Flexible energy systems Leveraging the Optimal integration of EVs deployment Wave

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Common smart charging definition

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List of Acronyms

Acronym	Meaning
AC	Alternating Current
AEV	All-Electric Vehicle
BMS	Battery Management System
BEV	Battery Electric Vehicle
CPO	Charging Point Operator
DC	Direct Current
DER	Distributed Energy Resource
DSO	Distribution System Operator
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EMSP	Electro Mobility Service Provider
FCEV	Fuel-Cell Electric Vehicle
FHEV	Full-Hybrid Electric Vehicle
V1G/G2V/CC	Grid-to-vehicle / Unidirectional Controlled Charging
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
MHEV	Mild Hybrid Electric Vehicle
MID	Measuring Instruments Directive
OCPP	Open Charge Point Protocol
OSCP	Open Smart Charging Protocol
OCPI	Open Charge Point Interface
PHEV	Plug-in Hybrid Vehicle
POD	Point of Distribution
SOC	State-of-charge
SOH	State-of-health
TLS	Transport Layer Security
TSO	Transmission System Operator
UC	Uncoordinated Charging
UX	User Experience
V2B	Vehicle-to-building
V2G/BC	Vehicle-to-grid / Bi-directional Coordinated Charging
V2V	Vehicle-to-vehicle
VGI	Vehicle-Grid Integration
WP	Work Package

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Executive Summary

The main aim of this deliverable is to lay down potential requirements for smart electric vehicle supply equipment (EVSE), concerning three aspects.

Firstly, we discuss the communication requirements. The EVSE needs to be able to connect to the internet or to an external control system, and this connection needs to be secure. Safety and interoperability should be supported by adopting accessible and standardized communication protocols for smart charging.

Secondly, we investigate dynamic charging control, first by defining how it differs for AC (on-board), and DC (off-board) charging. Then, we try to give recommended values for the time responsiveness of the EVSE in transmitting or activating the charging setpoint to the EV, and the granularity of the control with respect to the charging current.

Thirdly, we list the recommended parameters that should be measured and available to the EVSE and the smart charging actor, in order to optimize the charging session. Meter requirements according to the metering infrastructure directive and data storage and resolution are also discussed.

It must be noted that, listing the requirements is only a preliminary step in defining the concept of a "smart" EVSE. The following one should be the creation of a timeline for the EVs to follow those recommendations. Finally, a laboratory test protocol to check for compliance with the requirements also needs to be created.

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1. Background and Objectives

This deliverable lists the general requirements of a "smart" electric vehicle supply equipment (EVSE), which must be fulfilled in order to support the VGI services explored by FLOW – and listed in D1.3.

The purpose of listing these requirements is twofold.

Firstly, it allows FLOW partners to coordinate on the capabilities and properties needed for EVSEs used in the project's demonstration activities. Features such as the use of communication protocols, data measurements, response times and control granularity will have a bearing on the services which are implemented and tested in the project.

Secondly, the list of requirements can serve as an input to European legislation on what expectations should be put on contemporary charging equipment now and in the following years. This may be important to ensure a consistent and universal support of VGI across different brands and models of EVSEs.

We will present a number of requirements, either agnostic to unidirectional (V1G) or bidirectional (V2G) power control, or specific for V2G. These requirements are in different implementation stages, i.e., some of them are already met, whereas other features are still far from being available.

Our aim is to define what a generic smart EVSE "should" be, without defining a specific implementation timeline, and setting a baseline reference for the future work that will be performed in the FLOW project, which may experimentally prove that these limits have to be changed, in order to provide smart charging services.

It must be also remarked that, in the future, several sub-requirements considering both the charging type (AC or DC), and power directionality (uni or bi-directional) will probably be added. Especially DC V2G EVSEs may introduce more control capabilities and safety considerations.

The work presented in this deliverable draw from several projects and documents, such as SCALE D1.5 [1], Elaadnl Smart Charging guide [2], the National Agenda Charging Infrastructure (NAL) Smart Charging Requirements [3], the Flexible eMobility Reference Architecture Deliverables 1.1 and 1.2 [4], and the Italian Electrotechnical Committee Regulation 0-21, Attachment X "Electric Mobility Infrastructure Charge Controller" [5].

The deliverable has met all the objectives described in the task description.

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2. Requirements Overview

Here the authors start with presenting the three types of requirements that a contemporary smart EVSE should meet – namely relating to communication, dynamic charging control, and data and measurements. These are illustrated in the figure below. Further detail is provided in sections 3 to 5.

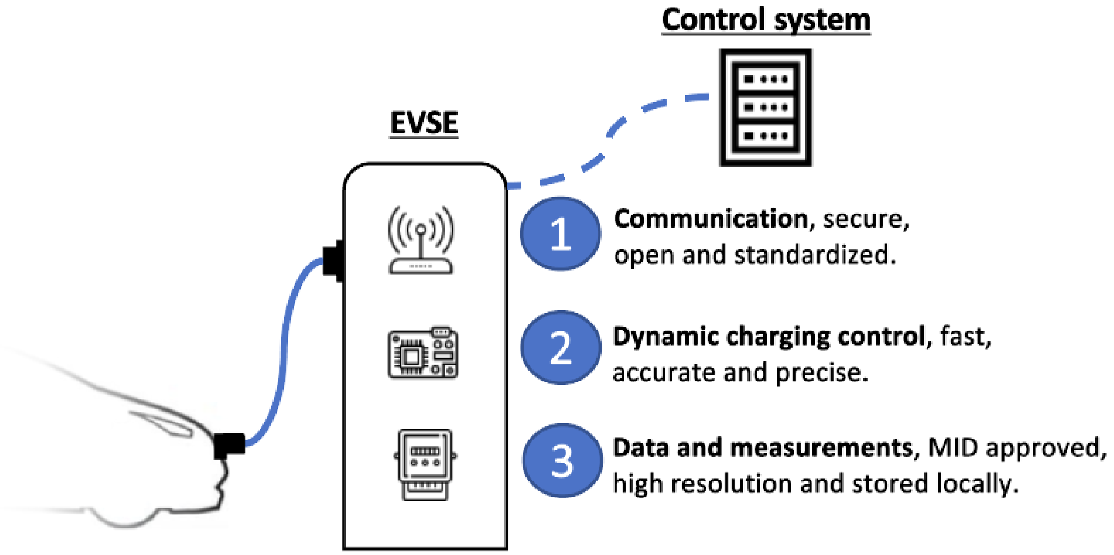

Figure 1. The three types of requirements for a smart EVSE.

Table 1. Smart EVSE Requirements (both already available and still in the implementation phase).

Type	Requirement	Description
Communication	Connected EVSE	The EVSE must be able to connect and stay connected to the internet, preferably through a cabled or 4G connection, and exchange information with both a local and an external control system.
	Security	The connection must use encryption and authentication to protect data, software, and interfaces. The best level of security should be targeted, preferably following the recommendations from ISO 15118-20, using TLS 1.3 certificates.
	Openness and standardization	The EVSE must use accessible and standardized protocols to support the communication between the EV and the EVSE. IEC 61851 should be considered as a fallback option, hence more advanced standards, such as ISO 15118-20, should be implemented. EVSE-CPO communication should be performed through the most updated OCPP version, which in the foreseeable future could be OCPP 2.0.1. It is also worth to mention the

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		IEC63110 – currently under development – that could be considered as a 2nd option if smart EVSE requirements were properly addressed
Dynamic charging control	Charging setpoint	A control system must be able to specify a charging power the EVSE must adhere to as an upper limit (AC), or a direct setpoint (DC). AC chargers are on-board, hence the setpoint is communicated as an "upper limit" to the battery management system, whereas off-board DC chargers can be directly controlled by interfacing to an external control signal.
	Responsiveness	For DC charging, changes in the setpoint must be fully implemented within 5 s, which happens to be slightly lower than the response time of a commercially available DC charger [6]. For AC charging instead, a change in the active charging setpoint coming from an external signal must be immediately communicated to by the EVSE to the EV's BMS, hence we propose a stricter recommendation of 1 s.
	Granularity	A charge limit or setpoint should be specified with a granularity of 1 A or less [7], [8]. This value, which is the one recommended by the IEC 61851 regulation, turns out to be a good compromise between accuracy and implementation complexity if a decent number of EVs are aggregated [9] and the charge setpoint is approximated to the closest integer value. Of course, the lower the attainable setpoint granularity, the more precise the response will be.
Data and measurements	Measurements	The EVSE's internal meter should, in addition to energy (kWh), be able to measure current (A), voltage (V) and frequency (Hz).
	MID approved meter	The internal meter should be MID (Measuring Instruments Directive) certified with an accuracy class B, or better.
	Data resolution and storage	The EVSE must be able to locally store data with a resolution of up to 1 second, correlated to a timestamp with an accuracy of at least 10 ms. Data should be transmitted to a secure location every 15 minutes, and at the end of each transaction. The local data storage should be kept for a minimum of one week, in case of EVSE malfunctioning or grid failure.

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3. Communication

The communication used between the recharging point and a trusted third-party system shall support a stable web connection, transmission security, and openness/standardisation of the protocols.

3.1 Connected EVSE

The EVSE must be connected to the internet either through a wired or wireless connection. This shall ensure that a trusted control system can access the recharging point for access to data and activation of the charge setpoint. The communication used between the recharging point and the trusted third-party system shall support interoperability and security.

The connection can be established through a wired connection (patch cable), a cellular/mobile modem (typically 4G) or through a Wi-Fi connection in a domestic environment.

While there may not be a hard requirement regarding which of the above methods the communication with the internet is established through – it is recommended to opt for either a wired connection or a 4G modem, as connection through Wi-Fi is generally seen as less reliable.

The best option would be to have redundant connections available so that, for example, a 4G modem could be used in case a cabled connection fails. This solution is however more expensive, as these practices are most commonly seen in the top range of market products only.

3.2 Security

A charging station with a connection to the Internet must always be secured against unauthorized use by implementing industry-wide security standards, protecting both the user and power grid/equipment data.

The following elements must be protected in terms of dynamic charging management of EVSEs:

- Communication and data sent to and from the EVSE.
- Data stored in the EVSE.
- Interface for managing/configuring the EVSE.

The cybersecurity issues become even more important if we consider that it should be possible to use multiple control topologies for the EV charging, and that multiple actors could be demanded the responsibility of smart charging (a CPO, the car manufacturer, the eMSP, a generic third-party provider).

<u>Data confidentiality</u> means that no third-party actor should be able to read any encrypted information in transit between two actors, whereas <u>data integrity</u> mandates the involved actors to understand if anyone has tampered with the data while in transit. Finally, <u>authenticity</u> guarantees that each actor knows the other is not being impersonated by someone else.

All the communications between the EVSE, an external control system, and a user interface must use end-to-end encryption, e.g., secure hypertext transfer protocol (HTTPS) or secure WebSocket (WSS) as both use Transport Layer Security (TLS) encryption and Public Key Infrastructure (PKI).

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At the moment, only ISO 15118-20 requires the use of TLS 1.3 client-server certificates, whereas OCPP 1.6 only requires TLS for two out of the three main security profiles that can be adopted by the involved actors. OCPP 2.0.1 introduces a security profile with a strong TLS requirement for all the involved actors, but still allows for the freedom of choice between the three profiles.

Guaranteeing these minimum cybersecurity requirements is important for:

- **the EV owners and the data stored in the EVSE:** actions must be taken so that unauthorized access to a charging station does not give access to it.
- **the power grid and equipment,** since an aggregated portfolio of EVSE connected to the electricity grid can be perceived as critical infrastructure, safety requirements for EVSEs should be higher than for ordinary consumer loads.

Mechanisms should be implemented to ensure the firmware is updated, secure boot is enabled, protection against unauthorized control attempts is active.

We can thus conclude that, a sufficient level of cybersecurity can only be partially achieved by implementing the security profiles available in OCPP 1.6 and 2.0.1. "End-to-end security" should be targeted - preferably in combination with IEC/ISO 15118-20 or future OCPP updates.

3.3 Openness and standardization

The use of common and open communication standards ensures that any third-party system can access the EVSE and apply operational setpoints. The communication should be standardized between the EV and EVSE, CPO and EVSE.

EV-EVSE Communication

The standard IEC 61851-Annex A is already used by virtually all EVs on the market for simple communication with the EVSE.

However, IEC 61851 is considered not future proof for a number of reasons:

1. It does not support bidirectional charging (V2G).
2. It does not allow for the EVSE to request information to the EV (SOC, SOH, charging efficiency, maximum current).
3. It does not allow the EV to notify the EVSE about its needs (minimum departure SOC requirements, predicted departure time).

Hence, ISO 15118-20 should be considered as a complement to IEC 61851, since it allows:

- To support bidirectional charging, and the use of the EV as a backup generator to either power up a remote load/microgrid (grid forming mode) or be used as a backup when connected to a network (grid following mode).
- Both the EV (scheduled control mode) and an external smart charging manager (dynamic control mode) to define the EV charging schedule, always considering the physical local grid limits.
- The EV to forward to the EVSE information such as the present SOC and battery capacity.
- A higher level of cyber-security (TLS 1.3).
- A more complete and straight forward identification of the EV when connected to the EVSE.

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While IEC 61851 should be considered as a fallback option and should always be available for EV-EVSE communication, we recommend that more advanced standards, such as ISO 15118-20, are implemented.

EVSE-CPO Communication

It should be set as a requirement for the Open Charge Point Protocol (OCPP) to be used to achieve interoperability for control through an external system. OCPP has been chosen since the protocol is currently the only widespread and open communication protocol able to connect any charging station to any external control system.

The last version of the protocol, i.e., 2.0.1, was released in 2018, and is not backwards compatible with OCPP 1.6 (an "old" station equipped with 1.6 will not be able to communicate with an EV that only supports 2.0.1).

We recommend that OCPP is implemented as native OCPP, i.e., implemented in the EVSE itself and not simulated through a server to mimic OCPP communication.

The main novelty points of OCPP 2.0.1 involve:

1. Support for scheduling from a local external control system: including a smart charging actor (e.g., CPO, eMPS, third-party), a home energy management system (ex. Modbus), or a grid operator (ex. OpenADR). The protocol also allows to set priorities in case contrasting schedules are received.
2. Exchange of driver's needs: including required energy to be charged, battery capacity, min/max currents, departure time. This allows any smart charging managing actor to formulate an optimal charging schedule, which is then validated by the EV.
3. Improved cyber-security: as already mentioned in section **Error! Reference source not found.**.

By the 2nd half of 2023, OCPP 2.1 should be available, and new possibilities will be included, such as: V2X operation, grid code compliance for EVs as "generating units", a possibility for the user to signal the EVSE not to perform smart charging ("priority" charging).

OCPP 2.0.1 should be the baseline (fallback) option, which must be ideally always supported by the EVSE, but we strongly recommend that version 2.1 is implemented as soon as possible, to allow for V2X operation, grid code compliance, and priority charging.

Finally, IEC 63110 "Protocol for management of electric vehicles charging and discharging infrastructures", which is expected to be completed by 2024, will try to standardize the functionalities of OCPP into an "official" technical regulation. Since most of its objectives are similar to OCPP 2.1, the two protocols are expected to overlap, hence the choice between the two should be based on their specific functionalities and scope of application.

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4. Dynamic charging control

The purpose of dynamic charging control is to operate the EV at a specific charging setpoint and set some specific responsiveness and granularity requirements with respect to the time required to pass the schedule to the EV, and the minimum change in power that can be set.

4.1 Charge setpoint

The overarching purpose of the dynamic charging limitation in AC chargers is to keep the applied charging power under a given value (a ceiling) by using the mechanisms provided by the IEC 61850-Annex A standard. This means that the EVSE sends a signal via the charging cable to the AC off-board charger, which is then obliged to adhere to this limit. However, the final charging parameters are determined by the EV's internal battery management system. The EVSE responsibility is thus limited to quickly forwarding a charging limitation to the EV. Note: the AC charger is bypassed when it is connected to a DC station.

For DC charging stations instead, the charger is in the EVSE, and the EV battery accepts whatever power request is received, respecting the constraints of the BMS. Hence, it is possible to directly control the charging/discharging power by interfacing the EVSE with an external control signal.

As far as dynamic charging control is concerned, the **Open Automated Demand Response (OpenADR)** protocol was created to provide grid flexibility services and exchange demand response signals with the DSO. The communication between the EVSE and the DSO is based on the IP addresses and is reliably implemented and commonly used in the US already.

Once the newest versions of OCPP are implemented, and the availability of more information regarding the EV needs and user preferences allows for the formulation of an optimal charging schedule, the natural evolution would be to implement one of the two CPO-DSO communication protocols for grid flexibility services provision.

4.2 Responsiveness

Responsiveness is of paramount importance to the performance of several flexibility services, most importantly the frequency related ones. Fast Frequency Reserve for example, requires a response from the EVs in the order of a few seconds, whereas Synthetic/Virtual Inertia demand an even faster response.

The signal transmission chain has to take the signal from the DSO/TSO to the aggregator, which modulates the power in response. Then the aggregator communicates with the EVSE or with the smart charging responsible, which could be the CPO, a Home Energy Management System, or any other agent. Thus, it is very important to reduce the response delay of the EVSE with regards to transmitting or communicating the setpoint to the EV charger.

The responsiveness requirements are based on the type of available EV charger:

- *AC (on-board): the delay in the application of the upper charging limit shouldn't be greater than 1 s, since the charger role is simply passing the limitation to the BMS, and additional delays could be present after that moment.*

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- *DC (off-board): the maximum delay can be looser, since the charging setpoint is directly implemented by the EVSE within the limitations of the min-max charging currents. Hence, since 7 s was found to be the typical delay of a commercially available DC chargers* [6]*, we recommend 5 s as an objective.*

4.3 Granularity

According to the IEC 61851 standard, the single-phase EV chargers should be able to modulate their power between 6 and 16 A in steps of 1 A [7], [8], which corresponds to a 230 W power in single-phase, and a 690 W power in three-phase.

For onboard charging using the pilot function described in IEC 61851 (IEC 61851-1 Annex A) it is possible to set charging limits with a granularity below 1 A. However, experimental work proved that applications such as frequency containment reserve (FCR) generally do not require a granularity finer than 1 A [9], provided a decent number of EVs are aggregated and the charging setpoint is be approximated to the closest integer value.

Nonetheless, a smaller value would benefit the provision of other flexibility services, such as local voltage regulation, where the single EV is used to stabilise the voltage at the bus it is connected to.

As such, we propose to use 1 A as a requirement for both on-board and off-board charging but recommend aiming at a lower target for an increased flexibility services provision efficiency.

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5. Data and measurements

The EVSE must be able to measure and store data that can subsequently be used to document consumption and the provision of flexibility/services. Cases where an aggregator rely on real-time measurements in its operation is not covered here – but may become relevant in the future.

5.1 Measurements

A limited number of measurements are obtained for AC charging by the EVSE through its communication interface with the EV and its internal meter:

1. **[From the EV]:** Connection state [True/False], whether an EV is connected and ready for charging. Maximum current [A] the EV can draw from the grid. These values are both obtainable through the commonly available IEC 61851 interface.

- **[From the meter]:** Amperage [A], electrical current per phase, Voltage [V], at the meter's point of connection, Active Power Load [kW], Energy [kWh], total charged energy.

However, as previously mentioned, current and future versions of the communication standards will allow the EVSE to obtain a greater number of parameters:

- ISO 15118-20: present SOC, battery capacity, required energy to be charged in the EV.
- OCPP 2.0.1: required energy to be charged, battery capacity, min charging current, departure time.

We would thus recommend the following additional measurements to be made available, in order to perform all the flexibility services listed in FLOW's D1.3.

From the EV:

- **Battery SOC [%]:** current state of charge of the EV, minimum required departure SOC.
- **Battery SOH [kWh]:** theoretical and currently available battery capacity, to limit degradation.
- **Vehicle Identification Number:** identification number of the EV connected to the charging station, as recommended in ISO 15118-20.

From the grid meter:

- **Frequency [Hz]:** either coming from a centralized measuring device, or a local one (as in OCPP 2.1).
- **EV Active Power Load [kW]:** the active power load consumption of the house is relevant for congestion management services, particularly for vehicle-to-building services. This value is generally provided by most EVSEs, but should be mandatory.
- **Active Power Exchange [kW]**: import/export at the point of connection, particularly relevant for voltage, frequency, and congestion management services.
- **Reactive Power Exchange [kVAr]**: import/export at the point of connection, particularly relevant for voltage and congestion management services.

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5.2 MID approved meter

The European Measuring Instruments Directive (MID) describes the approval procedure for measuring instruments – including electricity meters.

The use of MID can ensure that the meters used in charging stations are reliable and accurate enough to both document delivery of flexibility services and be able to document the delivery of effect-based services (e.g., frequency regulation). Moreover, the MID-certified meters are used to transfer, via the chosen communication protocol (e.g., OCPP), the energy consumption to the transactions recording system, so that it can be used as part of the final settlement of expenses.

Thus, we propose as a requirement that a smart charging station must contain a meter that meets the MID Class B executive requirements.

5.3 Data resolution and storage

The EVSE must be able to store data points with a resolution of up to one second. These values must be associated to a UTC time stamp with an accuracy of 10 ms or better.

We recommend that the data is transferred to a secure location every 15 minutes, which is a good tradeoff between data accuracy and size management, and at every transaction end time. In the event of EVSE failure or grid outages which will prevent data from being transferred, it is recommended that a minimum of one week of data can be stored locally on the EVSE.

Additionally, the EVSE internal clock should "keep the time" for at least one week and synchronize the internal clock at least every 24 hours, in order to avoid timestamp conflicts issues.

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6. Further requirements

Before 2030, it may become relevant to set more requirements for charging stations. These requirements may either be specific to V2X, which is the charging policy all of the protocols are trying to implement, or not.

6.1 V2X Requirements

The overarching direction of all the aforementioned EV charging communication protocols goes towards the implementation of V2X as a policy to be available in each charging point.

Hence, we think it might be interesting to list some of the future requirements that V2X-enabled EVSE will need to fulfil:

1. **V2X status notification:** the EVSE should clearly display its capability of applying V2X and notify the user that V2X is ongoing. This allows the EV owner to consciously decide whether he/she wants to participate (transparency).
2. **G2V/V2G alternation**: it should be possible to both charge and discharge the EV during the same session, so it is possible to tap into the full capabilities of the battery storage, even after the SOC reaches the upper limit.
3. **G2V/V2G billing:** separate registers in the same meter should be used to keep track of the charged/discharged energy, since the tariffs could be significantly different.
4. **Anti-islanding protection:** specific protections should be available when the EV is used to energize a house or a part of the grid, in case of fault conditions.
5. **Grid-code compliance:** since the EV becomes a source of active power, grid-code compliance should be required, following the most updated local technical regulation.

6.2 Future functionalities

Additional functionalities should be implemented to expand the range of services the EVs can provide:

- **Dynamic charging control** – directly specifying the set point for active charging power in AC chargers (not just as an upper charging limitation).
- **Power factor regulation** – regulation of reactive and active charging power.
- **Reactive power regulation** – independently from the active charging power.
- **Automatic voltage regulation** – voltage regulation as a function of active and reactive power.

Finally, in order to avoid the synchronization of a huge number of chargers, we recommend that two additional requirements are implemented:

- **Ramp function maximum rate** – define the maximum rate at which the charging power follows the setpoint [kW/s].
- **Randomized time delay function** – introduce randomized time lags in the change of power [s].

These would allow to avoid the synchronization of EV loading, and the overcompensation of imbalances on the network.

Stricter requirements can also be placed on control resolution, accuracy, precision, and activation time, to allow for a wider range of flexibility services to be implemented.

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Finally, in order to allow for free roaming of the EVs in the European network, the **Open Charge Point Interface (OCPI)** protocol was formulated, as a means to bridge the gap between the CPOs and eMSPs operating in the different EU countries. While still not widely implemented, OCPI could greatly benefit the EV owners and remove one of the greatest barriers to EV diffusion.

7. References

[1] J. Meersmans and F. Geerts, "SCALE D1.5 - Analysis of hard- and software requirements," 2023. Accessed: Jun. 30, 2023. [Online]. Available: https://scale-horizon.eu/?jet_download=5762

[2] F. Geerts *et al.*, "Smart Charging Guide - Elaadnl," 2020. Accessed: Jun. 14, 2023. [Online]. Available: www.elaad.nl

[3] NAL Working Group, "NAL's Smart Charging Requirements (SCR)," 2022.

[4] NKL Nederland, "Flexible eMobility Reference Architecture & Information Objects ECISS DELIVERABLE 1.1 & 1.2 Flexible eMobility Reference Architecture & Information Objects - D1.1 and D1.2," 2020.

[5] Italian Electrotechnical Committee, "CEI 0-21, Attachment X, Definition of an EV Charging Controller," 2023.

[6] A. Zecchino, A. Thingvad, P. B. Andersen, and M. Marinelli, "Suitability of Commercial V2G CHAdeMO Chargers for Grid Services," in *Proceedings of EVS 31 & EVTeC 2018*, APA, 2018.

[7] M. Marinelli, S. Martinenas, K. Knezović, and P. B. Andersen, "Validating a centralized approach to primary frequency control with series-produced electric vehicles," *J Energy Storage*, vol. 7, pp. 63–73, Aug. 2016, doi: 10.1016/J.EST.2016.05.008.

[8] M. M. N. Rezkalla, A. ; Zecchino, M. ; Pertl, and M. Marinelli, "Grid Frequency Support by Single-Phase Electric Vehicles Employing an Innovative Virtual Inertia Controller," *Citation*, 2023, doi: 10.1109/UPEC.2016.8113980.

[9] C. Ziras, A. Zecchino, and M. Marinelli, "Response accuracy and tracking errors with decentralized control of commercial V2G chargers," *20th Power Systems Computation Conference, PSCC 2018*, Aug. 2018, doi: 10.23919/PSCC.2018.8442488.

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