EVS32 Symposium
Lyon, France, May 19-22, 2019

How a DSO can use a flexibility market to economically maintain power quality in the local electric grid

Frank Geerts (*ElaadNL, Utrechtseweg 310, 6812 AR Arnhem, frank.geerts@elaad.nl)*, Marisca Zweistra (ElaadNL), Marcel Willems (Enexis*)*

Executive Summary

In a demonstration in Eindhoven Strijp-S we research how a DSO can use flexibility to have a cost effective grid infrastructure. The overall aim is to research how a DSO can use flexibility to maintain power quality in the grid economically. And create scalable and positive business cases for all stakeholders involved.

The approach is using flexibility for congestion management purposes. In the EU the role of the DSO is restricted; it can, simply put, manage the physical grid but taking on (possible) commercial roles such as an aggregator of flexibility is really beyond its scope. An external aggregator party is needed to operate flex sources in its network directly and trade that flexibility with a DSO. An aggregator can obtain flexibility in several ways, one option is to install their own flexibility assets in the grid. Another possibility is to aggregate the energy flexibility of end users, for instance smart storage unit and EV owners.

The demonstration in Eindhoven focusses on both the technical realization of the usage of flexibility for grid management purposes, as well as the realization of the business layer of flexibility trading between the DSO and aggregators. The desired outcome of the demonstration is to have a scalable and viable systems architecture and scalable and positive business cases for all stakeholders involved.

Within the demonstration the concept of flexibility marketplace is introduced. This marketplace can be used by aggregators to offer their flexibility to buyers. In the scope of the demonstration the buyers typically are network operators. The network operators use the market place to purchase flexibility based on their needs and preferences. A straight forward preference could be lowest price, however a higher priority need could be the guarantee of delivery. A scalable flexibility marketplace enables multiple parties in the same role (aggregator, DSO, etc.). In this demonstration we will look at the commercial aspect of the aggregator role, the trading of flexibility on the market, as well as the technical aspect: the management of EV’s and other devices, and actually aggregating their flexibility to have offerings with sufficient impact.
By looking explicitly at these different aspects of the aggregator role we will acquire the necessary knowledge about the mechanisms of pricing (the marginal price of flexibility of different flexibility resources), accumulating flexibility and the merit order of flexibility.

1. Eindhoven Strijp-S: Creative & cultural center of eindhoven

Eindhoven is the 5th largest city in the Netherlands, and traditionally a very industrialized high tech region. It is home to one of the biggest research and development communities in Europe, and birth place to successful multinationals such as Philips, ASML and DAF trucks. In 2016, the Eindhoven region was responsible for 25% of all Dutch exports, and 36% of all private Dutch R&D investments are done in this region. One of the focus areas of the Eindhoven city is to design & technology innovations in the region known as Strijp-S.

The history of Strijp-S is closely intertwined with the growth of electronics giant Philips. In the 70s, Philips reached its peak at Strijp: about 10,000 people work in this area on a daily basis. The area got its nickname ‘Forbidden City', because it used to be surrounded by fences and barriers. One could only enter with a valid pass. Eventually Philips left former industrial area Strijp-S. Since 2006, the redevelopment of Strijp-S is a very serious plan. The first buildings had been demolished and new activities came to the area, particularly the creative industries and the annual Dutch Design Week. These ‘quartermasters' shape the area more and more every year. But in the years to come, there is still a lot to be done! Currently, the area is mostly a mix of mainly SMEs and residential buildings.

In Strijp-S, all the elements of the smart grid will be tested, it's the combination of local storage, EV, smart loading, smart meters and distribution automation.

1.1 General eMobility from a DSO perspective

The Netherlands is a frontrunner in terms of EV adoption and the roll-out of public chargers. The increase of EVs and charging points leads to higher electricity demand during the existing load peaks on the grid, which can cause congestion problems and power quality issues in the distribution grid. Simultaneous charging of EVs, in combination with an intermittent load of distributed (sustainable) energy resources can cause congestion problems and power quality issues in the distribution grid. Reinforcement of the distribution grid can solve this issue, but is costly when designed for maximum peak loads. Therefore, DSOs are looking into alternatives, such as flexibility mechanisms for demand and supply, which can enable a more effective use of the distribution grid capacity.

Smart Charging of EVs can provide flexibility for the DSO. The term Smart Charging refers to the charging and discharging of an electric vehicle whereby the timing, speed and charging method (charging/discharging) is geared to the EV-driver’s preferences and market conditions then prevailing. For a DSO the charging pattern of EVs would be adjusted to the available capacity in the distribution grid. Furthermore, Smart Charging can facilitate the consumption of locally generated renewable energy.

Since 2015 multiple Smart Charging pilots have been initiated in the Netherlands. There is a comprehensive overview of about 11 Smart Charging initiatives and each pilot is analysed from various aspects. They conclude that although the current projects are mainly in the research phase. Smart Charging has the potential to become the standard method for charging EVs in the near future for its benefits for the power system. This conclusion was confirmed by the recent decision of two Dutch provinces (Gelderland, and Overijssel) to roll-out 4500 public chargers with Smart Charging as the default option.

Furthermore, preliminary results from other Smart Charging pilots have shown that the concepts of coordinated charging work in reality. For example, the results of FlexPower Amsterdam project indicate that the average charging speed at pilot stations was increased by 45% (from 4.05 kW to 5.86 kW) while reducing the charging power during peak times. Moreover, recent analysis of the EV data from the Smart Charging service of Jedlix show that during the evening peak, the energy demand of Smart Charging sessions was about 45% lower compared to that of regular charging sessions.

However, the aforementioned pilots do not 'represent' realistic models for local flexibility markets. The Dutch DSO Liander is aiming to test a flexibility market mechanism in a local grid (city of Nijmegen) by making use of the flexibility offered by a supermarket and an hotel. But this project does not include EV as source of flexibility.

Within the Interflex pilot in the Netherlands one aims to test a comprehensive flexibility market whereby stationary battery storage and EVs will be used as sources of flexibility. The Dutch Interflex pilot can be seen as an 'representative' testcase for future flexibility markets because different actors are involved (EV-drivers, grid operator, charging point operators, and aggregators). In addition, each actor is realistically represented in the pilot.

1.2 Flexibility market set-up

The flexibility market is developed and demonstrated in Eindhoven, the Netherlands, one of the demonstration locations of the EU Horizon 2020 project called Interflex, which aims to demonstrate and validate technologies and business models for the integration of distributed energy resources and flexibility in the electric distribution system.

In the Dutch field implementation a local marketplace is set up where the DSO can request flexibility from commercial aggregators. Commercial aggregators will trade on various markets to maximize their profits. This means that when a DSO requests flexibility, commercial aggregators will take this in consideration, and, if the price-range is right, will provide the DSO with a flexibility offer The commercial aggregators can control several flexibility resources that enable them to trade on the flexibility market. In this pilot the flexibility resources include EVs, storage and PV solar system. In this pilot so-called local aggregator physically manage the flexibility sources, based on an agreement with the commercial aggregator.

The flexibility from EVs in this pilot is unlocked via public charging points that are managed by a local aggregator (ElaadNL). The commercial aggregator (Jedlix) can enable/trade flexibility on these charging points, by means of a smart charging service/proposition to EV-drivers (see figure 1). The commercial aggregator offers flexibility to the DSO based on the expected smart charging sessions for the time slot the flexibility is requested.

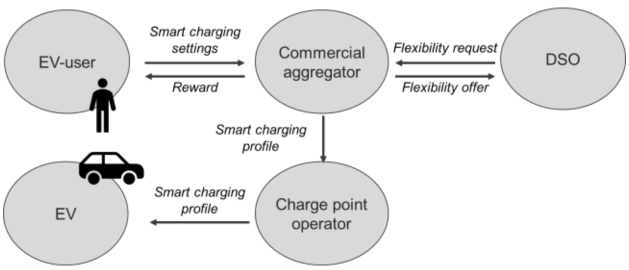

Figure 1: Schematic overview of the interactions between DSO, aggregator, CPO, and EV-use

1.3 Proposition for EV-drivers

EV-drivers are offered a smart charging service by which they can save on charging costs for each session with Smart Charging. The service guarantees the EV-driver that the car battery is charged according to the user's preferences. In exchange for their flexibility, the EV-driver receives a financial reward (0,05 €/kwh in this test).

To start using Smart Charging, EV-drivers download a Smart Charge app for free. When an EV-driver opens the app for the first time selects his country and the car brand. If the user wants to use Smart Charging at home he has to add his home location and select the energy supplier If the user wants to Smart Charge at a public charging station (like Strijp-S in Eindhoven) as well, he has to add his charging card number. Finally, the driver adds his bank details so he can receive the financial reward from a Smart Charging session.

When an EV-driver connects the car at a public charging point at Strijp-S he receives a push notification on his phone which tells him that it is possible to use Smart Charging. The driver opens the app, select the percentage of the battery that needs to be charged directly (and not available for smart charging), selects the leaving time and switches on Smart Charging.

In the app a charging profile is created based on the users' settings and the situation in the grid, and send it to the charging point. This is done when flexibility was requested for grid management at the time of the charging session and there are no consequences for the requirements of the EV-driver. After ending a Smart Charging session the EV-driver can see in the app how much his cost savings are. When the sum of these savings reaches € 5.- , the EV-driver can have the money transferred to his bank account.

1.4 Flexiblity Market Use Cases

The flexibility offer from EVs at each moment of day is dependent on several factors. First and foremost, the offered amount of flexibility will be derived from the total number of EVs which are simultaneously connected to the charging points. Second, based on the user preferences of the EV-drivers regarding the desired State of Charge (SoC) of their vehicles at the departure, and the expected departure time one will be able to define the aggregated amount of flexible EV load. Analyses of charging data have shown that there is large potential flexibility within the current charging behavior of the EV drives, and that this offered flexibility varies of time of day. Previous studies have been done mainly at the national (aggregated level). At the local grid level the situation is a bit different. So, in terms in of total volume the offered flexibility will be much lower. Also, its moments of availability might varies dependent on the type of users that will make use of the pilots' charging points.

The primary aim of the local flexibility market is to enable congestion management on distribution network level by making use of energy flexibility from the demand side of the energy system. In the demonstration the following use cases are examined:

1. Enabling ancillary services, congestion management, voltage support for PV integration using centralized, grid-connected storage systems to improve grid observability of prosumers, promoting batteries in multi-service approach.

2. Enabling the optimal activation of all available local flexibilities offered by the locally installed EVSE's for congestion management. This is done by allowing the DSO, who monitors the grid, to send flexibility requests to commercial aggregators. These commercial aggregators can, after a price agreement with the DSO and in cooperation with the Charge Point Operator (CPO), adapt charging schedules on EVSE's, thus providing the flexibility requested by the DSO.

3. Validating technically, economically and contractually the usability of an integrated flexibility market based on a combination of static battery storage and EVSEs.

1.5 Design of Flexiblity Market

The design of the flexibility market on a DSO level is based on mechanisms used in the TSO market. From the three different TSO services, i.e. the ancillary services, energy market and capacity market, only the ancillary services and energy market are used in this demonstration.

The system design is based as much as possible on existing technology that has proven its value on the market. Newly developed functionalities will make use of open standards and protocols, such as USEF, EVI and OCPI.

The workflow of the flexibility trading between an aggregator and a DSO is based on the workflow defined by the Universal Smart Energy Framework (USEF) initiative. The five phases of the USEF workflow, as shown in the figure below, were elaborated specifically to enable an Interflex flexibility market.

1.6 Physical test set-up

The physical test set-up is defined by the flexibility sources, the grid topology, congestion points and measurement equipment that are used for the validation of the use cases. The flexibility sources are the EVSEs, the smart storage unit and the PV installation. The grid topology of MV distribution network is typically ring-shaped, connecting various MV/LV substations and operated radially. The grid in the Strijp-S area, where the demonstration takes place, includes two substations. Four congestion points are defined: the two substations and one feeder at each substation that connects the EVSEs. Given that the current network is overdimensioned, we assume smaller size transformers than their actual power rating during the testing of the congestion management solutions, given that congestion problems are not expected, nor desirable in a test situation, with the current transformers. Measurement equipment is installed on the transformer (LV side) and on all outgoing LV feeders of the substations. Furthermore, bidirectional energy throughput, and total harmonic distortion are measured.

1.7 Innovative solutions in the use cases

Test scenarios are defined to test the innovative solutions of the use cases. Stepwise, these scenarios increment the complexity of the flexibility market:

- Scenario 1: Day-ahead market
- Scenario 2: Day-ahead market + static variable connection capacity
- Scenario 3: Day-ahead market + dynamic variable connection capacity
- Scenario 4: Day-ahead & intraday market + dynamic variable connection capacity

The relation between the tested innovations and the test scenarios is

Tested Innovations	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Electricity storage in batteries for congestion management (section 1)	X	X	X	X
Electric vehicle charging for congestion management (section 1)	X	X	X	X
Local flexibility market day-ahead & intraday (section 1)	X	X	X	X
Split roles commercial and infrastructure aggregator and single role per party (section 2.1)	X	X	X	X
Certainty profile sanction pricing (section 2.3.3)	X	X	X	X
Local flexibility market with multiple aggregators per congestion point (section 2.1)	X	X	X	X
Local flexibility market in combination with static variable connection capacity (section 2.4)		X		
Local flexibility market in combination with dynamic variable connection capacity (section 2.4)			X	X
Multi-iteration intra-day market (section 2.1)				X

1.8 Demonstration Results

For the purpose of this project 13 public charging points (26 sockets) have been installed in a test area called StrijpS in the City of Eindhoven. So, the chargers are already being used before the actual implementation of Smart Charging schemas. This group of first no-Smart Charging sessions provides some interesting insights in the regular charging habits of EV-uses in the area.

In total about 500 charging sessions have been taking place by 175 different users. On average the energy demand per session is about 11.5 kWh with a maximum of 70 kWh. The majority of the EV-drivers arrive before 10 AM and leave before 6 PM, but there is also a small number of sessions that start late afternoon and stay connected during night. The mean connection duration is about 7.5 hours, and on average each EV charges for about 2.8 hours.

Based on the first equation (flexibility based on time) we have calculated this indicator with two-hour time intervals.

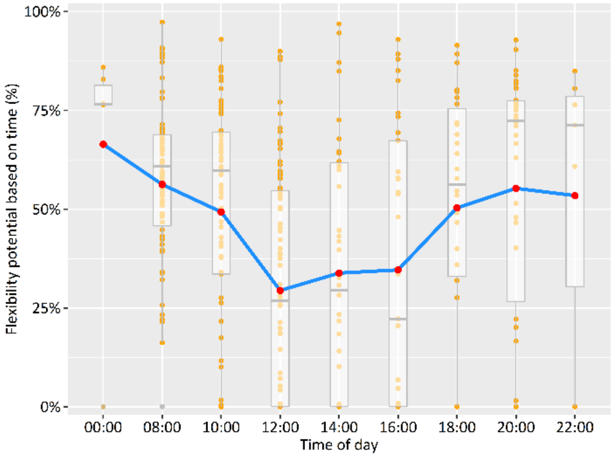

Figure 2: Distribution of flexibility potential (time based) based on regular charging sessions at Strijp S charging poles

The blue line in figure 3 represents the average flexibility potential for all charging sessions that started around a specific time slot of the day. The flexibility of each charging session is represented by an orange dot. In general, we can observe that on average the sessions starting before 10 AM and after 4 PM have more than 50% flexibility potential in terms of time. Also a certain amount of potential flexibility in terms of energy is assumable within these sessions.

In terms of user experiences, users are positive in general about the smart charging service. They like the idea of saving money with smart charging. Contributing to a more sustainable environment makes them proud as well. They seem willing to enable smart charging and the stimulus from the Jedlix app to do so will be key to providing flexibility for grid management.

Prelimenary conclusion is that Smart Charging of EVs can be a source of flexibility for grid management. Within the Interflex project the goal is to test a flexibility market with different actors, including Smart Charging of EVs. During the field tests in 2019 further analysis will take place concerning the actual flexibility potential and realization of the EVs, both in terms of time and energy. The EV-drivers will furthermore be consulted about their experiences. This can lead to insights in a realistic setting as to how Smart Charging of EVs can facilitate both EV-drivers and DSO to meet their needs.

Authors

Frank Geerts is Digital Innovator eMobility at Alliander and program manager Smart Charging at ElaadNL. He realizes IT innovations and solutions to facilitate and accelerate eMobility. He is currently engaged in the development of several Smart Charging solutions, fe in Amsterdam testing a new Grid Connection with flexible capacities and in the Utrecht area with Smart Solar Charging based on V2G. Before, Frank was project leader within the Mobi Europe project, which among other things has realized a smart charging plaza in the Amsterdam ArenA. At that time he was also IT manager at Allego. Frank plays an active role in the open standardization of e-mobility at national and international level. He is regular speaker on conferences throughout the world. He has more than 15 years in the energy sector, in different roles and for several energy companies in the Netherlands.