

Standards for EV charging and their usability for providing V2G services in the primary reserve market

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Summary

Transition to sustainable energy and transport is inevitable, which brings new challenges for the existing power grid. Meanwhile, electric vehicles (EVs) are becoming more widespread and their potential for grid support services is becoming more evident. However, such intelligent integration of EVs into a smart grid is highly dependent on infrastructure and communication. This work overviews and analyses the current state of available standards in the field of eMobility. It particularly focuses on their usability for enabling V2G services such as primary frequency regulation.

Keywords: smart grid, V2G (vehicle to grid), standardization, electric vehicle, communication

1 Introduction

As electric vehicles are becoming widespread, the future of transportation is becoming sustainable and emission-less. However, this transition in the transportation sector could create problems of increased loads in power systems. At the same time, power systems are transitioning to accommodate more stochastic renewable energy sources, which add the need for additional balancing power in the grid. One challenge could be turned into a solution to the other one: if intelligently integrated, EVs can provide solutions to existing and future grid problems, aiding renewable energy integration. EVs could support multiple grid services in both, transmission and distribution level, such as frequency regulation or local network balancing [1][2]. These services are identified and investigated in the NIKOLA project [3]. Some standards have already been analyzed for their ability to be used in grid services such as smart charging [4][5][6][7]. The goal of this paper is to give an overview of how well existing eMobility standards are suited for providing grid services by looking at the example of primary frequency regulation in Denmark and US. The paper is divided into following sections: firstly, the existing standards and specification in the eMobility infrastructure are introduced in Section 2; secondly, the protocols and implementations of V2G service provision are described in Section 3; thirdly, the V2G services are matched against the eMobility standards and specifications in Section 4; lastly the gaps and improvements are identified and summarized in the conclusion.

2 Standards for eMobility infrastructure

While active eMobility development has started not too long ago, each communication link in the infrastructure is already covered by a standard or a specification. This section will introduce and describe all charging related standards and specifications shown in the Figure 1. The figure represents a part of eMobility infrastructure that is relevant for grid service provision i.e. only the actors that are able directly influence the charging process. It consists of electric vehicle (EV) connected to the charging point electric vehicle supply equipment (EVSE). An EVSE is electrically connected to the grid and has a communication link to the charging point operator and aggregator. The role of the aggregator is to combine and control (dis)charging of a large number of EVs to provide grid services, while still satisfying individual user driving goals.

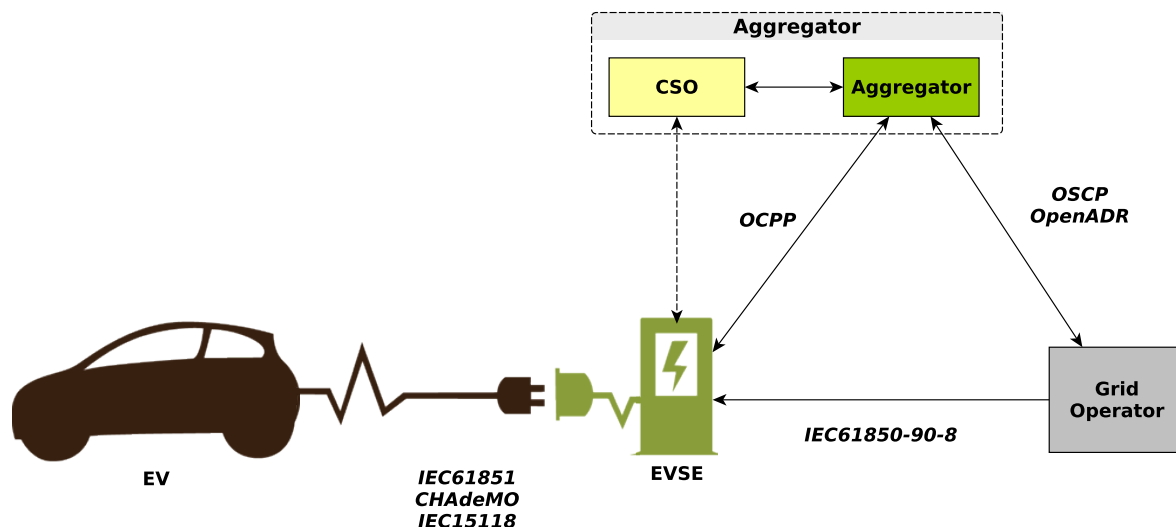


Figure 1: EV charging infrastructure with communication standards and specifications

2.1 EV to EVSE communication

The only physical communication link in the eMobility infrastructure is the link between EV and electric vehicle supply equipment (EVSE). It is mainly covered by IEC 61851 standard for AC charging and CHAdeMO specification for fast DC charging. Meanwhile, a new emerging standard called IEC/ISO 15118 is covering both AC and DC charging.

The IEC 61851 is a basic EV to EVSE communication standard defining the basic physical and safety requirements to enable EV charging. The communication according to this standard is done using a low level pulse width modulation (PWM) signal and voltage levels on a control pilot (CP) pin. After the vehicle has connected, the duty cycle of the PWM signal is indicating the maximum charging current in amperes the EV can charge with. This current limit can be dynamically adjusted by changing the duty cycle of the signal and the vehicle has to respond within 3 seconds. Additionally, the cable presence is indicated by plug present (PP) pin, which contains a resistor connecting to protective earth (PE) pin. The value of this resistor indicates the maximum current rating for that cable. It should be noted that there is an extension of this standard - IEC 61851-1 Edition 3 Annex-D, which extends the physical layer and adds minimal higher level communication descriptions. The US counterpart of this standard is called SAE J1772.

The ISO 15118 standard emerged to close the gap in communication requirements between EV and EVSE, defining the information transfer from EV to EVSE. The standard builds on top of the IEC 61851 and uses it as a fallback communication option if either party does not support the new protocol. The communication link is established using powerline communication (PLC) on top of the PWM signal running on the CP pin, that is the physical layer of the standard. On top of that an elaborate high level communication takes place, based on TCP/IP network setup with possible security features like transport layer security (TLS). The application layer of the communication protocol includes many information objects for existing and future eMobility services. Current implementations of the standard include such features as charging scheduling and identification for automated billing. Future implementations will include important features for grid service provision such as reactive power compensation and V2G support.

CHAdeMO is a protocol for a quick charging for electric vehicles, delivering up to 62.5 kW of high-voltage direct current (DC) via a special electrical connector. This protocol is the most widely deployed

DC (charging mode 4) fast charging protocol in the world. The communication is done using a familiar control area network (CAN) bus. Latest edition of the CHAdeMO specification added the possibility for bidirectional power transfer thus allowing V2G support.

As IEC 61851 was designed primarily to enable safe operation of EVs and EVSE while charging, it can only indicate the maximum limit of the charging current. Currently, only CHAdeMO specification actively allows bi-directional power flow thus enabling the use of EV battery for V2G services. Meanwhile, the future version of IEC/ISO 15118 will also expand the protocol to support such services.

2.2 Back-end communications

Communication between EVSE and EVSE operator (charging spot operator (CSO)) is not standardized yet. However, a popular specification called open charging point protocol (OCPP) is becoming a de-facto industry standard for this communication link. Additionally, an extension of a popular smart grid communication standard IEC 61850-90-8 has been made to extend a communication link from grid operators directly to EVSE. Multiple other specifications such as open smart charging protocol (OSCP) and open charge point interface (OCPI) are emerging to cover some missing links in eMobility back-end communications.

OCPP specification is developed by Open Charge Alliance (OCA) and meant for charging point to charging point operator communication [8]. It is primarily developed for charging point maintenance and operation, thus supporting many features like diagnostics, reservation, charging authorization and scheduling. This analysis is based on OCPP 1.6 specification.

A recent extension of a substation automation standard IEC61850 defines the information objects to control EV charging as distributed energy resource. A big part of IEC61850 and IEC61850-7-420 already covers eMobility domain, therefore IEC61850-90-8 mostly brings missing information objects such as EV and the EVSE nodes and means for charging scheduling.

As communication between EV aggregators/charging point operators and grid operators is a relatively new link, it is not yet covered by a standard. OSCP is also developed by OCA and is one of the first specifications that define the communication between CSO and grid operator e.g. distribution system operator (DSO). The DSO indicates the available grid capacity as a 24 hour prediction to the Charging Point Operator, which then distributes it by adjusting the charging rates.

Another specification that fits the needs of link is OpenADR [9]. It is developed to provide standardized communication protocol between grid utilities, operators and demand response (DR) providers helping facilitate automated demand response. It is not specifically meant for eMobility applications, but is designed to be generic enough to support many DR resources.

While back-end communications are a relatively new but actively developed area, with the most protocols being produced as specifications and are frequently updated. Such dynamic development allows for easy new feature introduction and bug fixing. Therefore back-end protocols are quickly enabling the features needed for V2G service provision.

3 EVs providing V2G services in Denmark and the US

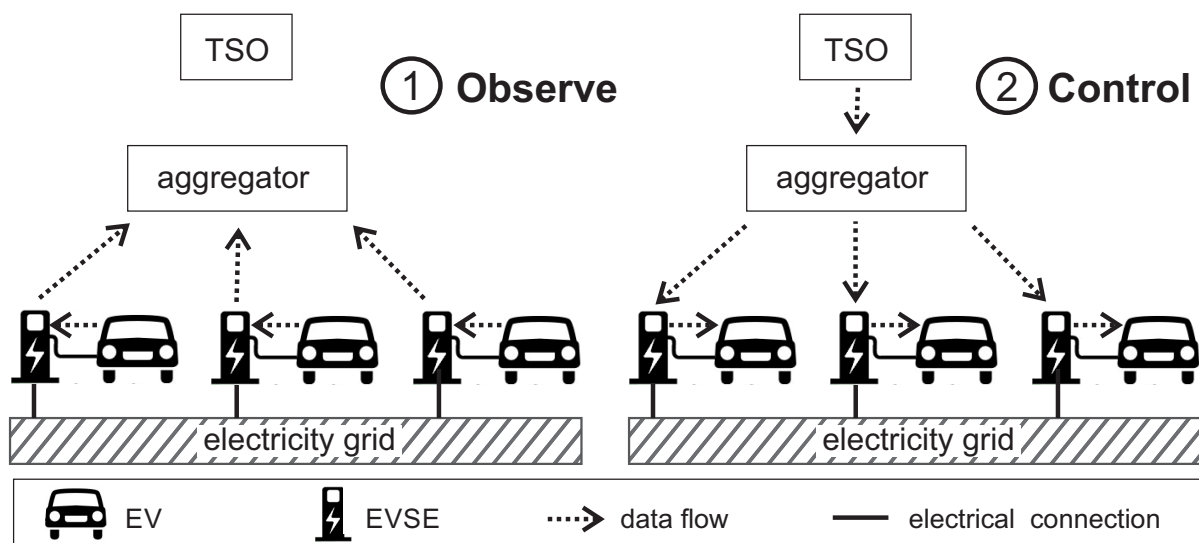


Figure 2: Interactions between aggregator, EVs and grid operator

At the University of Delaware (UDel) and Technical University of Denmark (DTU), researchers are providing regulation as ancillary service for the transmission system operator (TSO) by controlling the bidirectional power transfer between a fleet of EVs and the grid. At DTU the primary frequency reserve is provided in Energinet.DK grid [10]. At University of Delaware the synchronous reserve is provided in the PJM grid. To operate an EV fleet as regulation reserve, an aggregator uses 2 steps: (1) collect data from individual EVs and (2) control their (dis)charging power based on a TSO signal, see Figure 2. This TSO signal represents the imbalance on the grid, which needs to be restored by up-regulation (charge less or inject more) or down-regulation (charge more or inject less). At DTU, the TSO signal is a grid frequency measurement, where a value below 50Hz requires up-regulation, while a value above 50Hz requires down-regulation. In the rest of this section, each step is described, together with the key properties required from the used communication protocols.

3.1 Collect data from EVs

In order to calculate optimal control signals in step 2, the aggregator needs to gather as much information as possible from individual EVs. In this paper, we divide EV parameters in three groups: essential, quality-improving and optional parameters. These three categories of parameters are presented below: Essential parameters:

- Min. and max (dis)charging power
- State of charge in kWh
- Indication of plugged-in car
- Vehicle Identification Number

Quality-improving parameters:

- Required energy for driving
- Departure time

Optional parameters

- Car make and model
- Odometer reading
- Battery temperature

Essential parameters are required to provide regulation services. Without these parameters, even a basic operation is not possible. Quality-improving parameters are parameters that improve the quality of the provided regulation services. These parameters can improve the quality of service up to 25% [11]. Optional parameters are used for improving overall operation of the EV fleet, but have little influence on the quality of the provided regulation services.

3.2 Control EV (dis)charging

To control EV (dis)charging, the aggregator calculates control signals based on the information observed in step 1. For each EV a control signal is calculated, which is typically expressed in Watt. The main goal in this step is transferring the control signal, calculated by the aggregator, to each individual EV in a minimal time interval. In general, this time interval can be expressed as:

$$\tau_{total} = \tau_1 + \tau_2 + \tau_3 + \tau_4 \quad (1)$$

,where:

- τ_1 is the time required for transferring the TSO signal to the aggregator.
- τ_2 is the time required for communicating the EV control signal from aggregator to EVSE.
- τ_3 is the time required for communicating the EV control signal from EVSE to EV.
- τ_4 is the time required for the converter to ramp up or down the EV (dis)charging power.

The response delay directly influences the quality of service at both Energinet.DK and PJM. For providing the service at Energinet.DK grid, a response between 15-30 seconds is required. At least half of the reserve needs to be deployed within 15 seconds, while the rest of the reserve can be linearly interpolated response between 15 and 30 seconds Figure 3.

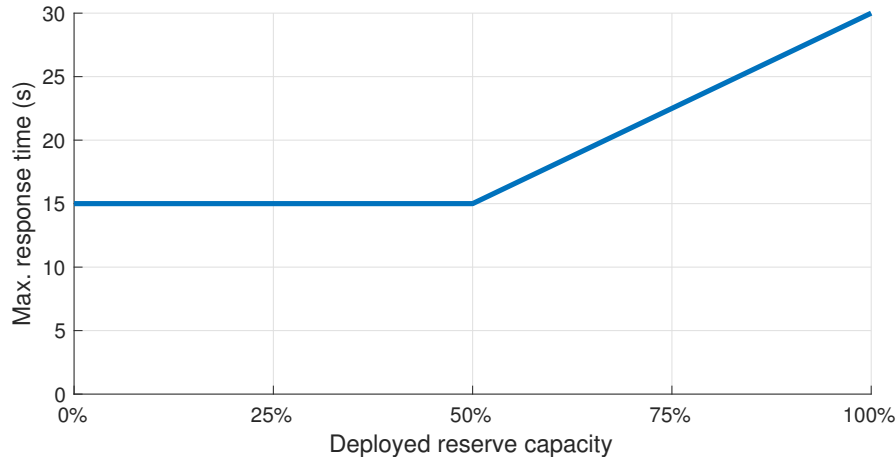


Figure 3: Ramping rate for a primary frequency reserve in DK2

When providing the service in the PJM grid, a performance score is calculated, which is used to measure the quality of service. This performance score consists of three components:

Correlation Quantifies the correlation between the requested regulation and the response of an EV fleet.

Time delay The time delay between requested regulation and a change in the response of the EV fleet.

Precision The difference between the requested regulation power and the provided regulation power.

The performance score is a scalar in the interval $[0..1]$, calculated every hour by PJM and reported back to the University of Delaware. At the university, researchers are seeking to have a score above 0.9 to maximize their earnings. This entails a highly correlated response, 1-3 seconds delay and 1-5% difference between request and response Figure 4.

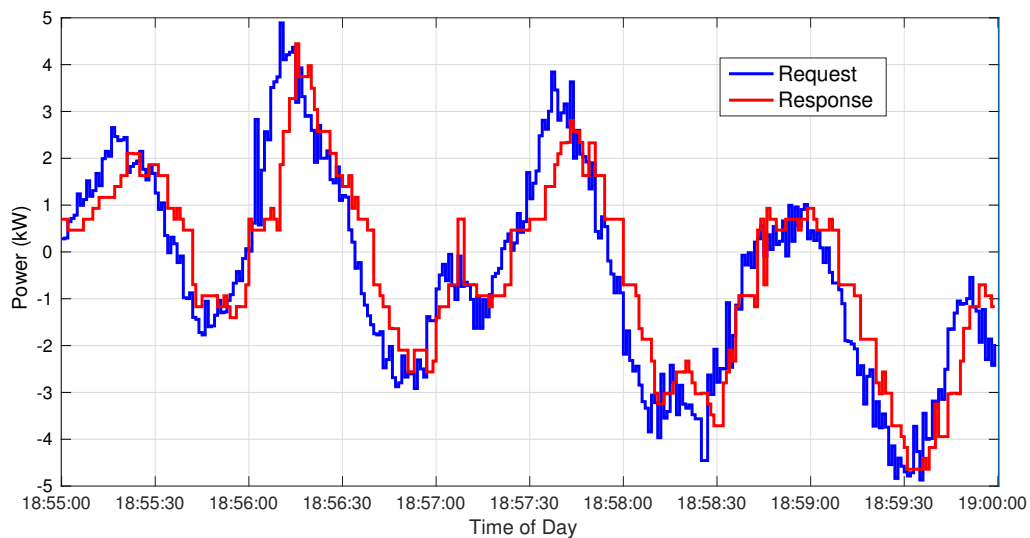


Figure 4: Example request and response curve for PJM grid service

4 Usage of standards for EV charging to provide V2G services in a primary reserve market

This section describes how the above mentioned standards can be used for providing V2G services in a primary reserve market. An overview of EV to EVSE communication standards with the highlighted features for grid service provision is shown in Table 1 and the same overview for EVSE to Aggregator in Table 2. Some parameters such as required energy for charging and departure time are implicit as part of the charging schedule feature. The values in brackets indicate that the feature is partially present or optional. The response times are maximum values taken from the standards.

Table 1: EV to EVSE communication standard/specification overview

Standard/ Specification	Power Control	V2G	SOC	Charging Schedule	Identification	Response Time
IEC61851	+	-	-	-	-	< 3s
IEC15118	+	(+)	(+)	+	+	< 60s
CHAdemo	+	(+)	+	-	-	< 1s

Currently widespread, IEC61851 charging standard is not well suited for providing precise grid services as it is missing almost all required features, because most implementations do not include digital communication. While IEC15118 appears to be almost ideal for grid service provision, the response time specifications for most requests in the current revision is way too slow. Additionally, SOC field is only optional, therefore not included in most implementations, and V2G specific fields are still left to be defined in the future revisions. Similarly, latest CHAdemo version includes V2G messages allowing bidirectional power flow, which enables it to provide symmetrical power services. However, it is missing such important features as build-in vehicle identification, possibility for charging schedule negotiation and communication security. Therefore it heavily relies on the need of user interaction and security of the physical connection.

Table 2: EVSE to aggregator communication standard/specification overview

Standard/ Specification	Power Control	V2G	SOC	Charging Schedule	Identification
OCPP	+	-	-	+	-
IEC61850-90-8	+	(+)	(+)	+	-

On the EVSE to aggregator communication side, the protocols are not as mature and developed as in the EV to EVSE link as this link is relatively new. OCPP was primarily developed by charging station operators. Additionally, OCPP is a specification developed by industrial alliance, therefore it is updated more often than a standard. Meanwhile, IEC61850-90-8 looks like it was developed to provide electrical services as it includes many electrical properties and a scheduling possibility.

As communication between the grid operators and aggregators is not standardized, in addition to more generic OpenADR, the EV specific OSCP was developed as one of the first attempts to make a specification for this link. Although it primarily covers only grid overload problem it is a good example of how the rest of grid services could be implemented.

5 Conclusion

As described in this work, most V2G services already provided in the real electricity grid are using existing eMobility standards to some extent. However, a unified approach that could incorporate the needed informational objects while being lightweight is still missing. As shown in Section 4, none of the standards cover all the required features to provide grid services. This issue is actively addressed in the research and demonstration projects like NIKOLA, where the findings are then forwarded to standardization committees such as IEC TC69. It should be noted that transition to smart grid and larger share of renewable energy sources is only starting, therefore current definitions of grid services will change. Meanwhile, it can already be predicted that the services will become more dynamic i.e. requiring faster

response and better precision. The analysis of the existing standards shows that only fast DC charging currently has the ability to provide future services. However, slower AC charging should not be dismissed, while the timing constraints for AC chargers are more relaxed, technically the built-in chargers are able to show the same timing performance as the DC charging systems. Another important issue, that is currently hindering the grid service provision by the EVs, is a lack of V2G protocol support in the charging communication. However, as noted in this paper, most standards are starting to incorporate the missing information objects in the latest revisions. Additionally to existing solutions from other emerging smart grid technologies like OpenADR, new EV focused specifications are starting to emerge e.g. OSCP and fill the communication gaps in the eMobility infrastructure. Finally, as most communication protocols become high level, data security problem arises. So far, only a few standards e.g. IEC15118 include security requirements as a part of the protocol specification, where most rely on implicit security of the communication link, which cannot always be guaranteed. Overall, the provision of existing grid services using EVs has already started and is largely implemented using current standards and their modifications that bridge the existing gaps. However, as the share of renewable energy in the grid will grow, the regulation services will become more dynamic and the standardization has to lead this change.

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