OSCP - AN OPEN PROTOCOL FOR SMART CHARGING OF ELECTRIC VEHICLES

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ABSTRACT

This paper presents an open information exchange protocol for smart charging of Electric Vehicles (EVs). The Open Smart Charging Protocol (OSCP) has been implemented in a challenging and successful field project at Dutch DSO Enexis. The project was executed in cooperation with charge service provider GreenFlux, Dutch public charge station operator EVNetNL and EV public charging knowledge center ElaadNL (both part of former Foundation e-Laad), IT solution providers and charge station vendors. Through standardization of the necessary information exchange, OSCP facilitates capacity based smart charging of EVs. It is a market model agnostic protocol. By defining messages regarding available capacity of the electricity grid it is a crucial element in establishing affordable charging infrastructures without the loss of EV driver comfort. OSCP can for example be used in smart charging uses cases as presented at CIRED 2011 [1] and 2013 [2].

INTRODUCTION

Currently, public and private charging infrastructures for EVs are being deployed in many countries around the world. To avoid vendor lock-ins and costly maintenance an interoperable and open protocol has been designed to communicate with EV charge points: Open Charge Point Protocol (OCPP). Charge station operators (CSOs) dealing with the operation of charge points benefit from OCPP as they can implement one OCPP compatible back-office system and thereafter purchase OCPP enabled charge points from different vendors. It is currently used by more than 800 members in 35 countries across the world [3][4].

Building infrastructures for charging EVs is a complex task. The main aim is maximizing EV driver's convenience, by using the available charging infrastructure and local grid capacity as efficiently as possible. Through application of ICT DSOs and EV market parties can optimize the grid usage and facilitate the integration of RES. This can avoid or minimize additional investments necessary for (large scale) EV charging. This is coined as 'Smart Charging' by Eurelectric [5][6]. As described, operation of charge points benefits from the OCPP protocol but an interoperable and open protocol for capacity based smart charging is currently not available.

This results in unnecessary barriers for EV market parties and DSOs interested in implementing smart charging. As discussed in [2] implementing smart charging in a liberalized context, calls for an interaction and corresponding information exchange between many actors: DSOs, charge stations, EVs, EV drivers, energy suppliers and possibly new market participants like CSPs and CSOs. Without standardized protocols for smart charging these information exchanges will be implemented on a project and ad-hoc basis resulting in extra costs, longer implementation times and a system that is not interoperable. To deal with these issues, Enexis in conjunction with GreenFlux developed the OSCP protocol. OCSP has been developed based on the same openness and interoperability principles as OCPP.

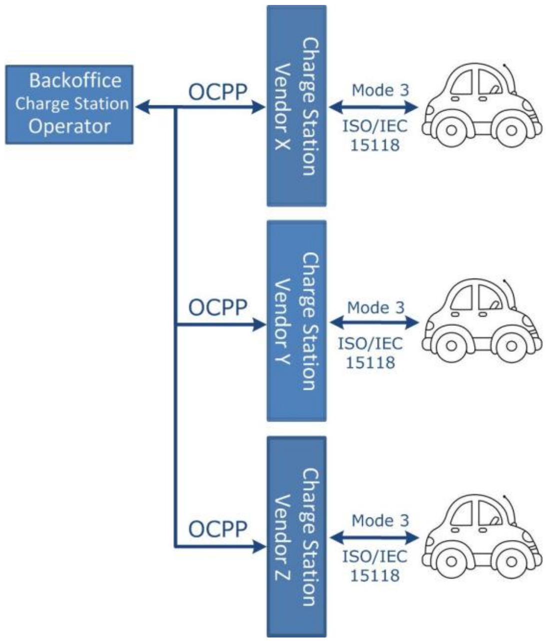

Fig 1: OCPP – vendor agnostic charge station communication

Figure 1 shows how OCPP offers charge station independent communication between charge station operators and charge stations. Herewith OCPP creates an interoperable market for charge station and back office vendors. In the following sections this paper shows how OSCP offers the same to DSOs and charge station operators that want to implement smart charging of EVs.

THE ROAD TO AN OPEN PROTOCOL FOR SMART CHARGING EVS

This section explains how the main characteristics of OSCP were derived. Firstly, it shows why OSCP is needed from a functional point of view by looking at the issues it can solve. Then an overview is given of the main requirements on the protocol based on the needs of the different actors involved in smart charging of EVs. Finally, it clarifies what approach was chosen in the implementation project at Enexis and GreenFlux and the main findings after executing this approach.

Why are smart charging of EVs and OSCP needed?

Electricity distribution grids have been deployed by utilities taking into account certain design rules:

Designed for peak usage - First of all an electricity grid is designed for peak usage. This means that the capacity of its components (mainly cables and transformers) needs to be enough to handle the biggest loads in time. The rationale for this design principle is the fact that most electric loads are non controllable by the DSO or any other actor and therefore the grid needs to be peak usage proof in order to avoid outages.

Simultaneity principle - Secondly the grid is designed in a hierarchical way where each parent node has less capacity than the sum of its children. E.g. primary substations have less capacity than the sum of their underlying secondary substations and a secondary substation has less capacity than the cables that leave the station and feed the houses connected to it. This design principle is applied because statistically, the end users of the grid (e.g. households) do not use the grid at their maximum contracted capacity at the same moment in time.

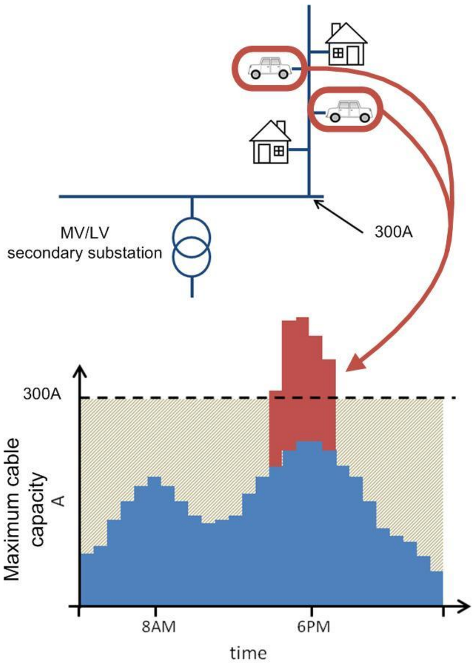

Fig 2: Impact of EV charging on LV grid operated by DSO

The cable the houses are connected to in *Figure 2* has a maximum capacity of 300A. In the picture 2 houses are shown, but in practice this can be 10 or more houses. Even if each house has a contracted capacity of 30A and we would have 10 houses, in practice they would not take 300A at the same moment in time. The blue area in the diagram shows what their total capacity usage would typically be. As shown in the picture this stays below the breaker protected capacity of 300A of the cable. If EVs would be connected to the grid they could cause problems. First of all the charging process of an EV takes hours undermining the simultaneity principle the grid design is based on. Secondly the EVs would typically be charged in the evening when their drivers come back from work. This could result in an extra significant capacity peak on a moment of the day that is already a peak without EV charging. This may result in capacity usage exceeding the breaker value. As a result the breaker would trip, leaving all of the houses without electricity supply.

One way of DSO to deal with this issue is to increase the capacity of its cables. That would however lead to an unnecessary expensive solution. One of the opportunities that charging of EVs offers, is the fact that the charging process can be controlled. Most EVs are parked for more time during the day than needed for charging them. This flexibility in the charging process can be used advantageously to use the (existing) grid capacity in a more efficient way without losing end user comfort. There is however not a standardised protocol for this purpose. The OSCP protocol has been designed to address this gap. It informs charge station operators via a forecast of the available capacity on a cable. This information can then be used by the operator to fulfil its customers wishes within the given capacity boundaries. *Figure 3* depicts what OSCP is meant for and how this could result in an EV charging related load that takes into account the available capacity.

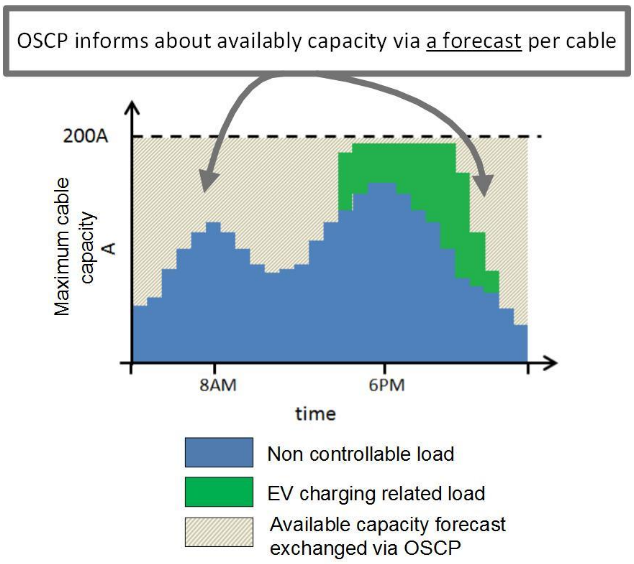

Fig 3: OSCP informs about available capacity forecasts

Requirements on OSCP and applied methods

In order for OSCP to be successful it needs to adhere to certain requirements:

Scalability – As an electricity grid will consist of a large number of cables the OSCP protocol should be scalable to deal with this. If for example 10 households are connected per cable a DSO servicing 3 million households would need to create forecast for a maximum 300.000 cables. In practice only a capacity forecast is needed for those areas where smart charging is implemented. To facilitate this, OSCP should be implemented in such a way that the DSO can exchange messages on cable level where as many cable forecasts as needed can be bundled per message.

Public, private at home – Although primarily targeted for the public charging domain the OSCP protocol should be setup in a generic way so that it can also serve private locations like parking lots and smart charging at home.

Islanding mode – Implementing smart charging implies that the electricity grid is not designed for peak usage. Instead it relies on the usage of ICT to control the load related to EV charging. As a result, the involved ICT becomes critical. The OSCP protocol should be able to deal with temporary outages on the ICT part of the solution. To avoid dependence on (costly) realtime ICT solutions, the protocol should rely on forecasts that are sent out for a time span of at least 24 hours. The updated forecasts can be sent on 15 minutes, hourly or any other convenient periods.

Market model agnostic – Although in each and one of the countries where OSCP will be implemented a country specific market model may exist, OSCP itself should be designed in a market model agnostic fashion. Herewith it can be adopted in more countries and it will be more resilient to market model changes.

Interoperability – OSCP should not impose any technological restrictions on the IT systems using it. A DSO or CSO back office vendor should be able to choose its own programming language, operating system, middleware solution, database vendor, etc. and still be able to implement OSCP in an acceptable way.

Privacy and security – Adding an ICT layer to the electricity grid facilitates smart charging of EVs. At the same time it comes with privacy and security risks that need to be dealt with accordingly. Amongst these risks one can think of energy theft to charge ones EV for free, unauthorized disclosure of personal data like information regarding when, where and by whom EVs were charged, destabilizing the (local) electricity grid by manipulating forecasts, etc. Because of the specific nature of the privacy and security related risks and the measures that need to be taken to deal with them, they are not discussed in this paper. The privacy and security aspects related to the usage of the protocol have been analysed by the digital security section of the Radboud University Nijmegen of the Netherlands in cooperation with domain experts from Enexis and ElaadNL. It has resulted in an end-to-end security design that was presented and published in December of 2014 [7].

FRAND capacity allocation – DSOs typically operate within a regulatory framework as they are monopolists in their service areas. In order to avoid misuse of smart charging it should facilitate fair, reasonable, and non-discriminatory (FRAND) capacity allocation. This is a challenge as more than one CSO could operate charge stations on the same cable. For now a solution using contracted capacity and historical usage on cable level as main variables for capacity allocation is used. In the future this might change based on regulation or country specific market choices. The protocol exchanges the result of the capacity allocation algorithm and is therefore resilient to changes in this area.

Implementation of OSCP in The Netherlands

During the design phase OSCP has been tested intensively in a smart charging implementation project, including the development of a smartphone app that enables interaction with the EV drivers and the adaptation of the OCPP 2.0 software of charge stations [8] so that they can handle smart charging related messages. This was done by Last Mile Solutions, a Dutch company specialized in the field of remote management of charge stations. *Figure 4* depicts the systems that were designed and developed to implemented smart charging using OSCP.

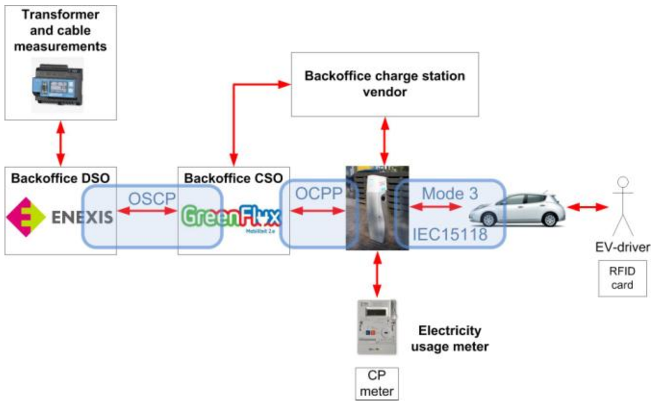

Fig 4: System overview OSCP implementation project

The main actors in smart charging using OSCP are the back offices of the DSO (in this case Enexis) and the CSO (in this case GreenFlux). In order for DSO Enexis to be able to send out the available capacity forecasts a forecasting algorithm has been defined. The algorithm has been implemented in a system that Enexis will use within its smart grid to make use of controllable loads: Enexis / Electricity Load Management Optimizer (ELMO). Charge station operator GreenFlux has implemented a system that can handle the capacity forecast messages from the DSO and use them whilst interacting with the EV drivers and the charge stations. The main goal of GreenFlux is to charge the EVs taking into account the capacity boundaries without its drivers loosing comfort, both in public and private areas. *Figure 5* shows a functional overview of the different components and the messages they exchange. During approximately one and a half year the system was designed, developed and tested.

Software engineering methodologies were used that take into account the challenges that come with an innovative domain like smart charging.

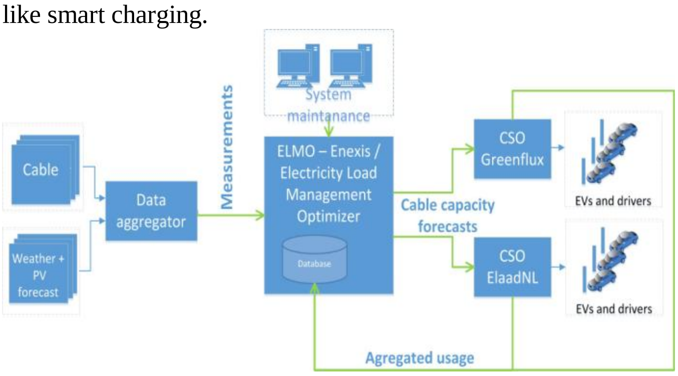

Fig 5: Functional overview systems implementation project

Through a so called agile approach the messages that should be exchanged were discovered and improved step by step. The results of these efforts are shown in the next section. Besides the messages that the OSCP protocol consists of, the DSO and CSO need to implement functionalities into their respective back offices in order to produce and consume these messages. As stated before Enexis developed ELMO for this purpose. ELMO is a system that is able to generate cable capacity forecasts for the next 24 hours. To do so it uses a mathematical algorithm that takes into account historical usage of the cable. It can also take local weather forecasts into account. *Figure 6* shows how the forecast of one of the cables looks like. In this case it concerns a cable at a private parking lot in Den Bosch on the 16th of December of 2014. The three solid lines correspond to the forecast of each phase and the three dashed lines correspond to the measured values on each and one of these phases. The forecast is done for the non controllable loads, in this case the usage of the cable excluding smart charging of EVs. The available capacity consists of the maximum capacity of the cable minus the forecast minus a safety margin to deal with inaccuracies in the algorithm.

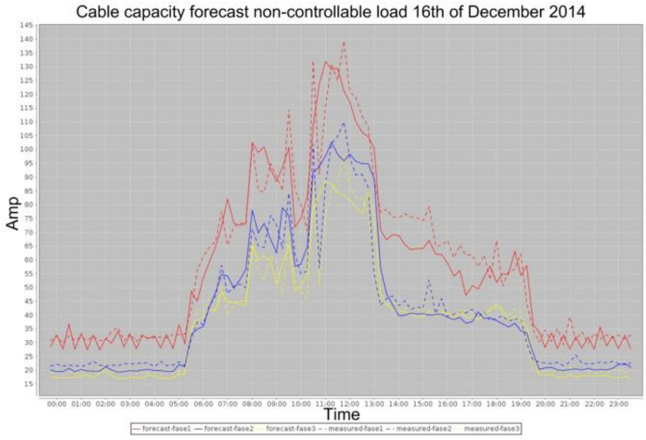

Fig 6: Example cable capacity forecast as generated by ELMO

RESULTS

After extensive verification and testing efforts, the first version of OSCP has been finalized. It facilitates the communication of forecasts of available cable capacity. *Figure 7* illustrates the core elements of OSCP and the parties involved in the information exchange. OSCP consists of two main messages that are explained briefly in the next paragraph: UpdateCableCapacityForecast and RequestAdjustedCapacity. OSCP enables a DSO to communicate in the same way with different CSOs operating in its region. The same holds for CSOs that operate in multiple regions that belong to different DSOs. In the picture below the interaction between the CSO and the charge station goes via OCPP en between the charge station and the EV via Mode 3 or ISO/IEC-15118. OSCP would however also work with other protocols. The main results of the project are the message definitions and the standardization of the protocol. These results are presented in the next section.

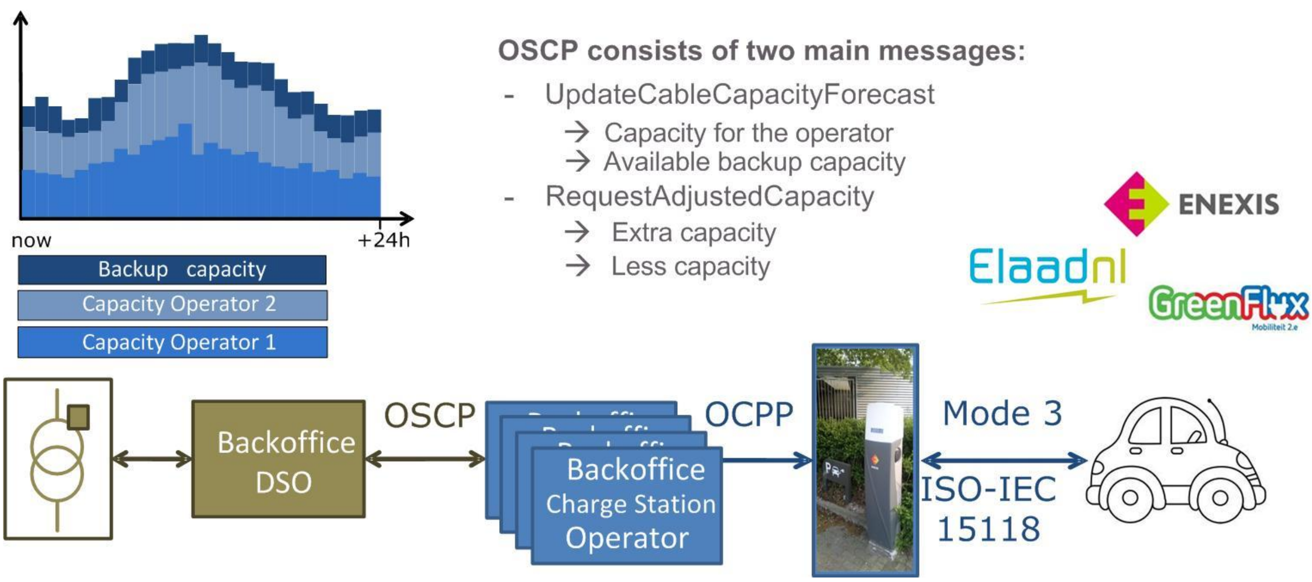

Fig 7: Depiction of the Open Smart Charging Protocol (OSCP)

OSCP messages

OSCP consists of two main messages:

UpdateCableCapacityForecast – This message is meant for the DSO to send out the forecasted cable capacity and the backup capacity to the CSO. Currently a frequency of sending out one forecast per cable per 15 minutes has been implemented. However, the frequency is not being mandated by the protocol. It is up to DSOs and CSOs to determine what frequency works best for their situation. The backup capacity is available for the CSOs so that they are able to request extra capacity when necessary. Currently the DSO assigns backup capacity to CSOs applying a first come, first served strategy.

RequestAdjustedCapacity – This message is meant for the CSO and enables a CSO to request extra capacity when necessary. The DSO can then decide, based on availability, to adhere to this request. The CSO could also use this message to return capacity to the DSO so that other CSOs can use it. In the future there could be a financial or other type of incentive to encourage this.

Besides the two main messages, OSCP contains three additional supporting messages:

GetCapacityForecast - This message enables a CSO to request a new forecast. This service only contains a request to which the answer will be an OK. Subsequently the DSO calls the UpdateCableCapacityForecast service for the corresponding CSO. DSOs and CSOs can decide whether to implement this optional message or not.

UpdateAggregatedUsage - This message is for communicating the total usage per CSO back to the DSO. This information is necessary for the DSO to verify how much capacity each CSO has used. Furthermore, it can be used by as an extra variable in the capacity allocation algorithm.

Heartbeat – This message enables the DSO to let the CSO know that the forecasting algorithm is still running and forecasts are being sent out periodically. Furthermore, the DSO uses this message to inform the CSO the time interval between each forecast it will receive so the CSO can act accordingly.

The specification and documentation of the 1.0 version of OSCP is available online for OCA members [8] and can be used by parties willing to implement OSCP.

Standardisation of OSCP

Based on the wide adoption of the OCPP protocol and the growing number of parties using it an organization was founded in 2014 to deal with further standardization of the protocol: Open Charge Alliance (OCA). With more than 50 members representing different stakeholders in the EV charging domain the OCA will promote the use and further development of open and interoperable EV charging related standards. As OSCP has been designed with the same principles in mind Enexis, GreenFlux and ElaadNL submitted this protocol to the OCA for standardization. OSCP was accepted by the OCA at the end of 2014 and its first version is now available to the OCA members. At the current stage of OSCP OCA offers a good balance of pragmatism and adaptability to develop a protocol like OSCP. Nevertheless, the OCA is not an official (international) standardization body. In the future the OCA members will evaluate if and when OSCP should be submitted to an official standardization body like the ISO/IEC.

CONCLUSION

The introduction of EVs leads to both challenges and opportunities. Smart charging enables an efficient usage of the electricity grid and charging infrastructure. It facilitates an affordable and reliable integration of electric loads that come with charging of EVs. OSCP is an open en interoperable protocol that enables DSOs and charge station operators to implement smart charging in a consistent way. It avoids specific and more costly implementations between individual DSOs and charge spot operators. Furthermore, back office vendors will have an increasing stimulus to implement smart charging in a standardized manner as adoption of the OSCP protocol grows. Although not addressed in this paper, an end-2-end security design has been produced that helps EV market parties implementing smart charging in a secured and privacy enhanced manner.

DISCUSSION

Although the C in OSCP stands for Charge it might as well have been Capacity as the protocol can be used for more generic purposes than capacity based smart EV charging only. It could also be used to exchange cable capacity forecasts in other domains where controllable loads are available. One can think of heat pumps, air conditioners and smart appliances inside houses that are disclosed via a Home Energy Management System. There the role of Charge Station Operator could be fulfilled by a Flexibility Operator or Aggregator where the households have a contract with.

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