

## SMART CHARGING ELECTRIC VEHICLES BASED ON A FLEXIBILITY MARKET

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### ABSTRACT

*Simultaneous charging of electric vehicles (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. A smart charging service for EVs in combination with a flexibility market can provide a distribution system operator (DSO) with flexibility for effective distribution grid management. With Interflex, we implement and evaluate a flexibility market as a means to match the flexibility that can be provided by EV's to the flexibility needs of a DSO. This paper provides initial insights in the potential for flexibility of the EVs and in user experiences. An initial analysis of charging sessions in the pilot area indicates more than 50% flexibility potential in sessions before 10 AM and after 4 PM. These sessions also suggest a certain amount of potential flexibility in terms of energy. In terms of user experiences, most users are willing to smart charge their car. They like the idea of saving money and contributing to a more sustainable environment.*

### INTRODUCTION

The Netherlands is a frontrunner in terms of EV adoption and the roll-out of public chargers [1]. 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 [2].

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 [3]. 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 [4]. They conclude that although the current projects are mainly in the research phase (except for [Jedlix](#) and [Maxem](#) which are commercial services) 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 of Tamis et al. (2017) was partly 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 [5].

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 [6]. 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 [7].

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 [8]. 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.

In this paper we will discuss the set-up of the pilot and initial results. The main question for the Dutch Interflex pilot is whether the flexibility market in combination with smart charging can effectively contribute to the DSO's flexibility need. To this end, the potential amount of available flexibility and the experiences of the EV-drivers are evaluated.

## PILOT SET-UP

### 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 [9].

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.

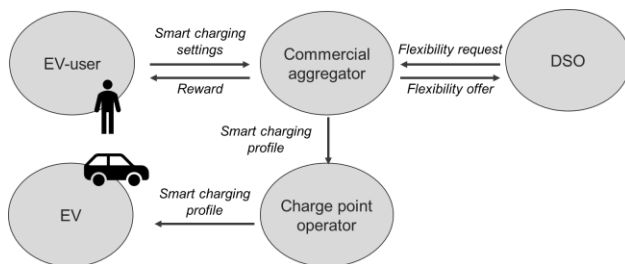


Figure 1: Schematic overview of the interactions between DSO, aggregator, CPO, and EV-use

### 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 the

Jedlix Smart Charge app for free. When an EV-driver opens the app for the first time he is creates an account first. Then he has to select his country and the car brand.

If the user wants to use Smart Charging at home he has to add his home location, select the energy supplier and add a valid and matching contract number. 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. See figure 2 for an impression of the user interface.

Jedlix creates a charging profile based on the users' settings and the situation in the grid, and send it to the charging point. 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, Jedlix can deliver flexibility during the Smart Charging session.

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.

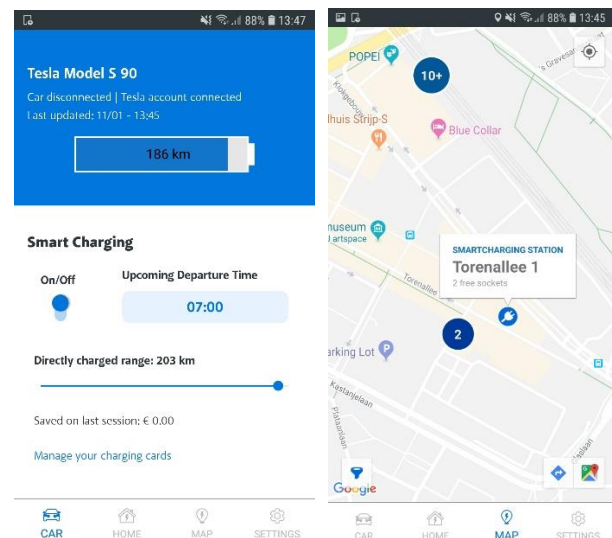


Figure 2: Screenshots of the Smart Charging app. Left: User settings for a smart charging session in the Smart charging session. Right: Map indicating public charging stations with smart charging option.

### Potential for flexibility

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 [10, 11]. 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 flexibility offer in terms of relative time budget to coordinate a charging sessions can be defined as follows;

$$Flexibility_{time} = \left(1 - \frac{Charging\ time}{Connection\ time}\right) * 100\%$$

Whereby the connection time is the total duration of a charging session, and the charging time is the fraction of connection time whereby energy transfer is taking place. Second, the flexibility offer based on the amount of energy demand that can be shifted within a specific charging session can be formulated as follows [10];

$$Flexibility_{energy} = \frac{Energy\ consumed\ beyond\ the\ initial\ (BAU)\ charging\ time}{Maximum\ possible\ energy\ consumption\ beyond\ BAU\ charging\ time}$$

Within the Interflex pilot the amount of flexibility is defined by the sum of flexibility of the available EVs per 15 minutes of time intervals to have the total amount flexible energy.

### **FIRST 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 and figure 3 below shows the results with two-hour time intervals.

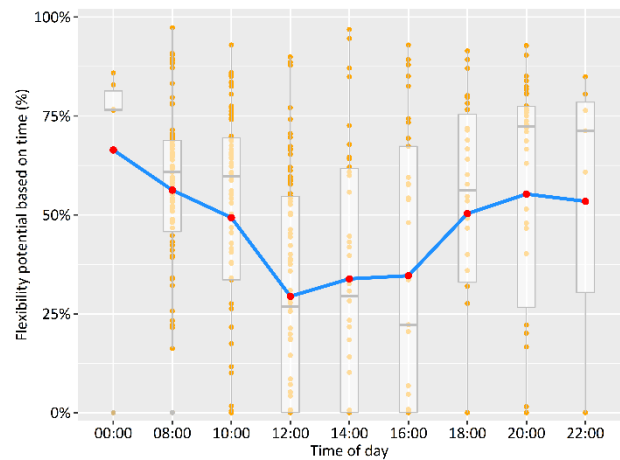


Figure 3: Distribution of flexibility potential (time based) based on regular charging sessions at Strijp S charging poles

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. These results are comparable with earlier studies [11]. Also a certain amount of potential flexibility in terms of energy is assumable within these sessions.

### Customer experiences

The Jedlix app has been used widely outside the Interflex pilot project. Based on personal interaction via customer service and questionnaires, we can share insights into why people use Smart Charging and what they like about it. The Interflex project allows for further insights into user experiences and how the user's settings relate to the flexibility potential of EVs on the flexibility market.

To stimulate smart charging over direct charging, the default is set to smart charging. Users generally accept this default and mostly set the departure time. Jedlix motivates the users via push notifications and mailings to improve their settings to get the most out of a smart charging session.

People use the app is to contribute to sustainability and to save money. Users understand that higher savings can be realized when the period of charging is longer. At public charging points, the parking time is often short compared to charging at home, but users do start smart charging sessions on public stations. It is easy to find a suitable charging point via the app.

In general, app users are positive about the smart charging service. The following quotes illustrate some of their experiences:

- *'Nice app! Installation went smoothly. Works Excellent.'*
- *'App works well. I have already earned the first euros with sustainable charging'*
- *'Easy app that saves money and the environment by automatically charging when there is overcapacity in the electricity network.'*
- *'Nice product. Another piece of the puzzle in the transition to a more sustainable vehicle fleet.'*

Jedlix frequently contacts users for feedback in order to improve their smart charging service. Users are also actively involved in, for example, prototype testing of new or improved screens before implementation. These efforts have contributed to, for example, improvements to the onboarding process and the content of error messages. The home screen and possibilities for smart charging settings are under development to further increase user friendliness and stimulate users for Smart Charging based on their preferences.

## CONCLUSION AND NEXT STEPS

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.

A first analysis was done for the regular charging sessions in the pilot area to get indication of the flexibility potential, showing that on average the sessions starting before 10 AM and after 4 PM have more than 50% flexibility potential in terms of time. These sessions also suggest a certain amount of potential flexibility in terms of energy.

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.

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.

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