D7.6 Lessons learned to draw business models in use cases NL#2 and NL#3
Version 1.0

Deliverable D7.6

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Short Description

Deliverable 7.6 focuses on use case 2 and 3 of the Dutch InterFlex demo. In this deliverable systems and interactions are described that were implemented to realize this use case, as well as the lessons learned.

Use case 2 describes the systems and interactions necessary to achieve a stable grid through flexibility that can be provided by adjusting charging profiles of electrical vehicles (EVs). Overall lessons learned are about organizing the right project circumstances to deliver the InterFlex framework such as: defining crucial project conditions, having a clear overview of the chain and related protocols and privacy by design.

Use case 3 describes the usability of an integrated flex market based on a combination of stationary battery storage and EV chargers. Overall lessons learned are about defining and filling in crucial project conditions, such as: defining a good baseline and the separation of concern, roles and responsibilities. Also has to be taken into account, an open protocol isn't always completely usable without making adjustments.

So far no meaningful preliminary results could be obtained regarding the KPIs, due to the complexity of the field tests. The scenario tests with stable setting are currently still ongoing, and results for the KPIs will be reported in the last deliverable (7.7).

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EXECUTIVE SUMMARY

This report focuses on use case 2 and use case 3, work package 7 from the Dutch InterFlex project team. This deliverable is one of the six WP7 deliverables for the Horizon 2020 project InterFlex.

Energy flexibility can be defined as a power adjustment sustained at a given moment, for a given duration, from a specific location within the network.

Smart grids rely on flexibility (or flex), to prevent congestion on the grid, in energy production and/or consumption to compensate for the increasing number of renewable energy sources that are far less predictable and controllable than traditional power plants.

In this deliverable systems and interactions are described that were implemented to realize this use case, as well as the lessons learned.

Use case 2 involves the systems and interactions necessary to achieve a stable grid through flexibility that can be provided by adjusting charging profiles of electrical vehicles (EVs). The EV infrastructure and chain from EV driver to distribution system operator (DSO) are described in this deliverable.

To arrange an optimal activation of flex systems, Charge Point Management System (CPMS), Flexibility Aggregation Platforms (FAPs) and interactions were implemented.

Conclusions from implementing use case 2

- An open protocol isn't always completely usable without making adjustments.
- Defining crucial project conditions (e.g. having enough EV drivers for this project) is necessary, and it is wise to meet these preconditions before the implementation phase of the project.
- A clear overview of the chain and related protocols is helpful to make sure the software chain is in line with the process requirements.
- Privacy law led to some limitations in the operator user interface between the aggregator, Charge Point Operator and charging session.

Use case 3 involves an integrated flexibility market where flexibility can be provided by two flexibility sources, namely a 'smart storage unit' (SSU) and EVs. The focus is on the technical framework for trading flexibility between multiple aggregators and the DSO in order to prove the concept and develop knowledge on the applicability and the future scalability of the concept.

The DSO and involved aggregators implemented a framework for trading flexibility. Different Flexibility Aggregation Platforms (FAPs) and an interface to the DSO (via USEF) are implemented. The FAP is operated by the commercial aggregator and is responsible for controlling the flexibility assets of the aggregator.

Conclusions from implementing use case 3

- Defining a good baseline is hard and hindered by the lack of a good method. Specification of a flexibility baseline during the project is necessary to proof flex has been delivered and to measure the project results.

- The separation of concerns, roles and responsibilities in the InterFlex architecture (FAP) worked very well, since it enabled the actors to focus on their key responsibility and key competences
- Open protocol isn't always completely usable without making adjustments; for the project it was preferred to work with open protocols.

The research approach consists in a day-ahead load forecast scenario that runs for two MV/LV transformers. During the field tests the developed systems are tested in a real life setting. The goal of the field tests is to assess the operation of a local flexibility market under realistic operating conditions and identify criteria for the proper functioning of such a market.

In this project there are KPIs formulated in the Grand Agreement. Also there are research questions to be answered that are aligned with the KPIs. During the field tests different market scenarios are tested under which the flexibility is procured.

Conclusions preliminary results

- The percentage of EV charging sessions is not adequate to solve the congestion problem yet. The number of EV charging sessions are high in reality and can cause serious congestion issues in the grid. Therefore, EV smart charging can be considered as a good solution as well. However, it is important to investigate better incentives and other approaches to improve the awareness and interest of EV drivers to take part in smart charging programs.
- Shifting the EV flexibility load from one to another time slot can result in higher risks for the DSO at the end.

Due to the complexity of the field tests, so far no meaningful preliminary results could be obtained regarding the KPIs. The scenario tests with stable setting are currently still ongoing, and results for the KPI will be reported in the last deliverable (D7.7).

General lessons learned that apply to all three use cases of the Dutch demonstrator will be input for deliverable D7.7.

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1. INTRODUCTION

1.1. What is energy flexibility and why is it important?

Smart grids rely on flexibility (or flex), to prevent congestion on the grid, in energy production and/or consumption to compensate for the increasing numbers of renewable energy sources that are far less predictable and controllable than traditional power plants. The required flexibility ultimately has to come from from smart devices in households, small medium enterprises, office buildings, electric vehicles (EVs), storage, etc.

Energy flexibility can be defined as a power adjustment sustained at a given moment, for a given duration, from a specific location within the network.

This flexibility may be used by third parties to help alleviate imbalance or congestion. Third parties will use different incentive schemes to unlock the flexibility potential, such as time of day pricing, real time pricing and feed in tariffs. These incentives should somehow be matched to the possibilities of smart devices to deliver energy flexibility.

1.2. Scope of the document

The information and views set out in this report are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

This deliverable is one of the six deliverables for the Horizon 2020 project InterFlex Dutch Pilot that describe the components that were built, lessons learned during the practical implementation issues in the first two and half year of the project and first results from field testing.

This document focuses on use case 2 and use case 3.

Use case 2 involves the systems and interactions necessary to achieve a stable grid through flexibility that can be provided by adjusting charging profiles of electrical vehicles (EVs). The EV infrastructure and chain from EV driver to distribution system operator (DSO) are described in this deliverable.

Use case 3 involves an integrated flexibility market where flexibility can be provided by two flexibility sources, namely a ‘smart storage unit’ (SSU) and EVs. The focus is on the technical framework for trading flexibility between multiple aggregators and DSO in order to prove the concept and develop knowledge on the applicability and the future scalability of the concept.

For reference, deliverable 7.5 has the same purpose as this document, but with the scope on use case 1. Use case 1 focuses on the smart storage unit and the systems required by a technical aggregator to connect it to the flexibility market.

A more in-depth specification of the several system components and the functions of InterFlex in the Netherlands is described in deliverable 7.1, 7.3 and 7.4.

In the last Work Package 7 deliverable, deliverable 7.7, the results are presented from the field test scenarios that are performed throughout 2019. These field test scenarios are based on the KPIs that are defined in the project (see deliverable 7.3). The purpose of the field test is to validate the market model for flexibility delivery for the DSO.

See also figure 1 for the scope and content of the different deliverables as mentioned above.

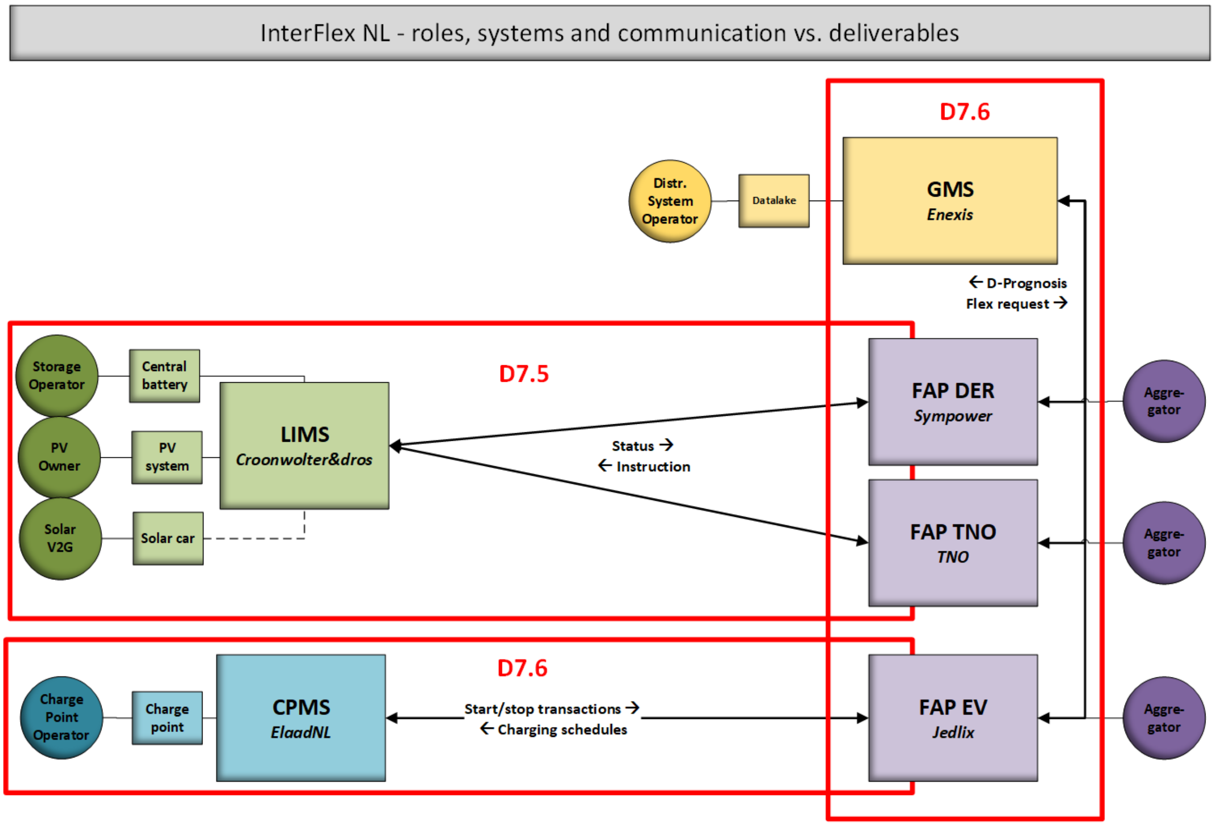


Figure 1 - Roles, systems and communication in relation to the deliverables

1.3. Notations, abbreviations and acronyms

The table below provides an overview of the notations, abbreviations and acronyms used in the document.

CA	Commercial Aggregator
CPMS	Charge Point Management System
CPO	Charge Point Operator
DALi-box	Distribution Automation Light – box measurement device
DER	Distributed Energy Resource
DSO	Distribution System Operator
EFI	Energy Flexibility Interface
EFI+	Energy Flexibility Interface extend version, designed for InterFlex
eMSP	eMobility Service Provider
ESCo	Energy Service Company
EVNetNL	Administrator charging points network
EVSE	Electric Vehicle Supply Equipment (in this document Charging Point)
FAP	Flexibility Aggregation Platform
FDM	Flex Decision Module
GMS	Grid Management System
KPI	Key Performance Indicator
LA	Local Aggregator
LIMS	Local Infrastructure Management system
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
PV	Photo Voltaic
RFID	Radio-frequency identification
SSU	Smart Storage Unit
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework
USEF+	Adapted version of USEF

Figure 2 - List of acronyms

2. IMPLEMENTATION EXPERIENCES USE CASE 2

This chapter describes the implementation of use case 2.

2.1. Use case 2

The goal of this use case is to enable the optimal activation of all available local flexibilities offered by the locally installed Electric Vehicle Supply Equipments (EVSEs) and the connected EVs for congestion management. This is done by enabling the DSO, who monitors the grid, to send flexibility requests towards commercial aggregators that can, via the CPO (Charge Point Operator), adapt charging schedules on EVSE's.

System architecture

The systems and interactions are that were implemented to realize this use case are:

- Charge Point Management System (CPMS) operated by the Charge Point Operators (CPO)
- Flexibility Aggregation Platforms (FAPs) operated by commercial aggregators

The Open Charge Point Interface protocol (OCPI) supports connections between Mobility Service Providers (eMSP) who have EV drivers as customers, and Charge Point Operators (CPO) who manage charging points via a Charge Point Management System (CPMS). In this case the commercial aggregators are TNO (FAP TNO), Jedlix (FAP EV) and Sympower (FAP Distributed Energy Resource). See the figure below for the system architecture.

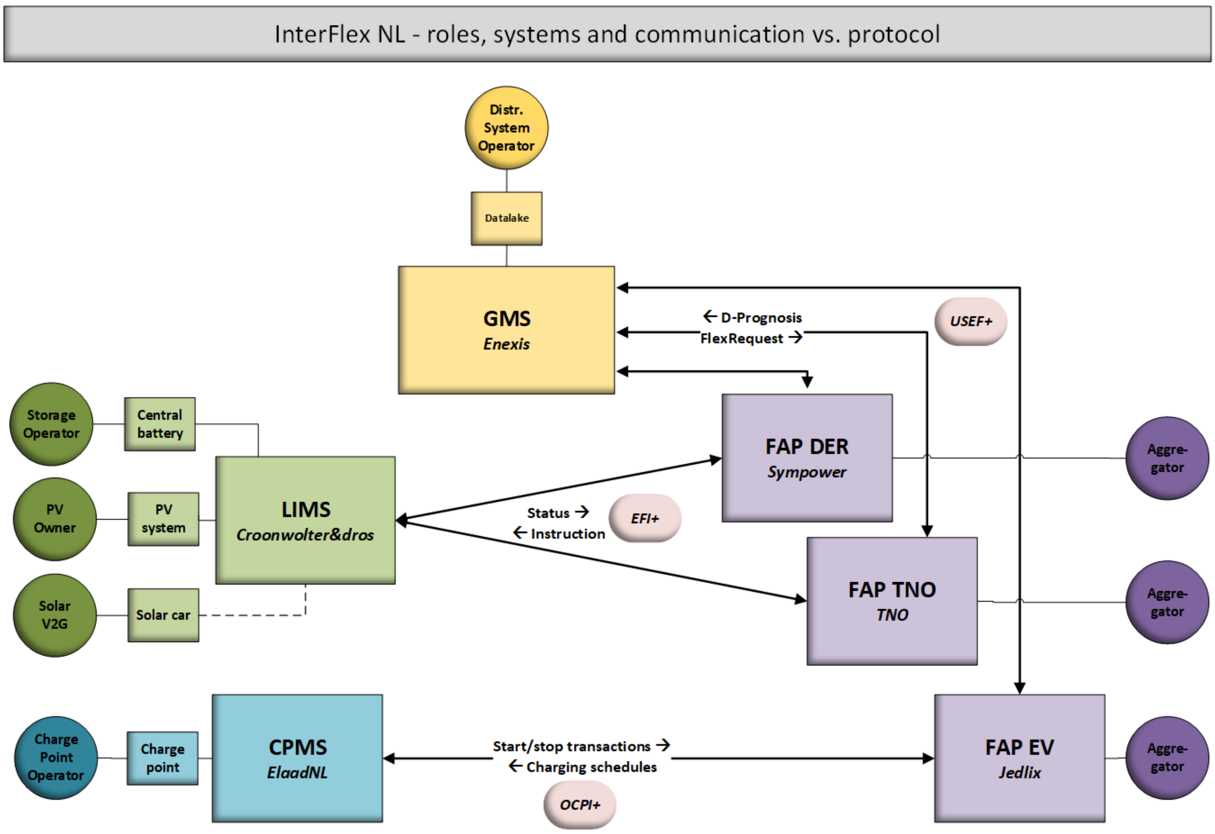


Figure 3 - System architecture

2.2. The OCPI Protocol in InterFlex

The Open Charge Point Interface (OCPI) is traditionally used between a Charge Point Operators (CPO) and an eMobility Service Provider (eMSP). This to allow roaming of the eMSP's customers on the charging points. An eMSP is a company offering an EV charging service to EV drivers. The EV driver has a service contract with the eMSP.

Information on charging locations, charging cards, tariffs and invoices is exchanged between these two parties. This protocol is what allows drivers with any charging card to charge at any charging point.

Aggregators are a new addition to the information exchange in EV charging. Aggregators introduce additional services that neither the CPMS nor the eMSP provide. To provide these services, they need access to similar information as what is being exchanged between the CPO and eMSP, which makes OCPI a natural choice for adding the aggregator to.

For this project, the OCPI protocol is expanded to include the functionalities required for aggregators. Functionally, this entails the following additions:

- Allow the aggregator to register charging cards with the CPO for which they want to receive real-time information. The driver should be able to 'sign up' with an aggregator by entering a number that is visible on their charging card.
- Have the CPMS send session information, not just to the related eMSP for the driver, but also to the aggregator. This includes information on where the driver is currently charging, how much energy is charged during the running session and whether or not the vehicle is still charging.
- Allow the aggregator to send 'charging profiles' (settings of maximum charging speed during specified time slots) to the CPMS, which are then sent to the EVSE to be applied to the running session. This allows the aggregator to control the charging speed during the running session, which is part of the service they provide.

Technically, the following additions have been made to the OCPI protocol:

- In addition to the existing /OCPI/eMSP/ series of endpoints, the CPMS implements a new endpoint at /OCPI/SCSP/ that provides the standard locations, sessions and tokens modules, and a new charging profiles module which was not present at the /OCPI/eMSP/ endpoints.
- The tokens module of the /OCPI/SCSP/ endpoint has a modified PUT handler (code to indicate success or failure) that allows the aggregator to register a card just by its 'visual number', which is the number printed on the card. This allows the aggregator to tell the CPMS that the card with that visual number has signed up for their service. The CPMS then matches that card's visual number to its existing database of cards that have been published by other connected eMSPs to link the card to the aggregator.
- The charging profiles module is an interface that allows the aggregator the CPMS to apply a charging profile to the charging session. The CPMS will send this charging profile as an OCPP-1.6 message to the relevant charging point, and will inform the aggregator of the result.
- The CPMS sends real-time sessions information to the aggregator, provided that the card for that session is registered with the aggregator first. This allows the aggregator to respond to these events with charging profiles.

- The CPMS sends real-time session information to the aggregator, provided that the card for that session is registered with the aggregator. This allows the aggregator to respond with charging profiles.

These modifications allows correct interaction between CPMS and aggregator. However, verifying whether the driver actually signed up for this service is impossible for the CPMS. Within the InterFlex project, this issue has not been resolved yet, but a few avenues for settling this have been explored. See appendix 1 for an overview of possible identifiers that might be used as an alternative for the hard coded registration.

2.3. CPMS and interfaces

The role of the CPMS in the InterFlex project

The Charge Point Management System (CPMS) is responsible for keeping track of the status of the charging points, for communicating with external parties about its locations and charging sessions, and to provide an interface for aggregators to control the charging speed of the charging stations. This system is primarily used by the CPO that exploits the charging stations. The charging stations connect directly to this system, and it is usually the only communications channel to a charging station.

In the InterFlex project, the CPMS sits between the aggregator and the flexible loads. It communicates using the Open Charge Point Protocol (OCPP) to the charging points, and the OCPI protocol to the aggregator system. The existing CPMS used to run the EVNetNL-charging point was extended with the OCPI modules as were mentioned in chapter 2.2.

Other arrangements for the aggregator to control the charging speed are available as well, but not used in the InterFlex project. Examples are that the aggregator would communicate to the vehicle manufacturer's systems to send messages to the vehicle, or that the aggregator would communicate to some local energy management system on a charging site that has a direct connection to the charging points.

Operator user interfaces of CPMS
The purpose of the protocol is to involve the EV driver in the smart charging and to prove his or her acceptance of flexibility transactions. The following points of attention apply:

- The driver needs to be able to decide on whether or not to hand over the EV for flexibility during each charging session.
- Involvement of multiple commercial parties in one charging session should be avoided when this is not adding to the benefit or comfort of the driver.
- Whenever an aggregator applies for flexibility, he needs to be able to prove he has permission from the involved driver to do so.
- Proof has to be sent to the CPO.

In this project, Jedlix is responsible for the flexibility requests and EVNetNL is the CPO. Jedlix has recruited EV drivers for the pilot and for these drivers, all identification numbers have been sent to EVNetNL. EVNetNL keeps a register of these identification numbers and checks each charging request with this register. If the charging request originates from a driver who is listed in the register, Jedlix is allowed to apply smart charging in this session, using OCPI charging profiles.

The figure 4 below shows the operator user interface between the aggregator, charge point operator (CPO) and charging session, currently in operation. An important aspect of the interface is to have a current validation of the charging request with the register of EVNetNL.

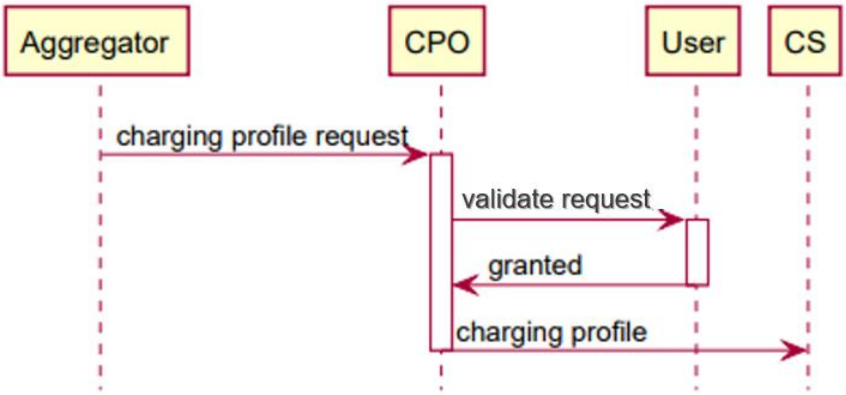


Figure 4 - Operator user interface

Experiences
This method has the following limitations:

- The database table in which the identification numbers are registered is hard coded. This makes is difficult to scale up.
- The CPO cannot check whether the registered ID's are up-to-date. Therefore, the CPO cannot know whether the aggregator still has permission of the EV driver.
- Not all IDs have the same format and need to be processed into a uniform format.
- There is no guarantee IDs will remain valid throughout the pilot.
- The procedure is unclear to EV drivers: a single permission may result in altered charging behavior per session, with no message to the EV driver with respect to duration and character of the altered charging behavior.
- The EV driver cannot yet indicate availability per session.
- It is difficult for the EV driver to withdraw permission.

2.4. Charging points

13 identical dual-socket charging points are used that support the OCPP 1.6 protocol for communicating to the CPMS over a GPRS data connection. These charging points are rated up to 3x16 A per socket, or 3x25 A combined current on both channels, and they will self-regulate the charging current of each socket to not exceed the station's maximum allowed current of 3x25 A when both sockets are in use. These sockets are standard IEC-62196 "Type 2" sockets that support three-phase AC (alternating current) charging. RFID is used for driver identification (using charging cards).

These charging points support the OCPP 1.6 smart charging features that enable the CPMS to send charging profiles that control the maximum charging current during different time slots.

Purchasing process

In a previous tender procedure, the Strijp-S site has selected the company Ecotap for delivery, installation, commissioning and maintenance of all the EVSEs on Strijp-S. For the project, Enexis respected this tender and ordered the EVSEs with Ecotap. The limited costs of these EVSEs allowed Enexis, following internal procedures, to directly order with Ecotap without a separate tender.

Experiences

The context of project can determine the choice of supplier. You can be bound to contracts of stakeholders, which can possibly influence the costs, timeline and outcomes of the project.
In this case the charging point supplier was already the contracted supplier for the Strijp-S area.

Testing and installation

The connection capacity of the network, at transformer level, was limited. Cable reinforcement was needed to have sufficient capacity available for the charging points. This required a lot of coordination and time among the municipality, the administrator of the Strijp-S area, the contractor and the DSO to get it settled.

The registration method of the central register systems of the DSO resulted in a different registration than would have been necessary for the pilot. A third party was needed for registration and connecting the charging points. This resulted in delays in the implementation of getting the charging points into operation.

The standard charging point supplier was chosen for the Strijp-S area in Eindhoven. During the installation of the charging points this caused operational delay. Between the parties who were involved in getting the charging infrastructure up and running there was miscommunication and partly unfulfilled agreements with the charging point manufacturer. On the other hand, by using the existing supplier, the charging points can remain after the end of this pilot.

The only difference between the charging point suppliers is the EVSEs weren't commissioned to the Ecotap back office, but to the Elaad back office as they are a partner within InterFlex. The delivery of the EVSEs went well. The commissioning gave problems. The communication controller was not suitable for Elaad (because the use of different software). This was replaced.

On the other hand, by using the existing supplier, the charging points can remain after the end of this pilot.

2.5. EV drivers / Participant recruitment

Flexibility on EVs is done with smart charging algorithms. The EV driver will get an incentive of 5 cents per kWh charged. With 5 cents per kWh, Jedlix thinks this is enough incentive for the user to actual use the product. The user can track the generated savings via registered Jedlix app that is available in the PlayStore (Android) and App Store (iOS).

For the project, EV drivers are asked to participate by charging on the InterFlex EVSEs and by using the Jedlix app for smart charging. The recruitment off these drivers was /is a challenge. For the recruitment the project used different channels. The demo area in Eindhoven, Strijp-S, is a combined industrial- and domestic area. There is a mix of traditional companies and start-ups. For networking and business purposes the Strijp-S area has a facilitating organisation. This organisation was used to get attention of the EV drivers in Strijp-S for the project. Additionally a website (www.interflexstrijp.nl/deelnemers) was made to inform the EV drivers and to give them the opportunity to register for the pilot.

All involved parties have a registration link on their own website that links to the registration landing page. The registration process makes it possible to track EV drivers who decided to participate in the pilot. The following details are asked via the registration form:

- Full name
- Email address
- Phone number
- Hybrid or BEV (checkbox)
- Relation with Strijp-S (checkbox)

Within 2 days, after receiving an application, Jedlix sends a confirmation e-mail including information about the InterFlex pilot, the charging locations and a tutorial about downloading/using the Jedlix app.

Furthermore, on social media promotion films are posted (https://youtu.be/7DJbYSq8AF0 and https://youtu.be/7Z5HGu5ycX8) to get the attention of the EV drivers and inform them about the pilot in a 'playful' way.

As for offline marketing, EVSEs are designed with a sticker of the InterFlex project that describes the pilot and gives the EV driver the possibility to download the Jedlix app by scanning the QR code. In addition to acquire new EV drivers, several flyer campaigns were launched at Strijp-S and special pamphlets were put on the charging cables of each electric car that charged at Strijp-S.

The result of above described marketing efforts are:

- 450+ people visited the registration landing page
- 27 people filled in the registration form on the registration landing page

See appendix 2 for more acquisition details.

Experiences concerning recruitment and business proposition to EV drivers

The recruitment process of new EV drivers was not as easy as expected. EV drivers probably charge their car during the night at home and not at Strijp-S. Another aspect that came along is that EV drivers did not know about the InterFlex charging locations, because they were placed at new locations on the Strijp-S area.

The onboarding of new registered participants went quite well. Most of the EV-drivers downloaded the Jedlix app after receiving the confirmation e-mail with more information about the pilot and tutorial of the app.
After the onboarding, the participant was ready to charge his/her car at one of the InterFlex charging points. We noticed, by analyzing the data, that most of the participants did not charge their car at one of these locations. During the upcoming months we will focus on

activating these registered EV driver by sending him/her e-mails and customized push-notifications via the Jedlix app. See appendix 3 for details about recruitment action.

3. IMPLEMENTATION EXPERIENCES USE CASE 3

This chapter describes the implementation of use case 3.

3.1. Use case 3

Use case 3 describes the usability of an integrated flex market based on a combination of stationary battery storage and EV chargers.

Multiple aggregators offer flexibility from different flexibility sources (Smart Storage Unit, rotating Photo Voltaic chargers and Electric vehicle chargers) on a flexibility market so that the DSO can procure flexibility from multiple parties for grid supporting services (e.g. congestion management). The DSO is competing for flexibility with other market parties; aggregators can sell their flexibility to the TSO if the TSO is willing to pay more.

The objective of this use case is threefold:
By implementing use case 3, DSO and involved aggregators test and validate a framework for trading flexibility between multiple aggregators and DSO in order to prove the concept and develop knowledge on the applicability and the future scalability of the concept.

By implementing use case 3, DSO and involved aggregators will gain an in-depth understanding on how flexibility can be traded between DSO and multiple-aggregators and how the required contracts and transactions can be formed and handled.

By implementing use case 3, the involved aggregators can validate the proposition for trading flexibility for multi-purpose to multi-party (e.g. congestion management + spot market trading). Therefore, they can gain knowledge on the monetary value of flexibility for their business.

3.2. USEF implementation

The communication interface between DSO and aggregator is based on the USEF framework. USEF is a market framework for trading energy flexibility that also provides the architecture, rules and protocol specification to make it work. This is broader than the InterFlex project, where communication related to the Transmission System Operator (TSO) and Balance Responsible Party is out of scope; that part of the USEF communication is not used.
It has been tried to use the exact USEF defined - DSO aggregator - messages as much as possible, however, additional custom attributes had to be added to some of the USEF messages. Furthermore, an additional message is added to the communication as a workaround for determining how much flexibility is actually provided by aggregators. The main reason for deviating from the USEF standard is that the standard was not able to foresee in the needs of the InterFlex project.
See also https://www.usef.energy/implementations/interflex-enexis/ and appendix 4 for more details about the USEF protocol.

Sanction price

The mechanism to distinguish between different flex characteristics is an important feature of USEF+. This mechanism is realized in the InterFlex project by the addition of a sanction price to a flexibility request. When a DSO sends out a flexibility request to an aggregator, it should add a sanction price value in USEF+. This sanction rationale behind the sanction price is that it should be paid by the aggregator in case that the aggregator did not deliver the flexibility. As a result, if the sanction price is relatively high, aggregators will not offer flexibility of sources that have a high uncertainty of delivery. On the other hand, when an aggregator is sure about the flexibility source to can deliver the flexibility, it will accept a higher sanction price. In this way, aggregators will first offer flexibility of DERs that have a high probability that the flexibility will be present. In case that the DSO needs more flexibility, it can send a new flexibility request but now with a lower sanction price, making it more attractive for aggregators to offer flexibility of DERs that are less likely to be present.

Experiences with USEF

In this section some experiences with USEF are explained. Although the market design of USEF is not necessarily restricted to day-ahead trade and contains descriptions of services for balancing and intra-day purposes as well. In this project the messaging specification and the XSD are initially designed such, that trading on day-ahead basis is implied. Intra-day trade for congestion management purposes is possible but the messages currently do not support trades that cover a period starting a certain day end, ending the next day. This makes it not yet possible to do an intra-day flexibility trade in the same manner as the EPEX (European Power Exchange) market, i.e. with a rolling horizon till the end of the next day.
Furthermore, there is a design decision related to congestion management that has disadvantages. All messages in the USEF specification that can be used for congestion management, are congestion point based. This means that all flexibility trading messages only consider one congestion point while there can be a relation between two (via the physical grid). As a result, it might be that solving congestion for congestion point A leads to extra congestion on congestion point B. Research should point out if this will only result in extra iterations or that it results in not finding a solution at all.

The figure 5 below shows for a specific congestion point, that the FAP TNO is capable to stay below the light yellow load curved requested by the DSO ('Congestion target max').

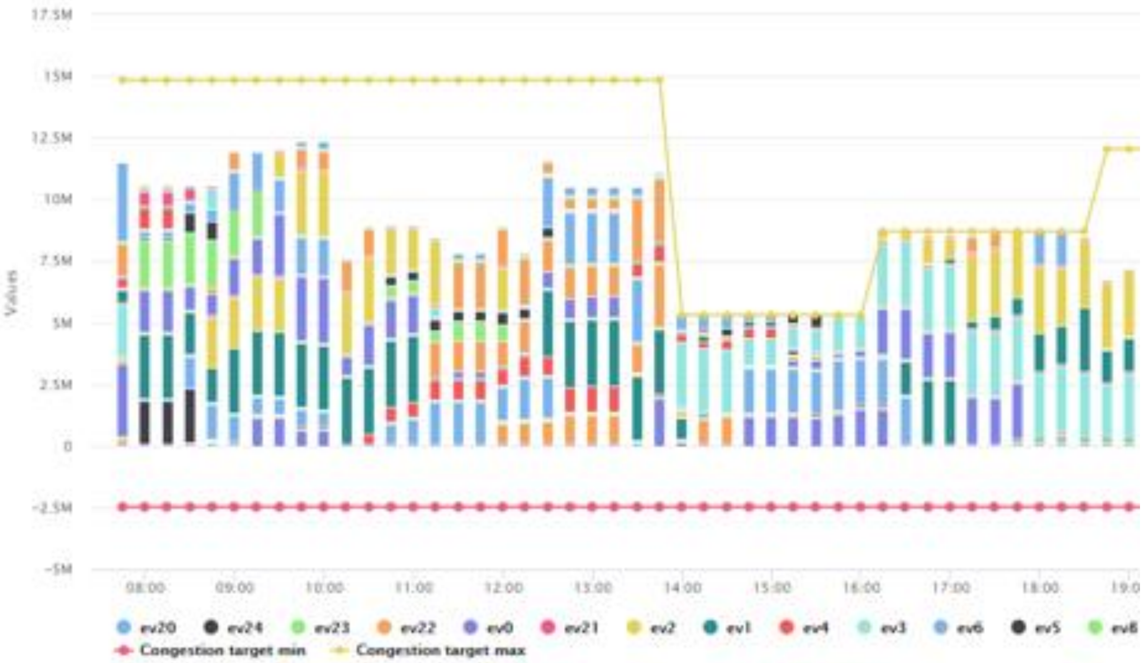


Figure 5 - Congestion management with sub clusters of an aggregator's portfolio

Experiences USEF model

- The definition of a baseline is not determined during the project. Because the baseline is not clear, it is not possible to prove if flex is delivered. Furthermore it is very difficult to see the impact of the flex request on congestion.

Experiences USEF messages

- The standard deployment is not easy to use, because:
  - There are some technical challenges causing the standard USEF installation to be not usable. An example is that it required installing a OS (Operating System) specific library, which was not feasible for the cloud-native software platform used (Mendix).
  - Not all content of the USEF messages is clear, which lead to discussions between the different project partners.
- Exact details on changes to USEF and additional agreements that were needed, can be provided on request, and have been shared with the USEF organisation as well.

3.3. FAPs

The Flexibility Aggregation Platform (FAP) is operated by the commercial aggregator and is responsible for controlling the flexibility assets of the aggregator. The FAP also provides an interface to the DSO (via USEF). This chapter describes the different FAPs, Distributed Energy resource (DER) and EV, how the architecture is created and the lessons learned.

One of the goals of the project is to study the economic value of flexibility when it is used for congestion management. This is achieved by the use and development of state-of-the-art technical solutions for congestion management and the establishment of contractual agreements and financial flows between parties. In the end, this will result in a flexibility value chain, which should help determining the value of flexibility. The basis for the value chain is the architecture developed in InterFlex, that is open for multiple entrants, and can exploit different type of flexibilities from different type of DERs on different markets.

System architecture
The figure 6 below shows an overview of the system architecture that is based on the concept of an open market for congestion management services. The DSO typically has a monopoly position and given the current legal framework, this is not likely to change soon. However, the architecture is based on the concept of a free market for flexibility because there are no regulatory restrictions and a free market allows competition. From market theory it will result in an economically efficient outcome, and as a consequence, this will reduce the costs for congestion management services. In addition, a free market for flexibility also allows aggregators to monetize flexibility on the energy markets, which strengthens their business case. To realize this, it is crucial that the market for flexibility is open and provides a level playing field for aggregators.

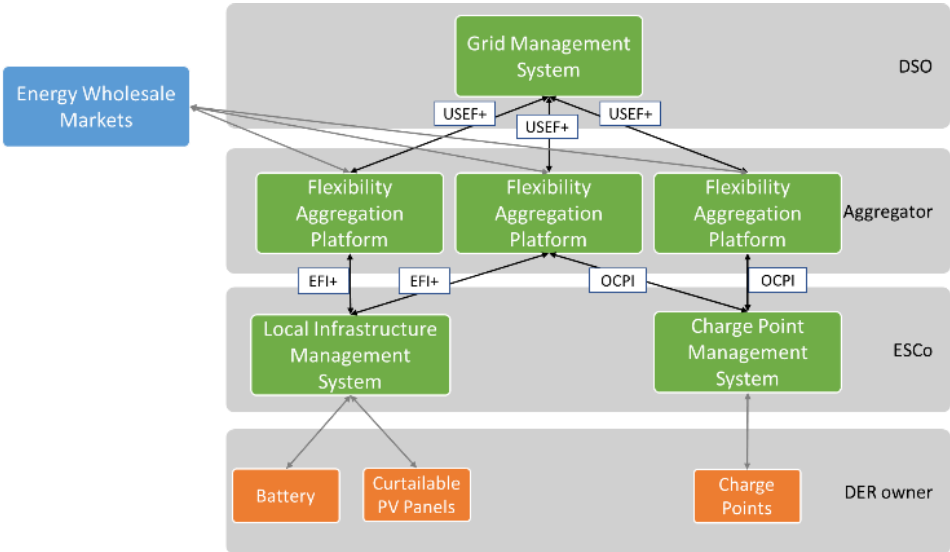


Figure 6 - InterFlex system architecture

A second requirement of the architecture is that it provides a scalable solution. The flexibility of DERs such as Electrical Vehicles (EVs) can only be used effectively for congestion management services and energy-market trading if it is based on large volumes/big numbers of EVs. In that case, prediction errors that the aggregator will inevitably face can be dealt with by the law of big numbers. This means that the architecture should be able to should support systems that count millions of DERs.

3.3.1. FAP TNO

This section describes the experiences with the FAP TNO.

Separation of responsibilities
To comply with the requirement of creating an open market for flexibility and the scalability requirement, the architecture features a clear separation of responsibilities and roles.

The first role of the architecture is that of a technical aggregator (in the figure 6 above ESCo - Energy Service Company). Technical aggregators are responsible for maintaining and operating DERs. They provide a communication interface to the party that takes the next role: the commercial aggregator.

The commercial aggregator connects to the technical aggregator, where it receives information about the flexibility characteristics. This information is used by the commercial aggregator to optimize the use of the offered flexibility for one or multiple optimization goals. These goals can include congestion management services and energy market positions.

The third role in the architecture is taken by the DSO. The main responsibility of the DSO is to transport electricity to/from all grid connections while maintaining a proper power quality in the LV/MV grid and preventing congestions. The DSO might want to use flexibility for this purpose and therefore it has a place in the architecture. The DSO in this way has created an open market for congestion management services (like a TSO creates a market for balancing). The subsystem in the architecture that the DSO uses for managing this, is called a Grid Management System, which forecasts congestion and dispatches congestion management services provided by the aggregators.

This separation of concerns and responsibilities in the InterFlex architecture works very well, since it enables the actors to focus on their key competences and key responsibility (i.e. exploiting flexibility on energy markets, managing electricity grids and managing device infrastructure).

Scalability
One of the characteristics of the architecture is that the level of abstraction increases from the bottom to the top, these abstraction layers increase the scalability. At the DER level parameters such as power consumption, voltages levels, device temperatures, availability over time, etc. are relevant. However, when a DSO wants to use flexibility of those DERs for congestion management, it shouldn't bother about all those details of individual devices. In contrary, it just should request what the need for flexibility is on an aggregated level (which already appears to be challenging). Therefore, in the architecture every layer adds another layer of abstraction. The technical aggregator translates DER specific parameters at its bottom to flexibility, a more abstract phenomenon, to the aggregator and make it available to aggregators. The aggregator translates the flexibility of devices to services such as congestion management services (based on location in the grid) for the DSO or other ancillary services on balancing markets (independent of location in the grid).

The aggregator, can based on device energy needs and the flexibilities of these devices, try to follow a certain load profile that best fits the energy markets and DSO requests for different congestion points. The following figure 7 gives an example of the Flexibility Aggregation Platform (FAP) TNO User Interface.

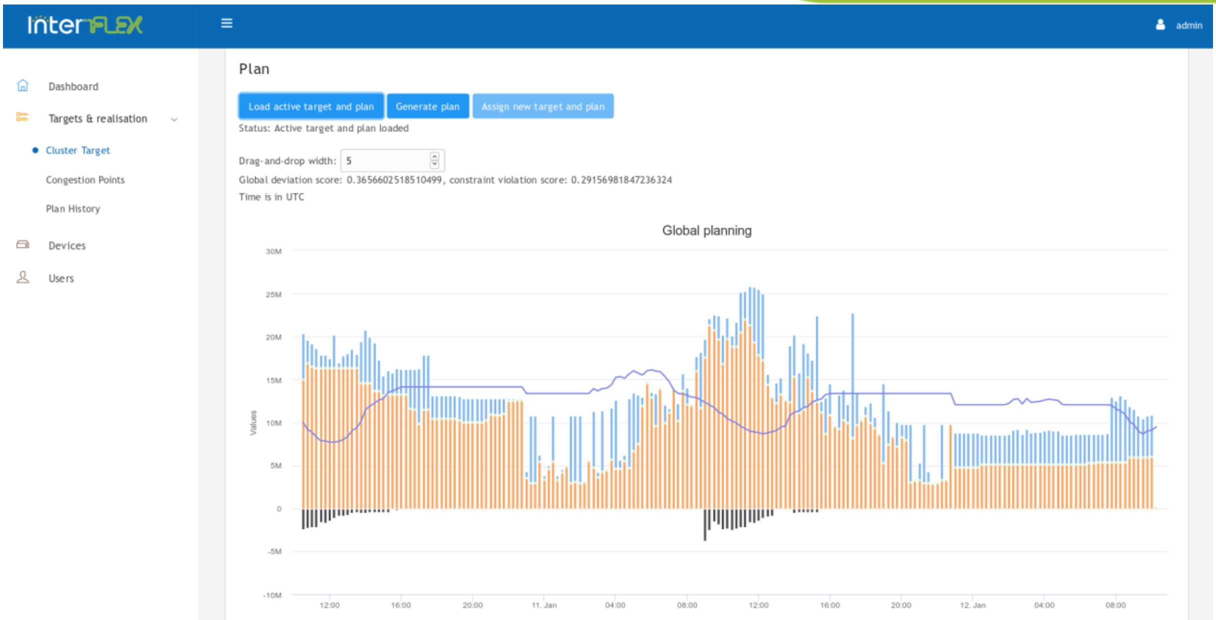


Figure 7 - User interface of Flexibility Aggregation Platform of TNO

The Flexibility Aggregation Platform that TNO is building focusses on future challenges and markets. For that reason the FAP TNO is able to control different DERs, is this project (partly simulated) EVs and the SSU. The platform should be able and is able to control DERs that are very predictable (like the SSU) and combine that with less predictable and controllable DERs like EVs. Further the FAP TNO can act on current and future energy markets. With future energy markets is meant: market behavior we expect in the future due to the large amount of intermittent renewable energy from wind and PV and additional demand from EVs and heating solutions. These future energy markets have been simulated and lead to a demand profile that the FAP TNO will follow in the research scenarios.

Experiences during implementation phase

- The separation of concerns and responsibilities in the InterFlex architecture worked well, since it enabled the actors to focus on their key responsibility and key competences (i.e. exploiting flexibility on energy markets, managing electricity grids and managing device infrastructure).
- Simulated markets and devices help to discover issues early and enable advanced pre-testing. This almost always speeds up development, although initially it seems extra effort.
- Keep focus on the total system scope. Due to the more technical communication protocol focus (day-ahead, PTU based) sometimes energy market features (like intra-day and especially balancing market and direct coupling with these markets) were less in focus in the early phase of the implementation. This makes sound balanced business model verification more difficult, since the market value of the balancing market was now not included. These energy markets are important for verification since it is expected that most revenues can be generated on electricity markets and not on congestion management markets. Still congestion management markets are important since they will create a more optimal system delaying or deferring grid investments, and create a more optimal and cost-effective system for the end-users and consumers.
- It is effective to work with open standards and modify what is needed, this prevents repeated mistakes.

3.3.2. FAP DER

System architecture

The figure 8 below shows an overview of the system architecture which Sympower built to trade flexibility of DERs with the GMS for congestion management purposes.

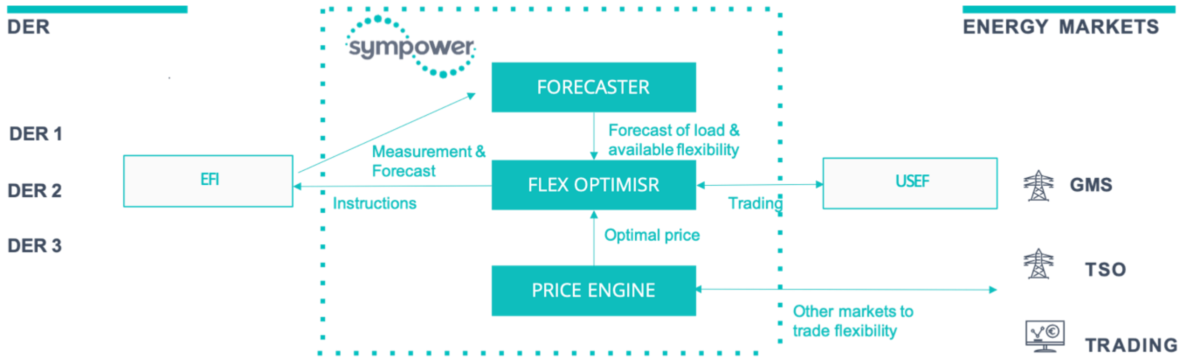


Figure 8 - System architecture FAP DER

One important focus of InterFlex is to look at the replicability and scalability of the solution built. That's the reason why USEF and EFI were chosen as protocols to interface with the GMS and LIMS respectively. Below a flow diagram (figure 9) of the different messages exchanged with the GMS and the LIMS is given.

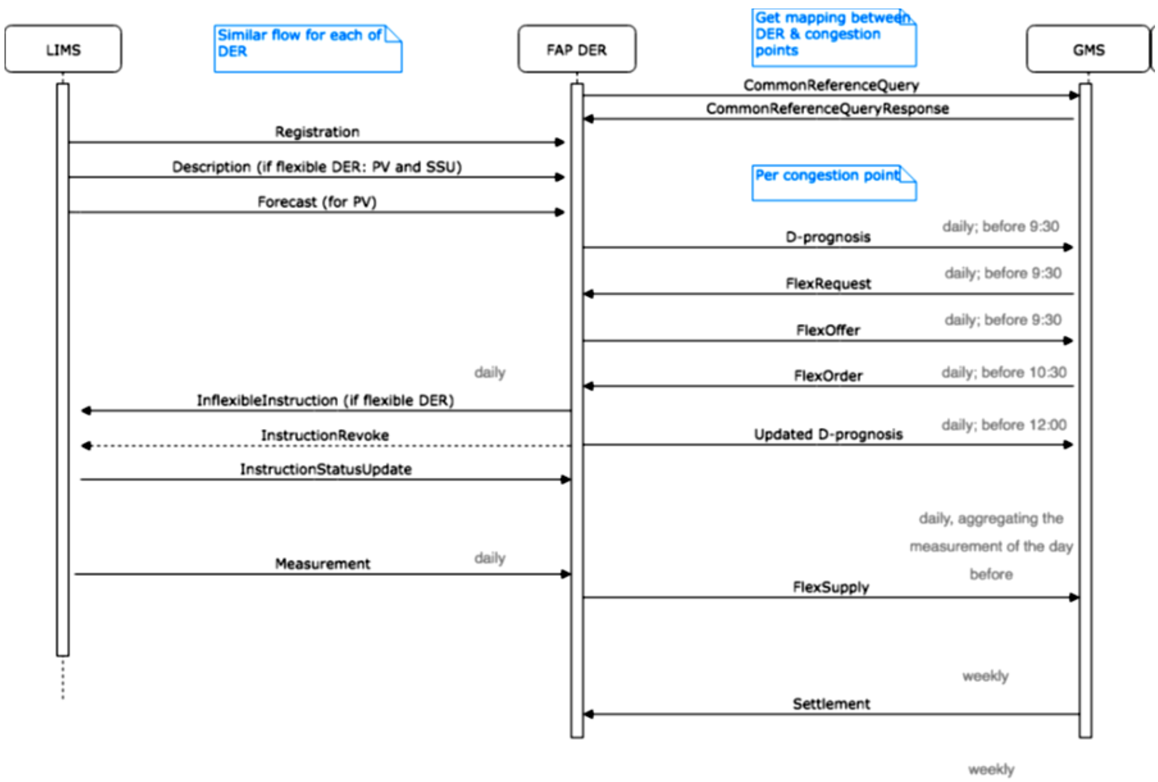


Figure 9 - Flow diagram Messages exchanging GMS and LIMS

Within Sympower's platform, the choice was made to use micro-services or 'modules' with the different key functionalities of trading flexibility on this new congestion management market.

The Forecaster micro-service is the module used to forecast the load of Sympower's portfolio. For InterFlex, the forecast is received per DER from the LIMS directly. For other markets Sympower is active in, the forecaster uses neural network models and different input parameters (based on the type of DER) to generate a forecast. This module allows Sympower to send a D-prognosis to the GMS in the context of InterFlex, but also to forecast the available flexibility to trade on the different markets.

The Price Engine module is the module which defines the optimal price we should trade flexibility for. In the scope of InterFlex, the day-ahead market price was used as reference, but other markets like ancillary services could be taken into account as well to define the optimal price.

The FlexOptimiser is the module defining the FlexOffer based on the FlexRequest received from the GMS, the PriceEngine output and the Forecaster output. More specifically, it defines the amount of flexibility Sympower can offer and for which price.

Experiences during implementation phase FAP DER

- Importance of having up-to-date specifications and align with the different parties involved before and during the implementation phase
    - Having frequent face-to-face meetings definitely helped, but we still faced some delays because of unclear specifications (EFI+, central database, units in different messages)
- Looking back, it would have been useful to include the test cases already in the 8 implementation sprints and built the interfaces around those. That would have allowed all parties to test both interfaces in the early stages and key functionalities at the same time.
- Having direct communication between developers helped a lot. We strongly recommend to have direct communication channels (e.g. Slack), including the developers of each party as well as product owners.

3.3.3. FAP EV

The FAP EV is the platform in between the GMS, CPMS and the EV driver. The figure 10 below shows an overview of the FAP EV system and the services and processes that are connected to the FAP EV.

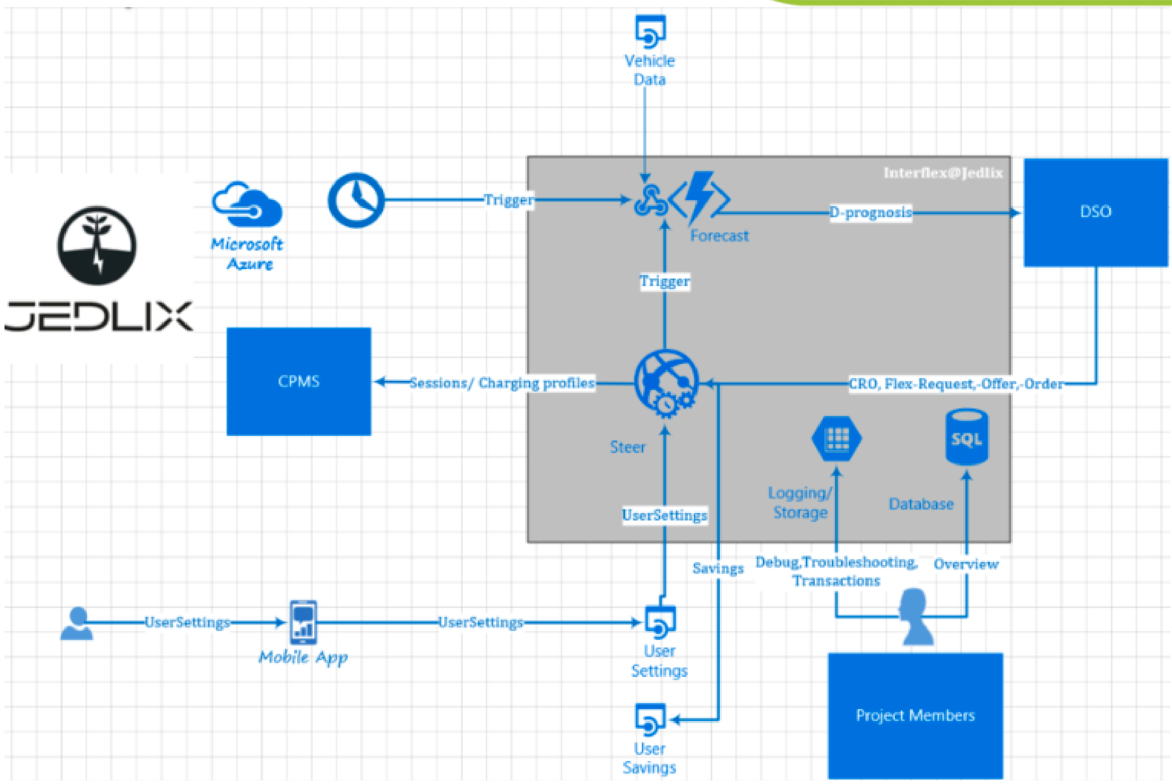


Figure 10 - FAP EV system

From the GMS the FAP EV takes care of all the USEF related messaging in such a way, that the DSO has a good understanding of the forecasted EV charging of the given congestion points. Charging data from the CPMS is input for the forecast. The connection with the EV driver is present to get all data needed to understand the user needs. This is for example the leaving time of the EV driver, which is taken into consideration when optimizing the charging process. The FAP EV can influence the charging profile of the EV by sending charging commands to the charging stations present in the CPMS.

While the communication between the GMS and the FAP EV is done a day before charging, the communication between the FAP EV and the EV driver and CPMS is done real-time. At the moment an EV driver starts charging, the FAP EV will make sure that user needs and network capacity restrictions, based on flexibility requested from the DSO, are taken into account. This happens in such a way that the FAP EV does not create any local congestion and is still making sure the charging needs of the EV driver are met.

The commercial aggregator receives compensation from the DSO for handling local congestion problems (based on the trade agreement on the flexibility market). The EV driver will get an incentive of 5 cents per kWh charged for smart charging (the FAP EV will get the user needs from the app and will optimize the charging in such a way that no local congestion is created). This is paid out to the EV driver and therefore, the EV owner is saving money by smart charging.

3.4. User interface EV-drivers (app)

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 creates an account first and adds the charging card number (see also Geelen, D., Refa, N., Spiering, R., 2019). The charging card information is needed for identification of the user at a charging point.

When the EV-driver has set up everything in the Jedlix app and starts charging at one of the InterFlex charging points a start charging message is sent from the CPMS to the FAP EV. The FAP EV only receives session data from charging cards that have been added in the app. When there is a match, the user receives a push notification (every charging session) that a smart charging session has started. At this moment the FAP EV will get all the user needs from the app and will optimize the charging in such a way that no local congestion is created.

The user needs are:

- Leaving time
    - The time the user wants to take the car for the next ride
- Direct charged range
    - The amount of kilometers that needs to be directly charged no matter the given leaving time

The current battery level of the car is needed for the charging session. Jedlix updates the charging process based on the users' needs and the situation in the grid.

After the charging session, the amount of savings is calculated by Jedlix and shown in the app. When the cumulated savings are 5 Euro or more, the user can have the savings paid out to his/her bank account.

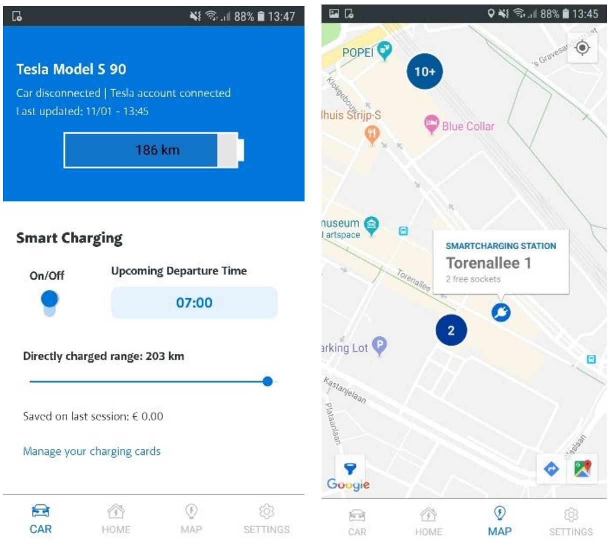


Figure 11- Screenshots of the smart charging app

Left: User settings for a smart charging session in the smart charging session.

Right: Map indicating public charging stations with smart charging option.

3.5. GMS

The main goal of the GMS (Grid Management System) is to predict congestion, and make the decision to request flex or not.

The GMS system is built within the Enexis organization. The system runs on two cloud platforms. The first one is Microsoft Azure, where the database and the decision modules run. The second part is the user interface which has been built in Mendix.

In order to use the available flexibility efficiently, the GMS system follows predefined steps, as you can observe in the figure 12 below (see also Steegh, Van Cuijk & Pourasghar Khomami, 2019).

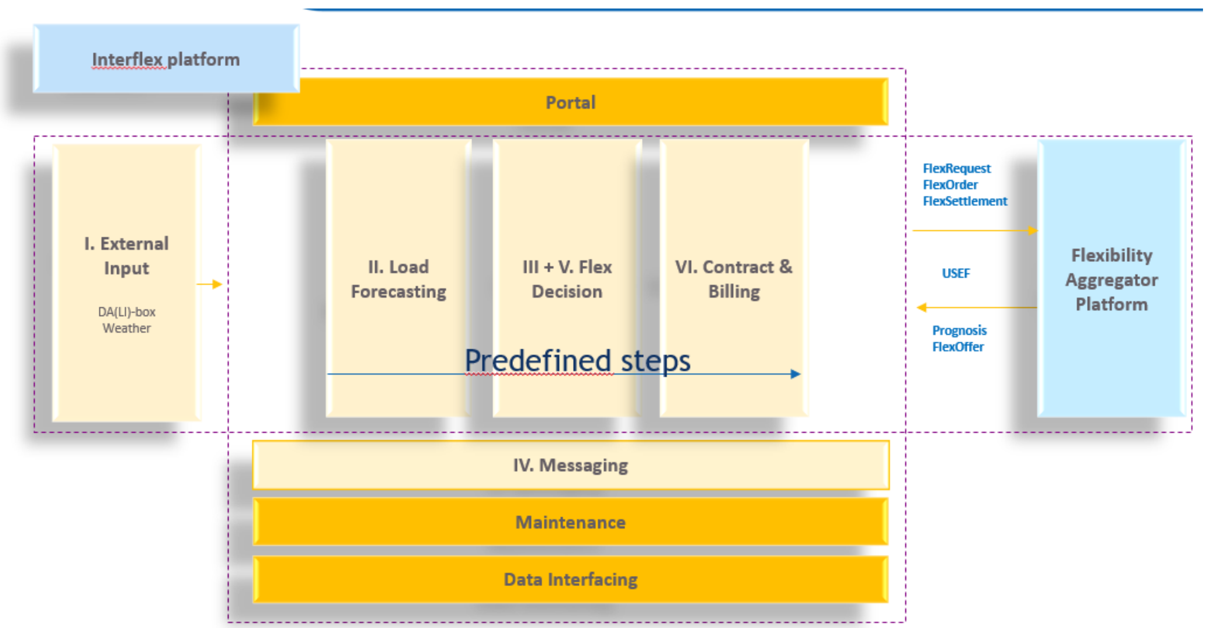


Figure 12 – Grid Management System

This chapter describes the steps that the GMS (Grid Management System) takes to judge and order the required amount of flexibility.

Step I: External input, receiving and storing historical data
The Enexis Distributed Automation Light (DALi) system is responsible for collecting grid data from the measurement devices installed at the Medium Voltage (MV)/Low Voltage (LV) station. Widespread role out of DALi boxes (see figure) is needed in order to improve the observability of the distribution grid. DALi is the Enexis light version of a SCADA system. The DALi-Box measurements include active/reactive power, voltage, current, harmonic distortion, open door and short circuits detection.

The DALi-box can measure on a transformer level and on all of the underlying feeders. The second data source for

Figure 13 - DALi-box

the GMS is weather data, which contains a local weather forecast including wind speed, temperature and solar irradiation. All the data is stored in a big data cloud environment for possible future use and to analyze trends. For the InterFlex project, two DALi-boxes have been installed in the local MV/LV stations.

Step II: LoadForecasting, the use of data to predict congestion
The figure 14 shows one out of two pilot locations in Strijp-S, Eindhoven. For the load forecast module, the historical 15 minute values (active power) are used.

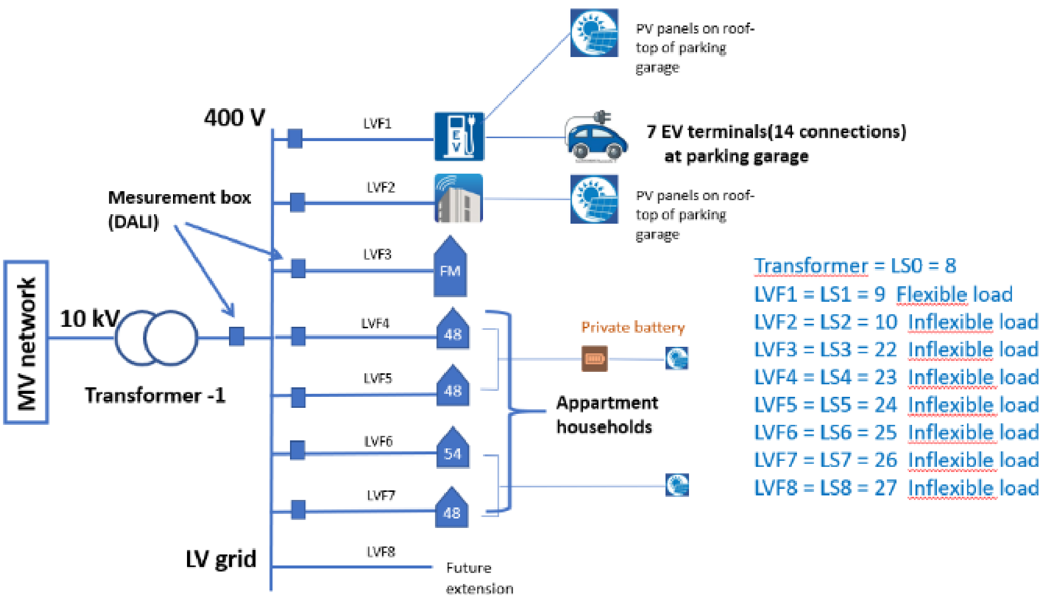


Figure 14 - Landscape pilot location Strijp-S

This historical sensor data as well as the weather forecast data (solar irradiance and wind speed) are input of the load forecasting module. The load forecast is divided in two parts including the flexible and non-flexible load. A load forecasting algorithm specialized at forecasting residential loads is developed. The algorithm provides a 48-hour rolling window forecast, with 15-minute resolution on a MV/LV transformer level. The flexible loads are forecasted by the aggregators and then sent to the GMS using the standardized USEF messages for receiving a D-prognose per aggregator per congestion point. The total load on a transformer level is measured by the DALi box

Step III: Flex decision, make a flex need decision
Primary goal is to devise a system which can run automatically without any human interaction. The decision module has been developed to decide whether flex is required. The basic logic of the decision is as following:

- If the maximum capacity of the transformer is less than the sum of the flexible and non-flexible load forecasts, then congestion is predicted and flex is needed.
- The second task of the decision module is to calculate how much the DSO is willing to pay to prevent the predicted congestions and how much financial risk is involved if the required flex cannot be delivered. This is defined by DSO as the proposed price

and the sanction price of the flex request (max price and minimum sanction price).

Step IV: Messaging, sending Flex requests and receiving Flex offers
In case flexibility is needed, the aggregators should be notified by the DSO. In order to notify the aggregators, a flexibility request is sent to them. This message contains how much flexibility is needed at what time. The connection between aggregator and congestion point is maintained in the GMS. Only those aggregators receive a flex request which are capable of solving the local congestion.

Step V: Flex decision, making a flex order decision
After the system has sent out the need and price for flexibility, aggregators can submit offers as a response to supply the requested flexibility. If more than one aggregator submits a suitable offer, an evaluation and selection procedure is started to determine which offer(s) should be adopted.

Step VI: flex settlement
The observed baseline is the base load profile which would happen if the aggregator did not deliver the flex. Since some flexible loads, such as EVs, are less predictable, this value allows the aggregators to specify what the baseline actually is. Delivered energy is the actual energy (positive or negative) that has been delivered by the aggregator. The difference between the actual situation when aggregator takes no action (observed baseline), and the actual delivered energy is defined as the delivered Flex. The flex settlement message is also a standard USEF message which is sent every week from the DSO to the aggregators. The amount of the aggregator's invoice received by DSO should to be equal to the sum of the flex settlement messages.

Experiences in building the GMS
Making use of new technologies, like big data, decentralization, smart products and (cheap) sensors provide us the opportunity to create a smart grid. This also means that ICT becomes a part of the core of an electricity grid. Creating multidisciplinary teams that understand new technologies as well as the electricity grid is essential.

During the building phase there where different teams that worked on different modules of the load forecast and flex decision in the cloud platform Azure:

- The infrastructure was developed and maintained by a dedicated project team.
- The data wrangling, to get and structure the data for use as input for the models, was also done by the project team.
- The decision modules and forecast modules where built by the Enexis' Data Science team. The team wasn't directly involved in the project. It's 'challenging' to ensure all project related information gets communicated properly, and the implementation gets transferred to the project's environment smoothly

Communication between the project team and the data science teams needs to be aligned immediately from the start of the project so that everyone's goals are aligned.

Development should be better aligned during the start of the project:

- Determine in what way the code will be built and delivered where (GitLab/GitHub/etc.).
- Not all things that are developed locally on a development system will run on Platform as a Service (Azure App Service).

- Because there was not always clear alignment upfront sometimes, we lost time on trying to find out how to deploy something to the cloud that was working perfectly fine locally.

Make things modular, right from the start:

- We ran into issues for which components could not easily be updated, as the updated functionality was not contained in separate modules.
- Right from the start when there's a sense that something should be a separate module, build it as a separate module. The benefit is that modules can be exchanged/updated more easily, because it won't impact your whole codebase.

Use external parameters and variables to make everything dynamic.

- This will make publishing code easier as no connection strings or other sensitive data are being exported.
- This will make it possible to modify parameters to process chains without code modification.
- This helps to align development frameworks so all developers can help each other when they run into challenges.

4. CHAIN TEST

This chapter describes the chain test.

Chain test principle

The purpose of the chain test was to validate whether the systems (see figure 1) of the flexibility market process perform from end to end according to the specified requirements. We tested happy and unhappy flows. In a happy flow scenario messages have been handled in line with the agreed process; messages in the chain are sent as expected. In an unhappy scenario the software chain is somewhere interrupted. We made a distinction between technical problems (e.g. system failure, malfunction of devices) and functional problems (e.g. not all flex is delivered). For both scenarios, happy and unhappy flows, it must be clear how they should be handled (e.g. sending an error message in case of disruption).

In a sprint backlog of the chain test we kept track of all the test scenarios and the issues to be solved. The flow steps and status were described in a test result document. A few times a week the progress was discussed with the test coordinators in a stand-up meeting project.

Chain test experiences use case 2

Unfortunately not all EV-chain test scenarios were tested before the field tests/research phase started due to a lack of actual test data and unclear requirements. The chain test led to finetuning of system components and a clear interpretation of some definitions in the chain.

Chain test experiences test use case 2:

- Install EV charging points right from the start of the project.

- Gather historical data of the EV charging sessions and if necessary simulating data right from the start of the project.
- Investigate how to match EV charging points to (the aggregated level of) congestion points already during the requirements phase.
- For EV there were no user interfaces available yet during chain test, that made it difficult to demo and understand the EV chain. Make sure user interfaces are implemented before starting the chain test.
- Clear overview of the chain and related protocols is necessary to make sure the chain is in line with the process requirements. Check already during requirements phase how to match EV charging points to the aggregated level of congestion points. Difficult aspect turned out to be the communication between the protocols; the translation of data from messages in one protocol to another protocol. OCPI works with charging points and drivers pass ID. USEF works with EAN codes connections and congestions points. It wasn't possible to match charging points with congestions points.

Chain test experiences use case 3
The chain test made clear if the requirements are clearly understood by the parties involved in the project. Obviously, it is not possible to have 100% complete requirements; the chain test led to f requirements (e.g. the direction of the flex values in the different messages).

The 'flex settlement' process step (in the end of the flex process) turned out to be not clear enough. It resulted in discussions on basic topics, like how to communicate the flex direction (consumption or production) in the software chain (via positive or negative values) and how to calculate proof of supply.

Experiences use case 3:
- Pay attention to requirements (specification of system functionalities) in each phase of the project (implementation, chain test, field test).
- Take enough time, and ask dedication from all the partners, to test the the software chain of the flex market. In this project a test period from 6 weeks was not enough to test the complete software chain, including bug fixes.
- When using more than one protocol in the chain, describe during the requirements phase the complete (chain) data flow. This to detect mismatches in an early phase.
- In order to do research with respect to the performance of the flexibility market, a database was created, separate from the production database. This way analysts could easily access to data to monitor the working of the flexibility market and to do in-depth analyses.
- It is important that the research team and development team (who set-up and manage the database) define together which data in which format has to be included. Because one gains experience and insights as the project progresses, it is also important to make sure that it is easy make adjustments to the database (for additional data and/or different formats).
- Having a test environment, besides a production environment (for each system in the software chain), helps to prevent interruption of the chain test.
- Having stand-up meetings, and accompaniment of test coordinators, was very helpful to keep focus on the chain test. Collaborative long-distance tools are useful because all project partners have offices located in different cities.

None of the project parties was available fulltime during the requirements, implementation and chain test phase. Also there was unplanned absences in the team due to sickness, holiday and project members have left the program due to job shifts. Despite part-time involvement of the parties a lot is achieved during the chain test period.

5. APPROACH AND RESULTS SCENARIOS

This chapter describes the research approach and the preliminary results.

5.1. Pilot set up

In this project, the day-ahead load forecast is run for two MV/LV transformers. See fig. 15 for the congestion points topology and specifications. Forecasting the inflexible load is done separately from flexible load. In the rest of the report, inflexible load forecast will be addressed as “Load Forecast”, and flexible load forecast (e.g. PV, SSU, EV) will be referred to as “D-prognosis”. Fig. 16 and Fig. 17 demonstrate the day-ahead load forecast of two congestion points during one week of April as an example. In these figures, the red curve shows the real measurements of the grid and the blue curve represents the load forecast. For both measurements and the load forecast, the flexible load feeder is excluded, since the flexible and inflexible loads are predicted separately. On one side, the inflexible load based on the DALi-measurements will be forecasted by Enexis. On the other side, each aggregator is responsible of forecasting the flexible load which is under their operation. The day-ahead flexible load forecast which is called D-prognosis will be sent by aggregators to the Grid Management System (GMS) in order to be added to the inflexible load forecast to get a total load profile. Finally, the total load profile as an input for the Flex Decision Module (FDM) can be created.

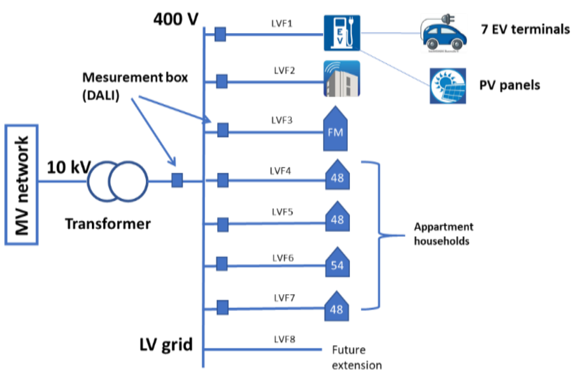


Figure 15 - Congestion points topology and specifications

Flex Decision module will determine the day-ahead flex need based on the total load forecast and the demonstration maximum capacity, called “demo max”. The demo max is a setting to cause virtual congestion on transformer level. In case that peak load exceeds the demo max, a flex need will be generated. It considers both positive and negative demo max thresholds i.e. the possibility of reverse power flow due to high PV generation. Flex need includes the magnitude of required flexibility, as well as the maximum desirable price and sanction price for each 96 PTU’s (Programme Time Unit) in a day, and each congestion point individually. A flex need will be sent as a flex request to each aggregator connected to each congestion point under two conditions. First, D-prognosis has been received from the aggregator; second, aggregator responds within a specific time window that the USEF-message has been received by them. If the aggregator does not send any D-prognosis or if it fails to receive the message, there will be no flex request, even though there is a flex need. However, the initial analysis shows that in more than 90% of the time, a flex need leads to a flex request. In case of overloading, flex request has negative sign which means the load must be reduced. In case of overproduction, flex request is positive which implies the load must be increased, or local energy generation be reduced.

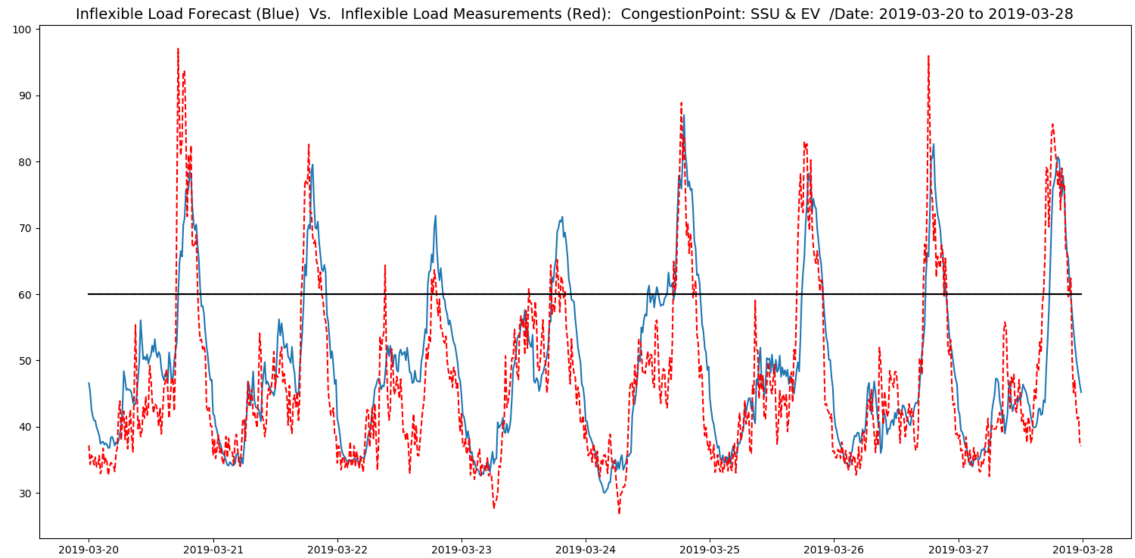


Figure 16 - Congestion point 5 (SSU & EV street)

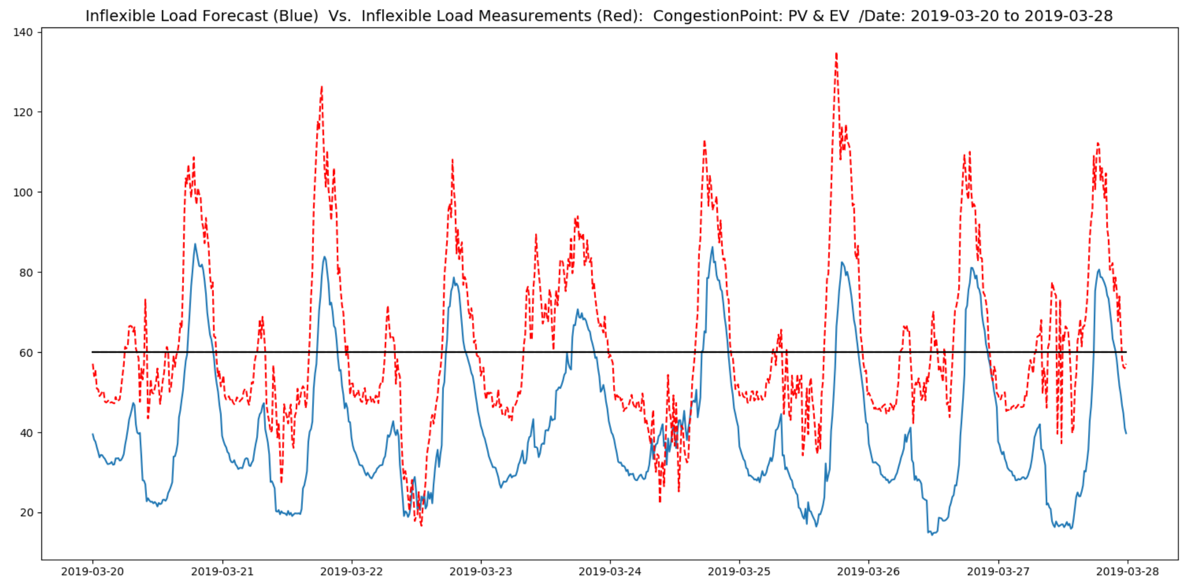


Figure 17 - Congestion point 8 (PV & EV parking)

5.2. Goal field tests

During the field tests the developed systems will be tested in a real life setting. Goal of the field tests is to assess the operation of a local flexibility market under realistic operating conditions and identify criteria for the proper functioning of such a market. During the field tests different market scenarios will be tested under which the flexibility is procured.

Test scenarios
Scenario 1: Day-ahead market
In this phase all flexibility in the local market is traded via a day-ahead market. Based on day-ahead forecasts the flexibility is requested, offered and (if possible) traded. Subsequently the different parties will follow the agreed profile for the next day. During the day no more deviations are possible on the local market.

Scenario 1a: day-ahead market with Sympower
In this scenario commercial aggregator Sympower controls the SSU and the PV; and Jedlix controls the EV.

Scenario 1b: day-ahead market with TNO
In this scenario commercial aggregator TNO controls the SSU and the PV; and Jedlix controls the EV.

5.3. Research approach

In this section the different research questions are outlined. Subsequently, sub questions are formulated per research question, and details are given on how these questions will be answered in the research. The research questions are formulated as follows:

1. How much flexible power and energy is needed in the network? When? Where?
2. How much flexible power is available in the network? When? Where?
3. What is the realized flexible power in the area?

Below figure 18 provides an overview of the relations between research questions 1 till 3. Question 1 focuses on the flex requested in the market. Question 2 focuses on what flex is offered and available in the market, where an overlap arises with the requests. This overlap is analysed in question 3.

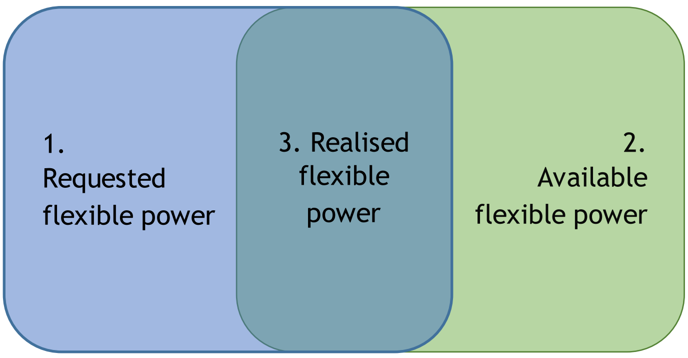


Figure 18 - Relation between research questions 1-3

Research question 1 – Necessary flexible power and energy
Sub questions

a. At what moments, what level of flexible power is requested?
b. At which congestion points, what level of flexible power is requested?
c. How much flexible energy is requested over the course of the day and other testing periods?

Data and methods
Based on the requested output profiles of the flex decision module it will be analysed how much flexible power was requested at each moment in time and at which congestion points this was needed. Additionally these profiles will be analysed to assess the total amount of energy requested over different periods (e.g. daily, weekly). The first analysis will focus more on the detailed level of the need for flexibility in numbers and exact location, whereas the second analysis will yield a more cumulative insight over time.

Analyses:
Plots will be made per congestion point for the flexibility profiles, the counts of upward or downward flexibility requested at each PTU and a distribution of the requested flexible power.

Research question 2 – Available flexible power
Sub questions

a. At what times, what level of flexible power is offered?
b. At which congestion points, what level of flexible power is offered?
c. Who offers the flexible power?
d. How much flexible energy is being offered during the day and over different testing periods?

Data and methods
Based on the offered flexibility profiles it will be analysed how much flexible power was offered at each moment in time and at which congestion points. Additionally these profiles will be analysed to assess the total amount of energy offered over different periods (e.g. daily, weekly). The first analysis will focus more on the detailed level of the offered for flexibility in numbers and exact location, whereas the second analysis will yield a more cumulative insight over time.

Analyses:
Plots will be made per congestion point for the flexibility profiles, the counts of upward or downward flexibility offered at each PTU and a distribution of the offered flexible power, also relative to the amount of requested flexible power.

The following KPI will be used to assess the offered and available flexibility.

The relative amount of flexibility made available by the LA to the CA:

$$\text{Flexibility}_{\%\,available\,field} = \frac{\sum P_{flexibility\,offered\,by\,LA\,to\,CA}}{\sum P_{Total\,theoretically\,available\,flexibility}} * 100$$

Research question 3 – Realised flexible power
Sub questions

a. At what moments, what level of flexible power is realised?
b. At which congestion points, what level of flexible power is realised?
c. How much flexible energy is exchanged over the course of different time periods (e.g. daily, weekly, …)
d. At how many and which moments does the offered flexibility (not) match the requested flexibility?
e. What is the ratio between the actual realised flexibility and the traded flexibility?
f. What is the ratio between the traded flexbility and the forecast available power?

Data and methods
Based on the actual traded and realised flexibility profiles it will be analysed how much flexible power was traded and at which congestion point. Additionally an analysis will be made on these profiles to assess the total amount of traded flexible energy. Furthermore a comparison will be made with the actual measured and realised profiles. Again insight will be made on a detailed level per PTU and per congestion point, as well as a more cumulative insight over several time periods. A more detailed analysis will also be done on the flex requests which could not be met (see Figure 16) and why.

The following KPIs will be used to assess the traded and realised flexibility:
The amount of flexibility traded with the DSO relative to the amount offered by the CA on the local market:

$$\text{Flexibility}_{\%\,traded\,DSO} = \frac{\sum P_{flexibility\,traded\,with\,DSO}}{\sum P_{flexibility\,employed\,on\,markets\,by\,CA}} * 100$$

The amount of flexibility offered on the local market by the CA relative to the amount it could theoretically offer:

$$\text{Flexibility}_{\%\,traded\,markets} = \frac{\sum P_{flexibility\,employed\,on\,markets\,by\,CA}}{\sum P_{flexibility\,offered\,by\,LA\,to\,CA}} * 100$$

The amount of flexibility traded with the DSO relative to the amount requested by the DSO:

$$\text{Flexibility}_{\%\,obtained\,DSO} = \frac{\sum P_{flexibility\,traded\,with\,DSO}}{\sum P_{flexibility\,requested\,by\,DSO}} * 100$$

5.4. Preliminary results

Setup congestion points
EV charging poles in street is connected to one congestion point together with SSU, and EV charging poles in parking garage is connected to another congestion point together with the PV. The details of the congestion points topology and specifications can be observed in Fig. 15. The flex request is sent to all the aggregators connected to each congestion point for the next 96 PTUs (every 15 min) a day ahead. This message includes the magnitude of the required flexibility (kW), the positive or negative sign (increasing/decreasing the load), the maximum price and the sanction price per PTU. In response to this message, each aggregator will send a flex offer, which also includes the same information.

Load Forecast

As can be observed in the Fig. 16 and 17, the load forecast of low voltage distribution grid and individual transformers cannot be as accurate as forecasting the aggregated load profile in the medium voltage level. Therefore, there is a noticeable forecast error which is due to fluctuations of low voltage load and can lead to high uncertainty. Aside from inflexible load forecast, D-prognosis done by aggregators for flexible loads such as EV, PV and SSU will also contribute to the forecast error. In the case of flexible loads, volatility and the consequences of the volatility, the uncertainty is even higher.

For both points, the congestion has been created virtually, since the real capacity of the transformer is higher than the peak load. In both figures, the black line illustrates the demonstration maximum (demo max) capacity of the transformer to cause virtual congestion. Demo max value affect the magnitude and the occurrence of the congestion; hence, determining this factor has strong impact on the research results, particularly the business model of the flex market. It is important to keep the Demo Max value fixed during the period of each scenario; otherwise, it can lead to unrealistic results. At the moment, the demo max for both transformers is set on 50 kW; however, it is still under experiment and expected to be adjusted again.

Flex Request & Flex Offer

Fig. 19 and Fig. 20 illustrate the comparison between flex request and flex offer for both EV street and EV parking garage, separately. The figures show the average value for the whole period of 1st till end of April. In this period of time, all the requested power values are negative which implies the overloading status. As it can be observed in both Fig. 19 and 20, EV offer cannot comply with the requested power properly. Flex offer is scattered through the 96 PTUs and does not match with the flex request in both timing and magnitude. Hence, the availability of EV as a flexibility resource is observed to be pretty low. In comparison between street charging and parking garage, it seems that there is a higher number of EV charging sessions in parking garage which can result in a higher chance of smart charging as well. This can be caused by the higher parking costs on the street and subsequently, the reluctance of spending long time parking there.

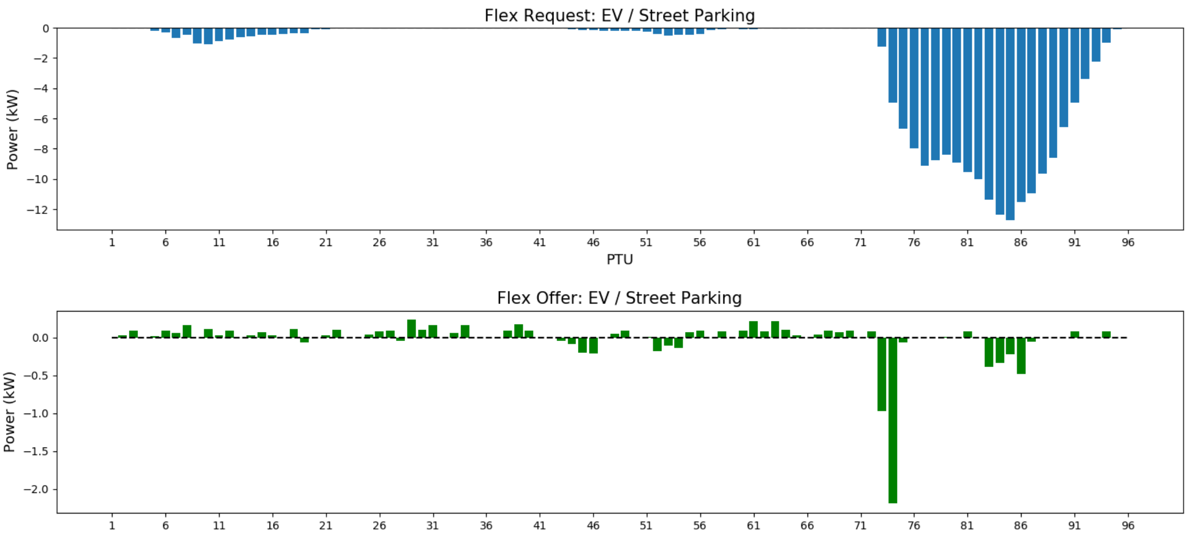


Figure 19 - Flex request vs. flex offer: average per PTU, congestion point 5

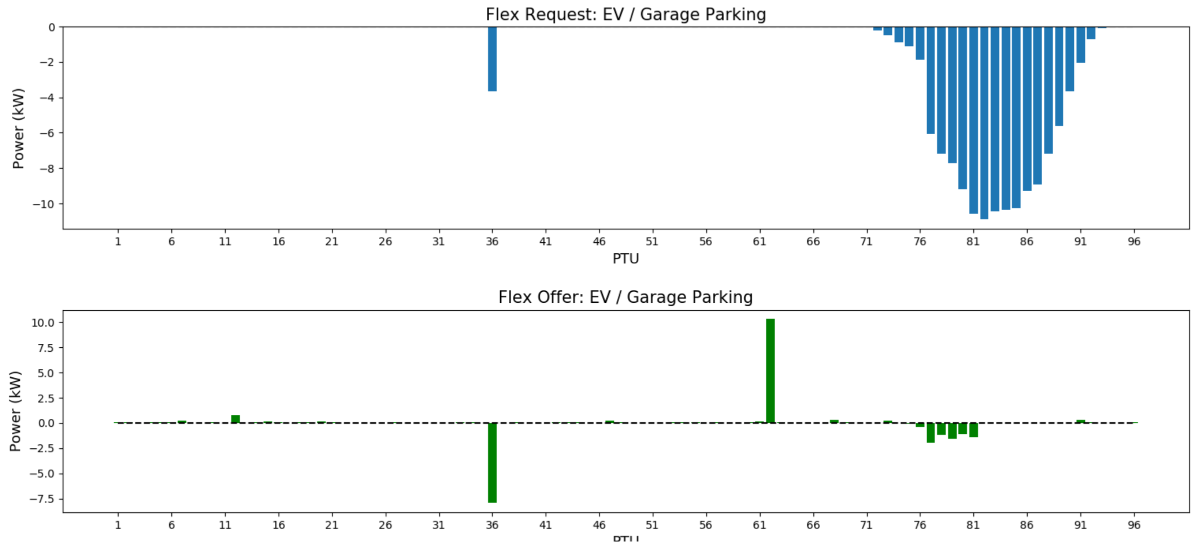


Figure 20 - Flex request vs. flex offer: average per PTU, congestion point 8

Flex Order & Flex Supply

Aside from EV availability as a flexibility resource, another important point is to be cost effective and reliable. Fig. 21 and 22 demonstrate the comparison between flex order and flex supply for EV. As it can be observed, flex order (fig. 21 and 22) can match with the flex offer(fig. 19 and 20) to some extent, but not completely.

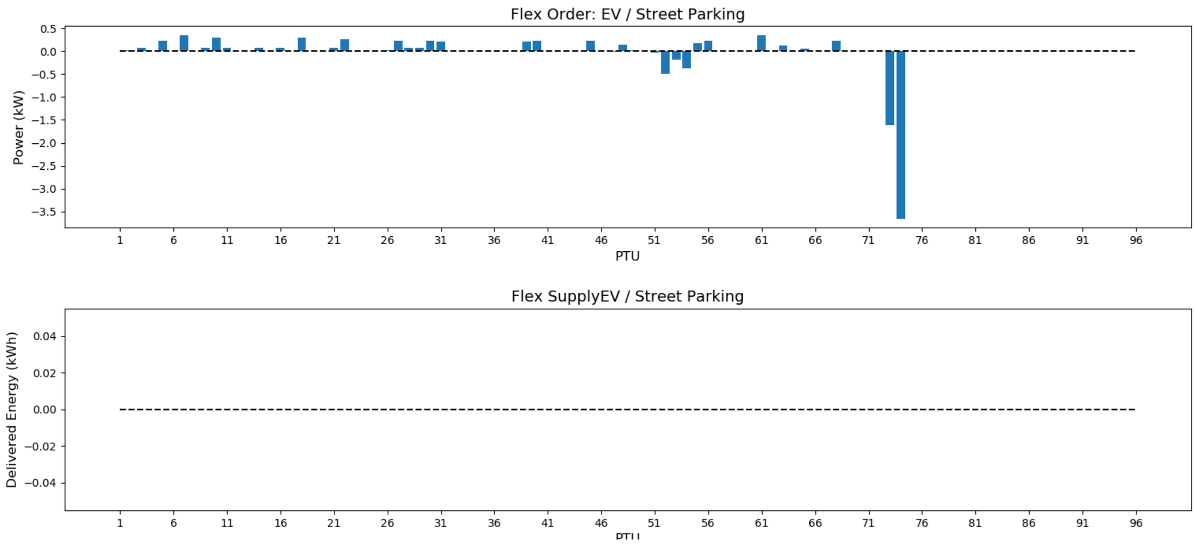


Figure 21 - Flex order vs. flex supply: average per PTU congestion point 5

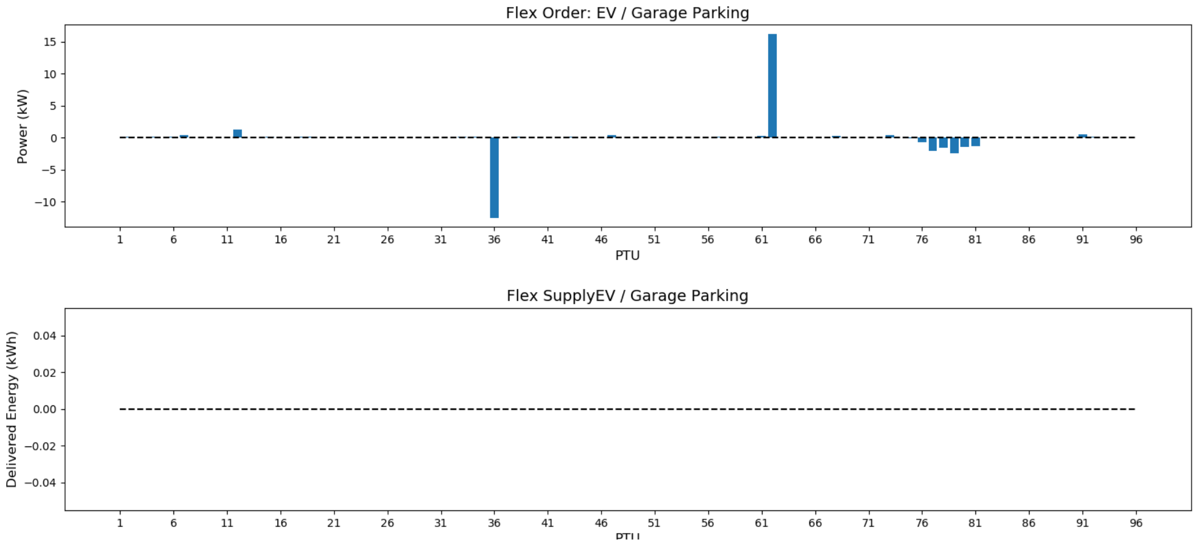


Figure 22 - Flex order vs. flex supply: average per PTU, congestion point 8

In some cases, the offered price is higher than the maximum price that DSO is willing to pay. Besides, there is no flex supply so far. Fig. 21 and 22 illustrates that the aggregator was not able to deliver the ordered flex, which implies the low reliability of this flexibility resource. Considering the sanction price, this can bring high risks and costs for the EV aggregator.

Conclusion & Discussion

In this pilot project, the amount of the participants in smart charging is estimated to be about 15% of the total EV charging sessions. This is already considered as a high participation percentage, since in general this number is less than 10%. Obviously, it is not adequate to solve the congestion problem yet. In reality, the number of EV charging sessions are quite high and can cause serious congestion issues in the grid. Therefore, EV smart charging can be considered as a good solution as well. However, it is important to investigate in better incentives and other approaches to improve the awareness and interest of EV drivers to take part in smart charging programs.

Moreover, in case of EV flexibility, the load is shifted from one time slot with high peak load to another time slot wit lower consumption. As it can be perceived from flex offer in Fig. 20, the shifted load can cause a new peak which is known as rebound effect. The new peak load can result in another congestion which needs to be solved in the intra-day process. The new congestion which has been created through the day-ahead management, imposes extra costs for the DSO. Rebound effect is a problematic and complicated issue which can yield to higher risks for the DSO at the end.

Due to the complexity of the field tests, so far no meaningful preliminary results could be obtained regarding the KPIs. There have been many changes, while fine tuning parameters (e.g. Demo Max) which are necessary for a realistic testing environment. The scenario tests with stable setting are currently still ongoing, and results for the KPI will be reported in the last deliverable (D7.7).

6. CONCLUSIONS & RECOMMENDATIONS

In this chapter describes the conclusions and recommendations regarding use case 2 and 3. General lessons learned that apply for all three use cases, will be input for deliverable 7.7.

IMPLEMENTATION USE CASE 2

The goal of this use case is to enable the optimal activation of all available local flexibilities offered by the locally installed Electric Vehicle Supply Equipments (EVSEs) and the connected EVs for congestion management. This is done by allowing the Distribution System Operator (DSO), monitoring the grid, to send flexibility requests towards commercial aggregators that will, through interaction with the Charge Point Operator (CPO), result in adapted charging schedules on EVSEs, making the necessary flexibility happen.

To arrange an optimal activation of flex systems, Charge Point Management System (CPMS) and Flexibility Aggregation Platforms (FAPs), and interactions were implemented. The Open Charge Point Interface protocol (OCPI) supports connections between Mobility Service Providers (eMSP) who have EV drivers as customers, and Charge Point Operators (CPO) who manage charging points via a Charge Point Management System (CPMS).

Conclusions implementing use case 2

- **An open protocol isn't always completely usable without making adjustments;**
  For the project it was preferred to work with open protocols. For the communication between CPMS and FAP EV OCPI seemed the best option. To make the OCPI protocol work for the project some adjustments had to be made. By doing so, the OCPI usability improved. This feedback is given back to the protocol owner.
- **Defining crucial project conditions is necessary, and to meet these preconditions before the implementation phase of the project.**
  Having enough EV drivers is an important project condition because it's necessary to have enough charging data (and historical charging data) to run the chain test. In this project we didn't have enough EV drivers/ charging data. Providing simulation data from CPMS would have been helpful to run the chain test.
- **Clear overview of the chain and related protocols is helpful to make sure the software chain is in line with the process requirements.**
  An overview of the chain and related protocols could have helped in making visible that the interaction between protocols has to be aligned to be able to send messages (translation of data from messages in one protocol to another protocol).
- **Privacy law led to some limitations in the operator user interface between the aggregator, charge point operator (CPO) and charging session (CS).**
  An important aspect of the interface is to have a current validation of the charging request with the register of EVNetNL. Privacy aspects (e.g. guarantee the aggregator still has permission of the EV driver) have to be taken into account by designing the operator user interface.

Recommendations use case 2

- Investigate in the requirements phase if, and what kind of adjustments have to be made to make open protocols work.
- Investigate the current situation in the field in an early stage, while writing the project proposal and during the start the project, and take action on crucial project conditions.

- Analyze the complete chain with related protocols and the interaction between these before implementing the chain.
- Privacy aspects have to be taken into account in the requirements phase, before implementing the operator user interface.

IMPLEMENTATION USE CASE 3

Use case 3 describes the usability of an integrated flex market based on a combination of stationary battery storage and EV chargers. Multiple aggregators offer flexibility from different flexibility sources on a flexibility market so that the DSO can procure flexibility from multiple parties for grid supporting services.

DSO and involved aggregators implemented a framework for trading flexibility. Different Flexibility Aggregation Platforms (FAPs) an interface to the DSO (via USEF) are implemented. The FAP is operated by the commercial aggregator and is responsible for controlling the flexibility assets of the aggregator.

Conclusions implementing use case 3

- **Define a good baseline is hard by lack of a good method.**
  Specification of a flexibility baseline during the project is necessary to proof flex delivered and to measure the project results. The definition of a baseline is not determined during the project, due to the lack of a good method to define the baseline. Because the baseline is not clear, it is not possible to proof flex is delivered. Furthermore it is very difficult to see the impact of the flex request on congestion.
- **The separation of concerns, roles and responsibilities in the InterFlex architecture (FAP) worked very well,** since it enabled the actors to focus on their key responsibility and key competences (i.e. exploiting flexibility on energy markets, or managing electricity grids, or managing device infrastructure)
- **Open protocol isn't always completely usable without making adjustments;**
  For the project it was preferred to work with open protocols. For the communication between GMS and FAP, USEF seemed the best option.
  To make the USEF protocol work for the project some adjustments had to be made. By doing so, the USEF protocol usability improved to USEF+. This feedback is given back to the protocol owner.

Recommendations use case 3

- Find a good method to define the flexibility baseline; this to proof flex is delivered and be able to measure the amount of flex delivered.
- Having basic definitions of the flex process (e.g. flex supply, flex offered, etc.) with a single point of truth is necessary to have common references.
- Separate concerns, roles and responsibilities in the architecture (FAP) to keep focus on key responsibility and key competences.
- Investigate in the requirements phase if, and what kind of adjustments have to be made to make open protocols work.

Conclusions preliminary results

- **The percentage of EV charging sessions is not adequate to solve the congestion problem yet.**
- In this pilot project, the amount of the participants in smart charging is estimated to be about 15% of the total EV charging sessions. This is already considered as a high participation percentage, since in general this number is less than 10%. Obviously, it

is not adequate to solve the congestion problem yet. In reality, the number of EV charging sessions are quite high and can cause serious congestion issues in the grid. Therefore, EV smart charging can be considered as a good solution as well. However, it is important to investigate in better incentives and other approaches to improve the awareness and interest of EV drivers to take part in smart charging programs.

- **Shifting the EV flexibility load from one to another time slot can yield out in higher risks for the DSO at the end.**
  Moreover, in case of EV flexibility, the load is shifted from one time slot with high peak load to another time slot wit lower consumption. As it can be perceived from flex offer in Fig. 20, the shifted load can cause a new peak which is known as rebound effect. The new peak load can result in another congestion which needs to be solved in the intra-day process. The new congestion which has been created through the day-ahead management, imposes extra costs for the DSO. Rebound effect is a problematic and complicated issue which can yield to higher risks for the DSO at the end.

Due to the complexity of the field tests, so far no meaningful preliminary results could be obtained regarding the KPIs. There have been many changes, while fine tuning parameters (e.g. Demo Max) which are necessary for a realistic testing environment. The scenario tests with stable setting are currently still ongoing, and results for the KPI will be reported in the last deliverable (D7.7).

7. REFERENCE LIST

Reference list

- R. Steegh, T. van Cuijk, D. P. Khomami, 2019, "Grid management system to solve local congestion", *CIRED 2019*, Madrid, June 2019.
- D. Geelen, N. Refa, R. Spiering, 2019, “Smart charging electric vehicles based on a flexibility market”, *CIRED 2019*, Madrid, June 2019.

Websites

- www.interflexstrijp.nl/deelnemers

8. APPENDICES

8.1. Appendix 1: Overview of possible identifiers

Overview of possible identifiers

Below is a list of identifiers that might be used as an alternative for the hard coded registration. All transactions in the table are described from the EV driver perspective, from the moment he registers at the charging point.

Identifier	Description	Known to CPO	Known to eMSP	Known to aggregator	Known to EV driver	Known to E-clearing
RFID	Chip in charging card	yes	no	no	yes/no*	no
Card number	Number on the charging card	yes/no**	no	no	yes	yes
Contract ID	ID of contract between eMSP and driver	no	yes	no	yes	yes
Customer details	Name, address, phone number etc.	no	yes	yes/no***	yes	no
App ID	An app used for charging, with an ID in it	yes	yes	no	yes	yes

Figure 23 - List of possible identifiers

* Only if the driver is able to read the Radio-frequency identification (RFID)
** Number on the card is not always actually there
*** Customers could be registered at a smart charging service anonymously.

The last row in the table above is fictitious, because a single app for charging is not available.

Assumption is eMSP will be the provider of the app, referring to the list of identifiers. For all alternatives, a third party is needed to validate the request the aggregator makes towards the CPO. Besides, the EV driver needs to use a unique code (for instance through RFID) to register at the CPO.

It's not clear which of the following options will be implemented in this project.

Options for solving the limitations in the current user identification and permision procedure

Option A: eMSP as intermediary
The EV driver already has a service contract with the eMSP. Therefore, the eMSP is a logical choice to act as validator. Whenever a request for flex comes through an eMSP, it can be automatically approved. A prerequisite of this solution is that the CPO needs to be able to check whether the request is actually from an eMSP. A digital signature is needed.

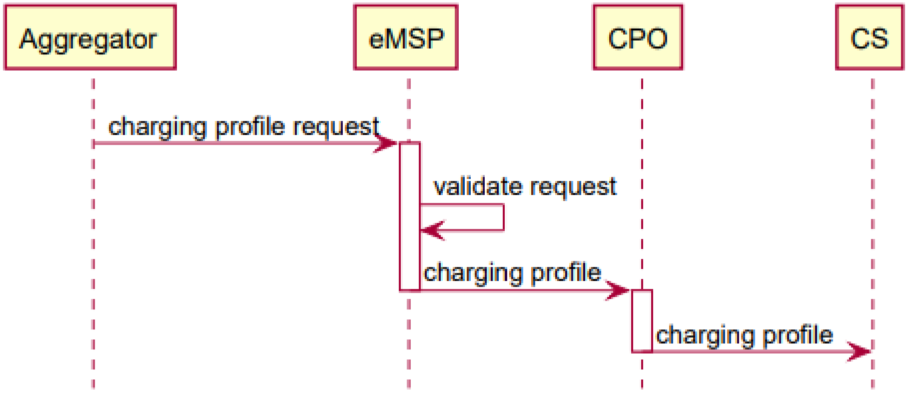


Figure 24 - eMSP as intermediary

The unique code with which the EV driver identifies himself at the CPO has to be known at the aggregator. The aggregator will include this code in the smart charging request. The eMSP validates whether the EV driver corresponding with the unique code is registered for the service.
It should be noted that in this situation, the eMSP role can be replaced by any independent organisation, as long as it is not linked with the aggregator.

Option B: eMSP as validator

Option B is comparable to option A. The aggregator sends a request to the CPO directly, which is subsequently validated by the eMSP. An advantage of this option is that the eMSP does not need to receive and process the actual charging profile.

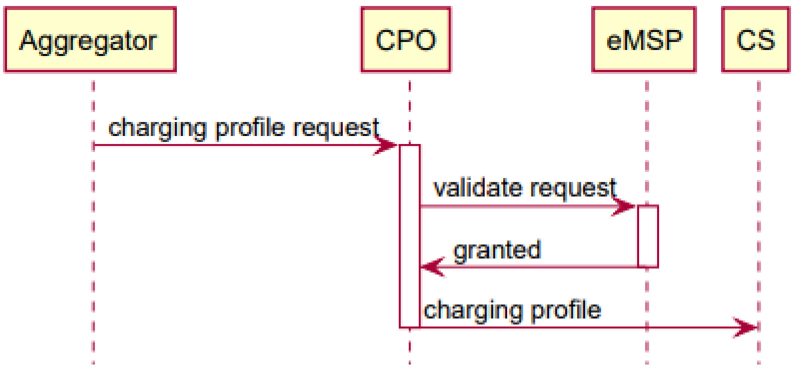


Figure 25 - eMSP as validator

It should be noted that in this situation, the eMSP role can also be replaced by any independent organisation, as long as it is not linked with the aggregator.

Option C: the EV driver as validator

This option offers the most possibilities but is also the most complicated to carry out.

The EV driver is made responsible for maintaining the smart charging services. The CPO could send a message to the cellphone of the EV driver with a link for authentication. In a more advanced stage, this could be done through an app which can remember certain preferences.

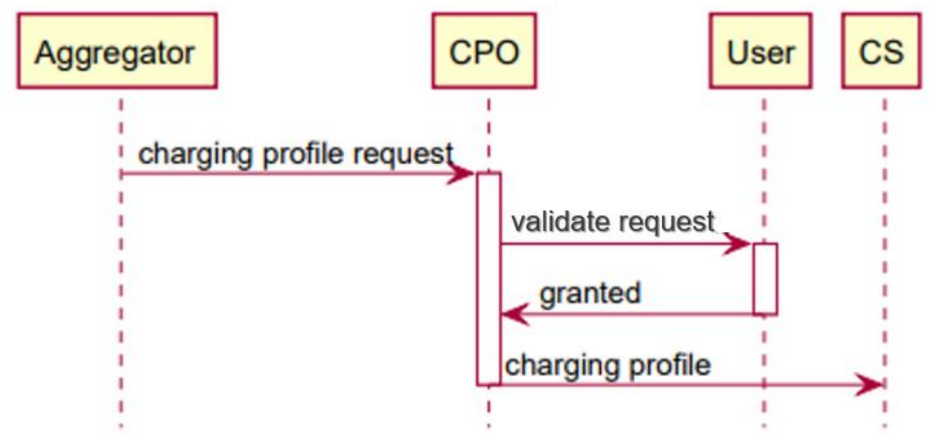


Figure 26 - EV driver as validator

In order to be able to carry out this option, the phone number of the EV driver needs to be known. This could be obtained through the eMSP.

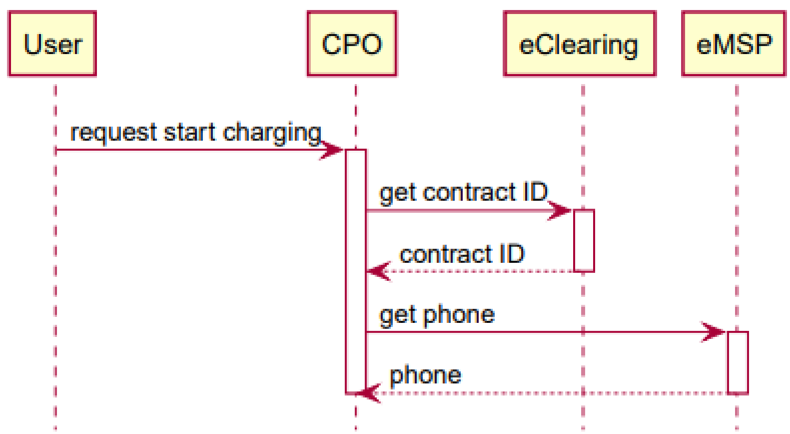


Figure 27 - EV driver as validator with phone number

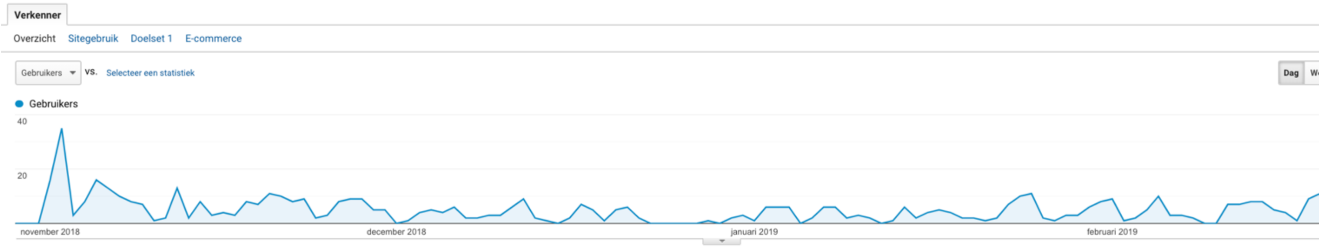
A benefit of this option is that the EV driver is directly involved in the smart charging process. No additional recruitment needs to be done, because drivers can be obtained on the spot. Transparency can increase when the CPO is allowed to send status updates to the EV driver.

Questions regarding this option, that need to be answered in additional research, include:

1) Is there any privacy law that prohibit the execution of this option?
2) Will the EV driver accept (sudden) text messages or will this reduce his willingness to participate in the flex market?
3) Is it possible for the driver to use a QR code at the charger to register the current session as a smart charging session?

8.2. Appendix 2: Acquisition details EV drivers

This appendix shows a report of the registration landing page to get insight in the acquisition of EV drivers.



Primaire dimensie: Bron/medium Bron Medium Zoekwoord Overige

Rijen weergeven Secundaire dimensie Sorteertype: Standaard geavanceerd

Bron/medium	Acquisitie			Gedrag			Conversies Doel 1: Registration	
	Gebruikers	Nieuwe gebruikers	Sessies	Bouncepercentage	Pagina's/sessie	Gem. sessieduur	Registration (Conversieratio doel 1)	Registration (Voltooiingen doel 1)
	459 % van totaal: 100,00% (459)	459 % van totaal: 100,00% (459)	663 % van totaal: 100,00% (663)	44,04% Gem. voor dataweergave: 44,04% (0,00%)	2,68 Gem. voor dataweergave: 2,68 (0,00%)	00:02:35 Gem. voor dataweergave: 00:02:35 (0,00%)	3,02% Gem. voor dataweergave: 3,02% (0,00%)	20 % van totaal: 100,00% (20)
1. (direct) / (none)	279 (58,61%)	279 (60,78%)	395 (59,58%)	45,57%	2,70	00:02:39	3,04%	12 (60,00%)
2. google / organic	147 (30,88%)	140 (30,50%)	203 (30,62%)	35,96%	2,94	00:02:55	1,48%	3 (15,00%)
3. futureofcharging.com / referral	20 (4,20%)	20 (4,36%)	25 (3,77%)	52,00%	1,84	00:00:44	0,00%	0 (0,00%)
4. linkedin.com / referral	6 (1,26%)	5 (1,09%)	6 (0,90%)	83,33%	1,17	00:00:14	0,00%	0 (0,00%)
5. 123formbuilder.com / referral	5 (1,05%)	0 (0,00%)	7 (1,06%)	100,00%	1,00	00:00:00	71,43%	5 (25,00%)
6. elaad.nl / referral	4 (0,84%)	4 (0,87%)	4 (0,60%)	50,00%	1,75	00:00:49	0,00%	0 (0,00%)
7. intranet.enexis.local / referral	3 (0,63%)	3 (0,65%)	4 (0,60%)	50,00%	2,50	00:01:03	0,00%	0 (0,00%)
8. t.co / referral	3 (0,63%)	2 (0,44%)	6 (0,90%)	66,67%	1,33	00:00:00	0,00%	0 (0,00%)
9. sympower.net / referral	2 (0,42%)	2 (0,44%)	4 (0,60%)	50,00%	2,75	00:04:20	0,00%	0 (0,00%)

Figure 28 - Google Analytics report of the registration landing page

(www.interflexstrijp.nl/deelnemers)

8.3. Appendix 3: Recruitment EV drivers

Figure 29 - InterFlex look-and-feel at charging locations

Figure 30 - Recruitment flyer

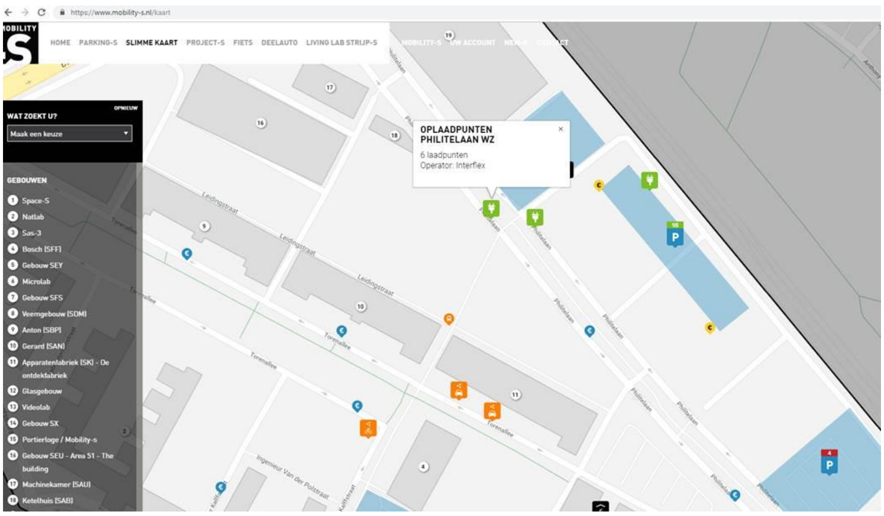


Figure 32 - Strijp-S parking map and charging points

Figure 31 - User acquisition pamphlet

8.4. Appendix 4: USEF - DSO aggregator interface

The Universal Smart Energy Framework (USEF) is a market design for the energy system of the future, comprising currently present roles and envisioned roles in the energy system. Part of this framework is a specification for congestion management services between the DSO and aggregator. This part of USEF is used in InterFlex because it has proven its value in real life and it is a fit-for-purpose choice for in the application in InterFlex. This fit-for-purpose is based on the observation that the USEF concept is a market-based solution that acknowledges and has been built on the idea that flexibility can be used for various kinds of purposes. Another reason is that USEF specifies the aggregator role that matches the aggregator role in the InterFlex architecture seamlessly. This means that the proposed abstraction layer for flexibility in the architecture can be realized by using USEF. The USEF specification also contains a XSD (XML Schema Definition) that specifies how the messages for congestion management should look like and it contains a thorough description of how the message flow should be realized.

Basically, the messaging flow for congestion management works as follows: if a DSO expects congestion in its grid, it will send out a flexibility request to the aggregators that are active on that congestion point. Aggregators subsequently determine their possibilities to meet the request and can send a flexibility offer to the DSO to indicate what they have to offer. The DSO may receive multiple flexibility offers and then considers which aggregators to send a flexibility order, establishing a deal between DSO and aggregator.

In the current USEF there is no possibility to express how likely it is that an aggregator has availability over its forecasted flexibility. For example, it is possible that the EVs need more energy than predicted, then it may be very difficult for an aggregator to deliver the promised flexibility. On the other hand, there might be another aggregator with a big battery for which it is much more likely that it can deliver the flexibility. However, the current USEF does not provide a manner to make a distinction between the flexibility of the two aggregators. This is a desired feature for which a possible solution is being tested in InterFlex. This results in a small difference with respect to the original USEF specification, therefore in InterFlex an adapted version of USEF is used, referred to as USEF+.