merger of connections into an existing pool, easing the process for DSOs.

Introducing a mechanism to cluster grid connections into a virtual maximum would empower commercial entities such as aggregators to offer enhanced services to EV drivers, particularly in congested areas, as they can prioritize drivers based on need. The needs of drivers will be known by aggregators through the eMSP app.



At Road DC charging



Figure 9.5 Use case, At road DC charging

Example characteristics:

- DC charging located besides a highway
- One connection with multiple charging stations
- The electricity contract has a fixed price
- Firm connection and transmission agreements
- Behind-the-meter local optimization is applied to prevent exceeding the connection capacity

In this scenario, the charging stations are situated alongside a highway, providing DC electricity primarily for drivers during their journeys. The objective here is to ensure quick charging sessions with minimal driver intervention. Consequently, smart charging services are utilized to optimize local energy consumption, preventing any overloads on the connection capacity and ensuring efficient charging times.

Given the focus on swift charging experiences, non-firm connection and transmission agreements are deemed less effective. As a result, the incentives offered by non-firm agreements are insufficient in this context.



Behind-the-meter clusters

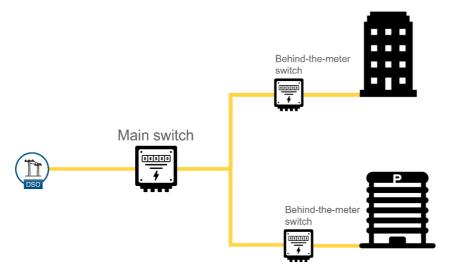


Figure 9.6 Example behind-the-meter cluster

The figure above illustrates a simple example of a behind-the-meter cluster setup. In this scenario, there is a main connection to the DSO. Behind the main connection, there are multiple individual connections, each with its own meter, functioning independently. The details of how this setup is implemented in the reference architecture are described below.

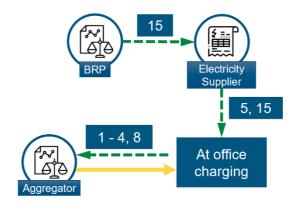


Figure 9.7 behind-the-meter clusters

Example characteristics:

- Behind-the-meter are additional connections with their own meters. For example, a business park with its own electricity network. Each business has its own connection to track its electricity consumption.
- Each individual business connection may have a different setup. One may have a fixed-price electricity contract, while the other may have dynamic pricing.
- The business connection is similar to the use case for charging at the office.
- Firm connection and transmission agreements between the business park grid and the DSO.
- Business park capacity is shared between the businesses on the park.

In this scenario, multiple connections must work together to ensure that the capacity of the fixed connection is not exceeded. Load balancing is similar to Figure 8.4. A behind-the-meter clustering mechanism allows



the aggregator to improve services. It helps to prioritise the charging of EVs according to the needs of the drivers.

The reference architecture at the different business connections may be different. However, they will receive control signals from a central aggregator to ensure that the overall capacity limit is not exceeded.



10 Conclusions and recommendations

The aggregator plays a key role in bringing together the electricity and e-mobility sectors. It is through this entity that the two separate domains can be integrated, allowing EVs to access the electricity market and make a positive contribution to the electricity system.

In the framework of market roles shown in Figure 9.1, the aggregator has a central position. It is responsible for smart charging and, thanks to this central position, can create value for both the electricity and the mobility sectors. Previously, the responsibility for smart charging within the electric transport domain was often attributed to the CPO role. Even though the CPO and Aggregator role are often fulfilled by the same party, this report proposes to put the smart charging responsibility solely with the aggregator. This distinction is made because of the pre-existing legal definition of the aggregator role within the European electricity domain, which is expected to accelerate the integration of EVs into the electricity grid.

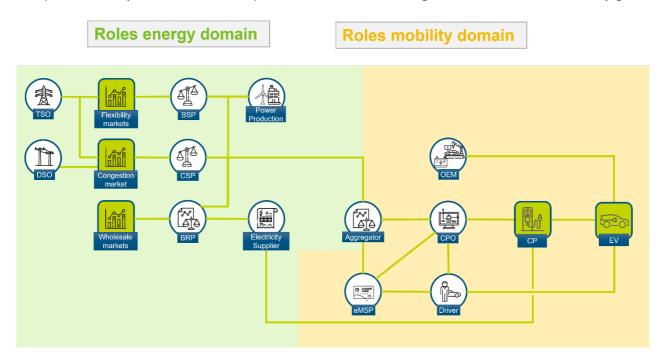


Figure 10.1 Market roles

Although the aggregator plays a central role between the two domains, it does not have direct access to all the data needed for smart charging. It is therefore crucial that data exchange is established without hindering the potential benefits of smart charging. However, there is currently no standard data protocol for data flows to the aggregator. The OpenADR and OCPI protocols are considered possible candidates to fill this gap, but they are not yet widely used and standardized for smart charging in terms of data exchange with the aggregator. In addition, there is already a high level of standardization of data protocols in the electric transport domain. However, the adaptation of V2X is partly hampered by the lack of access to battery data from electric vehicles. The ISO15118 protocol makes it possible to obtain battery data from EVs, but it has not yet been widely adopted. The most well established protocol for smart charging is the OCPP protocol, used for communication between the CPO and CP, which is supported by nearly all charge stations in Europe.

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Besides the lack of protocols, there is also a significant regulatory vacuum regarding smart charging and DSOs. While TSOs, BRPs, BSPs and energy suppliers have a legal basis to support control activities, DSOs do not have the same legal basis across the EU. As a result, the application of smart charging by DSOs in the European Union is currently very limited.

Based on the above findings, the following recommendations are made to promote smart charging and V2X. A first recommendation concerns the protocols needed to promote smart charging across Europe. This includes promoting protocols for communication with the aggregator. It is important to consider standardisation across the European Union. This will allow parties to fulfil the aggregator market role in different Member States. In addition to promoting a protocol to the aggregator, it is important for V2X that access to battery data is enabled. Due to the slow adoption of ISO15118 (see Section 6.2.2), it is essential that an alternative route through the OEM is made possible to fill this gap for the coming years. It is important not to create an alternative protocol to ISO15118, but to require the OEM to enable data sharing via (custom) APIs (some OEMs already have such APIs available).

Another suggestion is to provide a legal basis for DSOs to incentivise EVs to prioritise grid-friendly capacity requests. This could be achieved by adapting the legal framework to include non-firm connection and transmission agreements offered by DSOs. Under this arrangement, there should be an economic benefit to the optimal use of available capacity. Under this non-firm agreement, grid owners would pay for the bandwidth of capacity used in the electricity system, which could prove to be significantly more cost-effective than traditional firm connection and transport agreements. While the specifics of these agreements may differ between Member States and among DSOs, the essential aspect is to establish a legal framework that permits such non-firm arrangements.



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