Using OpenADR with OCPP

Combining these two open protocols can turn electric vehicles
from threats to the electricity grid into demand-response assets

Auke Hoekstra (Eindhoven University of Technology), Rolf Bienert (OpenADR Alliance),
Arjan Wargers (E-laad Foundation), Harmeet Singh (Greenlots), Paul Voskuilen (Alliander)

Abstract

If you are responsible for any part of the electricity grid, you are probably aware that a large share of renewable electricity and electric cars could lead to imbalances, blackouts, and force you to make large investments.

You are probably also aware that smart grids and demand response are a cost effective solution to this potential problem. This is made possible if electric cars with all their inherent power, storage and flexibility could become demand-response assets.

This paper shows you how to do this by combining the leading open protocol for demand response (OpenADR 2.0) and the leading open protocol for charging electric cars (OCPP).

We conclude by presenting a project using the approach outlined in this paper.

Keywords: Demand response, electric vehicles, open protocols, OpenADR, OCPP, smart grids, smart charging.

The Challenge

Facilitating the new reality of solar, wind and electric cars

Managing your grid is not what it used to be. Consumers are increasingly producing energy using solar panels. They also want to charge electric cars, which can use just as much electricity as all other appliances in a household combined. Electric cars also cause a sharp spike in energy use, right at the time when the grid is already taxed most. This challenge is compounded by large wind- and solar farms that deliver intermittent energy.

Your grid has to balance these new demands, but we all know how sensitive the grid is to peak loads. So before you know it, some unhappy combination of wind, solar and electric cars could lead to a blackout on your watch.

Solar cells have become *a* thousand times cheaper in the last 35 years and in the long run solar and wind are expected to be our dominant sources of energy. The coming years will probably see a quick ramp up in terms of installation.

Electric cars have appeared on the radar with cars like the Tesla Model S, which consumer reports said was the best car ever tested. By now almost every major manufacturer has a factory churning out electric cars, and "Dieselgate" has spurred on this development.
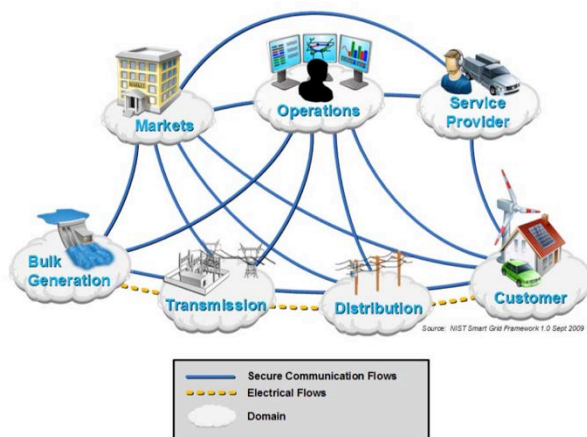
Electric cars are here to stay because of a combination of a 3x more efficient engine with cheaper, lighter and more durable batteries. A recent article in Nature concluded that light and durable lithium batteries had become four times cheaper in the last ten years alone and the trend is continuing undiminished for the forseeable future with developments like the Tesla Gigafactory. This combination is quickly making electricity the most suitable form of energy for cars.

So the challenge is clear: facilitate large amounts of clean energy production and consumption while at the same time keeping grid investments low.

Demand Response with OpenADR

Using OpenADR to tap into customer flexibility

The grid transports electricity from people who produce it to people who use it. The picture below provides a high level overview of this system: currently most energy is generated in bulk (left side of picture) and is transported using large transmission lines and smaller distribution networks until it arrives at the customer (right side of picture). Markets ensure optimal prices, operations ensure everything is running smoothly, and service providers offer deals to customers.

Source: NIST Smart Grid Framework 1.0 Sept 2009

However things are changing on the customer side. More and more households have a solar panel or a windmill that produces energy and an electric car that uses a large amount of energy can potentially cause problematic moments. This means clean energy and less addiction to fossil fuels but it also can cause unpredictable supply and demand on the edges of the electricity grid with increasing potential for imbalances that can cause a blackout.

Of course you could increase the capacity of the power lines but a more effective way to solve the problem is by using Demand Response (DR). Demand Response means that you use the flexibility that the consumer has available to minimize the mismatch between supply and demand.

Open Automated Demand Response (OpenADR) is an open and standardized way for electricity providers and system operators to communicate Demand Response (DR) signals with each other and with their customers using a common language over any existing IP-based communications network, such as the Internet. As the most comprehensive standard for Automated Demand Response, OpenADR 2.0 has achieved widespread support throughout the industry. As of this writing, there have been over 95 certified vendor implementations of OpenADR 2.0, from a number of companies including: Honeywell, AutoGrid, and IPKeys on the server end, and Greenlots, Universal Devices, and Fujitsu on the client side. (see http://products.openadr.org/)

OpenADR is most commonly being used in peak load management programs. However, the last few years have seen an increasing uptake of the standard for fast DR programs and auxiliary service which deploy DR resources within seconds to balance inconsistent generation from renewables. Distributed energy resources (DER) management and electric vehicle charging are also key aspects in many recent trials.

OpenADR 2.0 can communicate event messages, reports, registration services, and availability schedules for price- and energy usage-based programs.
(Download the full specification here)

A little history of OpenADR

The California energy crisis of 2002 served as the impetus for the effort that ultimately led to the creation of version 1.0 of the OpenADR standard. The Demand Response Research Center (DRRC), which is operated by Lawrence Berkeley National Laboratory (LBNL), created the standard with funding from the California Energy Commission's Public Interest Energy Research (PIER) program. Shortly after 2002, the DRRC worked with the California Investor Owned Utilities (IOUs) (Southern California Edison (SCE), San Diego Gas & Electric (SDG&E) and Pacific Gas & Electric (PG&E)) to jointly develop this technology through pilots and actual program implementations.

In 2009, OpenADR was included in the Smart Grid Interoperability Standards Framework, and the Federal Energy Regulatory Commission (FERC) identified OpenADR as a key standard for Demand Response. Additional standards work was performed by the Smart Grid Interoperability Panel (SGIP), which is being tasked by the U.S. National Institute of Standards and Technology (NIST) to oversee standardization of the Smart Grid.

The North American Energy Standards Board contributed to the effort by developing a set of requirements. The work to create version 2.0 of the OpenADR standard was performed by OASIS through its Energy Interoperation Technical Committee with assistance from the Utilities Communication Architecture International User Group's (UCAIug) OpenADR Taskforce. The OpenADR Alliance then took over and created the now common OpenADR 2.0a and 2.0b Profile Specifications with the accompanying certification programs. The mission of the OpenADR Alliance is to foster the development, adoption, and compliance of the Open Automated Demand Response (OpenADR) standards through collaboration, education, training, testing and certification.

Once work was completed on OpenADR 2.0, the standard was submitted to the International Electrotechnical Commission in Europe for adoption worldwide. IEC is the world's leading organization for international standards for all electrical, electronic and related technologies. OpenADR 2.0 is now available as IEC/PAS 62746-10-1.

OCPP to Manage Charging Stations

Electric vehicles can threaten the stability of your grid, but with OCPP you can turn them into demand response assets.

If OpenADR does demand response for "ordinary" appliances like air conditioners, why not electric vehicles (EV's)?
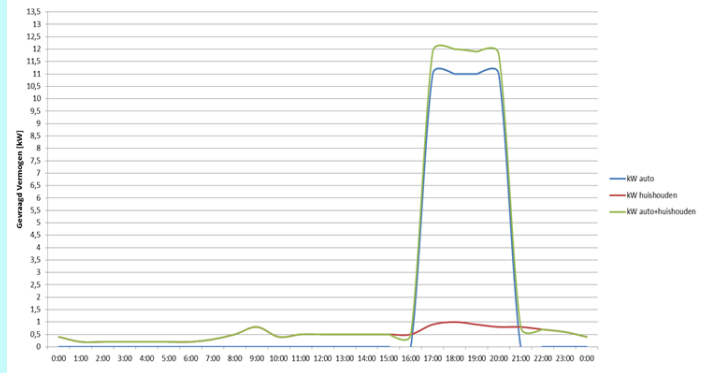
EV's are different from other appliances in that they can move around from connection to connection. Furthermore modern cars are highly intelligent and rather 'talkative' machines. They also often use a separate appliance called a charging station point to connect to the grid. This is where OCPP comes in.

OCPP gives the owners of charging stations the ability to monitor their charging stations remotely and to authorize usage. It is an open standard, independent of any charging station vendor or back-office system. The new version 1.6 makes it easy to conduct so called *smart charging.* Smart charging means that you can postpone or throttle charging behavior based on things like grid load and the availability of cheap and clean intermittent energy. Smart charging EV's is useful because they are more powerful and flexible than any other end user appliance connected to your grid (see intermezzo to the right).

A household with an electric car doubles its electricity use and when everybody plugs in their cars around the time they come home it could easily overload the electricity grid. On the other hand, when electric car batteries can be used as demand response or even vehicle to grid (V2G) assets they could instead help to balance the grid. This would improve resilience, prevent blackouts, enable larger amounts of renewable energy, and lower costs.

The impact of electric vehicles on the electricity grid

Load profile of an average household combined with a EV charging with 11 kW (3 phases 16A)

If we look at an average household in the USA it uses about 10.000 kWh of electricity while car use accounts for 30.000 kWh. If the cars become electric, their energy use drops to 7.500 kWh. So even though energy use would greatly decrease, household electricity use could increase by 75%.

(For Europe averages are 3.500 kWh for the home, 10.000 kWh for the gasoline car and 3.000 kWh for the electric car.)

Now let's illustrate the impact of an EV using a Tesla Model S. It has a 400kW motor and 20kW charger while a group of average households rarely peaks above 2 kW per household. Imagine everybody plugging in their Tesla at the same time…

But a car is also extremely flexible because it is usually parked more than 90% of the time. So if you see a peak in charging, chances are that most users are not inconvenienced if their charging is delayed by a couple of hours (especially if you give them an overrule option on their smartphone).

Even more becomes possible if the battery can also deliver power *to* the grid. This is called Vehicle to Grid or V2G. Tesla has recently started to sell a 10 kWh stand-alone battery for your home that essentially provides this functionality. Imagine what you could achieve using the much larger batteries in cars…

A little history of OCPP

The Open Charge Point Protocol (OCPP) was developed in 2009 in the Netherlands by the ElaadNL foundation, a collaboration of Dutch grid operators. They wanted an open standard that connected electric vehicles to back-office systems and the grid without lock-in by charge point vendors. The success surprised even the developers and the standard quickly became the de facto open standard in the industry, especially after bankruptcies in the USA illustrated the vulnerability of propriety standards.

In 2013 the Open Charge Alliance (OCA) was founded, bringing together EV charging hardware and software vendors, and charging network operators. OCA's mission is to foster global development, adoption, and compliance of the Open Charge Point Protocol (OCPP) and directly related standards through collaboration, education, testing, and certification.

One of the major improvements in OCPP 1.6 and 2.0 is native smart charging support.

It consists of 5 message sets that enable sending one or more load curve profiles to a charge point (CP) and receiving a charging schedule or need from the CP. The transaction ends with the central system sending a charge curve profile to the CP.

Combining OpenADR with OCPP

Let's walk through the process of combining OCPP and OpenADR to turn electric vehicles into demand response assets. You can refer to the schematic for a visual overview.

Our process flow starts after someone installs a charging station and configures it on an OCPP central server. There are two distinct methods for enabling charging stations on OpenADR:

1. Every Charging Station is registered with the OpenADR Virtual Top Node server
2. OCPP central server registers with the OpenADR Virtual Top Node server as an OpenADR Virtual End Node (VEN) and aggregates the participating charging stations.

The remainder of this document is based on the approach #2 above.

Register Charging Stations as a demand response asset

The charging station can use the OCPP message **BootNotification**. This is usually done using a secured over-the-air Internet connection and allows the charging station manufacturer to transmit all relevant aspects of the charging station to the back office system of the operator. Through this message the charging station is fully registered without the need for time-consuming and error prone manual data entry. From now on the charging station can be managed using OCPP with respect to things like starting and stopping transactions, remote problem solving and billing.

In order to use the charging stations in the context of OpenADR the charging station operator must come to an agreement with a party that uses OpenADR and has an interest in managing the charging stations as demand response assets. In this example we assume that this party is the grid operator.

The charging station operator and grid operator agree on a set of rules that can be applied to the charging behavior of charging stations. The MarketContext attribute that is part of every OpenADR message is used to map the right charging stations to the OpenADR signals from the grid operator and thus the agreed on rules are applied.

Now the charging stations have become demand-response asset in the OpenADR system (VTN) of the grid operator. In OpenADR terms the back office of the charging station operator now functions as a VEN and registers with the OpenADR Virtual Top Node server using *EiRegisterParty* registration service.. The OCPP central server will be able to translate OpenADR event signals into valid OCPP smartcharging messages and send those to the relevant charging stations on its network.

Start Transaction

In order to start charging the EV user presents identification to the charging station. This can be done with a simple RFID card but also with a smartphone app or (in the future) by the vehicle itself using new standards such as ISO 15118. As an open standard OCPP incorporates multiple ways to handle this authentication reliably and allows anyone to add new authentication methods. It can also use white lists that reside on the charging station so returning customers can start charging right away, even when the Internet connection of the charging station might be slow or temporarily unavailable.

After authentication the charging station sends a **StartTransaction** message to the back office of the Charging station Operator and charging commences. The user usually gets confirmation of that on both the charging station and the car.

Since the charging station is already registered as a demand response asset on the charging station operator, it is now ready to receive demand response event signals.

So the charge station operator does not send a signal to the grid operator every time a charging sessions starts. However, it can on a regular basis send information to the grid operator about the available response assets using the OpenADR EiReportService. This can provide a near realtime load value to the grid operator.

Reduce Load

Now assume that the grid operator finds that the grid is overtaxed and wants to reduce the power that is used by the demand-response assets in its OpenADR system.

Knowing that electric vehicles can react within seconds one can send out the OpenADR message to reduce the load. OpenADR defines an *iEvent* service that can be used to send demand response and pricing signals. The demand response notification can be sent using OpenADR Simple Events (for OpenADR 2.0a systems) or using more advanced LOAD_DISPATCH or LOAD_CONTROL events (for OpenADR2.0b systems)

What happens next can depend on multiple factors such as the car type and the contractual arrangements with charging station operator and EV user. As open protocols OCPP and OpenADR do not force you to use any party or arrangement. They simply accept contractual arrangements as input.

On receipt of an iEvent signal containing a demand response payload, the OCPP central server will check if the Market Context in the message applies to a charging station or a group of charging stations on the network. If it finds a match, the demand management data will be translated to OCPP message **SetChargingProfile**. This sends a schedule aka profile to the charging station specifying when to charge at what power. The result is communicated back to the OpenADR VTN system by the VEN (OCPP central server) so the grid operator is always aware of the current situation.
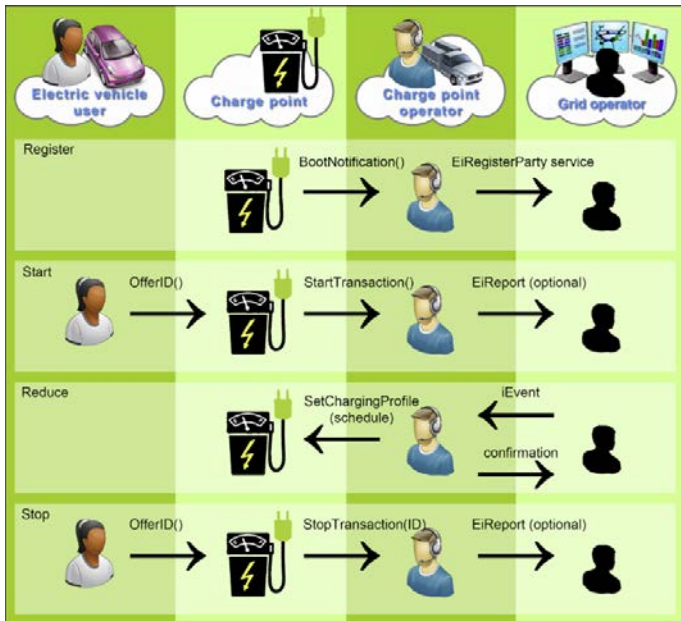
Stop Transaction

The EV user can stop the transaction by presenting his or her credentials once again., unplugging or using a mobile app.

The charging station sends an OCPP **StopTransaction** message to the back office of the charging station operator. Now the charging station is ready to start a new transaction.

The charging station operator can automatically and on predefined intervals provide the grid operator with a report detailing all relevant information pertaining to the charging activity that has been taking place using the *OpenADR 2.0 Report Service.*

Simplified message flow using OCPP and OpenADR[1]

A Demonstration at SCE

Southern California Edison's (SCE) used OCPP and OpenADR to implement smart charging at work

Greenlots, a global provider of open standards-based technology solutions for electric vehicles, and its partner EVSE LLC, a leading electric vehicle charging manufacturer, are supporting a California Public Utility Commission-approved workplace EV charging pilot for Southern California Edison (SCE), one of the largest electric utilities in the United States. SCE also ran a workplace EV charging pilot program in 2015 at a number of its sites in Southern California. The learning from the pilot will provide a better understanding of how consumer behavior changes in response to these signals and, ultimately, how EV demand response programs at the workplace will impact building loads, energy costs, and grid flexibility. The
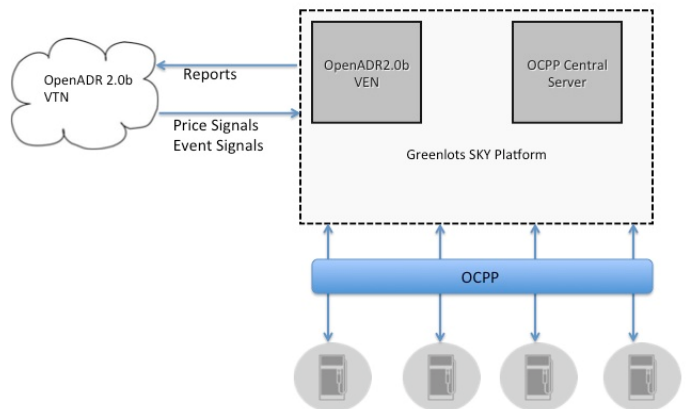
technology behind the workplace EV charging pilot conducted by SCE successfully combines OpenADR and OCPP. To conduct the pilot, SCE deployed 80 level 2 chargers for a consumer behavior study to test fee-based charging and demand response (DR) at various SCE work facilities. The project is among the first large scale pilots to combine OpenADR 2.0 and OCPP (version 1.5+) for electric vehicle charging. *The objective of the pilot is to examine how electric vehicle drivers respond to demand response events and dynamic pricing when charging their EVs at the workplace*.

Currently, SCE employees are able to plug-in when they arrive at work and opt into demand response using EVSE LLC's chargers and Payment Kiosk integrated with Greenlots' SKY OCPP system and SCE's Demand Response platform that uses OpenADR 2.0.

Each charging station registers with Greenlots OCPP server (charging station operator) via boot notification. The SCE workplace network is registered with the utility as an OpenADR end point. This makes every charging station in the SCE pilot registered with Greenlots as a demand-response asset in the OpenADR system

Greenlots' certified OpenADR 2.0 cloud based Virtual End Node (VEN) communicates with SCE's OpenADR Virtual Top Node (VTN) to obtain TOU pricing and is notified of demand events. The pricing information received via OpenADR - along with users' preferences - is then used to bill the EV drivers for the charging sessions.

SCE pilot implementation by Greenlots

---

[1] For clarity we have left out messages that simply acknowledge receipt of another message and we have limited ourselves to the most important messages.

The charging session information - including the duration and energy values - are communicated between the charging stations and Greenlots' central server over OCPP.

The energy values obtained by Greenlots over OCPP are easily translated into interval data values and reported back to the OpenADR VTN using OpenADR Report Service.

The solution also allows EV drivers to choose the level of charging (Level 2 or simulated Level1) and opt-in/opt-out of the events. The power limit on the charging stations is then set based on users' selection and active demand events, if any. OCPP 1.6 and 2.0 further introduces support for smart charging and smart charging profiles. Using the OCPP smart charging feature in this case, user selections and active event data can further be translated into OCPP smart charging profile and sent to the charging station.

It refers to the figure in the last paragraph but adds details that might have been skipped in the last paragraph. E.g. using a central server as an OpenADR Virtual End Node (VEN); using pricing signals for billing based on session times or meter values; load dispatch signals to obtain aggregate or individual EV charging load shed value; translate OpenADR events to OCPP 1.6/2.0 Smart Charging Profiles; and reporting from central server VEN to OpenADR VTN.

SCE has proposed a plan to install 30,000 charging stations within their territory in California. This program is called Charge Ready program and is currently awaiting approval from the California Public Utility Commission (CPUC). SCE is leveraging learnings from the pilot for Charge Ready OpenADR-based load management signals and how OCPP might be of use to customers for reducing costs and future proofing against stranded assets.

Conclusion

This paper outlines how to integrate Electric Vehicles into the electricity grid using the industry standards OpenADR and OCPP. It shows how these standards are complementary and allow you to create a smart charging ecosystem.

This paper is also a plea for the adoption of open standards that avoid vendor lock-in and create a level playing field for new entrants. This minimizes risk when engaging in long-term investments, for example in EV charging infrastructure.

Finally this paper aims to show that EVs can be valuable demand response assets when dealing with the increasingly intermittent renewable energy mix.

For more information

Eindhoven University of Technology
Auke Hoekstra (auke@aukehoekstra.nl)

OpenADR Alliance
Rolf Bienert (rolf@openadr.org)

E-laad Foundation
Arjan Wargers (arjan.wargers@elaad.nl)

Greenlots
Harmeet Singh (harmeet@greenlots.com)

Alliander
Paul Voskuilen (paul.voskuilen@alliander.com)