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Implementation of E-mobility architecture for providing Smart Grid services using EVs

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Abstract

This paper outlines the implementation and testing of a part of the e-mobility infrastructure relevant for providing smart grid services. The implementation is made using mainly open standards and protocols available in e-mobility field e.g. IEC61851 and Open Charging Point Protocol (OCPP). Implementation and testing results are described in detail emphasizing the shortcomings and needs for improvement. The testing is done using unmodified OEM vehicles participating in existing power grid services such as frequency regulation and load balancing.

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

1 Introduction

While EVs are largely viewed as additional loads on the transforming power grid, if intelligently integrated, they could provide solutions existing and future grid problems, e.g. aiding large scale renewable energy integration. EVs could provide higher quality grid services on transmission and distribution levels, such as faster frequency regulation and local grid balancing [1],[2]. These services were identified and implemented in the NIKOLA project [3]. Large scale application are currently being implemented in the Parker project [4]. To provide these grid services, various implementations of e-mobility charging architectures have been introduced. These charging and communication architectures are largely based on available e-mobility standards and specifications. Previous works have identified potential gaps in many of the communication standards and specifications for grid service provision [5], [6]. The goal of this work is to analyze an implementation of a part of e-mobility architecture using latest available open standards and specifications. Following the introduction the paper is divided into 4 sections. Section 2 presents the e-mobility architecture and discusses the relevant parts of it for implementation. Then in section 3 the implementation of the architecture is discussed. Section 4 discuses the the gaps in the used communication protocols and the way they are covered. Finally, the findings are summarized in the concluding section 5.

2 E-mobility architecture

E-mobility has a quite broad definition as it encompases all of the electric transportation. However, in the case of this work e-mobility is only concerned with electric vehicles also known as electric cars. An example of e-mobility architecture developed in COTEVOS project [7] is shown in Fig.1.

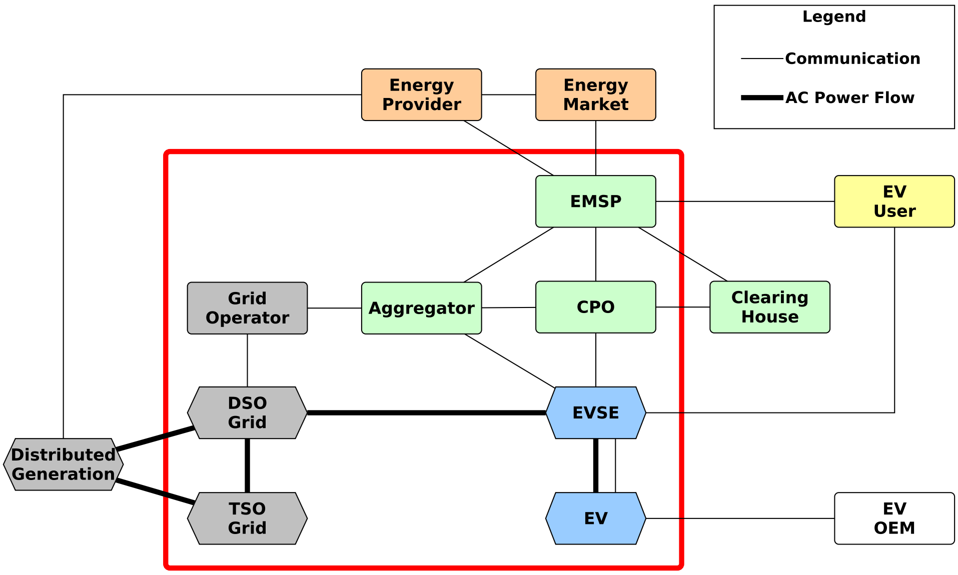

Figure 1: Updated E-mobility reference architecture from COTEVOS project showing actor/interface layer

The relevant part of the architecture for smart grid integration of EVs is highlighted in red. The communication protocols between the actors in the architecture are shown in Fig.2.

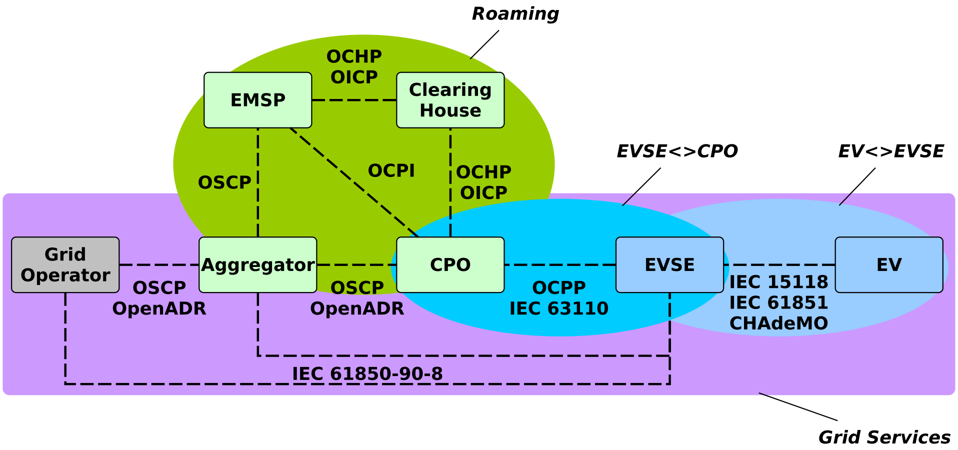

Figure 2: E-mobility architecture with communication protocols

The figure is an extension of overview presented in a EV related protocol study [8]. Here one can notice 4 main highlighted communication areas: EV to EVSE, EVSE to CPO, roaming related and grid service communication. This work is focusing on the grid service communication protocols. As can be seen in the architecture, most communication links are covered with multiple protocols defined by standards (e.g. IEC61851, IEC15118) or specifications (e.g. OCPP, OSCP, OpenADR). However, these protocols do not fully cover all the needed information and control features for the smart grid service provision using EVs.

The following section describes the implementation details of the grid service relevant part of the e-mobility architecture including component descriptions and communication protocols.

3 Implementation

The detailed implementation diagram can be seen in Fig.3.

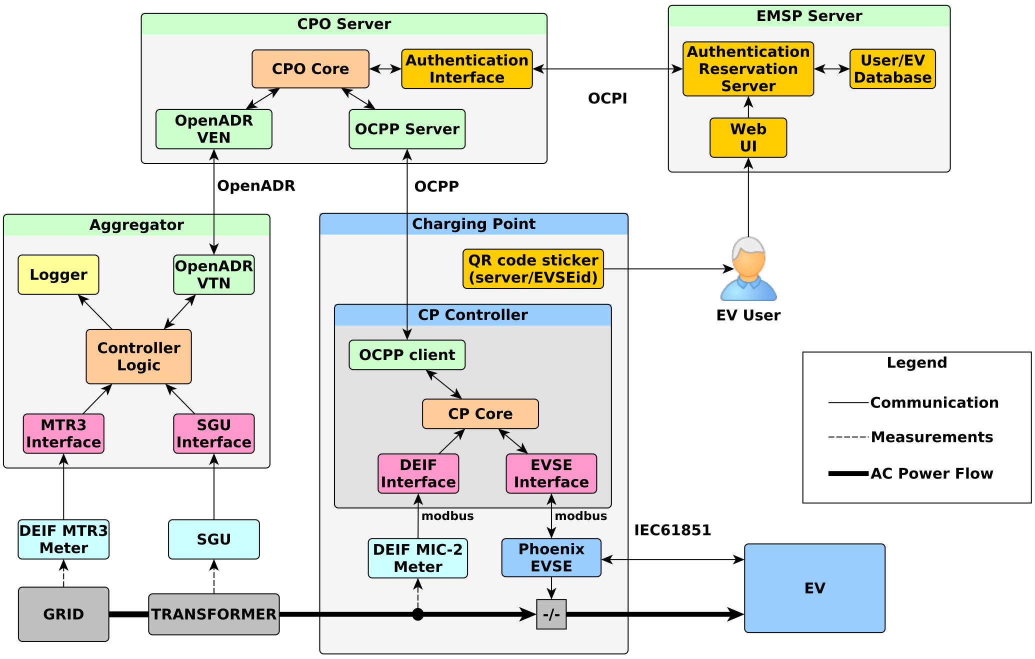

Figure 3: Detailed e-mobility architecture implementation diagram

The following actors of the architecture are used and implemented:

EV - Electric Vehicle - unmodified OEM vehicles with AC chargers using IEC61851 standard [9].

EVSE - Electric Vehicle Supply Equipment - custom made chargers assembled from off the shelf industrial components such as charge controller supporting IEC61851, relays and a microcomputer implementing OCPP version 1.6 support for the communication with CPO [10].

CPO - Charge Point Operator - controls and manages the EVSEs using OCPP protocol.

EMSP - E-mobility Service Provider - implements the actor between the EV user and a CPO, enabling charging spot reservation and charging authorization using OCPI protocol [11].

Aggregator - takes care of the communication with the grid operator and implements the smart grid service offered. The aggregator controls the vehicles via communication through CPO using OpenADR 2.0b specification [12].

The roles of the CPO, EMSP and the aggregator are split to provide modularity and ability to easily integrate with external actor e.g. another CPO.
The following communication standards are used in the implementation:

IEC 61851 - for EV to EVSE link - used as unmodified OEM vehicles, currently, only support IEC61851 standard for AC charging. The IEC61851 on the EVSE side is implemented by using Phoenix Contact EVSE controller.

OCPP 1.6 - for EVSE to CPO link - used as it is a de-facto standard for this link. Implemented in the microcomputer mounted inside the EVSE.

OCPI 2.1 - for CPO to EMSP link - chosen for the openness and maturity of the specification that covers the needs of the communication link. Implemented in the dedicated server, that also provides web interface for authorized EV users to login and enable the charging spot.

OpenADR 2.0b - for CPO to Aggregator link - chosen for maturity, openness and generic application capability. This allows for the aggregator to potentially combine EVs with other DERs to provide larger and more diverse grid services. The aggregator implements the role of the virtual top node (VTN) and the CPO implements the virtual end node (VEN). Another specification potentially fitting this link is Open Smart Charging Protocol (OSCP) [14]. However, it is mostly targeted at feeder capacity control thus limiting its' application for other grid services.

As the OCPI specification is primarily designed for roaming purposes, it is meant to support the communication between CPO and EMSP for providing grid services. Therefore, the CPO - EMSP link might use the OCPP message forwarding for communication purposes.
This setup will be used to test a few existing grid services.
The example smart grid services that are tested with the implementation are:

FCR-N - Frequency Controlled Normal operation Reserve - a DK2 reserve ensures that the equilibrium between production and consumption is restored, keeping the frequency close to 50 Hz, similar to primary frequency regulation [15].

Congestion Management - a modified charging service, used to prevent congestion on the feeder that EV is connected to.

Smart Charging - a modified charging service, meant for minimizing the charging price by accounting for actual and near future energy prices.

4 Communication

4.1 Communication requirements

It has been previously identified that the following information objects are essential for optimal grid service provision by EVs [5]. These information objects are:

(Dis)charging power limits - for estimation of EV controllability

State of charge - in kWh, for estimation of available flexibility.

Indication of plugged-in car - to determine if the charging point is occupied.

Vehicle Identification Number - or any other unique identifier needed for billing purposes.

Additionally, parameters like required energy for driving and estimated departure time are needed for estimating the available flexibility. This information greatly improves the quality of the service for the EV user.

4.2 Gaps in communication

The IEC61851 standard does not provide a digital communication link with the EV. It does however provide the indication of the plugged in vehicle and allows the EVSE to dynamically indicate the charging current limit. This functionality already enables the controllability needed for grid service provision. The lack of digital communication in IEC61851 requires alternative solutions for acquiring high level information from the EV. This functionality is important for reading the state of charge (SOC) and vehicle identification. The acquisition of the SOC information is solved by accessing it from the OEM backend. However, this feature is only available on the newer and higher end EVs. Vehicle identification is solved by prompting the user to login to enable the charging point. Vehicle model, battery size and maximum charging power is provided by the user when registering with the EMSP on the first use of the charging station. The quality improving parameters of desired battery SOC and estimated departure time may be implemented as additional user prompts in the EMSP web interface.
Actual charging rate is measured using a DEIF MIC-2 multi instrument device in the EVSE.

5 Discussion

Even though the implementation of the architecture for smart grid services currently requires many small workarounds for acquiring the necessary static and dynamic information, it is certainly possible. The standard that is posed to improve the situation and abolish the need for these workarounds is IEC15118. It enables high level communication link between the EV and EVSE and includes the majority of the use cases needed to provide grid services. However, the current edition of the standard does not position the necessary information objects e.g. SOC as a mandatory parameter. Nor does it support the time critical services by allowing for too long timeout values in the negotiation of the charging schedule.
Flexibility of the OCPP implementation permits for multiple fields in the communication messages to be optional, such as transaction identification is often a requirement from the EMSP and aggregator side. Moreover, OCPP version 1.6 still lacks the information fields to relay the necessary data from the EV to the aggregator e.g. SOC.
In addition to protocol gaps, current industrial implementations show, in contrast to architecture, no clear boundary between CPO and EMSP actors as their roles are often very much intertwined and performed by the same entity.

An important requirement that has not been in focus of this analysis is communication security. The protocols for each communication link have recommendations for securing the data exchange between the actors except for IEC61851 and OCPP. Improvements to the security of communication are promised in the OCPP version 2.0 [13].

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