BD4OPEM

Big Data for OPen innovation Energy Marketplace

Deliverable 7.3
Pilot 2 – Slovenian pilot description and results

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Abbreviations and Acronyms

Acronym	Description
ADMS	Advanced Distribution Management System
AMI	Advanced Metering infrastructure
ASM	Additional Surveillance Measure
BRP	Balance Responsible Party
CIM	Common Interface Model
CIS	Customer Information System
COSEM	Companion Specification for Energy Metering
CSV	Comma-separated Values
DER	Distributed Energy Resources
DLMS	Device Language Message Specification
DSO	Distribution System Operator
ELCE	Elektro Celje, d.d.
EMS	Energy Management System
EU	European Union
EV	Electric Vehicle
FR	Flexibility Request
GDPR	General Data Protection Regulation
GIS	Geopraphical Information System
GPS	Global Positioning System
HTML	Hyper Text Markup Language
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
ICOM	Intracom Telecom
ID	Identification
JSI	Institut "Jožef Stefan"
kA	Kiloampere
KPI	Key Performance Indicator
kVA	Kilovoltampere

Acronym	Description
kW	Kilowatt
kWh	Kilowatt Hours
LSTM	Long Short-term Memory
LTE	Long Term Evolution
LV	Low Voltage
MV	Medium Voltage
NILM	Non-intrusive Load Monitoring
NTL	Non-Technical Losses
OBIS	Object Identification System
ODT	Odit-e
OEDAS	Osmangazi Elektrik Dagitim A.S.
PV	Photovoltaic
PQ	Power Quality
SCADA	Supervisory Control and Data Acquisition
SM	Smart Meter
T	Task
UC	Use Case
UI	User Interface
UPC	Universitat Polit?cnica de Catalunya · Barcelona Tech
V	Volt
V2G	Vehicle to Grid
VUB	Vrije Universiteit Brussel
W	Watt
WP	Work Package

1 Executive summary

This deliverable documents all the work performed within T7.3, related to the Slovenian demonstration site (Pilot 2). It follows the methodology of implementation described in D7.1 "Large Scale pilots' methodology" [1].

The services implemented in this pilot are the following:

Table 1. The services implemented in Slovenian pilot

Service ID	Name of service (name of approach when relevant)	Service developer
S1.1	Topology	ODT
S1.2	Observability	ODT
S1.3	Predictive maintenance in electrical power systems (Predictive maintenance applied to smart meters)	JSI
S3.1	Grid disturbance simulations (Congestions forecast for day ahead)	UPC
S3.1	Grid disturbance simulations (Congestions control in distribution grids)	VUB
S3.1	Grid disturbance simulations (P1-related disturbances)	JSI
S3.2	Impact study PV, EV & new loads	ODT
S4.1	Inconsistencies in energy balance and power voltage	ODT
S4.2	Fraud patterns detection (UPC approach)	UPC
S4.2	Fraud patterns detection (JSI approach)	JSI
S5.1	Flexibility forecast (UPC approach)	UPC
S5.1	Flexibility forecast (JSI approach)	JSI

Service ID	Name of service (name of approach when relevant)	Service developer
S5.3	Flexibility aggregated services for DSOs (Flexibility-based AC OPF)	UPC
S5.3	Flexibility aggregated services for DSOs (Flexibility services for DSOs based on neural networks)	JSI
S6.1	Energy management at household or at community level (NILM approach)	JSI
S6.2	Forecasting services (JSI approach)	JSI

First, each service is presented succinctly and the use cases are reminded, based on Work Package 4 (WP4) inputs. The results of each service implemented in this pilot are then shown, but those results may vary in terms of quality, depending on the quality of data collected on the pilot site. This is why a data quality assessment has also been performed in order to bring insight and explanation on why those results were found.

2 Introduction

2.1 Purpose and intended audience

The BD4OPEM project aims to design, develop, and deploy a marketplace in order to provide innovative energy services for the reliable operation of the smart grid. These energy services will be provided through a marketplace, acting as an open, modular data analysis toolbox and facilitating data exchange and advanced usage. In this way, the data coming from the diverse energy domain sources will be put at the disposal of advanced energy service developers through a marketplace.

The main objective of WP7 is to oversee the implementation and demonstration of the services developed in the previous WPs. Through this implementation, the aim is to prove two points:

- That the tools developed are compliant with the given objectives and, if not, analyze and identify the reason for the difference and provide recommendations about the tool optimization to reach better results.
- That the Marketplace platform and the Analytics toolbox permits flexibility, replicability, and scalability of the services between data providers and service users with adapted features.

Overall, this work package consists in providing the input for the analysis of the impact of the whole system developed during BD4OPEM project and giving recommendation to optimize its use and management. It is as well the opportunity to gather feedbacks from different demonstration sites and their respective leaders upon the platform, the services, and the customer experience.

This document describes the results of the implementation of the services for the Slovenian demonstration site.

The main audience of this document is:

- WP7 partners themselves, to know the results of the project for the Slovenian demonstration site
- WP9 partners for the description of the processes and methodology which can be used in the latter exploitation of the platform.
- Future data providers or service users that want to interface with the BD4OPEM platform.
- Future algorithm developers or service providers that want to propose their own services to ELCE.

2.2 Relationship with other BD4OPEM tasks

This deliverable is related to different tasks within the BD4OPEM project:

- T7.1, Pilot Methodology and preparation of large-scale pilots, as this implementation is a first demonstration of the methodology described in this task.
- T7.2, T7.4, T7.5, as they are similar tasks.

- T7.6, in which the results of each demonstration site are tested and validated
- WP9, which will be able to use the results of each demonstration site for exploitation and replication purposes.

2.3 Structure

This document is divided into three main sections:

- The final description of the demonstration site, with the global perimeter, the specifics of the pilot and a recap table of the services implemented in this demonstration
- The services results for this demonstration site, with a reminder of the use cases, a data assessment and the services implementation conclusions
- A monitoring of project Key Performance Indicators (KPIs).

Then a final part will conclude with lessons learned from the pilot and from the service developers' perspectives.

Finally, two appendixes will detail the storylines of each service as well as the results of services testing in the Marketplace.

3 Final description of the Slovenian demonstration site

3.1 Global perimeter (update from D7.1)

Elektro Celje (ELCE) is one of Slovenia's five electricity distribution companies, covering approximately 22% of the country. It primarily serves the south and southwest Styria region, the Savinja valley, and the north Dolenjska region (Figure 1). Elektro Celje is responsible for the supervision, management, planning, and operation of the electricity distribution network, as well as the mai[ntenance, construction, and operation of electric power distribution lines that supply over 176.000 customers (more than 172.500 or 98% of whom were equipped with smart meters by the end of 2022)[2].

Elektro Celje's physical grid consists of high voltage (HV), medium voltage (MV), and low voltage (LV) lines. It operates around 16,200 km of lines and cables, most of which are LV and MV. Other equipment and assets include 20 HV/MV substations and approximately 3.500 MV/LV substations.

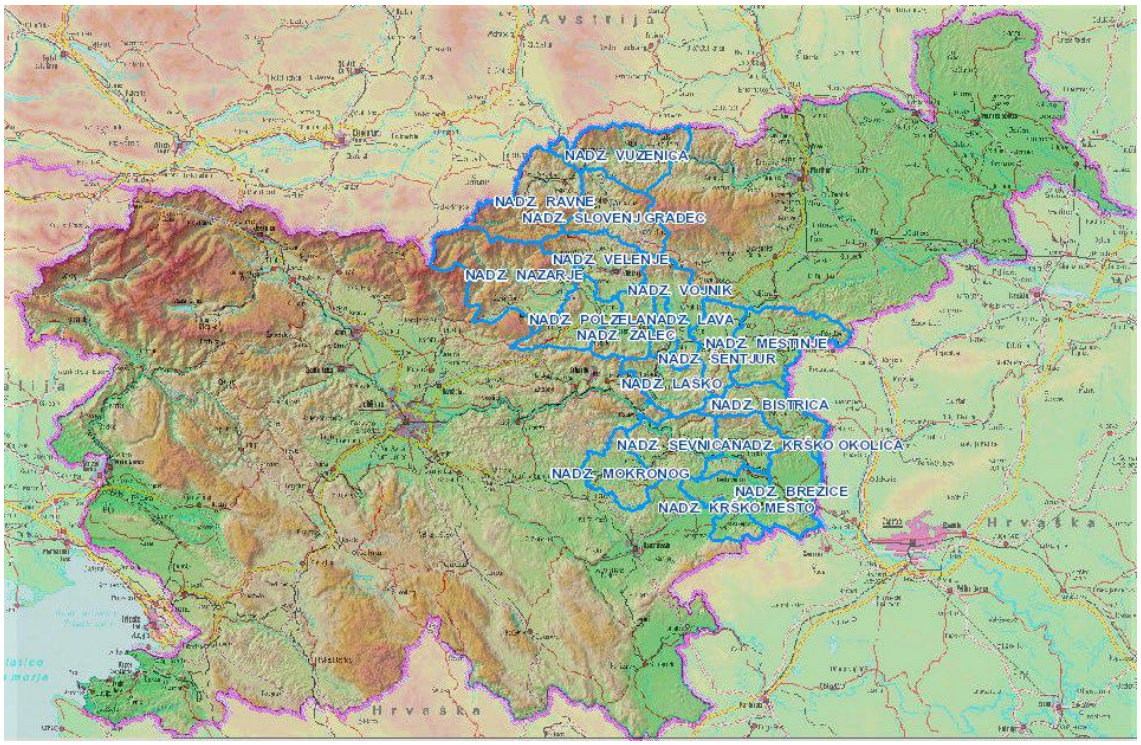


Figure 1. ELCE region in blue, divided into several supply and maintenance zones

Elektro Celje currently has 3,500 distributed energy resources (DERs) connected to its grid, which already contribute almost 8% of all energy flow into the distribution network. Grid monitoring shows that the integration of renewables is already causing several problems in the grid, mainly high voltage peaks and grid congestions, especially at the LV level. These issues also lead to increased technical losses, resulting in higher financial costs and lower quality indicators for delivered energy.

Given its high penetration of smart meter technology and grid observability, Elektro Celje is collecting increasing amounts of data each year. The next big challenge for

the distribution system operator (DSO) will be how to leverage this data effectively and extract valuable information from it, which will benefit end consumers by enabling more DER connections, better energy delivery, and higher grid utilization.

3.2 Specifics of the pilots (update from D7.1)

3.2.1 Data Sources

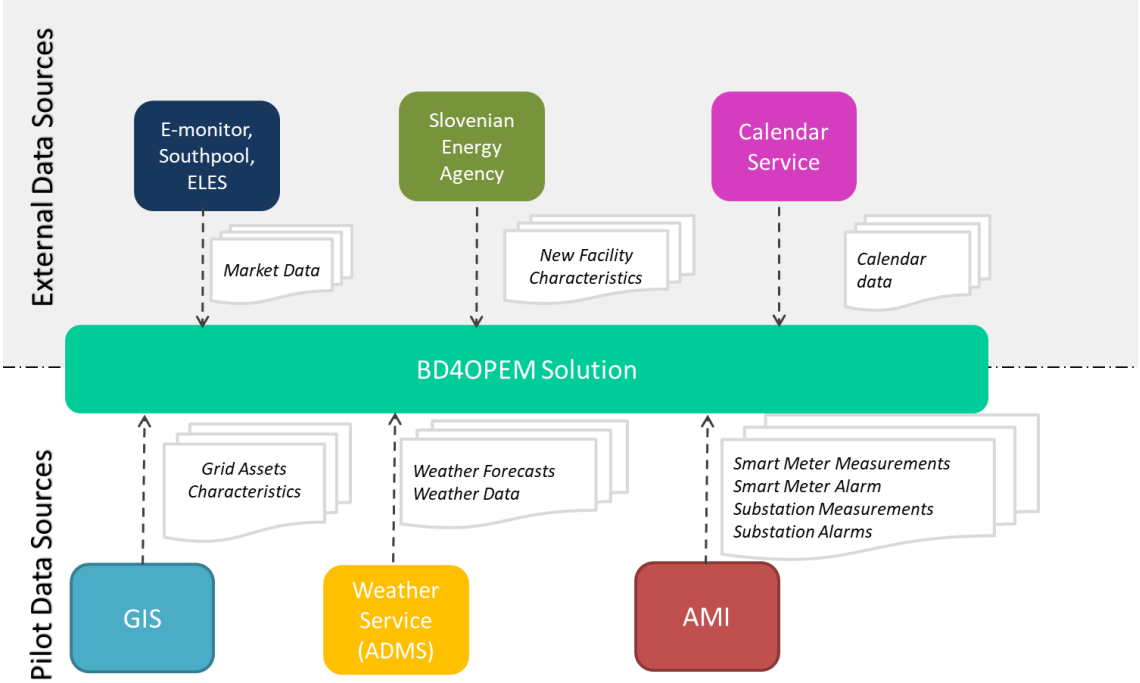


Figure 2. Elektro Celje data sources

The BD4OPEM pilot project, in which Elektro Celje participates, is primarily focused on using data services in LV grids where problems have been detected in the past. These selected grids are good use cases for service development, and they had to meet certain conditions to be applicable to BD4OPEM services.

- All data used shown in Figure 2 (e.g., smart meter data, GIS data, weather data) had to be of a sufficiently high quality to be usable.
- Data had to be accessible for use.
- Data sources had to be measure specific variables at measurement points (e.g., smart meters must support certain measurement registers).
- Data had to be already shown potential issues that can be solved by services (important for service validation).

If these conditions were meet, the collected data had great potential to validate the services for correctness of operation, which of course depends on the service in question.

The pilot site for grid disturbances, impact studies, non-technical losses, etc., consists of 14 LV grids with approximately 600 consumers. These consumers have newer generation smart meters that are more resilient to measurement errors,

communication blackouts, and in addition, they use more advanced technology, which means they also measure additional variables, such as phase voltages and currents. The 14 grids were pre-analysed and have shown several operational issues that are expected to be detected by the BD4OPEM services.

The pilot site for flexibility services consists of approximately 800 consumers located on an LV grid in the area of Elektro Celje. These consumers voluntarily participating in a dynamic tariffing project that took place for one year. The responses to different price signals by these consumers are being recorded and were used in flexibility services. In this test dataset, the consumers that meet the data requirements with the conditions listed above in mind were chosen.

For services based on real-time data (Figure 3), we installed new smart meters with an activated I1 interface and a kit consisting of an I1 module, an LTE modem, and a power supply at 6 pilot locations. The I1 interface is a one-way communication channel intended for end users of the distribution system for the implementation of energy efficiency measures. The meters are set to send a telegram every second and every hour, with the second telegram reporting the current values of variables that are important data for signal analysis. While the hourly telegram reports the accumulated energy.

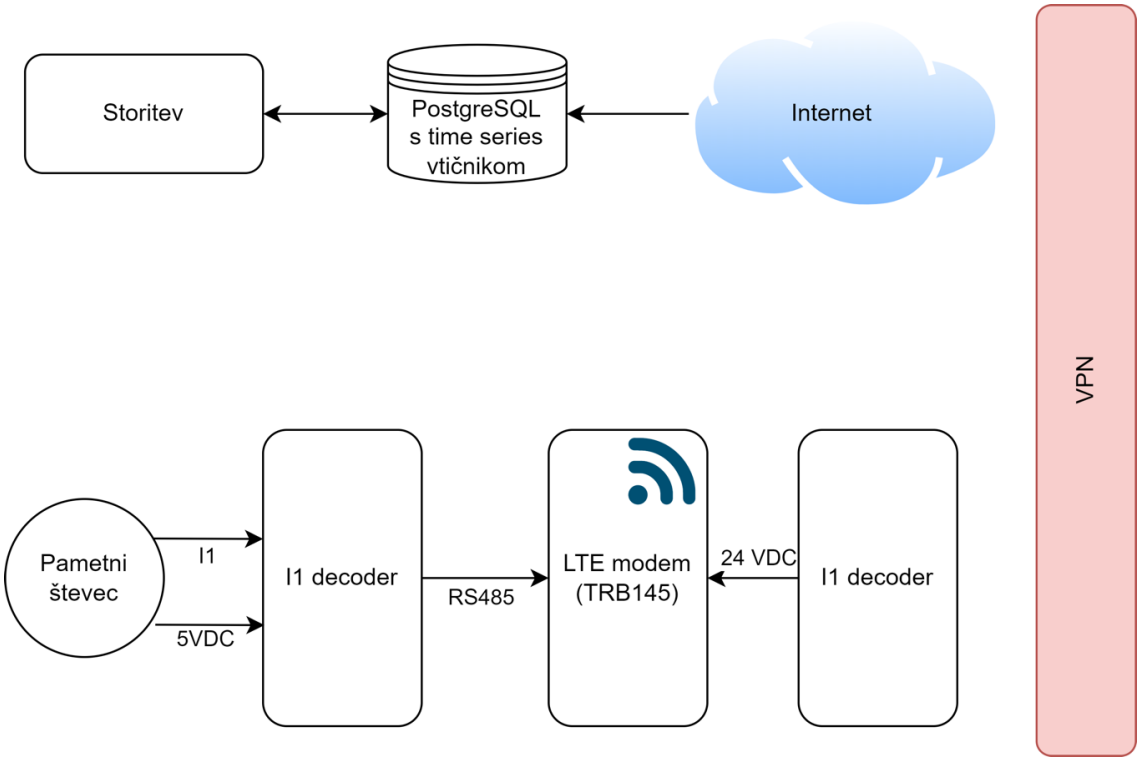


Figure 3. Block diagram showing communication from the user to the database

Lastly, the pilot site for predictive maintenance has been defined. This has been based on approximately 2.800 industrial customers with appropriate smart meters installed. These meters record internal errors that specify the meter's diagnostic. This data helps detect smart meters that are more prone to errors and have a higher probability of failure.

The data mentioned above is stored at Elektro Celje's information systems in accordance with GDPR and binding national laws. The biggest data sources of the pilot site were:

- **Advanced Metering Infrastructure (AMI)**

  Advanced Metering Infrastructure (AMI) is a digital system that collects and transmits data from electricity meters to utilities. It consists of smart meters, communication networks, and data management systems. AMI enables utilities to remotely read and monitor electricity consumption, as well as detect outages and tampering. It also provides customers with real-time information on their energy usage, which can help them to conserve energy and reduce costs.

  AMI systems include the following components:

  - Smart meters: Smart meters are electronic devices that measure and record electricity consumption in real time. They can also communicate this data to the utility wirelessly.
  - Communication networks: AMI systems use a variety of communication networks to transmit data from smart meters to the utility. These networks can include cellular, radio frequency (RF), and power line carrier (PLC) technologies.
  - Data management systems: Data management systems collect and store data from smart meters. They also analyse this data to identify trends and patterns in electricity consumption. This information can be used by utilities to improve the efficiency and reliability of their operations, as well as to develop new products and services for customers.

  AMI systems offer a number of benefits to both utilities and customers. For utilities, AMI can help to reduce costs, improve operational efficiency, and increase customer satisfaction. For customers, AMI can provide real-time information on energy usage, which can help them to conserve energy and reduce costs. AMI systems can also enable customers to participate in demand response programs, which can help to reduce the overall cost of electricity.

  For monitoring and managing meter data, Elektro Celje uses a tool called Advance Client.

- **Geographic Information System (GIS)**

  GIS is an independent information system, that Elektro Celje is using for tracking and managing its geospatial data about grid assets. The data about asset objects contain geography and spatial representation as well as asset attributes (e.g., transformer rated power, etc.). These are separated for different asset types such as lines, transformers, stations, circuit breakers, etc. and are written in GIS database which is based on relational models supported by Microsoft Server SQL technologies. The asset data that is interconnected also holds information about connectivity and topology, which is automatically calculated on regular periods. The data in the GIS system represents critical information in Elektro Celje for many other advanced systems such as SCADA/ADMS, LAMBDA, EAM (Enterprise Asset Management) and more. The largest use of these data is especially in grid planning and operations. When the grid is being planned GIS information determines the

loading or production capacities that grid planning engineers must consider. As such the tools used for grid planning also use GIS data to determine properties at connection points, where end-user is connected to Elektro Celje's grid.

- **Smart meter real-time stream data**

  The I1 interface is a unidirectional communication channel intended for end-users distribution system for the implementation of measures of efficient energy use. Interface on the meter Iskraemeco AM550 uses EIA485 physical layer in negated logic. Data sent via interface, is Device Language Message Specification/Companion Specification for Energy Metering (DLMS/COSEM) facilities that must be prepared according to distribution system operator specifications. Elektro Celje configured the meters so that the DLMS/COSEM objects were not equipped with attributes that would made it possible to identify each object with an OBIS code. Therefore, the COSEM objects were programmatically parsed from the dataset and their values listed in the same order in the JSON object. With this approach, by comparing the sequence of COSEM objects of the OBIS code from the counter configuration and the sequence of JSON object values, the data type and its value can be determined in the server system. Meters are set so that every second and the hour send a telegram, with the second telegram reporting the current values variables that are important data for signal analysis. While the hourly telegram reports the accumulated energy because it is the accumulated energy for a certain window, is also in the telegram they lose the fast instantaneous values needed to process the data. Hourly values are important as an additional control element and from the point of view of analyzing the type of energy in the network (e.g. phase shift analysis).

Table 2. Data sources for Slovenian Pilot

Data source	Data identification	Additional description	BD4OPEM ontology	Reference to standards
AMI	Historical data from consumers (10.000+): Active Power consumed and injected	All contained in csv file	Smart_Meter	CIM: meterMeasurements
AMI	Historical data from 203 substations: Active Power consumed and injected.	All contained in csv file	Smart_Meter	CIM: meterMeasurements
CIS	Consumption group, connected power, customer's ID (SMM code), upstream transformer station name or ID where customer is connected to,	Metadata in xlsx format from clients who participated in the DR program.	None	Self-made, based on ELCE data

Data source	Data identification	Additional description	BD4OPEM ontology	Reference to standards
	Low voltage feeder where customer is connected to.			
AMI	Event log	Export of events for 2.800 industrial meters in a csv file for predictive maintenance service.	None	
GIS	Coordinates, cable longitude, cable tips, cable material, nominal tension of cable, nominal current of cable, resistance, reactance, locations of measuring points.	GIS data of 14 LV grids in csv file.	Service_parameters	
AMI	Historical data from 14 substations: Active Power consumed and injected.	csv file	Smart_Meter	CIM: meterMeasurements
AMI	Historical data from end-users' smart meters, connected to 14 substations: Active Power consumed and injected, reactive power consumed and injected, voltage, current.	csv file	Smart_Meter	CIM: meterMeasurements
SCADA	Historical MV feeder measurements voltage, current, power factor	csv file	Smart_Meter	CIM: meterMeasurements
AMI	Historical data for EV charging stations and heat pumps: Active Power consumed.	xlsx file	activeEnergyImport	CIM: meterMeasurements
AMI	Historical data from end-users' smart meters for fraud detection service.	xlsx file	Historic_Fraud	CIM: meterMeasurements
CIS	Fraud descriptions, police records and photographs.		None	Self-made, based on ELCE data

Data source	Data identification	Additional description	BD4OPEM ontology	Reference to standards
-	Historical data: weather data	From ARSO (Slovenian Environment Agency). JSON file.	None	
-	Forecast for 1 week ahead: weather data	From ARSO (Slovenian Environment Agency).	None	
Smart meter real-time stream data	Real-time data from 6 smart meters via the I1 port: Volatge, Current, Active Power consumed and injected, Reactive Power consumed and injected, Energy.	1-second and 1-hour telegrams.	None	

3.2.2 Legal requirements

In the project framework, Elektro Celje, d.d., as DSO, provides data from metering, operation and control devices, and smart systems for analysis to meet the objectives of BD4OPEM.

The legal basis that enables the controller collection, storage, and disclosure of customer's personal data to the processor are 157th articles a), b), and č) of the Slovenian Energy Act – EZ-1 (Uradni list RS, št. 60/19 – uradno prečiščeno besedilo in 65/20) and 28th article of GDPR.

In addition, to respect Regulation (EU) 2016/679 (GDPR), all the data coming from metering is either anonymized (by aggregation) or pseudonymized.

In the first case, as the aggregated data is not linked to any specific user, its use respects therefore the privacy of Elektro Celje users and can be considered not personal data. Regarding the pseudonymization of the personal data, the access and process of the Elektro Celje data are regulated by the multi-lateral NDA agreement signed between Elektro Celje and all the data processors. The NDA defines the type data considered personal that the processors are allowed to access, as well as the purpose of processing them, which falls within the purpose of improving and operate the service of electricity distribution.

Elektro Celje in the application of the principle of data protection by design (Article 25 GDPR) considers from the beginning of the project design and throughout the project the privacy requirements, incorporating technical and organizational measures to ensure that the rights of data subjects are guaranteed.

3.3 Recap table of services to be implemented

Table 3 shows the list of services that were developed for the Slovenian demonstration site. Several different approaches were used for some services.

Table 3. List of the services to be implemented

Service ID	Name	Developer
S1.1	Topology	ODT
S1.2	Observability	ODT
S1.3	Predictive maintenance in electrical power systems	JSI
S3.1	Grid disturbance simulations	JSI
S3.1	Grid disturbance simulations	UPC
S3.1	Grid disturbance simulations	VUB
S3.2	Impact study PV, EV & new loads	ODT
S4.1	Inconsistencies in energy balance and power-voltage	ODT
S4.2	Fraud patterns detection	UPC
S4.2	Fraud patterns detection	JSI
S5.1	Flexibility Forecast	UPC
S5.1	Flexibility Forecast	JSI
S5.3	Flexibility aggregated services for DSOs	JSI
S5.3	Flexibility aggregated services for DSOs	UPC
S6.1	Energy management at household	JSI
S6.2	Energy forecasting of the demand	JSI

4 Services results for the Slovenian demonstration site

S1.1 – Topology results

Introduction of the service

Name: Topology
Category: Operation and maintenance
Task: T4.2
Location on the grid: LV

This service aims to retrieve the network topology (smart meters' substation, feeder and phase associations), and evaluate some network analytics (overloads, imbalances…) using such information.

Table 4. Use cases for the S1.1 service

Use case	Description
UC1	**As a:** DSO **I want to**: Identify associations between meters and substation **So that I can:** Estimate the loading rate of my secondary substations **Acceptance criteria:** Give associations between meters and secondary substations
UC2	**As a:** DSO **I want to**: Identify associations between meters and phase's feeder **So that I can:** Estimate the current imbalance and the voltage excursion on my feeders, and estimate the loading rate per phase of my substations **Acceptance criteria:** Give associations between meters and phase's feeder
UC3	**As a:** DSO **I want to**: Correct associations between meters and secondary substations **So that I can:** Update my assets database **Acceptance criteria:** The service receives a list of meter's attributes, data from GIS and meters' data. The service provides a file with corrected meter's attributes about their substation association with corresponding confidence level

Use case	Description
UC4	**As a:** DSO **I want to**: Correct associations between meters and phase's feeder **So that I can:** Update my assets database **Acceptance criteria:** The service receives a list of meter's attributes, data from GIS and meters' data. The service provides a file with corrected meter's attributes about their feeder's phase association with corresponding confidence level
UC5	**As a:** DSO **I want to**: Analyse my network regarding voltage and load rates **So that I can:** Locate voltage constraints Locate bottleneck **Acceptance criteria:** Meters with passed voltage excursion appear on my screen. Substations or feeders with passed overloads appear on my screen.
UC6	**As a:** DSO **I want to**: Qualify voltage level for constrained points Qualify load level for constrained points **So that I can:** Decide and rank reinforcement **Acceptance criteria:** I can access to statistical analysis of my network: - Substations and feeders load rate - Substation and feeder imbalances - Voltage plan

Topology results

The service objective is to address the DSO's need of retrieving the topology (meter-to-substation, meter-to-feeder and meter-to-phase associations), but also to analyze in depth the voltage plan and load levels of the LV grid to be able to know where to reinforce the grid or not, and prioritize the needed reinforcements.

For the Slovenian demonstration site, the results in the deployed webapp were the following:

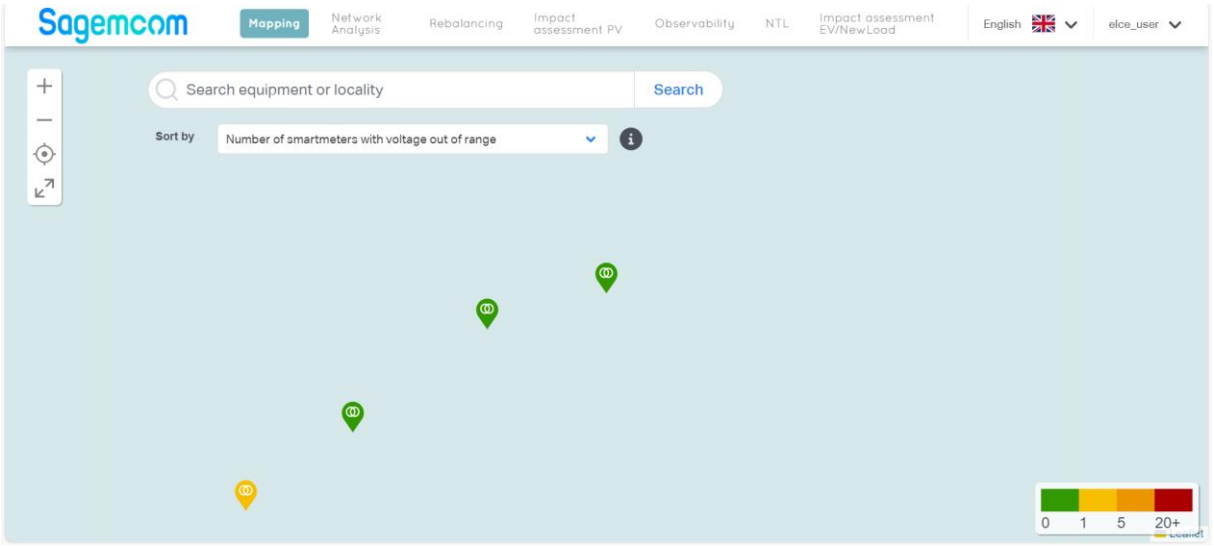


Figure 4. Mapping of the MV/LV substations for the Slovenian demonstration site, sorted by number of smart meters with voltage out of range

This first screenshot (Figure 4) shows the mapping of the LV grid for which data has been collected. In this case, the substations are sorted by number of smart meters with voltage out of range, but many other sorting possibilities do exist:

- Mean imbalance rate of smart meters on their imbalance periods
- Number of three-phased smart meters voltage imbalanced
- Time spent overload
- Time spent underload
- Time spent out of voltage range for all smart meters
- Max consecutive hours of fuse overload
- Max power imbalance referred to nominal power (referred to Sn)
- Load max rate
- Occurrences voltage out of range for all smart meters
- Cumulative time fuse overload
- Assured PV available in kW
- Installed PV load
- Number of smart meters allowing a PV domestic install
- Secondary substation max theoretical capacity
- PV load validated and waiting for connection
- Installed PV load reported to Pn.

Some of those classifications are only available when the service S3.2 is deployed (tab "Impact assessment PV" in the screenshot above).

For this demonstration, data has been anonymized, which explains why the substations are not localized in Slovenia.

Then, the topology use case itself is more detailed in the "Network Analysis" tab:

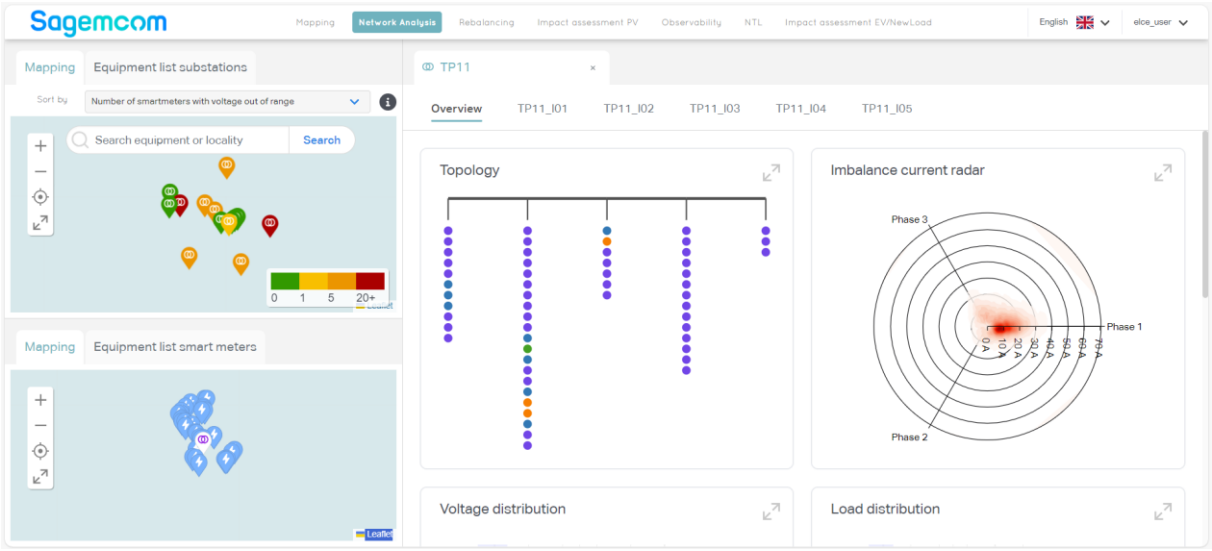


Figure 5. Network analysis tab with TP11 selected

When going into the "Network analysis" tab and selecting the TP11, the web page displays the Figure 5 above, with different types of data on screen.

The first thing to be noticed is that the topology has been retrieved, with 5 different feeders identified (TP11_l01, TP11_l02, TP11_l03, TP11_l04 and TP11_l05), a phase attributed to each single-phase smart meter, and the three-phased smart meters have also been identified in blue.

A mapping of the smart meters is also available in the bottom left part of the screen (Figure 6):

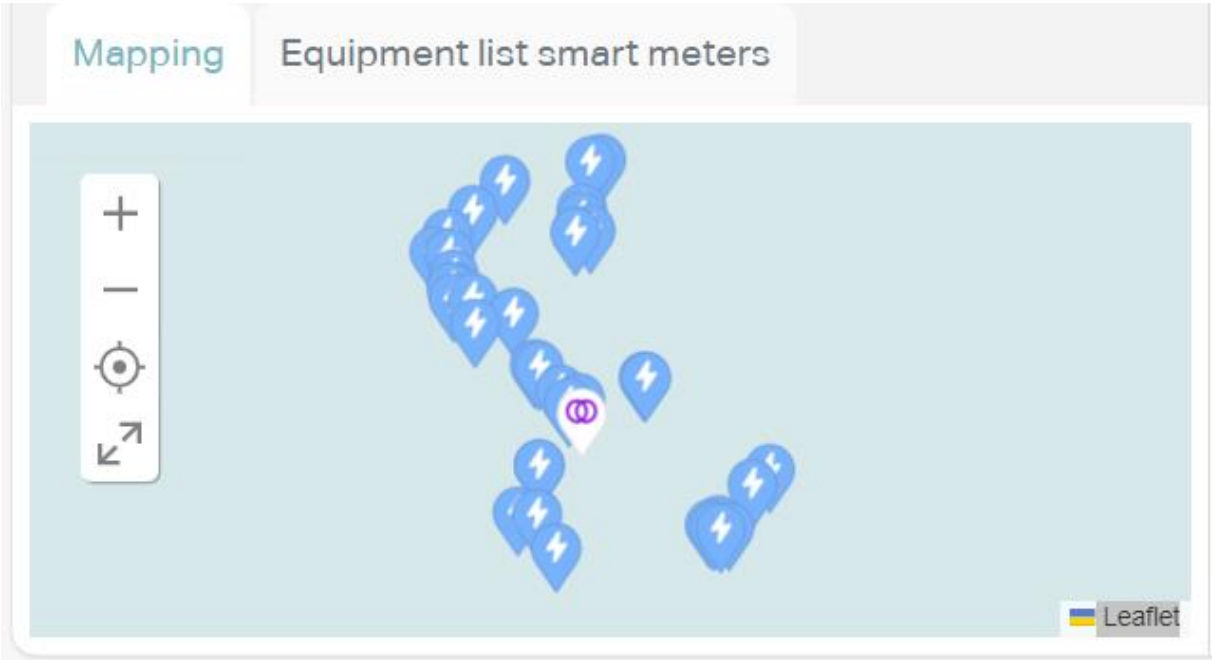


Figure 6. Equipment list smart meters for TP11

We can then deep dive into each widget available in this tab with this service:

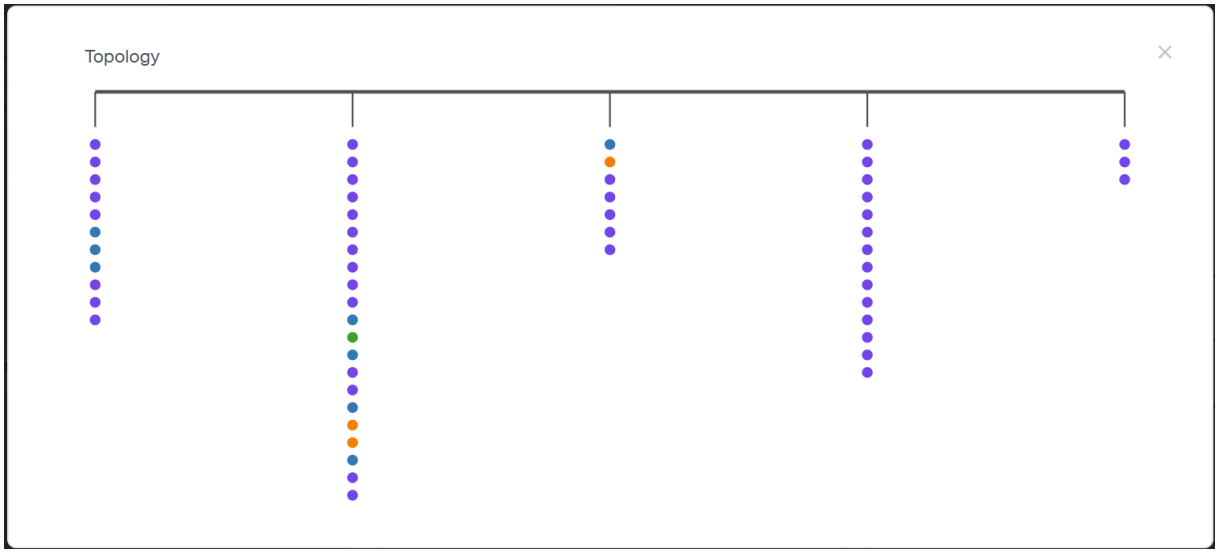


Figure 7. Topology widget for TP11

This widget (Figure 7) allows to visualize the meter-to-feeder, meter-to-phase associations: each branch represents a feeder and each colour represents one phase. The blue colour represents the three-phased smart meters.

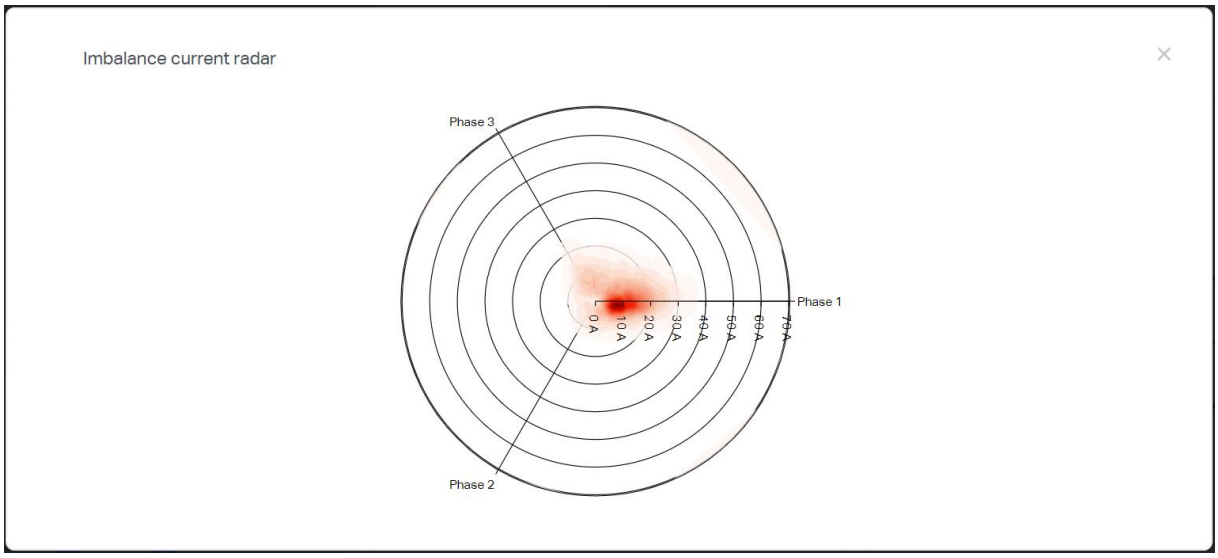


Figure 8. Imbalance current radar for TP11

This widget (Figure 8) allows the DSO to visualize the imbalance between the three phases of its substation (TP). In this case, the current shows that there is indeed an imbalance on this substation: the phase 1 appears to be more loaded than the two others.

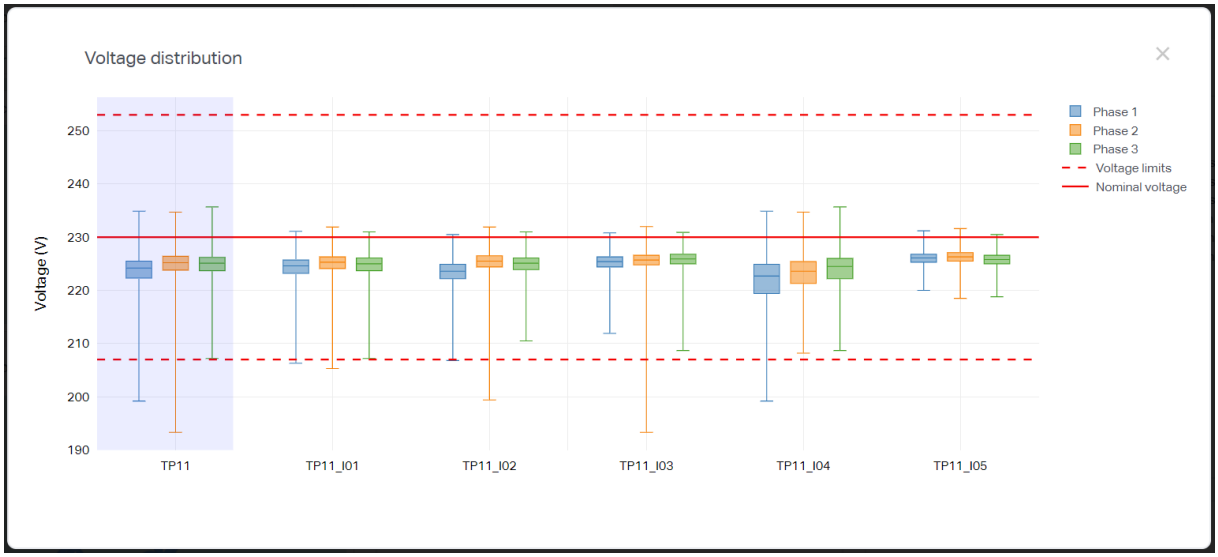


Figure 9. Voltage distribution widget for TP11

The following widget (Figure 9) shows the voltage distribution for TP11. On this specific substation, voltage excursions have been identified, in particular for TP11_I03 with values of voltage well below 207 V (230 V -10%). In particular, phase 2 seems to be more affected by those low voltage excursions, except for feeder TP11_I04 where phase 1 faces more voltage excursions.

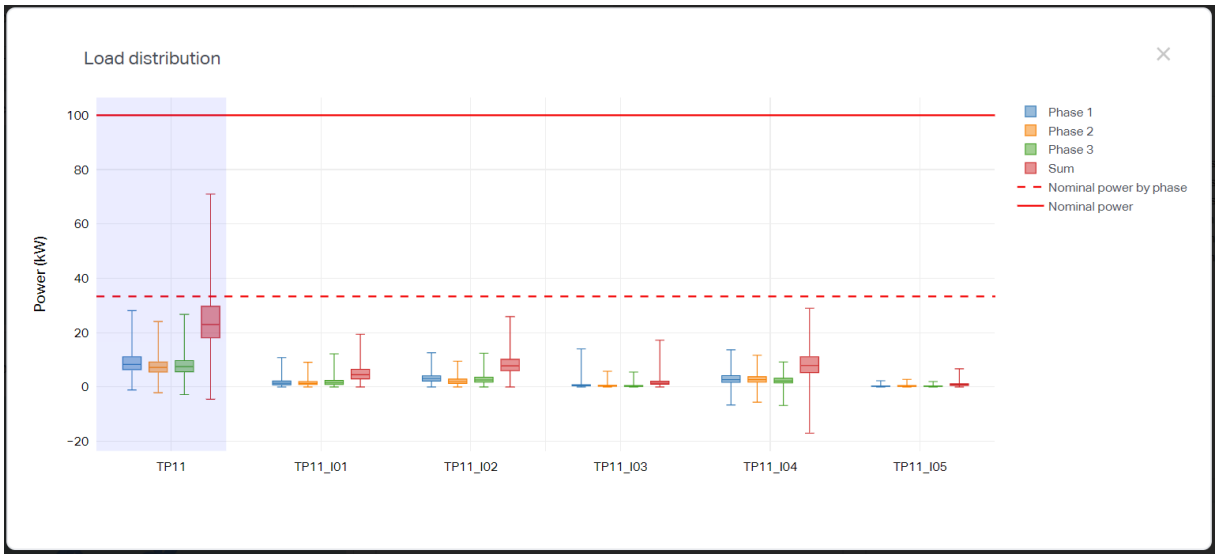


Figure 10. Load distribution widget for TP11

The widget above shows the load distribution for the TP11. The red boxplots show the sum of the power of the three phases for each feeder and also at substation level.

In this case, the substation seems to be well designed: the nominal power is 100 kVA while the maximum load observed is well below 80 kW.

It is also interesting to note that negative loads are displayed on this figure, showing that some PV production does exist on this substation, especially on feeder TP11_I04.

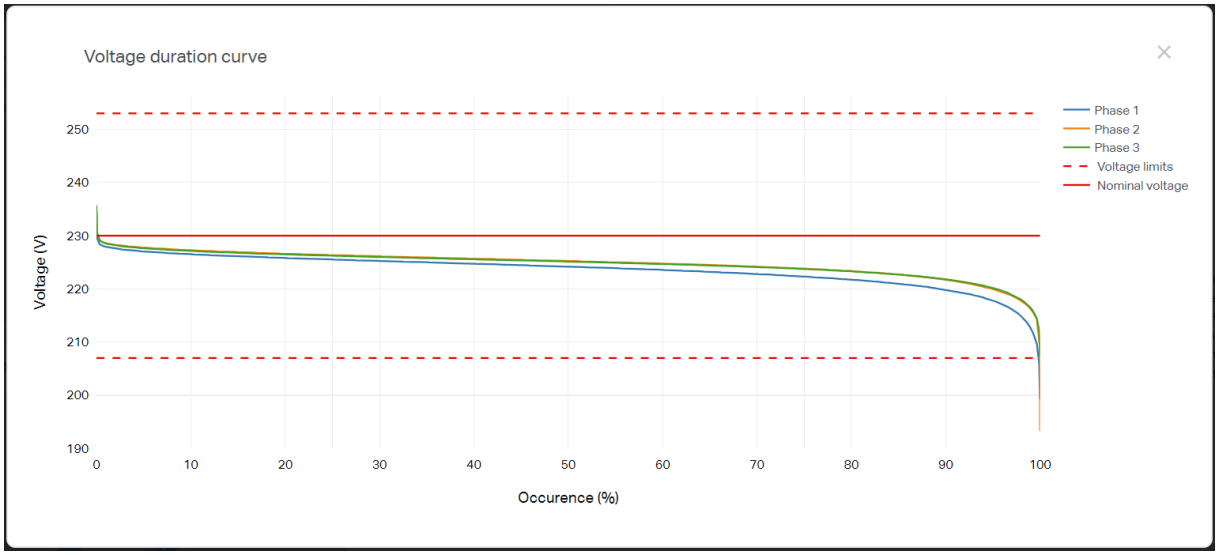


Figure 11. Voltage duration curve widget for TP11

The above widget (Figure 11) shows the duration curve of the TP11. This is a different representation of the Figure 11, in terms of occurrence. It enables the user to identify how often each phase is at which voltage level. In this case, the DSO will be able to see that the voltage excursions identified on its substation are very rare (around 0.1% of the time for phase 1, which is the most concerned by the voltage excursions in terms of occurrence).

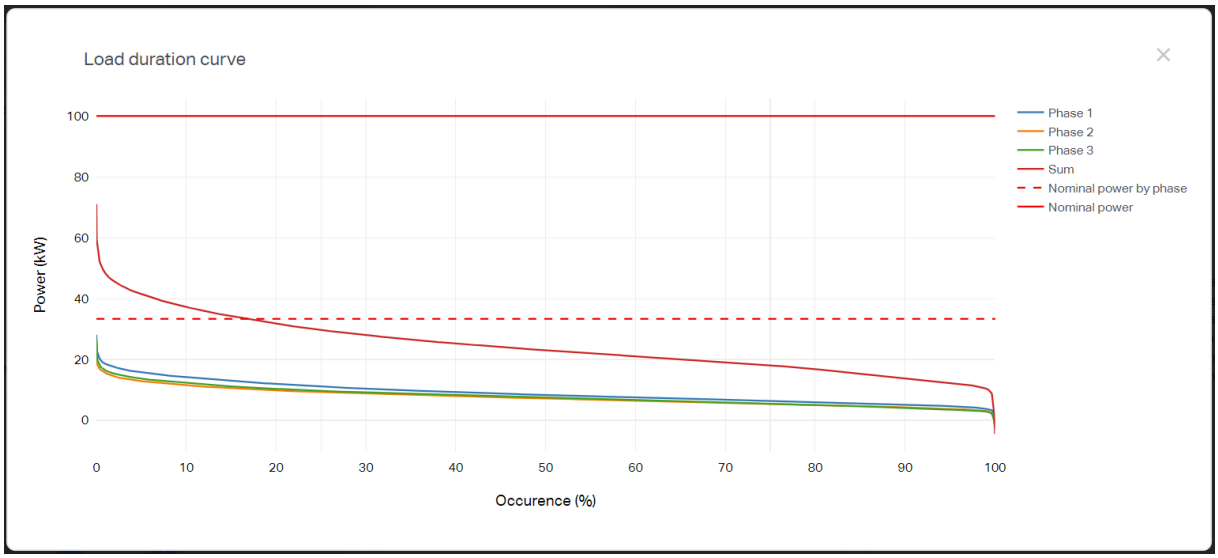


Figure 12. Load duration curve widget for TP11

The above widget (Figure 12) is another way to represent the Figure 10, in terms of occurrence. Here, the DSO can see that the substation is almost always loaded over 3 kW on each phase (99% of the time).

All the widgets presented above are also available for each feeder , to enable the DSO to see the details of its LV grid (Figure 13):

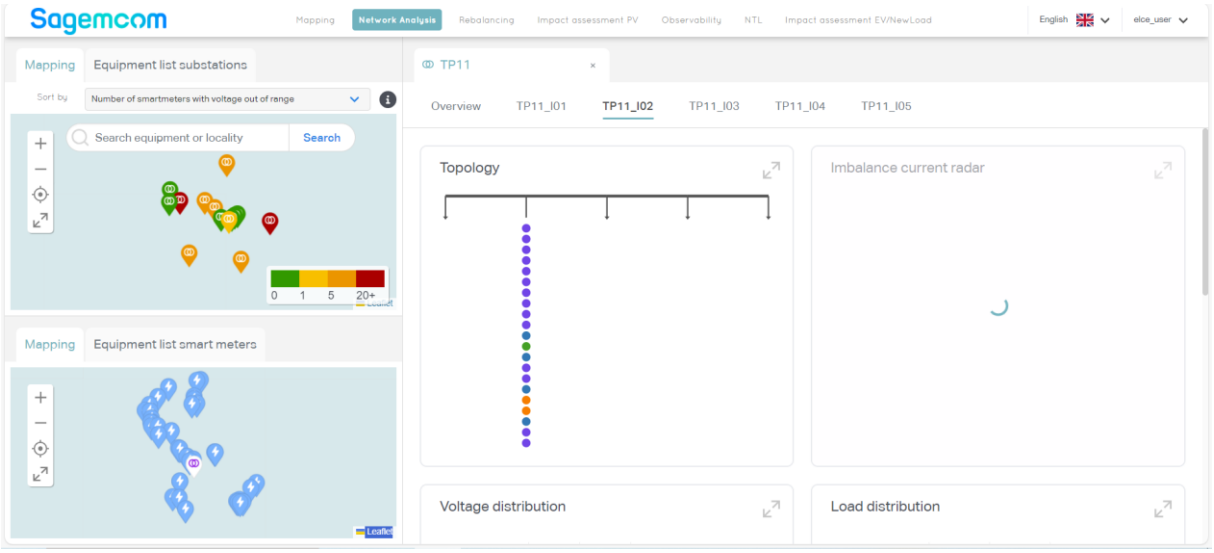


Figure 13. Network analysis tab at TP11_I02 level

Data assessment

The table below shows the data assessment for the presented service.

Table 5. Data assessment for Service S1.1

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
For each SM: Voltage profiles per phase	Smart_Meter	Good quality	High impact
For each SM: Active power profile per phase	Smart_Meter	Medium quality: good density of data, with average data, but summed power.	Low impact
Supposed level 1 topology: Smart meters / substations connectivity	Service_parameters	Good quality	High impact
Substation voltage profile	Secondary_Substation	Good quality	Low impact
Facultative: Reactive power profile per phase	Smart_Meter	Medium quality: good density of data, with average data, but summed power.	Low impact

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
Facultative: Geographical coordinates of meters	Location	Good quality (but anonymous)	Low impact
Facultative: Number of feeders per substation	Grid_Assets	Good quality	High impact
Facultative: GIS information, such as a priori meter-to-feeder mapping (to be corrected by algorithm)	Service_parameters	Good quality	High impact
Facultative: Substation power profiles	Secondary_Substation	Medium quality: good density of data, with average data, but summed power.	Low impact

Service conclusions

As a conclusion, the service S1.1 Topology has been successfully deployed in the Slovenian demonstration site. The confidence indexes of the topology itself (see Appendix B) could be improved by having power per phase instead of summed powers for the smart meters. The data collected by ELCE and integrated by ODT was overall of pretty high quality, which allowed a good deployment of the service on the Slovenian demonstration site.

To recap the results on the scope of the demonstration site, this service enabled to retrieve the topology of 14 substations. 8 of them face voltage excursions, 3 of them seem to be overloaded to a certain extent.

The retrieved topology can be summed up with the following figure:

Poste	SM change from	Number
1	TP01_I01 to TP01_I03	1
7	TP07_I03 to TP07_I02	16
9	TP09_I02 to TP09_I03	1
11	TP11_I01 to TP11_I03	1
	TP11_I04 to TP11_I01	1
Total changes		20

Source feeder	Number before algo	Number after-algo
TP01_I01	6	7
TP07_I03	21	37
TP09_I02	9	10
TP11_I01	11	11
TP11_I04	13	14

Target feeder	Number before algo	Number after-algo
TP01_I03	1	0
TP07_I02	16	0
TP09_I03	23	22
TP11_I03	8	7
TP11_I01	11	11

Figure 14. Sum up of the retrieved topology for the Slovenian demo site: comparison with the initial topology

The Figure 14 details the smart meters that have been changed from one feeder to another for each substation. These modifications have been proposed by the algorithm developed by ODT, with a very high confidence index (over 96% on average). In total, the algorithm proposed 20 changes to correct the topology sent ahead of the data analysis by the local DSO Elektro Celje.

In the future, other functionalities could be implemented on this demonstration site and included in the S1.1 Topology service such as rebalancing propositions to solve imbalances and voltage excursions. These propositions could be a way for the DSO to avoid costly reconfigurations of their LV network.

S1.2 – Observability results

Introduction of the service

Name: Observability
Category: Operation and maintenance
Task: T4.2
Location on the grid: LV

The objective of the observability service is to provide an estimation of the low voltage network state in real-time, by applying an artificial intelligence model to a real-time SCADA and optional weather data feeds. The network state, displayed in a dedicated user interface, includes smart meter voltages, as well as the loads of MV/LV substation and LV feeders. The artificial intelligence model is trained on historical smart meter, SCADA and weather data. The objective is to improve the network's operation and allow adequate flexibility management.

Table 6. Use cases for the S1.2 service

Use case	Description
UC1	**As a:** Operation technician **I want to**: Know in real time the status of the grid **So that I can:** Visualize an estimation of the load of MV/LV substations, LV feeders and the voltages of smart meters. **Acceptance criteria:**

Use case	Description
	1. I can visualise the real time (refresh rate to be defined according to real time data frequency) load at each distribution transformer & phase. 2. I can visualise the real time load at each feeder & phase. 3. I can visualise the real time voltage for each monitored meter.
UC2	**As a:** Operation technician **I want to**: Know in real time when there is an issue on the grid **So that I can:** React accordingly **Acceptance criteria:** 1. I can visualise in real time how close the power load of each distribution transformer is to the substation nominal value. 2. I can visualise in real time how close the current of each LV feeder & phase is to the corresponding fuse nominal value. 3. I can visualise in real time how close each meter is from a voltage excursion

In Table 6 are reminded the user story as designed and developed in the framework of the WP4 and reported in D4.3[3].

Demonstration site specificity and deployment perimeter

In the case of ELCE's demonstration site, the perimeter of deployment of the service S1.2 has been a subset of the 14 secondary substations for which there were AMI data gathering Active Energy, Reactive Energy, voltage and current from all smart meters, similar data from summation meter at substation level and GIS information. In addition to this AMI data, MV feeder SCADA measurement from the one supplying the secondary substations. This has been previously explained in Table 6. As no real time connection from the SCADA was available, the historical dataset has been used to simulate this real time data feed, by running the service in the past "as if" data was received in real time. The associated dataset is composed of data from October 2019 to January 2021.

Use Case 1

The service is available through a dedicated tab in the user interface, see (1) in Figure 15. In this landing page, the map displays locations were state estimation is being performed and the estimation timestamp is provided in (2).

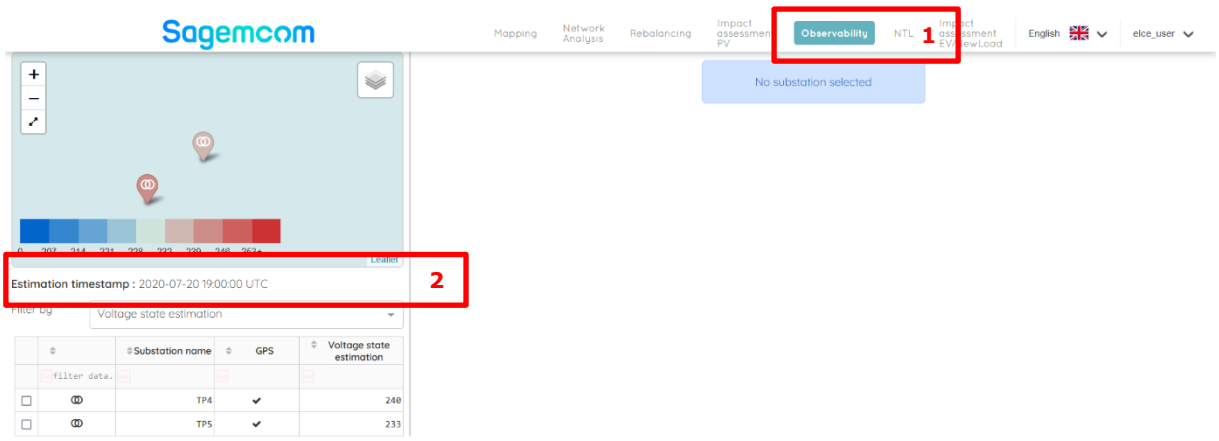


Figure 15. Observability landing page in ELCE

Under the estimation timestamp, a dropdown menu is available, it enables to select the type of estimation the user is looking for: "Voltage state estimation" or "Load state estimation", see Figure 16. Upon such selection, the map in the top left corner updates its colour and colour scale: the substations are displayed according to the state estimation algorithm result. In case the user would like to know the numerical value obtained by the algorithm, hovering the substation's pin makes the value appears, see Figure 17. At the moment, the deployed version does not provide feeder load's state estimation.

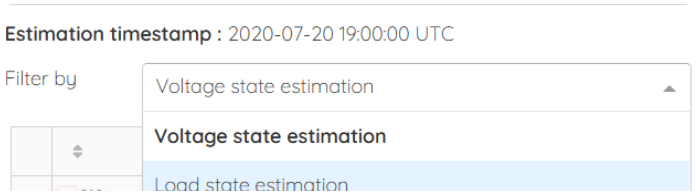


Figure 16. Observability dropdown menu

Figure 17. State estimation results displayed upon hovering

Use Case 2

For more details the user is invited to click on a given substation's pin. This action open the right-hand panel and display the smart meters on the map in case there coordinates have been shared. Under the "Substation load" tab, see (3) in Figure 18, two graphs are displayed, showing both Active and Reactive power measured (for the past) and estimated (for the present value).

Figure 18. Substation load state estimation in TP4

Under the "Smart meter voltage" tab, see (3) in Figure 18, one graph is displayed according to the selected smart meter on the map (5). The color scale being applied to the smart meters, the user is oriented towards the selection of the ones for which the values are the most alarming.

The graph shows 2 or 6 timeseries, for respectively single and three-phase smart meters. Both measured (for the past) and estimated (for the present value) are displayed.

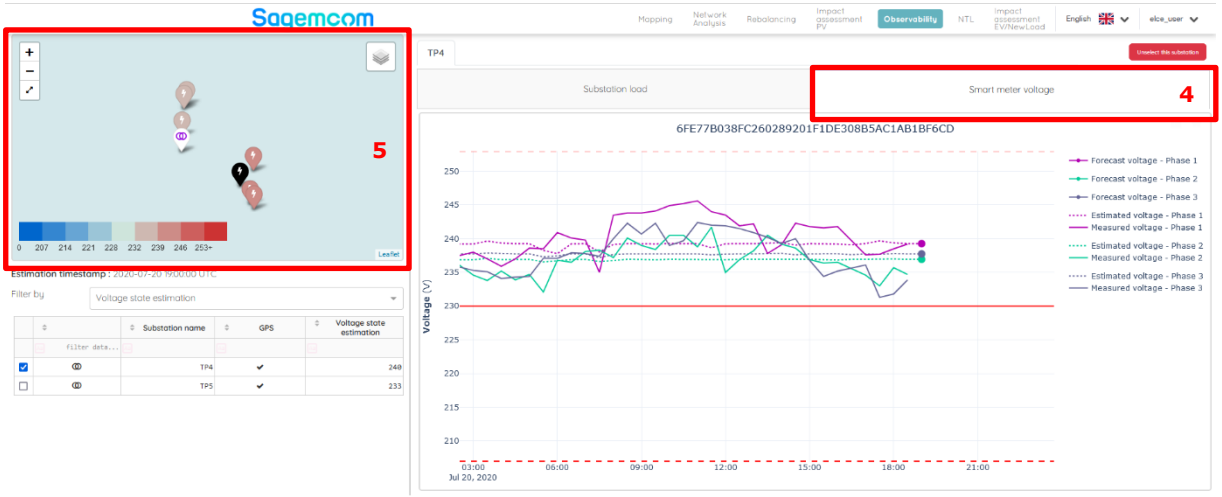


Figure 19. Smart meter voltage state estimation in TP4, one smart meter

Both tabs enable to assess how close present and short term past operating conditions are from the nominal value (nominal power for the secondary substation and nominal voltage, often 230 +/- 10%, for the smart meter's voltages). And make informed decisions to solve identified issues.

Data assessment

The table below shows the data assessment for the presented service.

Table 7. Data assessment for Service S1.2

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
For each SM: Voltage profiles per phase	Smart_Meter	Good	High impact
For each SM: Active power and / or current profiles per phase	Smart_Meter	Low: only one load curve for three phase meters, no load curve per phase. Specific preprocessing was necessary to split the load and run the algorithm	High impact
For each SM: Reactive power profiles per phase (optional)	Smart_Meter	Good	Medium impact
Geographical coordinates of meters (optional)	Location	Good and shifted for confidentiality purpose	Low impact on algorithm performance Improved quality of the user experience
Service S1.1 Topology	Service_parameters	Good	High impact
Training phase: Association of MV/LV substations with the MV assets monitored by SCADA	Service_parameters	Good	High impact
Training phase: Weather data (optional)	Weather data	Not available	Medium impact
Training phase: From the SCADA and each upstream medium voltage feeder: - Power and / or current profile per phase - Voltage profile per phase	Primary_Substation	Good	High impact
Operation phase:	Weather data	Not available	Medium impact

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
Real-time and recent historical weather data (optional)			
Operation phase: Real-time and recent historical SCADA data and MV data (power profiles per phase, voltage profiles per phase)	Primary_Substation	Not available	Simulation of a real time data feed, by running the service in the past

Service conclusions

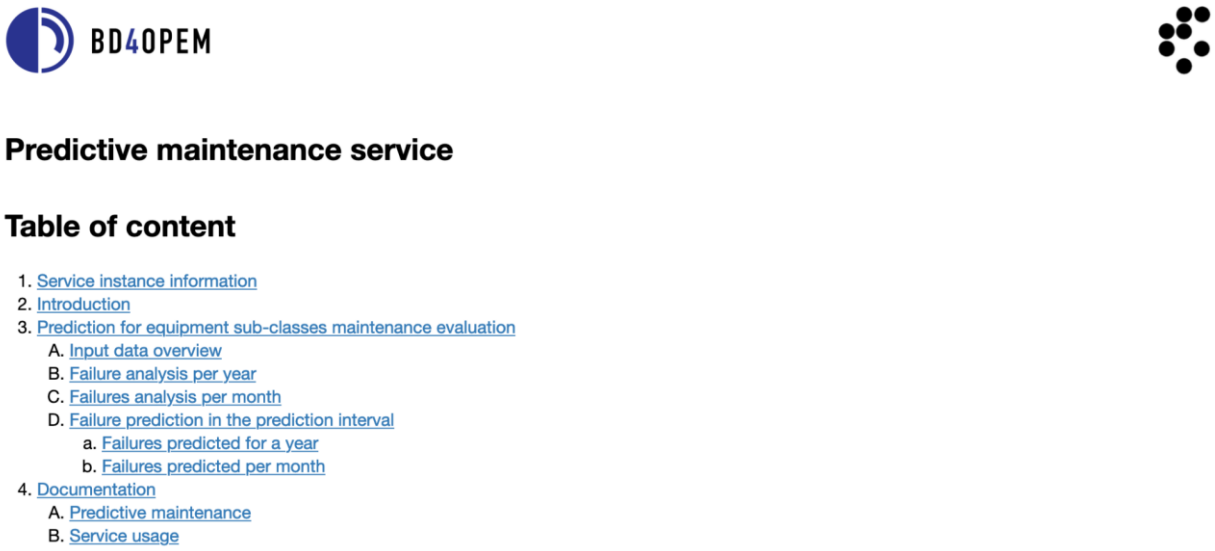
The deployment and testing of S1.2 on ELCE demonstration site offers a proof of concept for the real-time state estimation of low voltage network through the application of machine learning techniques. The integration of artificial intelligence models with real-time SCADA enhances the knowledge of the operating conditions of the network, offering insights into smart meter voltages and substation loads.

The user interface provides a functional display of network states, however it would require ergonomic improvements to refine the user experience and reach higher exploitability potential for a more intuitive and efficient utilization of the service by operators. Another challenge and area for improvement identified during the project is about the complexity of the machine learning models and their management through MLOps practices, as previously outlined in D4.3. This complexity poses difficulties in terms of maintenance, fine-tuning, and scalability. To address this, ongoing efforts are directed towards exploring simpler big data techniques, please refer to D7.2 [4] for this mater. This strategic shift aims to obtain a better tradeoff between performance and the scalability/maintainability requirements.

Importantly, the project has served as a valuable opportunity to collect premium datasets. These datasets consist in synchronous smart metering data and MV feeder SCADA measurements. They will contribute to future research activities and participate in fortifying the robustness of the service's approach. This data represents an asset for continuous improvement and evolution of the service, in order to make it ready for market reach when dynamic management of low voltage network will arise.

S1.3 – Predictive maintenance in electrical power systems

The service results are presented in a document accessible through the service results web page as explained in the previous Section. The results table of contentis presented in Figure 20. The report is split into three main sections, namely Introduction, Prediction for equipment subclasses maintenance evaluation and service documentation. The Introduction provides a brief introduction into the service while the documentation section provides brief documentation about the service usage.



Predictive maintenance service

Table of content

1. Service instance information
2. Introduction
3. Prediction for equipment sub-classes maintenance evaluation
   A. Input data overview
   B. Failure analysis per year
   C. Failures analysis per month
   D. Failure prediction in the prediction interval
      a. Failures predicted for a year
      b. Failures predicted per month
4. Documentation
   A. Predictive maintenance
   B. Service usage

Figure 20. S1.3 service report table of content for Slovenian pilot

The main content of the service report is related to input data overview, analysis of the failures per year and per month and failure predictions according to the selected prediction interval. The sections will be briefly introduced in this service report for the ELCE pilot case. The ELCE maintenance is related to failures of smart meters in the ELCE network.

Input data overview

Original data input is Figure 21. The dataframe reports in each row the life-cycle of the smart meters installed in Elektro Celje d.d. network. In every line the data of one smart meter is given, including with:

- Factory number: used as unique identifier of the meter, for counting
- Type name: type of the meter, will be later used for pivoting the data
- Producer name: will be used for pivoting the data
- Production year: will be used for pivoting the data
- Installement day
- Date of removal: will be used as potential date of failure
- Removal reason name: will be used to determine if the meter had had a failure

	Factory number	Type id	Type name	Producer id	Producer name	Production year	Measurement point	Day of installement	Date of removal	Removal reason id	Removal reason name	Type of failure id	Type of failure name	Date of last change
0	17711222	1339	E84CDV-01	1	ISKRAEMECO	2001	2177121	2001-11-20	2002-02-11 00:00:00	O	ODJAVA MKN	NaN	NaN	NaN
1	17569006	154	T31FV	1	ISKRAEMECO	1995	2163503	1997-05-07	2007-11-12 00:00:00	R	REDNA ZAMENJAVA MKN	NaN	NaN	NaN
2	17569006	154	T31FV	1	ISKRAEMECO	1995	2156854	2008-02-12	2020-05-06 00:00:00	R	REDNA ZAMENJAVA MKN	NaN	NaN	NaN
3	17569006	154	T31FV	1	ISKRAEMECO	1995	2162947	1997-05-06	1997-05-07 00:00:00	O	ODJAVA MKN	NaN	NaN	NaN
4	32008578	1350	E84CV-01	1	ISKRAEMECO	2002	2180455	2003-04-15	2014-01-27 00:00:00	R	REDNA ZAMENJAVA MKN	NaN	NaN	NaN
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
673086	737349	158	T2BD	1	ISKRAEMECO	1989	2149888	2003-11-28	2008-01-24 00:00:00	R	REDNA ZAMENJAVA MKN	NaN	NaN	NaN
673087	1061140	164	T22CD	1	ISKRAEMECO	1971	2057348	1994-01-01	1997-06-17 00:00:00	O	ODJAVA MKN	NaN	NaN	NaN
673088	1061140	164	T22CD	1	ISKRAEMECO	1971	2047153	1997-12-11	2009-11-18 00:00:00	R	REDNA ZAMENJAVA MKN	NaN	NaN	NaN
673089	1061140	164	T22CD	1	ISKRAEMECO	1971	2158452	2010-02-25	2015-08-18 00:00:00	A	IZGRADNJA AMI SISTEMA	NaN	POMANJKLJIVOST NI UGOTOVLJENA	2020-10-13 09:07:27.773190
673090	30662516	1639	ZMXI320CPU1L1D3	15	LANDIS+GYR	2015	2007834	2016-01-13	NaN	NaN	NaN	NaN	NaN	NaN

673091 rows × 14 columns

Figure 21. S1.3 ELCE pilot - input data overview

Below is an overview of the installed smart meters per smart meter producer. The data is summarized over the producer's name. Only two smart meter producers have a large portion of the meters installed, denoted with a Measurement point column, Iskraemeco and Landis+Gyr.

Producer name	Factory number	Type id	Type name	Producer id	Production year	Measurement point	Day of installement	Date of removal	Removal reason id	Removal reason name	Type of failure id	Type of failure name	Date of last change	Install year	Remove year	Life span	Install month	Install day	Install day of week	Install day of year	Remove month	Remove day
ISKRAEMECO	271055	403	386	1	75	201219	8328	9473	13	13	2	39	11897	34	34	62	12	31	7	366	12	31
LANDIS+GYR	140664	64	55	1	47	141264	4581	3588	12	12	3	34	12954	29	30	45	12	31	7	365	12	31
DANUBIA	549	10	10	1	24	281	252	476	5	5	0	1	2	13	20	20	12	31	7	186	12	31
ZAČASNI	220	9	8	1	34	236	182	221	6	6	0	3	6	17	22	22	12	31	7	146	12	31
SIEMENS	11	8	8	1	5	10	3	8	3	3	0	0	0	3	5	6	2	1	2	2	6	5
EAW	9	1	1	1	8	9	2	9	2	2	0	0	0	2	5	4	2	2	2	2	5	9
KRIŽIK	3	1	1	1	2	3	1	3	1	1	0	0	0	1	2	2	1	1	1	1	3	3
GANZ	2	1	1	1	2	2	1	2	2	2	0	0	0	1	2	2	1	1	1	1	2	2

Figure 22. S1.3 ELCE pilot - data summarized over producers

The next table shows the installations of the smart meters in the last 12 years. The first installations are shown as well on the end of the table indicating that already in 1920 there were 112 meters installed in the Elektro Celje network!

The installations in the last 12 years show intensive installations till 2019. After that the installations seem to be merely replacements of older installations or due to meter failures.

	Factory number	Type id	Type name	Producer id	Producer name	Measurement point	Day of installement	Date of removal	Removal reason id	Removal reason name	Type of failure id	Type of failure name	Date of last change	Install year	Remove year	Life span	Install month	Install day	Install day of week	Install day of year	Remove month	Remove day	Remove day of week	R
2022	636	7	7	2	2	636	85	5	3	3	0	1	4	2	2	3	7	31	6	85	4	5	3	
2021	4415	15	14	2	2	4407	326	51	4	4	0	1	51	2	3	4	12	31	7	275	11	23	6	
2020	9743	20	16	2	2	9775	564	252	6	6	0	4	370	6	5	9	12	31	7	342	12	31	6	
2019	14986	18	13	2	2	15431	771	507	7	7	0	6	804	7	6	10	12	31	7	354	12	31	7	
2018	14884	13	13	2	2	15642	952	708	6	6	0	15	1036	15	9	17	12	31	7	355	12	31	7	
2017	17069	21	16	2	2	20385	1320	1050	8	8	0	18	2034	11	9	16	12	31	7	359	12	31	7	
2016	9689	23	21	2	2	12898	1510	1128	9	9	0	17	977	16	14	18	12	31	7	364	12	31	7	
2015	13425	17	17	2	2	17501	1698	1344	11	11	1	22	1173	14	13	20	12	31	7	360	12	31	7	
2014	14681	30	26	2	2	19488	1881	1616	9	9	1	23	1267	14	13	20	12	31	7	363	12	31	7	
2013	15385	33	28	2	2	20995	2069	1828	11	11	0	28	1645	18	16	24	12	31	7	363	12	31	7	
2012	15148	41	35	2	2	20381	2311	2060	10	10	0	30	1583	26	24	35	12	31	7	362	12	31	7	
2011	21676	38	33	2	2	29326	2482	2394	11	11	2	31	1851	23	19	30	12	31	7	364	12	31	7	
.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
1947	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	
1944	1	1	1	1	1	2	2	2	1	1	0	1	1	2	2	2	2	2	2	2	2	1	1	
1939	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	
1930	1	1	1	1	1	2	2	2	1	1	0	0	0	2	2	2	2	2	2	2	2	2	2	
1920	112	4	4	2	2	113	4	1	1	1	0	0	0	3	2	3	4	3	4	4	1	1	1	

Figure 23. S1.3 ELCE pilot - installations over years

There is a number of reasons for a replacement of a smart meter (SM). The reasons are listed below, most interesting are:

- 'REDNA ZAMENJAVA MKN': normal SM replacement
- 'ODJAVA MKN': meter removal
- 'NEUSTREZNA MKN': meter does not fit the communication environment
- 'OKVARA MKN': SM failure

The smart meter failure is a category this report is interested in. There have been more than 25.000 SM failures in the history of Elektro Celje. In the table below the SM replacements are listed and sorted per number of replaced meters.

Removal reason name	Factory number	Type id	Type name	Producer id	Producer name	Production year	Measurement point	Day of installement	Date of removal	Removal reason id	Type of failure id	Type of failure name	Date of last change	Install year	Remove year	Life span	Install month	Install day	Install day of week	Install day of year	Remove month	Remove day	Remove day of week	Remove day of year
REDNA ZAMENJAVA MKN	233396	468	441	8	8	73	179078	7686	8744	1	1	29	2771	30	34	30	12	31	7	366	12	31	7	366
ODJAVA MKN	33515	351	328	6	6	64	35133	5986	7105	1	0	19	2443	34	32	31	12	31	7	366	12	31	7	366
NEUSTREZNA MKN	29440	269	249	6	6	64	28310	5793	5023	1	0	25	5362	30	30	24	12	31	7	365	12	31	7	364
IZGRADNJA AMI SISTEMA	28360	228	208	3	3	65	26822	4879	2415	1	1	27	11323	28	24	31	12	31	7	365	12	31	7	365
OKVARA MKN	25140	281	264	4	4	63	23950	5038	5127	1	0	39	4189	27	27	21	12	31	7	365	12	31	7	366
PILOTNI PROJEKT	2697	52	50	2	2	39	2683	930	267	1	0	5	501	19	11	14	12	31	7	339	12	31	7	195
PRESKUS NAKLJUČNEGA VZORCA	800	35	34	2	2	23	797	545	172	1	0	4	244	19	10	14	12	31	7	283	12	31	6	140
BRISANJE ZGODOVINE MKN	139	76	72	4	4	44	139	101	134	1	0	2	5	21	22	16	12	27	7	86	12	30	7	113
KONTROLA NA ZAHTEVO STRANKE	87	42	42	2	2	39	86	87	86	1	0	8	16	21	15	13	12	31	5	80	12	30	7	80
NEUPRAVIČEN PRIKLOP EL.ENERGIJE	60	32	32	2	2	31	60	55	45	1	0	3	8	16	7	14	12	25	7	51	12	24	6	45
UKRADENA MKN	39	31	31	2	2	22	38	32	35	1	0	2	5	17	20	13	11	19	6	31	10	21	6	35
NI PODATKA	16	10	10	2	2	13	16	16	14	1	0	0	0	10	5	9	11	13	6	16	8	12	5	14
DVOJNIK 24	9	6	6	1	1	7	9	8	7	1	0	1	1	7	4	7	6	5	5	7	4	7	4	7

Figure 24. S1.3 ELCE pilot - smart meter replacement reasons

Failure analysis per year

In this section the smart meter failures per year will be analyzed. The reason for meter replacement that will be analyzed is `OKVARA MKN` which indicates the meter failure. The failures will be analyzed according to meter `Producer name/Type name/Production` year data and traced according to the `Installed year` and `Remove year` data feature.

In the Figure 25 the installs of the smart meters in the Elektro Celje network are tracked. Only the top 10 meter `producer/types/production year` combinations are presented. There was a large number of ISKRAEMECO meters installed in 2011. To better see the other meter combinations patterns the top meter in 2011 will be removed from the list and presented in the Figure 26.

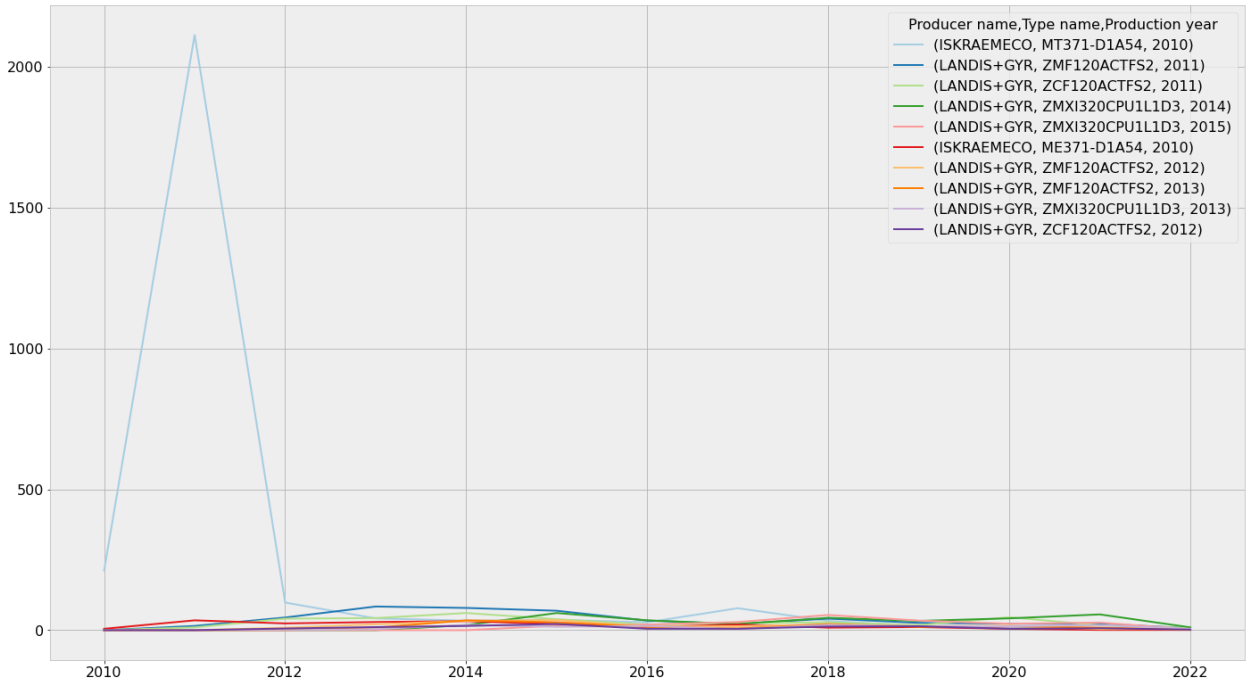


Figure 25. S1.3 ELCE pilot - Top 10 meter failures per year in period from 2010 to 2021

The figure below presents the failures in the Elektro Celje network. The general trend indicates decline of the number of failures over the years. The year 2022 failures could be a bit misleading since not the whole year is covered in data.

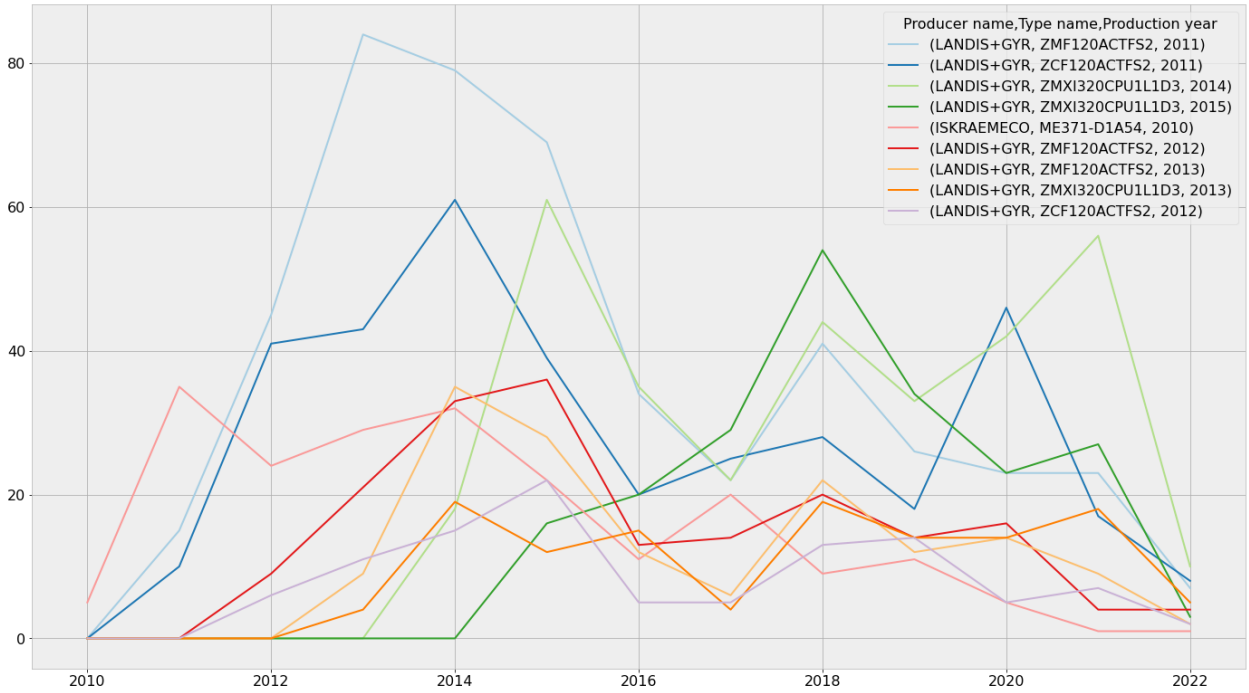


Figure 26. S1.3 ELCE pilot - selected meters failures in period from 2010 to 2021 per year

The figure below better presents the trends and patterns of installment over the last decade in Elektro Celje network. In general, the trend of installation of these particular meters is falling over the years. There could be a number of reasons for such a trend but it is likely that new `producer/types/production year` combinations are installed in larger quantities. The last year in the figure could be misleading since not the whole year 2022 is covered in the data. Please note that the number of installments over the years have failed but the trend is not as drastic as shown for the meters with the top number of failures. It is likely that newer meters are replacing the older ones being installed in the last decade.

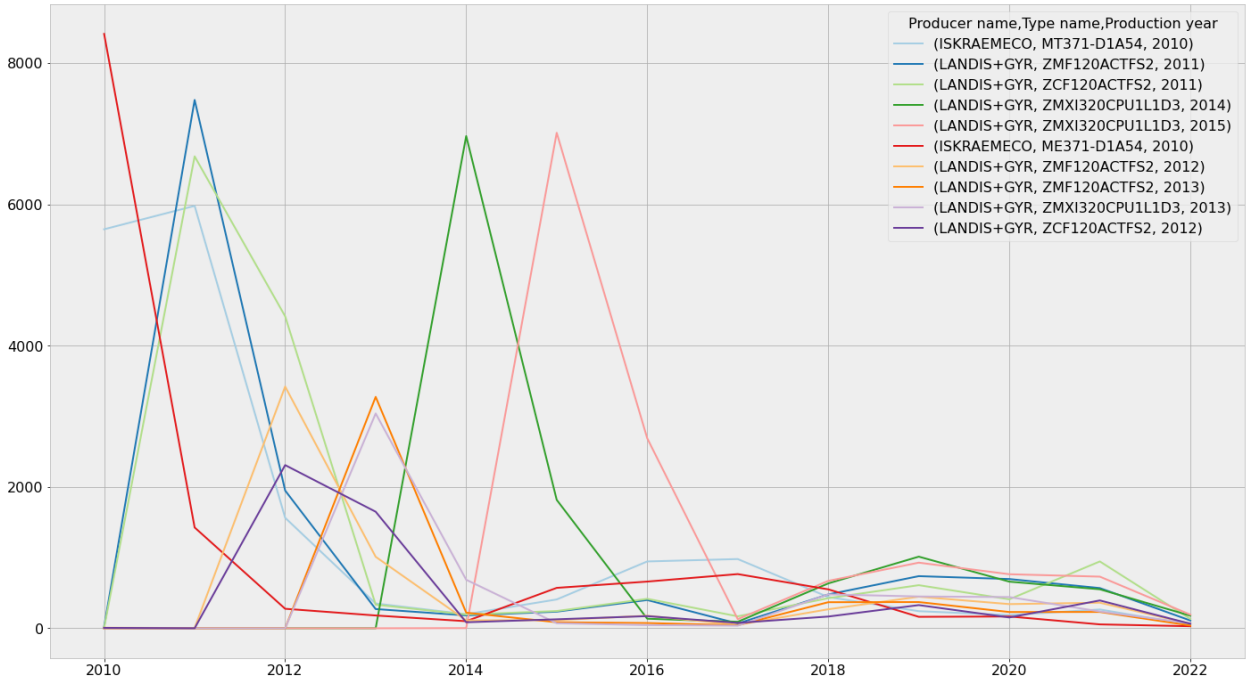


Figure 27. S1.3 ELCE pilot - installments of top 10 meters per year in period from 2010 to 2021

The last figure presents a percentage of replaced meters according to installed population per year. The values of installations and removals of meter `producer/type/year of production` are calculated as cumulative sums and then expressed as percent of all removals compared to all installations. The calculation explains the high percentage of replacements of `('ISKRAEMECO', 'MT371-D1A54', 2010)` combination after year 2011 since the high number of replacements in year 2011 - almost 20% of entire population.

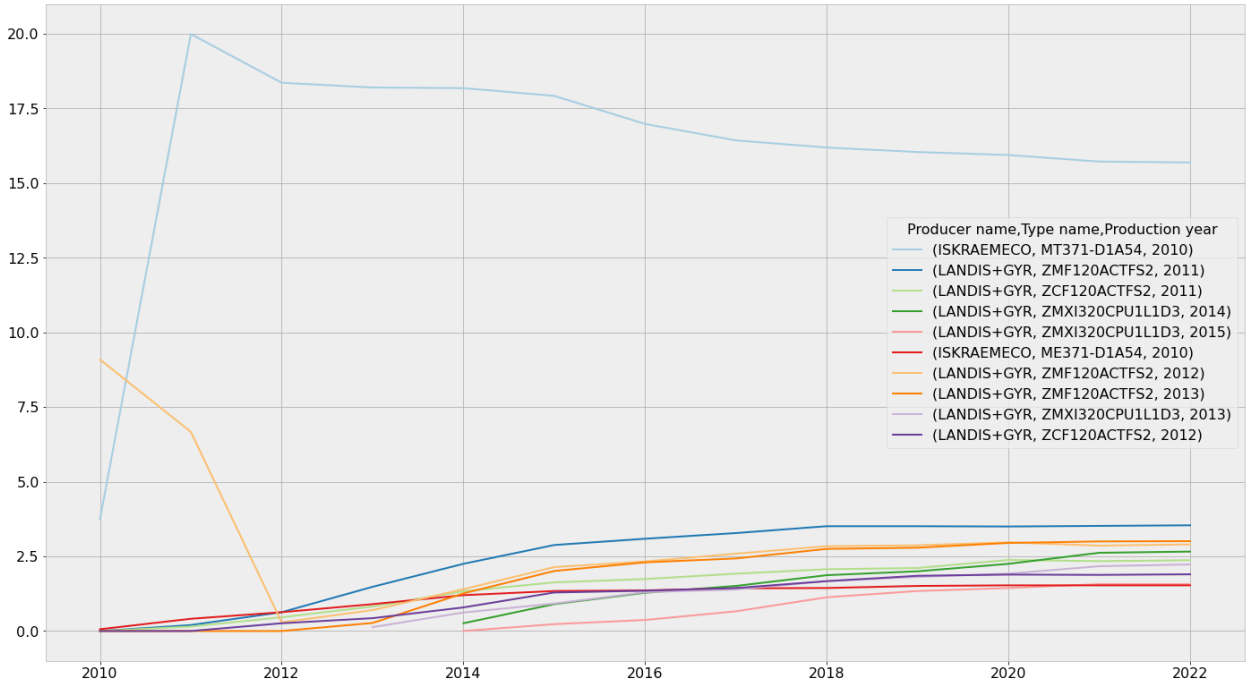


Figure 28. S1.3 ELCE pilot - percentage of failed meters according to installed meters in period from 2010 to 2021 per year

Failures analysis per month

In this section the meter failures will be analyzed according to failures and installs over years and months in the network of Elektro Celje. The analysis is similar to one explained in the previous section on analysis of failures over years. in this section only the differences and specifics of `year/month` combination will be pointed out.

Below the removals of the smart meters over the period from January 2010 to November 2021 are presented. The number of removals of the `('ISKRAEMECO', 'MT371-D1A54', 2010)` meter type is very high and the other removals are not well presented in the figure.

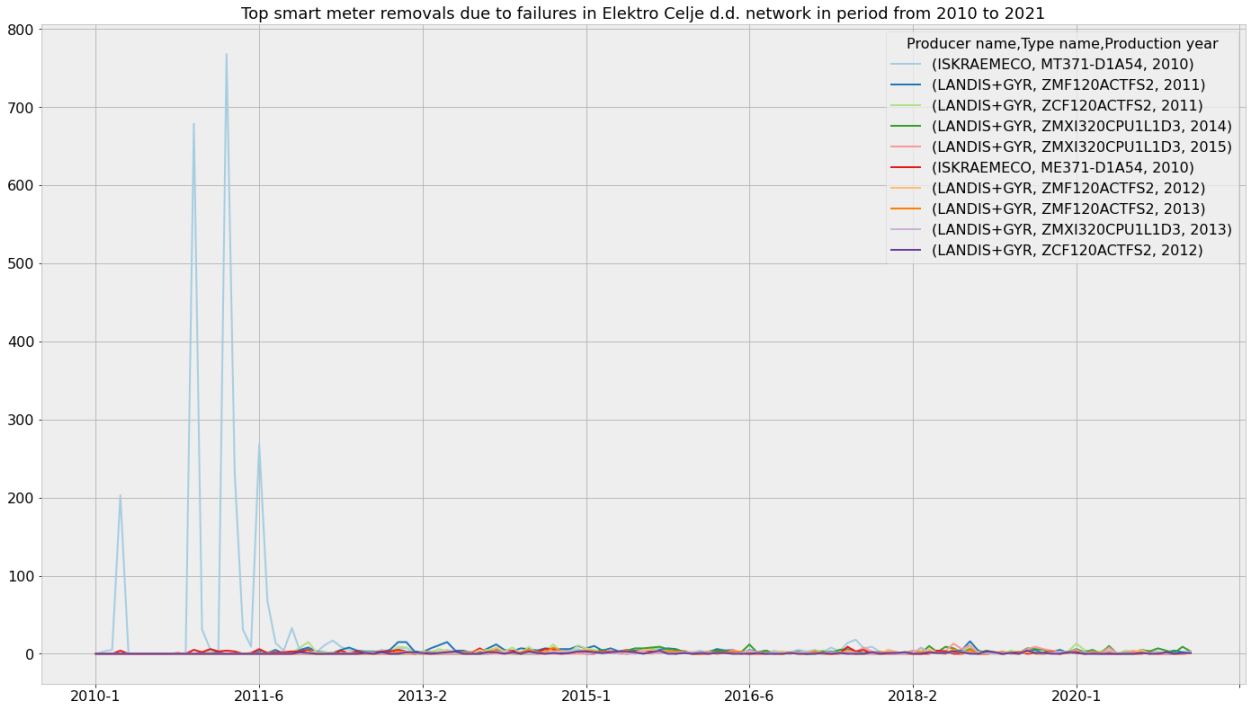


Figure 29. S1.3 ELCE pilot - top 10 smart meter types removals from 2010 to 2021 per month

The removal of the rest of the top ten meters (meters placed from second to tenth) is presented below. There seems to be no ordinary pattern of removals due to failures. The failures of the meters seem to be hard to predict.

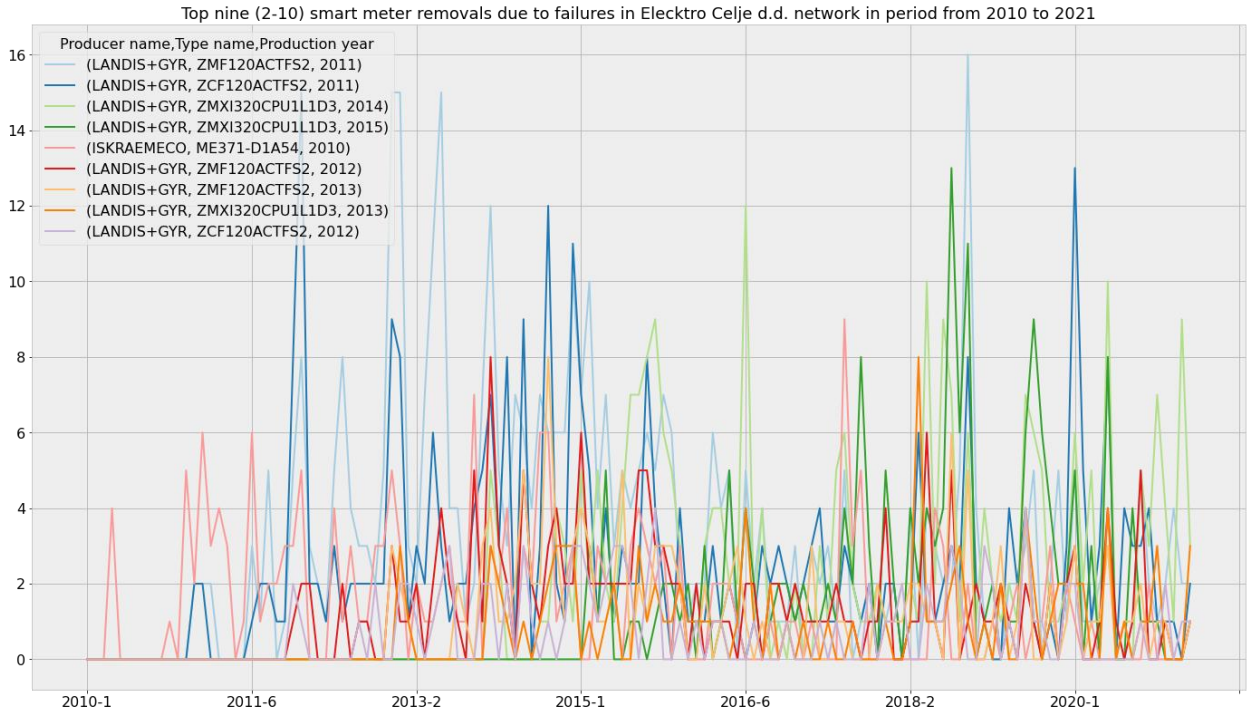


Figure 30. S1.3 ELCE pilot - selected smart meter types removals from 2010 to 2021 per month

The monthly installation figure of the top 10 meters is presented below. The graph shows a larger number of installations at the beginning of the meter lifecycle and a lower number of installations at later time.

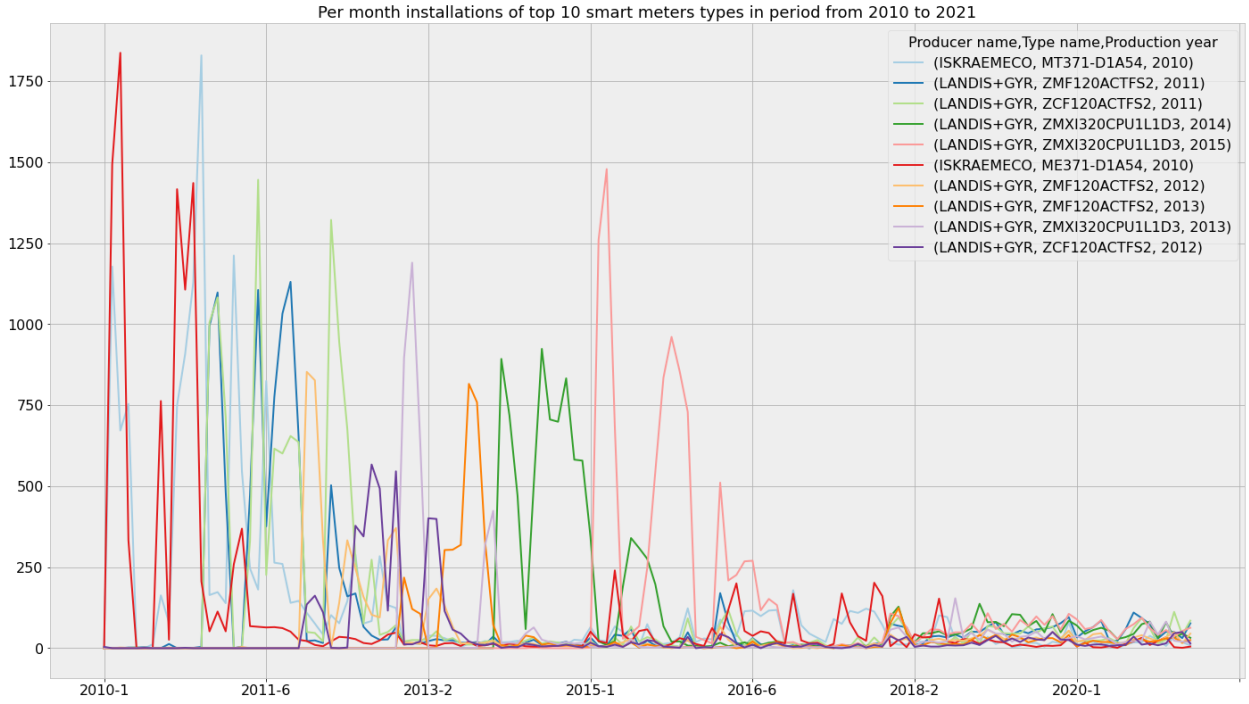


Figure 31. S1.3 ELCE pilot - per month installations of top 10 meters with failures in period from 2010 to 2021

The last figure presents the percentage of removals according to installations. Similar to the yearly analysis, the percentage is based on the ratio of cumulative sums of removals to cumulative sums of installations. The percentage appears quite predictable, except for meters with a large number of replacements at the very beginning of their lifetime. The jump in percentage, evident in many lines, is influenced by a large number of batch installations during certain periods, which reduces the ratio between removed and installed meters. While the figures may be enticing for predictions, their usefulness for predictive purposes is questionable. Due to the cumulative nature of the metrics the dynamics observed in failures seems to be suppressed. One pattern that can be observed is the larger number of failures after new batch installations. The percentage seems to bounce back quite rapidly which could indicate a larger number of failures of freshly installed meters.

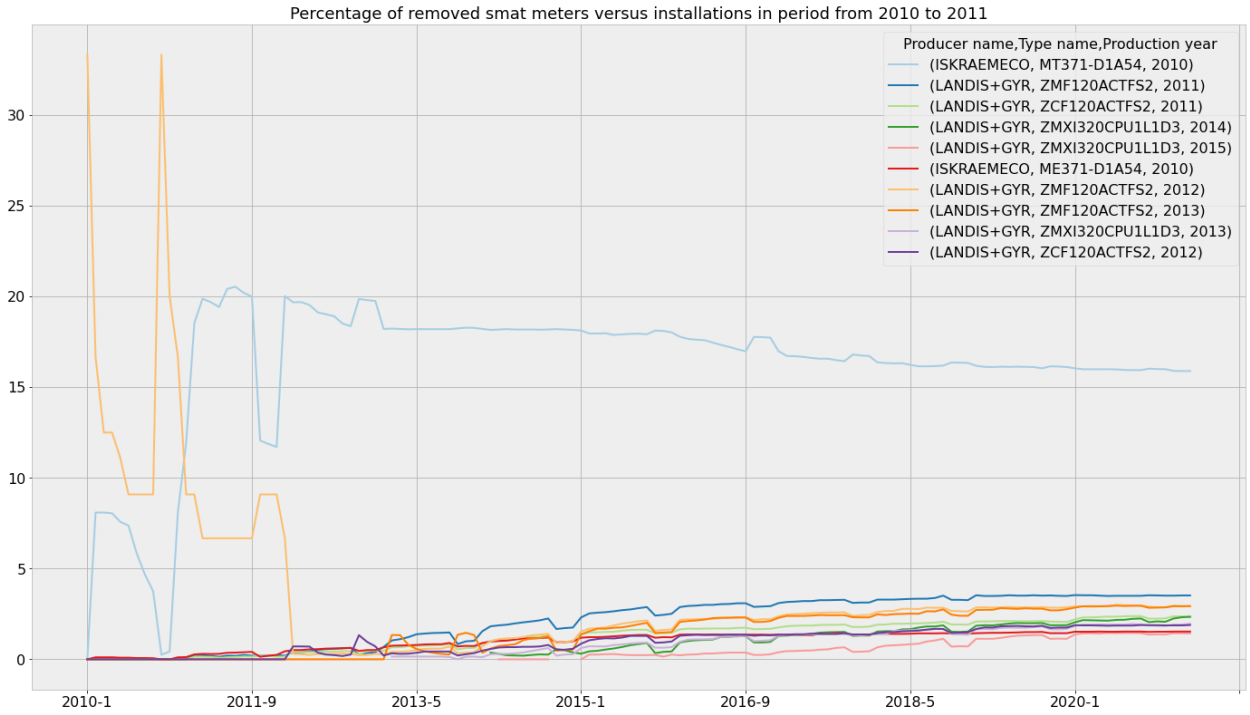


Figure 32. S1.3 ELCE pilot - percentage of removals according to installations of top 10 meters in period from 2010 to 2021

In the wide table below the top 10 smart meter types being replaced due to failures in Elektro Celje network are presented with their failures percentage according to installations per month. The months with a double of failures compared to the previous month are marked as bold. This is a calculated value when the `max_failures parameter` is set to 0%.

Producer name	Type name	Production year	2010-1	2010-2	2010-3	2010-4	2010-5	2010-6	2010-7	2010-8	2010-9	2010-10	2010-11	2010-12	2011-1	2011-2	2011-3	2011-4	2011-5
ISKRAEMECO	MT371-D1A54	2010	0.00	**8.09**	8.09	8.05	7.58	7.37	5.84	4.67	3.75	0.25	0.43	**8.09**	11.91	18.53	19.87	19.69	19.42
LANDIS+GYR	ZMF120ACTFS2	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.23**	0.23	0.19	0.14
	ZCF120ACTFS2	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.14**	0.14	0.13	0.09
	ZMXI320CPU1L1D3	2014	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
		2015	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
ISKRAEMECO	ME371-D1A54	2010	0.00	**0.11**	0.11	0.11	0.09	0.09	0.07	0.07	0.06	0.00	0.00	**0.11**	0.12	**0.27**	0.30	0.29	0.30
LANDIS+GYR	ZMF120ACTFS2	2012	33.33	16.67	12.50	12.50	11.11	9.09	9.09	9.09	9.09	**33.33**	20.00	16.67	9.09	9.09	6.67	6.67	6.67
		2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ZMXI320CPU1L1D3	2013	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
	ZCF120ACTFS2	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 33. S1.3 ELCE pilot - Flagged smart meter failures according to max_failures parameter

S3.1 – Grid disturbance simulations results

UPC approach: Grid elements congestions detection

Introduction of the service
Name: Grid Disturbance Simulations.
Category: Operation and maintenance.

Task: T4.1
Location on the grid: MV grid, LV Grid

This service predicts possible congestion scenarios for the day-ahead operation planning on a low-voltage and/or medium-voltage grid by applying machine learning techniques (e.g., Linear Regression, Neural Networks). The output contains information such as the location and time of possible congestions in the grid and suggests improvements by means of swapping between phases at connections or consumers where problems occur.

Table 8. Use cases for the S3.1 service – UPC approach

Use case	Description
UC1	As a grid analyst, you wish to know in advance the forecast of the demand you are facing in your loads for the next day
UC2	As a grid analyst, you want to know if you are going to have congestions in your lines, following the forecasted loads. This is necessary to plan the flexibility dispatch (if available) for the next day

Use Case 1

Reviewing the forecasted demand, the service offers the deterministic forecasted demand for aggregated sources, the total amount of power in the grid for each hour, as shown in Figure 34. This is an interesting result as the analyst can now where is going to be the peak hour in a first glance to the service UIs, which in this execution there are two peaks at 12:15h and 19:15. It is also possible to check and analyse the forecasted demand for each of the loads in the grid, with the help of the dropdown in the right. The analyst can select a specific load, which can be of more interest to the DSO, for any particular reason. In Figure 35, we can observe the profile of the load 132389 in a day-ahead. This can be done with any other load. Additionally, the analyst can download the table in excel form, as seen in Figure 36, of the results for all the loads in case they wish to generate more detailed reports.

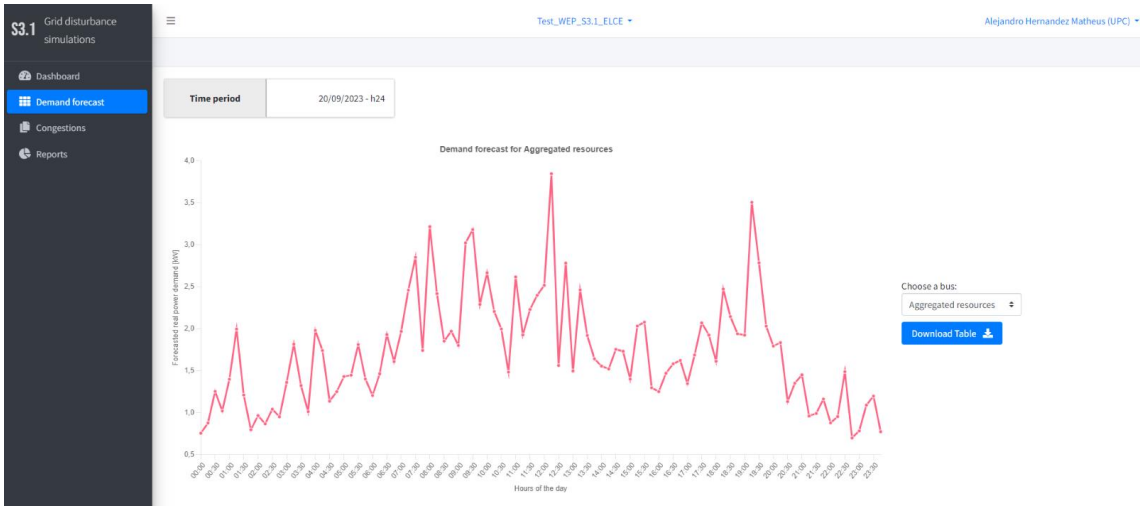


Figure 34. Aggregated demand

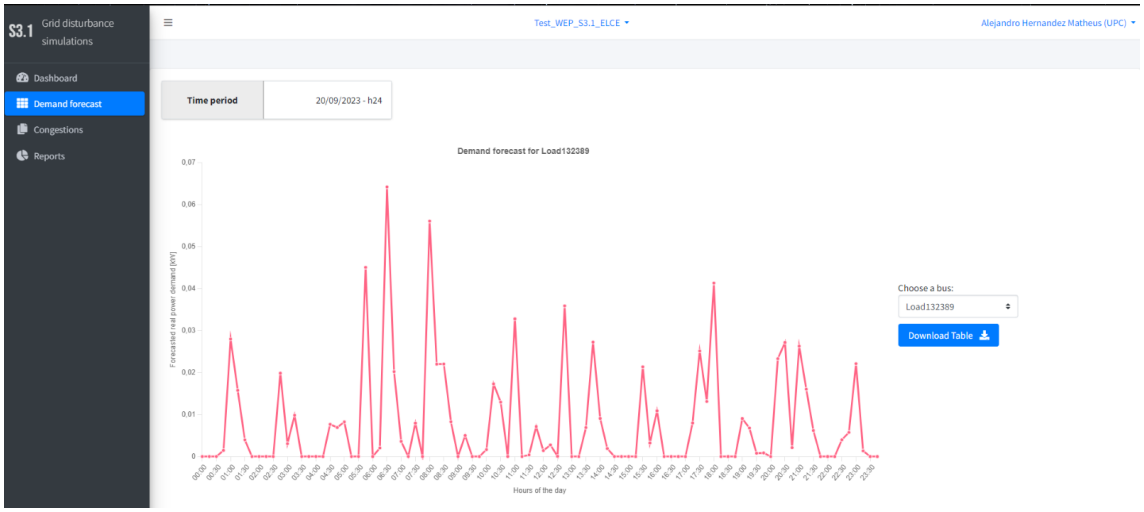
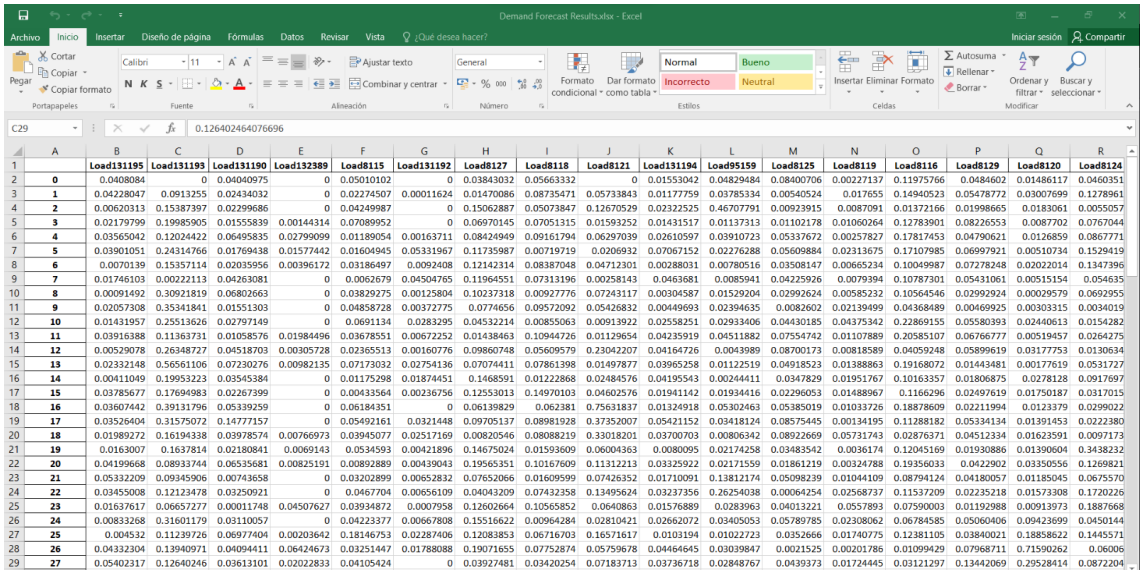


Figure 35. Forecast Demand for Load 132389



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		Load131195	Load131193	Load131190	Load132389	Load8115	Load131192	Load8127	Load8118	Load8121	Load131194	Load95159	Load8125	Load8119	Load8116	Load8129	Load8120	Load8124
2	0	0.0408084	0	0.04040975	0	0.05010102	0	0.03843032	0.05663332	0	0.01553042	0.04829484	0.08400706	0.00227137	0.11975766	0.0484602	0.01486117	0.0460351
3	1	0.04228047	0.0913255	0.02434032	0	0.02274507	0.00011624	0.01470086	0.08735471	0.05733843	0.01177759	0.03785334	0.00540524	0.017655	0.14940523	0.05478772	0.03007699	0.1278961
4	2	0.00620313	0.15387397	0.02299686	0	0.04249987	0	0.15062887	0.05073847	0.12670529	0.02322525	0.46707791	0.00923915	0.0087091	0.01372166	0.01998665	0.0183061	0.0055057
5	3	0.02179799	0.19985905	0.01555839	0.00144314	0.07089952	0	0.06970145	0.07051315	0.01593252	0.01431517	0.01137313	0.01102178	0.01060264	0.12783901	0.08226553	0.0087702	0.0767044
6	4	0.03565042	0.12024422	0.06495835	0.02799099	0.01189054	0.00163711	0.08424949	0.09161794	0.06297039	0.02610597	0.03910723	0.05337672	0.00257827	0.17817453	0.04790621	0.0126859	0.0867771
7	5	0.03901051	0.24314766	0.01769438	0.01577442	0.01604945	0.05331967	0.11735987	0.00719719	0.0206932	0.07067152	0.02276288	0.05609884	0.02313675	0.17107985	0.06997921	0.00510734	0.1529419
8	6	0.0070139	0.15357114	0.02035956	0.00396172	0.03186497	0.0092408	0.12142314	0.08387048	0.04712301	0.00288031	0.00780516	0.03508147	0.00665234	0.10049987	0.07278248	0.02022014	0.1347396
9	7	0.01746103	0.00222113	0.04263081	0	0.0062679	0.04504765	0.11964551	0.07313196	0.00258143	0.0463681	0.0085941	0.04225926	0.0079394	0.10787301	0.05431061	0.00515154	0.054635
10	8	0.00091492	0.30921819	0.06802663	0	0.03829275	0.00125804	0.10237318	0.00927776	0.07243117	0.00304587	0.01529204	0.02992624	0.00585232	0.10564546	0.02992924	0.00029579	0.0692955
11	9	0.02057308	0.35341841	0.01551303	0	0.04858728	0.00372775	0.0774656	0.09572092	0.05426832	0.00449693	0.02394635	0.0082602	0.02139499	0.04368489	0.00469925	0.00303315	0.0034019
12	10	0.01431957	0.25513626	0.02797149	0	0.0691134	0.0283295	0.04532214	0.00855063	0.00913922	0.02558251	0.02933406	0.04430185	0.04375342	0.22869155	0.05580393	0.02440613	0.0154282
13	11	0.03916388	0.11363731	0.01058576	0.01984496	0.03678551	0.00672252	0.01438463	0.10944726	0.01129654	0.04235919	0.04511882	0.07554742	0.01107889	0.20585107	0.06766777	0.00519457	0.0264275
14	12	0.00529078	0.26348727	0.04518703	0.00305728	0.02365513	0.00160776	0.09860748	0.05609579	0.23042207	0.04164726	0.0043989	0.08700173	0.00818589	0.04059248	0.05899619	0.03177753	0.0130634
15	13	0.02332148	0.56561106	0.07230276	0.00982135	0.07173032	0.02754136	0.07074411	0.07861398	0.01497877	0.03965258	0.01122519	0.04918523	0.01388863	0.19168072	0.01443481	0.00177619	0.0531727
16	14	0.00411049	0.19953223	0.03545384	0	0.01175298	0.01874451	0.1468591	0.01222868	0.02484576	0.04195543	0.00244411	0.0347829	0.01951767	0.10163357	0.01806875	0.0278128	0.0917697
17	15	0.03785677	0.17694983	0.02267399	0	0.00433564	0.00236756	0.12553013	0.14970103	0.04602576	0.01941142	0.01934416	0.02296053	0.01488967	0.1166296	0.02497619	0.01750187	0.0317015
18	16	0.03607442	0.39131796	0.05339259	0	0.06184351	0	0.06139829	0.062381	0.75631837	0.01324918	0.05302463	0.05385019	0.01033726	0.18878609	0.02211994	0.0123379	0.0299022
19	17	0.03526404	0.31575072	0.14777157	0	0.05492161	0.0321448	0.09705137	0.08981928	0.37352007	0.05421152	0.03418124	0.08575445	0.00134195	0.11288182	0.05334134	0.01391453	0.0222380
20	18	0.01989272	0.16194338	0.03978574	0.00766973	0.03945077	0.02517169	0.00820546	0.08088219	0.33018201	0.03700703	0.00806342	0.08922669	0.05731743	0.02876371	0.04512334	0.01623591	0.0097173
21	19	0.0163007	0.1637814	0.02180841	0.0069143	0.0534593	0.00421896	0.14675024	0.01593609	0.06004363	0.0080095	0.02174258	0.03483542	0.0036174	0.12045169	0.01930886	0.01390604	0.3438232
22	20	0.04199668	0.08933744	0.06535681	0.00825191	0.00892889	0.00439043	0.19565351	0.10167609	0.11312213	0.03325922	0.02171559	0.01861219	0.00324788	0.19356033	0.0422902	0.03350556	0.1269821
23	21	0.05332209	0.09345906	0.00743658	0	0.03202899	0.00652832	0.07652066	0.01609599	0.07426352	0.01710091	0.13812174	0.05098239	0.01044109	0.08794124	0.04180057	0.01185045	0.0675570
24	22	0.03455008	0.12123478	0.03250921	0	0.0467704	0.00656109	0.04043209	0.07432358	0.13495624	0.03237356	0.26254038	0.00064254	0.02568737	0.11537209	0.02235218	0.01573308	0.1720226
25	23	0.01637617	0.06657277	0.00011748	0.04507627	0.03934872	0.0007958	0.12602664	0.10565852	0.0640863	0.01576889	0.0283963	0.04013221	0.0557893	0.07590003	0.01192988	0.00913973	0.1887668
26	24	0.00833268	0.31601179	0.03110057	0	0.04223377	0.00667808	0.15516622	0.00964284	0.02810421	0.02662072	0.03405053	0.05789785	0.02308062	0.06784585	0.05060406	0.09423699	0.0450144
27	25	0.004532	0.11239726	0.06977404	0.00203642	0.18146753	0.02287406	0.12083853	0.06716703	0.16571617	0.0103194	0.01022723	0.0352666	0.01740775	0.12381105	0.03840021	0.18858622	0.1445571
28	26	0.04332304	0.13940971	0.04094411	0.06424673	0.03251447	0.01788088	0.19071655	0.07752874	0.05759678	0.04464645	0.03039847	0.0021525	0.00201786	0.01099429	0.07968711	0.71590262	0.06006
29	27	0.05402317	0.12640246	0.03613101	0.02022833	0.04105424	0	0.03927481	0.03420254	0.07183713	0.03736718	0.02848767	0.0439373	0.01724445	0.03121297	0.13442069	0.29528414	0.0872204

Figure 36. Table of demand forecast in excel form

Use Case 2

For the analysis of the of the congestions, this tool offers a congestion where the analyst can see the forecast current, in kiloAmpers (kA), for each of the lines in the distribution grid. As seen in Figure 37, the figure shows the behaviour for the first line of the grid. The limit of the line, calculated with the required data to contract the service, is also shown for the analyst to know if there is going to be a congestion.

Figure 37. Line 12 forecast

Additionally, in the report tab, the analyst can observe line by line the probability of congestions and this value translated to kA. Also, the report shows the number of total congestions in the grid, which for this particular case is 0.

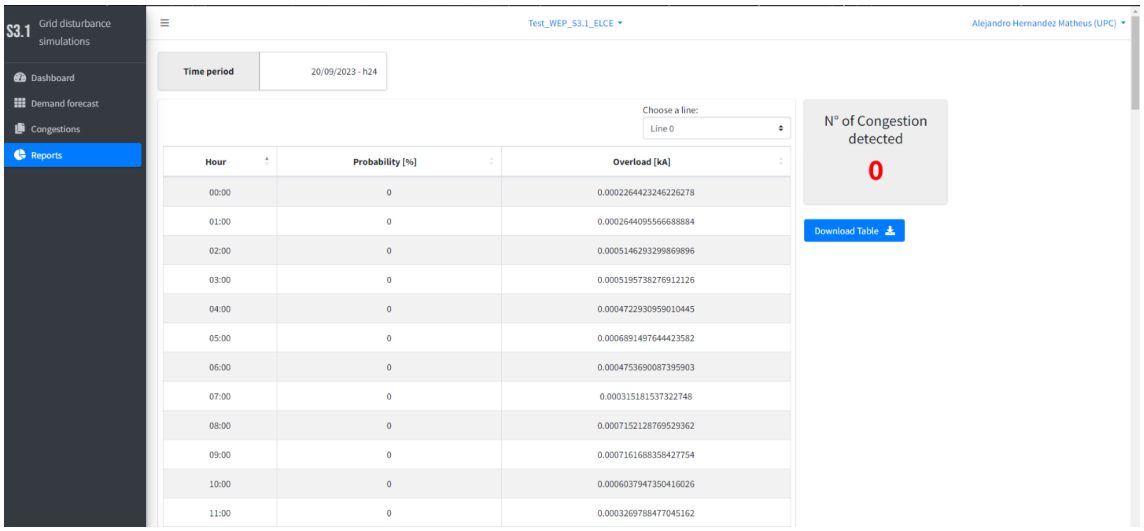


Figure 38. Report tab

Data assessment

The data required to establish the service mainly comprehends topology and grid parameters of the grid, as well historical measurements from either transformers or loads within the grid. The specific data files for this service can be observed in

Table 9

Table 9. Data Assessment for the S3.1 service – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
Grid Topology	Service_parameters	Missing some parameters of cables	High
Historical measurements	Smart_Meter	No missing points to create historical profile	High

Service conclusions

The results of the service are highly useful for DSOs. This type of information is especially useful in highly congested grids. However, it is very sensitive to the input data. Also, the fact that the machine learning models are trained with a fixed topology, it is an important drawback to be used on grids that change their topologies often. In the case of the Slovenian pilot, there are not many congestions historically. As a matter of fact, it is difficult to measure congestions in lines, which is an opportunity area for this service. The approach could be different by exploring congestions in voltages. Additionally, it is a very data intensive service, so adding features and prediction variables adds more complexity to its execution.

Additionally, some feedback raised during the testing of the service is as follows:

- The forecast figures could benefit from actual measurements of the loads, to help the analyst with past days investigations.
- Lines results should be given in Amperes (A), instead of kiloAmperes (kA)
- Information about the conductor should be given, as this helps the analyst with the decision making. This also applies to transformers with different cooling systems.
- In the Report Tables, the maximum thermal limit should be given, to provide reference.

JSI approach: Power quality issues and voltage disturbances analysis

Introduction of the service

Name: Grid disturbance simulations.
Category: Operation and maintenance.
Task: T4.1
Location on the grid: LV grid

Due to load fluctuations and intermittent power generation at various locations, distribution systems are susceptible to line and transformer overloads. In addition, excessive simultaneous energy consumption in a specific part of the network can lead to an undervoltage problem. On the other hand, excessive simultaneous generation can lead to an overvoltage problem. This service aims to solve the above problems by performing the LV grid simulations and identifying possible solutions to improve power quality (PQ).

Table 10. Use cases for the S3.1 service – JSI approach

Use case	Description
UC1	As DSO you want to analyse LV grid to increase ingestion capabilities for RES.
UC2	As DSO you want to analyse LV grid to improve voltage profiles at the end-user
UC3	As DSO you want to analyse LV grid to minimize investment costs for reinforcing the grid

Use Case

As a DSO, the primary objective is to improve the capabilities of the existing low-voltage grid to increase the feed-in of renewable energy with minimal investment costs while complying with PQ requirements or addressing potential existing PQs. Most critical are the voltage levels at the end consumers/prosumers. In the worst-case scenario, the largest voltage fluctuations are observed at the end consumers/prosumers that are furthest away from the substation or have high loads or generators.
In the case of ELCE, one substation with many end users was simulated. Specifics of the network is that it consists of households with some degree of PV penetration and and without commercial or industrial operation. These lead to fluctuations on the grid, especially during the weekdays when most people are working outside the simulated part of the grid, the usage is minimal and PV generation is highest. The topology of the grid under consideration is shown in Figure 39. Topology of the grid under consideration.

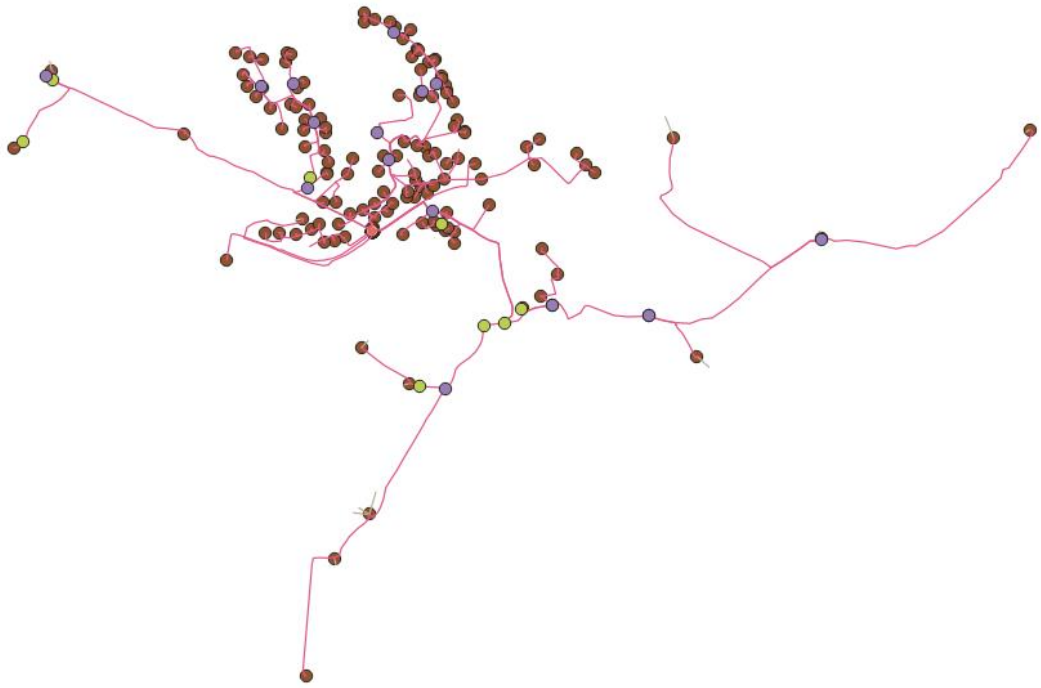


Figure 39. Topology of the grid under consideration

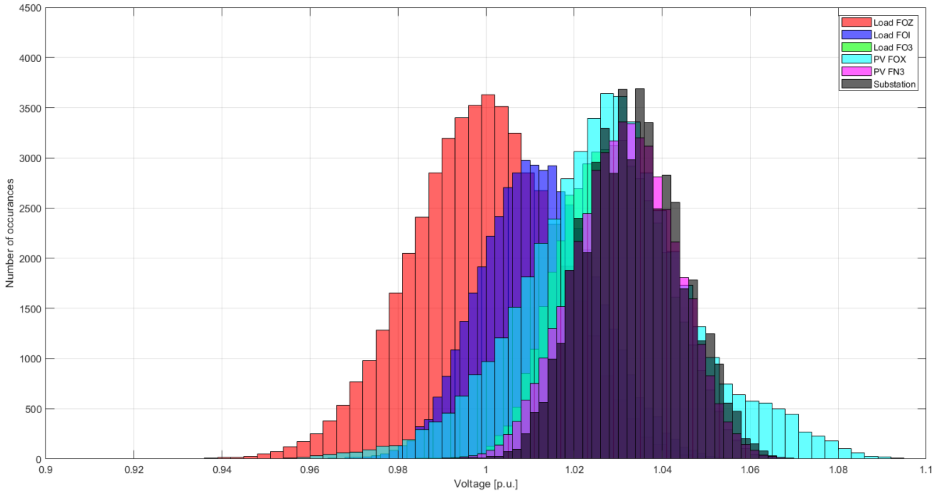


Figure 40. Initial histogram of normalized voltages at different nodes on LV Grid

The initial conditions on the grid are shown in Figure 40. As we can see on different parts of the grid, the voltages are sometimes very close to a 10% deviation from the nominal voltage. To reinforce the grid, increase the RES ingestion capabilities and improve voltage profiles, we have simulated different scenarios:

1. Tap changer change
   With each tap, the tap changer allows the voltage on the substation to be raised or lowered by 2%. The advantage is it can lower the voltage overshoots

at PVs. However, it simultaneously lowers the voltage at already critical loads with under-voltage issues. The advantage of the tap change is that it is the cheapest solution to solve the overvoltages or undervoltages, but not both simultaneously. Figure 41 shows the improvement after the tap change. The highest voltages have been moved away from the 1.1 limit.

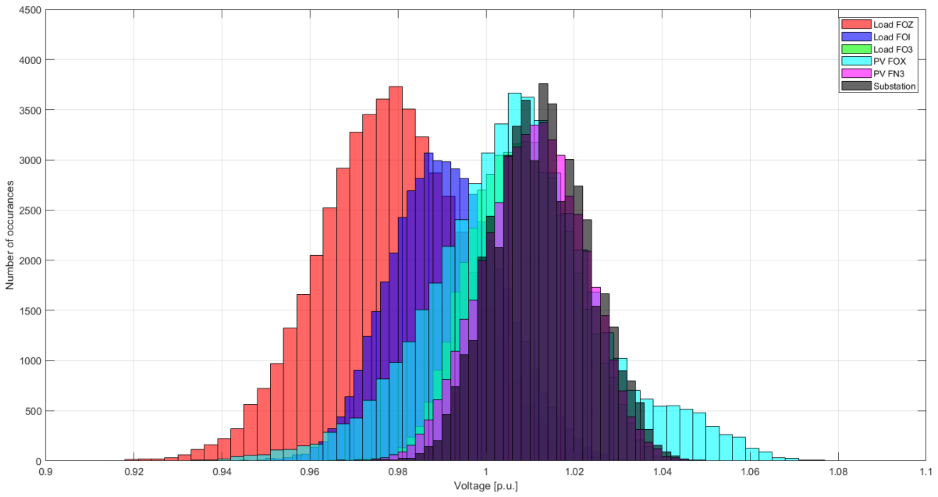


Figure 41. Normalized voltage histogram at different nodes on LV Grid after a -2% tap change

2. Grid reinforcement
   Grid reinforcement is done either by cable change or by adding a parallel cable to an existing one. We have changed the cabling in one section to the nodes with the lowest voltages. The results are shown in Figure 42. The lower voltages have greatly moved towards nominal voltage.

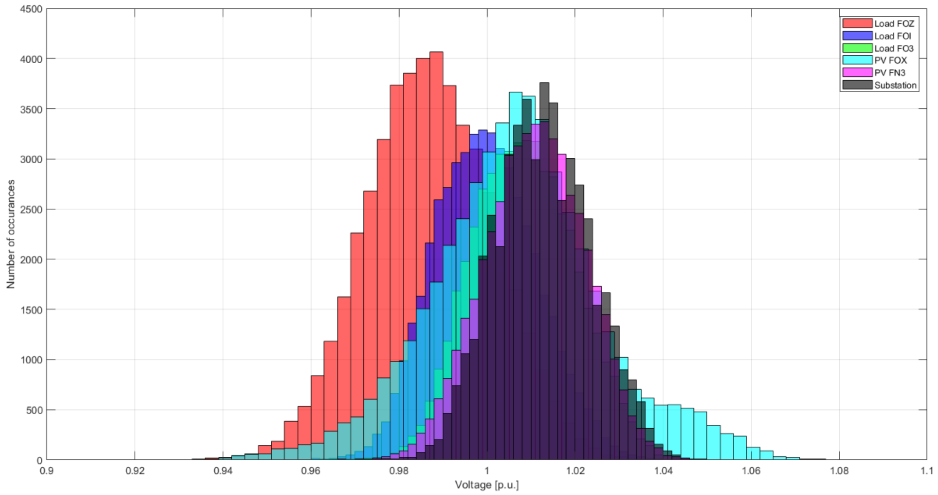


Figure 42. Normalized voltages histogram at different nodes on LV Grid after adding a cable between the two most critical points

Data assessment

The table below shows the data assessment for the S3.1 service – JSI approach.

Table 11. Data Assessment for the S3.1 service – JSI approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
Grid Topology	Service_parameters	Good	High
Historical measurements	Smart_Meter	Good	High

Service conclusions

The service addresses challenges arising from load fluctuations, intermittent power generation, and potential disturbances, aiming to improve voltage profiles.

The results of the service are useful for DSOs to efficiently plan the investment costs for reinforcing the grid. DSOs can use the information provided by the service to:

- Identify the specific areas of the grid that are most in need of reinforcement.
- Prioritize investment in grid reinforcement projects.
- Select the most cost-effective grid reinforcement solutions.
- Assess the impact of different reinforcement options on the grid.

In addition, DSOs can use the service to plan for the future integration of renewables. The service can help DSOs to:

- Identify the impact of different renewable energy scenarios on the grid.
- Develop strategies for integrating renewables into the grid in a reliable and cost-effective manner.
- Ensure that the grid is prepared for the increased variability and uncertainty associated with renewable energy generation.

Overall, the service can help DSOs to improve the reliability, quality, and efficiency of their electricity grids, while also supporting the integration of renewable energy.

VUB approach: Congestion control in distribution grid networks

Introduction of the service

Name: Grid disturbance simulation
Category: Operation and maintenance.
Task: T4.1
Location on the grid: LV grid

This service predicts possible congestion scenarios for the day-ahead operation planning on a low-voltage and/or medium-voltage grid by applying machine learning techniques (e.g., Linear Regression, Neural Networks). The output contains information such as the location and time of possible congestions in the grid and

suggests improvements by means of swapping between phases at connections or consumers where problems occur.

Table 12. Use cases for the S3.1 service – VUB approach

Use case	Description
UC1	As system operator/grid planner, you want to acquire insights on the actual grid topology in terms of which user affects one another.
UC2	As a grid analyst, you can monitor the extent to which voltage violations occur in your grid, and at the same time determine how many of these can be reduced by applying phase rebalancing.
UC3	Grid analysts may also want to evaluate the influence of new assets such as solar photovoltaics and/or electric vehicles.

Use Case 1

By analysing the consumption and voltage profiles provided, the service offers insights into which consumer ID will affect another consumer (neighbouring ID), based on the phase to which the consumer is connected. For instance, if the analyst selects a consumer "ID 19", results from the algorithm will provide an overview of the affected IDs in terms of voltage deviation per kilowatt of extra consumption at consumer 19, see Figure 43. In this particular example, a deviation in the consumption of consumer 10 will mainly affect consumers 57 and 6 which are connected to phase A and phase B respectively. This implies that consumer ID 19 is a three phase consumer.
On the other hand, next to the impact at consumer level, a grid operator may wish to get an overview of how the grid topology is, and thus which consumers are connected within the same feeder. Using correlation matrices and other clustering techniques, an estimation of the at feeder level is visualized (Figure 44). The grid operator can now identify at grid level which consumers influence each other. Besides from the plot, the UI summarizes the different feeders that the algorithm has detected (displayed left of the plot).
Finally, the results from the analysis can be exported (in a zip file format). Since all the graphs are interactive, i.e. a user can interactively hover on top of them, the exported version of these graphs are in the html format. An example output file is shown in Figure 45.

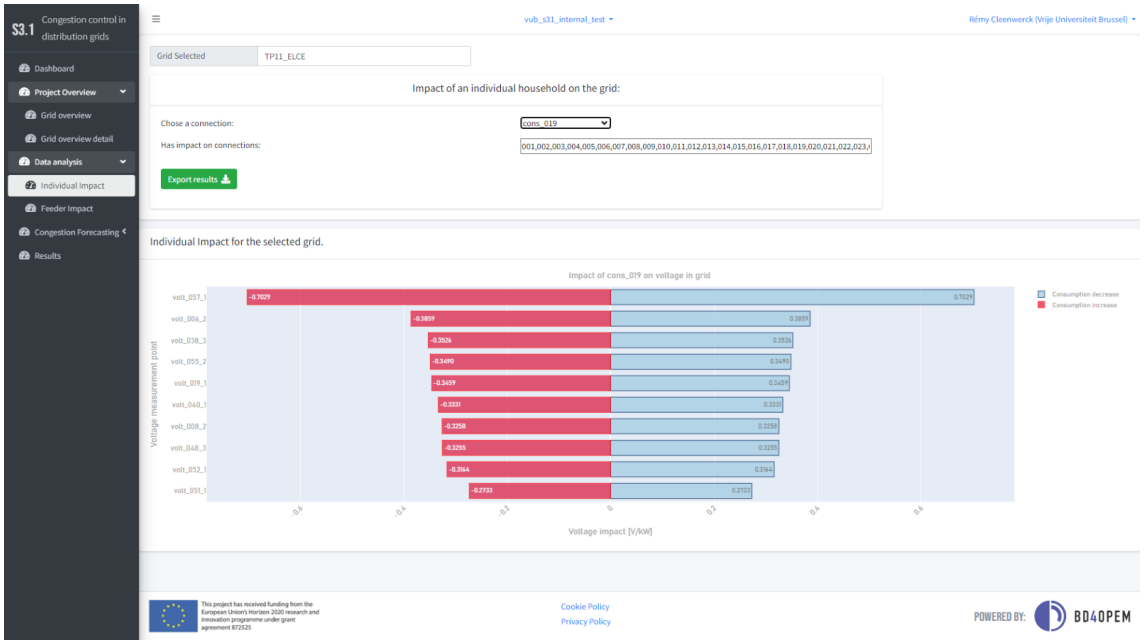


Figure 43. Individual impact of consumers

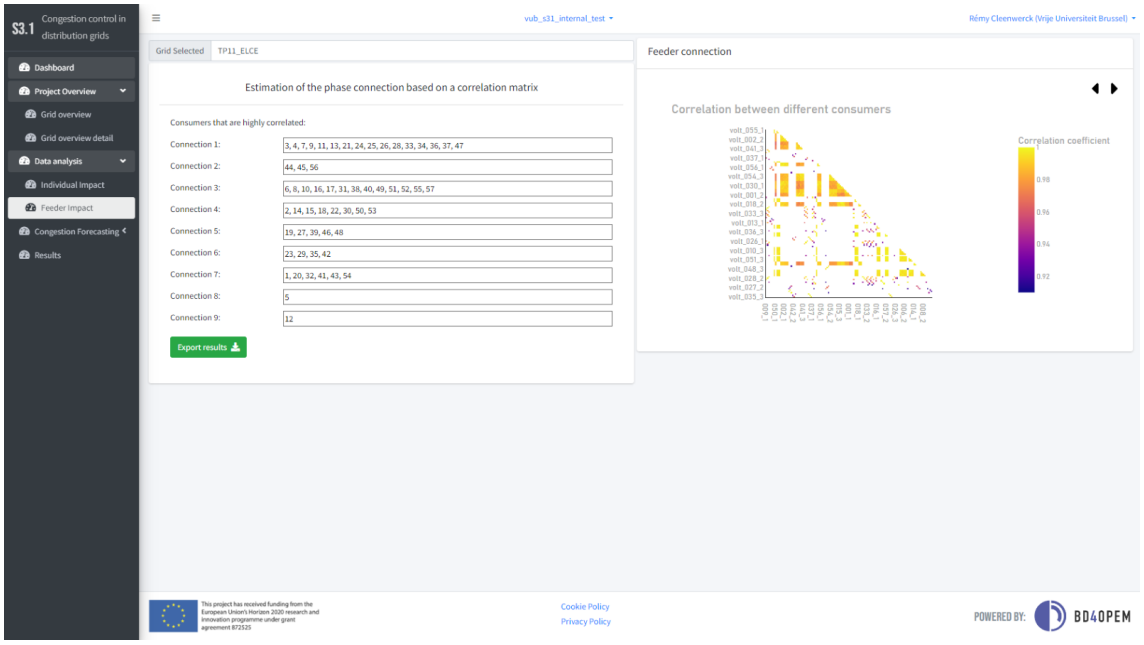


Figure 44. Feeder impact of consumers

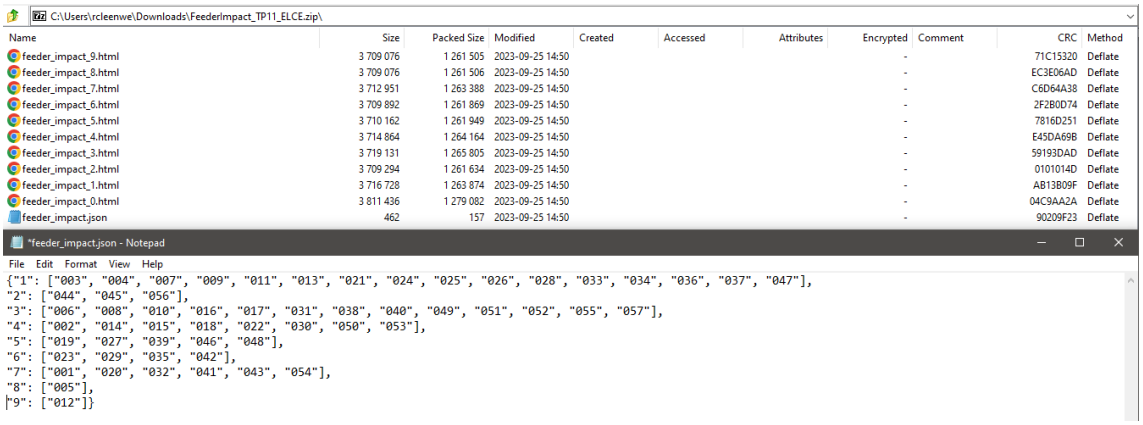


Figure 45. Exported files

Use Case 2

Grid analysts and operators need to run power flows in order to evaluate the feasibility of expanding the low-voltage networks or to integrate renewable energy sources, electric vehicles and heat pumps. In order to facilitate this aspect, the UI provides a rapid indication of the amount of voltage violations that can be expected on the studied network, Figure 46.

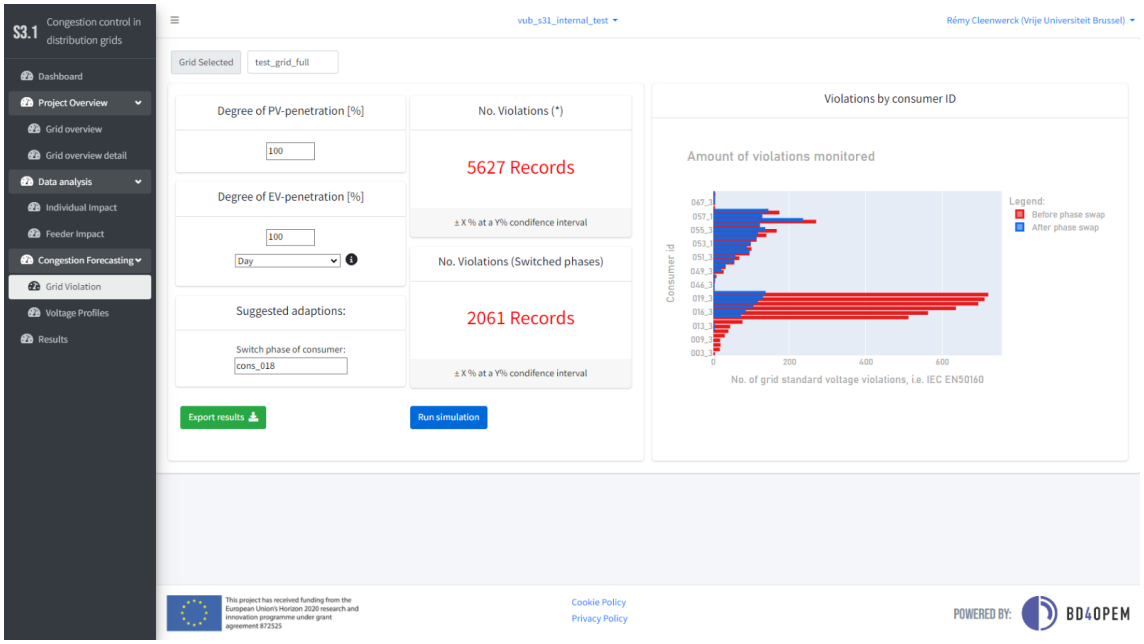


Figure 46. Voltage violation estimation

The UI allows the grid operator to select the scenario of interest, e.g. 50% PV penetration and 0% EV penetration etc. A visual representation of the number of violations is given on the right side of the UI, here the impacted IDs are represented with the no. of violations before a phase swap (red) and the remaining violations after introducing a phase rebalancing (blue). The right side of the UI shows the no. of violations recorded during the giving timeframe of the dataset, and the case if a phase swap would be introduced.

NOTE appending the stochastic consumption and/or generation profiles on top of the historical data provides valuable insights to the grid planner. However, it remains an

estimation and for real cases will highly depend on the EV charging and the weather data.
The 'export results' function provides all the required information from the UI, such as the 'violations_start', 'violations_after', 'swap_id', 'neighbour', 'start_phase' and target_phase' within a json file.

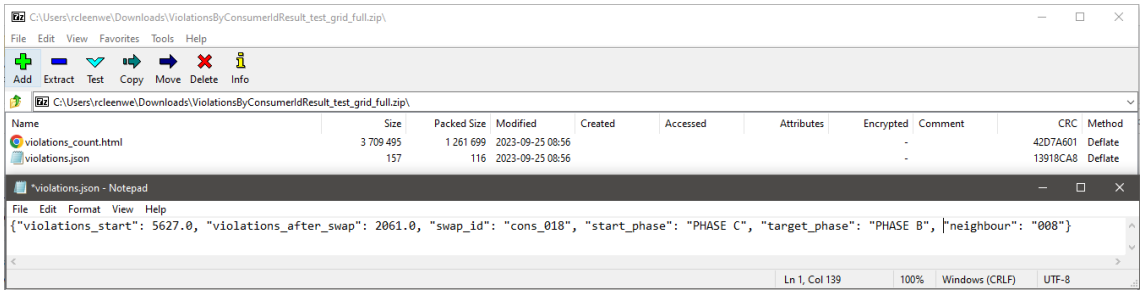


Figure 47. Export voltage violations results

Use Case 3

Finally, the last use case is interesting for grid planners as they may wish to get a better understanding of how the voltage profiles of the consumers within their network evolves for different scenarios, especially for the integration of electric vehicles and PV-systems. To help the grid operator in this task, the UI allows to select a specific ID and analyse the network's bottlenecks, Figure 48.

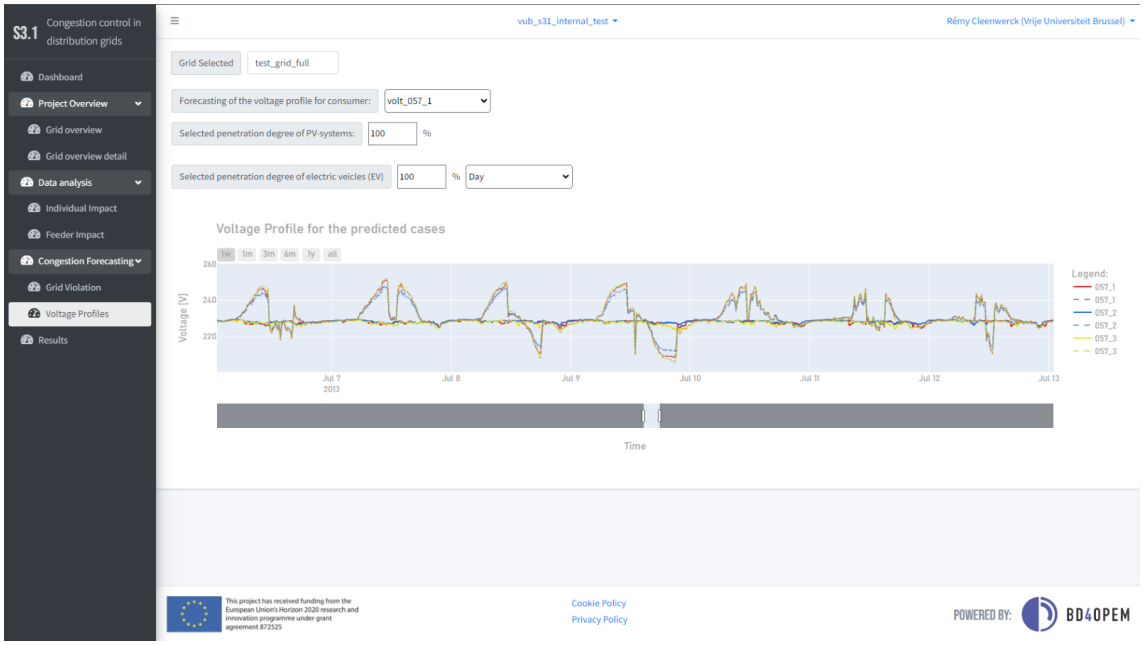


Figure 48. Voltage profiles for a specific scenario

Here, the planner can distinct the predicted voltage (dashed line) with the actual historical voltage (solid line).
To conclude the 'Results' tab summarizes the grid congestion reduction and provides an 'Export all results' button that downloads the previous .html and .json documents.

Data assessment

The table below shows the data assessment for the S3.1 service – VUB approach.

Table 13. Data Assessment for the S3.1 service – VUB approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
AMI : Historical data: Voltage, Current, Active Power consumed and injected, Reactive Power consumed and Injected and Power Factor	Smart_Meter	Good	High

Service conclusions

Feedback provided during the testing of the service highlighted the effectiveness of the service and the degree to which the results are useful for DSOs. The outcome of the congestion forecasting helps grid operator to plan, and also assess the feasibility of incorporating new assets such as electric vehicles or PV systems. Nevertheless, as generic PV profiles and EV profiles are utilised in the service, this limits the accuracy of the studied case. Furthermore, the integration of these assets is associated to a complete distribution of these assets at each household with a certain scaling factor. While DSOs might be more interested in specific cases where they can select the amount of EV and or PV a specific household ID.

During the testing of the service some interesting feedback was provided for which DSOs and other service users could benefit from:

- The UI is a very useful for DSOs, a suggestion to optimize and broaden its usability is to add heat pumps as another asset to simulate. This is currently a challenge within the Slovenian networks as during the winter the temperatures can drop far below zero and during the summer the heat pumps are used for cooling.

S3.2 - Impact study PV, EV & new loads results

Introduction of the service

Name: Impact Study PV, EV and new loads
Category: Planning
Task: T4.1
Location on the grid: LV

This service allows to estimate the capacity of a network to accommodate new solar panels (PV), EVs, or consumers, regarding the limitations of the network (voltage excursions or overload). The second functionality of this service is to evaluate the impact of a new installation (PV, EV, or new load) by estimating the residual capacity after this installation.

Table 14. Use cases for the S3.2 service

Use case	Description
UC1	**As a:** Planning operator of the DSO **I want to**: Know the already installed production at each smart meter **So that I can:** Plan better the reinforcements in the medium voltage grid and have a simpler communication inside and outside of my structure **Acceptance criteria:** When I query a smart meter, I get the installed production instantly in kWp
UC2	**As a:** Planning operator of the DSO **I want to**: Know the production / additional load capacity of all my smart meters **So that I can:** Accept a production / additional load insertion request with a given nominal value that does not exceed the maximal available capacity **Acceptance criteria:** When I query a smart meter, I get the maximal value of PV installable instantly in kWp
UC3	**As a:** Planning operator of the DSO **I want to**: Visualise the production / additional load capacity of a smart meter with respect to the phase **So that I can:** Provide the optimal phase for production / additional load insertion on each smart meter **Acceptance criteria:** When I run a new production / charge simulation with my requirements, the optimal phase is given as a result
UC4	**As a:** Planning operator of the DSO **I want to**: Simulate the installation of a new production / additional load **So that I can:** See how the new installation influences the rest of the grid **Acceptance criteria:** I can add a new production / additional load in simulation and see the residual capacity per meter. I can also

	add a smart meter to the waiting list, it will be considered in all subsequent simulations.

In Table 14 are reminded the user story as designed and developed in the framework of the WP4 and reported in D4.2.

To better explain the workflow to the user in the case of a PV installation, the following Figure 49 links all use cases together.

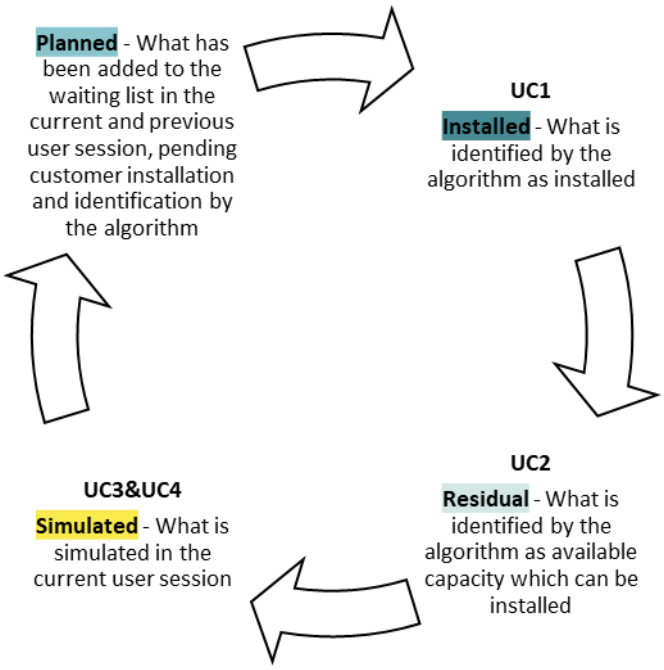


Figure 49. Impact study workflow

According to the demonstration site specificities, PV use cases have been adapted and deployed with the following results.

Demonstration site specificity and service deployment perimeter

In the case of ELCE's demonstration site, the perimeter of deployment of the service S3.2 has been the 14 secondary substations for which there were AMI data gathering Active Energy, Reactive Energy, voltage and current from all smart meters, similar data from summation meter at substation level and GIS information.

Because there are 14 secondary substations, the user interface adaptability for scaling the service is tested. The top left map (0) in Figure 50 gather all the secondary substations analyzed and enable to navigate from one to another from the map or from its search bar.

For confidentiality purposes, all coordinates have been modified (here appearing in the mediterranean sea).

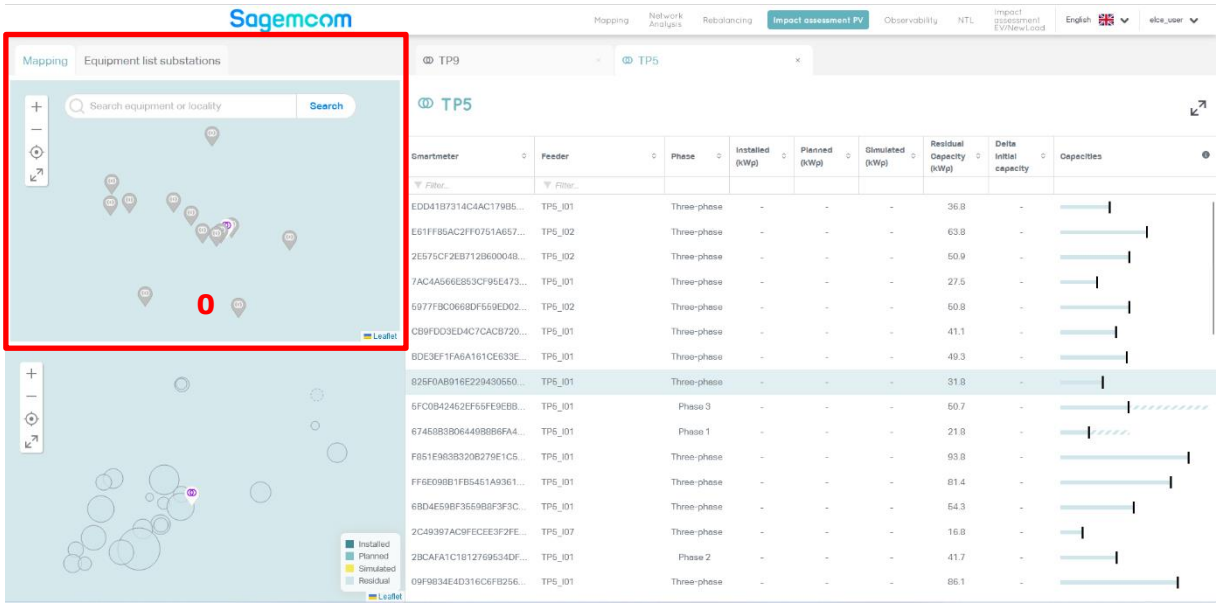


Figure 50. Navigation through the demonstration site (map)

In case a table which can be sorted is more appropriate to identify the right transformer, a dedicated tab (0bis) next to "Mapping" enables to do so, see Figure 51.

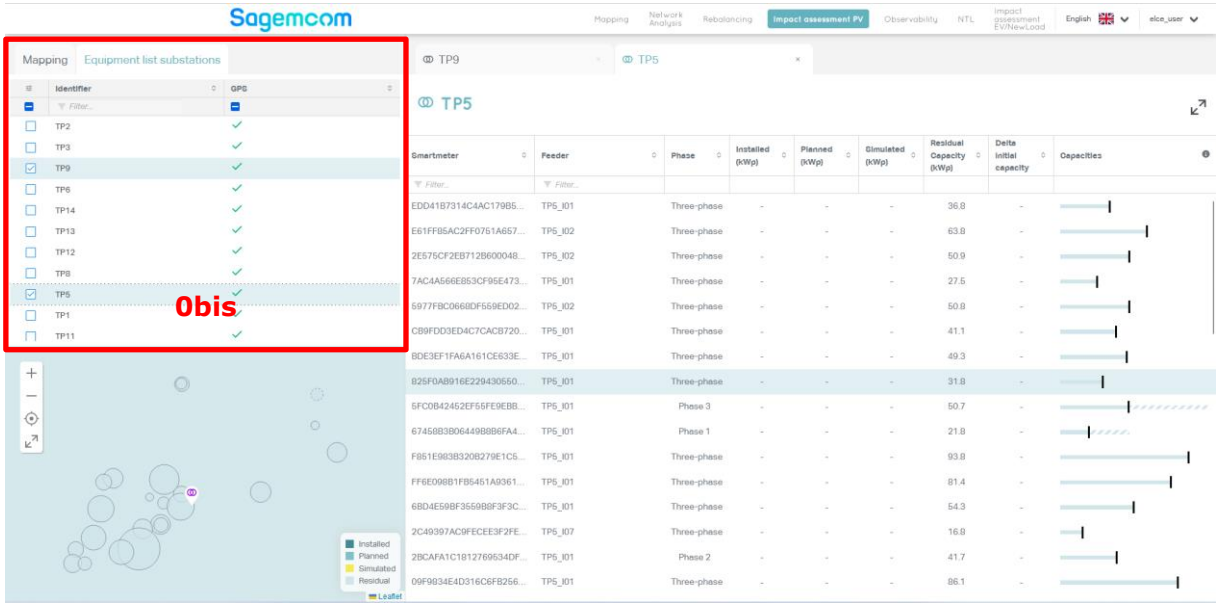


Figure 51. Navigation through the demonstration site (table)

Use Case 1

No PV installation was detected from the demonstration site data, therefore the user interface does not report any. If there was installation, the "Installed" column (1) and the "Capacities" column (2) would display such capacity accordingly, in **dark green** in Figure 52. As smart meters coordinates were available, a circle of the same color which size would have been proportional to the installed capacity would be displayed on the focus map in the bottom left map (3).

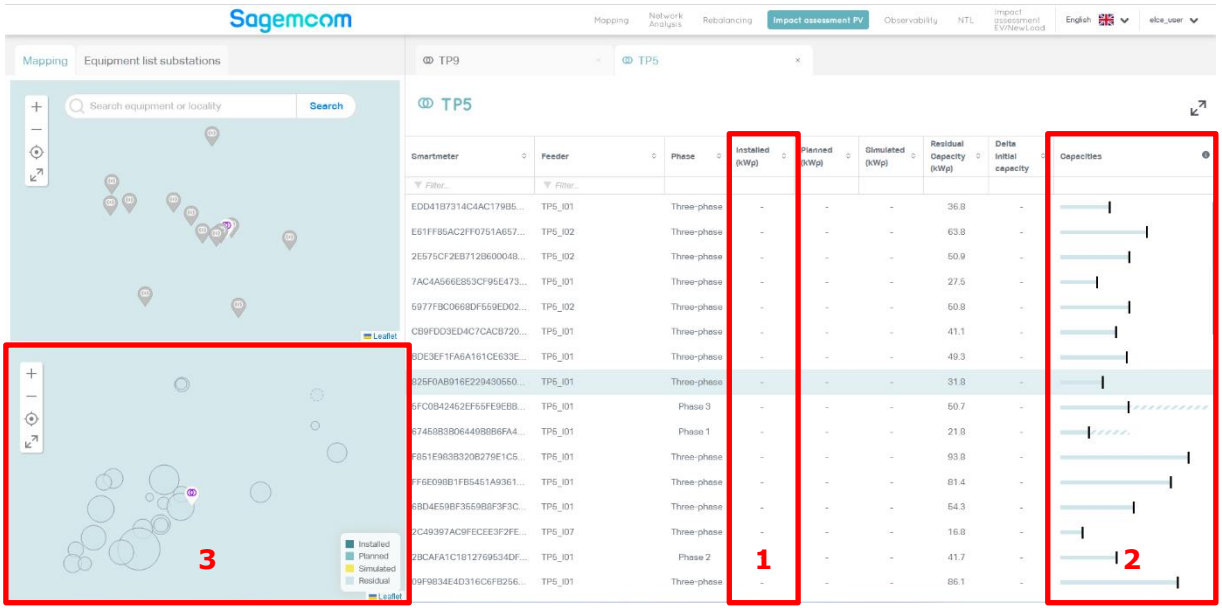


Figure 52. Installed capacity in TP5

Thanks to this information, the operator is aware of the current production level of a part of the grid, while other databases regarding PV installations might reflect an outdated picture (installation decommissioned without noticing the DSO), not yet valid (installation validated by the DSO but not yet commissioned) or not behaving as expected (underperforming assets compared to kWp installed due to low maintenance, shadows…). This detection, based on production data provides an accurate kWp equivalent of the installations.

Use Case 2

Upon customer's request, the operator can navigate to the associated transformer through map (0) or list (0bis) and get access to the residual production capacity of the customer's smart meter. Such capacity is available in the "Residual Capacity" column (4) and can be visualized together with the installed capacity in column (2) in **light blue**, see Figure 53.

Having the smart meters coordinates available, a **light blue** circle which size is proportional to the residual capacity is displayed on the focus map in the bottom left map (3).

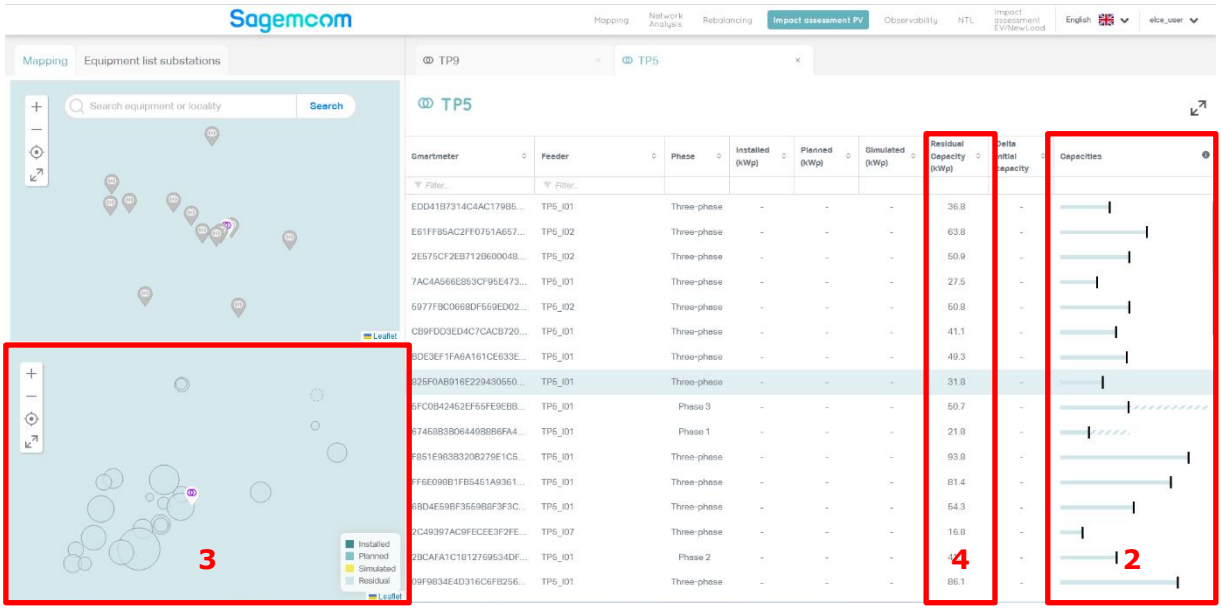


Figure 53. Residual capacity in TP5

The optimization model computes the simulation taking into account two different constraints:

- The addition of an installation which power is equivalent to the residual capacity must not trigger additional voltage excursions.
- The addition of an installation which power is equivalent to the residual capacity must not make the transformer go beyond its nominal capacity.

Use Case 3 and 4

By clicking on one of the smart meter in the table (5) see Figure 54, a modal window opens, see Figure 55.

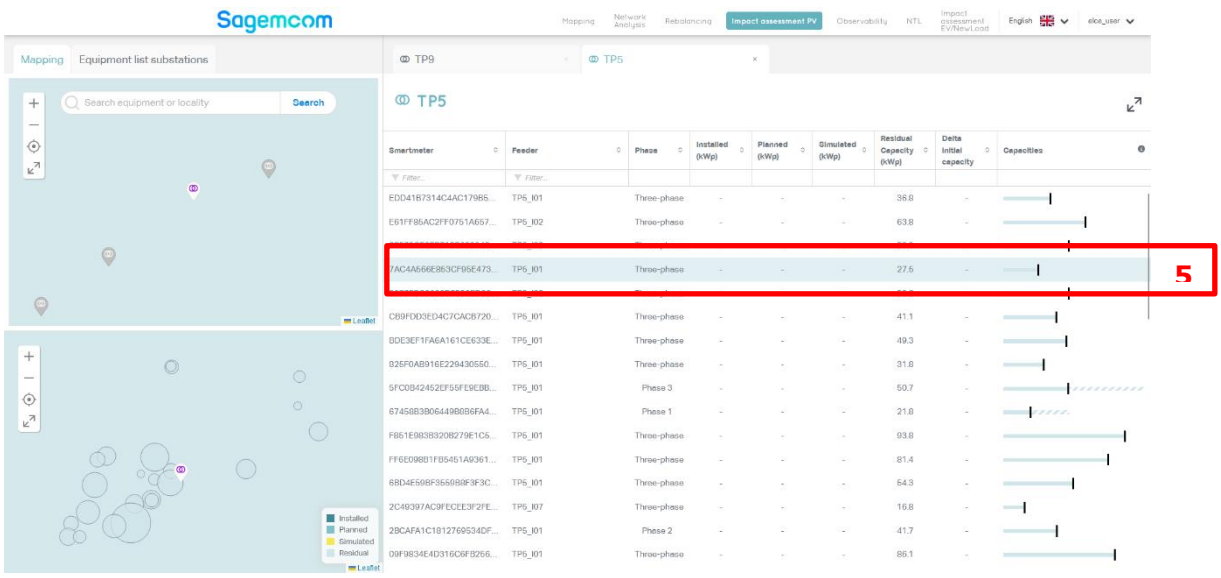


Figure 54. Access to modal window to launch the simulation in TP5

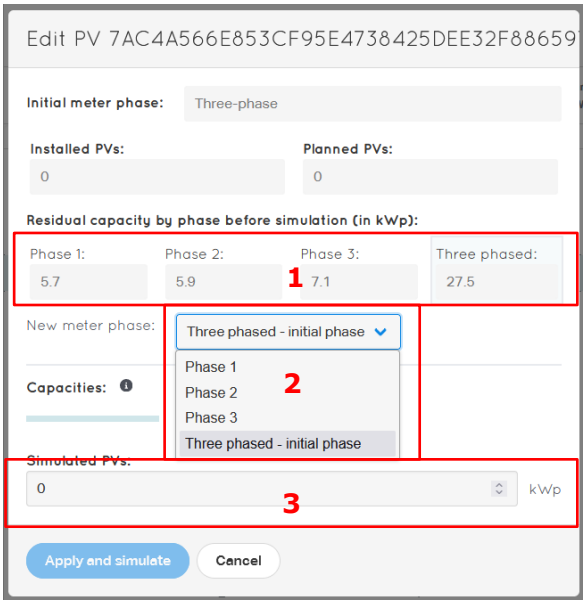


Figure 55. Modal window for phase selection and kWp configuration in TR8101

This modal embeds all the different configurations possible to simulate a new installation. The service analyses the LV network under a 3-phase paradigm and not following the classical single-phase approximation for LV studies. This enables to unlock additional capacity by considering not only the available capacity of the phase on which the smart meter is connected to but also the one of other phases at the same point in the network or the one considering a three-phase installation.

From a user perspective, all capacities are displayed in the cells in (1), by default the current smart meter configuration is selected but if the user would like to perform a change, a drop-down menu (2) enables to change the phase or type of installation.

Once this is done, the user can enter the requested capacity (as long as it is below the computed residual capacity) and click on "Apply and simulate".

When the computation is done the "Simulated" column is updated with the new installation configured by the user. In case a change in the phase has been performed, the user interface indicates so by displaying an exclamation mark next to it ( ). In the "Capacities" column, the installation can be visualized together with the installed capacity and the residual capacity in **yellow**, see Figure 56. Similarly to other capacities, a **yellow** circle which size is proportional to the simulated capacity is displayed on the focus map in the bottom left map (3).

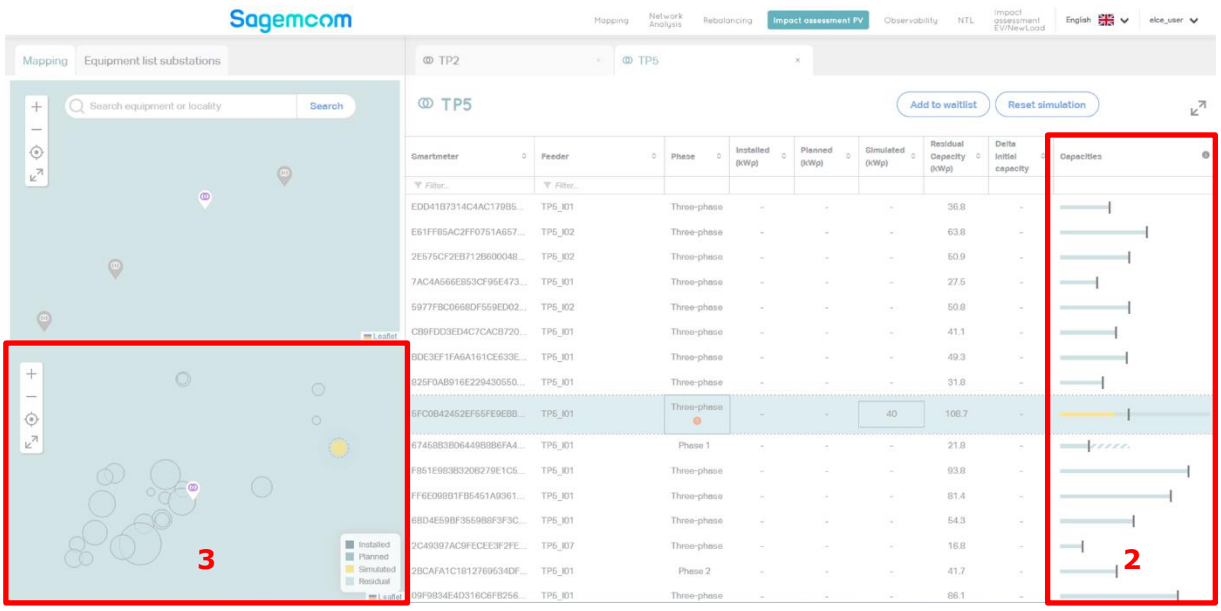


Figure 56. Simulated capacity in TP5

The residual capacity of all other smart meters and the delta compared to the previous situation are updated in the relevant columns.

If the user is satisfied with the simulation results, the button "Add to waitlist" enables saving the information. The simulated installation changes status to "Planned", updating the columns and switching the capacity from **yellow** to **medium blue**. This planned installation will be taken into account for future simulation and transferred to "Installed" status when the algorithm will identify it.

Regarding EV and new load, a dedicated tab, see (1) in Figure 58, following the same approach has been developed and deployed. However, the workflow is slightly changed because "EV and new loads" are not predictable electrical loads, compared to PV and therefore the "Installation assessment" in UC1 is not relevant, see updated Figure 57.

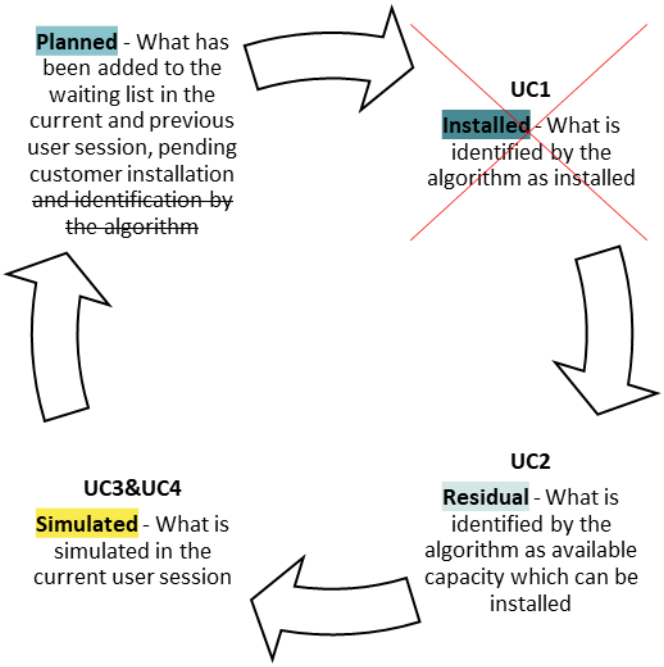


Figure 57. Workflow for EV and new loads impact assessment

The residual capacity is considered in the worst-case scenario: upon simulating a given additional load at a delivery point, the model runs the simulation with this point having a constant additional power equal to such load. Both constraints for PV remain the same:

- To do not trigger additional voltage excursions.
- To do not make the transformer go beyond its nominal capacity.

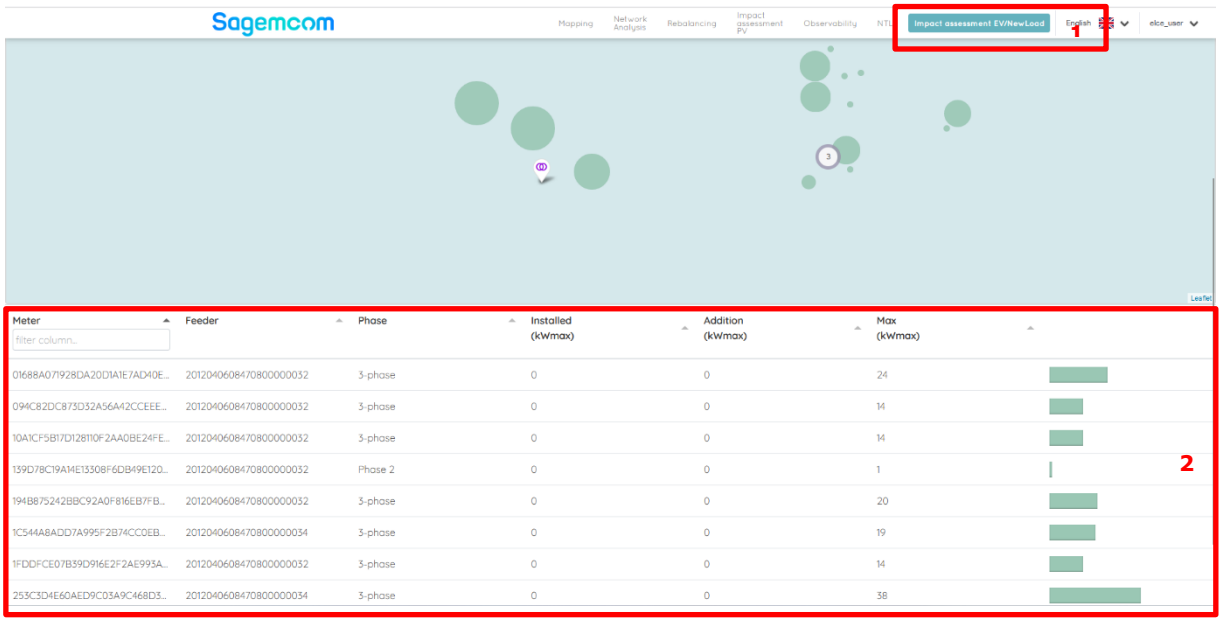


Figure 58. EV/New load tab for TP03

A similar table, see (2) in Figure 58, provides the different capacities across the workflow. Upon clicking on a smart meter line, a modal window opens and enables to simulate the addition of an EV charging infrastructure, see Figure 59.

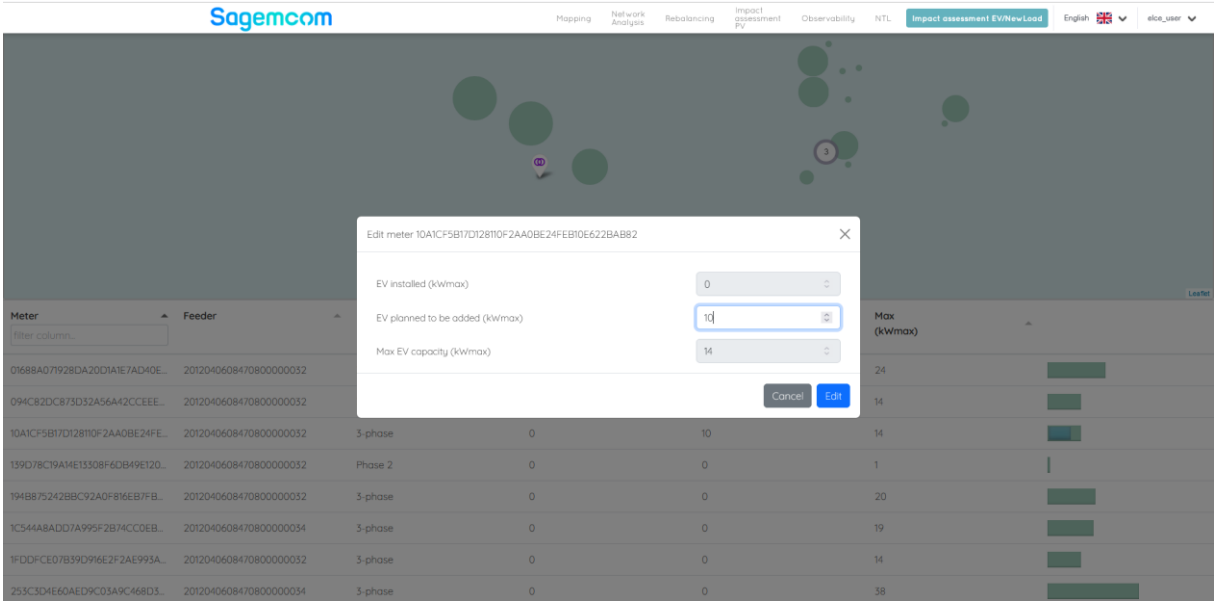


Figure 59. EV addition modal window in TP03

Such addition can be computed in the model and then saved for later user sessions.

Data assessment

The table below shows the data assessment for the S3.2 service.

Table 15. Data assessment for the S3.2 service

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
For each SM: Voltage profiles per phase	Smart_Meter	Good	High impact
For each SM: Active power profiles per phase	Smart_Meter	Low: only one load curve for three phase meters, no load curve per phase. Specific preprocessing was necessary to split the load and run the algorithm	High impact
Reactive power profile per phase (optional)	Smart_Meter	Good	Low impact
Geographical coordinates of	Location	Good and shifted for confidentiality purpose	Low impact on algorithm performance

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
meters (optional)			Improved quality of the user experience
Substation power and voltage profiles (optional)	Secondary_Substation	Good	Low impact
Weather irradiance time series (optional)	Weather data	Not available	Low impact

Service conclusions

The deployment and testing of S3.2 Impact Study PV, EV and new loads in the ELCE demonstration site offers a proof of concept that showcases its viability for broader demonstration site with the case here of 14 secondary substation. The integration of geographical coordinates improved a lot the user experience compared to other demonstration site where it was not available. It enables a more intuitive and navigable user interface, enhancing the accessibility and clarity of the results. This appears as a key aspect in the designed service.

The project enabled to thoroughly test the service across different demonstration site. Future work should focus on three key aspects highlighted by the project's experience: validation, computation time and additional features.

First, a cross validation of results with on-site installation and before-after evaluation of capacities would be interesting to bring additional trust to the results.

Second, the latest version of the model has long computation time which jeopardize the user experience. This is especially true in this demonstration site as the depth of the dataset is important. Improving it is necessary to provide a more efficient and responsive service, with higher scalability.

Finally, EVs and new load tab is not as advanced as the PV tab. This is because EVs do not benefit of the same predictability and regulatory maturity as PV does, especially when it comes to flexible behavior which are still under design in most markets. This service is a significant milestone into ODT's journey to address EV's related planning issues but further market research and need assessment are required. As the industry evolves, aligning the service with the growing demands and complexity of integrating new technologies such as EVs will be essential for its exploitation.

S4.1 – Inconsistencies in energy balance and power-voltage results

Introduction of the service

Name: Inconsistencies in energy balance and power voltage
Category: Fraud detections
Task: T4.1
Location on the grid: LV

This service gives the insight to locate non measured energy in low voltage networks. It will identify substations with missing energy (performing an energy balance), smart meters with nearby missing power probability, and smart meters with a significant bypass probability.

Table 16. Use cases for the S4.1 service

Use case	Description
UC1	**As a:** Grid operator **I want to**: Quantify non-technical losses at substation level **So that I can:** Investigate more deeply on substations with significant non-technical losses **Acceptance criteria:** A statistical analysis of the energy balance between metering data and substation data is displayed (boxplots, time duration curves)
UC2	**As a:** Grid operator **I want to**: Locate meters that are likely to be bypassed **So that I can:** Send a team on the field, at the right location, to verify the meter **Acceptance criteria:** A list of the meters with their probability of being bypassed is displayed Meters are displayed on a map with a radius proportional to their probability of being bypassed
UC3	**As a:** Grid operator **I want to**: Locate meters that are likely to have NTL nearby **So that I can:** Send a team on the field, at the right location, to verify the meters **Acceptance criteria:** A list of the meters with their probability of having NTL nearby Meters are displayed on a map with a radius proportional to their probability of having NTL nearby

Service results

The service objective is to address the DSO's need to locate the missing energy and identify the probable bypassed smart meters on its LV grid. For this purpose, the service S4.1 has been deployed on ELCE demonstration site.

When selecting the TP10 in the "NTL" (Non-Technical Losses) tab, the web app displays the following screen:

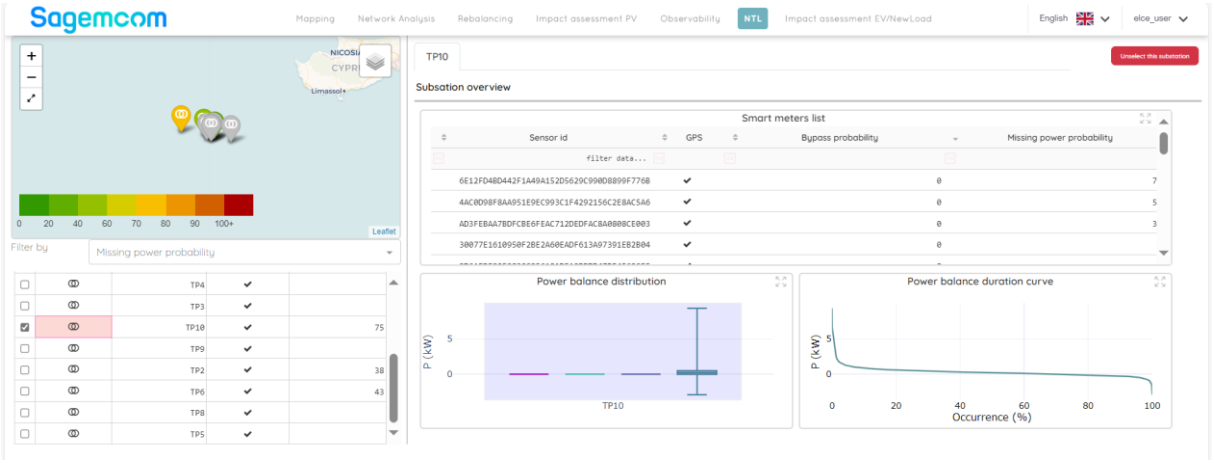


Figure 60. NTL tab when the TP10 is selected for ELCE demonstration site

On the top left side of the screen is displayed the mapping of the LV grid. The substations can be ordered by:

- Bypass probability
- Missing power probability
- Average power balance estimation

In the case of the Figure 61, the metric selected was "Missing power probability".

Then, it is possible to go into more detail with each of the three widgets proposed in the web application.

Smart meters list

Sensor id	GPS	Bypass probability	Missing power probability
filter data...			
6E12FD4BD442F1A49A152D5629C990D8899F776B	✔	0	75
4AC0D98F8AA951E9EC993C1F4292156C2E8AC5A6	✔	0	52
AD3FEBAA7BDFCBE6FEAC712DEDFAC8A0808CE003	✔	0	30
30077E1610950F2BE2A60EADF613A97391EB2B04	✔	0	1
2D6AFBF9059830C956101DFA2BBDD47BE4F69CF5	✔	0	1
E0CEC4C8FDBB7166233FAFB1D915A5242DB82202	✔	0	0
7ECE9EE5752E656E9ED52A195484E986DCBDE981	✔	0	0
E6D7F61F07F6DC2C355FFE07F85668C011D7D2FA	✔	0	0
F0CCD8929C92FFC75F5FC7A5269496027CECBCAA	✔	0	0
6CAB4D8315DA115F5DCD4C2800E5ED2EE61ADC6B	✔	0	0
3689602A84DFEC2D896F2D93D0086305A0029C33	✔	0	0
92285ED30271BE3C1F0F912C29CC6F0DFE259DAB	✔	0	0
B6A87177344A7C625580F9C6A299C7389FBCE3C7	✔	0	0
6EE38094FD4B701D522DE11855C192A38C826546	✔	0	0
B9B4F4C7BAF7AB4008CD4C4B6CFC0DFED2AF3C24	✔	0	0

Figure 61. Smart meters list for TP10 in the NTL tab

This shows the bypass probability and the missing power probability for each meter of the selected substation (here, TP10). In this case, the bypass probability is at 0% for each meter. However, missing power probability is greater than 0% for 5 smart meters on this substation, and above 30% for three of them.

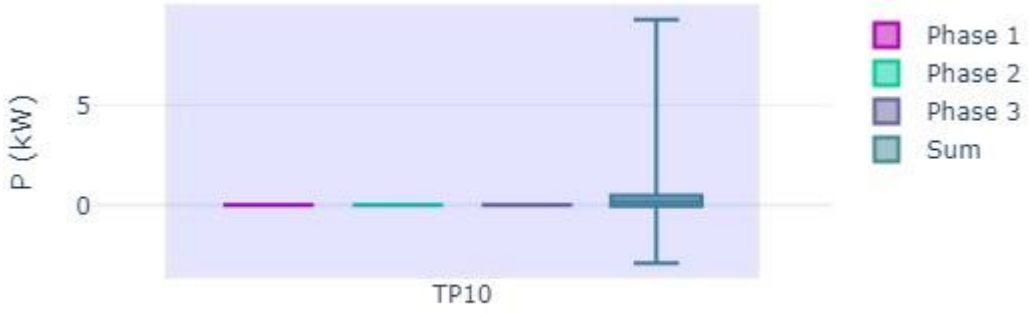


Figure 62. Boxplot of power balance distribution

The next widget shown on Figure 62 shows the distribution of power balance (total power measured at substation level minus total power measured at smart meters level). This graph is in this case incomplete because the data collected on this demonstration site is aggregated for the active powers of the smart meters (see data assessment hereafter). The DSO can still see the summed power balance. In this case, the power balance exceeds often 5 kW. It is also notable that the power balance is sometimes negative, which indicates that it is possible that some production is not measured.

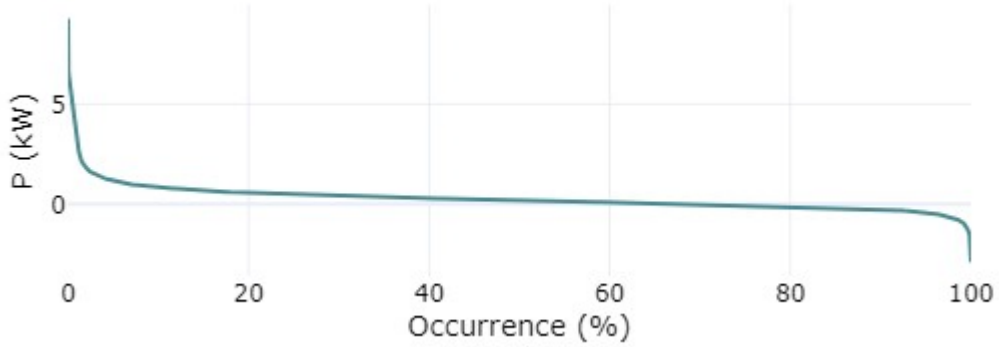


Figure 63. Power balance duration curve for TP10

This final widget available in the NTL tab show the same information as Figure 63 but in terms of occurrence. It shows that the power balance is above 2 kW around 1.5% of the time and lower than 0 kW around 30% of the time.

Data assessment

The table below shows the data assessment for the S4.1 service.

Table 17. Data assessment for S4.1 service

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
For each SM: Voltage profiles per phase	Smart_Meter	Good quality	High impact
For each SM: Active power profiles per phase	Smart_Meter	Medium quality: good density of data, with average data, but summed power.	High impact
Substation power profiles	Secondary_Substation	Medium quality: good density of data, with average data, but summed power.	High impact
Reactive power profile per phase (optional)	Smart_Meter	Medium quality: good density of data, with average data, but summed power.	Low impact
Geographical coordinates of meters (optional)	Location	Good quality (but anonymous)	Low impact
GIS information (optional)	Grid_Assets	Good quality	High impact on topology, so high impact on S4.1
Substation voltage profile (optional)	Secondary_Substation	Good quality	Low impact

Service conclusions

As a conclusion, the service S4.1 Inconsistencies in energy balance and power voltage has been successfully deployed in the Slovenian demonstration site. The service could be improved by having power per phase instead of summed powers for the smart meters, as it would enable the display of the energy balance per phase. The data collected by ELCE and integrated by ODT was overall of pretty high quality, which allowed a good deployment of the service on the Slovenian demonstration site.

To recap the results on the scope of the demonstration site, this service enabled to identify five smart meters with greater than 0 probability of having missing energy, and three smart meters with 30% or more probability of having missing energy.

S4.2 – Fraud patterns detection results

UPC approach: Fraud patterns detection

Introduction of the service
Name: Fraud Patterns Detection
Category: Fraud Detection
Task: T4.1
Location on the grid: LV Smart Grid

This service detects, classifies and identifies fraud based on the Non-Technical Losses (NTL) curve pattern by applying machine learning algorithms for clustering and classification. The output contains valuable information for the DSO, such as the magnitude, the duration and the type of fraud. The system also flags possible culprits and includes a graphic of each NTL case detected. The recent results are presented in one tab, while the historical frauds are displayed separately. The user can verify or deny each instance after a field inspection to calculate the accuracy and improve the service.

Table 18. Use cases for the S4.2 service

Use case	Description
UC1	**As a**: DSO **I want to:** Have practical information about the frauds in my grid **So that I can:** Carry out field inspections and calculate the corresponding fines without allocating many resources. **Acceptance criteria:** Identify current transformers with NTL, classify the fraud by type, find magnitude and duration of fraud and flag possible culprits, if any.
UC2	**As a:** DSO **I want to:** Have a quick and clear overview of the frauds in my grid **So that I can:** Calculate and assess losses, prepare reports and take decisions accordingly. **Acceptance criteria:** Summarize total number of frauds, recovered power and show a distribution of frauds by type.

Use Case 1

The service runs periodically, displaying the latest results in the Recent Results tab of the Visualization section, as shown in Figure 64. This screen shows a table with various information about the detected frauds. Among this information, we find the magnitude of the NTL in kW, obtained with statistical methods, and the duration in days, allowing the operator to calculate the corresponding fine. It also shows the type of fraud and the probability of it being correct, obtained by probabilistic classification algorithms. Finally, in some cases of fraud due to squatting, smart meters with anomalous patterns are indicated, with a probability that they are committing fraud. This flagging is done using clustering algorithms to detect abrupt pattern changes. With all this information, the DSO can optimize field inspections and alert the police if necessary.
These same results can be downloaded in Excel and CSV format so the user can manipulate them at will. Figure 65 shows the table of recent results in Excel format.
When the NTL detection system is executed again, the frauds that were previously in "Recent Results" are moved to the table in the "Historical" tab. As shown in Figure 66, this table contains the same elements as the recent results table, with the addition of the date of detection. Both tabs allow the user to sort the frauds by probability, type, magnitude or duration and filter them. Figure 66 displays the historic frauds sorted by magnitude (descending).

Finally, the service allows the user to explore the load curve pattern of the detected fraud by clicking on "View Graph". Figure 67 shows the graph of one of the frauds due to squatting in the Elektro Celje network.

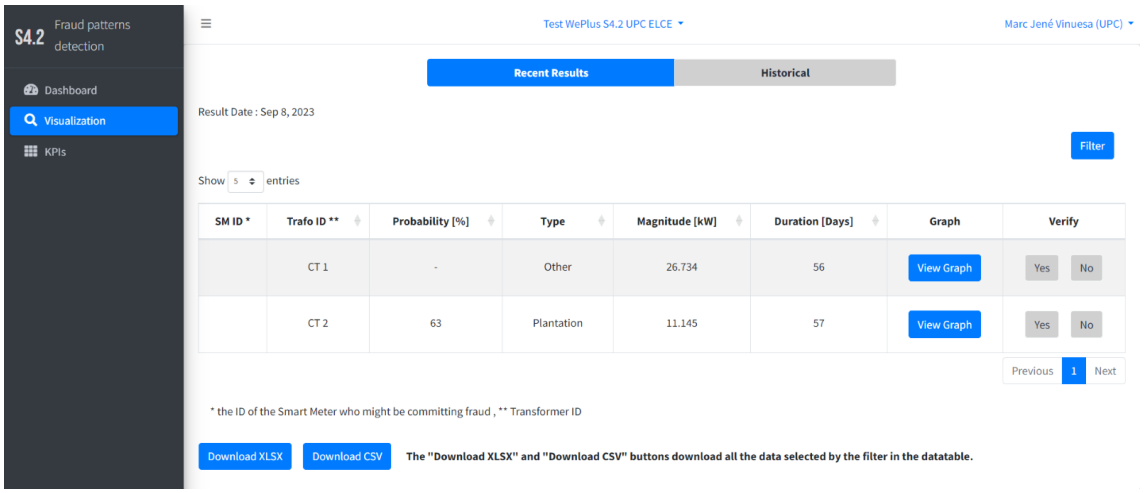


Figure 64. Recent Results

	A	B	C	D	E	F	G
1	SM ID	Trafo ID	Probability [%]	Type	Magnitude [kW]	Duration [dd]	Verified
2		CT 1	-	Other	26.734	56	null
3		CT 2	63	Plantation	11.145	57	null

Figure 65. Table of recent frauds in Excel form

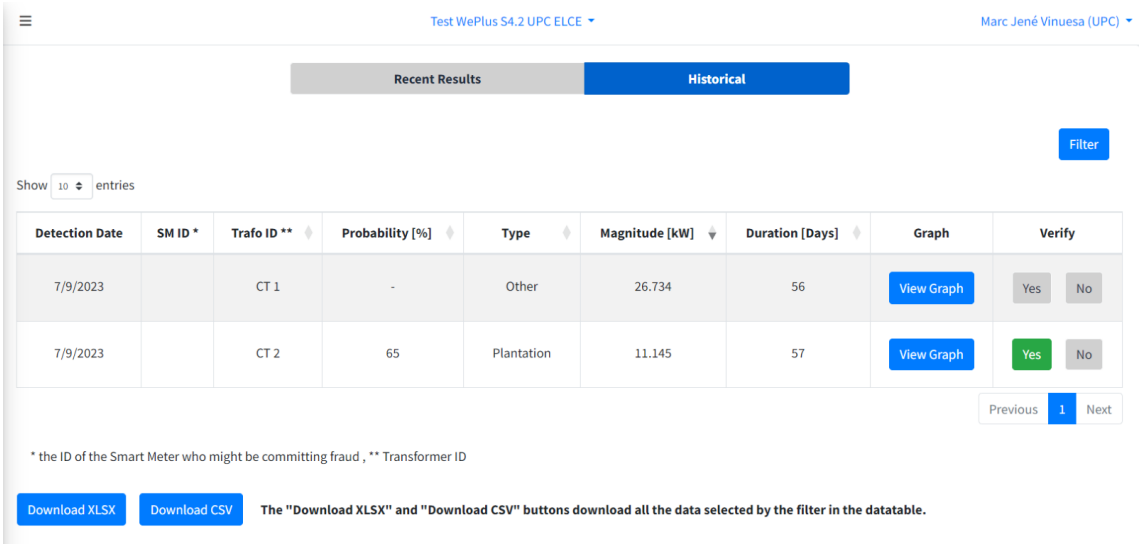


Figure 66. Historical frauds sorted by magnitude (descending)

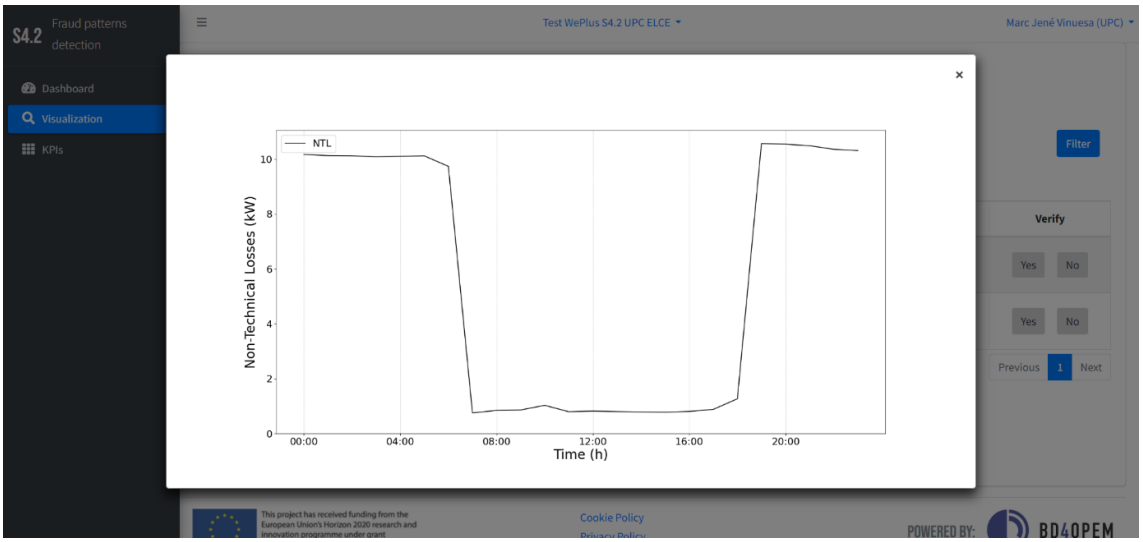


Figure 67. Load curve of fraud due to squatting

Use Case 2

Sometimes, the DSO may want a quick and clear view of fraud in his network for loss calculation, reporting and strategic decision-making. That is why the service offers a KPIs tab, as shown in Figure 68, with a summary of the detected frauds, the total power of these and a distribution according to typology. This same screen also shows the algorithm's accuracy, which considers the frauds verified and denied by the user. The user can download this summary of the results in PDF format.

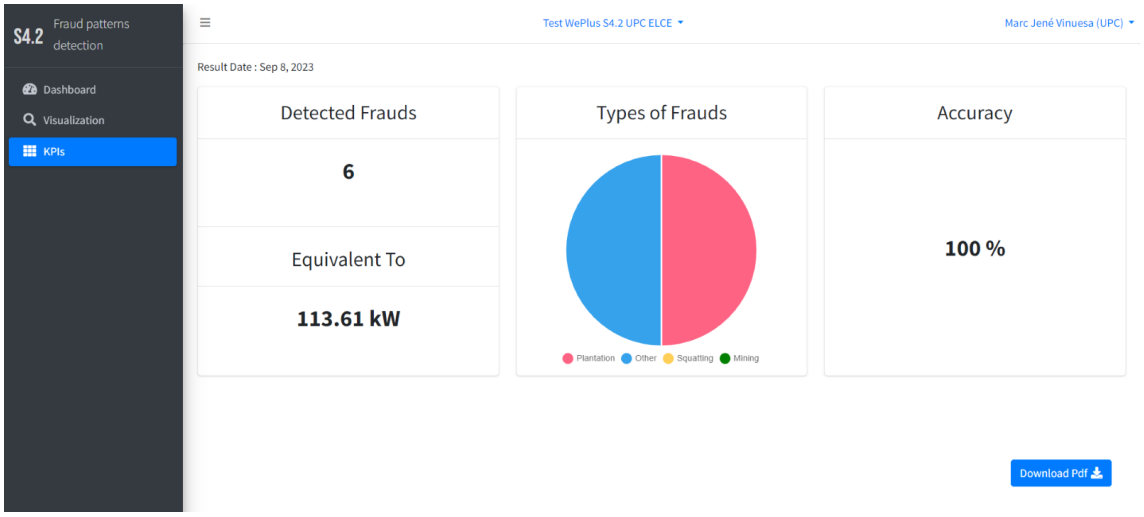


Figure 68. Service KPIs

Data assessment

The data assessment can be observed in Table 19.

Table 19. Data assessment for the service 4.2 – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
For each SM: Active power profile	activeEnergy	Ok.	None.
Substation power profile	activeEnergy	Ok.	None.
Historical frauds detected with a classification label	Historic_Fraud	Only two plantation-type fraud datasets were used. It was possible to test the service thanks to a joint training dataset with the other pilots.	Very High. With two frauds of a single type, it is not possible to construct an algorithm that classifies fraud by type. A joint dataset was used to test the algorithm.

Service conclusions

During service testing, it has been proven to work and obtain valuable information for the user. In a distribution grid, frauds can differ in type, magnitude and duration, and knowing these characteristics can facilitate the DSOs' task of preparing field inspections.

The service performs well in classifying the type of fraud, although due to the lack of cases of cryptocurrency mining fraud and other types of fraud, the algorithm has not been tested with a large number of classes.
With Elektro Celje, it was found that, although the training dataset only had two of its historical frauds, with a joint dataset the algorithm also correctly classifies the type of fraud.

After testing the algorithm with Elektro Celje employees, they were asked to provide feedback, which was pretty positive.

In the future, we plan to incorporate the feedback given by the project pilots and improve the algorithm with the following points:

- Expand the training database with more and more diverse frauds.
- Calculate the technical losses using the network topology.
- Improve the formula for calculating the probability of the correct type.
- Make an algorithm with dynamic training that allows adding newly detected frauds to the training dataset.

JSI approach: Fraud patterns detection

Introduction of the service

The service results are presented in a document accessible through the service results web page as explained in the previous Section. The results table of content is presented in Figure 69. The report is split into 8 major sections. At first there are sections on service instance information and introduction into the report. The service instance section provides information when and on which data the service instance has been run. The introduction section explains the goals of the service and briefly introduces the results.

The last sections are related to a potential examination of the data directly in the report through in HTML based spreadsheet visualization libraries that enable the examinator to quickly check the profiles for potential evidence. The last section is the documentation of the methods and procedures used in the preparation of the report.

The rest of the sections with illustration of some of the results related to the Slovenian pilot will be discussed below.

BD4OPEM

Non Technical Losses report

Table of content

1. Table of content
2. Service instance information
3. Introduction
4. NTL data overview
   A. Data visualisation
   B. Loss visualisation
   C. NTL data summary
5. Study of the loss
   A. Loss summary
   B. Loss clustering
   C. Clustered loss time spans
6. Differences in consumption statistics at appearance of the loss
7. Sliding differences
   A. Sliding scores
8. Detection based on consumption prediction
9. Data insights
   A. Dataset technical info
   B. Dataset descriptive statistics
   C. Dataset access
      a. Daily averages
      b. Weekly averages
10. Report summary
11. Documentation
    A. Loss analysis
    B. Differences in consumption statistics
    C. Sliding differences and scores

Figure 69. S4.2 service report table of content for Slovenian pilot

NTL data overview

The next section is on NTL data overview where the substation data together with the loss in the observed time frame is presented as can be seen in Figure 70 The profiles are visualized in a way that they are quickly cross comparable over the entire period.

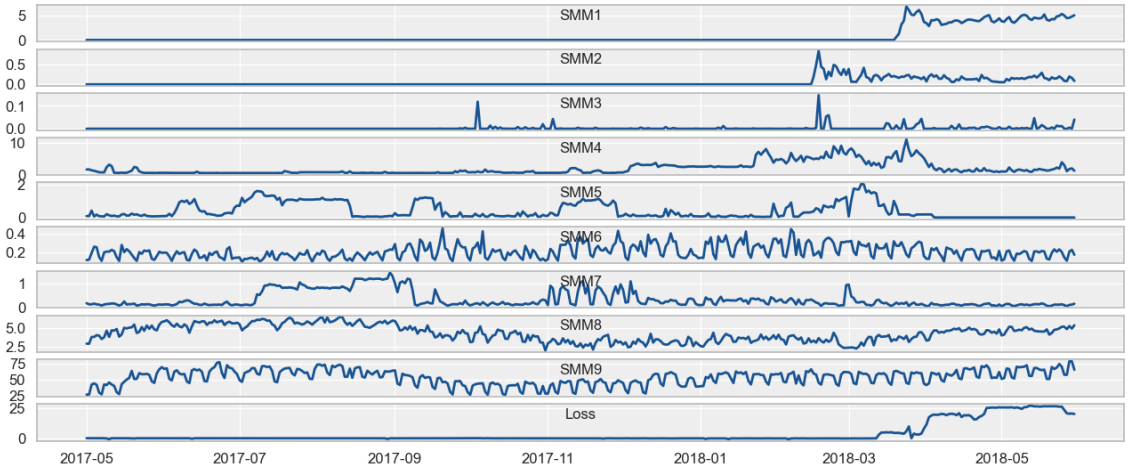


Figure 70. Profiles Slovenian pilot, with the loss

Study of the loss

The next section is concerned with a study of the loss. The days of the loss are clustered according to basic statistical variables, namely mean, max value, min value, standard deviation and peak-to-peak value. Values are calculated for each day and the clustered by K-Means clustering algorithm. Results of clustering is presented in Figure 71. The clustered day consumptions are plotted on original loss curve and colored per their cluster membership.

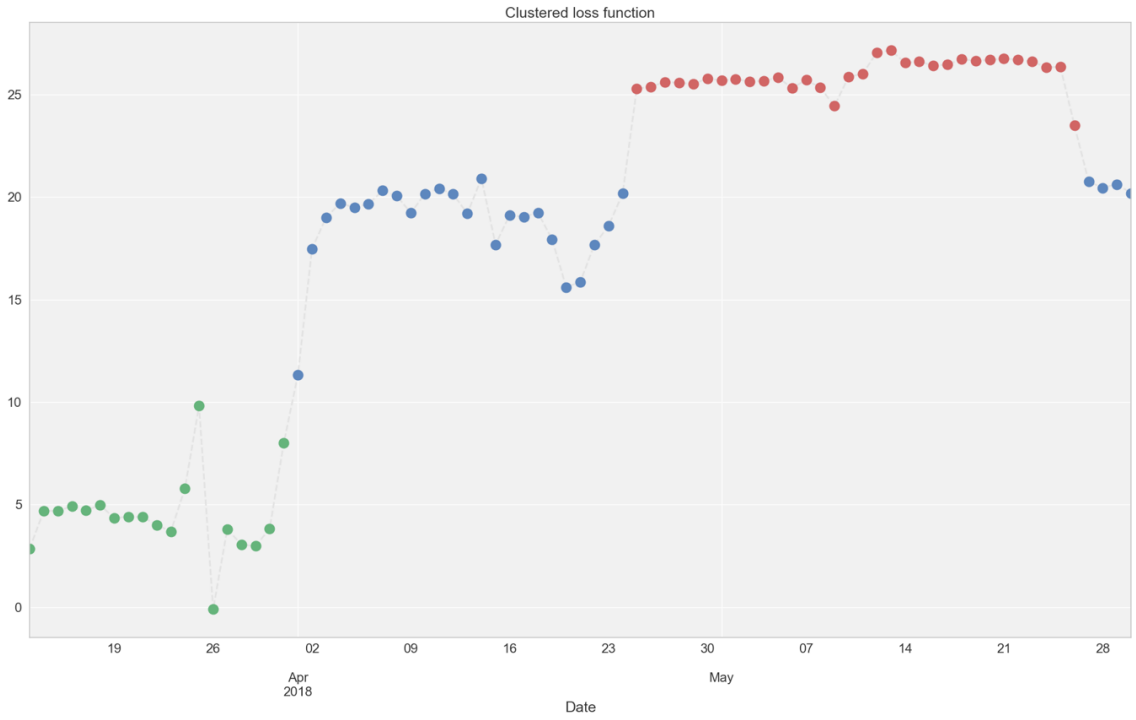


Figure 71. Study of the loss, Slovenian pilot

The method is useful in cases when the loss is related, for example, to detecting pot growing plantations. The clustered days of the loss are well related to the growing cycles of the plants, as can be seen in Figure 72. The clusters time spans in days are given in Table 20. The clusters time spans correspond to plantation cycles. The cycles result in different statistical variables and thus clustering to different clusters.

The method enables the investigator to understand what the loss consumption has been used to and narrow the investigation in the field for particular type of the loss.

Table 20. Loss clusters time span, Slovenian pilot

	Start	End	Span
1	2018-04-01	2018-03-13	19 days
2	2018-04-25	2018-04-01	24 days
3	2018-05-27	2018-04-25	32 days

Differences in consumption ststistics at appearance of the loss

To study the substation profiles further the profiles consumption statistics is compared as the statistic before the occurrence of the loss and the statistics after occurrence of the loss. The comparative combined statistics is calculated according the following equation:

$$combined = \frac{statistics\_before_{t<t_{loss}}}{0.01 + statistics\_after_{t>t_{loss}}}$$

The combined statistics is then calculated for all observed statistics, mean, standard deviation, maximal, minimal and peak-to-peak value. The profiles are clustered according to these values in three clusters and then plotted in mean/std plane as is seen in Figure 72. The method results in three clusters, where two profiles stand out and are grouped in separate clusters. The profiles are candidates for closer inspection and are suspectable as a culprit for the NTL loss.

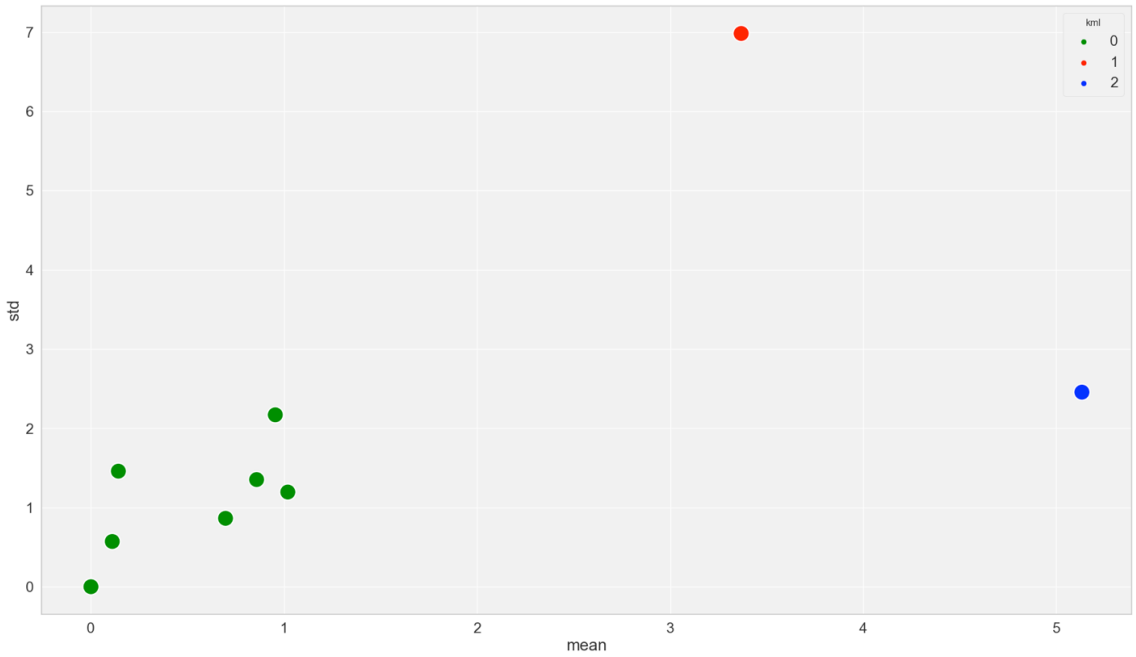


Figure 72. Clustered profiles regarding combined statistics comparing behavior of the profile before and after occurrence of the loss in Slovenian pilot

Sliding differences

A step further from the previous statistics are the sliding differences. The combined statistics as explained in the previous section is used on data split between one before the slider and the other after the slider. The slider is a virtual time on the time axis that shifts from left to right in on a week interval. Each dot on the individual graph presents the sliding difference between the consumption being observed so far and the consumption that will follow. All the dots values are calculated according to the formula given in the previous section. With the vertical lines the start of the loss is indicated. The investigator should be interested in the profiles which sliding statistics changes most at the time of occurrence of the loss.

In Figure 73 the sliding statistics for mean is presented. It can be seen that there is one profile with a peak of change close to the occurrence of the loss. The profile is a primary suspect for investigation in the NTL case.

The report provides sliding differences plot for each statistic separately.

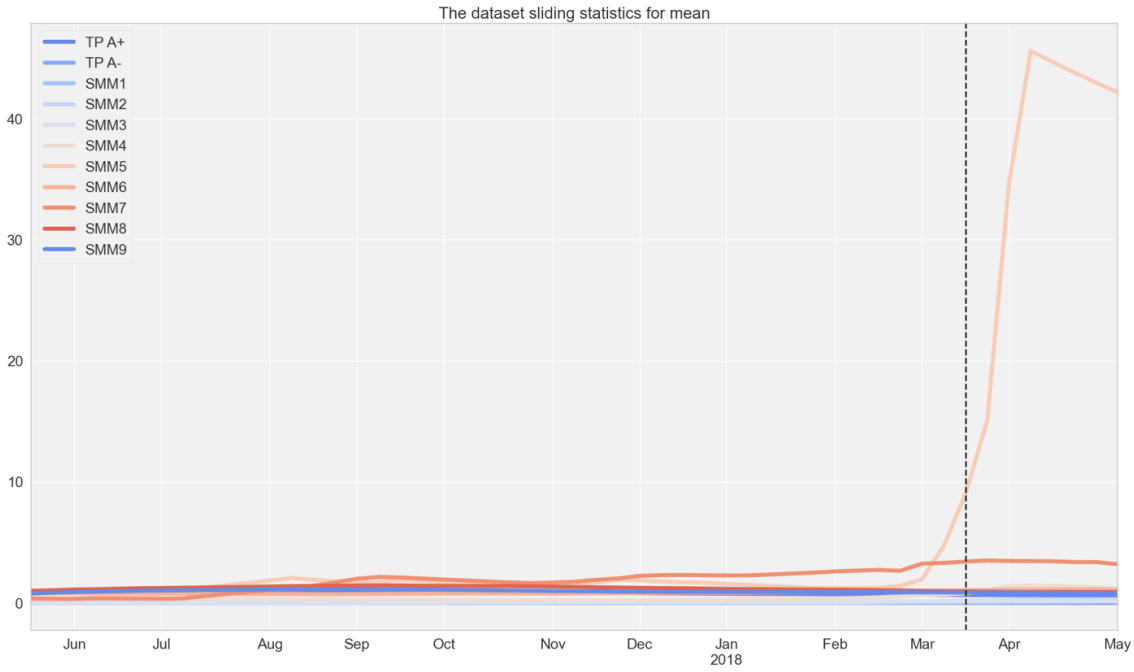


Figure 73. Sliding statistics for mean, Slovenian pilot. Sliding statistics for mean, Slovenian pilot

Sliding scores

The results in previous section can be further explored with sliding scores. Sliding scores are given to profiles at each time of the split as is presented in Table 21. The scores are given to the profiles with max value for each statistics at each split of the data. The table proposes scoring according to each statistics. The top score is given to changes in mean value, the others are valued more equally.

Table 21. Sliding scores

	mean	std	max	min	ptp
Score	8	2	3	2	2

If the scores are applied to the profiles the most exposed/different profiles get the highest scores. For the profile labeled SMM5 we can see that the sliding score raises sharply and got the highest at the time of the loss start (dashed vertical line) and remained as such after this time.

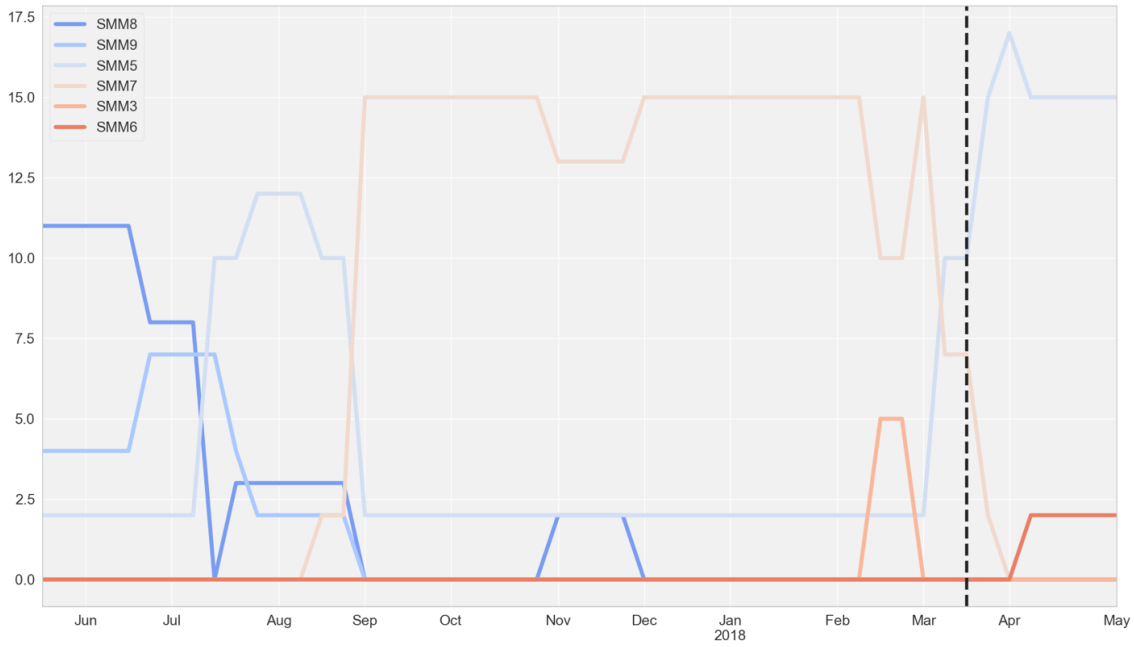


Figure 74. Sliding scores, Slovenian pilot

Detection based on consumption prediction

Another set of indicators for the source of the NTL loss detection is a forecast of the consumption of the individual profiles. For each profile the consumption is predicted week by week according to previous consumptions. An example prediction for the profile SSM5 is presented in

Figure 75. Example profile consumption prediction, Slovenian pilot. In the figure it can be well seen why the sliding scores in the previous section were the highest for the smart meter in question.

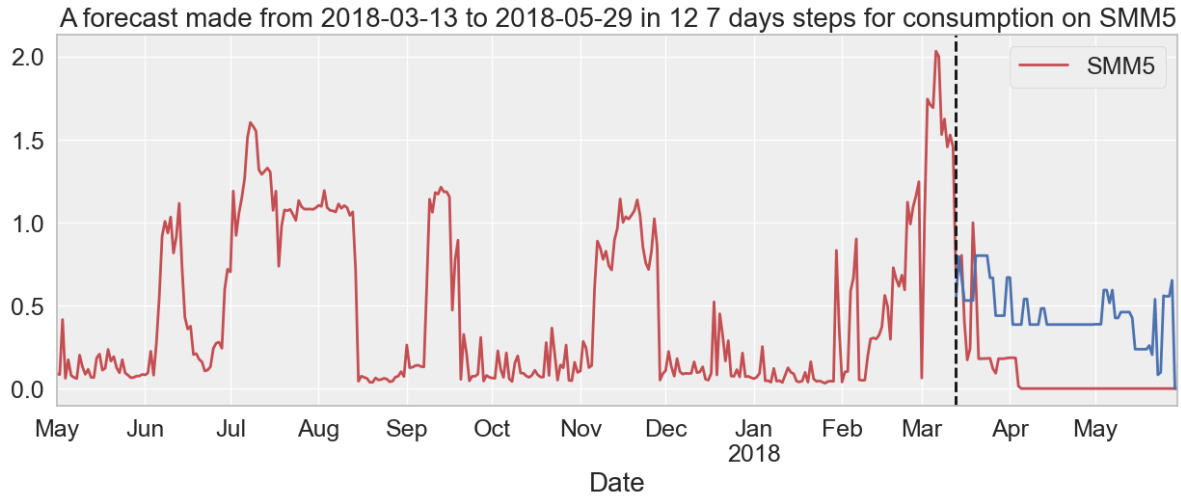


Figure 75. Example profile consumption prediction, Slovenian pilot

For all the predictions the following scores have been observed:

- diff: a difference sum between prediction and consumption
- absdiff: an absolute difference value sum between prediction and consumption
- mean: mean value of the difference values
- absmean: mean value of absolute difference values
- sqroot: a square root value of the differences

Based on these scores in Canovellas case the two smart meters indicated in Table 22 have the highest rank based on the prediction differences. Again, these two meters should be considered as potential culprit for further investigation.

Table 22. Highest score based on profile consumption predictions, Slovenian pilot

	diff	absdiff	mean	absmean	sqroot
SMM9	308.093858	608.458368	3.899922	7.702005	85.834004

S5.1 – Flexibility Forecast results

UPC approach: Flexibility forecast

Introduction of the service
Name: Flexibility forecast
Category: Flexibility and demand response
Task: T4.3
Location on the grid: LV grid and/or MV grid

This service aims to forecast the available flexibility within an aggregator's portfolio in order to know how much flexibility can be activated in a specific time horizon. The objective is to provide the aggregator with a tool to estimate flexibility and provide this service to different stakeholders, such as the Distribution System Operator (DSO) or the Balance Responsible Party (BRP) in later stages and services

Table 23. Use cases for the S5.1 service – UPC approach

Use case	Description
UC1	**As a:** aggregator, you want to know in advance the flexibility available on the grid. **I want to:** know in advance the flexibility available on the grid. **So that I can:** so I can optimise my portfolio **Acceptance Criteria:** When I run the Flexibility forecast service I obtain the hourly flexibility forecast for the next day.

Use Case 1

The aggregator selects the assets it wants to take into account and run the model. He can then access the prediction of the available flexibility for the next day hour by hour with the "forecast" section.
Figure 76 shows the graph on the UI representing the forecast, with the KPIs used to interpret the curve on the right.
We can observe there is for instance a prediction of three peaks of Flexibility Availability at 7h, 9h, 12h, and a plateau from about 15h to 17h30. It means we can only use flexibility during these hours.
The analyst can download the graph (it will be downloaded as in Figure 77) and the data as an excel file (as in Figure 78).

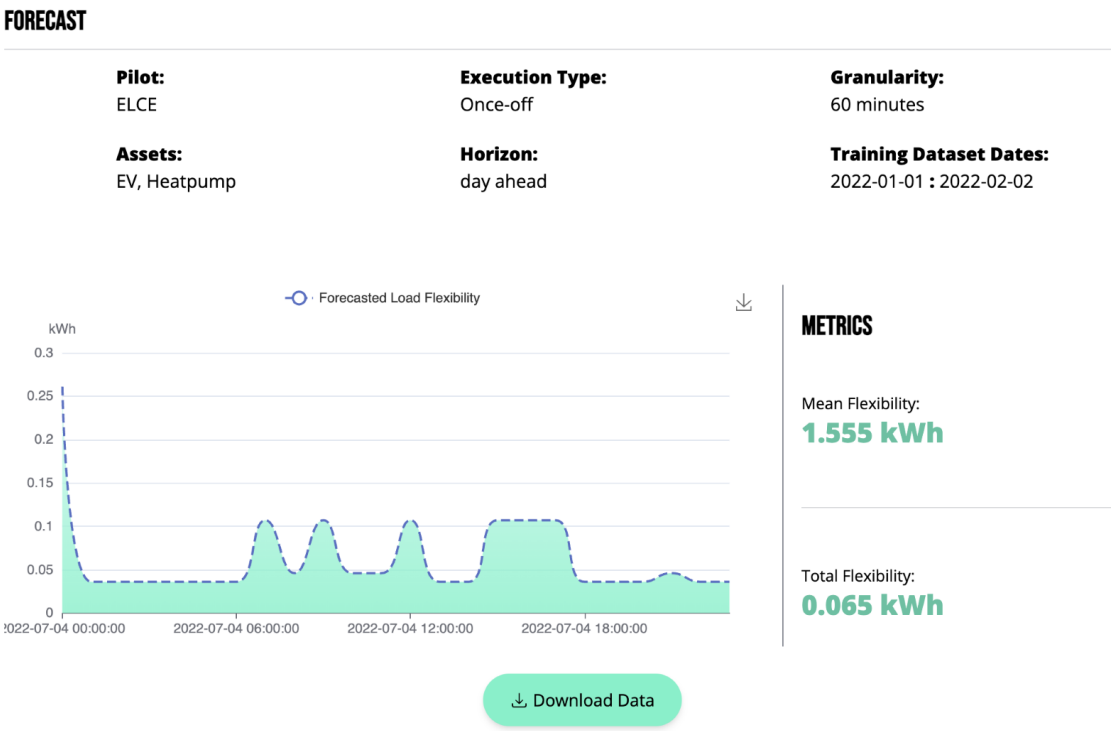


Figure 76. Forecast 24h ahead of Flexibility Availability ("Forecast" section of the UI)

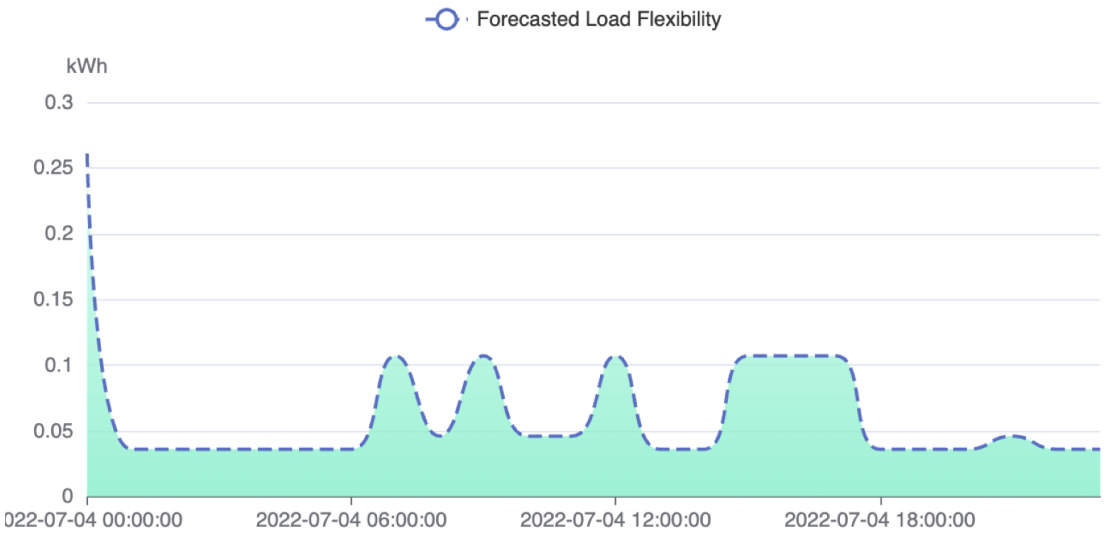
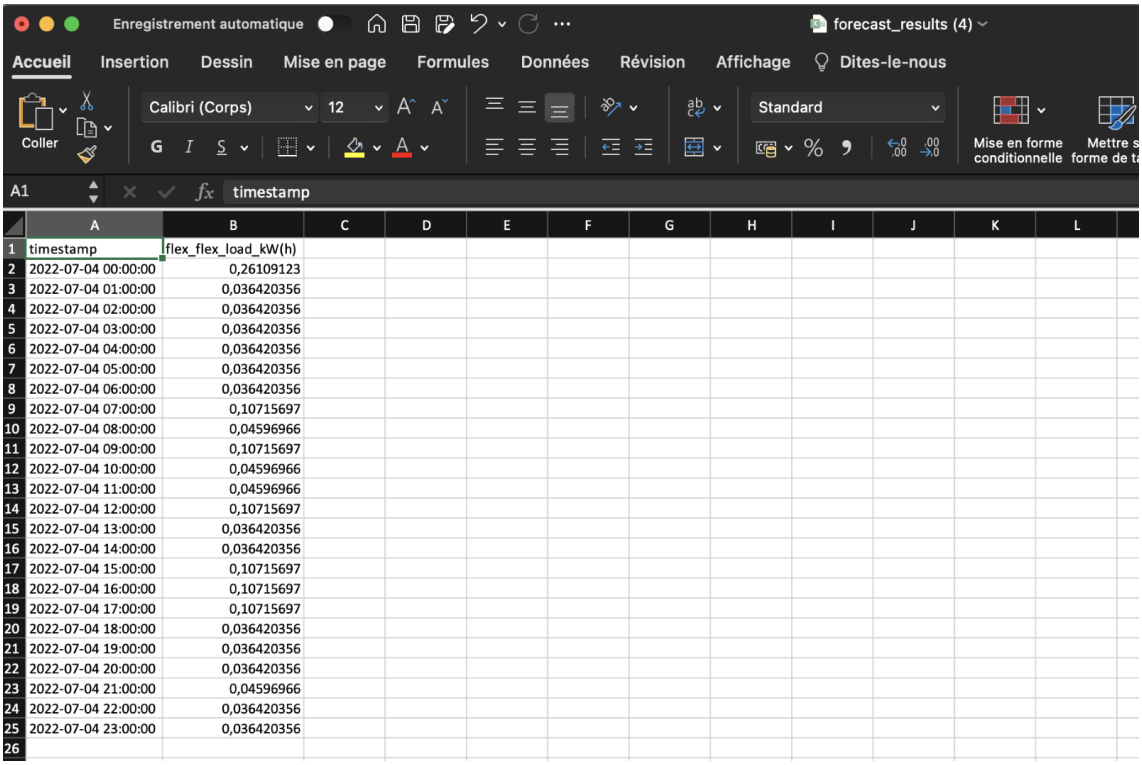


Figure 77. Plot downloaded from the UI



	A	B
1	timestamp	flex_flex_load_kW(h)
2	2022-07-04 00:00:00	0,26109123
3	2022-07-04 01:00:00	0,036420356
4	2022-07-04 02:00:00	0,036420356
5	2022-07-04 03:00:00	0,036420356
6	2022-07-04 04:00:00	0,036420356
7	2022-07-04 05:00:00	0,036420356
8	2022-07-04 06:00:00	0,036420356
9	2022-07-04 07:00:00	0,10715697
10	2022-07-04 08:00:00	0,04596966
11	2022-07-04 09:00:00	0,10715697
12	2022-07-04 10:00:00	0,04596966
13	2022-07-04 11:00:00	0,04596966
14	2022-07-04 12:00:00	0,10715697
15	2022-07-04 13:00:00	0,036420356
16	2022-07-04 14:00:00	0,036420356
17	2022-07-04 15:00:00	0,10715697
18	2022-07-04 16:00:00	0,10715697
19	2022-07-04 17:00:00	0,10715697
20	2022-07-04 18:00:00	0,036420356
21	2022-07-04 19:00:00	0,036420356
22	2022-07-04 20:00:00	0,036420356
23	2022-07-04 21:00:00	0,04596966
24	2022-07-04 22:00:00	0,036420356
25	2022-07-04 23:00:00	0,036420356
26		

Figure 78. Excel view of the data downloaded from the UI (actual values y and prediction)

The "model info" section can also provide insights for the aggregator to better understand the data and compare possible future models (metrics available) as it is presented on Figure 79.

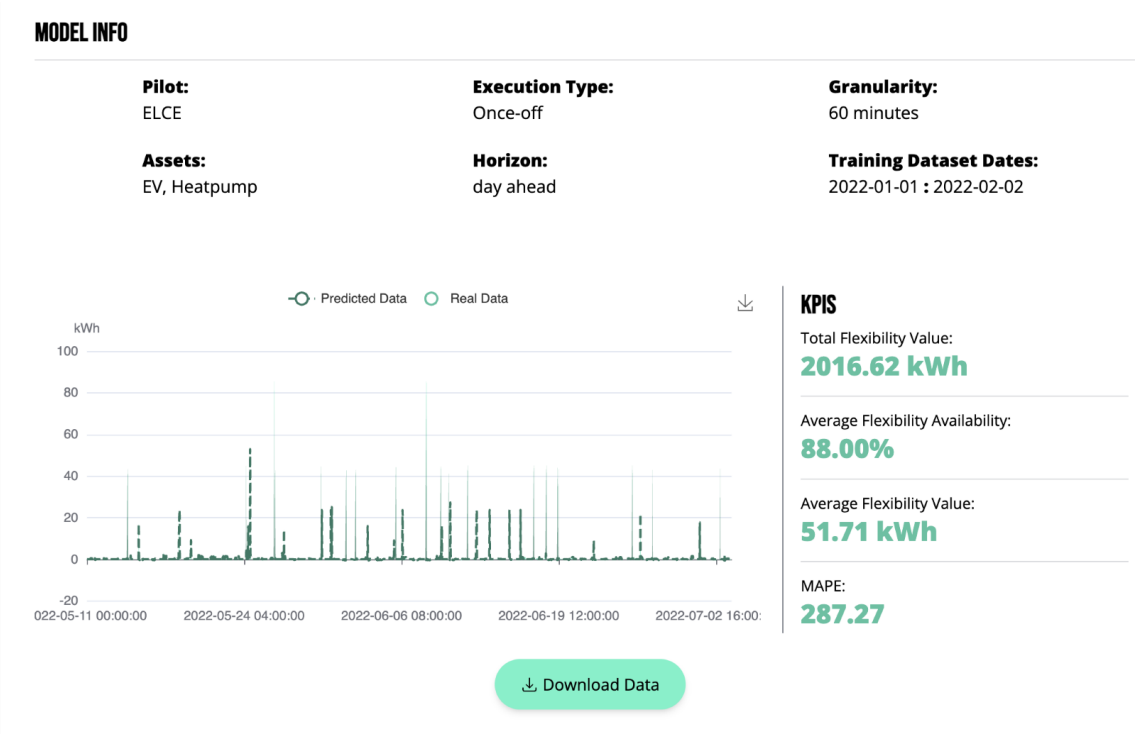


Figure 79. "Model info" section of the UI

Data assessment

The data assessment can be observed in Table 24.

Table 24. Data assessment for the S5.1 service – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
EV	activeEnergyImport	Good	High
Heatpump	None	Medium	High

Service conclusions

The results are useful for DSOs and BRPs as an additional tool to be able to monitor which flexibility they should buy or not.

The grid does have enough storages available to allow a real flexibility along the day, even if more needs to be done to have more vehicles offering flexibility.

Further improvement thanks to the feedbacks from the testing of the service can be an automatization of the service allowing the user to have the KPIs without running the model manually every day, also the possibility to zoom in the plot of the UI to better understand and interpret the forecast and training predictions.

JSI approach: Flexibility forecast

Introduction of the service

The service results are presented in the HTML report in the services tab. The report has a name and table of content. In this case the service report head for Elektro Celje service results is presented. The ToC shows a section with reports on the service instance information so the service user can check the parameters used by the script. The next sections are Flexibility model, Forecasted flexibility event and Service KPIs. Each section's results are explained below.

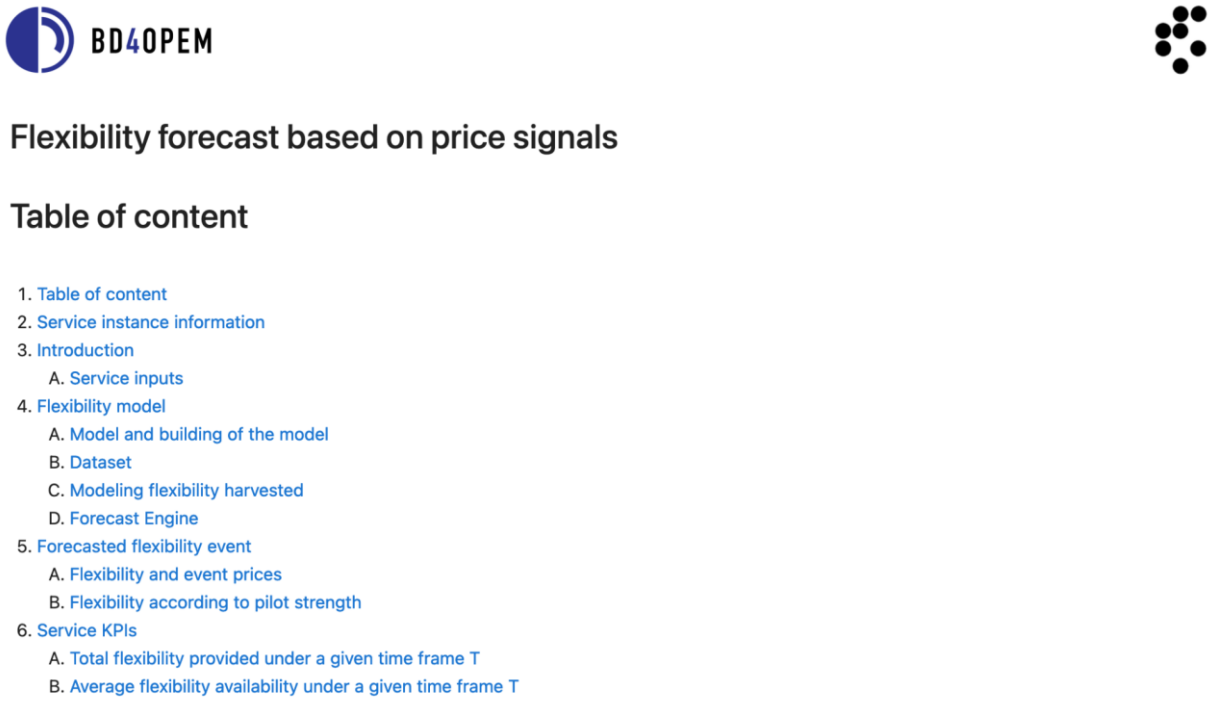


Figure 80. S5.2 service report table of content for Slovenian pilot

Flexibility model

In the section the day selected for estimating the flexibility is presented, as can be seen in the Figure 81. The modeling of the flexibility is briefly explained.

The region consumption for the target day and region, Thursday, 18th of November 2021, in ELCE network shows the daily profile in the network. The daily profile is based on combined consumption at 209 transformers with 15 minutes resolution. The daily profile shows atypical consumption for a household region with evening peak roughly at 18:00.

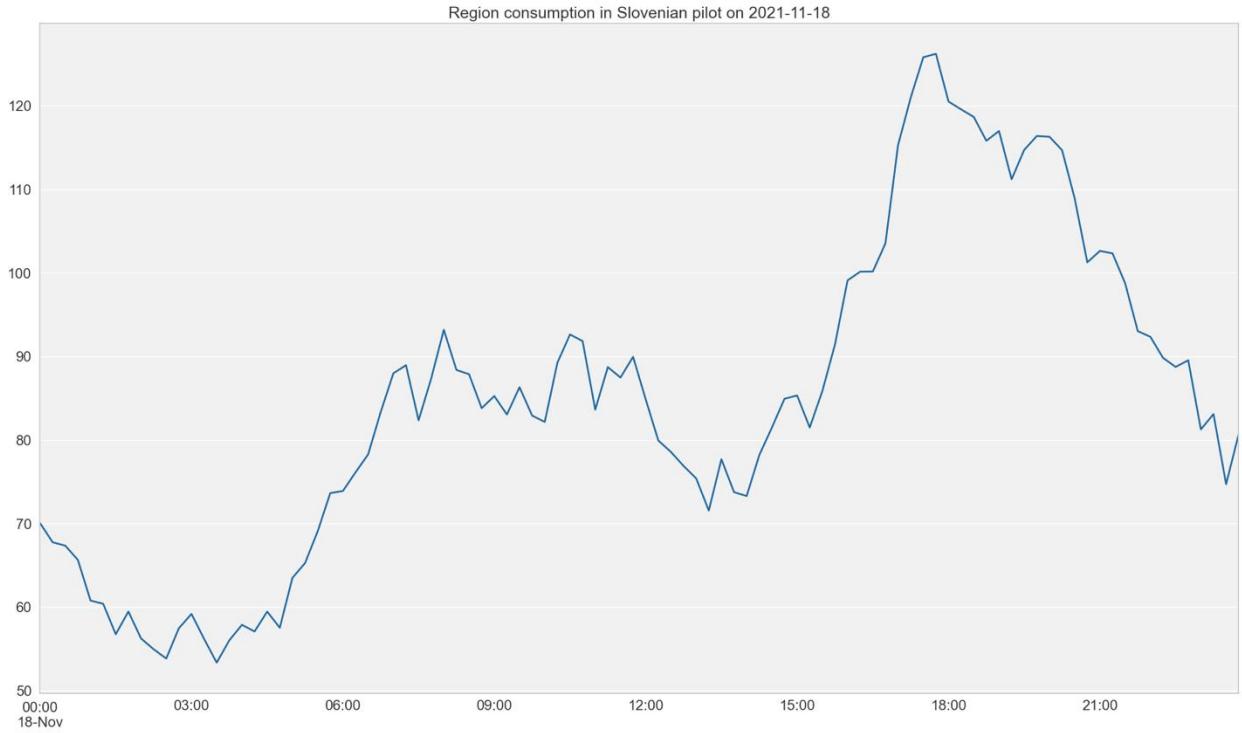


Figure 81. Region consumption in Slovenian pilot on 2021-11-18

Forecasted flexibility event

The flexibility event of two hours has been estimated in the figure below. The event itself is marked with the shaded area. In all six hours of the consumption are presented, two hours before the event, two hours after the event and 2 hours of the event itself. All in all, 24 of 15-minute values of flexibility are estimated. The event is modeled as the data is available in 15-minute intervals. If the data was available at 1-hour intervals the data values are filled in with extrapolation.

In the figure can be seen that the flexibility prediction starts slowly after event interval with strongest effect at the peak of the real consumption. The effect of the flexibility event is predicted to last also after the event.

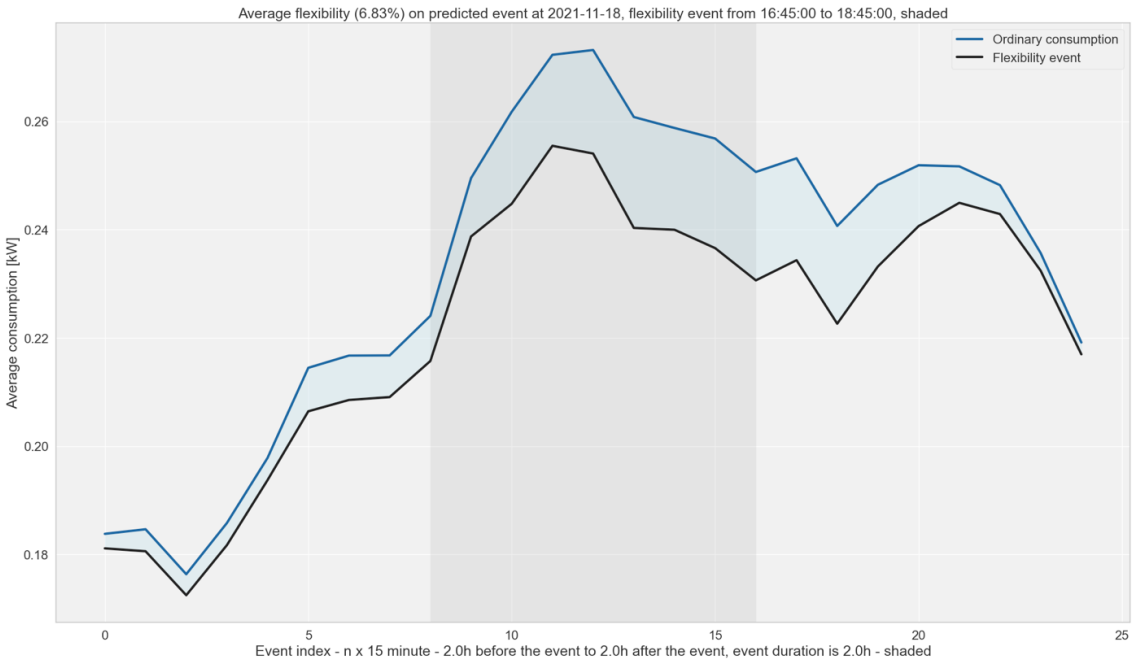


Figure 82. Average flexibility on predicted event at 2021-11-18

The figure below shows the effect of the price change on the user's response on demand flexibility. It can be seen that the price scale has a significant effect on the user's demand flexibility. However, further increase in the price will not add much more to the flexibility harvested. Thus, price change should be designed according to the arctan function as after a certain point, consumers become numb to the further price change.

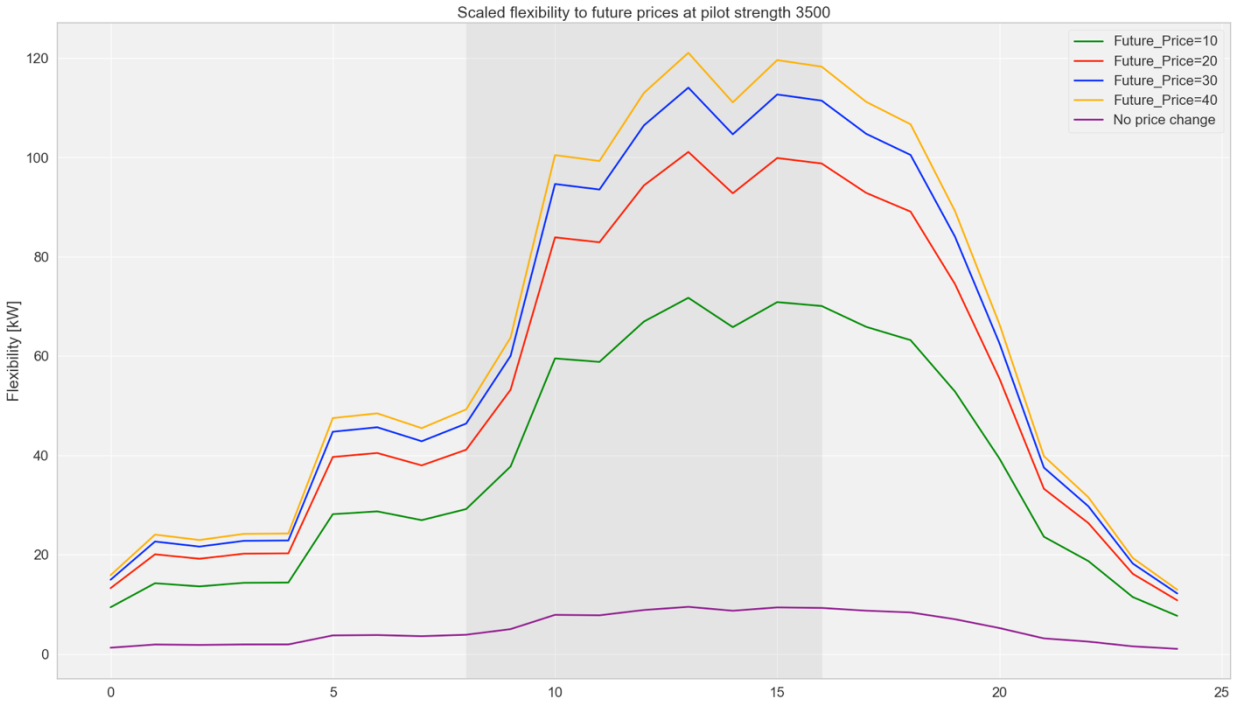


Figure 83. Scaled flexibility to future prices at pilot strength 3500

The figure below shows the effect of the change in pilot strength on the harvested demand flexibility. It can be seen that the increase in the pilot strength has a significant effect on the amount of flexibility harvested. The prediction of the flexibility harvested is linearly related to the number of smart meters involved in the event implementation.

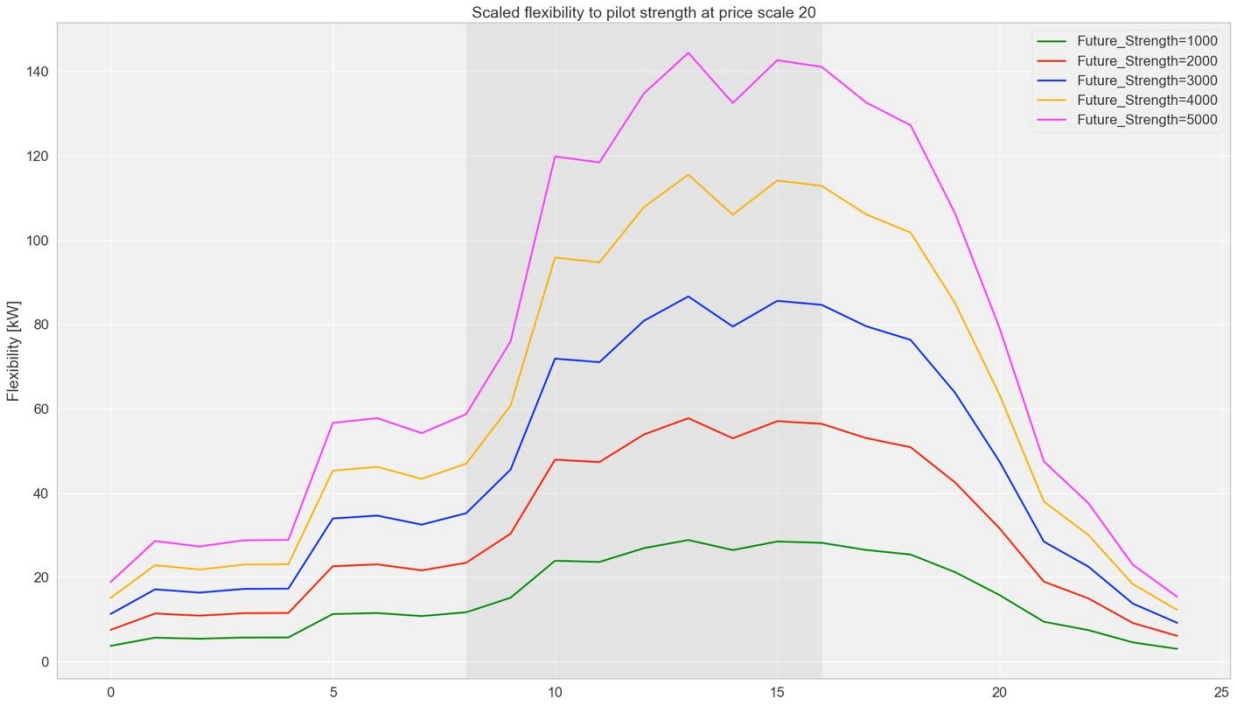


Figure 84. Scaled flexibility to pilot strength at price scale 20

S5.3 – Flexibility aggregated services for DSOs results

UPC approach: Flexibility-based AC OPF

Introduction of the service
Name: Flexibility Aggregated services for DSOs
Category: Flexibility and Demand Response
Task: T4.3
Location on the grid: MV/LV network

DSOs are one of the main stakeholders to purchase flexibility services instead of changing the network topology or curtailing power for congestion management. This service calculates the flexibility request for the DSO for a correct operation of the network and sends that request to the aggregator, the entity providing the flexibility. This section considers two different approaches for mitigating and managing distribution network operation. UPC approach presents a methodology for mitigating distribution network congestion based on a flexibility-based AC-OPF approach, while JSI approach presents a methodology for congestion management based on neural networks and LSTM.
Under the network operation timeframe, the DSO faces two main problems, which are congestion management based on over currents, and voltage/reactive power control based on under and over voltages. The first one consists in avoiding the thermal overload of system components by reducing peak loads where a failure due to overloading may occur. The latter, voltage/reactive power control, is based on

using load flexibility by increasing or decreasing loads and generation sources to avoid exceeding the voltage limits, typically, when PV systems generate significant amounts of electricity.
This tool aims to provide DSOs with the possibility to calculate the required flexibility to be activated in a specific time period and location. The objective is to provide information to the DSO to manage the efficiently the expected congestion. Additionally, this service aims to provide a tool for DSOs to calculate flexibility within the grid and generate insights for future management of the grid. With the output of this service, it is expecting to reduce DSO investments in grid reinforcements by profiting from the available flexibility.

Table 25. Use cases for the S5.3 service – UPC approach

Use case	Description
UC1	**As a:** DSO analyst, **I want to:** generate a congestion management plan for the next day **So that I can**: gain insights into congestion management and the efficiency of flexibility sources. **Acceptance criteria:** The system displays flexibility source values, congestion percentages, and detailed flexibility insights for selected days.
UC2	**As a:** DSO analyst, **I want to:** evaluate the grid I managed before and after my dispatch of flexibility. **So that I can:** directly assess the impact of the flexibility request on line loading and voltage improvements. **Acceptance criteria:** The system displays snapshots of the grid pre and post-flexibility request for any chosen hour and allows downloading of these images, along with the power injection of flexibility sources per bus throughout the day.

Use Case 1

After the service is executed for a specific day, we can observe several interesting values for the flexibility of the flexible sources as shown in Figure 85. The service offers the possibility to observe values related to the flexibility sources. In this case, we can see that the flexibility sources capacity needed to clear congestions is 0.53%. This is a very low value that means that there not that many congestions in the grid for this specific day. Also, we can observe the usage of the flexibility sources, in terms of times instances (for ELCE is a frequency of 15 minutes). For most of the sources is only 1, confirming that there are not many instances in the day where the grid is stressed. However, we observe that the congestion clearing is 100%, so for that specific case, the sources installed in the grid are enough to cover and avoid congestions, as seen in Figure 87.

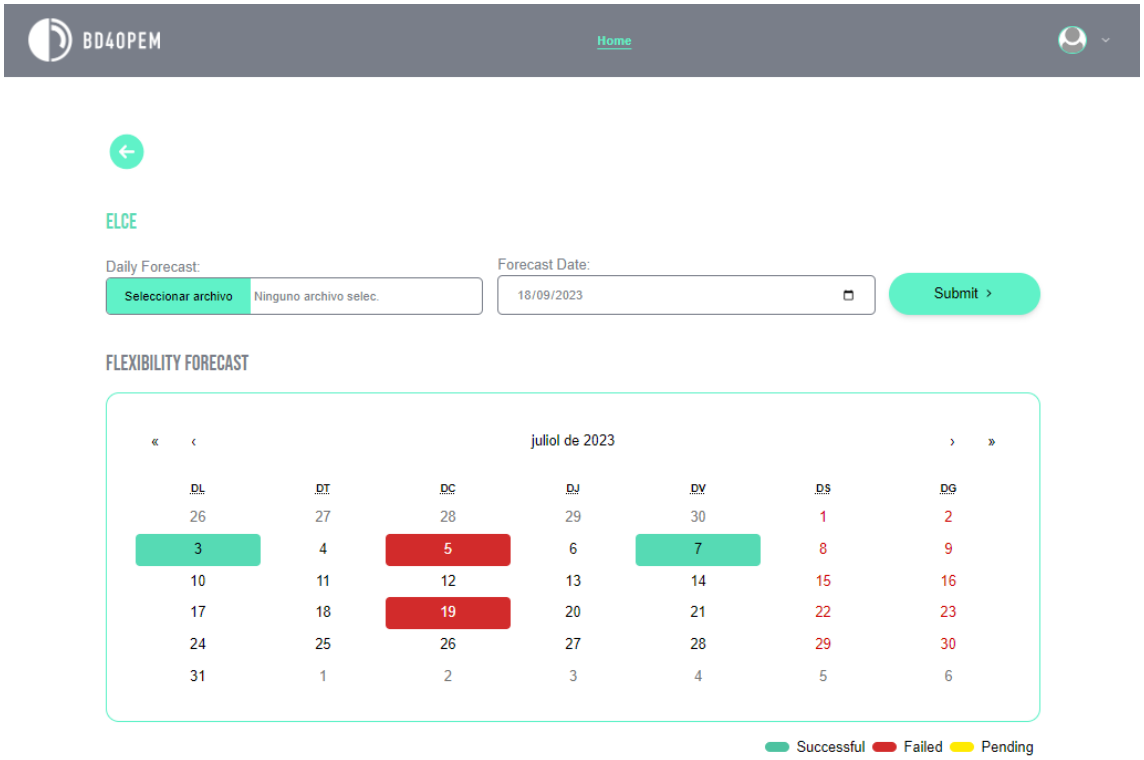


Figure 85. Service UI Execution Home

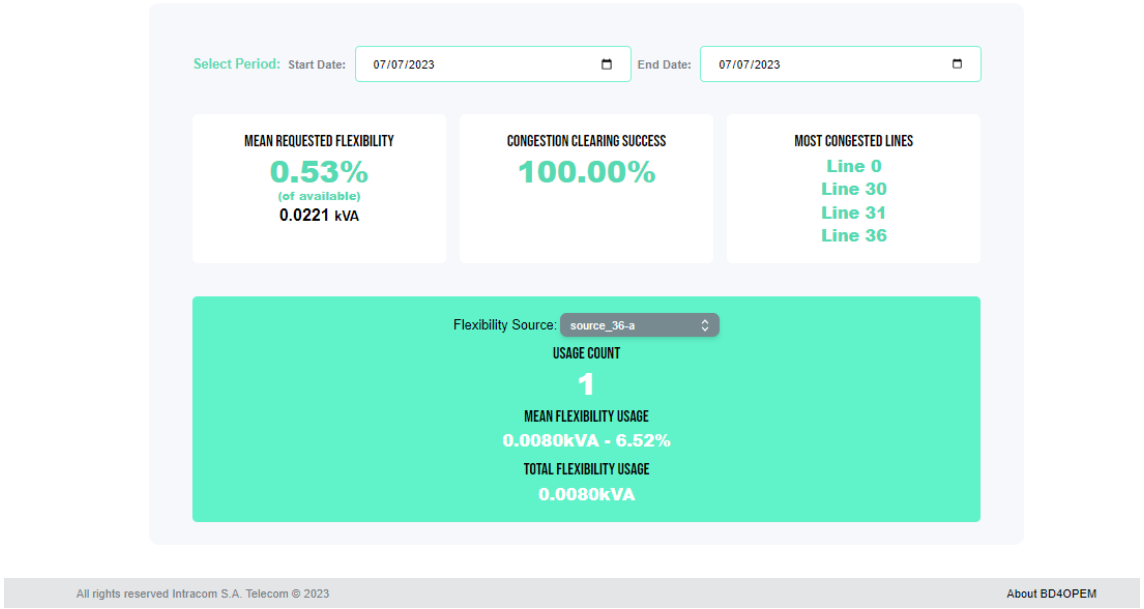


Figure 86. Service UI Execution Home

When selecting the specific day, it is able to retrieve more information about the needed flexibility. From the requested flexibility field, it is possible to see that not much flexibility is needed for this case 0.02 kVA. However, this number is appropriate given that ELCE grid is LV. Also, we can observe the most loaded lines and hour with higher load. Additionally, we can observe the statistics for each of the flexibility sources used.

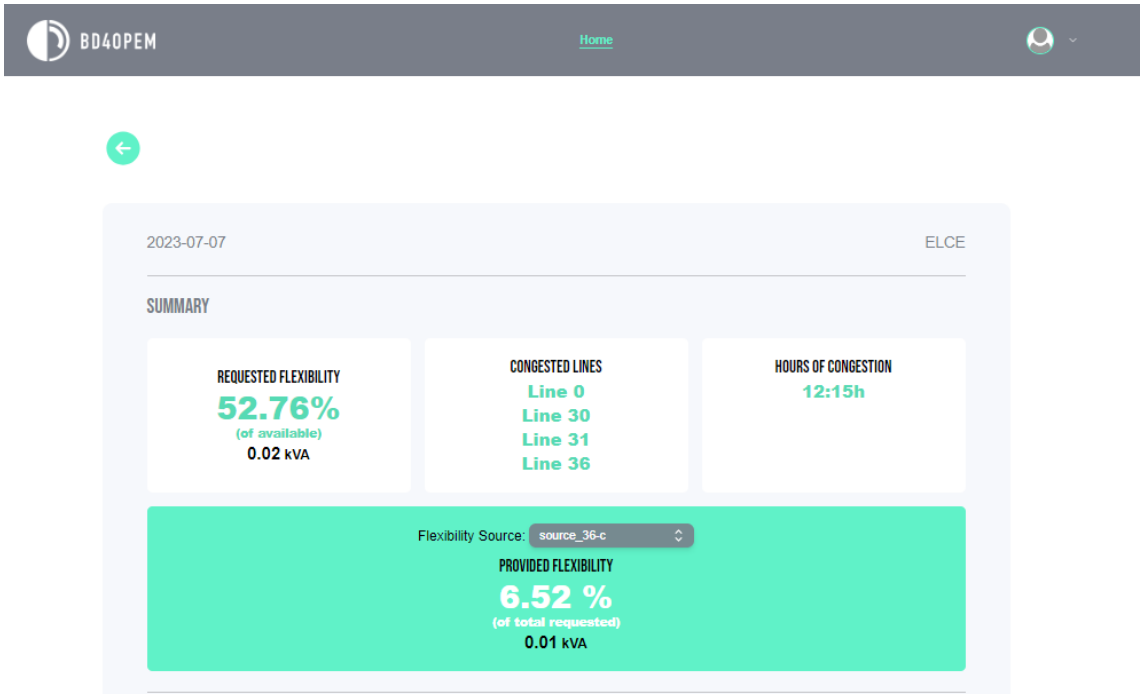


Figure 87. Forecast Day results

Use Case 2

One important feature that this service offers, is the possibility to see the grid before and after the application of the Flexibility Request (FR) calculated by the algorithm. This is important as the analyst is able to see actually the reduced loading of the lines and improvement of voltages, if any. In Figure 88, it is possible to see the snapshots of the grid before and after of the FR, for any desired hour. The images can be downloaded for any posterior purpose desired by the analyst. Additionally, the analyst can also observe the injection of power of the flexibility sources per bus during the whole day, as shown in Figure 89.

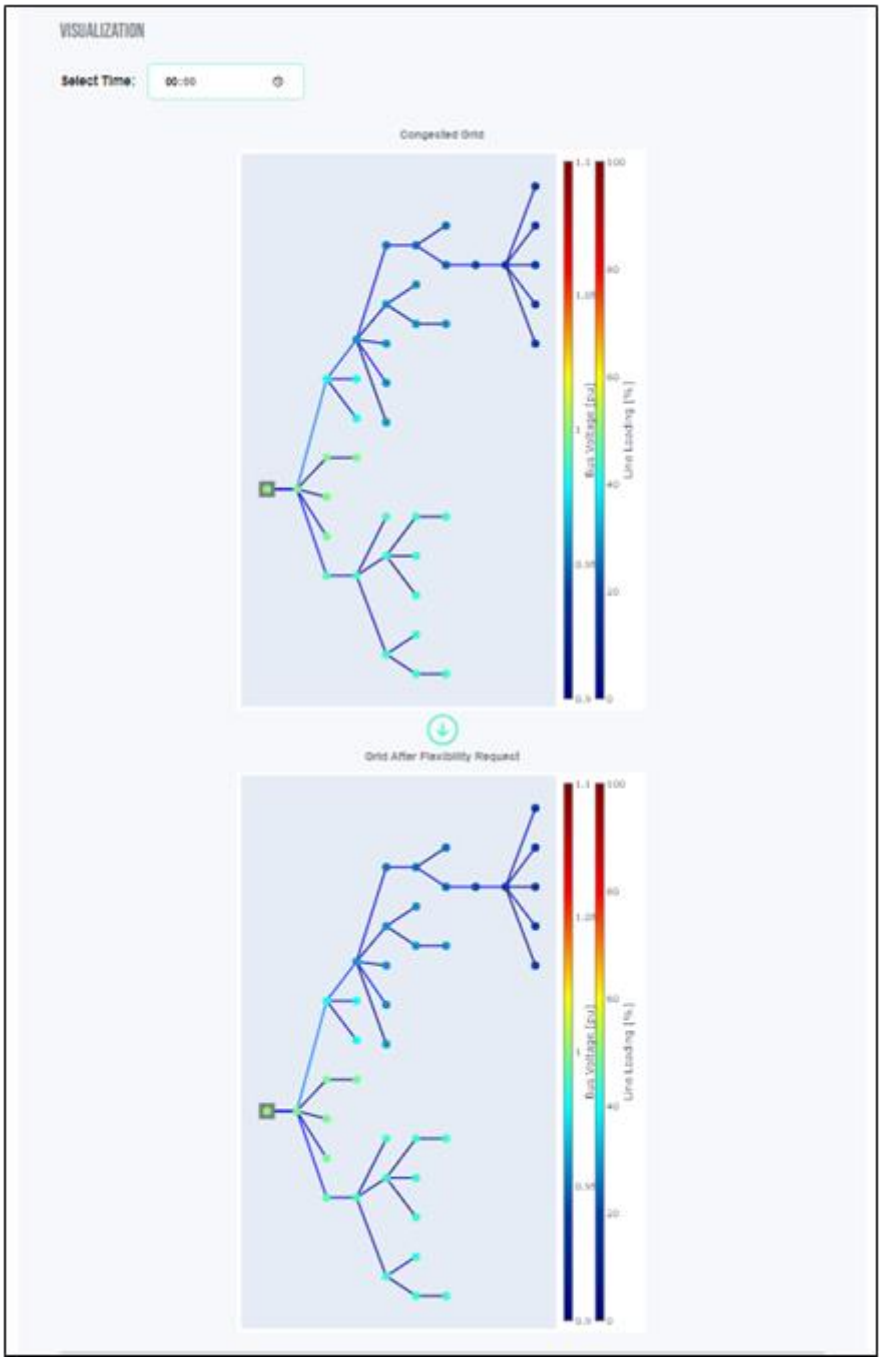


Figure 88. Flexibility Request

Figure 89. Flexibility sources injection

Data assessment

The data required to establish the service mainly comprehends topology and grid parameters of the grid, and forecast calculations. The specific data files for this service can be observed in Table 26.

Table 26. Data assessment for the S5.3 service – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
Grid topology	Featurecollection	Full information of topology	GIS was provided, missing some parameters of cables

Service conclusions

The service offers interesting results and information to the analyst and user. However, its functionality is subjected to the regulations and configuration of flexibility markets where the DSOs is. The service's objective is to present the user information regarding flexibility procurement, however, there are many details regarding this type of procurement. Nonetheless, the service's current output is very interesting to have a first look to flexibility needs within the grid. For future iterations, the service could benefit from more details regarding the flexibility sources in the grid as input. For the development, the service can add more explanation on the flexibility request, aligned with current strategies of the DSO.

Additionally, feedback raised during the testing of the service is as follows:

- The red values for weekends in the calendar in the UI home calendar can be misleading.
- The values of the flexibility sources should be given in KW and not KVA.
- In the last figure (Figure 89) the indices should relate to the actual name of the buses, as then it is difficult to recognize to which bus they flexibility sources are connected.

JSI approach: Flexibility services for DSOs based on neural networks

Introduction of the service

The service results are presented in the HTML report in the services tab. The report has a name and table of content. In this case the service report head for the ELCE service results is presented. The ToC shows a section with reports on the service parameters so the service user can check the parameters used by the script. The next sections are Predictions and Event planning, which results are explained below.

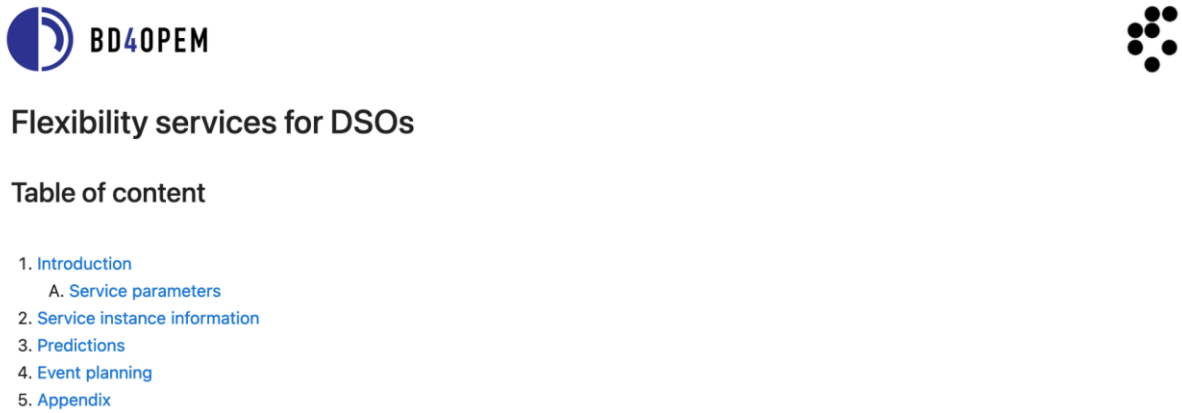


Figure 90. S5.3 service report table of content for Slovenian pilot

Predictions

The predictions are based on a ELCE data from 209 substations in primary residential area. The substation consumptions have been summarized and the sum has been used for predictions.

The predictions section reports on the importance of the features and errors in fitting the predictions to the train and test set. The results could be used to understand how good the algorithm is for predictions based on the provided data and which features are considered most important.

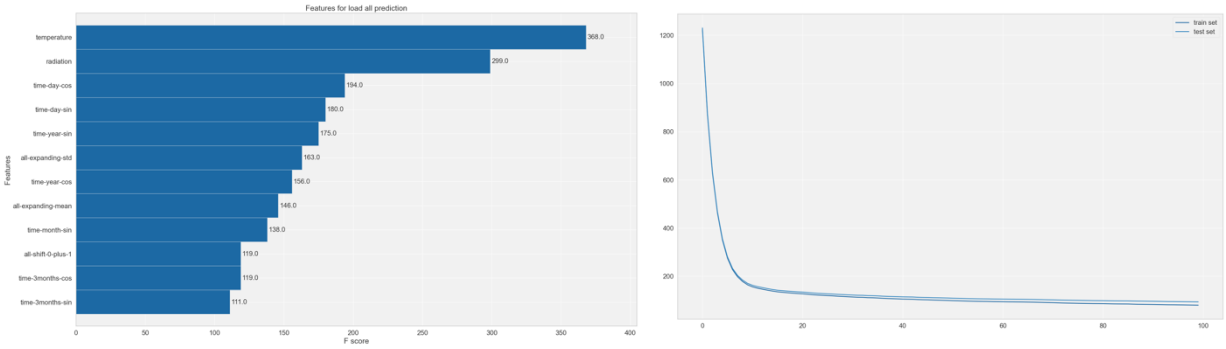


Figure 91. Features for load all predictions

From the features It is possible to see that the most important is the temperature which is followed by the radiation. The fitting of the test and train set shows that the predictions should be quite good.

Below are given the predictions for the selected week in the end of January 2022. We see the amplitudes of the predicted consumptions, in red, are well off the consumption realization, in blue.

It is possible to see that the predictions for the beginning of the week are good but the predictions for the last three days are bad. The reason for bad predictions is the data of the substations consumption. The data for the last three days is not complete due to slow smart-metering data propagation. Some data is late for three days, more for 2-days and even more for the day minus one (D-1). The situation reflects clearly on the consumption forecast.

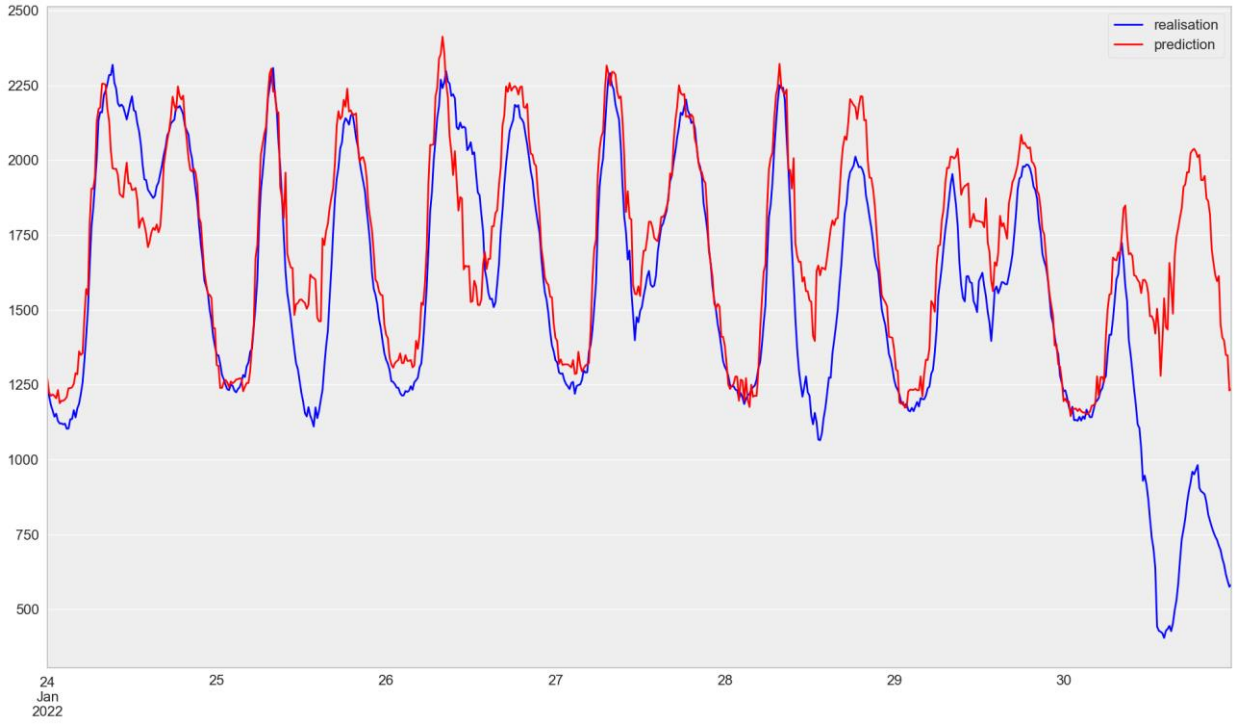


Figure 92. Predictions for the end of the January 2022

The accuracy of the results is given in the next table. The most important parameter for the service is the Peak hour difference. Based on this parameter the event intervals for the flexibility events are chosen. For the data in question it can be seen that there are some errors in peak time forecast but the peaks are always forecasted

in the 2 hour interval of the event except for the last day for the reasons already discussed.

date	peak error [%]	min error [%]	corr	ptp [%]	std [%]	mean [%]	error [kW]	MAE	MSE	RMSE	Peak hour difference
2022-01-24	14.92	-9.62	0.945687	12.20	17.80	1.94	3.7	114.143291	21015.671253	144.967828	0 days 01:15:00
2022-01-25	3.43	-44.65	0.917253	10.01	8.40	-7.52	-11.1	133.519435	35436.291522	188.245296	0 days 00:15:00
2022-01-26	1.68	-8.93	0.840310	-2.05	5.90	-1.42	-2.5	160.957062	39178.053801	197.934468	0 days 00:30:00
2022-01-27	1.78	-5.43	0.980096	3.76	0.82	-4.21	-7.1	77.235456	9446.615238	97.193700	0 days 00:30:00
2022-01-28	-3.17	-51.76	0.886607	3.36	-0.25	-12.10	-18.3	190.634317	60365.129693	245.693162	0 days 00:00:00
2022-01-29	-3.05	-6.23	0.942235	-10.43	-13.41	-8.28	-12.7	130.616594	25930.334310	161.028986	0 days 00:45:00
2022-01-30	-1.50	-280.42	-0.060565	32.37	20.20	-57.38	-53.7	564.223264	515793.777756	718.187843	0 days 10:15:00

Figure 93. The accuracy of the results for the Slovenian pilot

An example event day presented below is Wednesday, 25th of January 2021. In the table above it is possible to see the peak prediction is 15 minutes off and the proposed interval fits the realization consumption well. The suggestion of the event for the DSO seems to be correct.

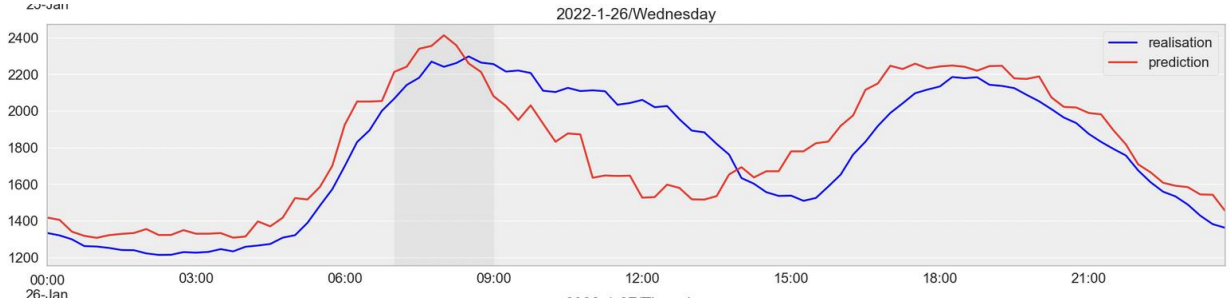


Figure 94. Event day, 25th of January 2021

S6.1 – Energy management at household level

Introduction of the service

Name: Loads, generation, energy storage management at individual household or community level
Category: Smart houses, buildings and industries
Task: T4.4
Location on the grid: Low Voltage (LV) network.

Energy management at household level is controlled by the energy management system (EMS), which controls and monitors the system for the optimal operation of appliances in the household/building. The aim of the EMS is to make the best possible use of the availabe energy and to provide additional flexibility services for third

parties through incentive programmes. Based on the availability of the equipment at the EMS, the EMS can optimise various optimization criteria in which the prosumer is mainly interested:

- Cost optimization
- Maximising the use of renewable energy

EMS can signal to the end user how to set the respective device and when to start/activate the flexible device.

Table 27. Use cases for the S6.1 service

Use case	Description
UC1	As a prosumer, I want to optimize the use of flexible systems to minimize my energy bill.
UC2	As a prosumer, I want to maximize self-consumption of PV energy

Use Case

This use case aims to minimize the total electricity bill and maximize self-consumption of energy at the household level.
The prerequisite for this use case was the installation of the appropriate hardware. The installation of smart meters and modems at the end users included the provision of a decryption and forwarding kit consisting of an I1 module, an LTE modem and a power supply unit, which were installed at the pilot sites in the main electrical cabinet next to the meter, Figure 95. The I1 module converted the data from the I1 interface into JSON format and transmitted it via the RS485 interface, while the LTE modem sent the data securely to the server for storage in the database via an encrypted LTE connection. The standardized installation process took two days at all six pilot sites, with varying degrees of difficulty due to the crowded equipment cabinets. Despite a configuration error when setting up the meters, which was later rectified remotely, data collection was able to begin successfully. It was ensured that the minimum functional requirements for the measurement and communication devices, as specified in the system operating manual, were met, including a unidirectional communication channel and standardized data forwarding intervals. In addition, the system meter supplied the external communication modules with a minimum power of 0.576 W.

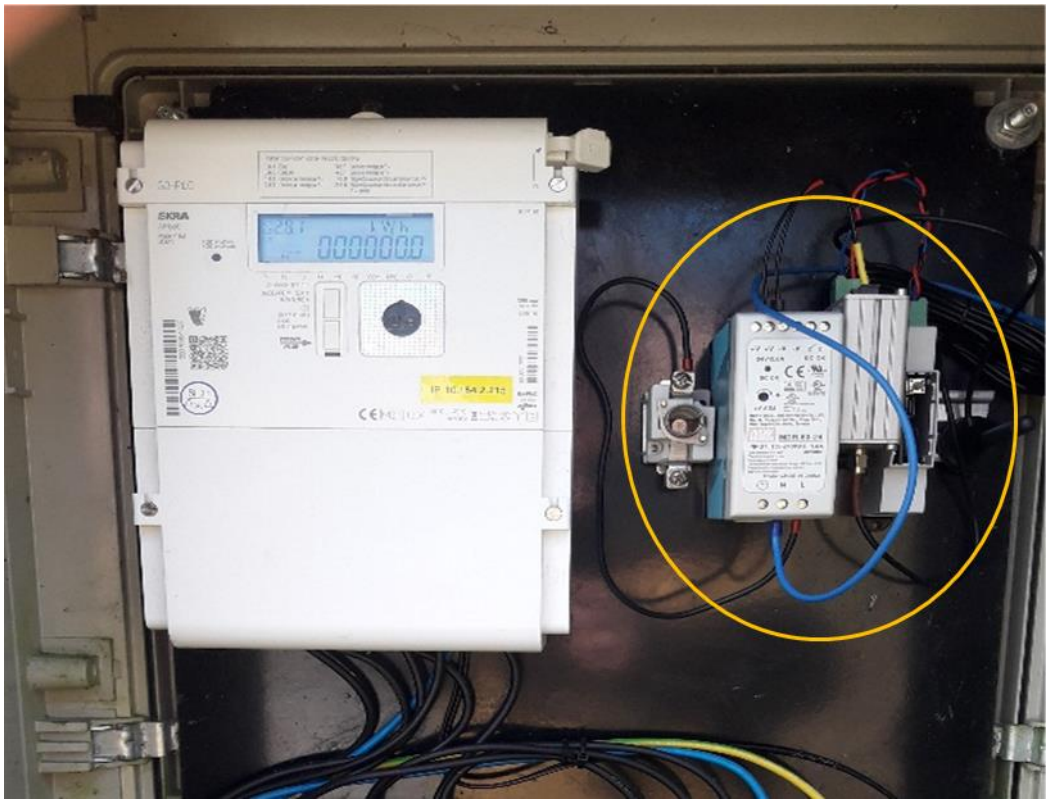


Figure 95 . Installed kit for decrypting and transmitting I1 data in meter cabinets at end user

Together with S6.2, the S6.1 service forms a complete system for forecasting and managing users' assets. Therefore, both services have a common user interface, Figure 96. In S6.1, the last tab, Schedule, is the most important part. Here the user can choose what kind of optimization he wants to perform with the disaggregated data. Given that it is not possible to have full control over the assets, the service suggests the schedule. The execution of the schedule is up to the user. The service uses disaggregated data (PV, HVAC, EV and background) to perform the optimization. The user can set the flexible buffer window, which has a direct impact on comfort. So it depends on the user how much comfort he is willing to sacrifice to improve self-consumption or reduce the energy bill.

Figure 97 shows the results of maximizing self-consumption with a predefined buffer window. The weather on the day in question was mostly cloudy and there were rain showers,. Even though the optimization resulted in 3 kWh, higher self-consumption is possible with intelligent management of flexible loads.

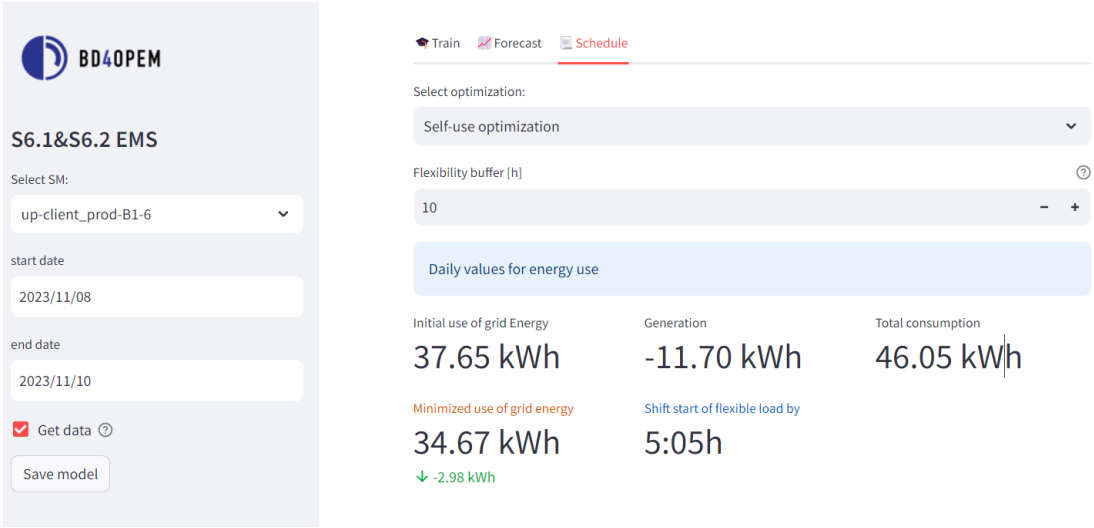


Figure 96. The user interface of the service with Schedule tab settings and results

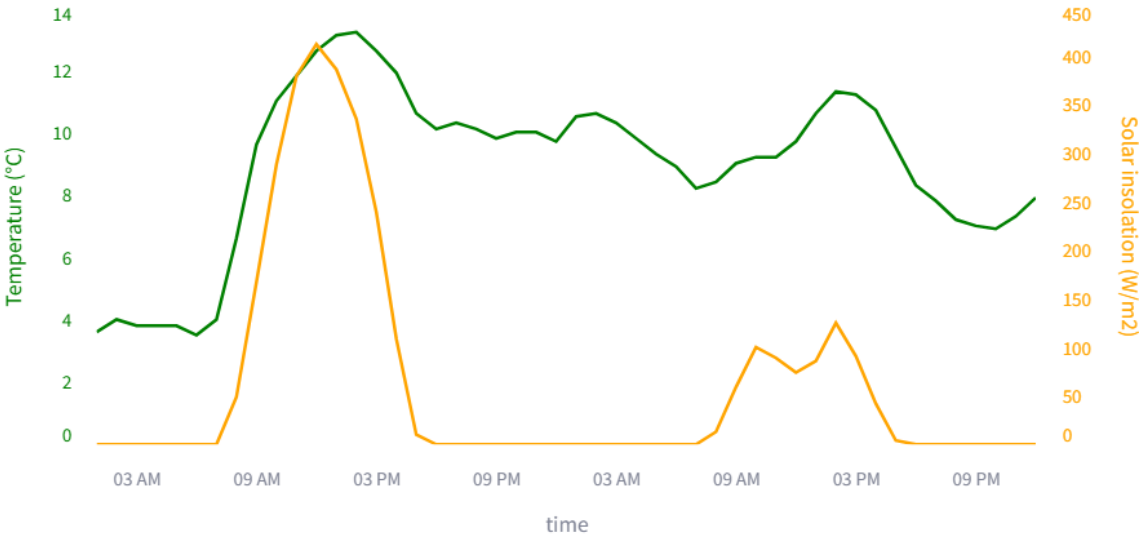


Figure 97. Forecasted weather for the location

Data assessment

The data assessment can be observed in the Table 28.

Table 28. Data assessment for the S5.3 service – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
SM data from I1 port	None	Good quality	Medium
Forecasting	None (Part of S6.2)	Good quality	High

Disaggregation	None (Part of S6.2)	Sufficient quality	Medium

Service conclusions

The service focuses on the generation and load management of individual households and is proving to be extremely beneficial for prosumers and distribution system operators (DSOs). By optimizing energy consumption through the energy management system (EMS), the service enables prosumers to minimize energy costs, maximize self-consumption of renewable energy and participate in incentive programs for additional flexibility.
For DSOs, the service provides valuable insights into user behavior that can be used for local grid management to improve stability and power quality. The user-configurable buffer windows provide a balance between convenience and energy efficiency. Future developments could further extend user control and refine the optimization criteria. Multivariate optimization, where the requirements of both sides (user and DSO) are met, could take the service to a new level where all parties can benefit from using the EMS system.

S6.2 - Energy forecasting

Introduction of the service

Name: Energy forecasting
Category: Smart houses, buildings and industries
Task: T4.4
Location on the grid: smart meter and/or behind-the-meter.

The energy forecast service is used to predict profiles for the baseline, the energy of flexible asset and the RES generation curves in households. Using non-intrusive load monitoring, the service breaks down the consumption of individual devices behind the meter using aggregated smart meter data. The service breaks down the following data: HVAC, EV, PV and background consumption. These are the largest loads available and can be used most effectively for shifting without impacting user comfort too much. Anonymization of usage profiles related to consumer behaviour is enforced when used outside the prosumer's premises to ensure data privacy. The service is offered on-demand and offline and offers prosumers full control over their data and services.

The profiles obtained from the assets are the input for the S6.1 EMS service, where the profiles are used in various optimization processes to optimize energy bills or increase self-consumption of energy generated from renewable sources.

Table 29. Use cases for the S6.2 service

Use case	Description
UC1	As end-user I want to predict my consumption and generation for next day to optimise the energy bill

UC2	As PV owner I want to predict PV production for next day to sell or optimize the self-usage of the energy

Use Case

The use case for S6.1 involves predicting baseline and flexible asset demand and generation curves within a short-term horizon. This is particularly beneficial in situations where complete control over the assets is difficult. By using NILM for a non-intrusive breakdown of consumption, the service can estimate what type of equipment is behind the anonymized SM. For example, Figure 98, it is possible to see the historical and forecasted consumption of a simple dual retired type of household without PV or flexible assets (HVAC or EV). The disaggregated profile is shown in Figure 99, as no PV or flexible assets were detected.

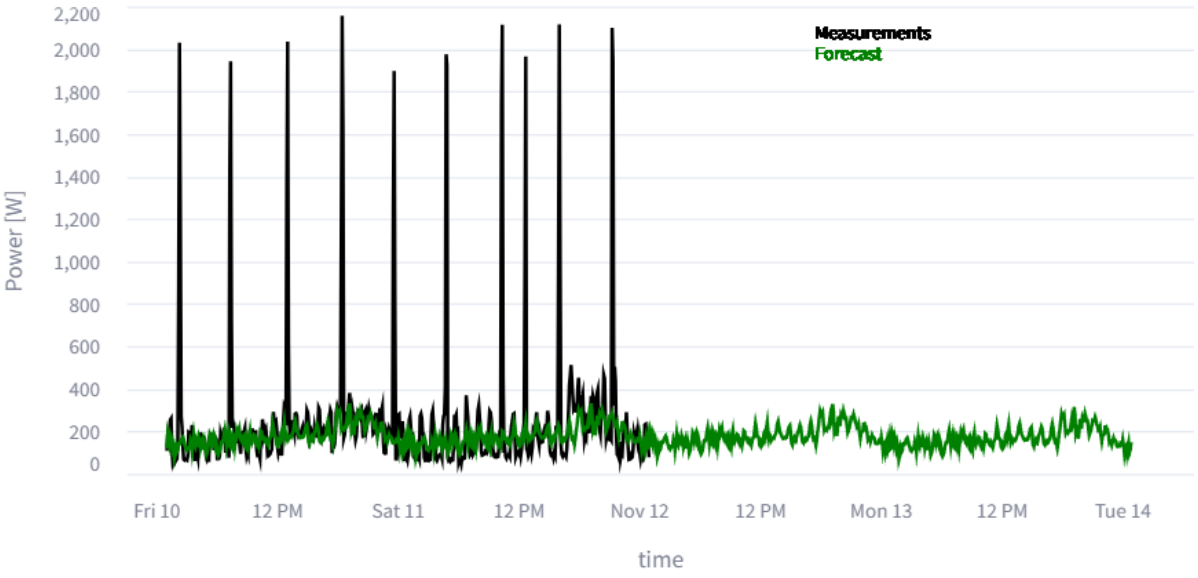


Figure 98. Forecasting SM consumption of a household without RES, HVAC or EV

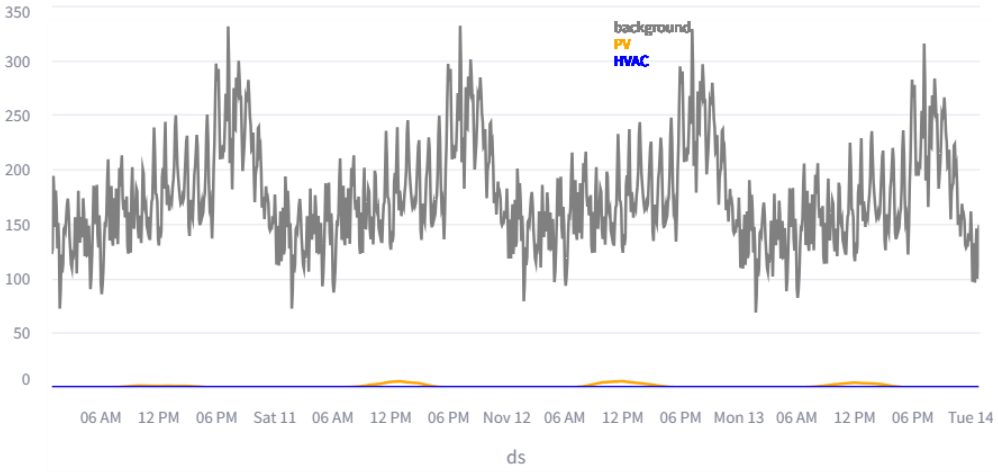


Figure 99. Disaggregated household profiles without RES, HVAC or EV

Another energy consumption forecast for a household is shown in Figure 100. This time the household has HVAC and PV, which was also correctly recognised by the disaggregation algorithm, Figure 101.

Together with S6.1, the S6.2 service forms a complete system for forecasting and managing users' assets. Therefore, both services have a common user interface, as shown in the previous section with the description of S6.1 description.

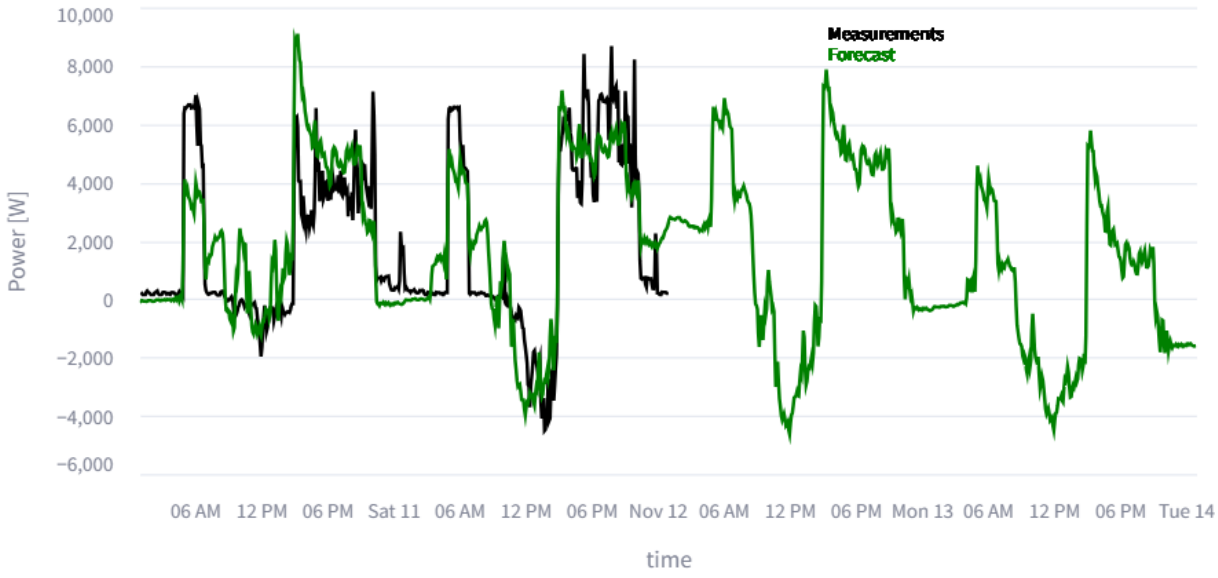


Figure 100. Forecasting SM consumption of a household with RES and HVAC

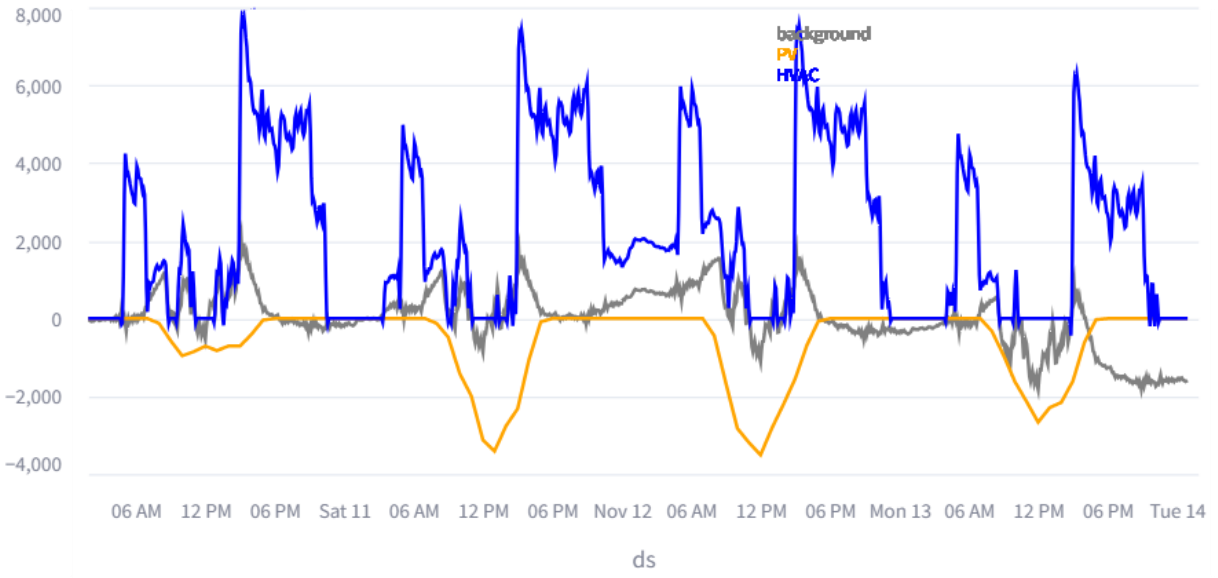


Figure 101. Disaggregated profiles of a household with RES and HVAC

Data assessment

In the Table 30 is presented data assessment for S5.3 service – UPC approach.

Table 30. Data assessment for the S5.3 service – UPC approach

Data source needed	BD4OPEM ontology	Data quality assessment	Impact of the quality on the service
SM data from I1 port	None	Good quality	Medium

Service conclusions

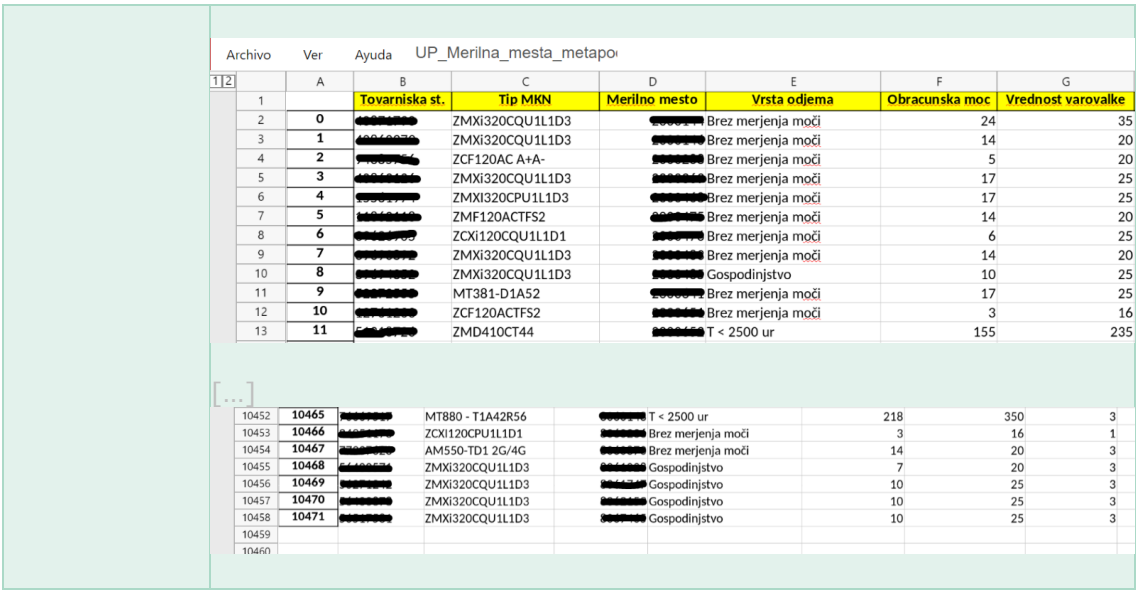
The service focuses on forecasting SM data, with the possibility of disaggregating the SM data into RES generation and flexible load profiles. This can be used for further analysis and optimization processes, as shown by S6.1. However, the disaggregated profiles could also prove beneficial for distribution system operators (DSOs) to perform a more thorough analysis of the low-voltage area of the grid and formulate schedules to address congestion and power quality (PQ) issues at the substation level.

The main challenges lie in the manual activation of flexible assets, the hardware required for the service and the need for sufficient historical data to create accurate models. Nevertheless, the forecasting tool with disaggregation function does not require supervised learning and can be easily deployed.

5 Project KPIs to be monitored in this deliverable

KPI 1.2: Dimension of data providers and volume of data managed

KPI Name:	Dimension of data providers and volume of data managed
KPI ID	1.2
Global objective	Large-scale dimension of demonstrator activities
Owner	EyPESA – Lluis Canaves Navarro
Definition	This KPI is targeting the dimension of data providers and volume of data managed, and aiming to include the following objectives: • O1.1. Relevance of pilot activities with respect to involved users, making sure there is a clear impact both in terms of technology/equipment and with respect to number of users involved. • O1.2. Involvement of different actors and impact on multiple stakeholders in the energy value chain. • O1.3. Scalability and replicability analysis to provide the needed means to both scale up from demo to large scale solutions and prove the same solution on multiple and different scenarios. As stated in the GA, the initial 1.2 KPI statement was the following: "Data providers that are DSOs have to provide data from at least 50.000 smart meters". However, during the development of the project it was detected that due to the huge variety of services needing other types of data apart from the SMs (i.e. market data or GIS data), and their partial unavailability in the 3 pilots, the target was unrealistic. Furthermore, OEDAS does not have SMs installed in their grid, except in few exceptional cases, and therefore cannot be considered for this KPI. Finally, in a later stage it was defined the target to 10.000 SMs for each pilot, only for ELCE and EyPESA. This number also considers not only the basic consumption curves, but also other parameters from SMs useful for the different services.
Involved partners	The involved partners are DSO's partners EyPESA and ELCE, and the data lake manager (WEP).
Calculation process and Formula	For ELCE, the calculation of smart meters sharing information is not needed. That is because it was taking a big sample of Smart Meters gathered in a single document, and through an automatized program, the information was uploaded in the data space. Also, worth mentioning some services that were using different data and it will be summed to the total amount of Smart Meters.
Unit	Number of Smart Meters
Target	Data providers that are DSOs and with high SMs deployment have to totally provide data from at least 20.000 digital meters.
Results at the end of the project	The total amount of Smart Meters sharing information, as seen in the picture above was 10.457 smart meters. It is also necessary to add 6 more counters from which it was drawn data in real time (JSI server). Then, 8 EV charging stations exporting data and 2 meters related to heat pumps. Finally, the final result is 10.473 smart meters.



Archivo Ver Ayuda UP_Merilna_mesta_metapo

	A	Tovarniska st.	Tip MKN	Merilno mesto	Vrsta odjema	Obracunska moc	Vrednost varovalke
2	0	[redacted]	ZMXi320CQU1L1D3	[redacted]	Brez merjenja moči	24	35
3	1	[redacted]	ZMXi320CQU1L1D3	[redacted]	Brez merjenja moči	14	20
4	2	[redacted]	ZCF120AC A+A-	[redacted]	Brez merjenja moči	5	20
5	3	[redacted]	ZMXi320CQU1L1D3	[redacted]	Brez merjenja moči	17	25
6	4	[redacted]	ZMXI320CPU1L1D3	[redacted]	Brez merjenja moči	17	25
7	5	[redacted]	ZMF120ACTFS2	[redacted]	Brez merjenja moči	14	20
8	6	[redacted]	ZCXi120CQU1L1D1	[redacted]	Brez merjenja moči	6	25
9	7	[redacted]	ZMXi320CQU1L1D3	[redacted]	Brez merjenja moči	14	20
10	8	[redacted]	ZMXi320CQU1L1D3	[redacted]	Gospodinjstvo	10	25
11	9	[redacted]	MT381-D1A52	[redacted]	Brez merjenja moči	17	25
12	10	[redacted]	ZCF120ACTFS2	[redacted]	Brez merjenja moči	3	16
13	11	[redacted]	ZMD410CT44	[redacted]	T < 2500 ur	155	235

10452	10465	[redacted]	MT880 - T1A42R56	[redacted]	T < 2500 ur	218	350	3
10453	10466	[redacted]	ZCXI120CPU1L1D1	[redacted]	Brez merjenja moči	3	16	1
10454	10467	[redacted]	AM550-TD1 2G/4G	[redacted]	Brez merjenja moči	14	20	3
10455	10468	[redacted]	ZMXi320CQU1L1D3	[redacted]	Gospodinjstvo	7	20	3
10456	10469	[redacted]	ZMXi320CQU1L1D3	[redacted]	Gospodinjstvo	10	25	3
10457	10470	[redacted]	ZMXi320CQU1L1D3	[redacted]	Gospodinjstvo	10	25	3
10458	10471	[redacted]	ZMXi320CQU1L1D3	[redacted]	Gospodinjstvo	10	25	3
10459								
10460								

KPI 2.1: Data coming from renewable technologies

KPI Name:	Data coming from renewable technologies
KPI ID	2.1
Global objective	Technological choice and provision of tools contributing to the Digital Marketplace for Energy
Owner	OEDAS – Ibrahim Tastan
Definition	Considering the uptake of renewable energy, it is important to have available data from different renewable technologies to shape adequate services. This KPI consist in the number of data sources available from different technologies. As some of the idential RE Sources are connected to the transmission level and services and pilot areas are tacling distribution level, the scope of KPI is therefore extended to renewable technologies and new technologies; like Energy Storage Systems, Heat Pumps, EV Chargers and V2G Chargers.
Involved partners	The involved partners are demonstration sites
Calculation process and Formula	$\left[\frac{\sum Renewable\ Energy\ Tech.Assets + \sum\ New\ Tech.assets}{No\ of\ Services\ in\ Pilot} + \frac{No\ of\ RE\ source\ types\ and\ new\ Tech\ typ}{Services\ Using\ "RE\ Tech.\ and\ New\ Tech.\ Assets}\right.$
Unit	Ratio
Target (Adapted)	Data available from 1 renewable energy asset (wind, PV Hydro, Geotermal) and 3 new technologies (ESS, V2G Charger, Heat Pumps, DC Chargers, etc.) Calculation result $\left[\frac{A}{B}+\frac{C}{D}\right] > 1$ should more than 1, A: No of Renewable Energy Tech. Assets +No of New Tech. Assets B: No of Services in pilot C: No of RE source types and New Tech typs D: Services Using "RE Tech. and New Tech. Assets" Datas in pilot
Results at the end of the project	Elektro Celje contributed aggregated data on electricity production from PVs for 14 secondary transformer stations, 8 DC Chargers and 2 Heat Pumps. So Parameter A is 14+8=24 and parameter C is 3 (different assets). A: No of Renewable Energy Tech. Assets +No of New Tech. Assets 24 B: No of Services in pilot 11 C: No of RE source types and New Tech typs 3 D: Services Using "RE Tech. and New Tech. Assets" Datas in pilot 5 Result : $\left[\frac{24}{11}+\frac{3}{5}\right] = 2{,}78 > 1$ Succeded.

6 Lessons learned & Conclusions

6.1 Lessons learned – Pilot's perspective

As electricity distributors, we have been collecting vast amounts of data from various sources, including smart meters, GIS systems, and billing systems. Despite this wealth of information, we have not been able to fully utilize it to improve our network operations. We recognize the potential of data to enhance our network management but lack the expertise to extract meaningful insights from it.

To address this challenge, we joined the BD4OPEM consortium, seeking partnerships with experts who could transform our data into practical services that would enable us to operate our distribution network more efficiently, especially on the low-voltage side. We were particularly interested in services that could help us forecast electricity demand and production, detect commercial losses in the network, improve network observability, and provide flexibility services.

At the beginning of the project, we discovered that our data was not in a usable format. In some cases, it was not clean or standardized, and, in some cases, it was not collected at all. Additionally, there were gaps in the data. Once the data was cleaned and standardized, our partners were able to develop services that could potentially benefit Distribution System Operators (DSOs).

The testing phase of the services highlighted the advantages of using data analytics to improve distribution network management. During testing, we also provided comments and ideas that will allow service providers to improve the service.

Since we are developing a big data platform within our company, we are exploring the possibility of integrating some of these services into our platform.

This project has emphasized the importance of data quality and accessibility in gaining valuable insights. We have also learned the value of collaboration within the consortium, which has allowed us to overcome knowledge gaps and explore innovative solutions for efficient distribution network management. And on the other hand, solution providers and service developers have become aware of network operators' needs and the problems they face.

6.2 Lessons learned – Service developer's perspective

From the service developers' perspective, the Elektro Celje (ELCE) pilot has been an invaluable source of challenges and insights. The integration of data services in low-voltage (LV) grids, where historical issues were identified, has provided practical scenarios for service development. The conditions set for data applicability, such as data quality, accessibility, and relevance to potential service problem-solving, have proven to be essential criteria for successful service validation.

The ELCE pilot has been the place to deploy different services, including grid disturbances, impact studies, non-technical losses, flexibility services, real-time data services, and predictive maintenance. The pilot's focus on 14 substations with approximately 600 consumers, equipped with newer generation smart meters,

demonstrates a proactive approach to addressing operational challenges in the distribution network.

6.3 General conclusions

The Elektro Celje pilot within the BD4OPEM project serves as a comprehensive testing ground, encompassing a wide array of services aimed at enhancing the efficiency and resilience of the electricity distribution network. The successful implementation and testing of services in LV grids with real-world challenges validate the scalability and adaptability of the developed tools.

The rich dataset derived from various sources, including the Advanced Metering Infrastructure (AMI), Geographic Information System (GIS), and real-time stream data from smart meters, contributes to the project's success. The collaboration with developers, such as ODT, JSI, UPC, and VUB, reinforces the project's commitment to a diverse range of expertise and was a success.

As Elektro Celje faces challenges associated with high renewable energy integration, data management, and grid optimization, the lessons learned from this pilot will undoubtedly inform the ongoing refinement of the BD4OPEM platform. The legal compliance with data protection regulations and the proactive adoption of privacy measures underscore Elektro Celje's commitment to ensuring a secure and ethical deployment of smart grid technologies.

Looking ahead, the insights gained from the ELCE pilot will not only contribute to the continued improvement of the BD4OPEM platform but will also serve as a valuable reference for other electricity distribution companies and service developers seeking to navigate the complexities of energy services deployment in dynamic grid environments.

7 Appendix A: Storylines

S1.1 – Topology

Contract service

1. Go to the Marketplace main page and go to the search bar and look the service *"Topology and network analysis".*
2. Select the service desired
3. Contract the service, following the default and/or required contract parameters. Upload the data as required.
4. Execution of the service

Usability testing

5. After executing the service, follow the indicated steps to test several aspects.

    a. Go to *https://app.bd4opem.odit-e.com* and try to login (Figure 102).

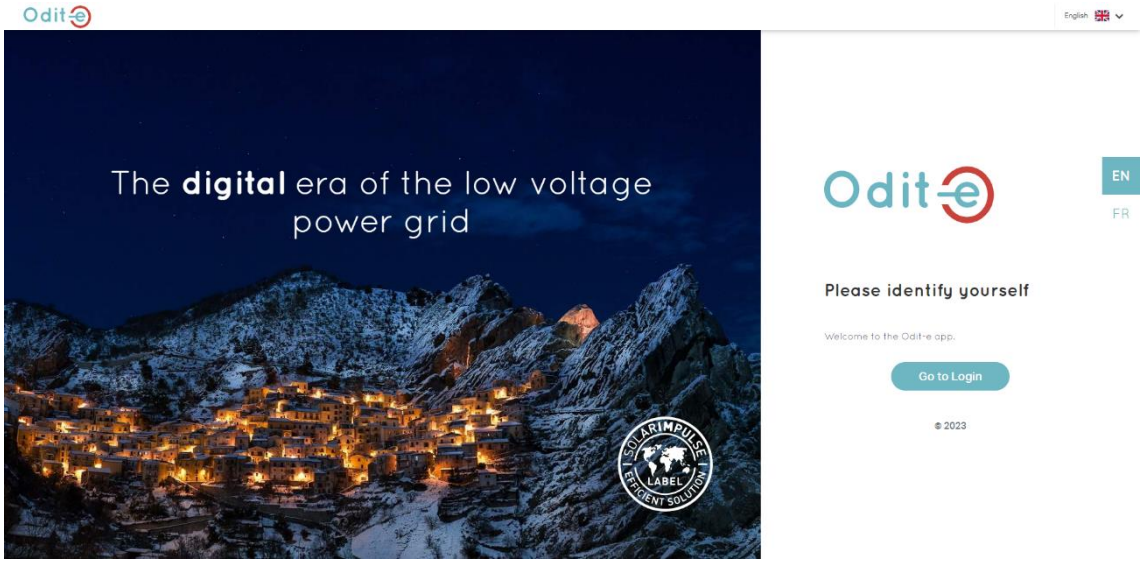


Figure 102. Odit-e app

    b. If login succeed, you should see a map with all your secondary substations (**Figure 103**).

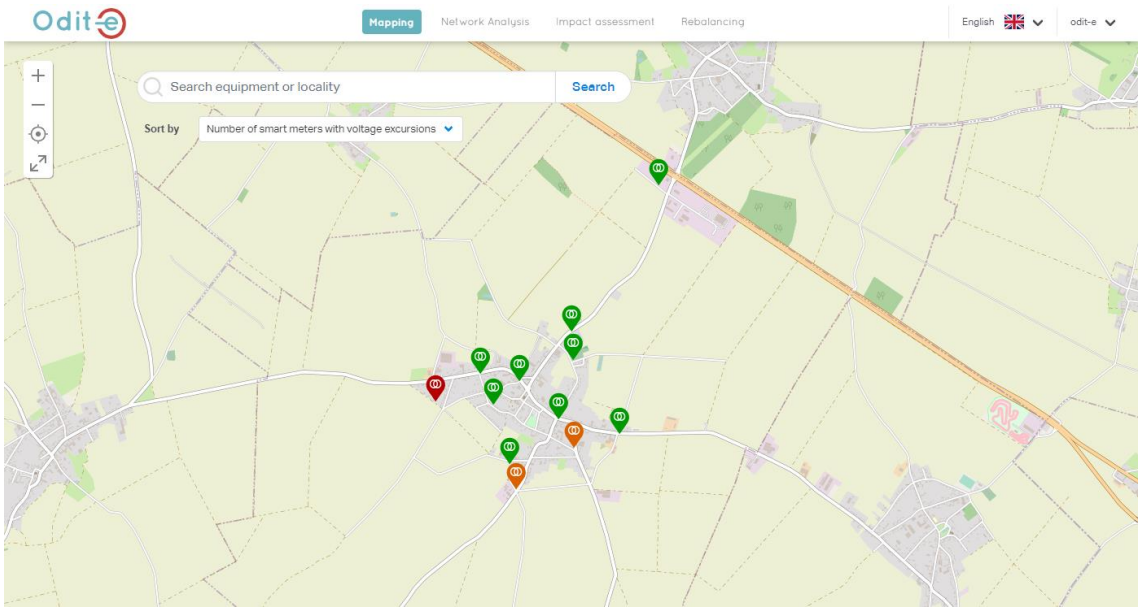


Figure 103. Map with all secondary substations

c. Click on a substation. A panel should open and display all smart meters linked to the substation (Figure 104). If GPS coordinates are given, smart meters should also appear on the map.

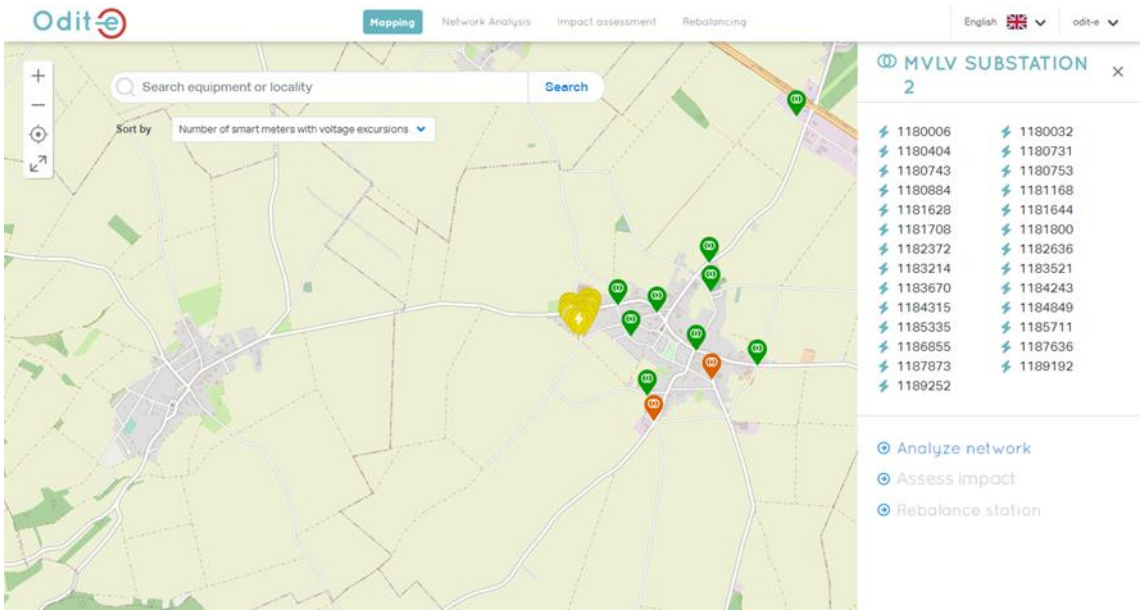
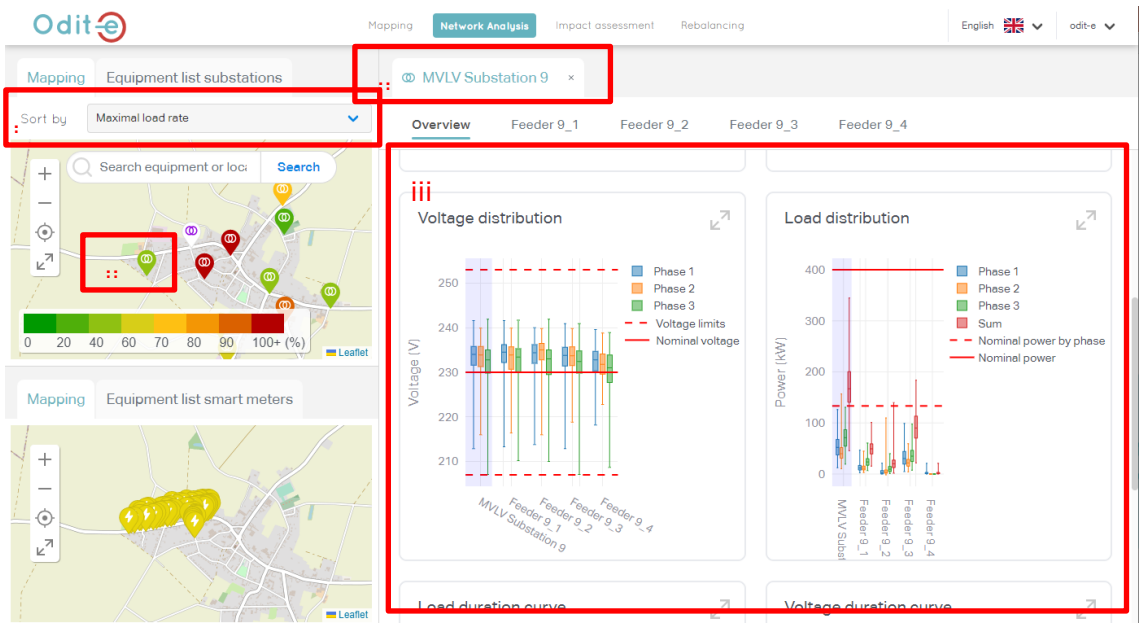
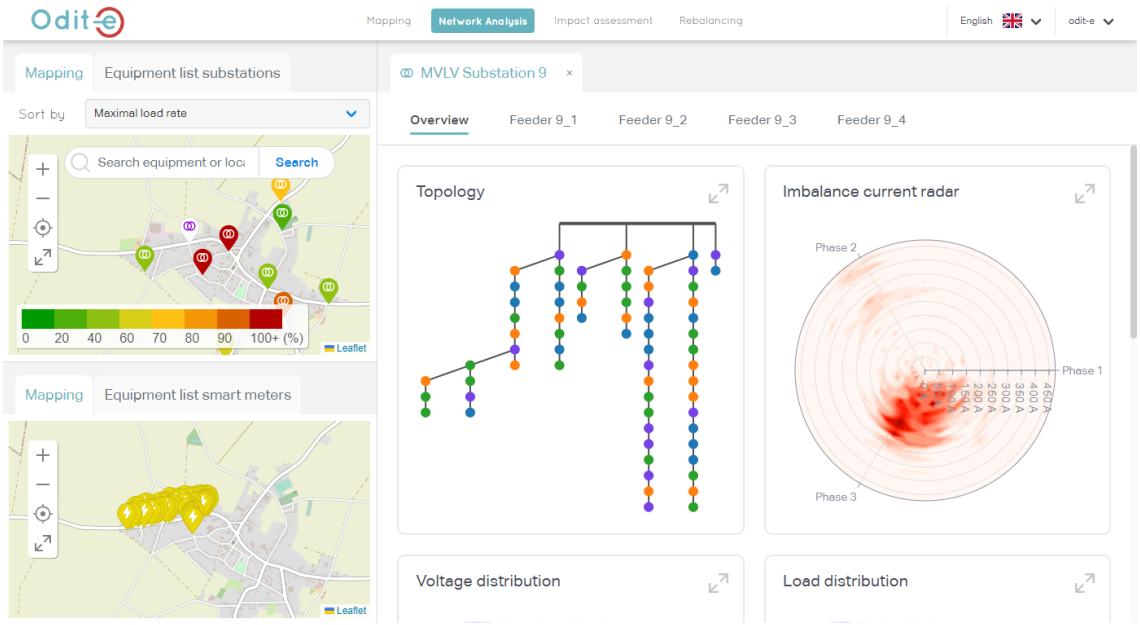


Figure 104. Display of all smart meters connected to the selected substation

d. You can then click on *Analyze network* or on *Network analysis* tab to open the network analysis. On the network analysis page, you should be able to:
    i. Change filter on map to sort substation by load rate, imbalance rate, etc.
    ii. Select a substation by clicking on it

iii. For a selected substation, see different graphs : single wired topology, imbalance current radar, voltage and load distribution, voltage and load time duration curves (Figure 105).





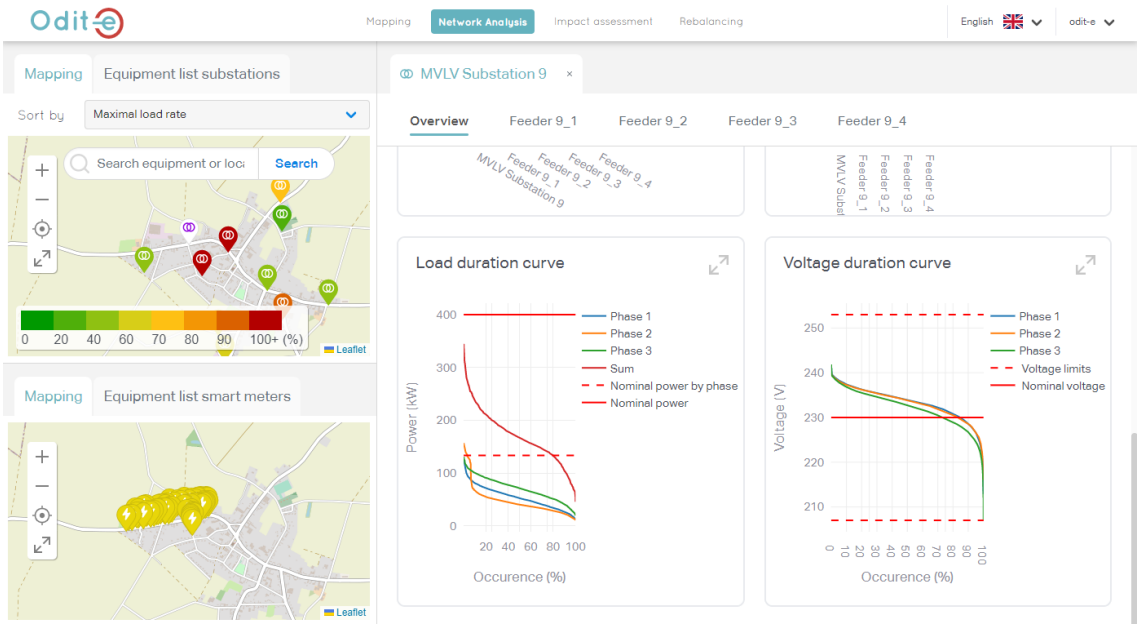


Figure 105. Single wired topology, imbalance current radar, voltage and load distribution, voltage and load time duration curves

6. Fill the questionnaire provide following the results and experience perceived after following the previous steps.

S1.2 – Observability

Contract service

1. Go to the Marketplace main page and go to the search bar and look the service "*Observability*".
2. Select the service desired
3. Contract the service, following the default and/or required contract parameters. Upload the data as required.
4. Execution of the service

Usability testing

5. After executing the service, follow the indicated steps to test several aspects.

    a. Go to *https://app.bd4opem.odit-e.com* and try to login (Figure 106).

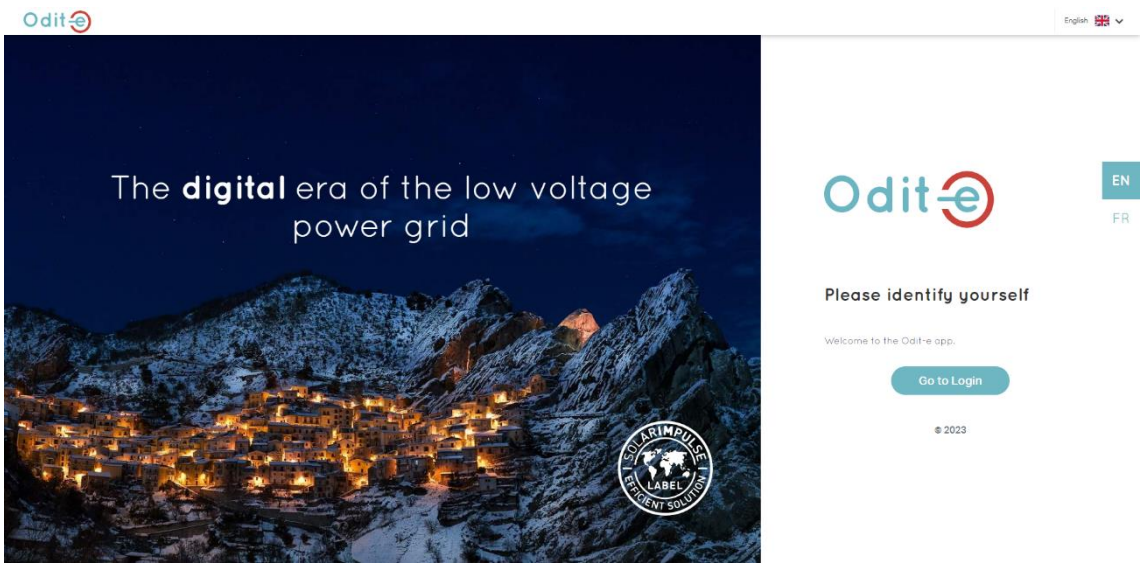


Figure 106. Odit-e app

b. If login succeed, you should see a map with all your secondary substations (Figure 107).

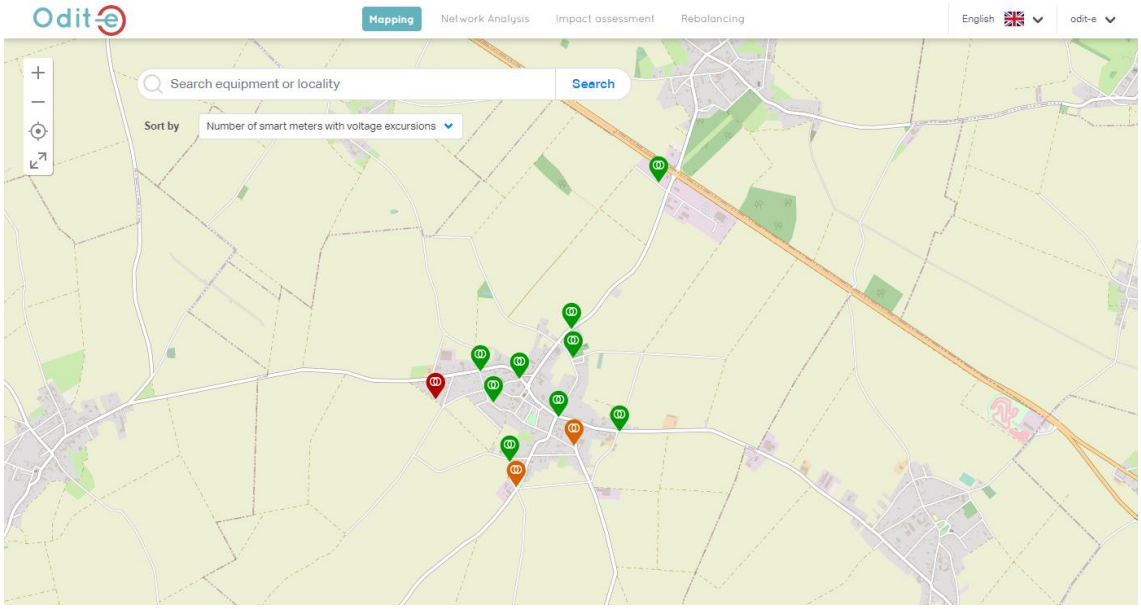


Figure 107. Map with all secondary substations

c. Click on a substation. A panel should open and display all smart meters linked to the substation (Figure 108). If GPS coordinates are given, smart meters should also appear on the map.

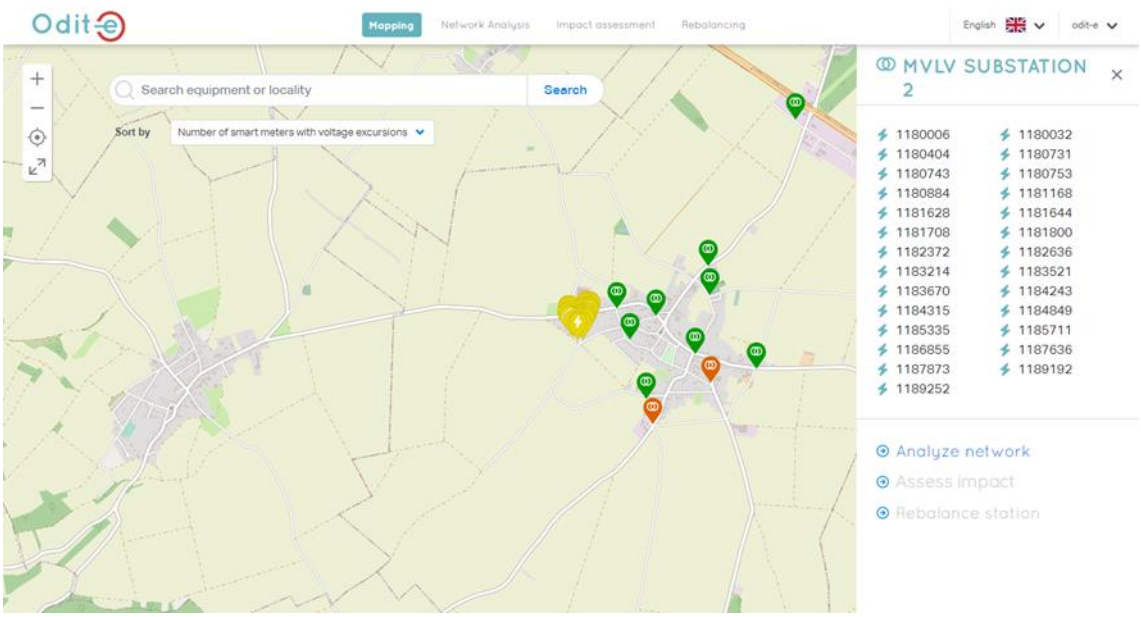
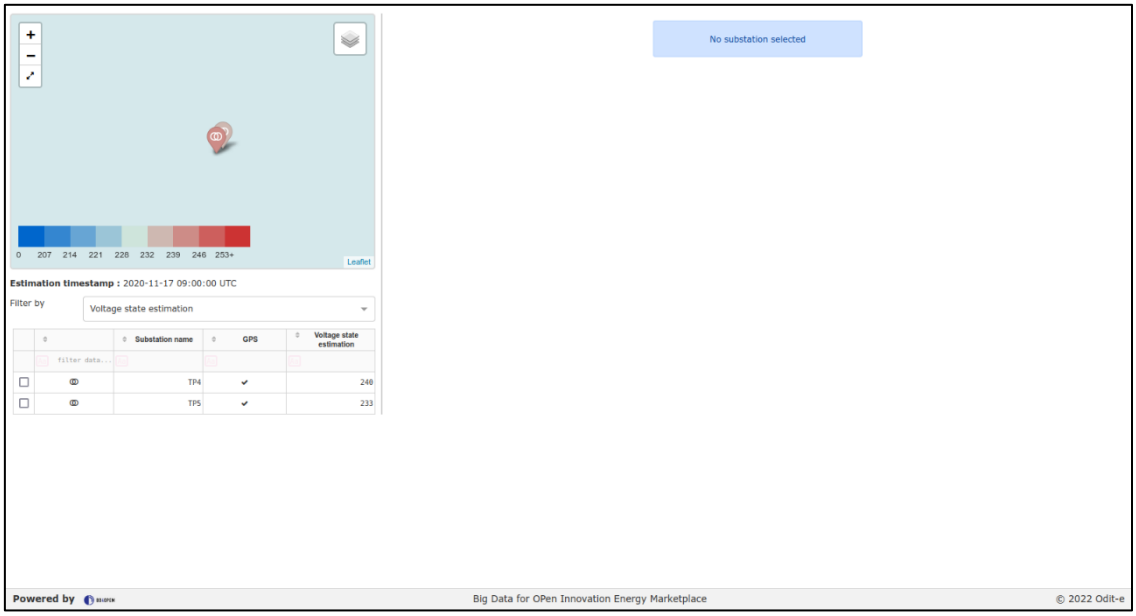
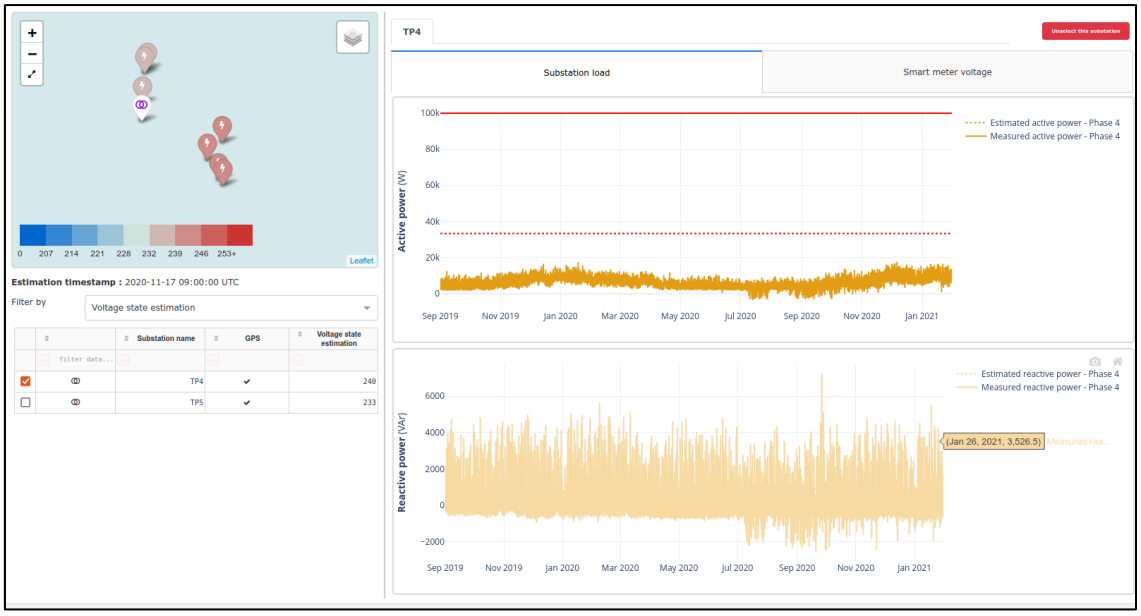
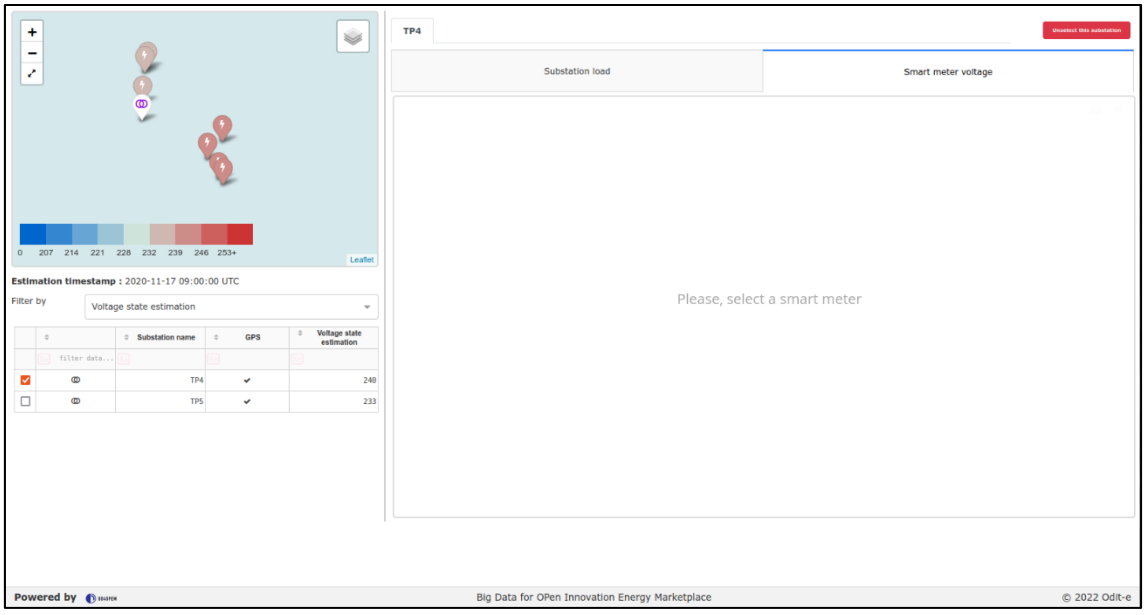


Figure 108. Display of all smart meters linked to the substation

d. You can then click on *Observability* tab to open the low voltage network state estimation. On the observability page, you should be able to:
    i. Change filter on map to switch between voltage or load state estimation.
    ii. Select a substation by clicking on it
    iii. For a selected substation, see different graphs: active and reactive load estimated and measured (if available)
    iv. Once a substation is selected, you may select on the map a smart meter to get its voltage state estimation (Figure 109).




TP4
Unselect this substation
Substation load
Smart meter voltage
Active power (W)
Estimated active power - Phase 4
Measured active power - Phase 4
Reactive power (VAr)
Estimated reactive power - Phase 4
Measured reactive power - Phase 4
(Jan 26, 2021, 3,526.5)
Estimation timestamp : 2020-11-17 09:00:00 UTC
Filter by
Voltage state estimation
Substation name
GPS
Voltage state estimation
TP4
TP5


TP4
Unselect this substation
Substation load
Smart meter voltage
Please, select a smart meter
Estimation timestamp : 2020-11-17 09:00:00 UTC
Filter by
Voltage state estimation
Substation name
GPS
Voltage state estimation
TP4
TP5
Powered by
Big Data for OPen Innovation Energy Marketplace
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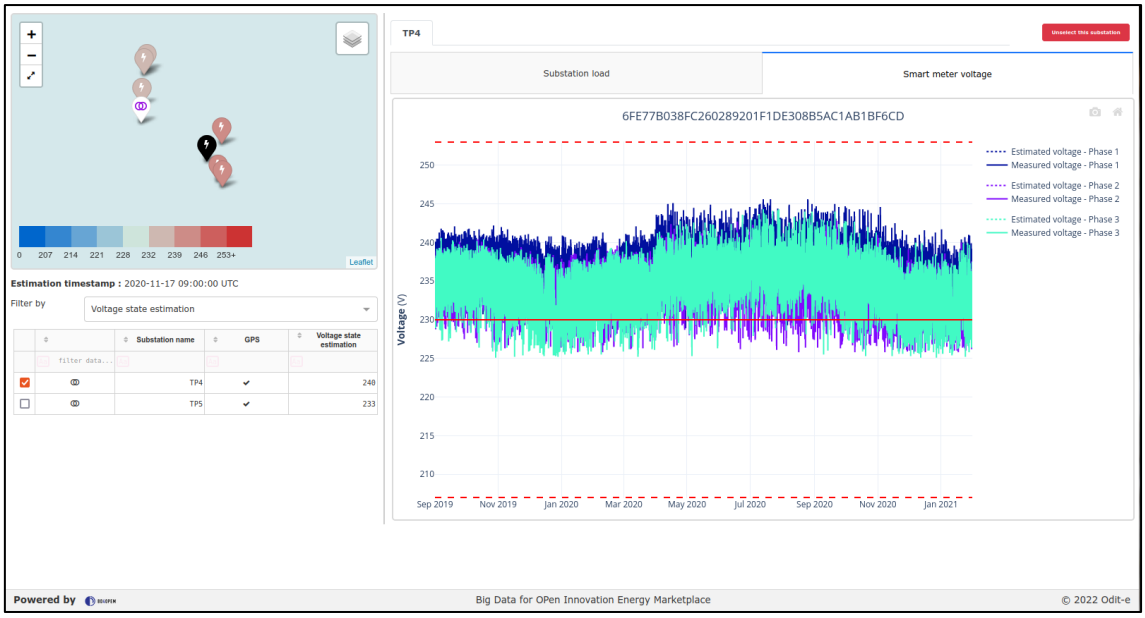


Figure 109. Voltage state estimation of the selected smart meter

6. Fill the questionnaire provide following the results and experience perceived after following the previous steps.

S1.3 - Predictive maintenance in electric power systems

Introduction

The predictive maintenance service provides a solution for a class of predictive maintenance challenge that is common in energy services networks and systems. The challenge addressed is to detect sub-classes of equipment with maintenance probability deviating from normal of the class.

The prediction solution utilizes forecasting to predict possible failures of classes of equipment in the next period or maintenance cycle. The forecasting is applied separately to each class of equipment, for example smart meter, concentrator, etc. The forecasts are observed in dependence on the sub-class of the equipment, for example for type of smart meter, smart meter producer, smart meter series, year of production, and similar. For the sub-classes of the equipment the solution tries to estimate if some of the sub-classes will have a significantly larger number of failures - or greater than the expected - then the others in the future. Such sub-classes are flagged and reported to the service user.

The service can be run either standalone as a Jupyter notebook or through an ASM framework.

For the service a reasonable set of maintenance data about a class of equipment is needed. A set of failures/errors recorded for the equipment in a larger time span is needed, with rough time estimates of failures/errors. The foreseen minimal granularity is a month. The time span should be longer than three years.

The service takes two parameters:

- maintenance_period: specifies the period of maintenance to be monitored, either a year or a month
- max_failures: max failures to be observed in the period in percent to flag the subclass of equipment for inspection. 0% triggers internal calculation for proper max_failures value.

Data contract

First, we need a data contract for the service. On the "Search" page of the Marketplace, we search for "predictive maintenance" data. It should be the only result (Figure 110).

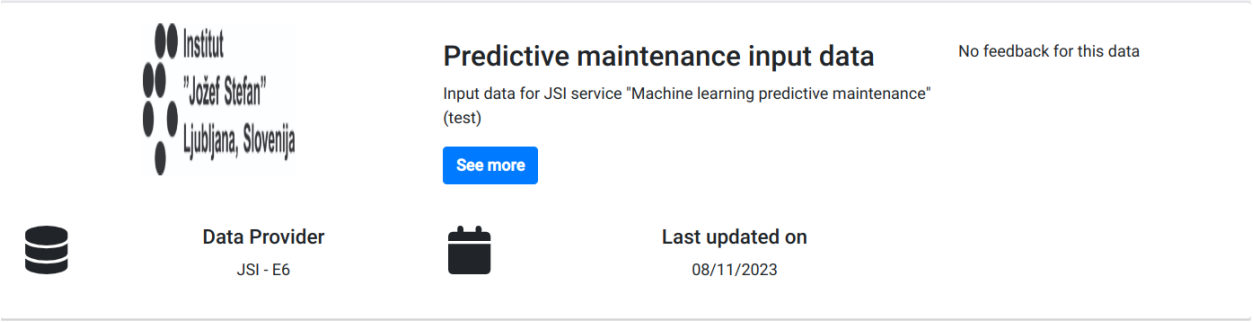


Figure 110. Contracting data for S1.3 (JSI)

Click on "See more", then "Contract data" at the very bottom. Give the contract whichever name, for example "S1.3 data". For the data period, select today's date as "From", and whichever date in the future as "To". Finally, press "Submit" (Figure 111).

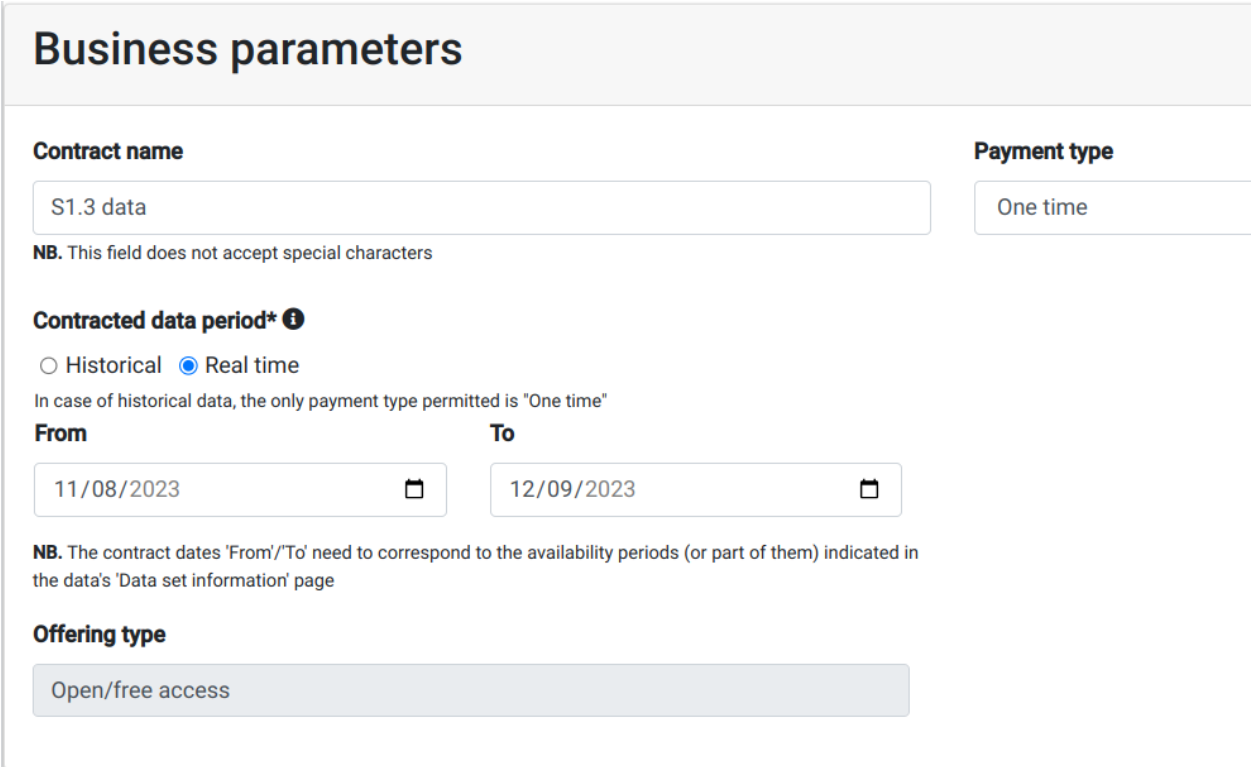


Figure 111. Business parameters for S1.3 (JSI)

Service Provisioning receives the data contract right after the "Submit" button is pressed. You should be able to see your data contract request in the "My Data" page, with the role "Data User" (Figure 112). The contract status should be COMPLETE.

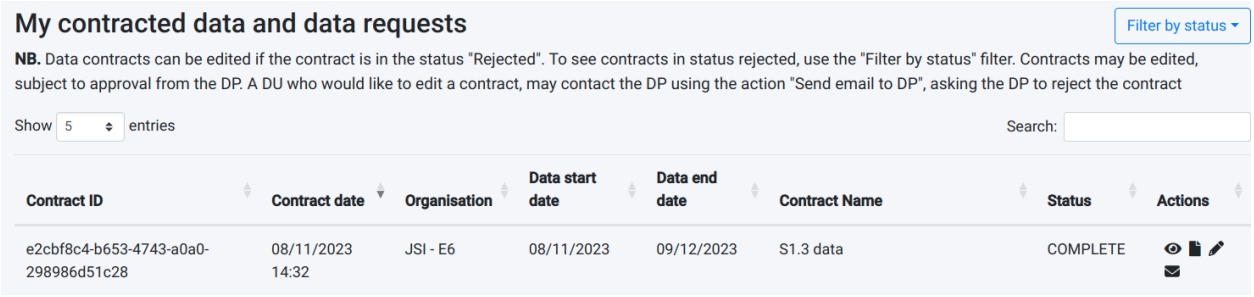


Figure 112. Displey of contracted data and data requests for S1.3 (JSI)

However, to be able to use the data contract, it needs to be approved and activated by the Data Provider (in this case, JSI). Approving and activating the data contract will advance the contract status from COMPLETE to APPROVED, and then to ACTIVE. Once contract status is ACTIVE, it can be selected when contracting a service, as we will see shortly.

Service contract

Contracting a service follows similar steps as contracting data. Service S1.3 can be found on the Marketplace under the name "Machine learning predictive maintenance". Under "Advanced search", we can also select "JSI - E6" organization to filter the results (Figure 113).

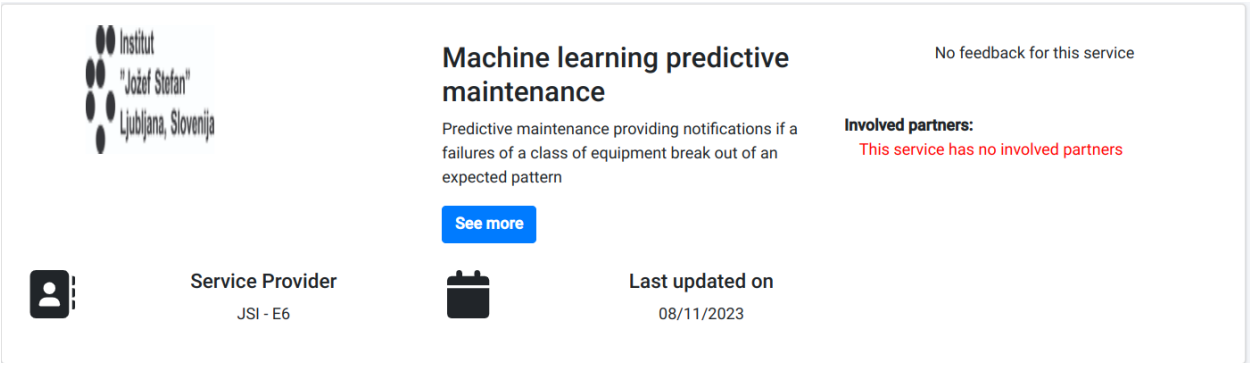


Figure 113. Contracting Servis S1.3 (JSI)

Click on "See more", and then "Request new service" at the top of the page. We first fill in the business parameters, same as for the data contract. Contract name can be whatever, for example "S1.3 test contract [today's date] - ELCE". Leave "Payment type" as is, and select the contract period (Figure 114).

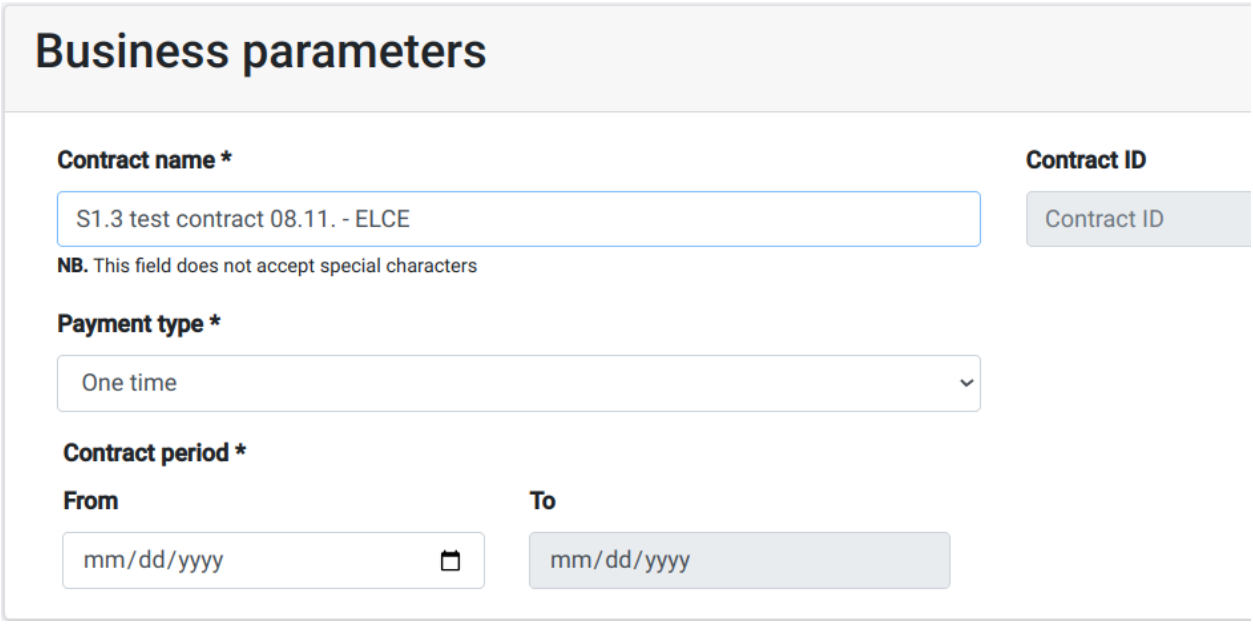


Figure 114. Business parameters of Servis S1.3 (JSI)

Next, we select the technical parameters (Figure 115). Select one value for each technical parameter. A description of each parameter can be seen in the image.

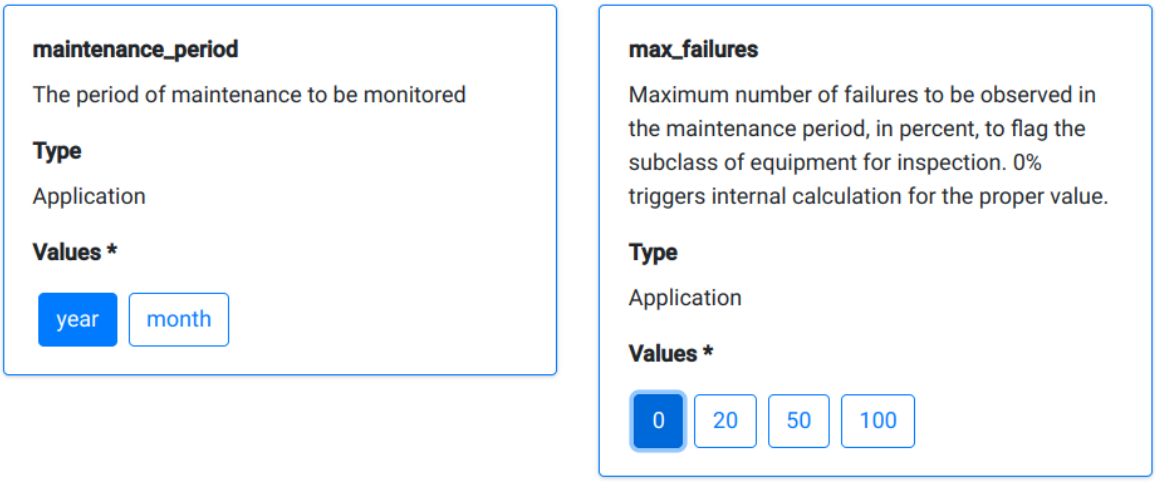


Figure 115. Technical parameters of Servis S1.3 (JSI)

We then select the corresponding data contract. Find the "S1.3 data" (or whatever name you put) data contract, check it, and click "Confirm". The data contract will not be present unless it was activated by the Data Provider. Be sure to also select "Yes" for "Enable immediate execution", otherwise the service will not actually be run in the ASM module (Figure 116).

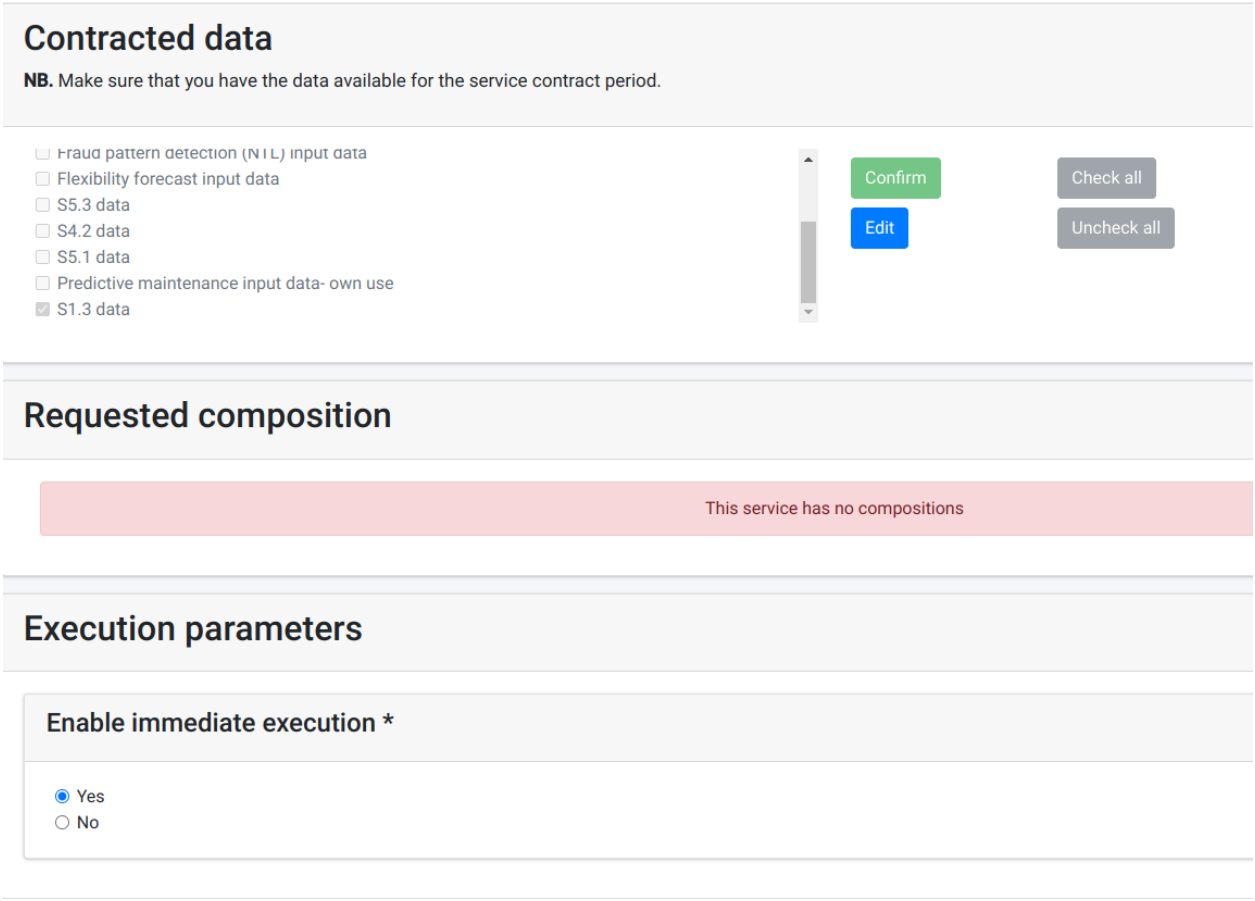


Figure 116. Corresponding data contract of Servis S1.3 (JSI)

Finally, click on the "Request service" button at the bottom. Similarly as for the data contract, Service Provisioning receives the contract right after the button is pressed. You should be able to see your service contract request in the "Service requests" table, found on the "My Services" page, with the role set to "Service User". The contract, provisioning and execution status should be as in the Figure 117.

Figure 117. Technical parameters of Servis S1.3 (JSI)

Running the service

Similarly, to be able to use the service contract, it needs to be approved and activated by the Service Provider (in this case, JSI). Immediately after the contract is activated, an instance of the S1.3 service will be started in the ASM module. This will happen because the service is set to be auto instantiated *if* immediate execution was set to "Yes".

As soon as the contract is activated, i.e. the service starts executing in ASM, the Marketplace will provide us with a link to our front-end, where we can see the logs

and results of the service. This link is accessible via the "Go to service" button, present in the corresponding entry in the "Service requests" table (Figure 118).

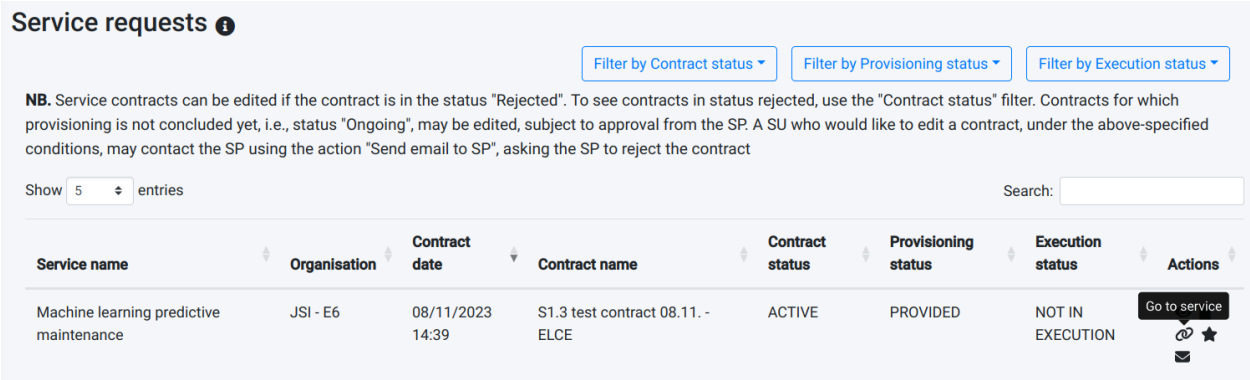


Figure 118. Technical parameters of Servis S1.3 (JSI)

Clicking on the "Go to service" button takes us to our front-end (Figure 119).

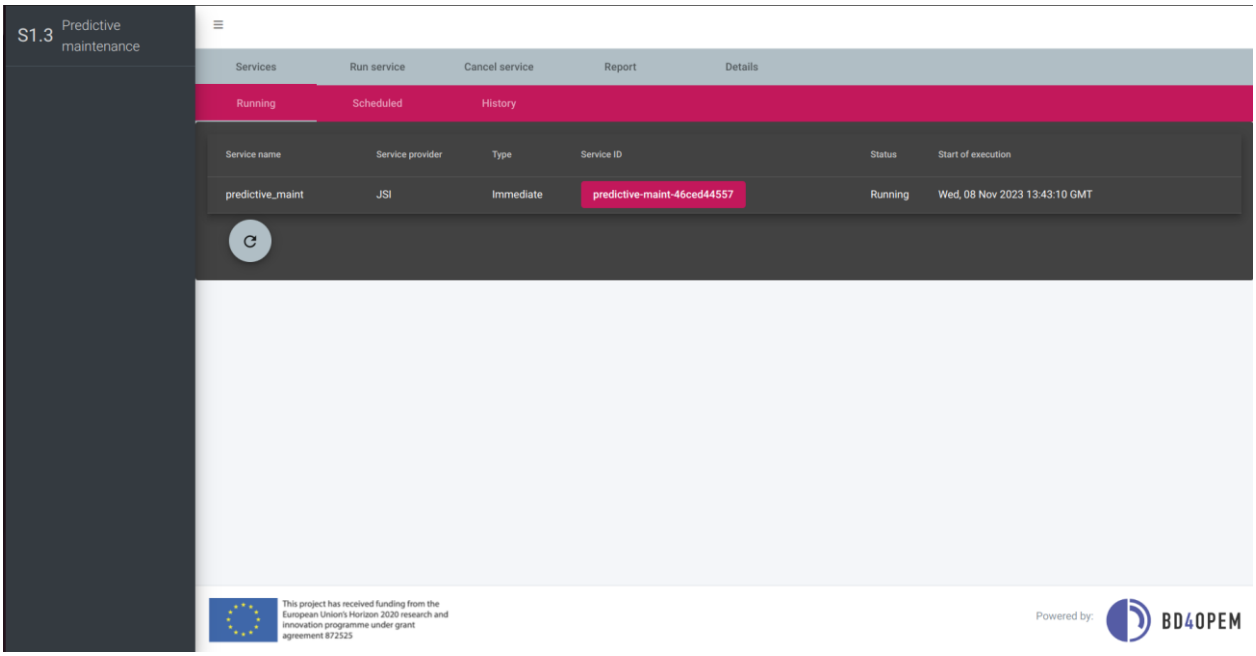


Figure 119. Details page

If the service is still executing, it should be present in the "Running" tab. Clicking on the ID in the "Running" tab will take you to the "Details" page and stream any logs of the service.

If the service has finished, we should be able to find it in the tab "History". You can click on the refresh button to see whether it has. By clicking on the service ID in the "History" tab, the report i.e result of the service will be fetched and you will be automatically moved to the "Report" tab (Figure 120).

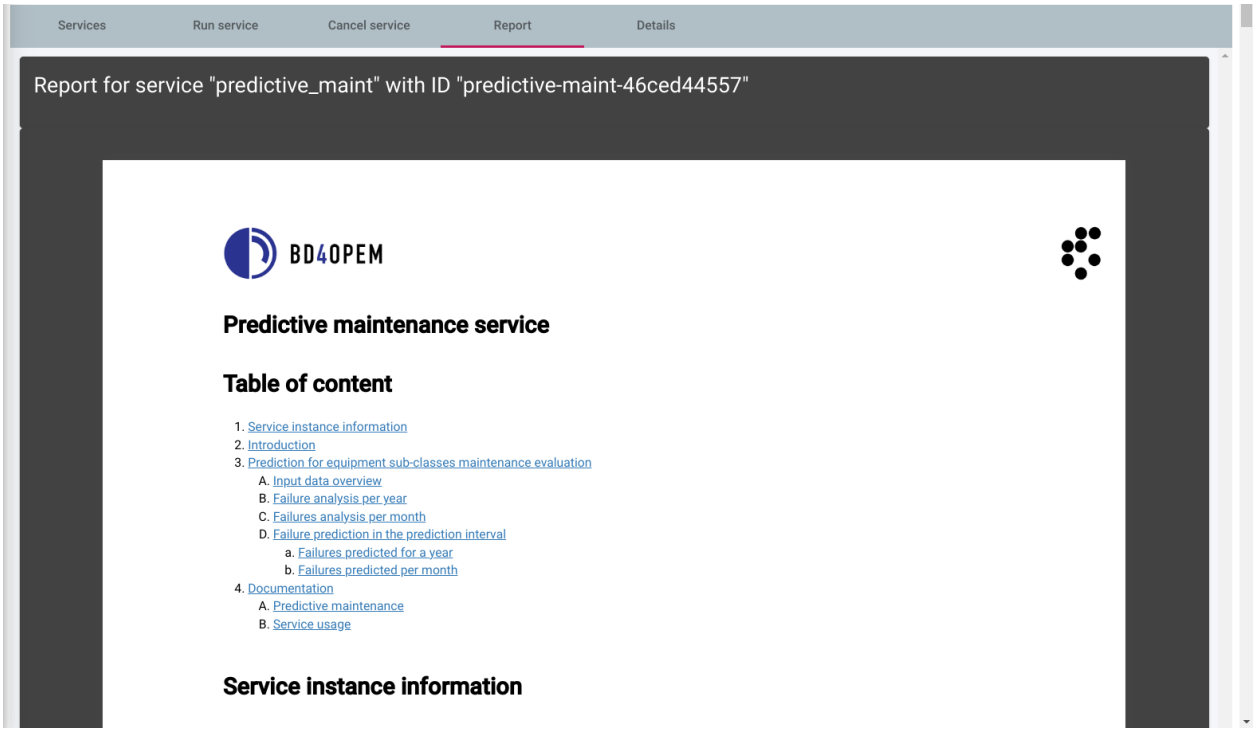


Figure 120. Tab with resaults of the Servis

Additionally, by clicking on the tab "Details", you will be able to see the technical parameter values you selected, as well as any stdout and stderr logs of the service.

S3.1 Grid disturbance simulations

S3.1 – Grid disturbance simulations

1. Contract the service with the demanded parameters.
2. You will get your contracts on top. Select the desired to investigate (Figure 121).

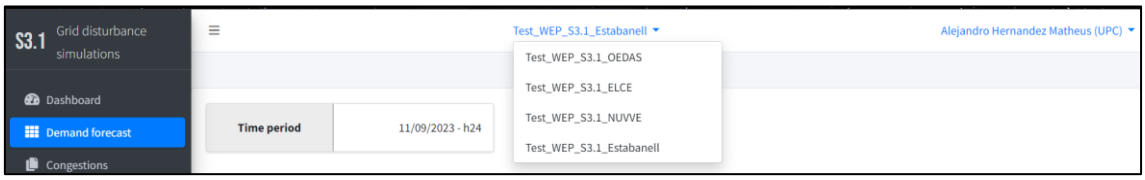


Figure 121. Contracting service

3. Go to *Demand Forecast* tab and browse to several loads from the breakdown list and check the demand forecasted for a few loads and evaluate the response for each plot.
    a. Check first aggregated demand (Figure 122).

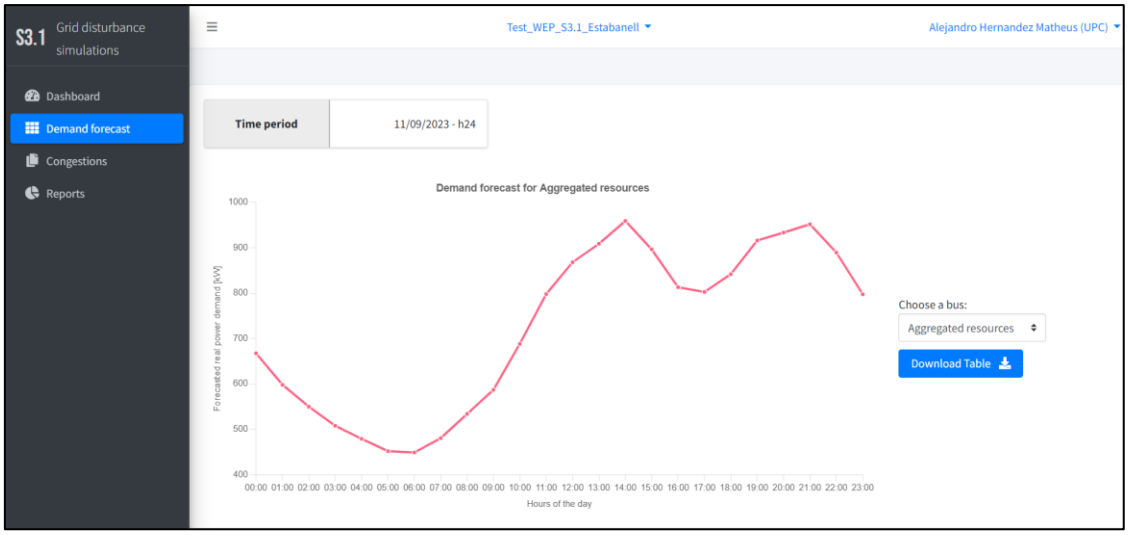


Figure 122. Displey of aggregated demand

b. Scroll through the dropdown list and review the forecast of other loads (Figure 123).

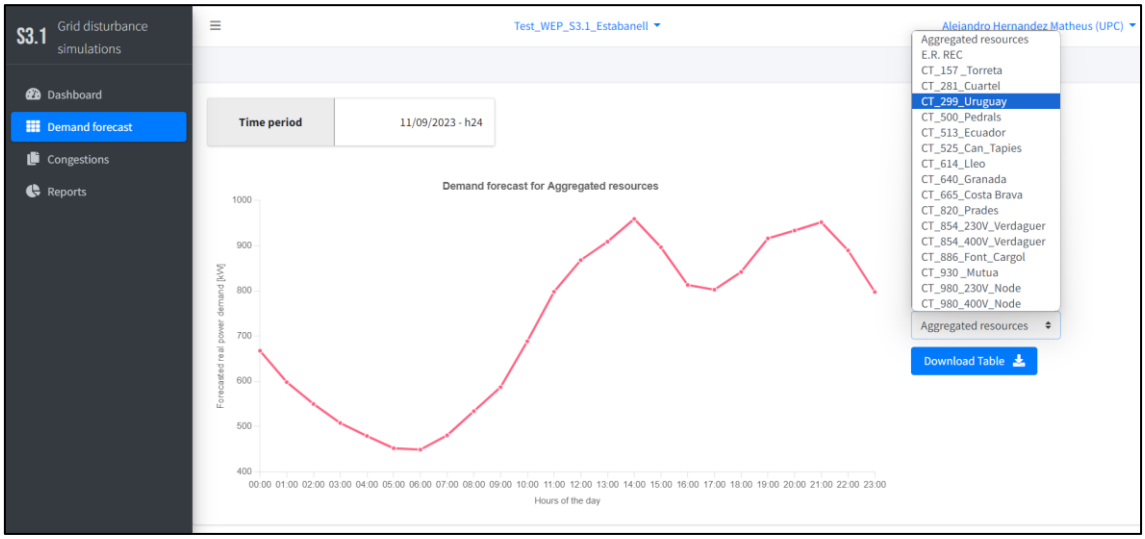


Figure 123. Dropdown list and forecast of other loads

4. Move to *Congestions* and select different lines to analyze their congestions, if any. Select to show the forecasted behavior for *Line* 1 - Figure 124 and *Line 2* – Figure 125. Following, select the *download button* to get the results in excel format for further analysis.

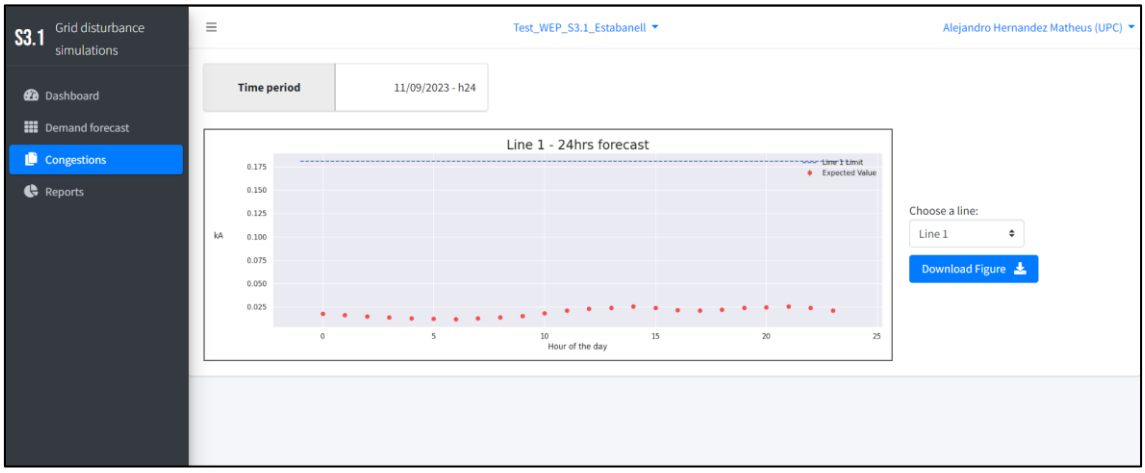


Figure 124. Congestion line 1

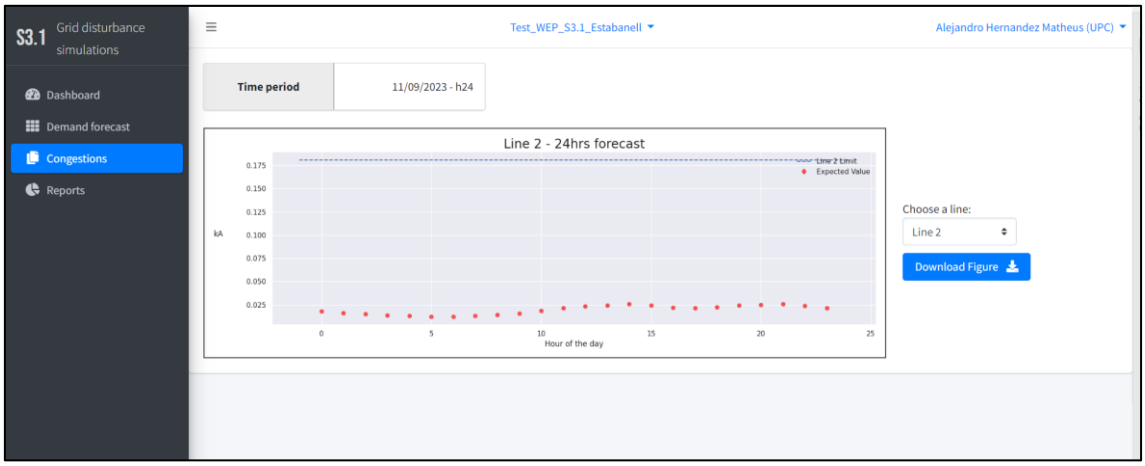


Figure 125. Congestion line 2

5. Go to *Report* tab (Figure 126), scroll down to appreciate the probabilities of congestions for all the lines for the all times of the day. Finally, push the *download file* button to obtain the report in excel form.

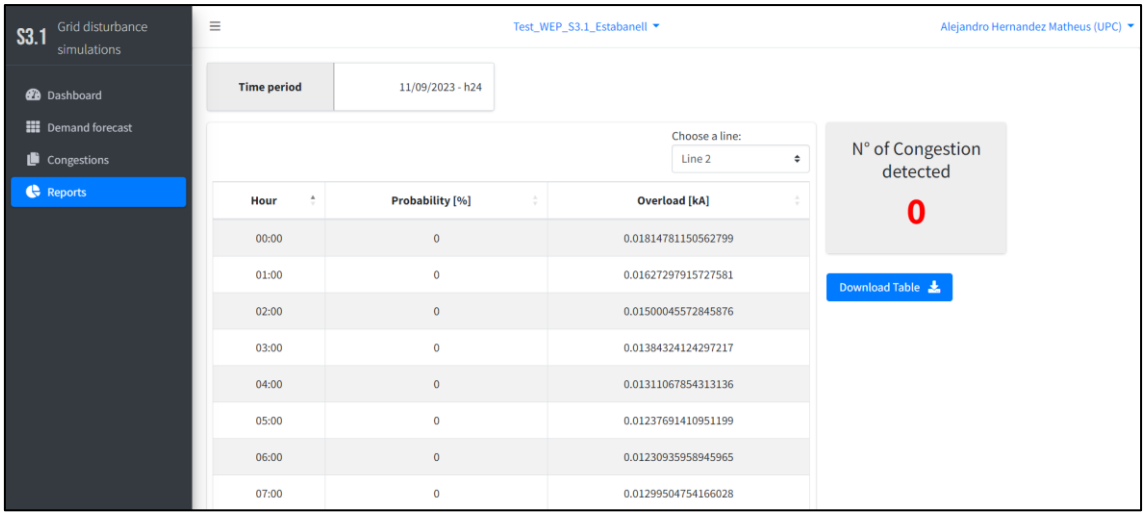


Figure 126. Report tab

S3.1 – Grid disturbance simulations

1. Go to the Marketplace main page and go to the search bar and look for the service "*Grid disturbance simulations: PQ-related disturbances".*
2. Select the desired service
3. Contract the service, following the default and/or required contract parameters. Upload the data as needed.
4. Execution of the service through the marketplace or by login to the marketplace and running http://s31jsi.bd4opem.eu/
5. Usability Testing: After executing the service, follow the indicated steps to test various aspects
   a. Figure 127 shows the available contracts for this service. You can select the appropriate one.

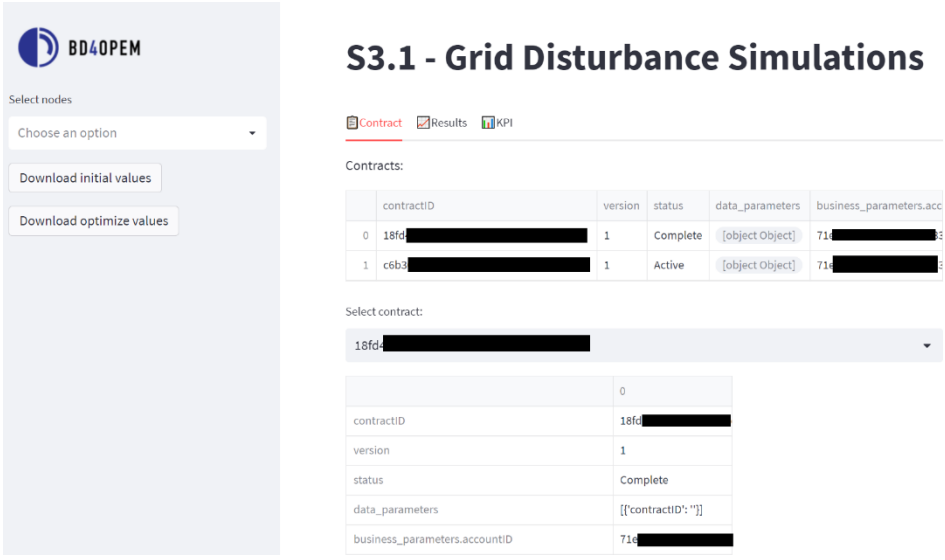


Figure 127. Available contracts for Service S3.1 (JSI)

   b. Go to the Results tab where you will see the topology of the grid that was simulated. On the left sidebar, you can select the nodes in which you are interested. After choosing the nodes of interest, the graphs will be shown

below the topology figure with initial and optimal values for selected nodes (Figure 128). Due to transparency, only 5 nodes can be chosen; otherwise, the graphs are overcrowded.

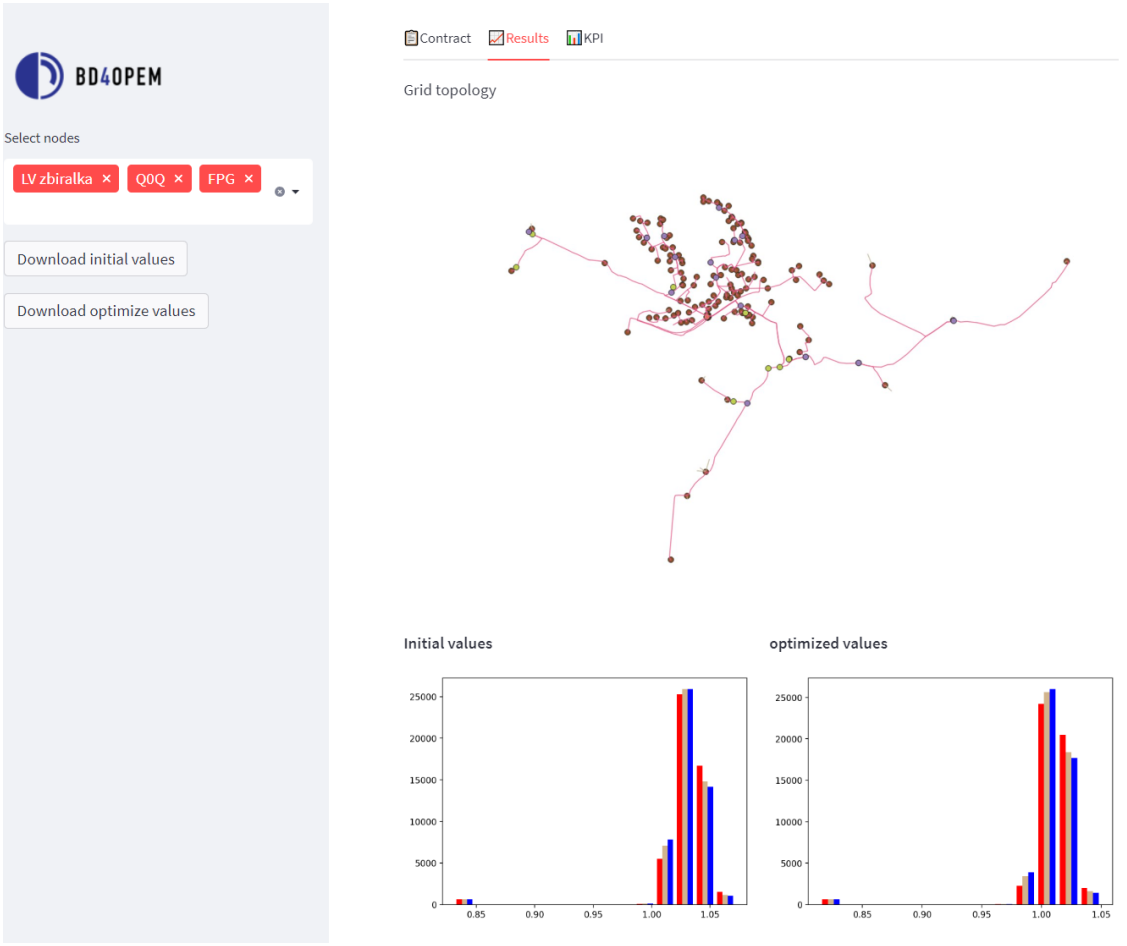


Figure 128. Grid topology

c. Move to the KPI tab to see each node's KPI (Figure 129). KPI<1 means there was some improvement obtained with the measures taken. Since these are manual simulations, all possible measures are defined before simulation and only the optimal is shown.

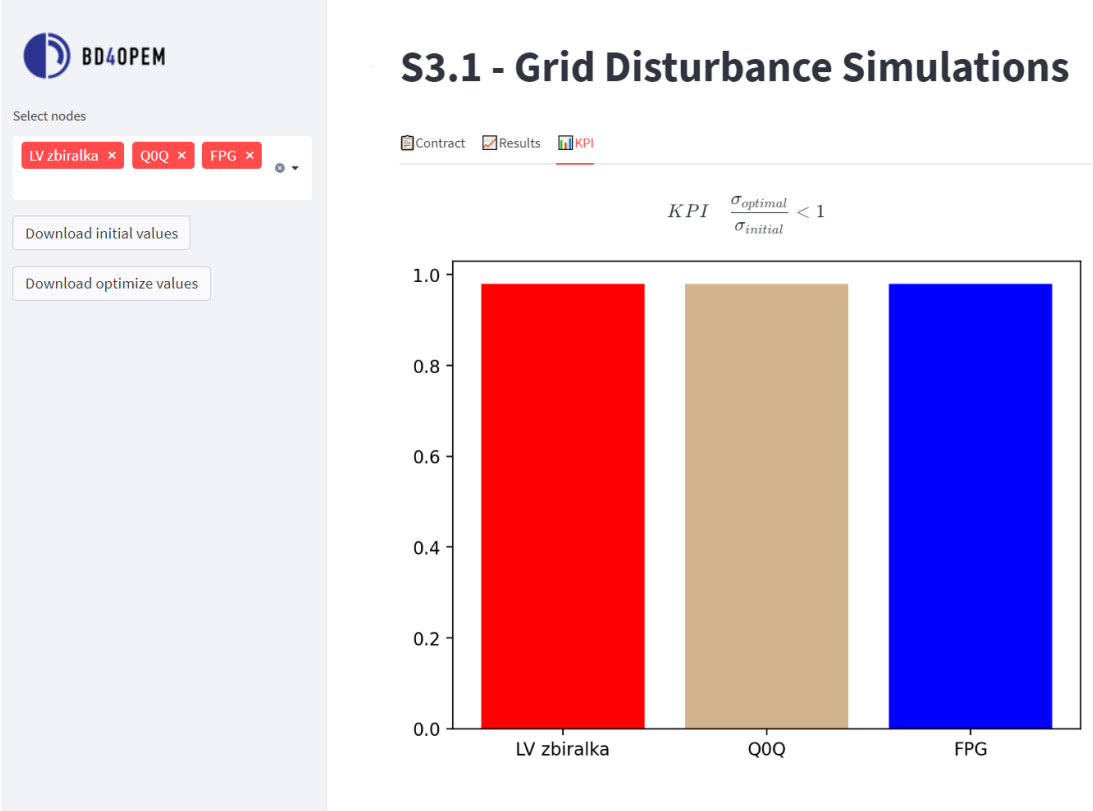


Figure 129. KPI for Service S3.1 (JSI)

d. On the left side, you have two buttons to download all the numerical data of the initial state of the grid and for optimal value in CSV format.

6. Fill out the questionnaire following the results and experience perceived after the previous steps.

S3.1 – Grid disturbance simulations

[IMPORTANT !] Data should be contracted prior to the service contracting, this in order to contract the service with the required data, see pt. 3.

1. Go to the Marketplace main page (https://marketplace.bd4opem.eu/) and using the search bar, look for the service *"Congestion control in distribution grids"* (Figure 130).

Figure 130. Congestion control in distribution grids

2. Select the desired service (‘**See more**’) and follow the instructions.
   NOTE: the contract period is the period during which the service will be accessible.

3. Contract the service, following the default and/or required contract parameters. Select the data as needed by checking the box of the data (Figure 131):

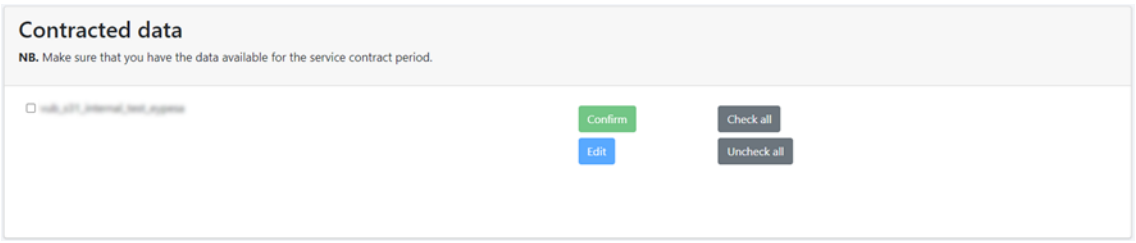


Figure 131. Contacted data

Once the service has been approved by the ‘**Service Provider**’ on the marketplace you can proceed to the next steps :

4. Execution of the service through the marketplace, make sure you are logged in as ‘**Service User’**, see top right corner. Click on ‘🔗’ to access the service (Figure 132):

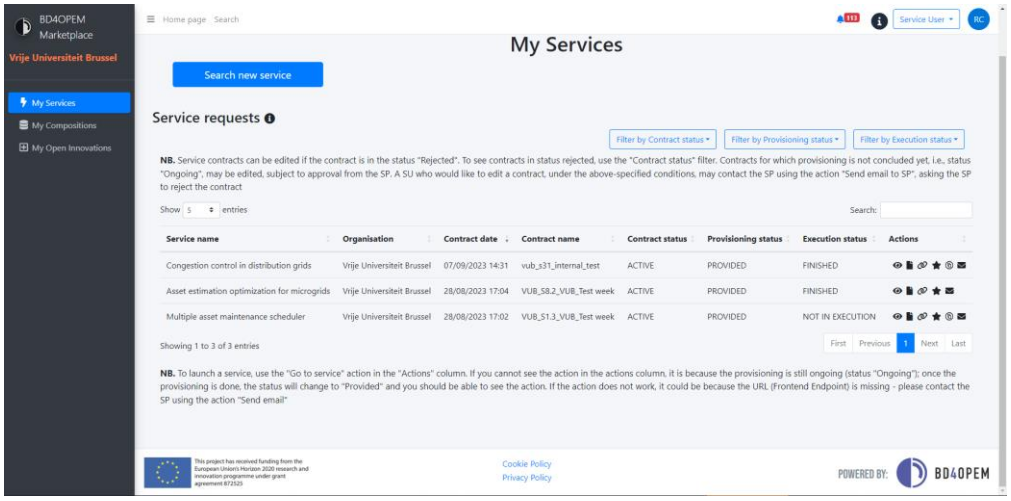


Figure 132. My Services

Or after being logged in on the the marketplace, you can directly run the service by navigating to : https://s31vub.bd4opem.eu/.

5. **Usability Testing**: After executing the service, follow the indicated steps to test various aspects.

   a. Initial screen displays the ‘***Dashboard***’ including information such as the contract duration and latest update (Figure 133).

      NOTE: your contract ID appears at the top.

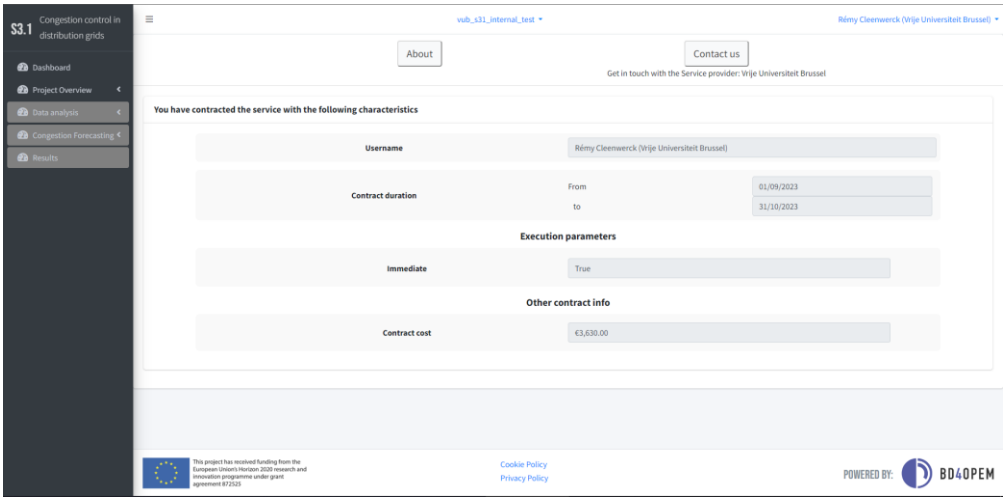


Figure 133. Displey of contract ID

b. Go to the '***Project Overview***' tab, there you will find a list of all the projects you created including details such as the amount of grids you added to each project and a description of the project (Figure 134).

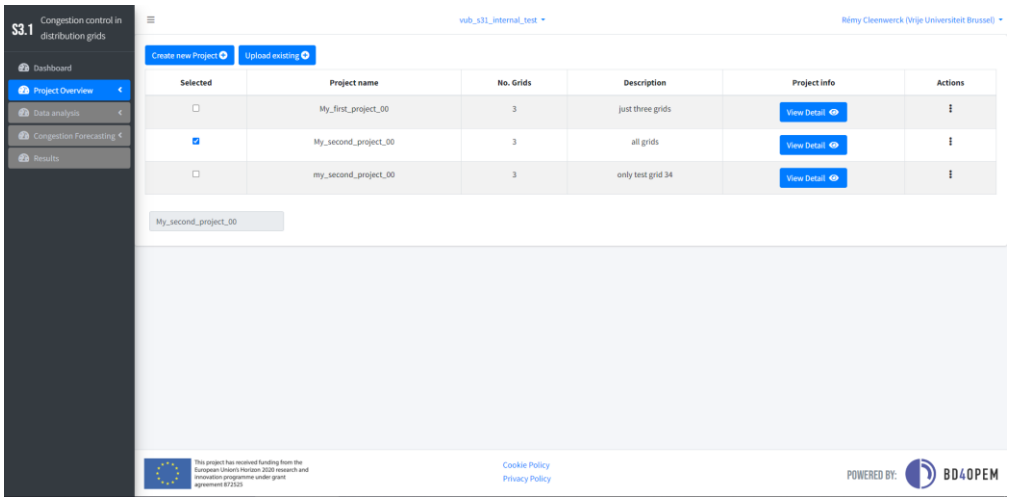


Figure 134. "Project Overview" tab

This tab will return an blank page for first time users, the next steps will guide you through the project creation. Other actions such as editing and uploading can be undertaken as well, see next pages.

The first action is to create a new project. By clicking on the '***Create new Project***' button, a pop-up screen will appear (Figure 135):

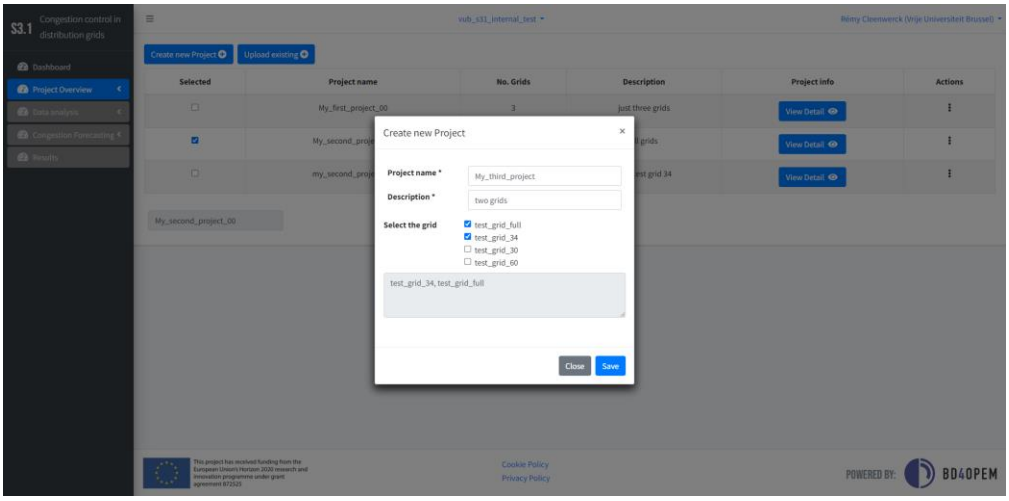


Figure 135. New project

Here you can select your uploaded grids (i.e. contracted data) and make a selection of the grids you want to use for the simulations. In the example, we contracted four grids for the service.

Another possibility is to edit an existing project. For instance if you wish to modify the description or add new grids. Therefore, under the column '***Actions***' click on '⋮' for the grid you want to make changes, and hereafter click on '***Edit***'. The following pop-up screen will appear where you can perform your modifications (Figure 136):

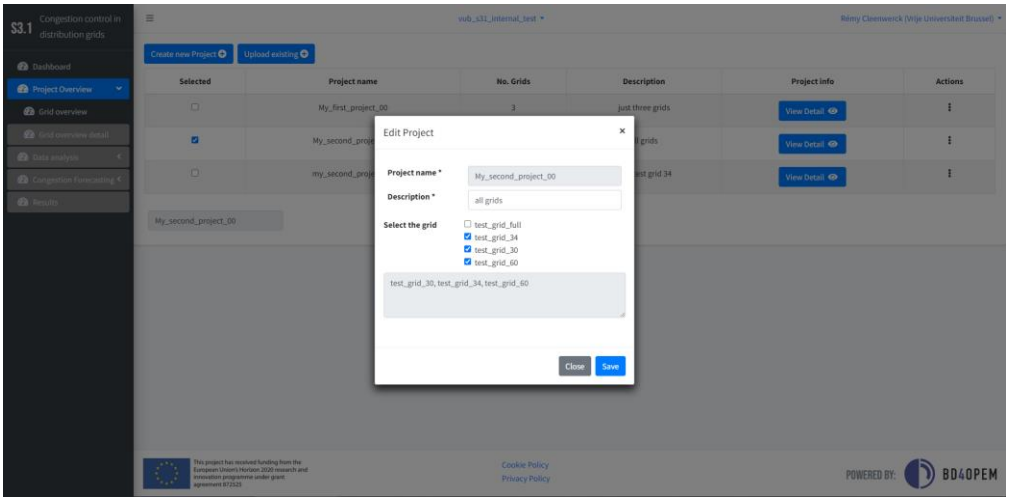


Figure 136. Edit the project

c. Once a grid is selected, you can access the '***View Detail***' button which offers an overview of the grids within the selected project, in this example 'My_second_project_00'. Next to the list of grids within the project, it also provides information on *(i)* the training status – i.e. if the forecasting models have previously been trained or not –, *(ii)* the amount of connections the grid has, etc. (Figure 137):

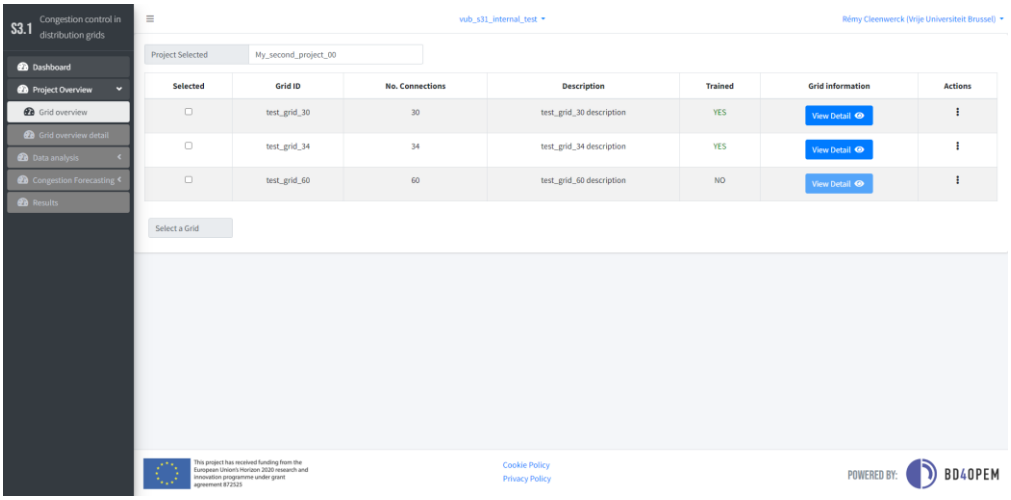


Figure 137. Displey of the details - overview of the grids

d. One can also check details of the grids through the '***View Detail***' button. There you can analyse each of these connections for the selected grid. On the bottom of the page, another '***View details***' button is displayed (Figure 138).

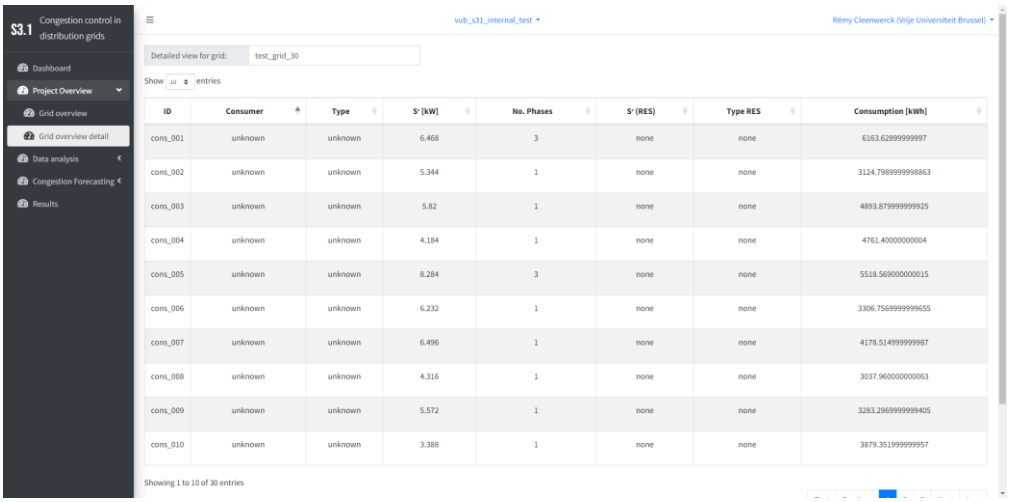


Figure 138. Displey of the details of the connections for the selected grid

The latter redirects you to the a graphical visualization of the consumer, allowing to inspect the "*Consumption profile*" from each consumer Figure 139):

Figure 139. Consumption profile

As well as the "*Voltage profile*" (Figure 140):

Figure 140. Voltage profile

e. Next, for a trained grid, you can either select '***Access Results***' on the '***Grid Overview***' tab or navigate through the menu in the left panel and click on '***Data Analysis***' to inspect both the "individual impact" and "feeder impact".

   The '***Individual impact***' tab allows you to inspect the influence each connection point has on other users. A graph represents the deviation that the selected connection point caused to neigbouring connection points in terms of V per kW (Figure 141).

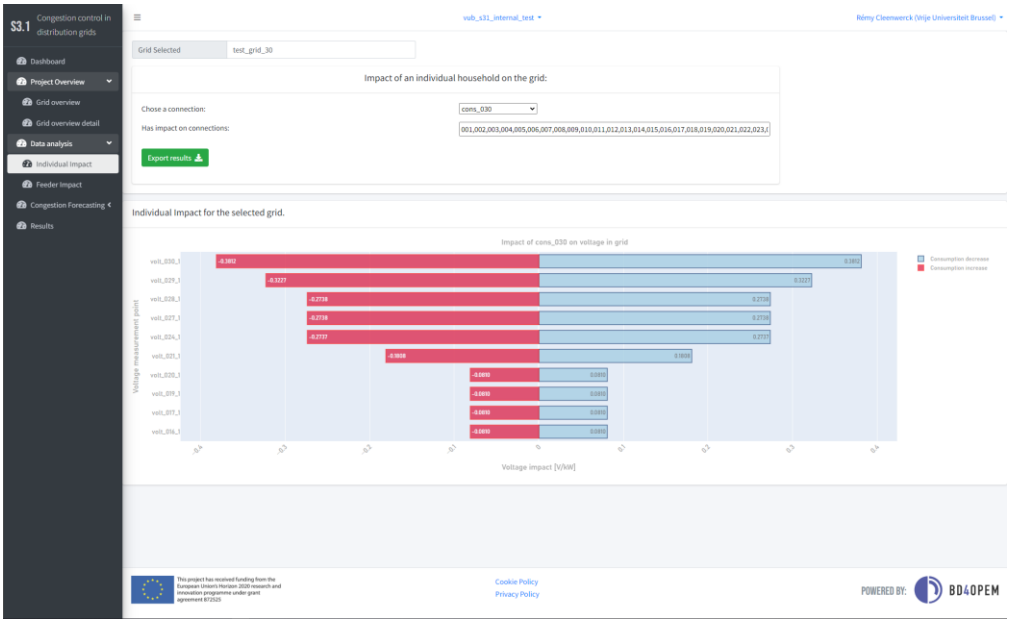


Figure 141. Individual impact

f. On the other hand, provided that the grid topology is not at hand, the '***Feeder impact***' guides you through heatmaps that cluster all the connections points into groups which are highly correlated to each other.

   Arrows on the top help you to navigate through the graphs of each individual group. Initially, the complete overview is given.

   NOTE: Be aware that for large grids with a high number of connections, this might results in unreadable plots! To avoid this, go to the individual groups (Figure 142).

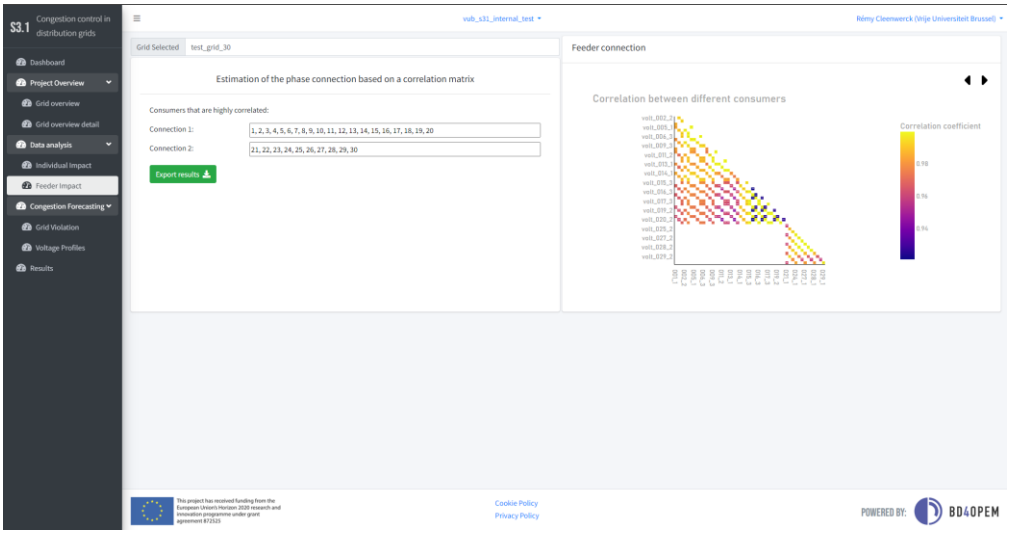


Figure 142. Feeder Impact

g. Finally, the '***Congestion Forecast***' tab presents the results of the forecasting simulations, see '***Grid violation***'. To inspect the influence of stochastic grid disturbances invoked by renewable energy sources such as PV systems or electric vehicles (EVs), you can use the penetration level [%] through

respective dropdown menu[1]. In case of the electric vehicles there is a distinction between "day" time or "night" time charging (Figure 143).

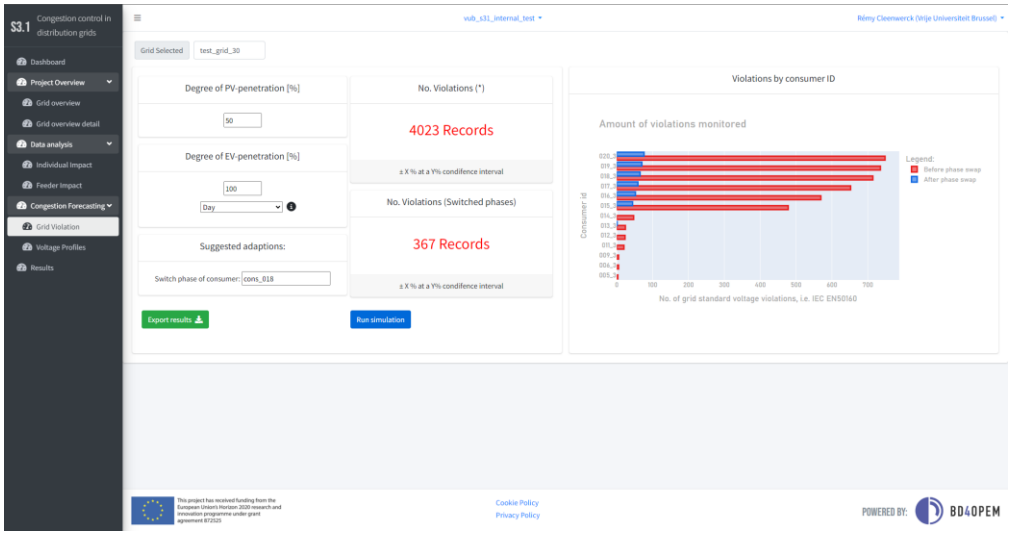


Figure 143. Grid violation

As can it can be derived from the figure, the amount of violations is given for the studied scenario, i.e. forecasted case including the PV and EVs, as well as for an optimization. The latter is an objective function that aims at reducing the amount of violations within the distribution network, through the application of suggestive phase swaps. A figure demonstrates the reduction of violations for the different consumer IDs.

1 Penetration degrees are defined as follows :

- A PV profile is appended on top of the consumption profile. These PV profiles are produced for each consumer individually, based on a reference profile in per unit. Each consumer has a profile allocated in which the annual yield corresponds to his annual consumption (ratio 1:1). Consequently, a penetration rate of 50% implies that the annual production amounts half the annual consumption.
- For the EVs : a reference EV charging profile is appended to the consumption profile.

h. Another tab within the '***Congestion Forecasting***', is the '***Voltage Profiles***' tab. Here you can analyse the deviations in terms of voltage for a given connection, caused for the selected scenario (see previous tab). Results are given for the case pre- and post integration of the stochastic disturbances (i.e. PV and EVs) (Figure 144).

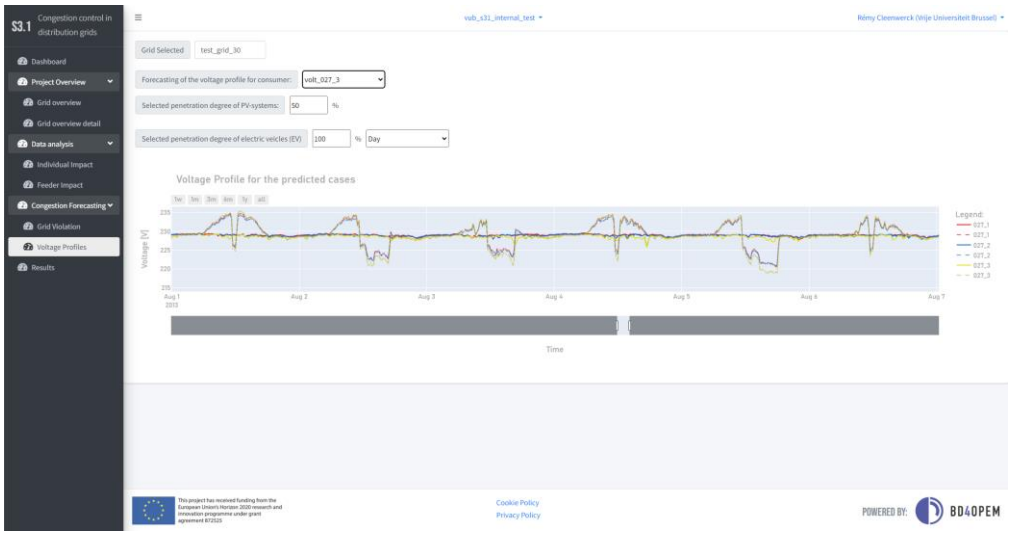


Figure 144. Voltage profiles

i. Finally, for a defined scenario – all results and figures can be downloaded in the '***Results***' tab (Figure 145).

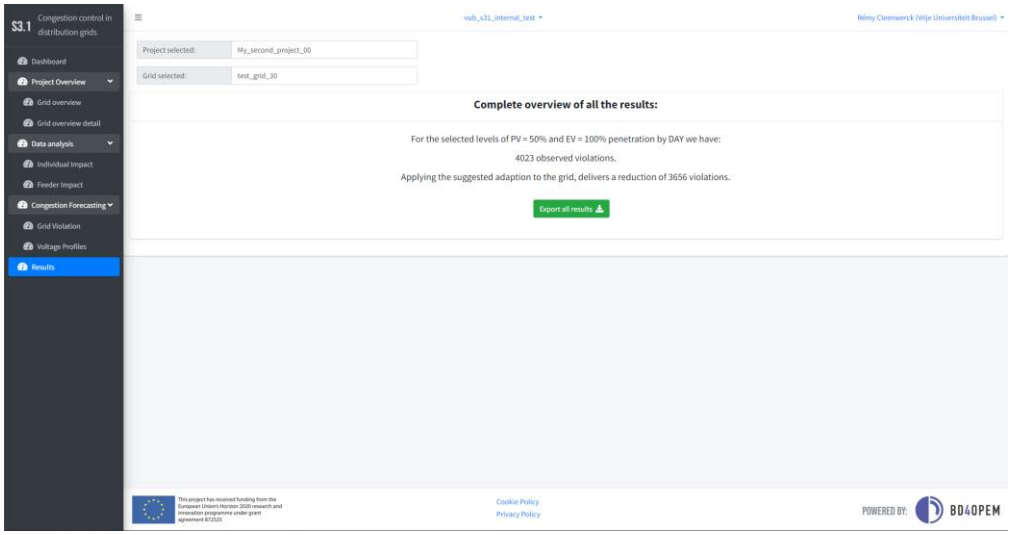


Figure 145. Results

S3.2 - Impact study PV, EV & new loads

Contract service

1. Go to the Marketplace main page and go to the search bar and look the service *"Impact study PV, EV and new loads".*
2. Select the service desired
3. Contract the service, following the default and/or required contract parameters. Upload the data as required.
4. Execution of the service

Usability testing

5. After executing the service, follow the indicated steps to test several aspects.

    a. Go to https://app.staging.bd4opem.odit-e.com and try to login (Figure 146).

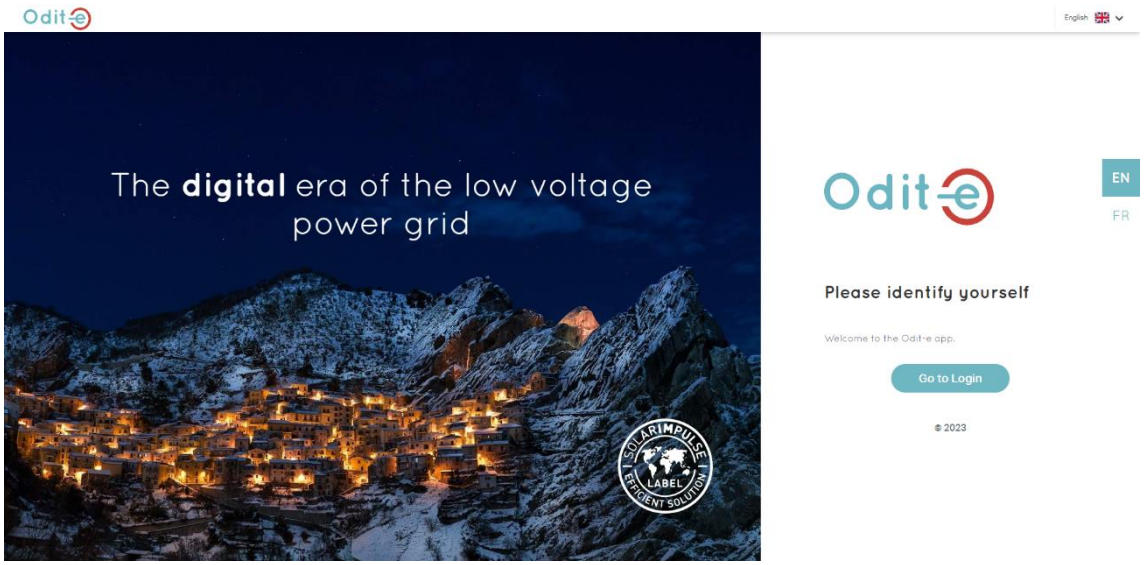


Figure 146. Odit-e app

    b. If login succeed, you should see a map with all your secondary substations (Figure 147).

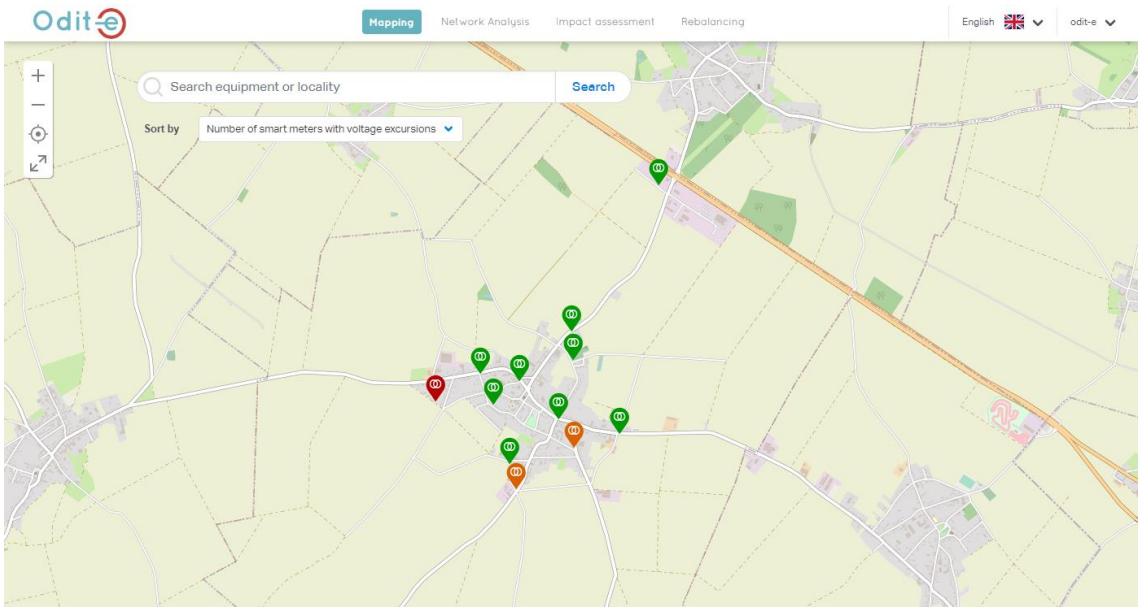


Figure 147. Map with all secondary substations

c. Click on a substation. A panel should open and display all smart meters linked to the substation (Figure 148). If GPS coordinates are given, smart meters should also appear on the map.

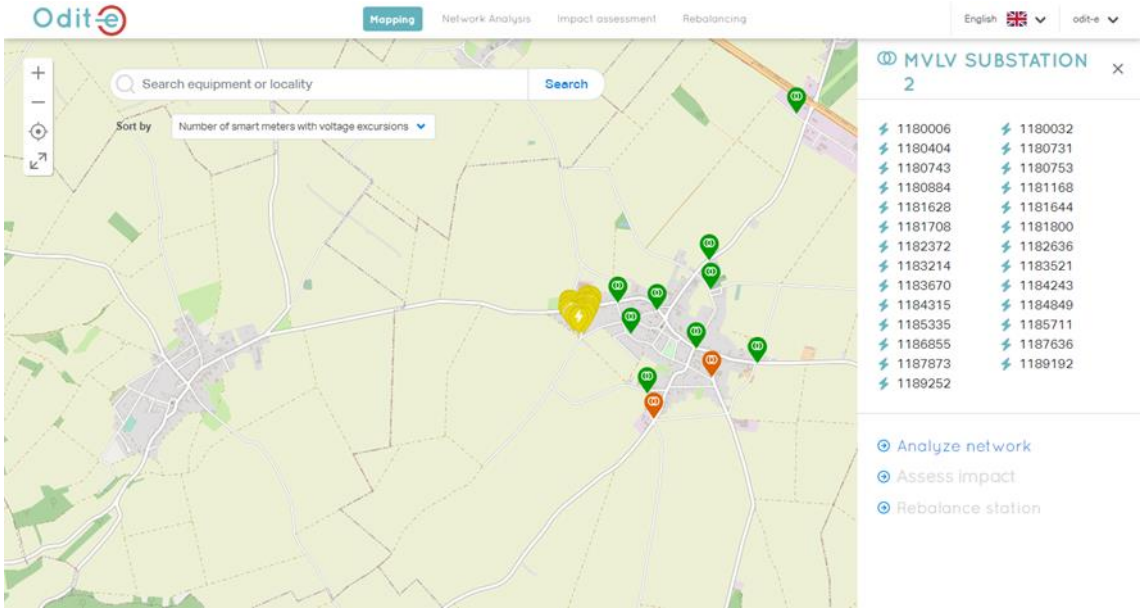


Figure 148. Display all smart meters linked to the substation

d. You can then click on "*Impact assessment*" tab, or "*Assess impact*" button, to open the impact prediction tool (Figure 149). On the impact study page, you should be able to:
    i. Select a substation by clicking on it.

ii. For a selected substation, smart meters will appear on the map (if GPS coordinates are available) and a table with all smart meters and their PV capacities.

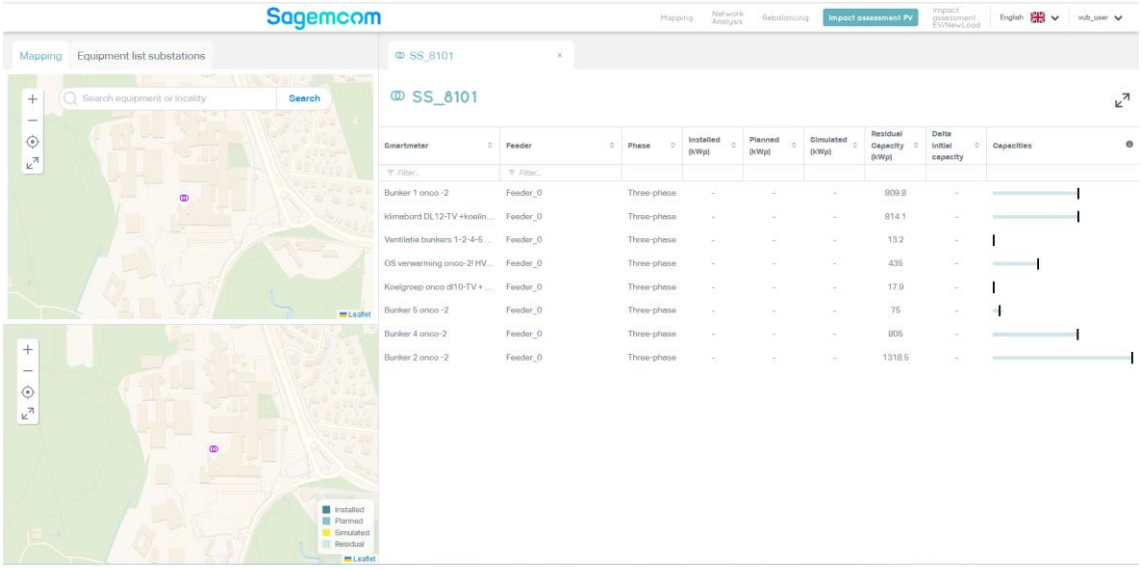


Figure 149. Impact prediction tool

iii. You can then select a smart meter from the map or in the table to add PV and click on "*Apply and simulate*" button to simulate the residual capacities for all other smart meters (Figure 150).

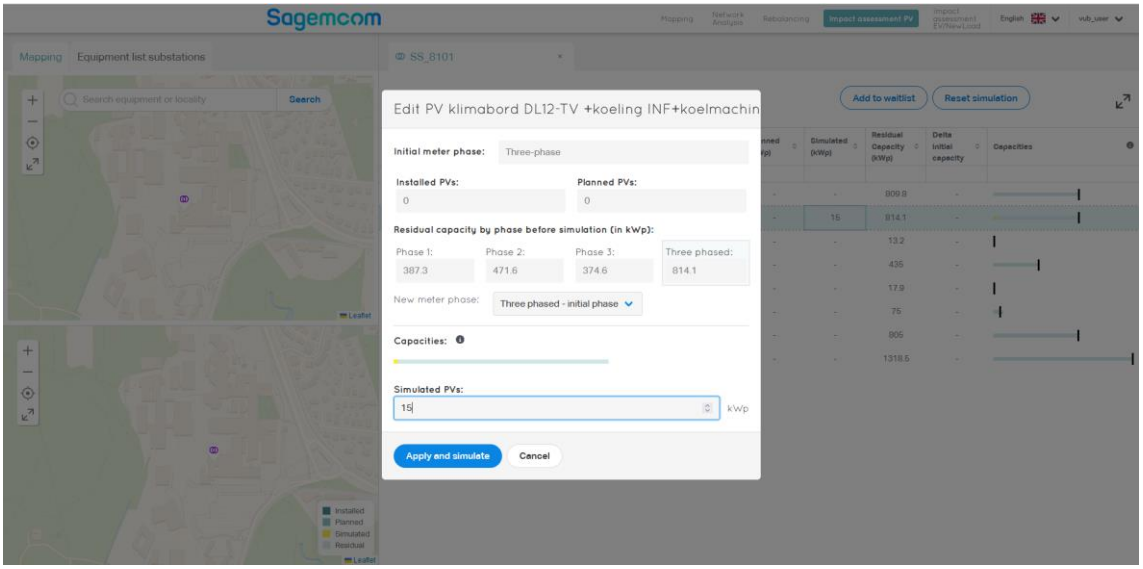


Figure 150. Smart meter selection tab

iv. You can add simulated PVs to the waiting list by clicking on the "*Add to waitlist*" button. The waiting list is persistent: you will find them again, when you will reconnect to assess the impact

of a future connection. The workflow is the following (Figure 151):

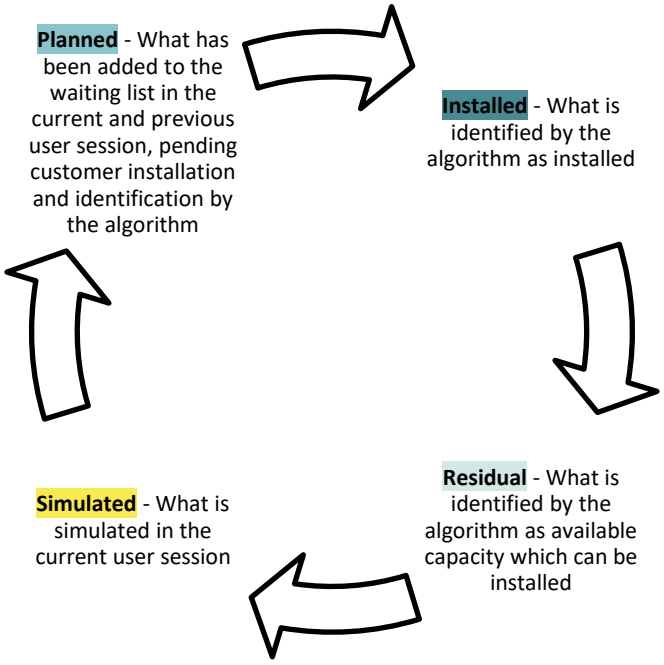


Figure 151. The work flow

e. You can finally click on "*EV & New load"* tab (Figure 152) to open the impact prediction tool for EV and new loads. On this page, you should be able to:
   i. Select a substation by clicking on it.
   ii. For a selected substation, smart meters will appear on the map (if GPS coordinates are available) and a table with all smart meters and their EV or new load capacities.
   iii. You can then select a smart meter from the map or in the table to add a constant new load and simulates by clicking on "Compute" button the residual capacities for all other smart meters.

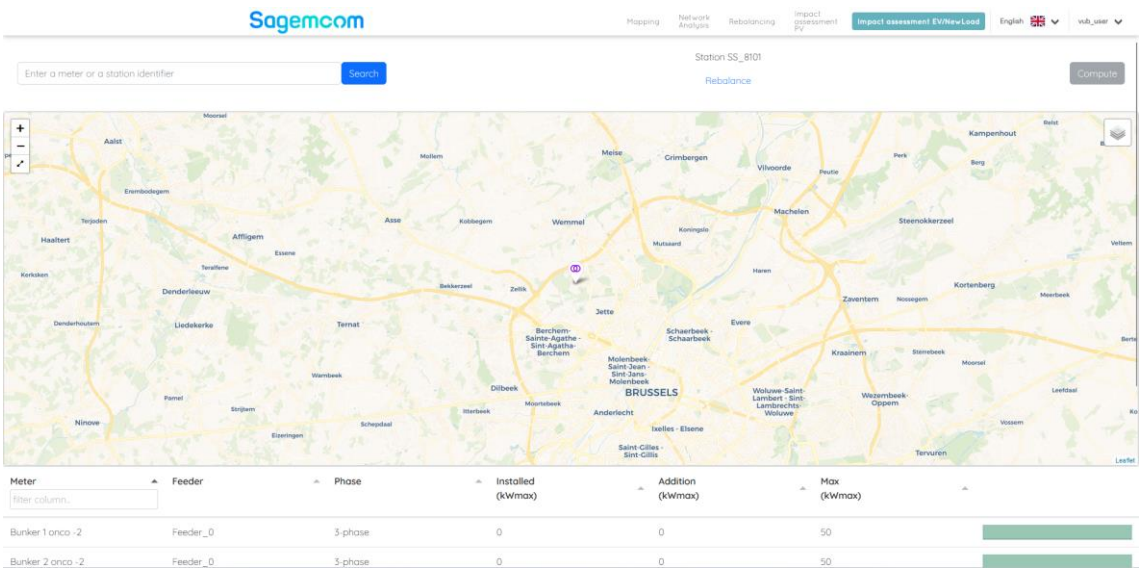


Figure 152. The "EV & New load" tab

6. Fill the questionnaire provide following the results and experience perceived after following the previous steps.

S4.1 – Inconsistencies in energy balance and power-voltage

Contract service

1. Go to the Marketplace main page and go to the search bar and look the service "*Inconsistencies in energy balance and power-voltage".*
2. Select the service desired
3. Contract the service, following the default and/or required contract parameters. Upload the data as required.
4. Execution of the service

Usability testing

5. After executing the service, follow the indicated steps to test several aspects.

    a. Go to *https://app.staging.bd4opem.odit-e.com/* and try to login (Figure 153).

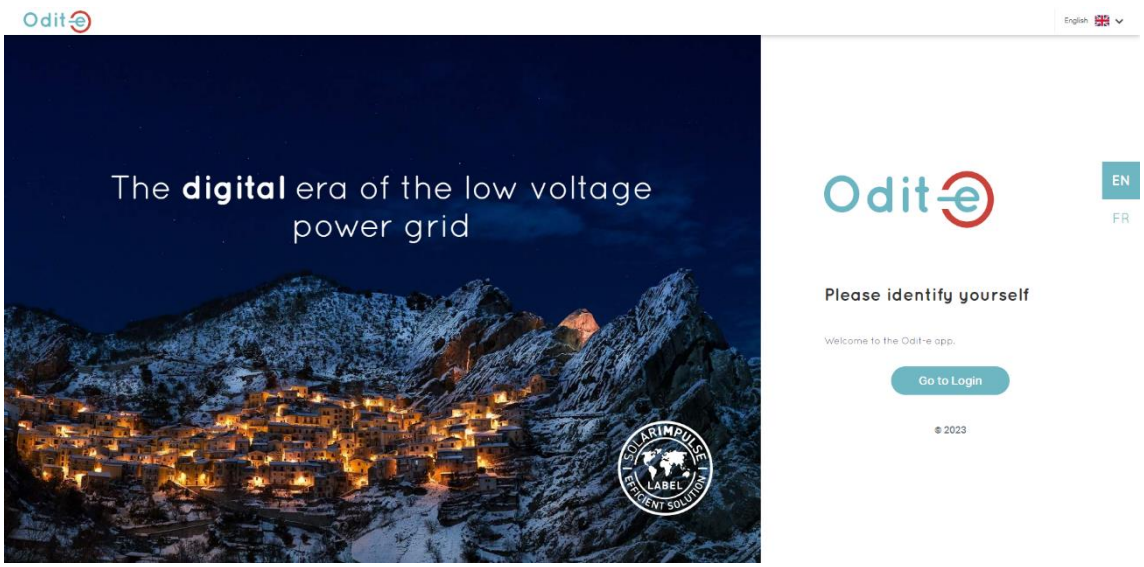


Figure 153. Odit-e app

b. If login succeed, you should see a map with all your secondary substations (Figure 154).

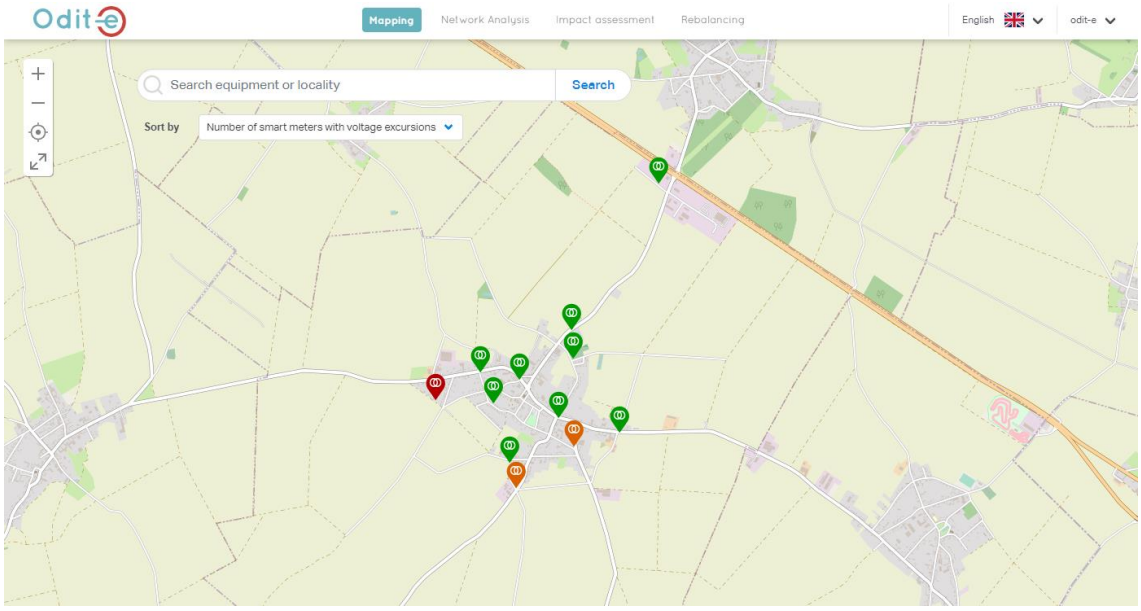


Figure 154. Map with all secondary substations

c. Click on a substation. A panel should open and display all smart meters linked to the substation. If GPS coordinates are given, smart meters should also appear on the map (Figure 155).

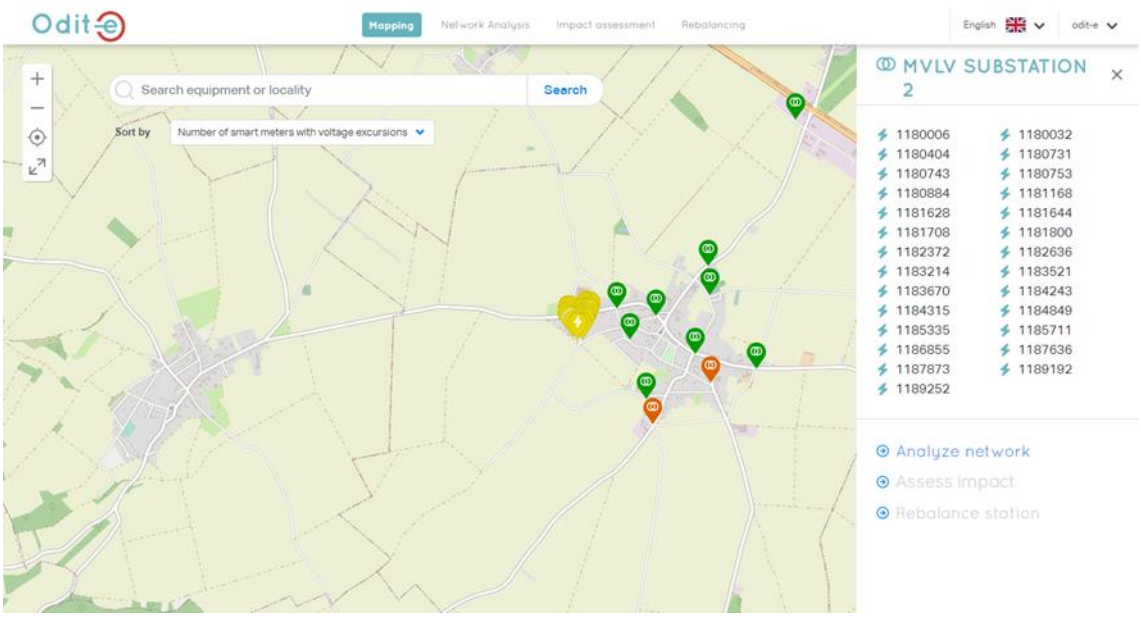


Figure 155. Display of the all smart meters linked to the substation

d. On the top right corner there is a "PTN" tab allowing you to access to the "*Inconsistencies in energy balance and power-voltage" service*

   i. Colored substations are the one for which the calculation could be performed. Click on a given substation to access to the analysis.
   ii. For a selected substation, see different information:
      i. Table of the smart meters with **probability of bypassing** and **missing power probability** in the neighborhood of the meters (Figure 156).

Smart meters list

Sensor id	GPS	Bypass probability	Missing power probability
filter data...			
27E54B2A1E54E7C69D520B16FCC491CDB04AEA0E	✔	0	43
77B262D2774D36976ACC1C066803A25B180A9DFE	✔	0	0
77C2AF2ADFD9B6395C3332CD9AAB81F452293A4A	✔	0	10
D66C524871AA11C5F5C0F5075D46B51EA79FC13F	✔	0	0

Figure 156. Table of the smart meters with probability of bypassing and missing power probability in the neighborhood of the meters

The drop down menu allow to color the meter considering the level of these indicators (Figure 157).

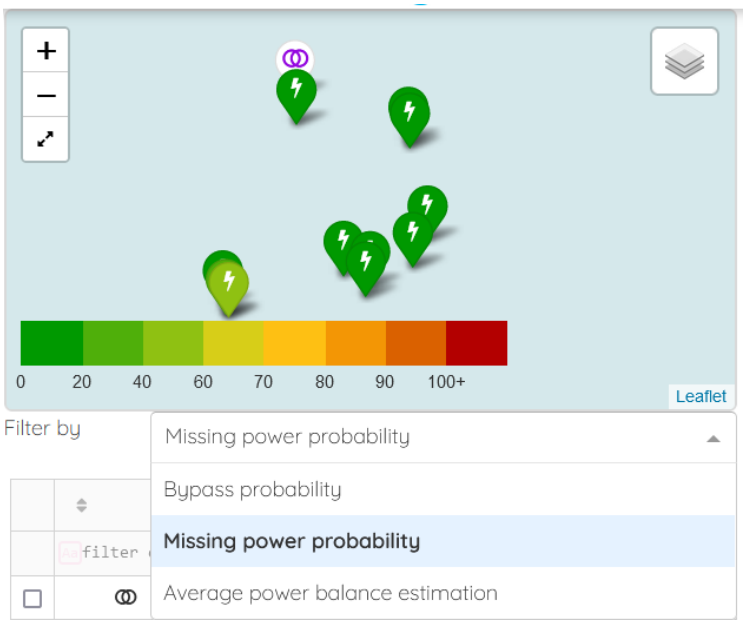


Figure 157. The drop down menu for coloring the meter considering the level of indicators

iii. Load curve and boxplot of the power balance to identify the frequency and volume of non-measured energy in the secondary substation.

1. Fill the questionnaire provide following the results and experience perceived after following the previous steps.

S4.2 – Fraud patterns detection

S4.2 – Fraud patterns detection

1. Go to the Marketplace main page and go to the search bar and look the service *"Fraud Pattern Detection".*
2. Select the service.
3. Contract the service, following the default and/or required contract parameters. Contract the required data.
4. Execution of the service through the marketplace or by login to the marketplace and running https://s42upc.bd4opem.eu/ .

Usability Testing:

5. After executing the service, follow the indicated steps to test several aspects
   a. Go to *Dashboard* tab to check the contract parameters. The *About* button provides a short and long description of the service. There's also a *Contact us* button (Figure 158).

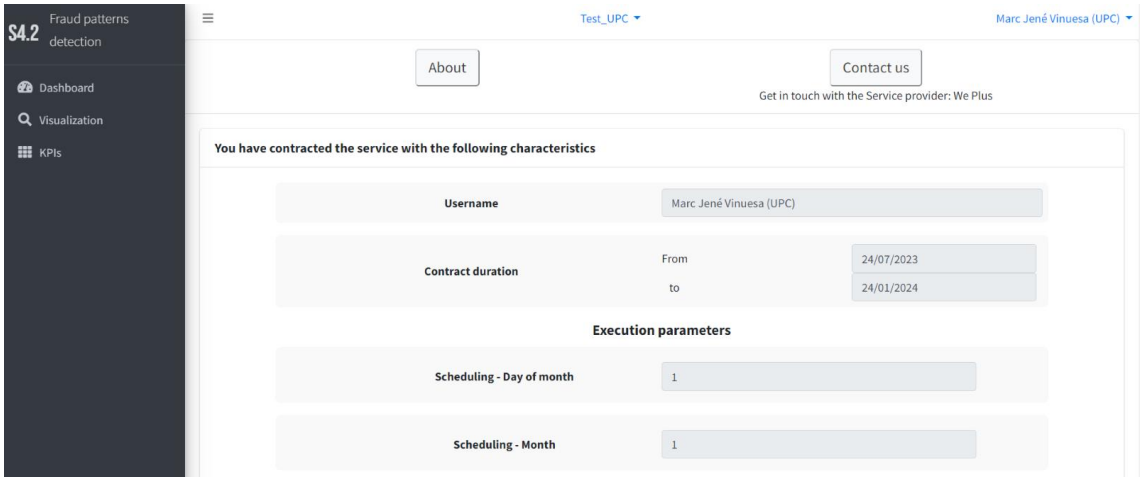


Figure 158. Contracts parameters for Servis S4.2 (UPC)

b. Go to *Visualization* tab and check the *Recent Results* (Figure 159). You can sort them by *Probability [%], Magnitude [kW]* (Figure 160) or any other column. Select the *View Graph* button of one of the frauds to see the NTL daily curve. Change the number of entries (rows) by selecting it at the upper left part of the screen. Go to the *Filter* button to filter the table by type of fraud, magnitude or other variables. A fraud should be verified or denied after undergoing a field inspection to calculate the accuracy and improve the algorithm (Figure 161). The *Historical* tab registers all the detected frauds and not only the most recent ones. By denying a fraud, this should be deleted from the *Historical* tab the next time the service is executed. To download the visible results, select the button *Download XLSX* or *Download CSV*.

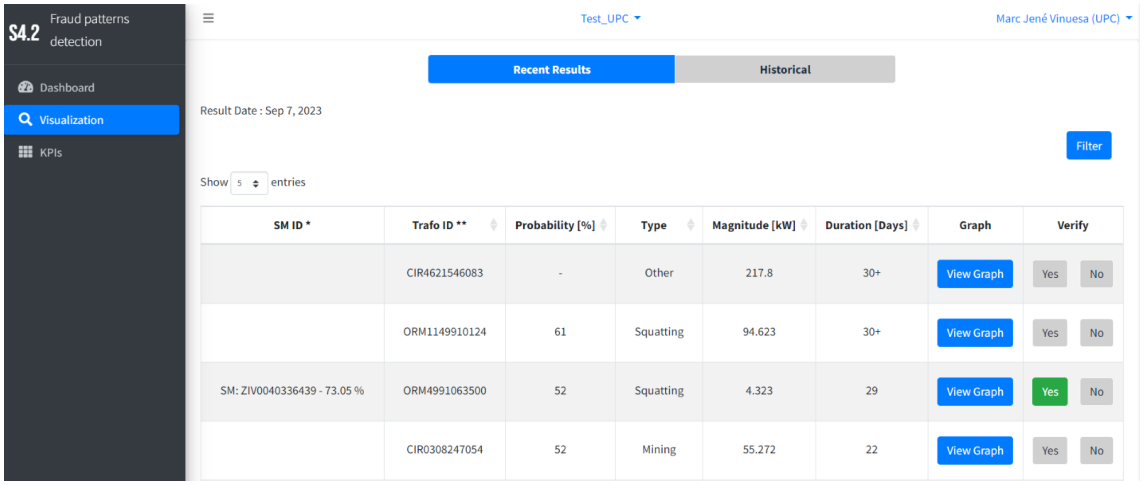


Figure 159. Visualization tab

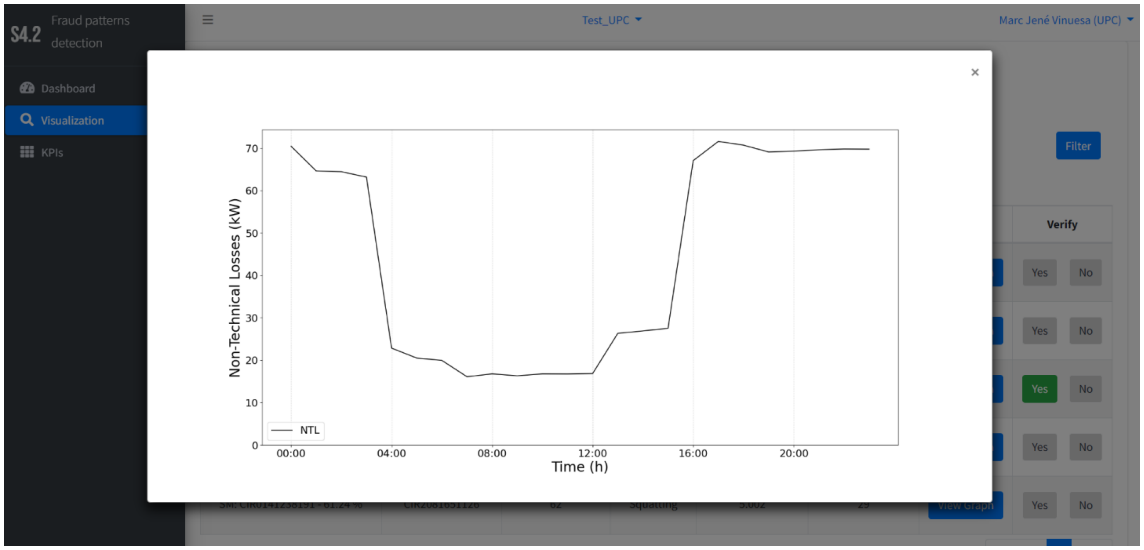


Figure 160. Magnitude

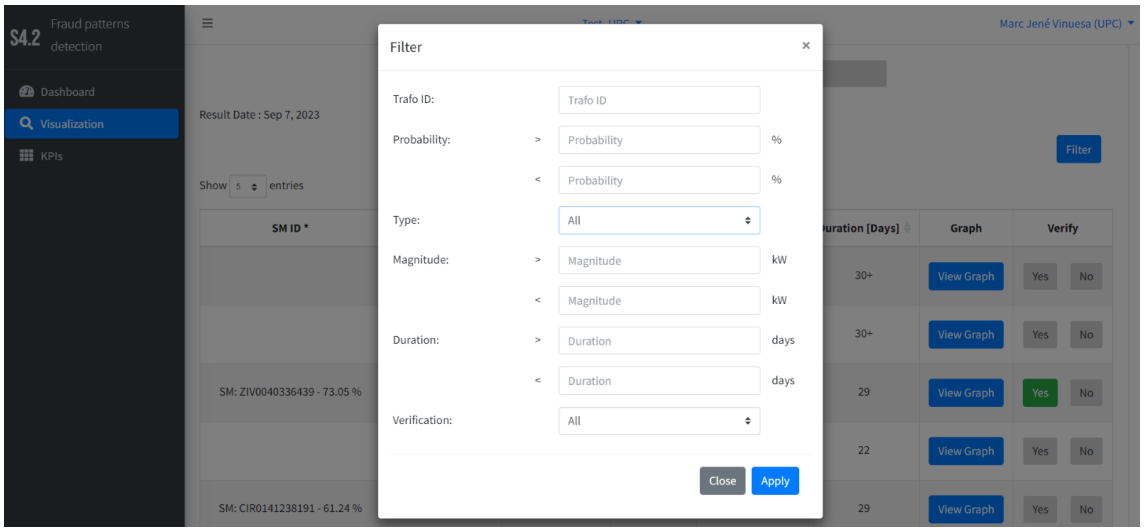


Figure 161. Filter

c. Go to *KPIs* tab to appreciate the total number of detected frauds, the power recovered by disconnecting the fraudulent consumer, the accuracy of the service and the distribution of *Types of fraud* of the contract. Select the *Save results* button to obtain the report in excel form.

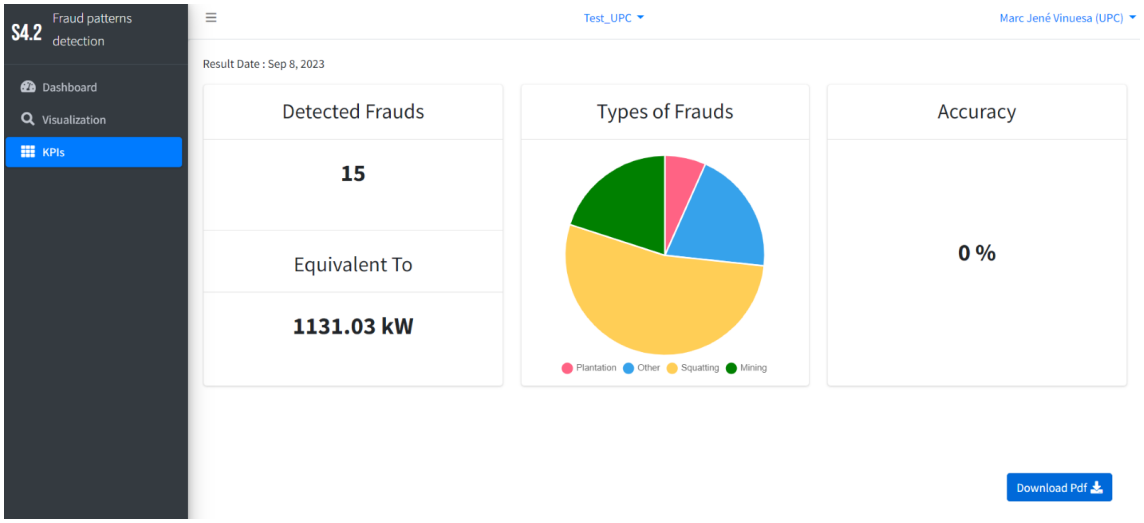


Figure 162. KPI tab

6. Fill the questionnaire provided following the results and experience perceived after following the previous steps.

S4.2 – Fraud patterns detection

Introduction

The Non-technical losses service developed by JSI is intended to support an investigator of the non-technical loss in his/her research. The tool requires bubble data for its processioning. The bubble data is the data of all the smart meters and related transformer station in a given timeframe. The tool should be able to compute the loss as a difference between the substation meter consumption and the sum of all consumption of related smart meters. Besides, the data should cover a substantial period before the loss and the period till after the discovery of source of the losses. Of course, the tool can provide the results before discovery of the loss source.

In the sections below the Marketplace user interface will be used to acquire the data contract, service contract and to run the service with specific service technical parameters. The storyline will reveal how to access the service report. On the end some brief explanation will be given about the service results.

Data contract

First, we need a data contract for the service. On the "Search" page of the Marketplace, we search for "fraud pattern detection" data. The one shown in the Figure 163 is the correct option.

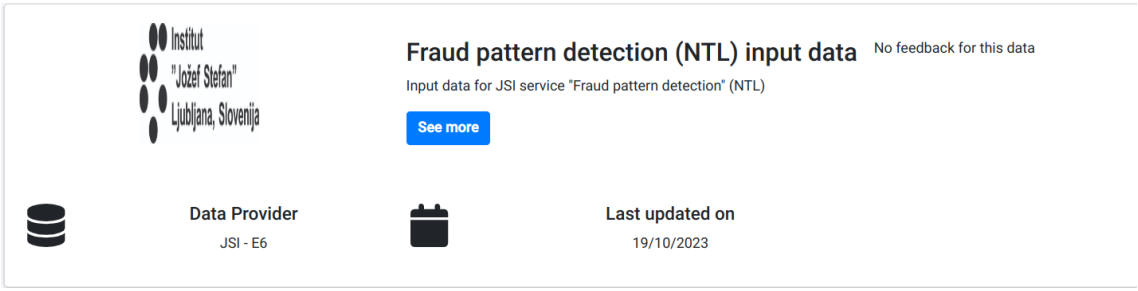


Figure 163. "Data contract" tab

Click on "See more", then "Contract data" at the very bottom. Give the contract whichever name, for example "S4.2 data". For the data period, select today's date as "From", and whichever date in the future as "To". Finally, press "Submit" (Figure 164).

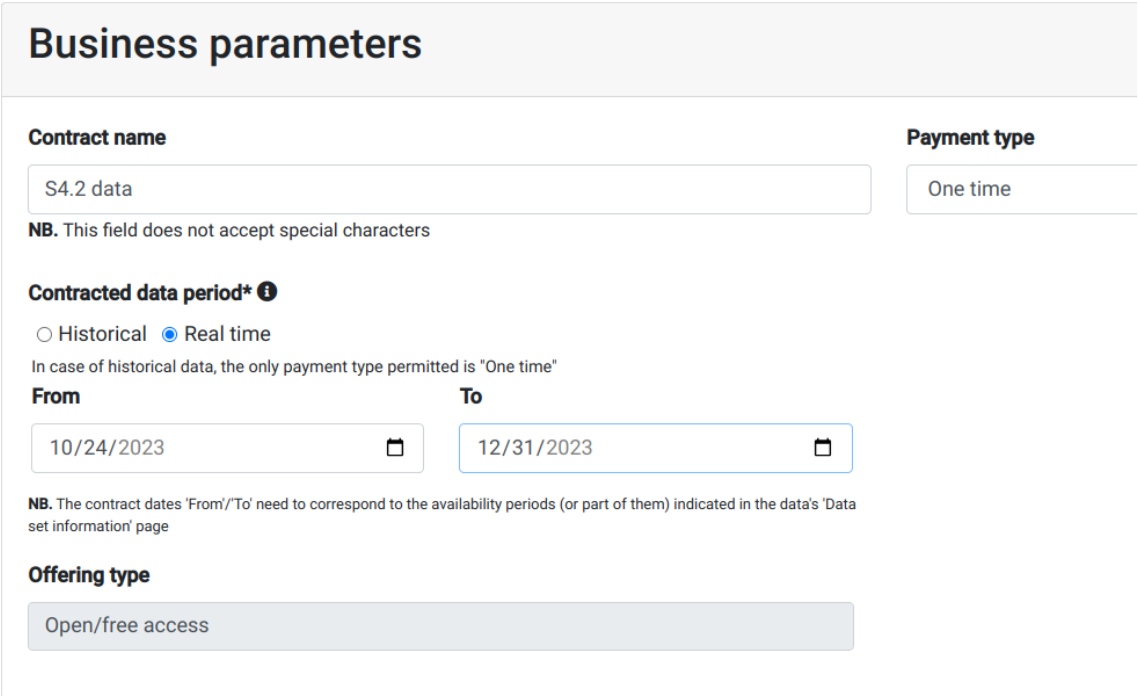


Figure 164. Businness parameters

Service Provisioning receives the data contract right after the "Submit" button is pressed. You should be able to see your data contract request in the "My Data" page, with the role "Data User". The contract status should be COMPLETE (Figure 165).

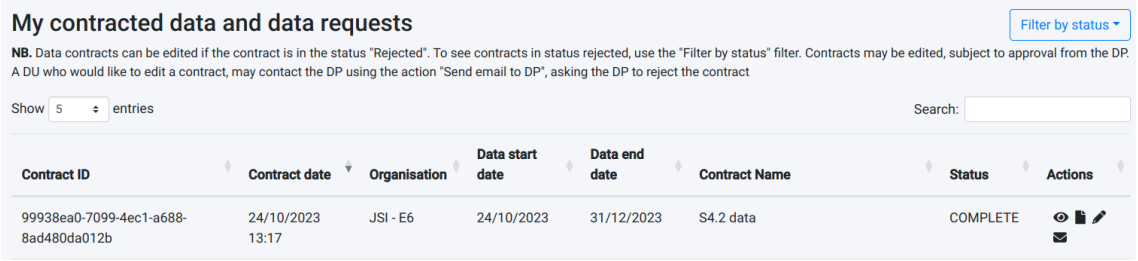


Figure 165. Displey of contracted data and data requests

However, to be able to use the data contract, it needs to be approved and activated by the Data Provider (in this case, JSI). Approving and activating the data contract will advance the contract status from COMPLETE to APPROVED, and then to ACTIVE. Once contract status is ACTIVE, it can be selected when contracting a service, as we will see shortly.

Service contract

Contracting a service follows similar steps as contracting data. Service S4.2 can be found on the Marketplace under the name "Fraud pattern detection" (Figure 166). Under "Advanced search", we can also select "JSI - E6" organization to filter the results.

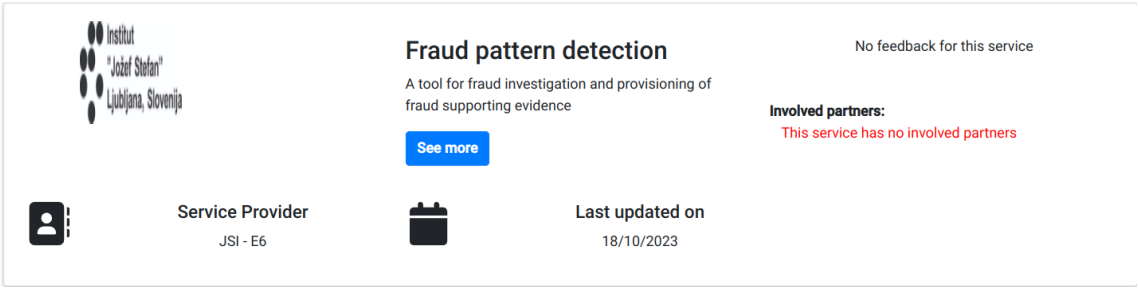


Figure 166. Contracting a service

Click on "See more", and then "Request new service" at the top of the page. We first fill in the business parameters, same as for the data contract. Contract name can be whatever, for example "S4.2 test contract [today's date] - ELCE". Leave "Payment type" as is, and select the contract period (Figure 167).

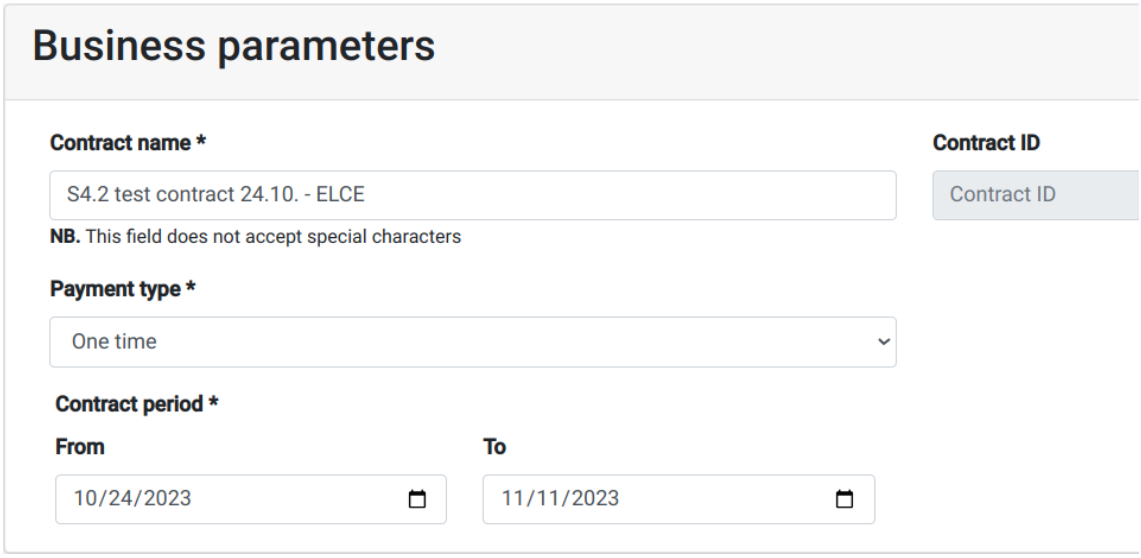


Figure 167. Business parameters for Servis S4.2 (JSI)

Next, we select the technical parameters (figure below). Select one value for each technical parameter. A description of each parameter can be seen in the image. Since we selected the Slovenian pilot, we choose the "case" parameter accordingly.

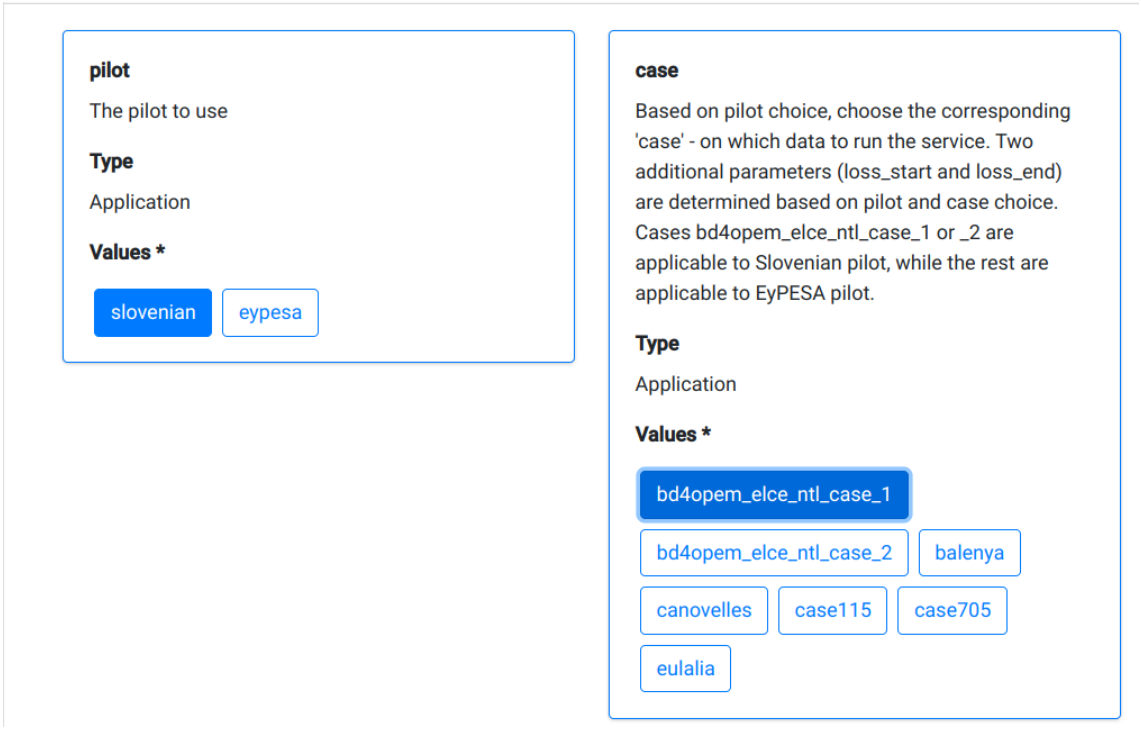


Figure 168. Technical parameters for Servis S4.2 (JSI)

We then select the corresponding data contract. Find the "S4.2 data" (or whatever name you put) data contract, check it, and click "Confirm". The data contract will not

be present unless it was activated by the Data Provider. Be sure to also select "Yes" for "Enable immediate execution", otherwise the service will not actually be run in the ASM module (Figure 169).

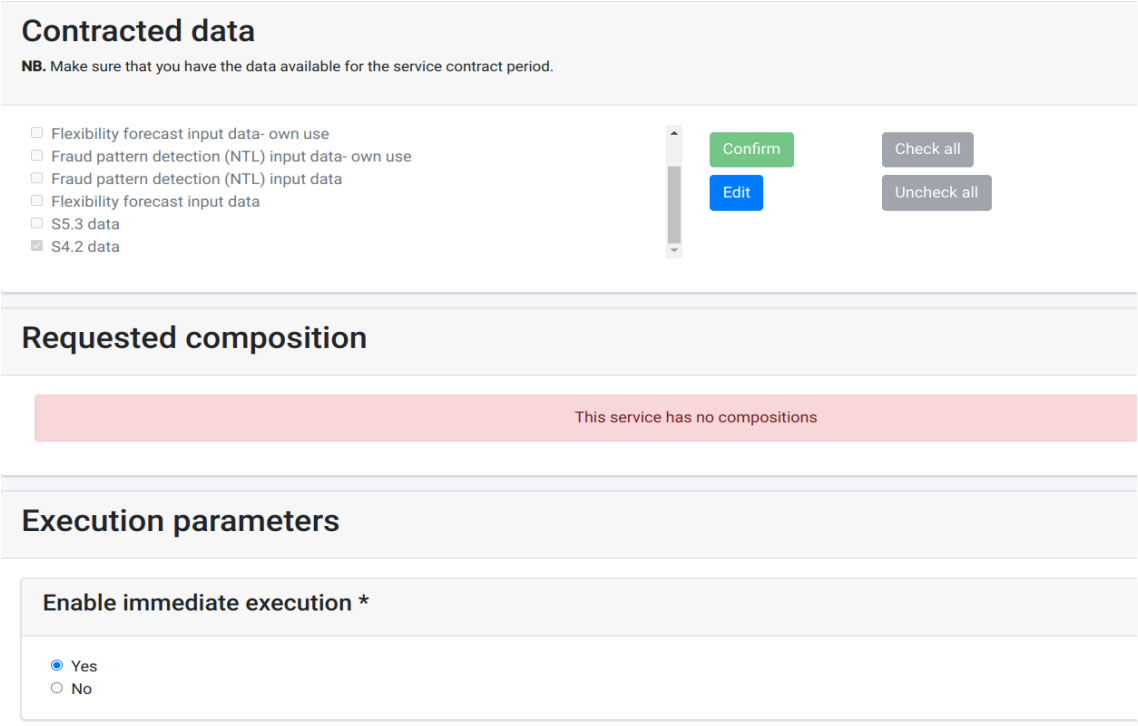


Figure 169. Contracted data for Servis S4.2 (JSI)

Finally, click on the "Request service" button at the bottom (Figure 170). Similarly as for the data contract, Service Provisioning receives the contract right after the button is pressed. You should be able to see your service contract request in the "Service requests" table, found on the "My Services" page, with the role set to "Service User". The contract, provisioning and execution status should be as in the below image.

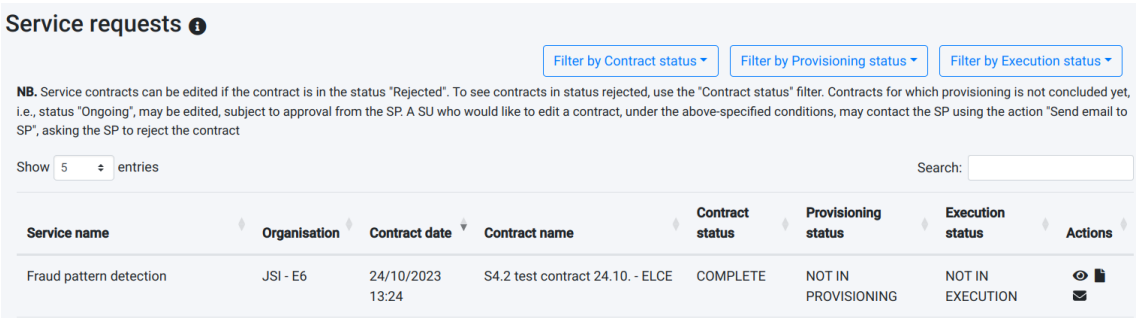


Figure 170. Service requests

Running the service

Similarly, to be able to use the service contract, it needs to be approved and activated by the Service Provider (in this case, JSI). Immediately after the contract is activated, an instance of the S4.2 service will be started in the ASM module. This will happen because the service is set to be auto instantiated if immediate execution was set to "Yes".

As soon as the contract is activated, i.e. the service starts executing in ASM, the Marketplace will provide us with a link to our front-end, where we can see the logs and results of the service. This link is accessible via the "Go to service" button, present in the corresponding entry in the "Service requests" table (Figure 171).

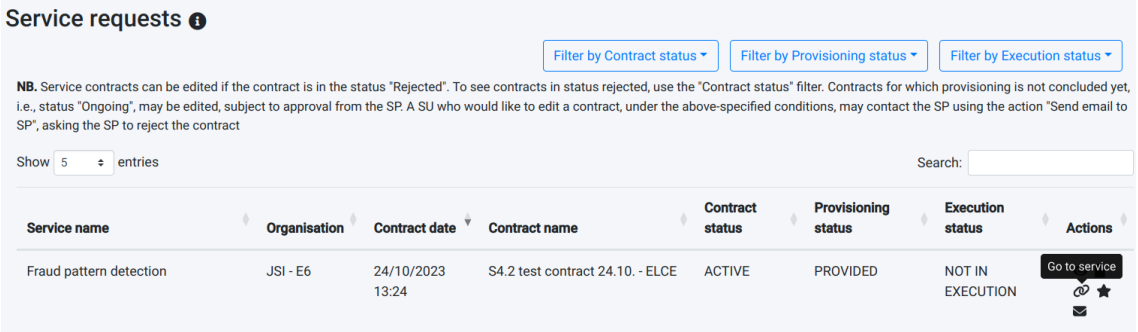


Figure 171. "Service requests" table

Clicking on the "Go to service" button takes us to our front-end (Figure 172).

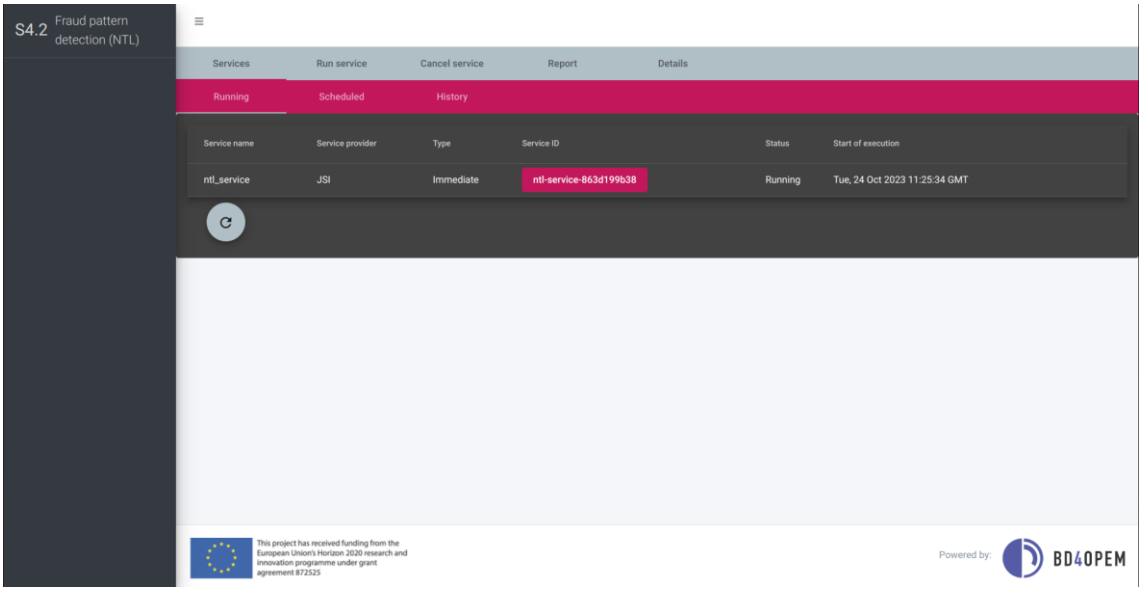


Figure 172. Details page

If the service is still executing, it should be present in the "Running" tab. Clicking on the ID in the "Running" tab will take you to the "Details" page and stream any logs of the service.

If the service has finished, we should be able to find it in the tab "History". You can click on the refresh button to see whether it has. By clicking on the service ID in the "History" tab, the report i.e result of the service will be fetched and you will be automatically moved to the "Report" tab (Figure 173).

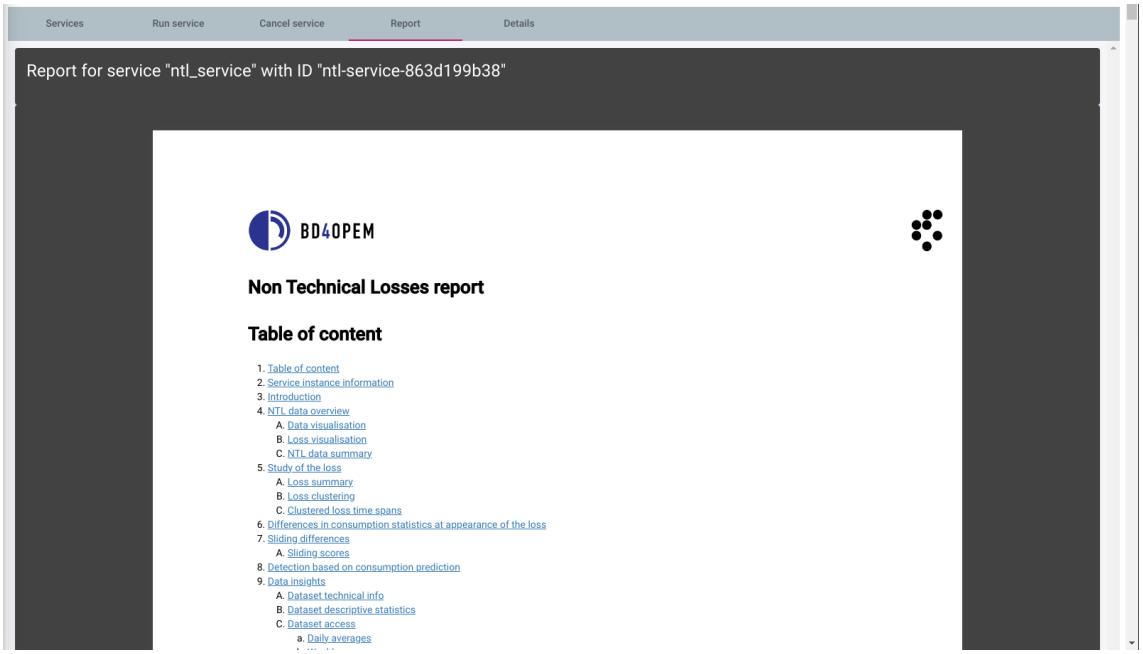


Figure 173. "Report" tab

Additionally, by clicking on the tab "Details", you will be able to see the technical parameter values you selected, as well as any stdout and stderr logs of the service.

S5.1 - Flexibility forecast

S5.1 – Flexibility Forecast

1. Go to the Marketplace main page and go to the search bar and look for the service "Flexibility Forecast".
2. Select the service desired.
3. Contract the service, following the default and/or required contract parameters.
4. Upload the data as required.
5. Execution of the service. On the initial menu: create new execution.
    a. Click on "Add Forecast Model" (Figure 174).

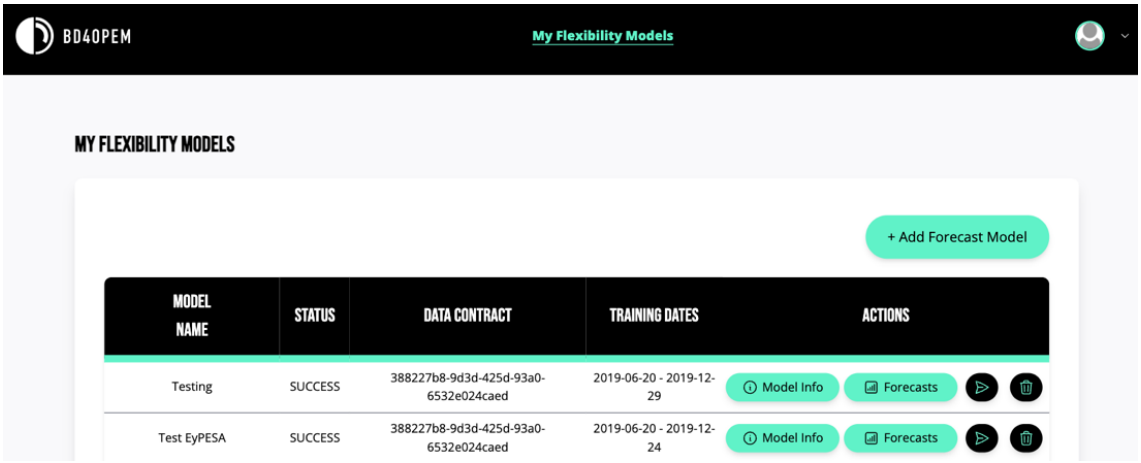


Figure 174. Flexibility models

b. Fill the following information to initiate the forecast (Figure 175 and Figure 176).

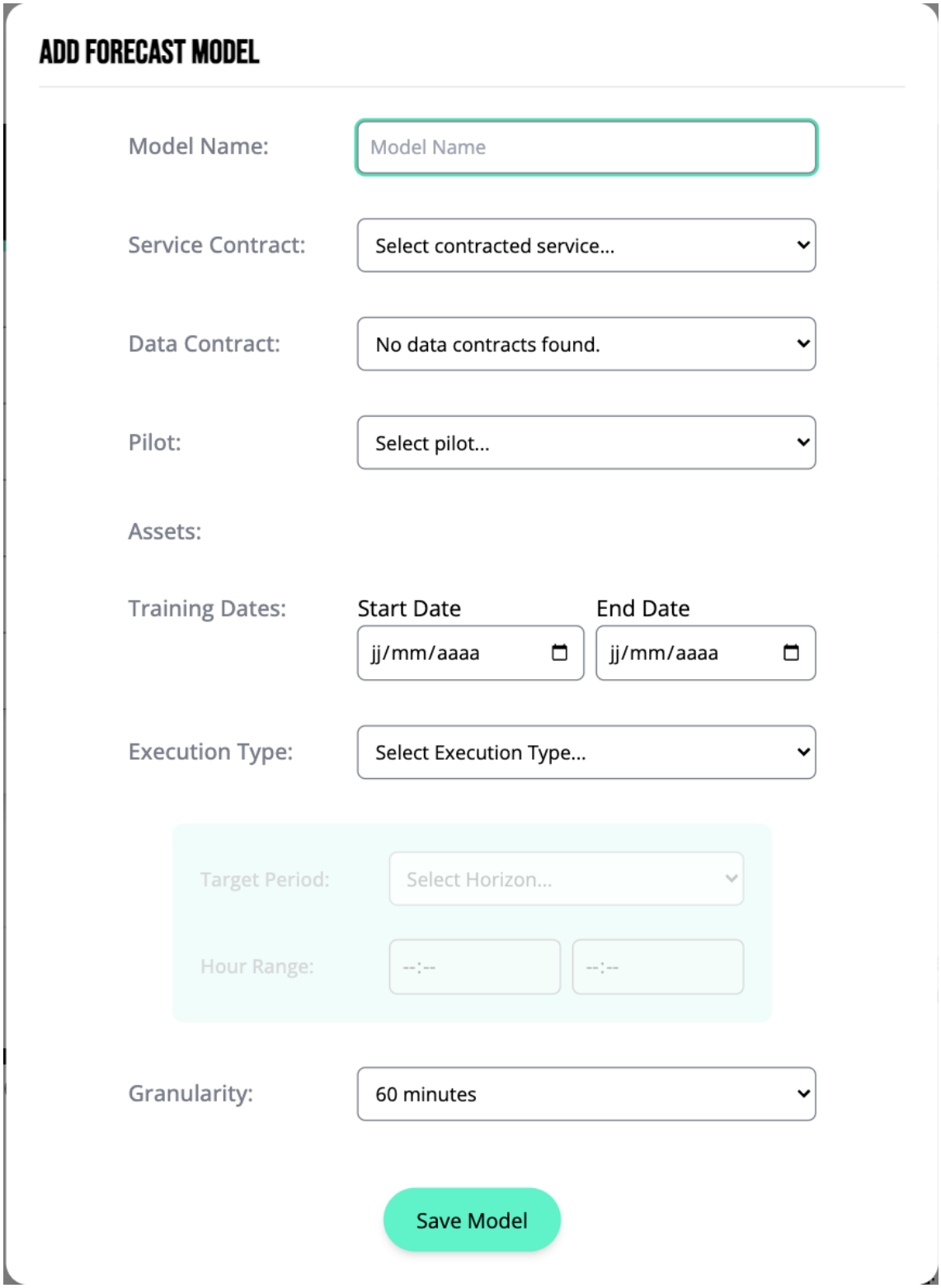


Figure 175. Adding forecast model

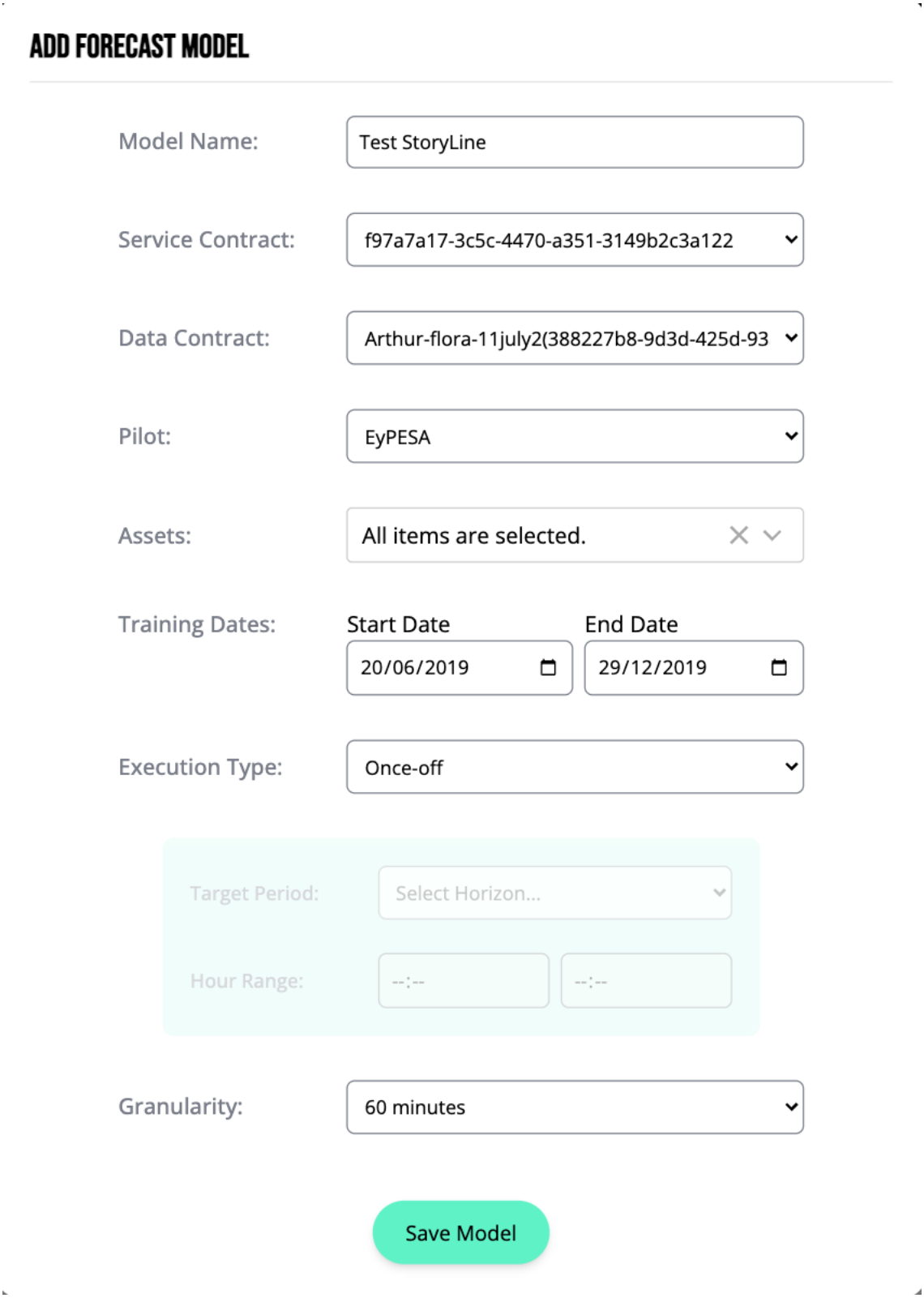


Figure 176. Added forecasting mode

6. Save it and the model appear in your forecast models (**Figure 177**).

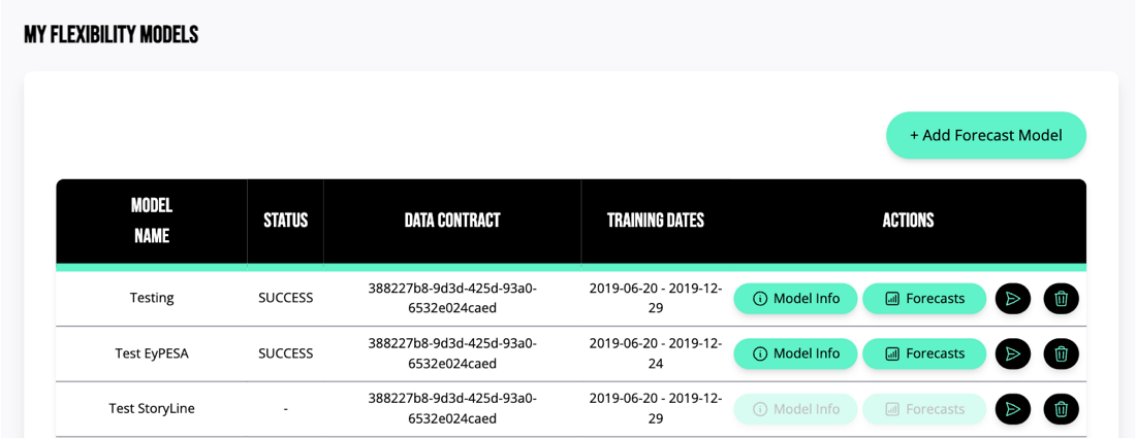


Figure 177. Forecast models

To make it run, click on the right arrow button.

Changing its status to "pending" (Figure 178):

Figure 178. Model info"and "forecasts pending image

and then to success, enabling the tabs "model info" and "forecasts" (**Figure 179**):

Figure 179. Flexibility Model info and forecasts

7. Usability Testing: On the initial menu: check previous executions.
    a. Click on the "Model Info" tab, scroll down to discover the following (Figure 180):

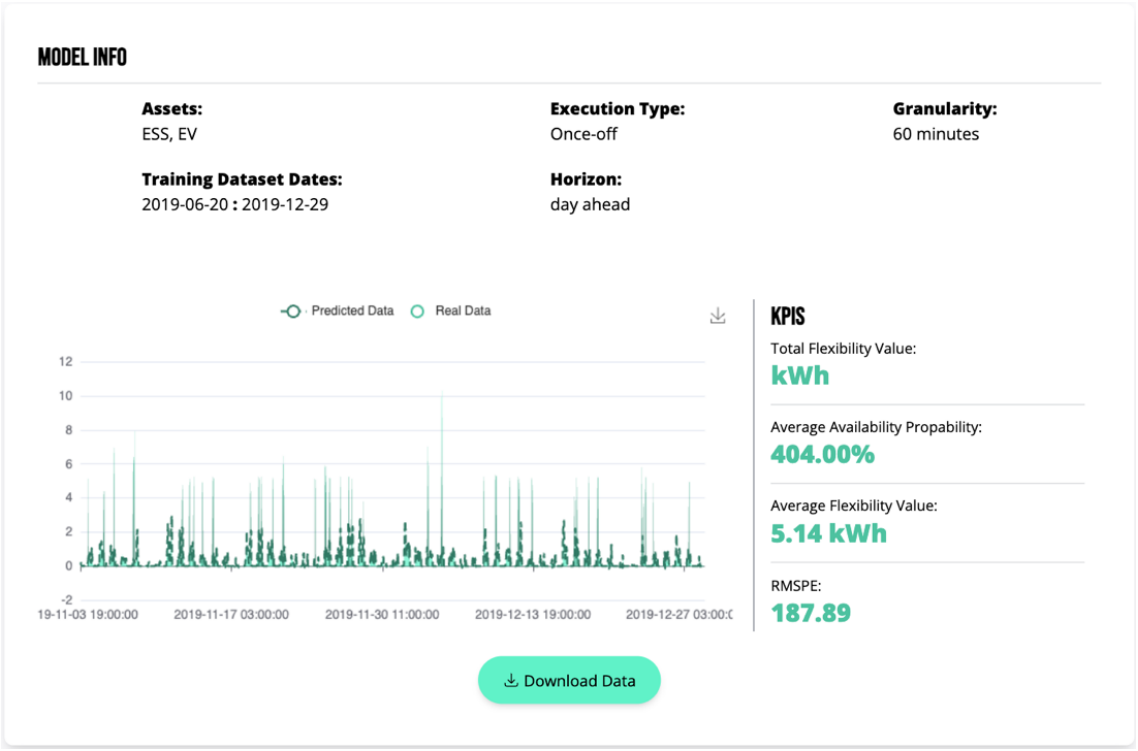


Figure 180. "Model Info" tab

It will deliver the information on the selection and the training results (real flexibility estimated and the forecasted) with the corresponding KPIs.

b. Select the »forecast« tab (Figure 181):

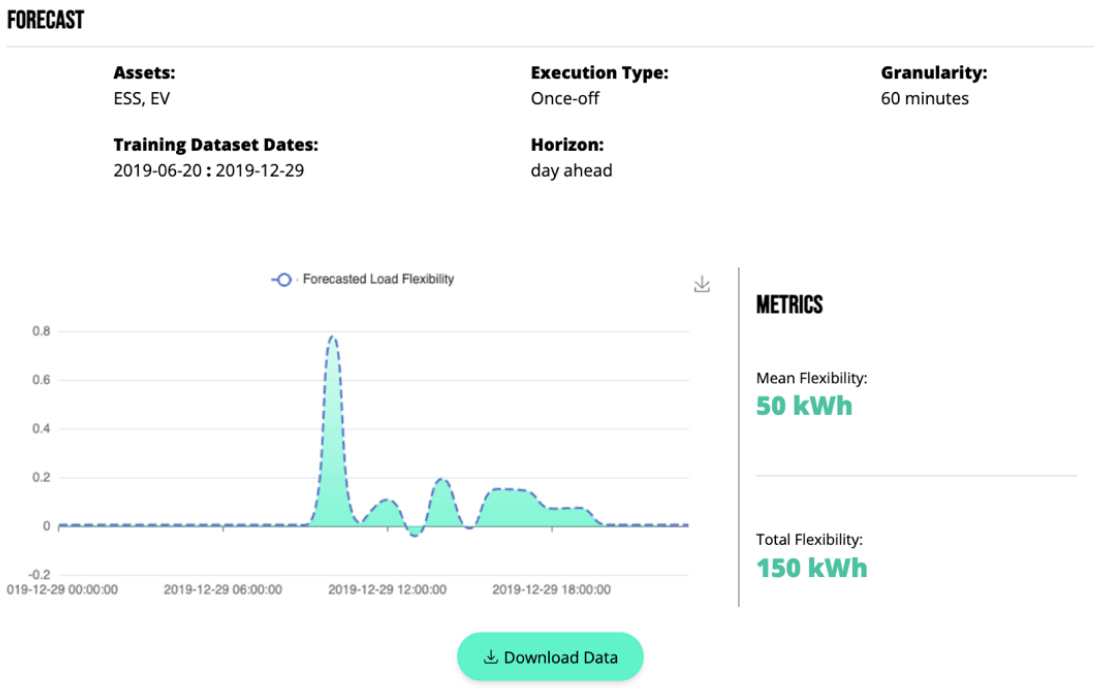


Figure 181. "Forecast" tab

It will deliver the information on a graph with the results of the forecast for the next day. Also, the metrics of flexibility are presented: total and mean flexibility values. Click on "Download Data" to be able to export a CSV file with the forecasting results and on  to download the chart.

S5.1 – Flexibility Forecast

Introduction

Being able to predict a customer's reaction to a price change is useful in a real-time power pricing setting where consumers are sensitive to changing rates. This study suggests estimation of aggregated load flexibility based on the historical price-response dynamics of consumers and demonstrates how one-way price signals can be utilized to control the aggregated electricity consumption.

The proposed approach requires aggregated historical consumption data along with the historical and future weather information to estimate "price-based" demand-side flexibility.

In the next sections the steps needed to contract the service and request execution are presented. On the end the service results obtainable through the report are briefly presented. Before dwelling into the service contracting, provisioning and execution a brief introduction to the flexibility model is given in the next section.

About the flexibility model

The model has been prepared during BD4OPEM project in cooperation with UiW (Use it Wisely) national project, led by Elektro Celje and supported by JSI. The UiW project has been supported by the Agency for Energy of Slovenia which enabled positive and negative critical peak network tariffs in a region of Elektro Celje network. During peak hours the network fee was 10 times higher as at ordinary hours. The Agency decree enabled 100 hours of positive critical peak tariff per year. Based on this the projects have organized 41 2 hours flexibility events in 2021.

The model has been built on a dataset containing the 15 minute-resolution electricity consumption datasets from 791 households in Elektro Celje region. The dataset time span was from September 1, 2019 to December 31, 2021. The dataset was trimmed by removing the customers with missing load and finally 462 customers were used for the analysis. The dataset contains 41 events of 2-hour duration scheduled at different times and days in the year 2021. The dates of the events were carefully selected. The distribution of the events over working days was almost even. The model is therefore suitable for working days though it seems to provide reasonable results for weekends and holidays as well. We have also used the weather data such as temperature, precipitation and radiation of the same region as users to increase the accuracy of our forecast model. The same data – features - need to be provided for the model to provide flexibility forecast.

Data contract

First, we need a data contract for the service. On the "Search" page of the Marketplace, we search for "flexibility forecast" data. There will be a few results, but we select "Flexibility forecast input data" (Figure 182).

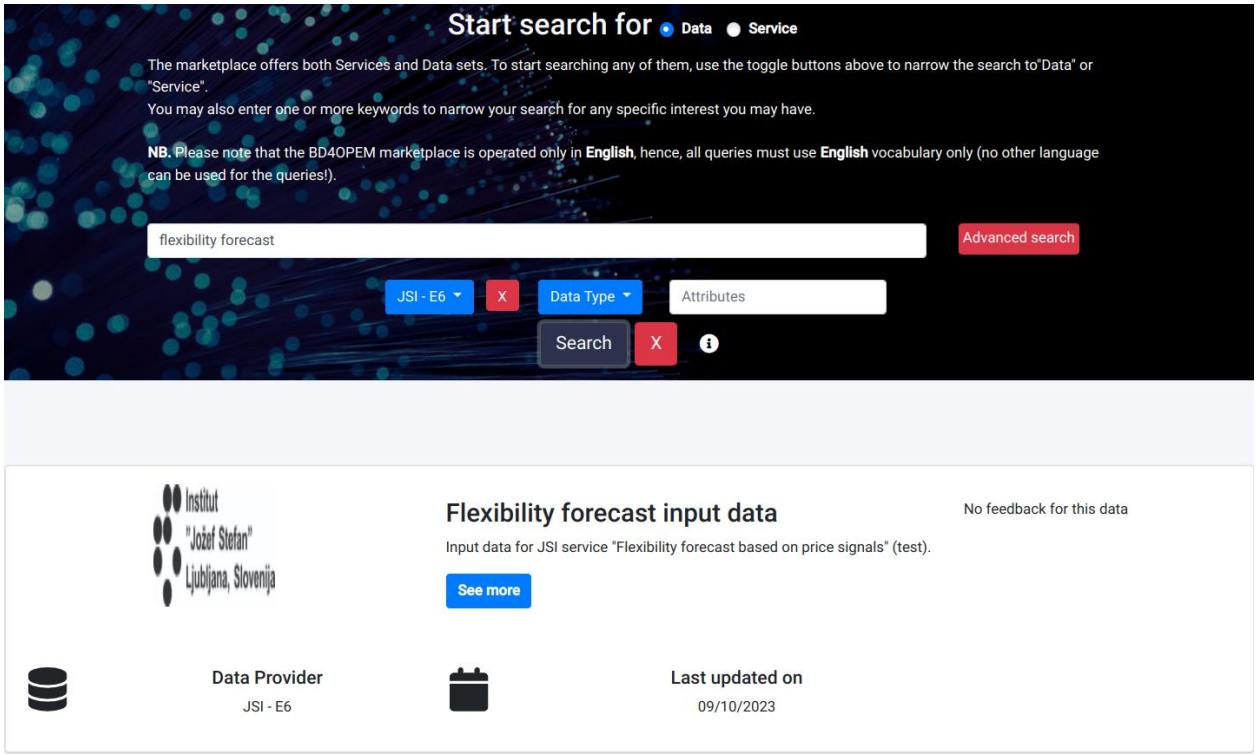


Figure 182. Data contracting

To make a data contract, click on "See more", then "Contract data" at the very bottom. Give the contract whichever name, for example "S5.1 input data" For the data period, select today's date as "From", and whichever date in the future as "To". Finally, press "Submit".

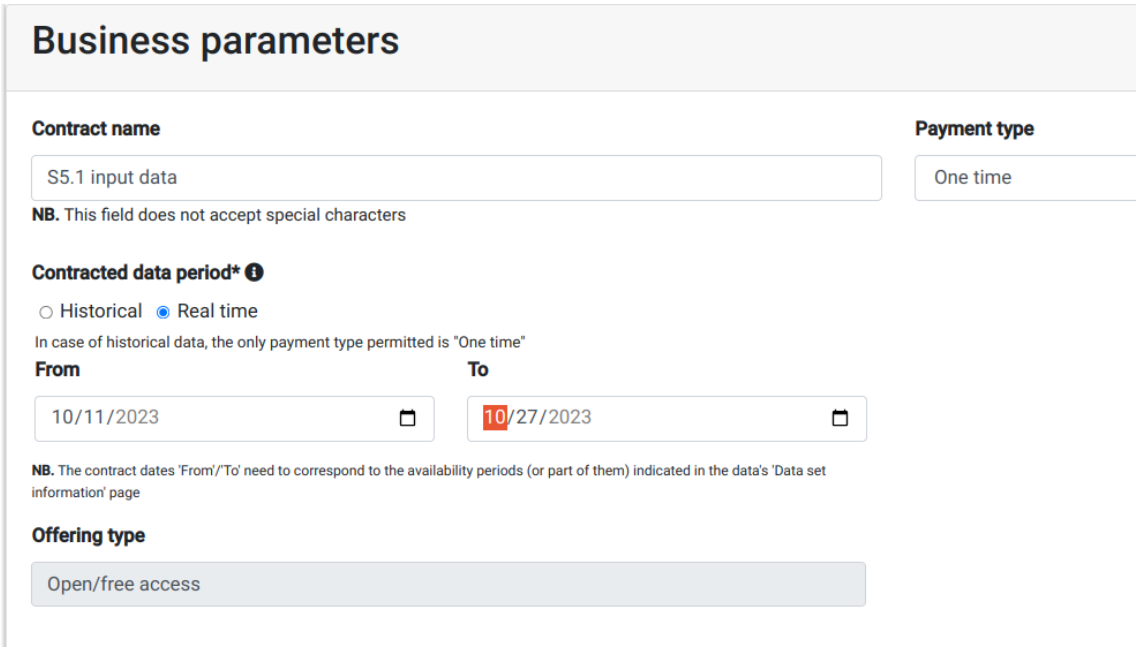


Figure 183. Business parameters

Service Provisioning receives the data contract right after the "Submit" button is pressed. You should be able to see your data contract request in the "My Data" page, with the role "Data User". The contract status should be COMPLETE (Figure 184).

Figure 184. Contracted data and data requests

However, to be able to use the data contract, it needs to be approved and activated by the Data Provider (in this case, JSI). Approving and activating the data contract will advance the contract status from COMPLETE to APPROVED, and then to ACTIVE. Once contract status is ACTIVE, it can be selected when contracting a service, as we will see shortly.

Service contract

Contracting a service follows similar steps as contracting data. Service S5.1 can be found on the Marketplace under the name "Flexibility forecast based on price signals". Under "Advanced search", we can also select "JSI - E6" organization to filter the results (Figure 185).

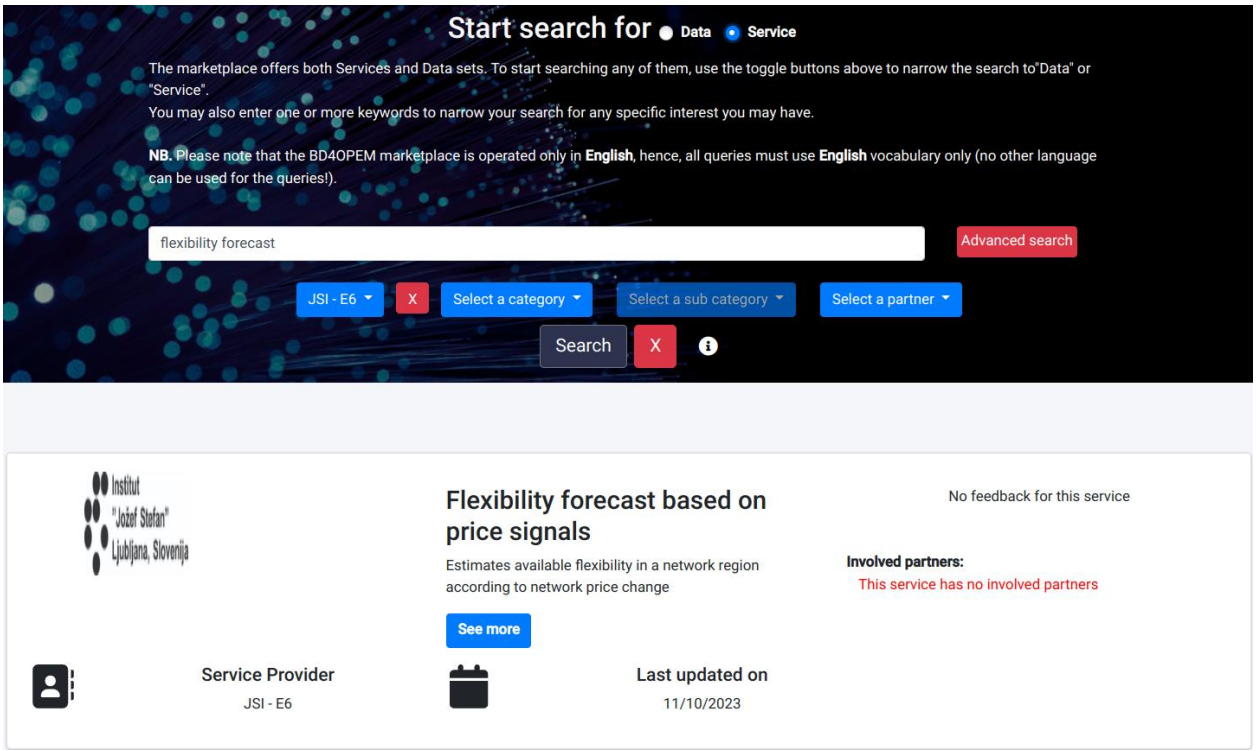


Figure 185. Servis contracting

Click on "See more", and then "Request new service" at the top of the page. We first fill in the business parameters, same as for the data contract. Contract name can be whatever, for example "S5.1 test contract [today's date]". Leave "Payment type" as is, and select the contract period (Figure 186).

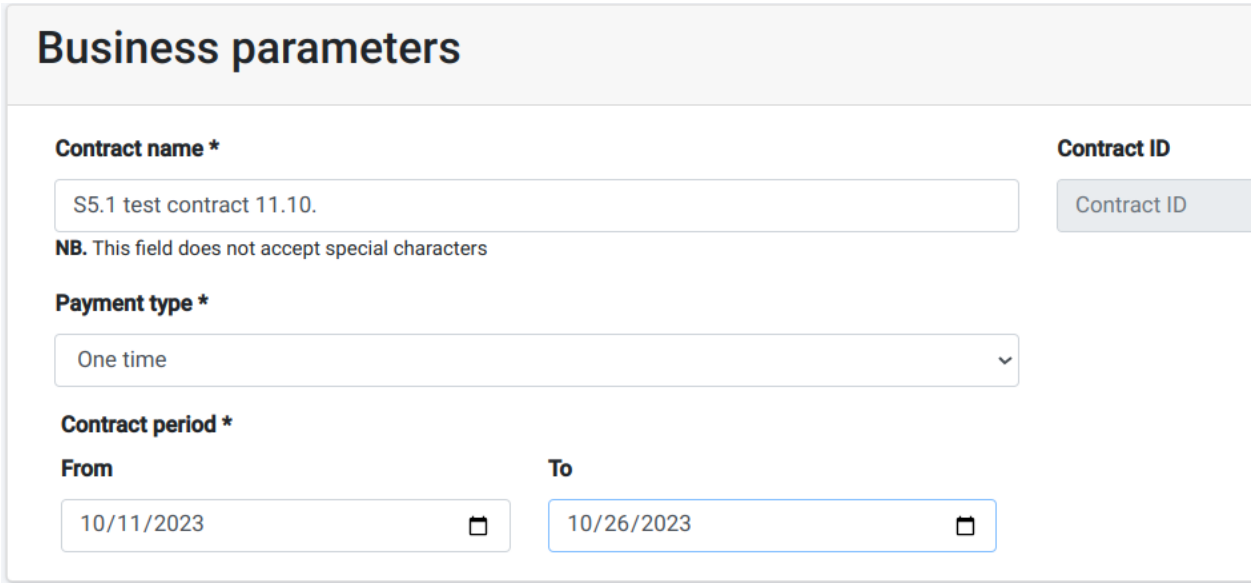


Figure 186. Filling business parameters

Next, we select the technical parameters. Select one value for each technical parameter. A description of each parameter can be seen in the image. The most important one to select is the pilot - this essentially determines whose data will be used during execution. The parameter "pilot_strength" should be the approximate number of smart meters in the planned event (Figure 187).

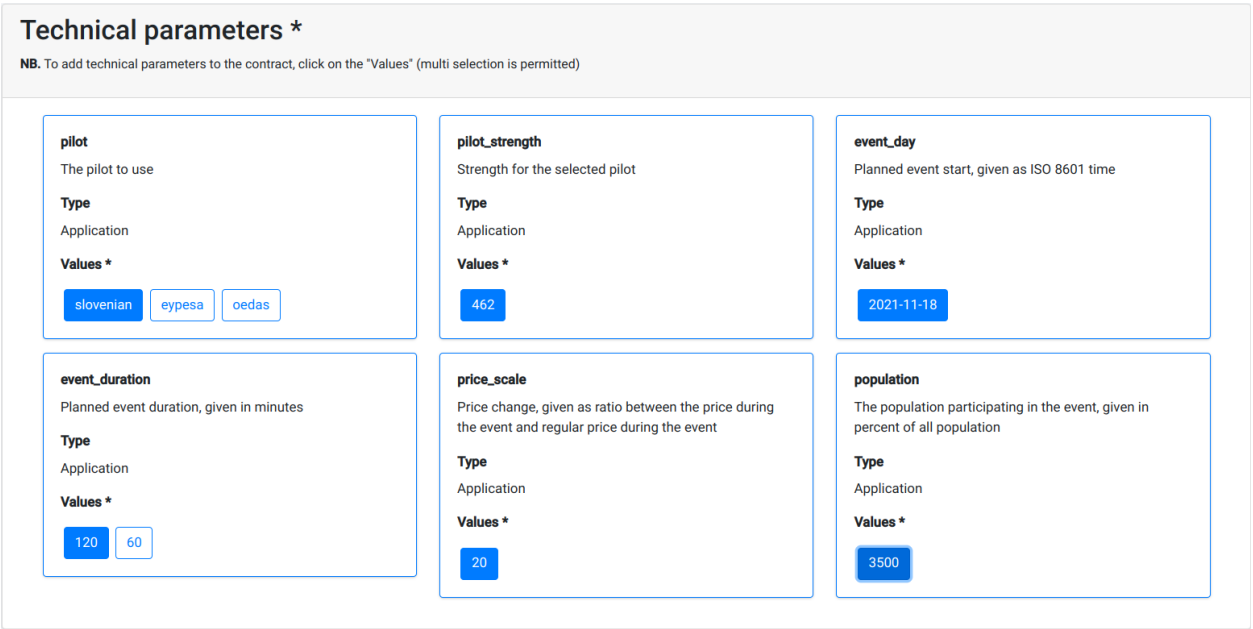


Figure 187. Technical parameters of the Service S5.1

We then select the data contract. Find the "S5.1 input data" (or whatever name you put) data contract, check it, and click "Confirm". The data contract will not be present unless it was activated by the Data Provider. Be sure to also select "Yes" for "Enable immediate execution", otherwise the service will not actually be run in the ASM module (Figure 188).

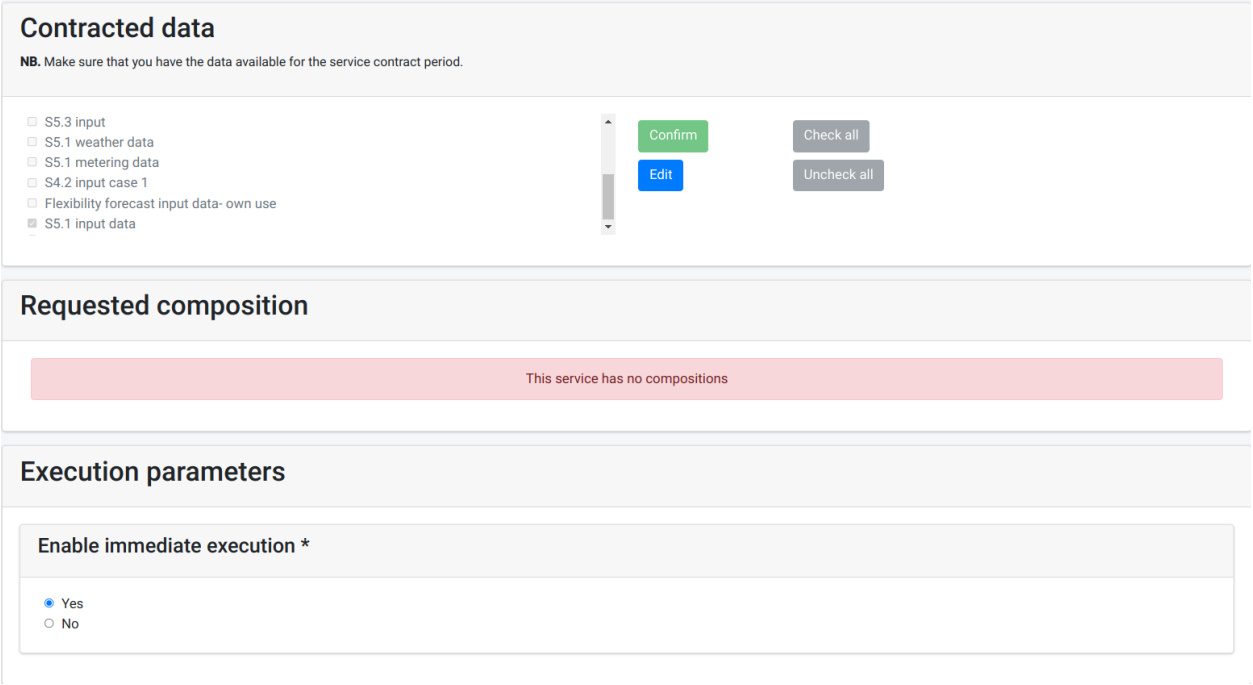


Figure 188. Contracted data for the Service S5.1

Finally, click on the "Request service" button at the bottom. Similarly as for the data contract, Service Provisioning receives the contract right after the button is pressed. You should be able to see your service contract request in the "Service requests" table, found on the "My Services" page, with the role set to "Service User". The contract, provisioning and execution status should be as in the Figure 189.

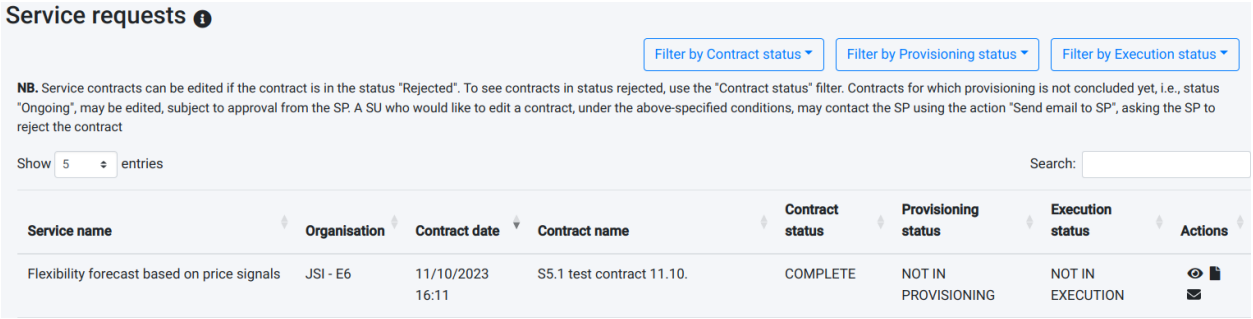


Figure 189. Service requests

Running the service

Similarly, to be able to use the service contract, it needs to be approved and activated by the Service Provider (in this case, JSI). Immediately after the contract is activated, an instance of the S5.3 service will be started in the ASM module. This will happen

because the service is set to be auto instantiated *if* immediate execution was set to "Yes".

As soon as the contract is activated, i.e. the service starts executing in ASM, the Marketplace will provide us with a link to our front-end, where we can see the logs and results of the service. This link is accessible via the "Go to service" button, present in the corresponding entry in the "Service requests" table (Figure 190).

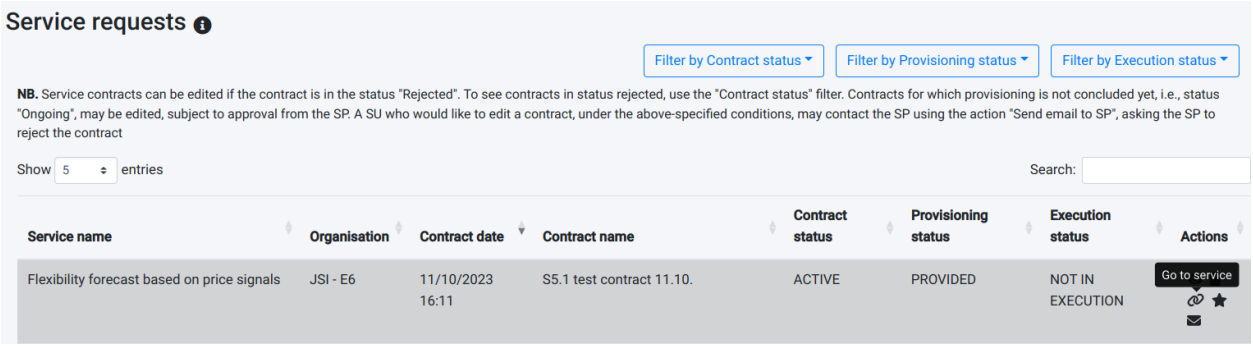


Figure 190. "Service requests" table

Clicking on the "Go to service" button takes us to our front-end (Figure 191).

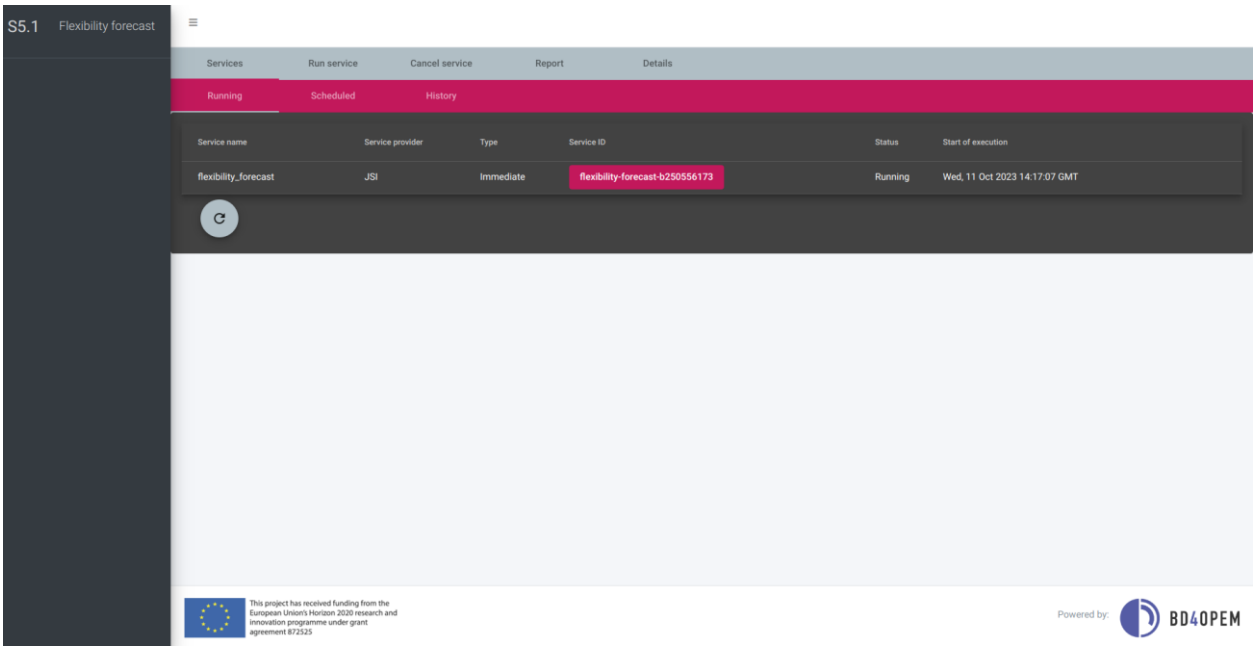


Figure 191. Details page

If the service is still executing, it should be present in the "Running" tab. Clicking on the ID in the "Running" tab will take you to the "Details" page and stream any logs of the service.

If the service has finished, we should be able to find it in the tab "History". You can click on the refresh button to see whether it has. By clicking on the service ID in the "History" tab, the report i.e result of the service will be fetched and you will be automatically moved to the "Report" tab.

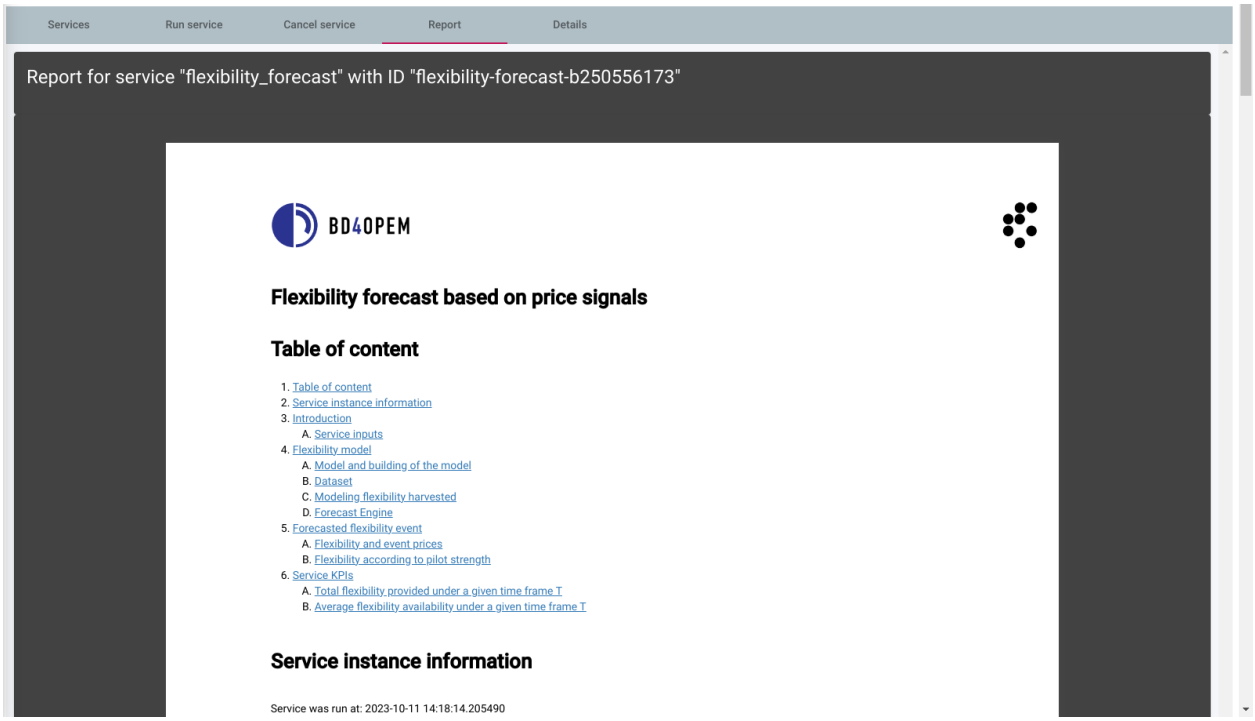


Figure 192. "Report" tab

Additionally, by clicking on the tab "Details", you will be able to see the technical parameter values you selected, as well as any stdout and stderr logs of the service.

S5.3 - Flexibility aggregated services for DSOs

S5.3 – Flexibility aggregated services for DSOs

1. Contract the service with the demanded parameters.
2. Select the pilot/grid (Figure 193).

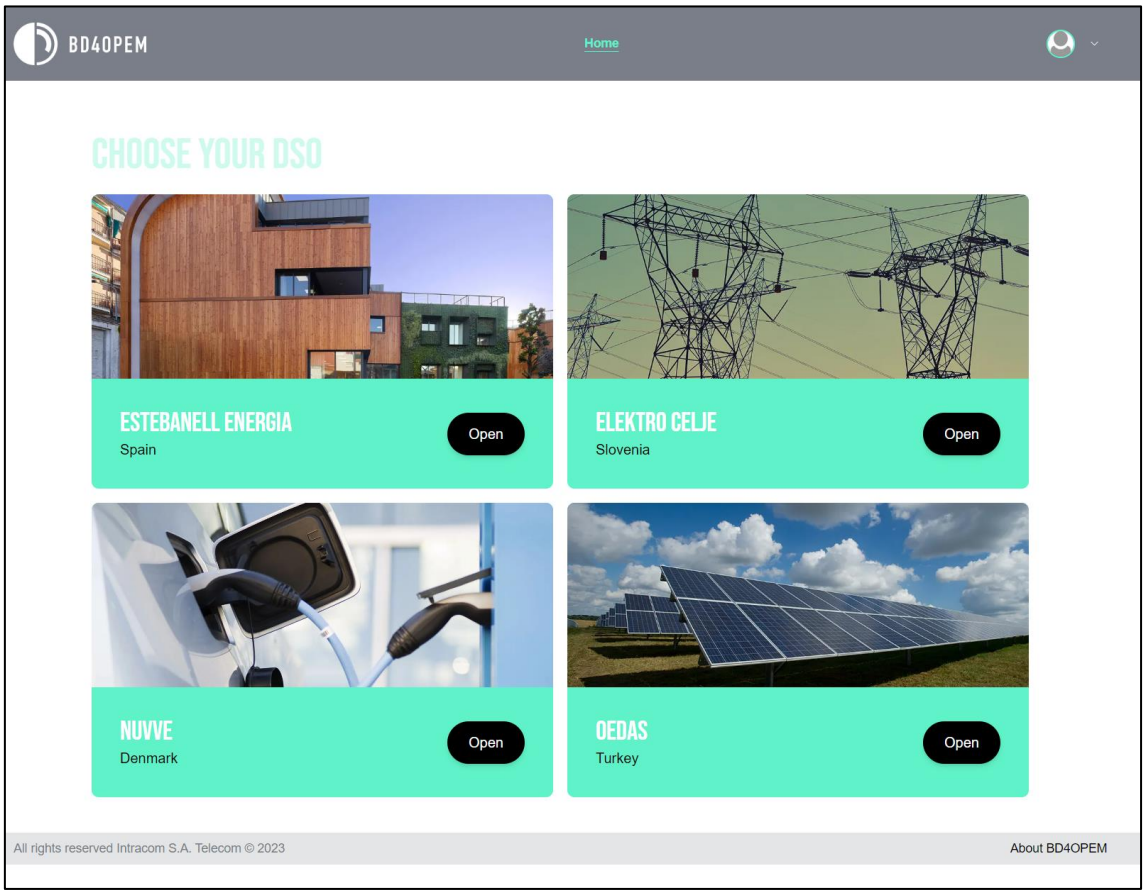


Figure 193. "Pilot selection" tab

3. Upload the *daily forecast* (Figure 194). The daily forecast file corresponds to the excel file with the forecast for all loads for the next day. Select the date accordingly to such forecast. Then select *Submit*.
   The forecast files are the following with their forecasted date:

   - Estabanell: Estabanell_forecast-1.xlsx (21-07-2023)
   - CELJE: ELCE_forecast-1.xlsx (07-07-2023)
   - NUVVE: NUVVE2_b_forecast-1.xlsx
   - OEDAS: OEDAS_forecast-1.xlsx (13-07-2023)

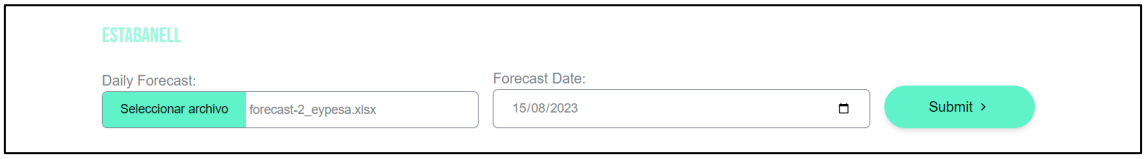


Figure 194. Selecting of forecasting data

4. The service will start the execution for that specific day. Wait until the service is completed, hence, *Successful* (Figure 195).

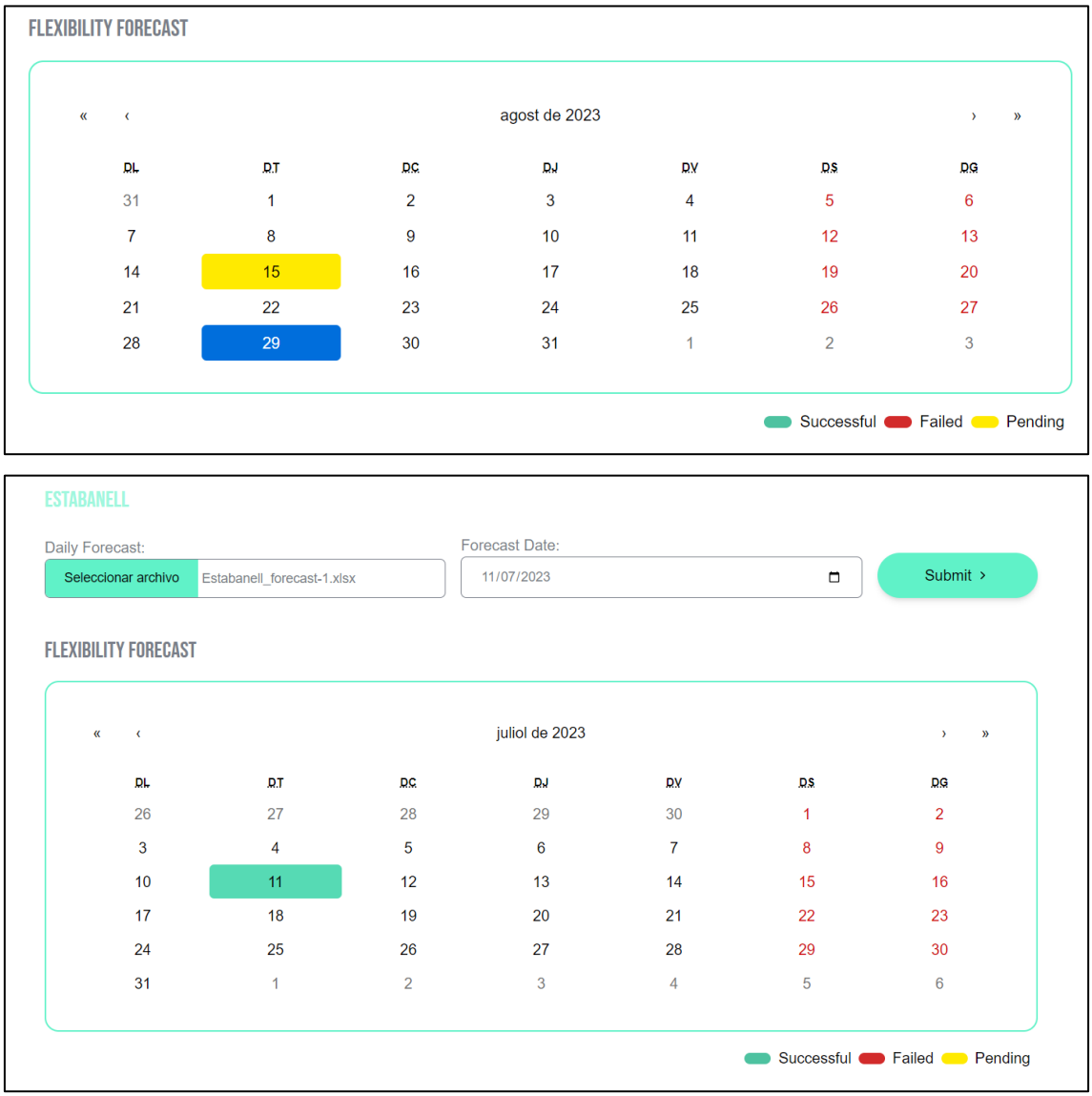


Figure 195. Daily forecast

5. Technical Testing: After executing the service, explore the performance factors of the period selected.
    a. Select period. If you only have given data for one day, just select that day. (Like the example in this StoryLine) (Figure 196).

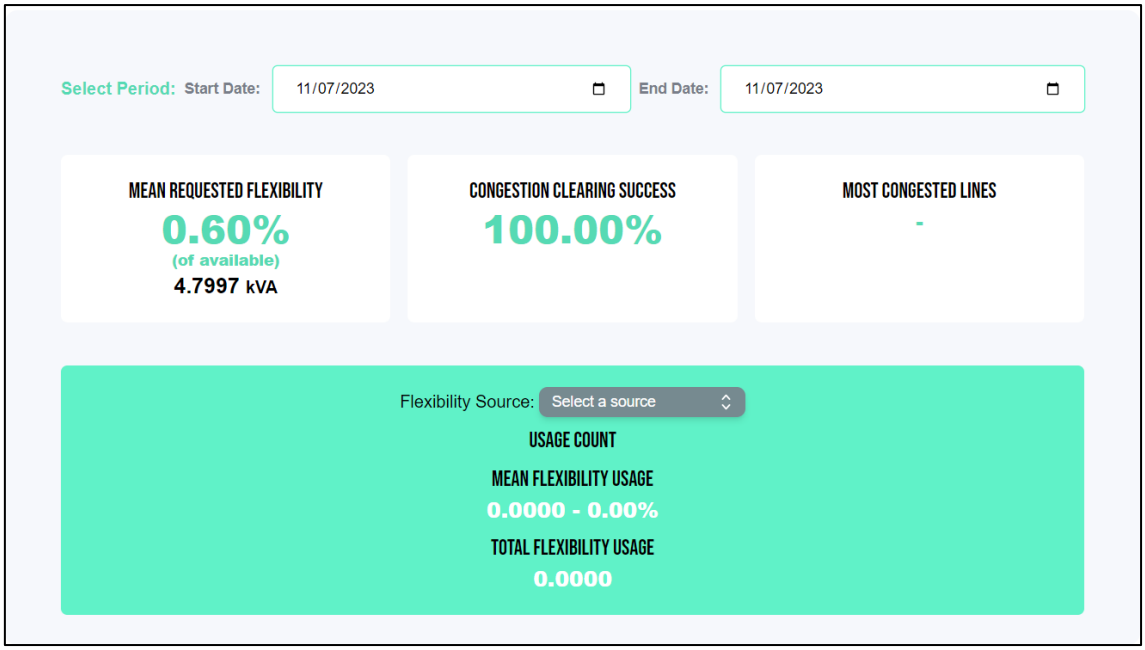


Figure 196. Flexibility forecast/ Selected period

b. Evaluate the results provided in this tab by verifying the summary values of Requested Flexibility and Congested Lines.
c. Scroll down and check the flexibility source ID dropdown list. Explore sources ID1 y ID2 and check their values (Figure 197).

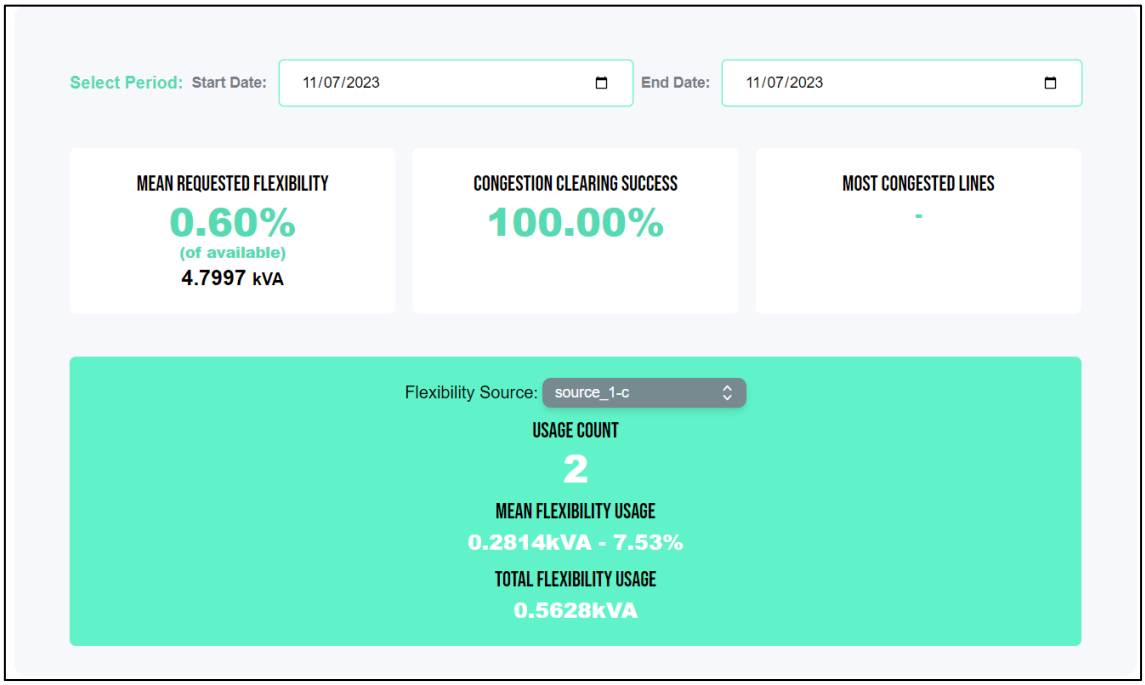


Figure 197. Control screen

d. Repeat the previous two steps for different available dates.

6. Click on the date on the calendar to get the visualizations of the results of that day (Figure 198).

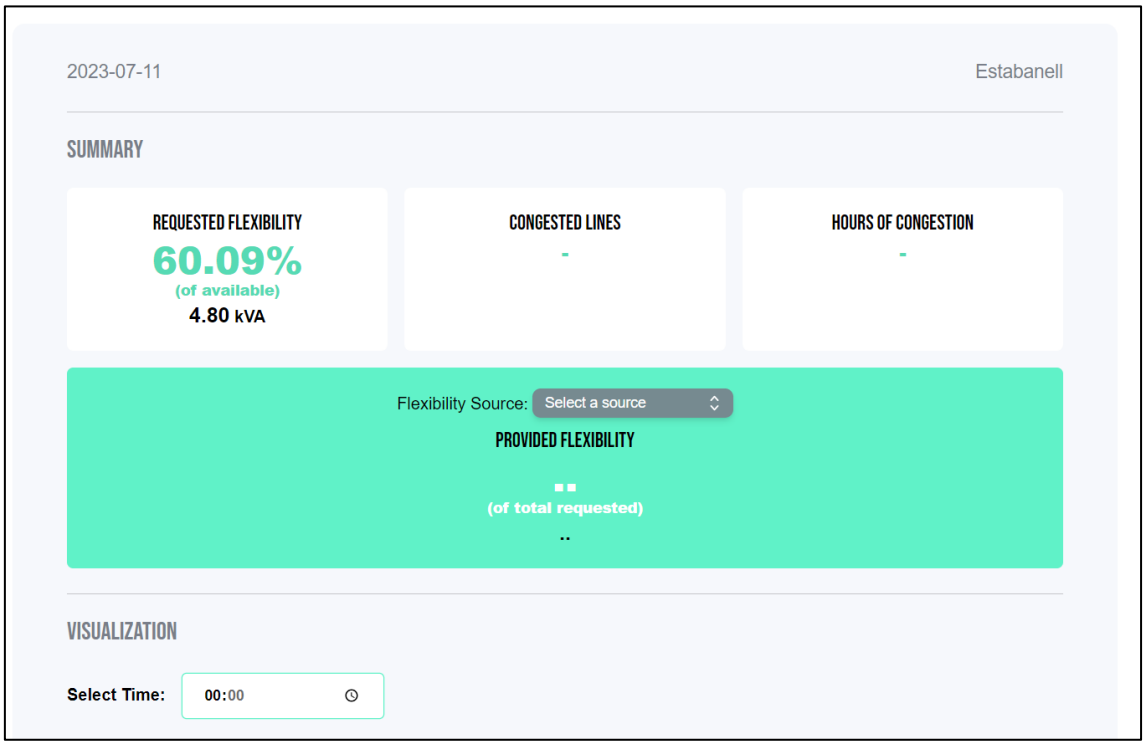


Figure 198. Summary

a. Change different times of the day. The figures depict the grid before and after the execution of the service. This corresponds to the use of the service to calculate the appropriate amount of flexibility to overcome the forecasted congestions in the grid (Figure 199).

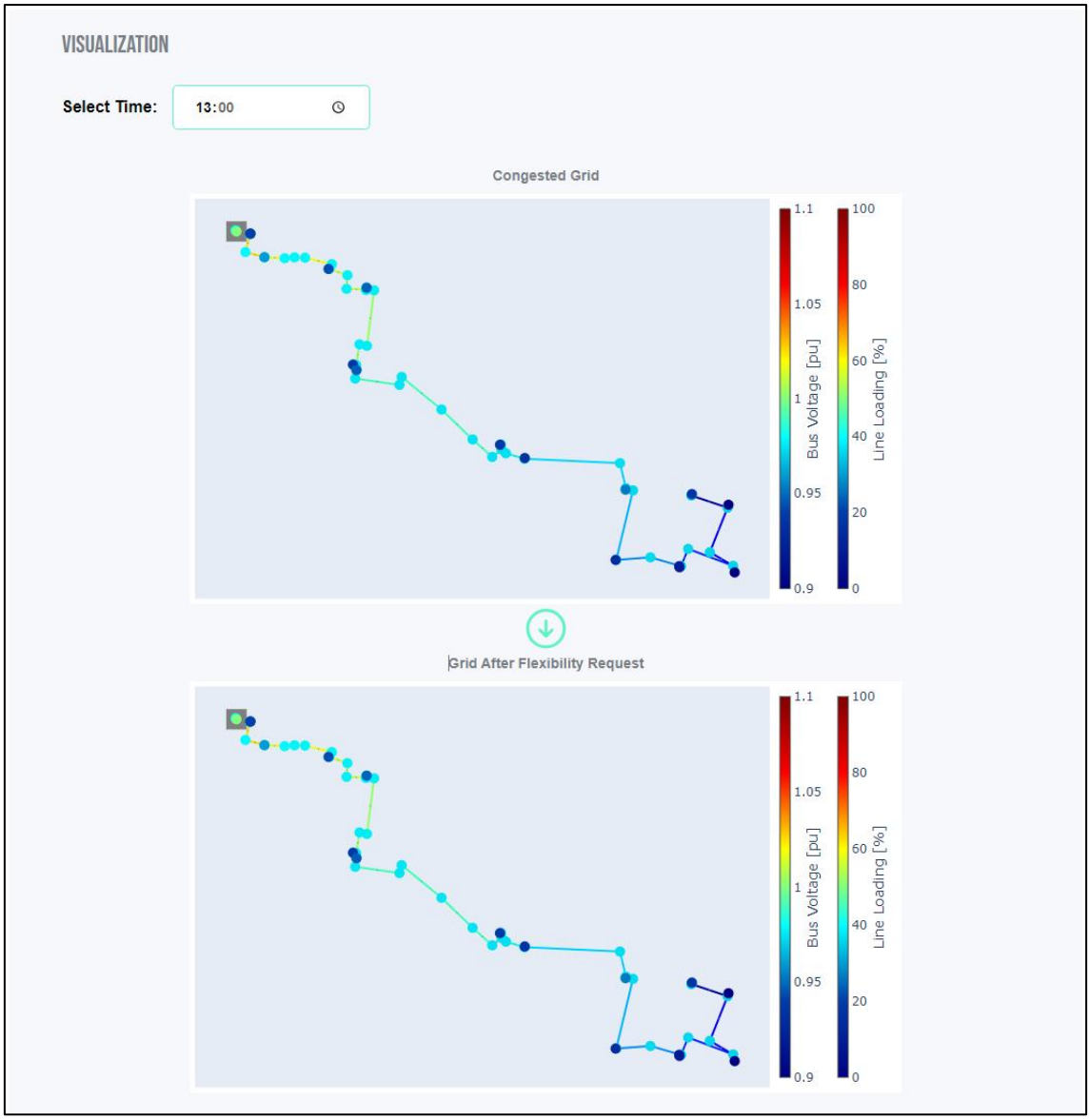


Figure 199. Visualization

b. Download figures for the most congested time of the day.
c. Following up the last step, make sure you can observe the image correctly after downloaded locally or in any other form.

7. Scroll down once again and position yourself in the preview of data (Figure 200).
   a. In this section you are you going to select different buses IDs and explore their behavior
   b. Download the data in excel form.
   c. Open data downloaded file and explore further results to make sure everything works.

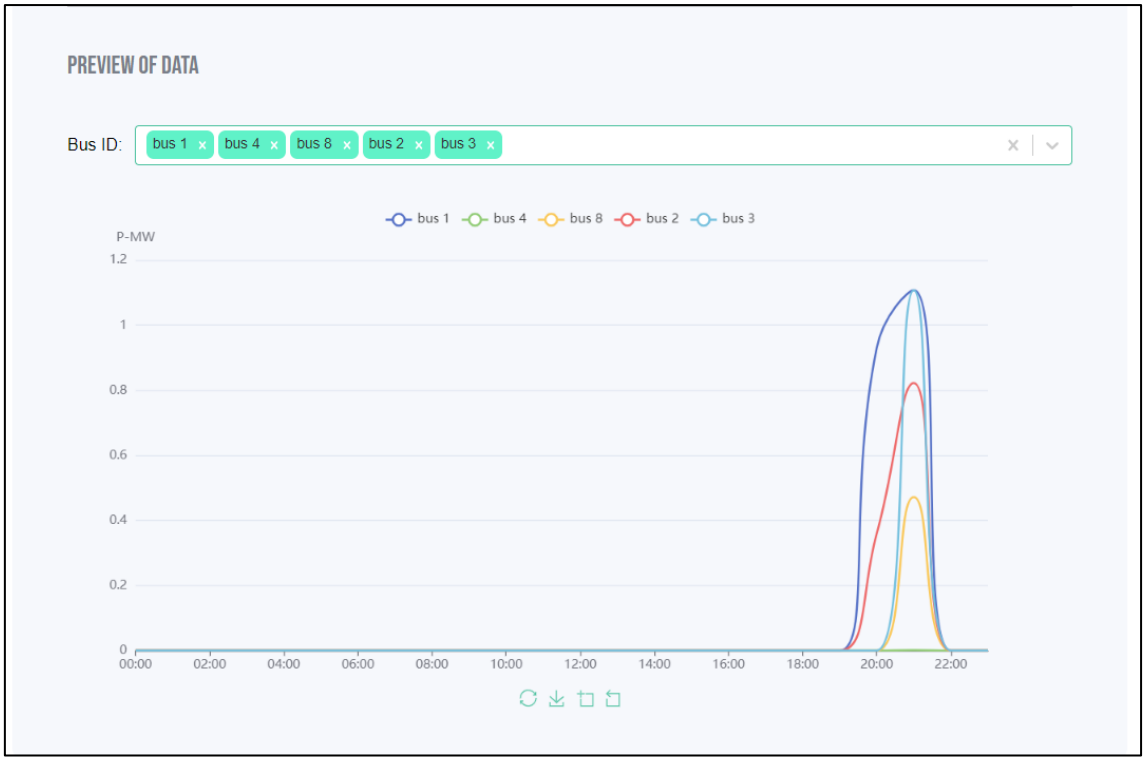


Figure 200. Preview of DATA

S5.3 – Flexibility aggregated services for DSOs

Introduction

Flexibility services for DSOs provide necessary services for the DSOs to schedule flexibility events in a region of their network. The services provide a prediction of consumption in the target region and propose an event schedule at the time of the peak.

The service requires historic data of the region's consumption and weather forecast for the region. The service has been used with the following weather parameters: temperature, radiation and precipitation. At least temperature should be available.

The prediction of the consumption depends on the available weather forecast. More days of the forecast are available, longer can be the consumption prediction. For example, in Elektro Celje Case, if there are seven days of weather prediction data available the consumption can be predicted for a week in advance. Since the consumption is based on smart-metering and the metering is considered to be D-1, the effective prediction is less than a week long. The number of days is further reduced since the D-1 data is usually not good enough for prediction. Large portions of the network data is available as D-2 data. In summary, an effective prediction is only 5 days long.

The predictions in this story line are shown on historic data so the service can be more easily evaluated. Working on the edge and predicting into the future requires a flowing stream of data.

In the next sections the steps needed to contract the service and request execution are presented. On the end the service results obtainable through the report are briefly presented.

Data contract

First, we need a data contract for the service. On the "Search" page of the Marketplace, we search for "flexibility services for DSOs" data, as seen in the Figure 201.

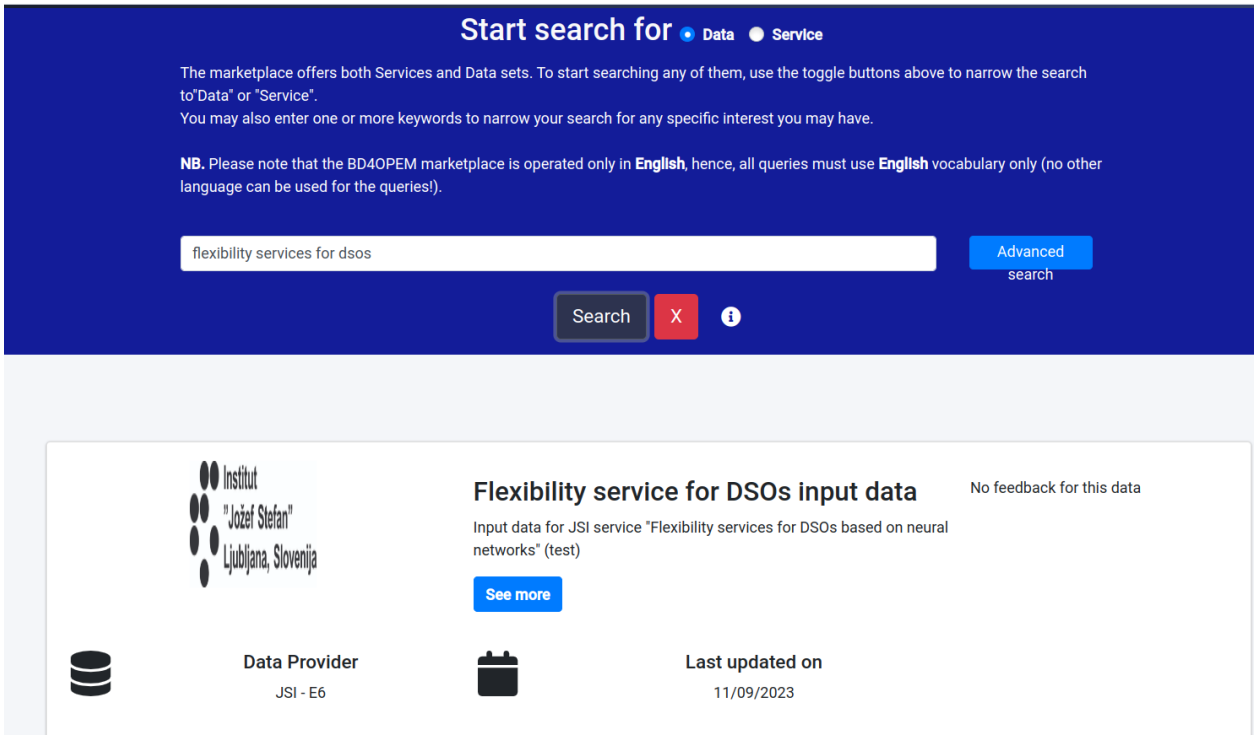


Figure 201. Data contract

To contract this data, click on "See more", then "Contract data" at the very bottom. Give the contract whichever name, for example "S5.3 input". For the data period, select today's date as "From", and whichever date in the future as "To". Finally, press "Submit" (Figure 202).

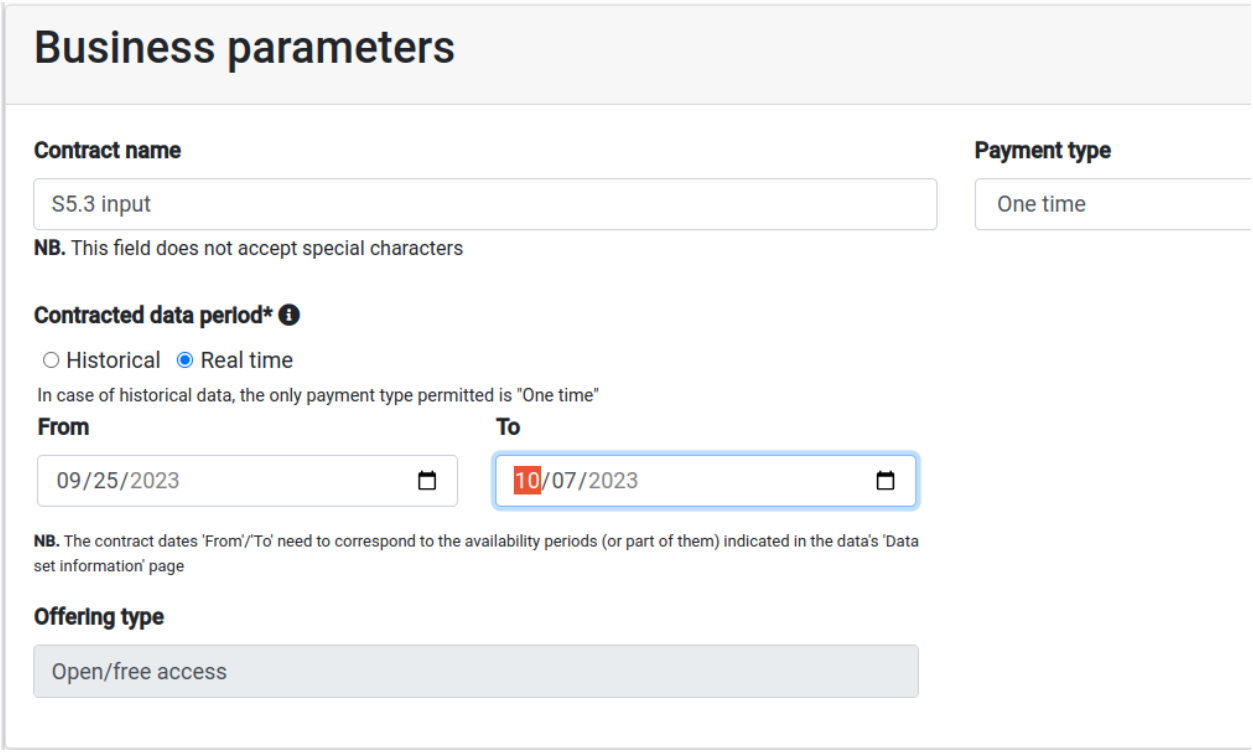


Figure 202. Business parameters

Service Provisioning receives the data contract right after the "Submit" button is pressed. The Service Provisioning details are shown in the Figure 203.

The following image shows the corresponding log entry in the SP module, indicating the data contract was received.

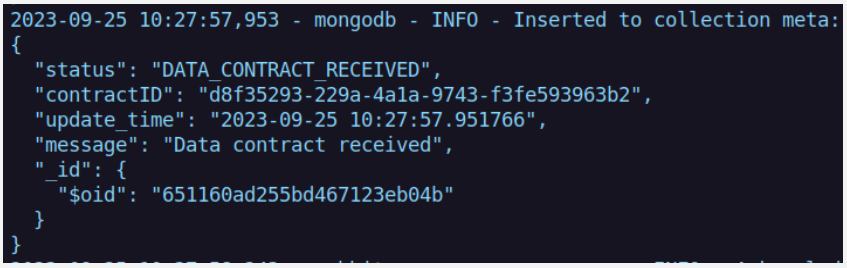


Figure 203. Data contract entry display

You should be able to see your data contract request in the "My Data" page, with the role "Data User". The contract status should be COMPLETE (Figure 204).

Figure 204. Contracted data and data requests

However, to be able to use the data contract, it needs to be approved and activated by the Data Provider (in this case, JSI). Approving and activating the data contract will advance the contract status from COMPLETE to APPROVED, and then to ACTIVE. Once contract status is ACTIVE, it can be selected when contracting a service, as we will see shortly.

Service contract

Contracting a service follows similar steps as contracting data. We first search for service S5.3, flexibility services for DSOs. Under "Advanced search", we can also select "JSI - E6" organization to filter the results.

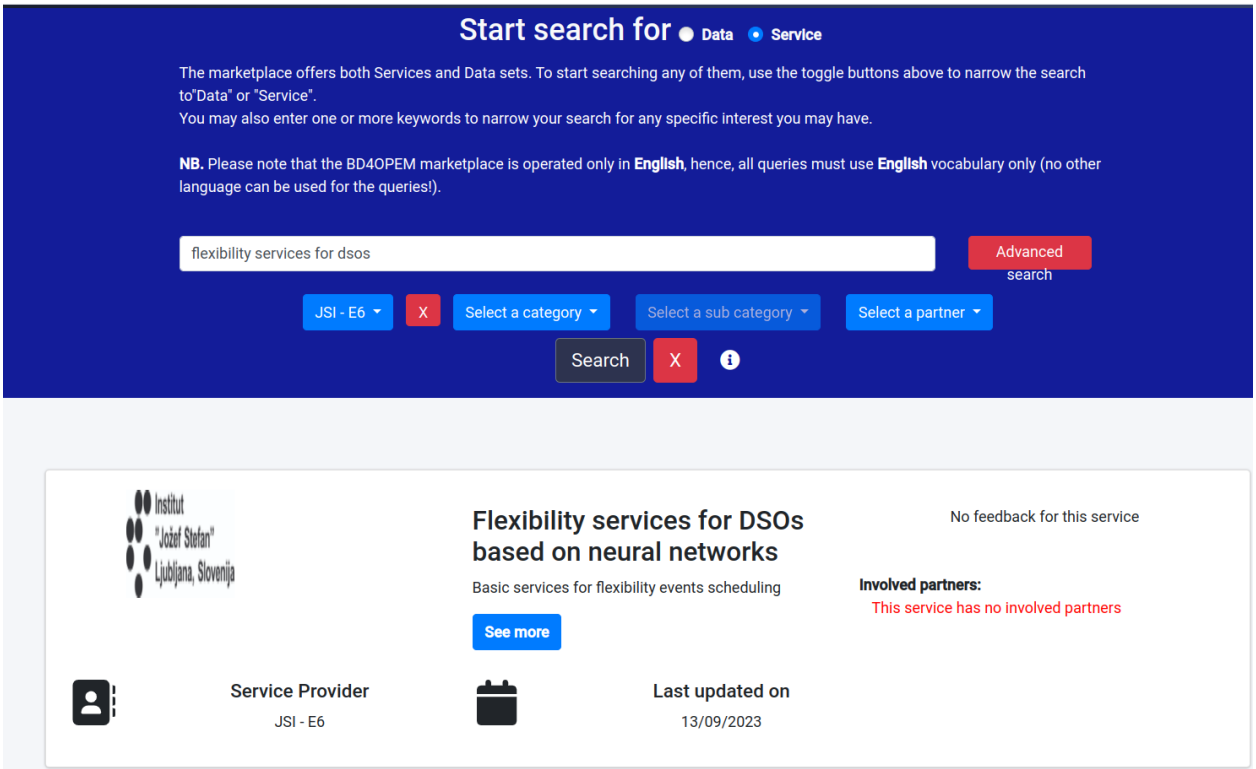


Figure 205. Flexibility services for DSOs based on neural networks

Click on "See more", and then "Request new service" at the top of the page. We first fill in the business parameters, same as for the data contract. Contract name can be whatever, for example "S5.3 test contract [today's date]". Leave "Payment type" as is, and select the contract period (Figure 206).

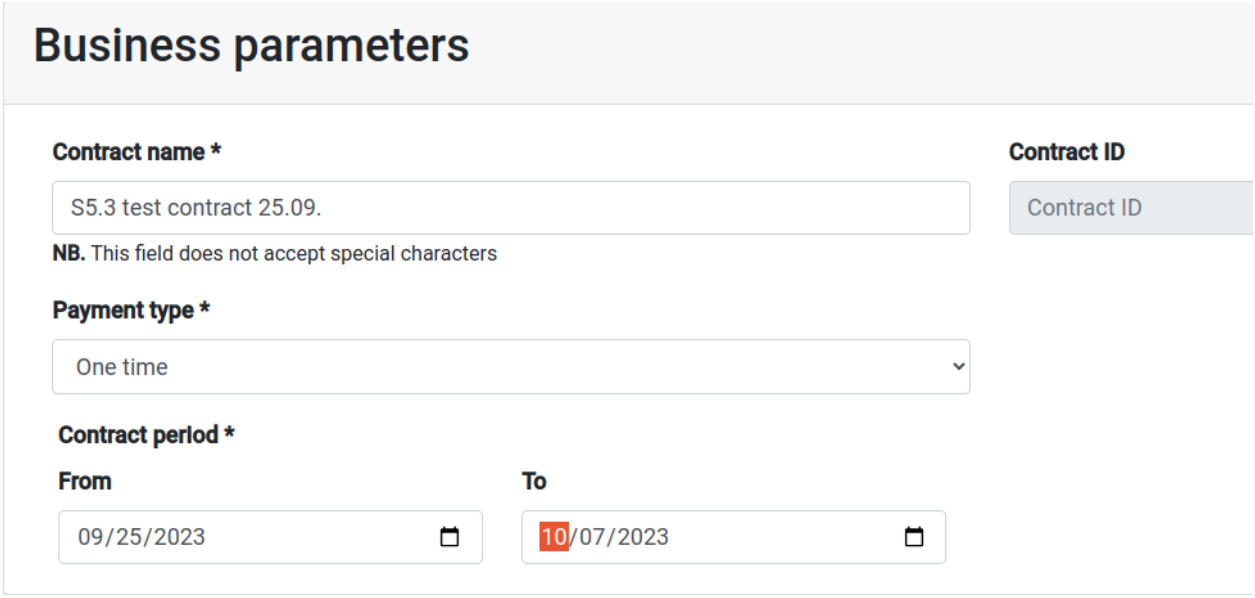


Figure 206. Business parameters of the Service S5.3

Next, we select the technical parameters. Select one value for each technical parameter. A description of each parameter can be seen in the image. The most important one to select is the pilot - this essentially determines whose data will be used during execution (Figure 207).

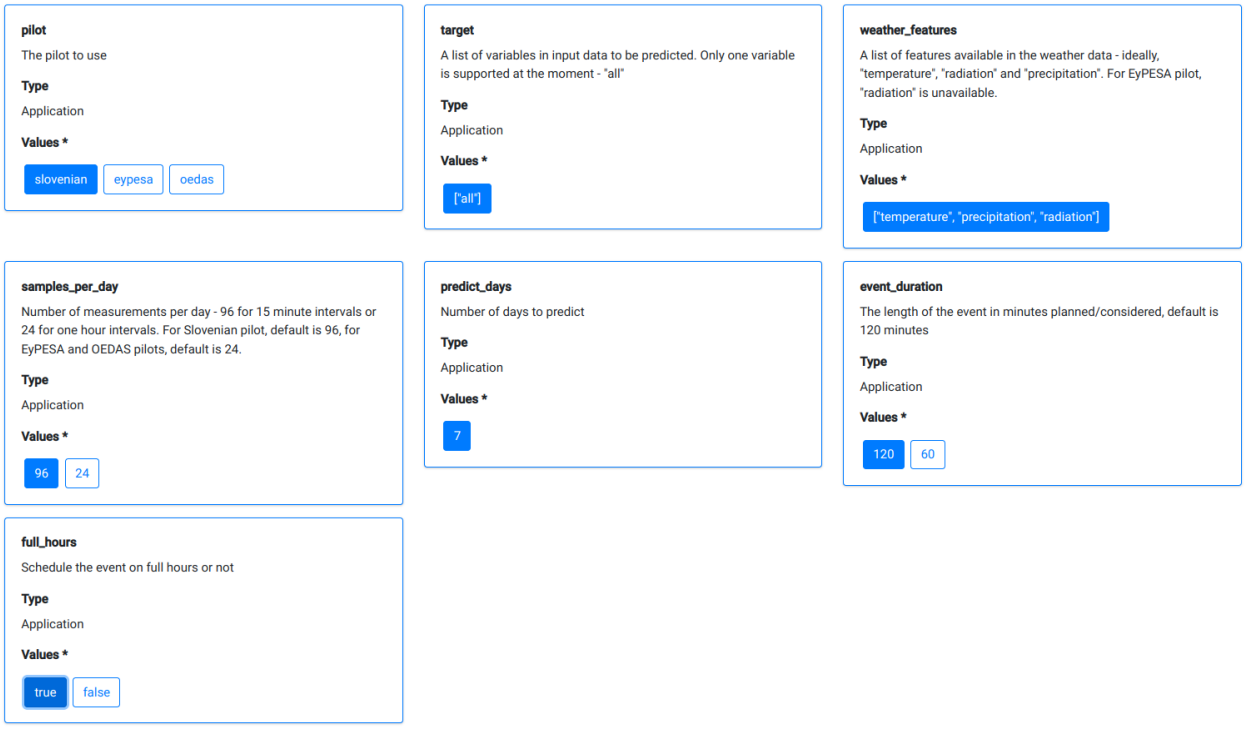


Figure 207. Parameter selection

We then select the data contract. Find the "S5.3 input" (or whatever name you put) data contract, check it, and click "Confirm". The data contract will not be present unless it was activated by the Data Provider. Be sure to also select "Yes" for "Enable immediate execution", otherwise the service will not actually be run in the ASM module (Figure 208).

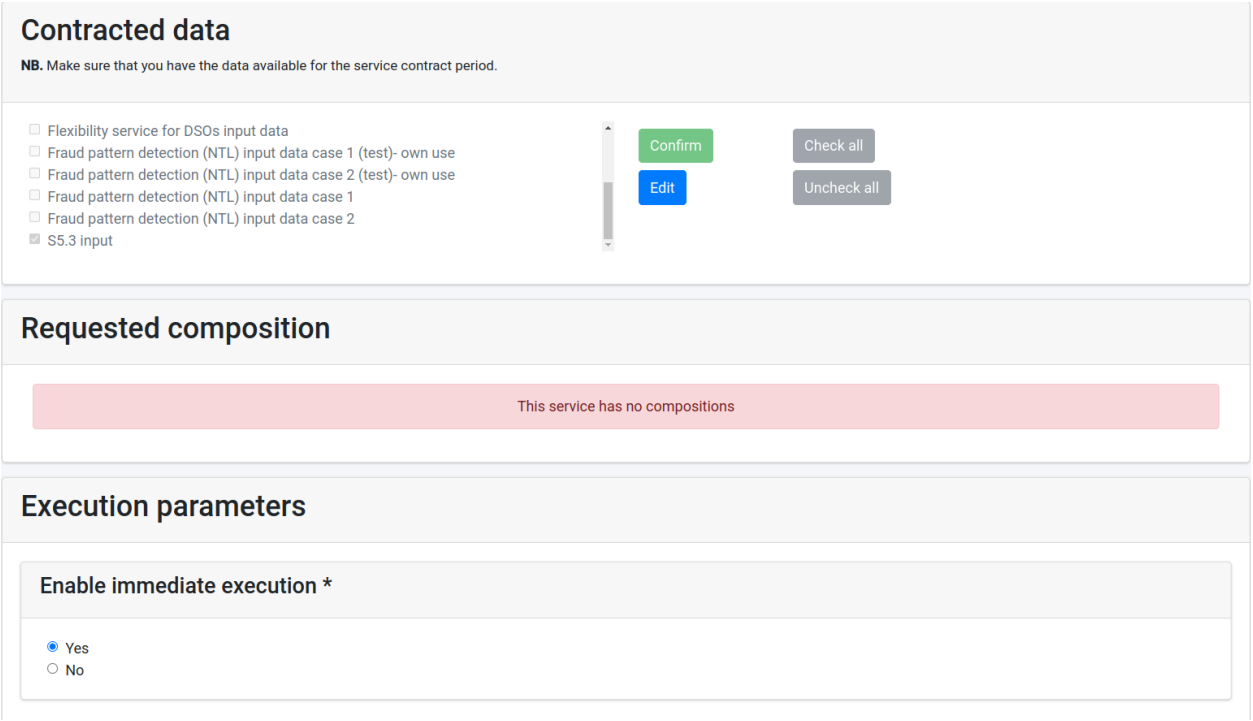


Figure 208. Stages

Finally, click on the "Request service" button at the bottom. Similarly as for the data contract, Service Provisioning receives the contract right after the button is pressed (Figure 209).

We can see the corresponding log entries in the SP module, indicating that the service contract was received, and in short, that everything is okay.

```
2023-09-25 10:32:14,442 - mongodb - INFO - Inserted to collection meta:
{
  "status": "SERVICE_CONTRACT_RECEIVED",
  "contractID": "ca85f245-f6da-45f7-8887-e0a8a40d853c",
  "update_time": "2023-09-25 10:32:14.440261",
  "message": "Service contract received",
  "_id": {
    "$oid": "651161ae255bd467123eb04d"
  }
}
2023-09-25 10:32:14,670 - mongodb - INFO - Inserted to collection meta:
{
  "status": "CONTRACT_AVAILABLE",
  "contractID": "ca85f245-f6da-45f7-8887-e0a8a40d853c",
  "update_time": "2023-09-25 10:32:14.668001",
  "message": "Service and data contracts available",
  "_id": {
    "$oid": "651161ae255bd467123eb04e"
  }
}
```

Figure 209. SP Module

You should be able to see your service contract request in the "Service requests" table, found on the "My Services" page, with the role set to "Service User". The contract, provisioning and execution status should be as in the Figure 210.

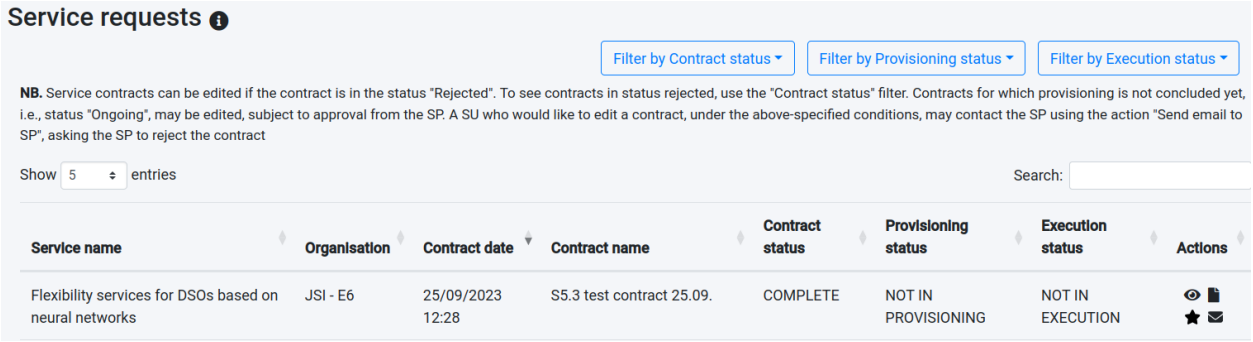


Figure 210. Service Requests

Running the service

Similarly, to be able to use the service contract, it needs to be approved and activated by the Service Provider (in this case, JSI). Immediately after the contract is activated, an instance of the S5.3 service will be started in the ASM module. This will happen because the service is set to be auto instantiated *if* immediate execution was set to "Yes" (Figure 211).

The following image shows a screenshot of running so-called pods (think of them as microservices) in the ASM module in our Kubernetes cluster. We can see that one of them is called "fs-dsos-<random strings>" - this pod is executing an instance of S5.3 i.e. flexibility forecast for DSOs service.

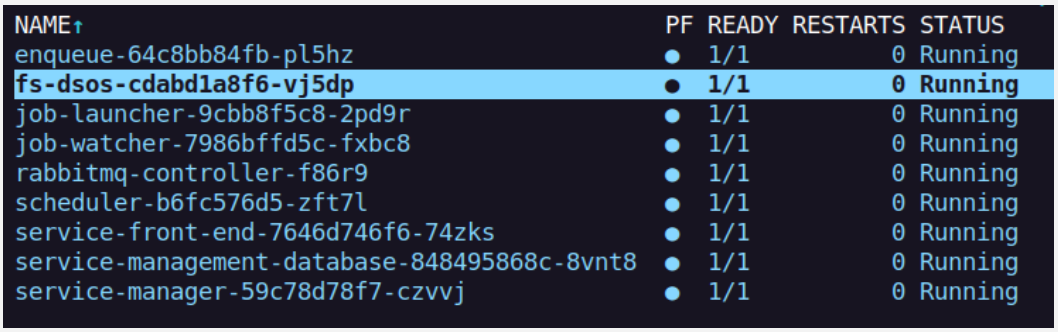


Figure 211. Elasticity estimation screenshot for DSO's service

As soon as the contract is activated, i.e. the service starts executing in ASM, the Marketplace will provide us with a link to our front-end, where we can see the logs and results of the service. This link is accessible via the "Go to service" button, present in the corresponding entry in the "Service requests" table (Figure 212).

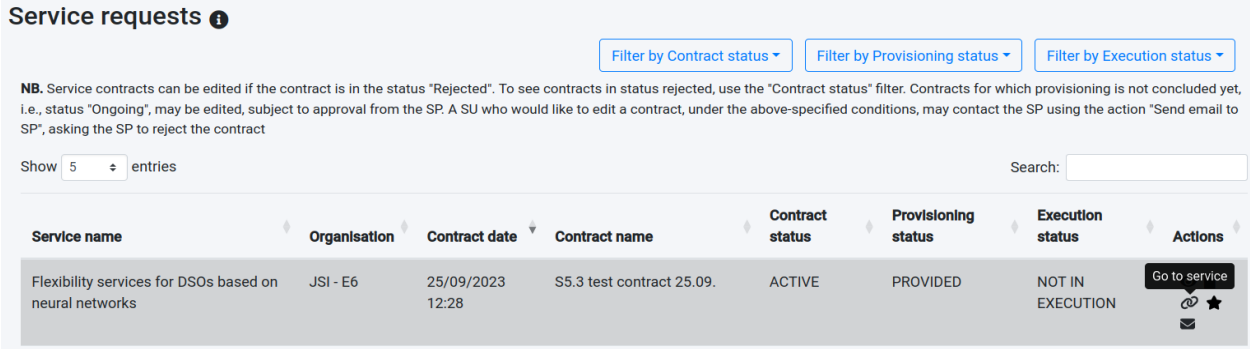


Figure 212. Service requests status screen

Clicking on the "Go to service" button takes us to our front-end.

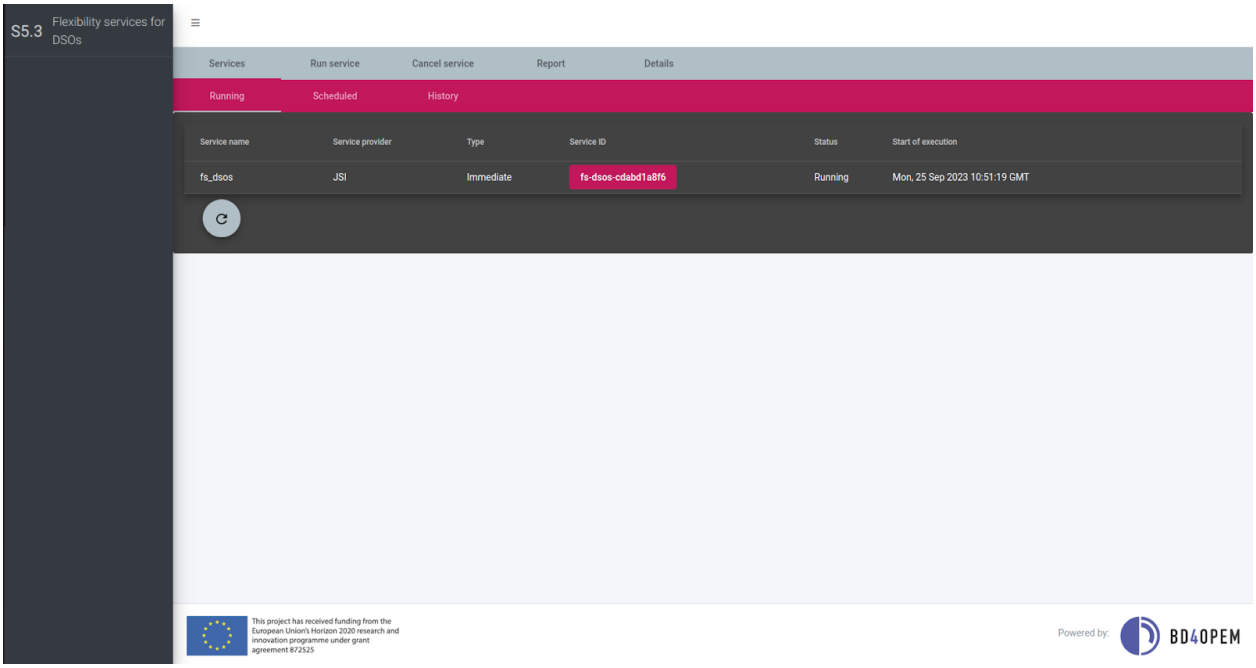


Figure 213. Details page

If the service is still executing, it should be present in the "Running" tab. Clicking on the ID in the "Running" tab will take you to the "Details" page and stream any logs of the service.

If the service has finished, we should be able to find it in the tab "History". You can click on the refresh button to see whether it has. By clicking on the service ID in the "History" tab, the report i.e result of the service will be fetched and you will be automatically moved to the "Report" tab (Figure 214).

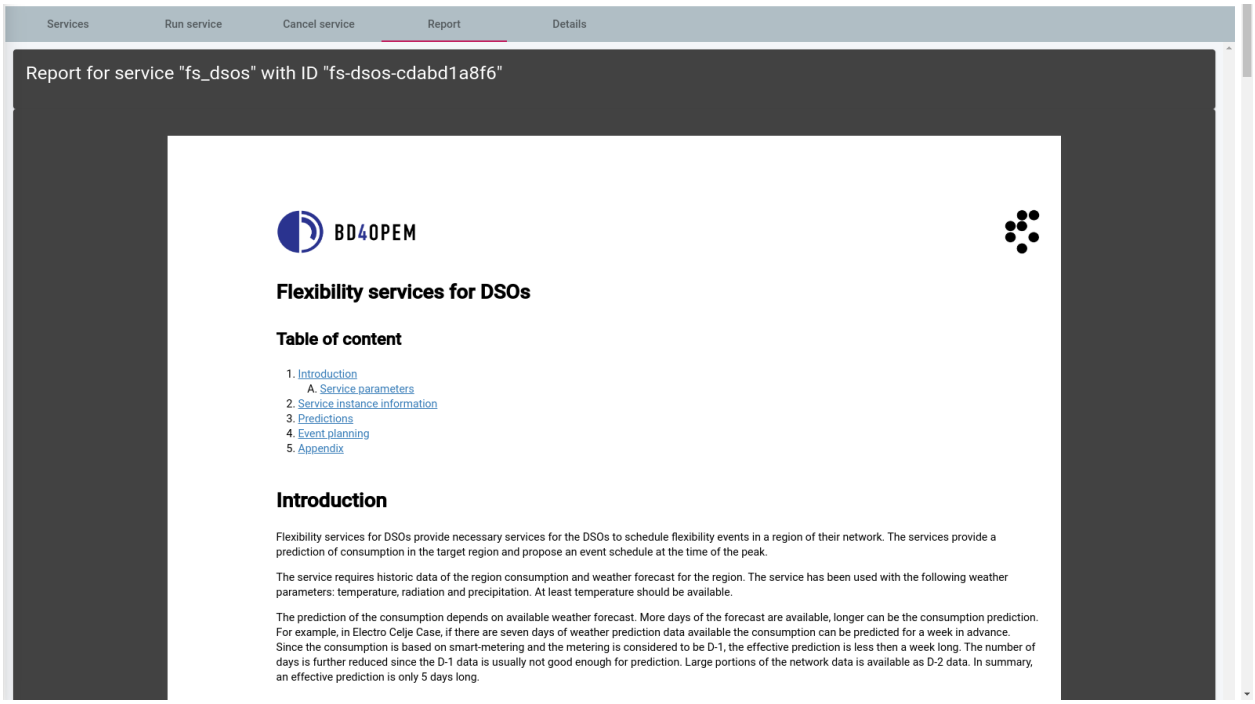


Figure 214. "Report" tab

Additionally, by clicking on the tab "Details", you will be able to see the technical parameter values you selected, as well as any stdout and stderr logs of the service.

S6.1 – Energy management at household or at community level & S6.2 Energy forecasting

1. Go to the Marketplace main page and go to the search bar and look for the service "Energy management at household or community level".
2. Select the desired service
3. Contract the service, following the default and/or required contract parameters. Upload the data as needed.
4. Execution of the service through the marketplace or by login to the marketplace and running http://s61jsi.bd4opem.eu/
5. Usability Testing: After executing the service, follow the indicated steps to test various aspects
    a. On the left of the initial screen you can select a household in the zone and the appropriate start and end data for analysis (Figure 215).

Figure 215. Selected a household in the zone and the appropriate start and end data for analysis

b. The first tab is "Train" where you find the related weather data for the selected period. The data will be shown for the selected SM by selecting *get data* on the left panel. These can be further used for training the model. Pressing the button *train* will execute the model training for a specified period using shown data. Once done, you will see the agreement for the last two days and the two-day forecast. At this point, you can save the model for further use or replace the existing one (Figure 216).

Figure 216. Shown data for the selected SM

c. Moving to the *Forecast* tab, you will see the model's performance for the last two days and forecast for the next two days. If the results are

not good you can return to the first tab and retrain the model (Figure 217).

Figure 217. Model's performance for the last two days and forecast for the next two days

d. Move to the *Schedule* tab to select optimization criteria. According to optimization criteria, the schedule will be generated.

8 Appendix B: Service testing & Service KPIs

S1.1 – Topology

Service Testing

Service	**Service1.1 Topology**
Algorithm provider	**ODT**
Solution provider	**ODT**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	13/02/2023

Service testing summary

Marketplace testing

Functional Test ID	Functional Test	Test responsible	Check	Comments
Service1.1_ODT_MK.1	Service contracts management	ODT	●	The complete contractual workflow is working as expected
		ELCE	●	

Functional and KPIs testing

Table 31. Testing Summary Table

Pilot	Functional Test ID	Functional Test	Test responsible	Check	Comments
SLOVENIA	Service1.1_ODT_FT.1	Active service contracts collection	ODT	●	
	Service1.1_ODT_FT.2	Data collection	ODT	●	
	Service1.1_ODT_FT.3	LV networks topologies evaluation	ODT	●	
	Service1.1_ODT_FT.4	Results export	ODT	●	
	Service1.1_ODT_FT.5	Client's access	ELCE	●	
	Service1.1_ODT_KPI	KPIs validation	ODT	●	

Usability testing

UI Critical errors

UI Non-critical errors

UI Recommendations

Marketplace testing

Table 32. Service1.1_ODT_MK.1 Service contracts management

Marketplace Test Description	Test Actions	Test responsible	Check
1. Contract service	Find service in marketplace by searching it with one of the following keywords: • Topology, AI, digital twin, smart meters, correction GIS, rebalancing phase	ODT	●
	Select service to see details about it	ODT	●
		ELCE	●
	Contract the service	ODT	●
		ELCE	
	Validate contract (data validation)	ODT	●
		ELCE	

Service Functional and KPIs Testing Actions

Table 33. Service1.1_ODT_FT.1 Active service contracts collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
2. Active service contracts collection through the UnifiedAPI	List all the active and approved contracts	ODT	Slovenia	●
	Get the data tokens linked to the contracts	ODT	Slovenia	●

Table 34. Service1.1_ODT_FT.2 Data collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
3. Data collection through the UnifiedAPI	Get contract data from the data lake	ODT	Slovenia	●
	Pre-process data in Odit-e format	ODT	Slovenia	●

Table 35. Service1.1_ODT_FT.3 LV networks topologies evaluation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
4. Low voltage networks topologies evaluation	Found a topology for each low voltage network	ODT	Slovenia	●
	Perform the network analysis of each low voltage network (data computation for each network analysis widget)	ODT	Slovenia	●

Table 36. Service1.1_ODT_FT.4 Results export

Functional Test Description	Test Actions	Test responsible	Pilot	Check
5. Results export in Odit-e database and visualization	Save algorithms results in database	ODT	Slovenia	●
	Results are visible on the webapp	ODT	Slovenia	●
	Webapp credentials sent to the customer	ODT	Slovenia	●

Table 37. Service1.1_ODT_FT.5 Client's access

Functional Test Description	Test Actions	Test responsible	Pilot	Check
6. Customer access to the results	The customer successfully connects to the webapp	ELCE	Slovenia	●
	The customer sees the results on the webapp	ELCE	Slovenia	●

Table 38. Service1.1_ODT_KPI KPIs validation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
7. KPIs (see **Erreur ! Source du renvoi introuvable.**)	All KPI (excepted #5) are computed	ODT	Slovenia	●
	Validate KPI #1	ODT	Slovenia	●
	Validate KPI #4	ODT	Slovenia	●

Table 39. List of service KPIs

#	KPI	Description	Calculation	Expected value
1	Computation time	The time between the start of execution of the service and the provision of the results, for one substation (~100 smart meters)	tresults – tstart	Should be under 5 minutes for 3 months of data
2	Number of meters analysed	Total number of meters analysed by the service through the platform	∑nmeters	
3	GIS correction rate	Feeder and secondary substation prediction mismatch ratio	Total number of meters with a predicted feeder or secondary substation different than the GIS, relative to the total number of meters	Depends on GIS quality
4	Confidence index	A float between 0 and 1 output by the topology algorithm, assessing Odit-e's confidence in its prediction.	Average prediction confidence, output by the algorithm	Should be over 0,8

5	[Require field validation] GIS correction validation	Feeder and secondary substation correction validation rate	Number of validated correction propositions / Number of correction propositions	To be performed afterwards, and should be over 80%

1. Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Critical errors	Screen shots and description	Reporter
Type of error (login….)		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Non-critical errors	Screen shots	Reporter
Type of error (font size….)		

UI Recommendations

Provide recommendations for improving the front-end UI

Recommendations	Screen shots	Reporter
Recommendation 1		

S1.2 – Observability

Service	**S1.2 Observability**
Algorithm provider	**ODT**
Solution provider	**ODT**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	25/11/2023

Service testing summary

Marketplace testing

Functional Test ID	Functional Test	Test responsible	Check	Comments
1.2_ODT_MK.1	Service contracts management	ODT	●	The complete contractual workflow is working as expected
		ELCE	●	

Functional and KPIs testing (Responsible: Algorithm dev)

Table 40. Testing Summary Table

Pilot	Functional Test ID	Functional Test	Test responsible	Check	Comments
SLOVENIA	1.2_ODT_FT.1	Active service contracts collection	ODT	●	Access to contract database has been successfully tested
	1.2_ODT_FT.2	Data collection	ODT	●	Data access through data lake has been successfully tested, tested instance on

					manually ingested data on simulated real time environment
	1.2_ODT_FT.3	LV networks state estimation	ODT	🟡	Validated in expert testing session, feeder's estimation not computed
	1.2_ODT_FT.4	Results export	ODT	🟢	Validated in expert testing session
	1.2_ODT_FT.5	User access	ELCE	🟢	Validated in expert testing session
	1.2_ODT_KPI	KPIs validation	ODT	🔴	KPIs were not computed in this instance

Usability testing

UI Critical errors
NA

UI Non-critical errors
Number of significant figures

UI Recommendations
NA

Marketplace testing

Table 41. 1.2_ODT_MK.1 Service contracts management

Marketplace Test Description	Test Actions	Test responsible	Check
8. Contract service	Found service in marketplace by searching it with one of the following keywords: • Observability, machine learning, state estimation, voltage plan, real time, AI	ODT	🟢
	Select service to see details about it	ODT	🟢
	Contract the service	ELCE	🟢
	Validate contract (data validation)	ODT	🟢

Service Functional and KPIs Testing Actions

Table 42. 1.2_ODT_FT.1 Active service contracts collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
9. Active service contracts collection through the UnifiedAPI	List all the active and approved contracts	ODT	Slovenia	●
	Get the data tokens linked to the contracts	ODT	Slovenia	●

Table 43. 1.2_ODT_FT.2 Data collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
10. Data collection through the UnifiedAPI	Get contract data from the data lake for training the model	ODT	Slovenia	●
	Collect data regularly, before each state estimation	ODT	Slovenia	●
	Pre-process data in Odit-e format	ODT	Slovenia	●

Table 44. 1.2_ODT_FT.3 LV networks state estimation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
11. Low voltage networks state estimation	Observability model qualified	ODT	Slovenia	●
	Voltage level estimation for each meter	ODT	Slovenia	●
	Estimation of the power flowing through the substations per feeder/phase	ODT	Slovenia	●

Table 45. 1.2_ODT_FT.4 Results export

Functional Test Description	Test Actions	Test responsible	Pilot	Check
12. Results export in Odit-e database and visualization	Save algorithms results in database	ODT	Slovenia	●
	Webapp credentials sent to the customer	ODT	Slovenia	●

Table 46. 1.2_ODT_FT.5 User access

Functional Test Description	Test Actions	Test responsible	Pilot	Check

13. Customer access to the results	The customer successfully connects to the webapp	ELCE	Slovenia	●
	The customer sees the results on the webapp	ELCE	Slovenia	●

Table 47. 1.2_ODT_KPI KPIs validation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
14. KPIs (see table hereafter)	All KPI are computed each week	ODT	Slovenia	●
	All KPI are validated	ODT	Slovenia	●

#	KPI	Description	Calculation	Expected value
1	Observability rate of the smart meters voltage	Number of observed grid state values (voltages), with respect to all observable values in %.	Nb of observed value/Nb of observable value	>98%
2	Observability rate of the LV feeders currents	Number of observed grid state values (currents), with respect to all observable values in %	Nb of observed value/Nb of observable value	>98%
3	Observability rate of the MV/LV substation apparent powers	Number of observed grid state values (apparent powers), with respect to all observable values in %.	Nb of observed value/Nb of observable value	>98%
4	Accuracy of the load estimation at substation level	Comparison between estimated load at substation level and measured one with respect to nominal power	Mean absolute percentage error	<15%
5	Accuracy of the load current estimation at low voltage feeder level	Comparison between estimated current load at feeder level and measured one with respect to feeder nominal current	Mean absolute percentage error	<20%
6	Voltage estimation accuracy at meters level	Comparison between estimated voltage at feeder level and measured one	Mean absolute error	<3V

Usability testing

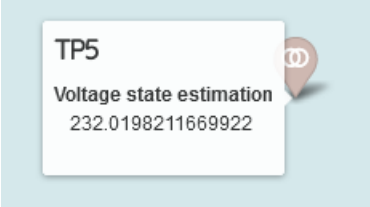
UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Critical errors	Screen shots and description	Reporter
NA		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Non-critical errors	Screen shots	Reporter
The number of significant figures should not be that high considering the precision of the state estimation		ODT

UI Recommendations

Provide recommendations for improving the front-end UI

Recommendations	Screen shots	Reporter
NA		

S1.3 – Predictive maintenance in electrical power systems

Service	**S1.3 - Predictive Maintenance**
Algorithm provider	**JSI** – Dušan Gabrijelčič
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	21/11/2023

Service testing summary

Functional and KPIs testing

Table 48. Testing Summary Table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	ELCE_1.3_JSI_FT.1	Create data contract	●	ELCE	
	ELCE_1.3_JSI_FT.2	Activate data contract	●	JSI	
	ELCE_1.3_JSI_FT.3	Create service contract	●	ELCE	
	ELCE_1.3_JSI_FT.4	Activate service contract	●	JSI	
	ELCE_1.3_JSI_FT.5	Service execution and results	●	ELCE	

Usability testing

Table 49. Usability testing

UI Critical errors
/

UI Non-critical errors
/

UI Recommendations
/

1. Service Functional and KPIs Testing Actions

Pilot: Slovenian

Table 50. ELCE_1.3_JSI_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
	Search for the data set "Predictive maintenance input data" on Marketplace. Click on "See more" and "Contract data".	●

1.Create data contract		
	Enter business parameters and click "Submit"	●

Table 51. ELCE_1.3_JSI_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.Activate data contract	Approve the data contract from functional task 1 - data contract structure and parameters are okay	●
	Activate the data contract - data contract can now be used in service contracts	●

Table 52. ELCE_1.3_JSI_FT.3 Functional Test Task 3

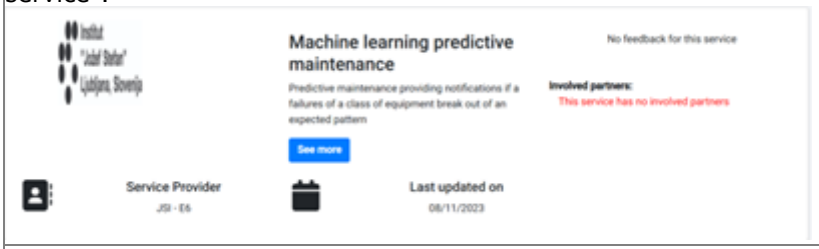
Functional Test Description	Test Actions	Check
3.Create service contract	Search for the "Machine learning predictive maintenance" service on the Marketplace. Click on "See more" and then "Request new service". 	●
	Enter business parameters	●
	Select the corresponding service parameters: 	●
	Select data contract created in functional task 1 and activated in functional task 2	●
	Click on "Yes" for "Enable immediate execution"	●
	Click on "Request service" to send the service contract	●

Table 53. ELCE_1.3_JSI_FT.4 Functional Test Task 4

Functional Test Description	Test Actions	Check
4.Activate service contract	Approve the service contract from functional task 3 - contract structure, business and technical parameters are okay, data contract selected and immediate execution enabled	●

	Activate the service contract - this will make an instance of the service	●
	ASM invoked	●
	Data accessed through the data lake	● *Comment: Data has been uploaded in service Docker image*
	Read technical parameters and run the correct service (predictive maintenance by **prediction**)	

Table 54. ELCE_1.3_JSI_FT.5 Functional Test Task 5

Functional Test Description	Test Actions	Check
5.Service execution and results	Upon activation of service contract, click on "Go to service" button for the corresponding service contract, found in the "Service requests" table on "My Services" page for "Service User": 	●
	UI accessed after clicking "Go to service button"	●
	Notebook executed - service no longer in "Services" -> "Running" tab	●
	Click on service ID in "Services" -> "History" tab to fetch report	●

2. Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 55. UI critical errors

Critical errors	Screen shots and description	Reporter
/		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 56. UI non-critical errors

Non-critical errors	Screen shots
/	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 57. UI recommendations

Recommendations	Screen shots
/	

S3.1 – Grid disturbance simulations

UPC approach: Grid disturbance simulations

Service	**S3.1 Grid Disturbance Simulation**
Algorithm provider	**UPC** – Alejandro Hernandez
Solution provider	**WEP**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	15/08/2023

Service testing summary

Functional and KPIs testing

Table 58. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
SLOVENIA	**SLOVENIA_S3.1_UPC_FT.1**	Data Ingestion	●		Brief description of the error detected
	SLOVENIA_S3.1_UPC_FT.2	Review Load forecasts	●		
	SLOVENIA_S3.1_UPC_FT.3	Evaluate Lines behaviour	●		
	SLOVENIA_S3.1_UPC_FT.4	Analyse Report Tab	●		
	SLOVENIA_S3.1_UPC_KPI.5	KPIs	●		
	PILOT_SP.3.1_UPC_EX.1	Execution times	●		

Usability testing

Table 59. Usability testing

UI Non-critical errors
Font size
Limit axis

UI Recommendations
Provide recommendations for improving the front-end UI

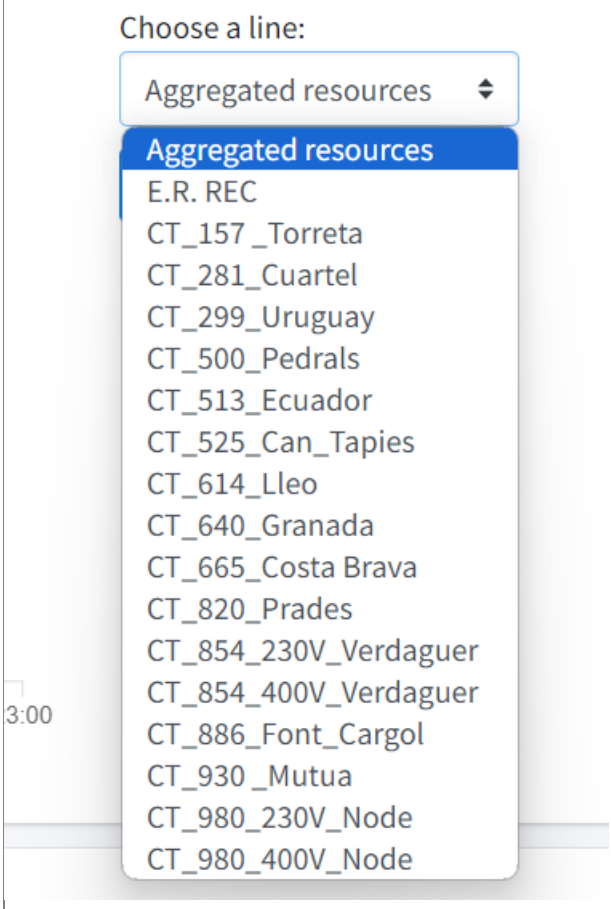
1. Service Functional and KPIs Testing Actions

Pilot: Slovenia

Table 60. SLOVENIA_S3.1_UPC_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
1.Data Ingestion	Make sure the data from the pilot is correctly ingested for the service.	●
	Verify there are no NaN values	●

Table 61. SLOVENIA_S3.1_UPC_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.Review Loads forecast	Check Aggregated Loads forecast plot	●
	Check dropdown list working Working  Comment: The caption should be "Choose a bus" or "Choose Load".	●
	Verify Load1 button from dropdown list to plot	●

Functional Test Description	Test Actions	Check
	Verify Load2 button from dropdown list to plot	●
	Verify download file button	●

Table 62. SLOVENIA_S3.1_UPC_FT.3 Functional Test Task 3

Functional Test Description	Test Actions	Check
3.Evaluate Lines behaviour	Check *Lines* tab button to be sent to new window	●
	Select *Line1* from dropdown	●
	Select *Line2* from dropdown	●
	Verify download file button	●

Table 63. SLOVENIA_S3.1_UPC_FT.4 Functional Test Task 4

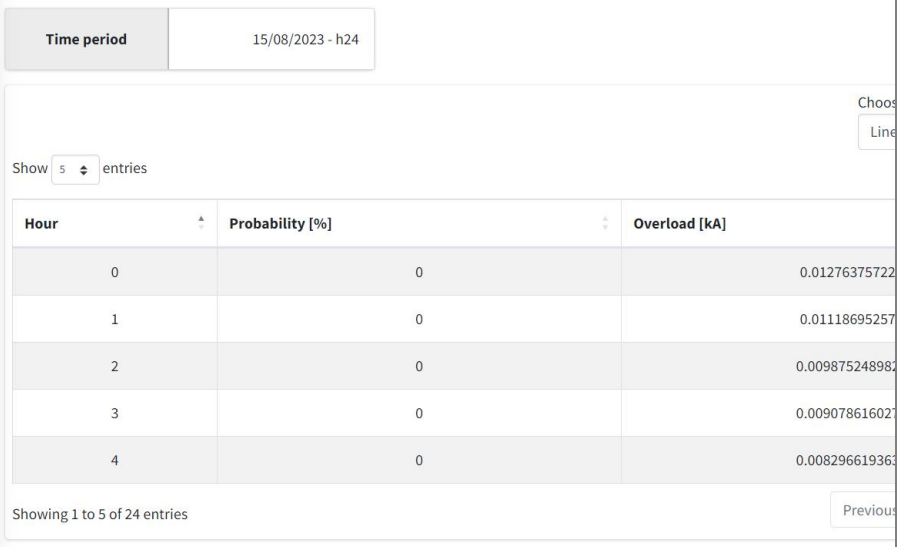
Functional Test Description	Test Actions	Check
4.Analyse Report Tab	Check *Report* tab button to be sent to new window	●
	Verify the results for all lines for all hours  Comment: I think the table should show the 24 hrs for default, instead of needing to select the number of entries. Additionally, the hour column should be in hour format: e.g 00:00, 01:00, …. Also, the labels of the columns [Hour, Probability and Overload] should be centered.	●
	Download report in excel form	●

Table 64. SLOVENIA_S3.1_UPC_KPI.5Functional Test Task 5

Functional Test Description	Test Actions	Check
5.KPI	KPI benchmark/range comparison number of congestions found	●

Table 65. PILOT_SP.3.1_UPC_EX.1 Functional Test Task 6

Functional Test Description	Test Actions	Execution time local/front-end	Check
6.Execution time	Executing algorithm for Use Case 1	10 s/ 60 s	●
	Training algorithm for algorithm	60 s/ 70s	●

2. Usability testing

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 66. UI non-critical errors

Non-critical errors	Screen shots
Font size	Font sizes in the whole UI is good.
Limit axis	N/A

UI Recommendations

Provide recommendations for improving the front-end UI

Table 67. UI recommendations

Recommendations	Screen shots
Recommendation 1	The recommendations have been made in section 1.

VUB approach: Grid disturbance simulations

Service	**S3.1 Grid Disturbance Simulation**
Algorithm provider	**VUB** – Rémy Cleenwerck
Solution provider	**WEP**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	30/03/2023

Service testing summary

Functional and KPIs testing

Table 68. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
SLOVENIA	3.1_VUB_FT.1	Data ingestion	●	VUB	*Data manually uploaded*
	3.1_VUB_FT.2	Review model training	●	VUB	
	3.1_VUB_FT.3	Evaluate Data analysis	●	VUB	
	3.1_VUB_FT.4	Analyse Congestion Forecasting	●	VUB	*Does not converge*
	3.1_VUB_KPI	KPIs	●	VUB	*Error caused by FT.4*
	3.1_VUB_EXEC	Execution time	●	VUB	

Usability testing

Table 69. Usability testing

UI Critical errors
Most errors solved in usability
One error persists : convergance of the simulation – error frond-end or back-end ? TBD

UI Non-critical errors

Samll details on the column names and data that is not present in the harmonized structure, and can thus be omitted.

UI Recommendations
Tornado diagram could provide more than 10 IDs.
Dropdown selection should only be the consumer ID, not including the '_phase'

1.Service Functional and KPIs Testing Actions

Table 70. 3.1_VUB_FT.1 Data ingestion

Functional Test Description	Test Actions	Pilot	Check
1.Data ingestion	Make sure the data from the pilot is correctly ingested for the service.	ELCE	●
		EYPESA	●
	Verify that during the 'project creation' : the selected grid data is appended to a project and the meta data (.json file) is correctly generated.	ELCE	●
		EYPESA	●
	Check if '*Grid Overview*' tab visualizes all the smart meter data (Consumer – No. Phases,..)	ELCE	●
		EYPESA	●
	Check if the visualization of the '*Voltage Profile*' for a selected smart meter ID (in a project) works.	ELCE	●
		EYPESA	●
	Check if the visualization of the '*Load Profile*' for a selected smart meter ID (in a project) works.	ELCE	●
		EYPESA	●

Table 71. 3.1_VUB_FT.2 Review model training

Functional Test Description	Test Actions	Pilot	Check
2.Review model training	Check if '*Run Simulation*' modifies the status of a selected grid, i.e. 'Trained' : {YES / NO}.	ELCE	●
		EYPESA	●
	Check if '*scaler_x.pickle*', '*scaler_y.pickle*', '*trained_model.pickle*' are generated.	ELCE	●
		EYPESA	●

Table 72. 3.1_VUB_FT.3 Evaluate Data analysis

Functional Test Description	Test Actions	Pilot	Check
3.Evaluate Data analysis	Verify if plot is generated for a selected smart meter from dropdown menu 'Choose a connection' in the '*Individual impact*' tab	ELCE	●
		EYPESA	●
	Verify if the cluster plot is shown when opening the '*Feeder impact*' tab	ELCE	●
		EYPESA	●
	Check if plots per group are shown when selecting the arrows next to the plot. [Only valid if multiple groups are listed.]	ELCE	●
		EYPESA	●

	Verify '*Export results*' function. [Downloads the meta data (.json file) and figures.]	ELCE	●
		EYPESA	●

Table 73. 3.1_VUB_FT.4 Analyse Congestion Forecasting

Functional Test Description	Test Actions	Pilot	Check
4.Analyse Congestion Forecasting	Fill in other values for '*Degree of PV-penetration*'.	ELCE	●
		EYPESA	●
	Fill in other values for '*Degree of EV-penetration*'.	ELCE	●
		EYPESA	●
	Select another profile for '*Period of charging*'.	ELCE	●
		EYPESA	●
	Inspect results after '*Run simulation*' button is accessed (based on Degrees of PV/EV penetration and Period of charging). – 'Voltage Profiles' tab	ELCE	●
		EYPESA	●
	Verify '*Export results*' function. – 'Voltage Profiles' tab [Returns .json file with info : no. of violations, suggested phase-swap and figure.]	ELCE	●
		EYPESA	●
	Verify that a plot is generated based on the '*Select user id*' button. – 'Grid Violation tab	ELCE	●
		EYPESA	●

Table 74. 3.1_VUB_KPI KPIs

Functional Test Description	Test Actions	Pilot	Check
5.KPIs	KPI benchmark/range comparison number of voltage violations forecasterd	ELCE	●
		EYPESA	●
	KPI benchmark/range comparison number of voltage violations reduced	ELCE	●
		EYPESA	●

Table 75. 3.1_VUB_EXEC Execution time

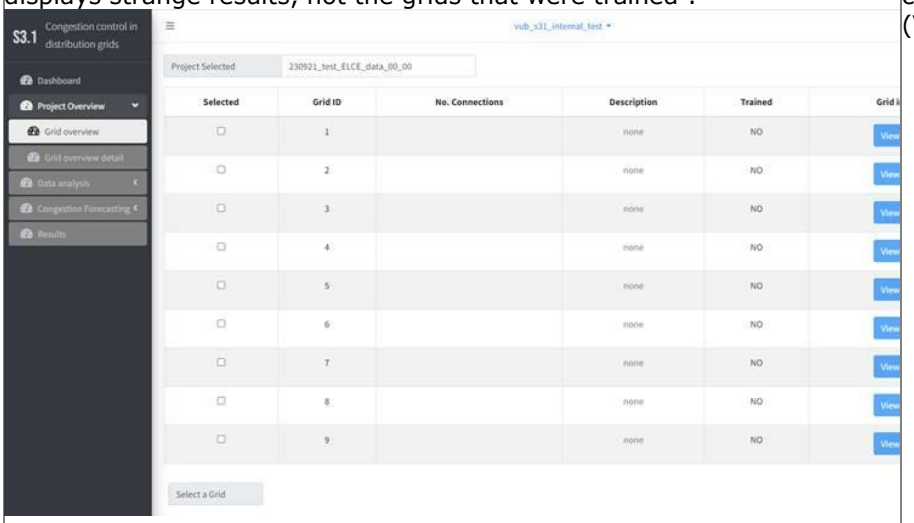
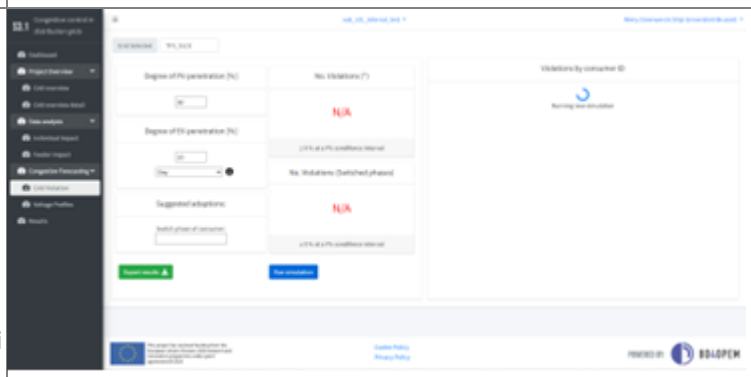
Functional Test Description	Test Actions	Execution time local/front-end	Check
6.Execution time	Executing algorithm for Use Case 1	XX s/ XX s	●
	Training algorithm for different models	3min / 15min	●

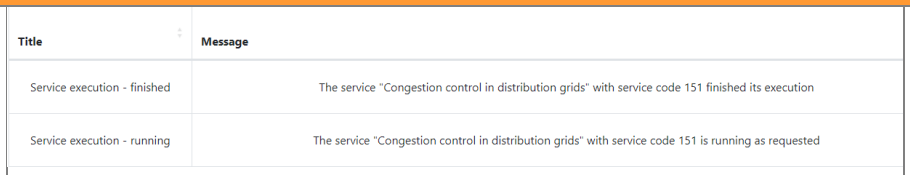
2.Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 76. UI critical errors

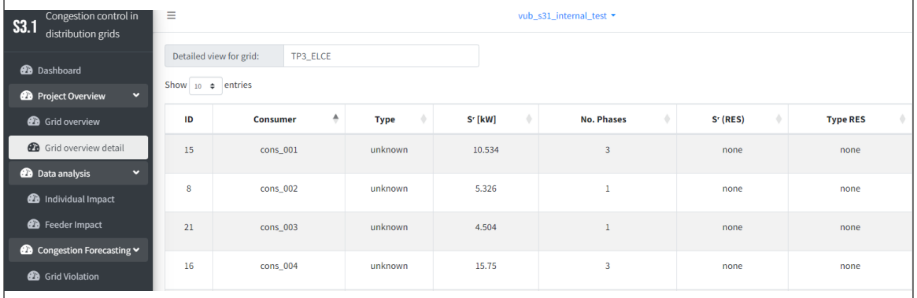
Critical errors	Screen shots and description	Reporter
Accessibility tabs	- Service 'Dashboard' tab not accessible after scrolling to the others tabs, i.e. only when opening service ; error solved	Rémy Cleenwerck (VUB)
Project creation	- 'Project overview' : project shows a value for the "no. grids" while after accessing the 'View details' it is empty. : error solved	Rémy Cleenwerck (VUB)
Table generating wrong values after training the grid	While training a grid inside a project, the service status changes to running and after to finished. However, the the 'Grid Overview' tab displays strange results, not the grids that were trained :  SOLVED : The problem the API that was populating the table and was not able to find the "project_meta.json" correctly. (Daniele Gastaldo – WEP)	Rémy Cleenwerck (VUB)
Error while running the simulation ('Analyse congenstion' tab):	 Status changes in the marketplace :	Rémy Cleenwerck (VUB)

Critical errors	Screen shots and description	Reporter
	 But simulation does not converge.	

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 77. UI non-critical errors

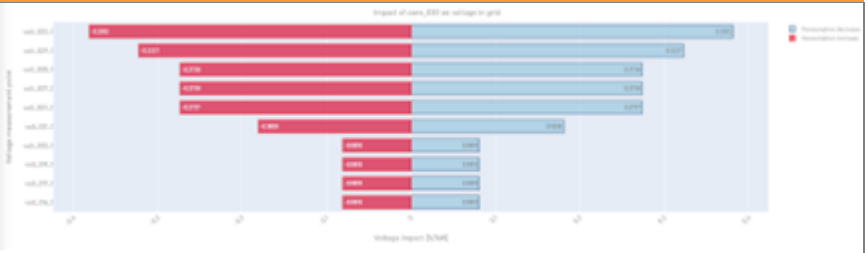
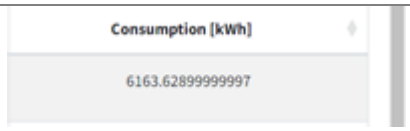
Non-critical errors	Screen shots
1.Type of consumer is not defined in harmonized data and could thus be hidden. 2.'S_r' should be 'P' as it is active power and not apparent. 3.Type RES can	 Solution would be to change "Type (RES)" with "RES" and the column values could then be defined as True or False.

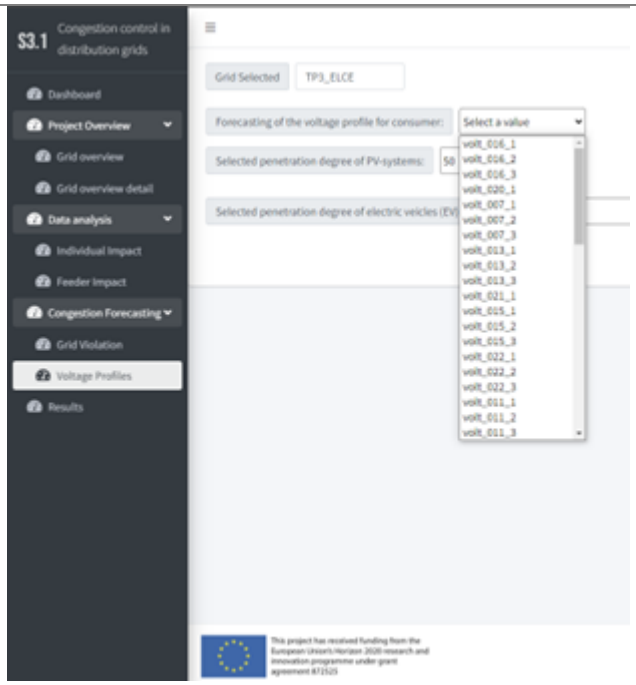
Non-critical errors	Screen shots
not be found in the harmonized data and thus can be omitted. 4.'S_r (RES)' also not in harmonized data so could as well be omitted.	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 78. UI recommendations

Recommendations	Screen shots
Tornado diagram should <u>not</u> be restricted to solely 10 users (to be solved by algo. dev.)	
Float values in tables should be restricted to 3 digits (to be solved by algo. dev.) : Solved in algo.	

•'Select a value' could be changed in : "Select a consumer ID" ; •The dropdown menu should display consumer IDs only and not including the phase e.g. '_1' or '_2', '_3' ;	

S3.2 - Impact study PV, EV & new loads

Service	**S3.2 Impact study**
Algorithm provider	**ODT**
Solution provider	**ODT**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	10/11/2023

Service testing summary

Marketplace testing

Functional Test ID	Functional Test	Test responsible	Check	Comments
3.2_ODT_MK.1	Service contracts management	ODT	●	The complete contractual workflow is working as expected
		ELCE	●	

Functional and KPIs testing (Responsible: Algorithm dev)

Table 79: Testing Summary Table

Pilot	Functional Test ID	Functional Test	Test responsible	Check	Comments
SLOVENIA	3.2_ODT_FT.1	Active service contracts collection	ODT	●	Access to contract database has been successfully tested
	3.2_ODT_FT.2	Data collection	ODT	●	Data access through data lake has been successfully tested, tested instance on manually ingested data
	3.2_ODT_FT.3	LV networks modelling	ODT	●	Validated in expert testing session
	3.2_ODT_FT.4	Results export	ODT	●	Validated in expert testing session
	3.2_ODT_FT.5	User access	ELCE	●	Validated in expert testing session
	3.2_ODT_KPI	KPIs validation	ODT	●	Not shared on a regular basis, offline calculation Computation time is long

Usability testing

UI Critical errors
NA

UI Non-critical errors
Issue with the display of headers

UI Recommendations
NA

Marketplace testing

Table 80: 3.2_ODT_MK.1 Service contracts management

Marketplace Description	Test	Test Actions	Test responsible	Check

15. Contract service	Found service in marketplace by searching it with one of the following keywords: • Renewable energy, modelling, integration, low voltage grid, AI, digital twin, photovoltaic, electric vehicles	ODT	●
	Select service to see details about it	ODT	●
	Contract the service	ELCE	●
	Validate contract (data validation)	ODT	●

Table 1.

Service Functional and KPIs Testing Actions

Table 81: 3.2_ODT_FT.1 Active service contracts collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
16. Active service contracts collection through the UnifiedAPI	List all the active and approved contracts	ODT	Slovenia	●
	Get the data tokens linked to the contracts	ODT	Slovenia	●

Table 2.

Table 82: 3.2_ODT_FT.2 Data collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
17. Data collection through the UnifiedAPI	Get contract data from the data lake for training the models	ODT	Slovenia	●
	Pre-process data in Odit-e format	ODT	Slovenia	●

Table 3.

Table 83: 3.2_ODT_FT.3 LV networks modelling

Functional Test Description	Test Actions	Test responsible	Pilot	Check
18. Low voltage networks modelling	Low voltage networks models (Digital Twins) trained	ODT	Slovenia	●
	PV capacity estimation for each smart meter	ODT	Slovenia	●

	EV or new load capacity estimation for each smart meter	ODT	Slovenia	●

Table 84: 3.2_ODT_FT.4 Results export

Functional Test Description	Test Actions	Test responsible	Pilot	Check
19. Results export in Odit-e database and visualization	Save low voltage networks models in database	ODT	Slovenia	●
	PV, EV and New load capacities estimations are available on the webapp	ODT	Slovenia	●
	Webapp credentials sent to the customer	ODT	Slovenia	●

Table 85: 3.2_ODT_FT.5 User access

Functional Test Description	Test Actions	Test responsible	Pilot	Check
20. Customer access to the results	The customer successfully connects to the webapp	ELCE	Slovenia	●
	The customer sees the results on the webapp	ELCE	Slovenia	●
	The customer can simulate PV, EV or new load insertion	ELCE	Slovenia	●
	The customer can add to the waiting list the simulated PV insertions	ELCE	Slovenia	●

Table 86: 3.2_ODT_KPI KPIs validation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
21. KPIs	All KPI are computed each week (excepted #3)	ODT	Slovenia	●
	All KPI (excepted #3) are validated	ODT	Slovenia	●

#	KPI	Description	Calculation	Expected value	Offline calculation
1	Runtime	Runtime of the algorithm with a substation with 100 three-phase meters and one year of data	tresults – torder	<150s	Initialization takes 3 hours (with data ingestion, preprocessing, deployment, training).

					Iterative simulation takes less than a minute but must be improved for better UX
2	Number of meters analysed	Total number of meters analysed by the service through the platform	∑nmeters	-	605
3	Impact prediction accuracy	[Require field intervention] Calculates the accuracy of the forecasted impacts, by training the model before or after the field intervention, then estimating smart meters voltage over the other time interval.	MAE of smart meters voltage estimation	<3V	Not applicable because no field validation
4	Digital twin accuracy	Estimation of the digital twin accuracy out of trainning regression domain	MAE of smart meters voltage estimation	<3V	Not computed

2. Usability testing

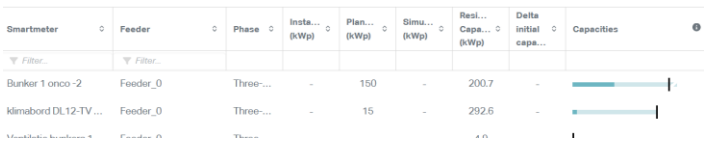
UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Critical errors	Screen shots and description	Reporter
NA		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Non-critical errors	Screen shots	Reporter
Tables header cannot be seen completely neither be made broader		ODI

UI Recommendations

Provide recommendations for improving the front-end UI

Recommendations	Screen shots	Reporter
NA		

S4.1 – Inconsistencies in energy balance and power-voltage

Service	**S4.1 Inconsistencies in energy balance and power-voltage**
Algorithm provider	**ODT**
Solution provider	**ODT**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	13/02/2023

Marketplace testing

Functional Test ID	Functional Test	Test responsible	Check	Comments
4.1_ODT_MK.1	Service contracts management	ODT	●	
		ELCE	●	

Functional and KPIs testing (Responsible: Algorithm dev)

Table 87: Testing Summary Table

Pilot	Functional Test ID	Functional Test	Test responsible	Check	Comments
SLOVENIA	4.1_ODT_FT.1	Active service contracts collection	ODT	●	
	4.1_ODT_FT.2	Data collection	ODT	●	
	4.1_ODT_FT.3	LV networks modelling	ODT	●	
	4.1_ODT_FT.4	Results export	ODT	●	
	4.1_ODT_FT.5	User access	ELCE	●	
	4.1_ODT_KPI	KPIs validation	ODT	●	

Usability testing

UI Critical errors

UI Non-critical errors

UI Recommendations

Marketplace testing

Table 88: 4.1_ODT_MK.1 Service contracts management

Marketplace Test Description	Test Actions	Test responsible	Check
22. Contract service	Found service in marketplace by searching it with one of the following keywords: • Non-technical losses, digital twin, AI, fraud detection, topology	ODT	●
		ELCE	●
	Select service to see details about it	ODT	●
		ELCE	●
	Contract the service	ODT	●
		ELCE	●
	Validate contract (data validation)	ODT	●
		ELCE	●

Service Functional and KPIs Testing Actions

Table 89: 4.1_ODT_FT.1 Active service contracts collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
23. Active service contracts collection through the UnifiedAPI	List all the active and approved contracts	ODT	Slovenia	●
	Get the data tokens linked to the contracts	ODT	Slovenia	●

Table 90: 4.1_ODT_FT.2 Data collection

Functional Test Description	Test Actions	Test responsible	Pilot	Check
24. Data collection through the UnifiedAPI	Get contract data from the data lake for training the models	ODT	Slovenia	●
	Pre-process data in Odit-e format	ODT	Slovenia	●

Table 91: 4.1_ODT_FT.3 NTL detections

Functional Test Description	Test Actions	Test responsible	Pilot	Check
25. NTL detections	Low voltage networks models (Digital Twins) trained	ODT	Slovenia	●
	Energy balance evaluated for each substation with recorded data	ODT	Slovenia	●
	Bypass probability for each smart meter	ODT	Slovenia	●
	Nearby missing power probability for each smart meter	ODT	Slovenia	●

Table 92: 4.1_ODT_FT.4 Results export

Functional Test Description	Test Actions	Test responsible	Pilot	Check
26. Results export in Odit-e database and visualization	Algorithm results saved in database	ODT	Slovenia	●
	Results are available on the webapp	ODT	Slovenia	●
	Webapp credentials sent to the customer	ODT	Slovenia	●

Table 93: 4.1_ODT_FT.5 User access

Functional Test Description	Test Actions	Test responsible	Pilot	Check
27. Customer access to the results	The customer successfully connects to the webapp	ELCE	Slovenia	●
	The customer sees the results on the webapp	ELCE	Slovenia	●

Table 94: 4.1_ODT_KPI KPIs validation

Functional Test Description	Test Actions	Test responsible	Pilot	Check
28. KPIs (see **Erreur ! Source du renvoi introuvable.**)	KPI #1 is computed each week	ODT	Slovenia	●
	KPI #2 and #3 are validated after field validation	ODT	Slovenia	●

Table 95: List of service KPIs

#	KPI	Description	Calculation	Expected value
1	Number of meters analysed	Total number of meters analysed by the service through the platform	∑nmeters	-
2	Bypass accuracy	[Require field validation] Fraction of correct detected bypassed meters	Number of meters with correct detection / Total number of detection	>30%
3	NTL_nearby_accuracy	[Require field validation] Fraction of correct detections	Number of correct detections / Total number of detection	>30%

3. Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Critical errors	Screen shots and description	Reporter
Type of error (login….)		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Non-critical errors	Screen shots	Reporter
Type of error (font size….)		

UI Recommendations

Provide recommendations for improving the front-end UI

Recommendations	Screen shots	Reporter
Recommendation 1		

S4.2 – Fraud patterns detection

UPC approach: Fraud patterns detection

Service	**S4.2 FRAUD PATTERN DETECTION**
Algorithm provider	**UPC** – Marc Jené
Solution provider	**WEP**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	01/09/2023

Service testing summary

Functional and KPIs testing

Table 96. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test respons.	Comments
ELCE	ELCE_4.2_UPC_FT.1	Functional Test Task 1	●	UPC	
	ELCE_4.2_UPC_FT.2	Functional Test Task 2	●	UPC	**Magnitude values use commas as decimal separators. SM ID field is not working in the Historical tab.**
	ELCE_4.2_UPC_FT.3	Functional Test Task 3	●	UPC	
	ELCE_4.2_UPC_FT.4	Functional Test Task 4	●	UPC	**Problems with the *Verify* CTAs.**
	ELCE_4.2_UPC_FT.5	Functional Test Task 5	●	UPC	**The table have some "hidden values" that make it impossible to sort by some variables. Errors also related to the decimal separators.**
	ELCE_4.2_UPC_FT.6	Functional Test Task 6	●	UPC	**Downloading buttons not working.**
	ELCE_4.2_UPC_FT.7	Functional Test Task 7	●	UPC	**Squatting fraud with negative values -> Change Technical Losses parameter to solve this.**
	ELCE_4.2_UPC_KPI.1	KPIs Task 1	●	UPC	**The KPIs screen is not working at all.**
	ELCE_4.2_UPC_EXEC.1	Execution times pilot 1	●	UPC	

Usability testing

Table 97. Usability testing

UI Critical errors
Decimal separators should be consistent and not compromise other functionalities.
Verify CTA buttons should work properly.
Downloading buttons are not working.
KPIs screen is not working.

UI Non-critical errors
Recent Results and *Historical* tables shouldn't have "hidden columns".
Squatting fraud have negative values -> Change Technical Losses parameter from 5% to 1%

UI Recommendations

1. Service Functional and KPIs Testing Actions

Pilot: ELCE

Table 98. PILOT_4.2_UPC_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
1.*Dashboard:* Service first steps	Log-in to the UI through the BD4OPEM Marketplace is successful.	●
	Check the characteristics of the contract shown in the *Dashboard.*	●
	Test the *About* action box.	●
	Test the *Contact us* call to action.	●

Table 99. PILOT_4.2_UPC_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.*Visualization:* Review Frauds'	Check values from each column in the "Recent results" tab. All values should be coherent and appropriate. Comment: Magnitude values have decimal separators, while probability of fraudster (in 'SM'), has dot decimals.	●

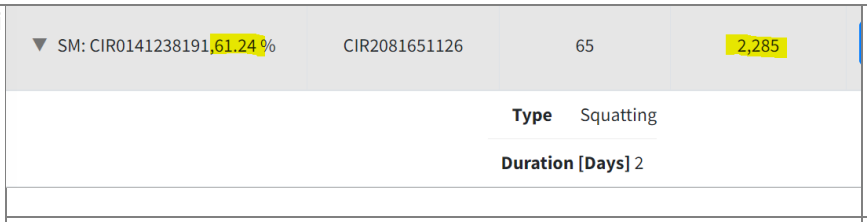
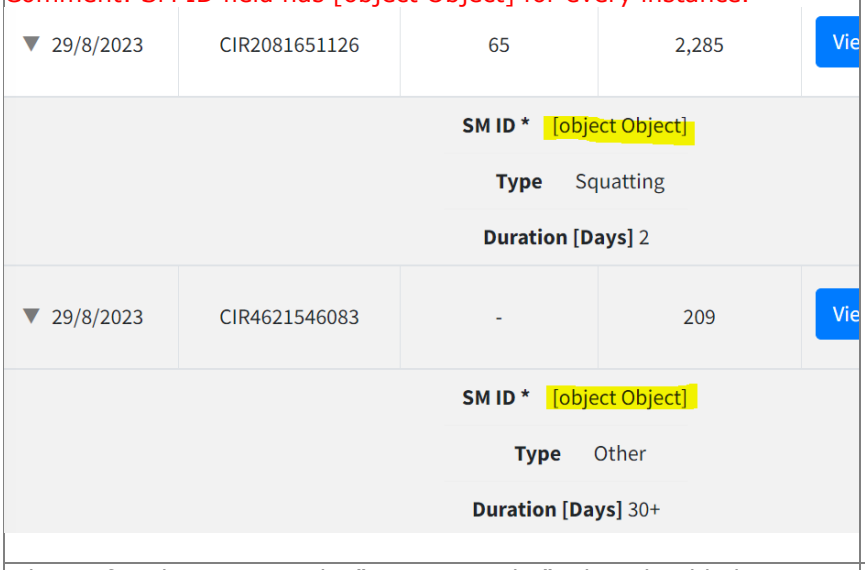
Information		
	Check values from each column in the "Historical" tab. All values should be coherent and appropriate. Comment: SM ID field has [object Object] for every instance. 	
	When a fraud appears in the "Recent results" tab it should also appear in the "Historical" tab with the same values.	

Table 100. PILOT_4.2_UPC_FT.3 Functional Test Task 3

Functional Test Description			Test Actions	Check
3.*Visualization:* Tab navigation (recent/historical)			Go to the "Recent results" tab. It should only show the results from the last execution (The example use case contains 5 grids).	
			Go to the "Historical" tab. It should show the historical frauds with a "Detection date" column.	

Table 101. PILOT_4.2_UPC_FT.4 Functional Test Task **4**

Functional Test Description	Test Actions	Check

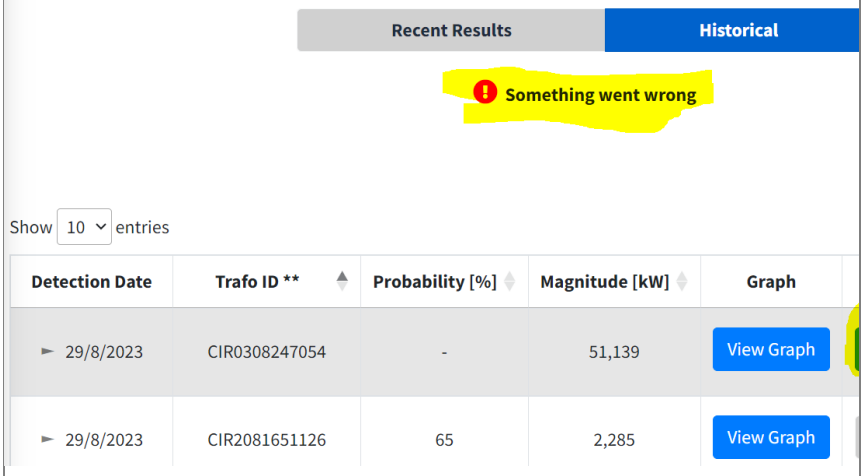
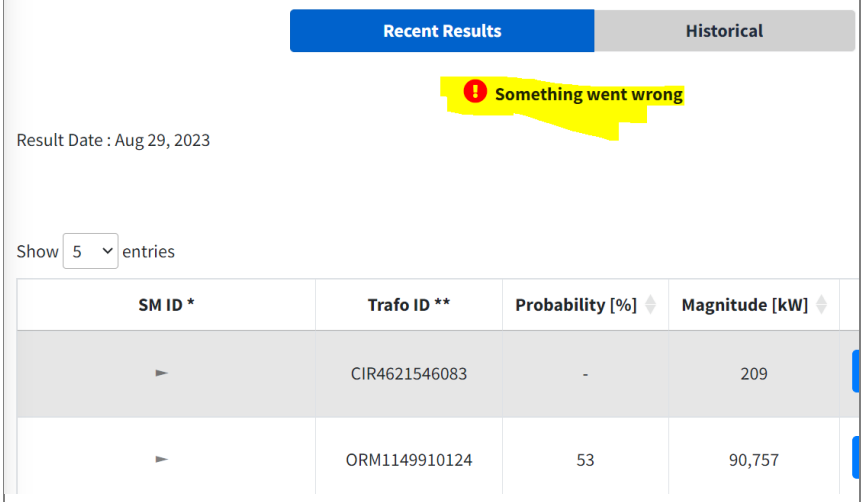
4.*Visualization:* Verify functionality	Mark one fraud as true (Verify = Yes) in the "Historical" tab. Comment: When clicking *Yes*, a text saying "! Something went wrong" appears. If switching to the *Recent Results* tab and going back to the *Historical* one, the verification mark disappears. 	●
	Mark one fraud as false (Verify = No) in the "Recent results" tab. Check whether it is shown in the "Historical" tab. Comment: Same thing as before. If switching to *Historical*, the fraud still appears as nothing happened. 	●

Table 102. PILOT_4.2_UPC_FT.5 Functional Test Task 5

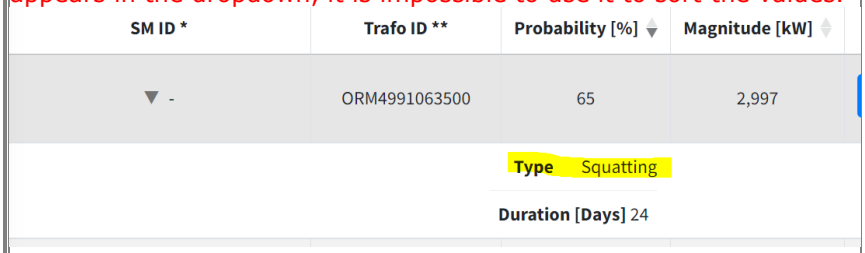
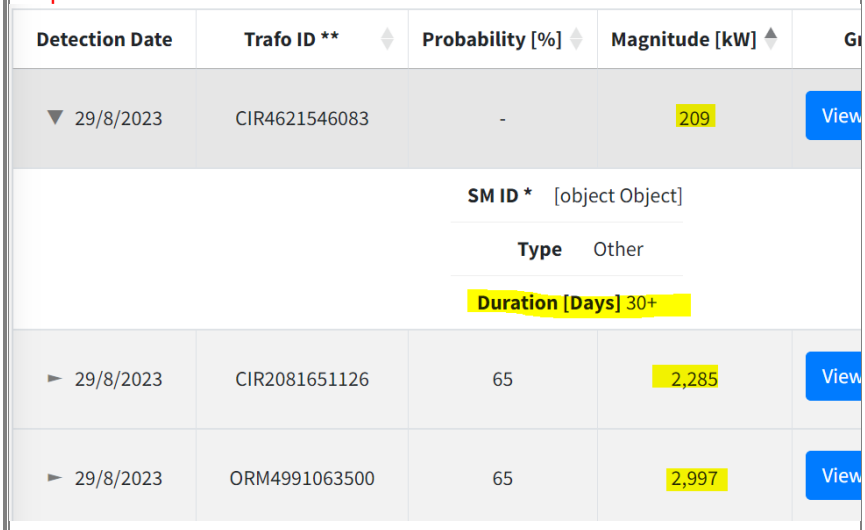
Functional Test Description	Test Actions	Check
5.*Visualization:* Filter functionality	In the *Recent Results* tab, sort the frauds by Probability and Type. Comment: Sorting by Probability works fine. However, since the Type appears in the dropdown, it is impossible to use it to sort the values. 	●
	In the *Historical* tab, sort the frauds by Magnitude and Duration. Comment: Maybe because the Magnitude values use comma as separators, the sorting isn't properly performed. As above, the sorting by Duration isn't possible because it appears in the dropdown. 	●
	Open the filter bubble by clicking on the button.	●
	Filter historical data by Magnitude (> 30 kW and < 100 kW)	●
	Filter recent data by Type	●

Table 103. PILOT_4.2_UPC_FT.6 Functional Test Task 6

Functional Test Description	Test Actions	Check
6.*Visualization:* Download results	Download results in .xlsx Comment: Button not working	●
	Download results in .csv Comment: Button not working	●
	Filter the dataset and download results from historical frauds due to "Plantation" Comment: Surprisingly, the button only works with filtered data, but not always.	●

Table 104. PILOT_4.2_UPC_FT.7 Functional Test Task 7

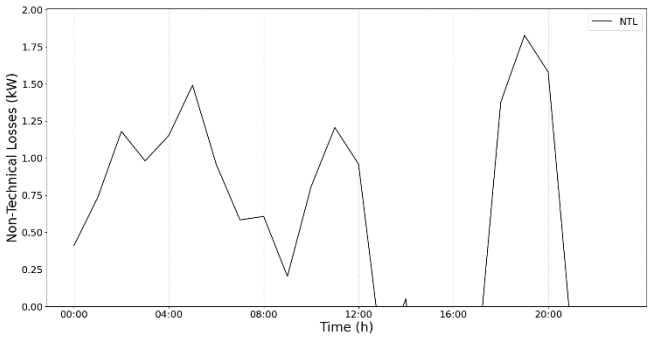
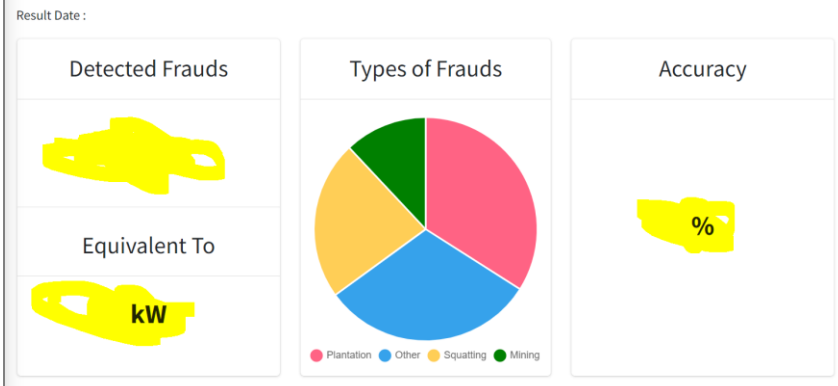
Functional Test Description	Test Actions	Check
7.*Visualization :* View graph	Check the graph of a specific fraud due to Squatting. It shows the average daily load curve of the fraud. It is coherent. Comment: The graph contains negative values. Since this is not really coherent, the best way to solve it is by changing the Common Parameter 'techloss' from 5 to 1, assuming the technical losses of the grid are really small. 	●
	Check the graph of a specific fraud due to Plantation. It shows the average daily load curve of the fraud. It is coherent.	●
	The graph has the daily load profile of the fraud with hours in the X axis and Power in kW in the Y axis.	●

Table 105. PILOT_4.2_UPC_FT.8 Functional Test Task 8

Functional Test Description	Test Actions	Check
8.*KPIs*	Check detected frauds. Comment: Something occurs with KPIs, as they are not showed properly. 	●
	Check power recovered. Comment: Same as above.	●
	Check accuracy. Comment: Same as above.	●

Functional Test Description	Test Actions	Check
	Check percentage of types of frauds. The labels should be consistent with the types from the list of frauds. Sum = 100%. Comment: Mining appears with a 12% even though there are no Mining frauds in the *Historical* screen.	●
	Verify one of the detected frauds. Check if the KPIs are updated. Comment: Not tested due to previous errors.	●
	Download pdf. Comment: Not working.	●

Table 106. Execution time

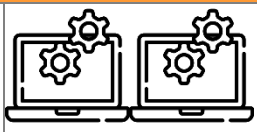
Functional Test Description	Test Actions	Execution time local/front-end	Check
9.Execution time	Executing algorithm for Use Case 1	- s/ - s	●
	Executing algorithm for Use Case 2	- s/ - s	●

2.Usability testing

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 107. UI non-critical errors

Non-critical errors	Screen shots
Font size	
Limit axis	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 108. UI recommendations

Recommendations	Screen shots

Recommendation 1	
Recommendation 2	

JSI approach: Grid disturbance simulations

Service	**S3.1 Grid Disturbance Simulation**
Algorithm provider	**JSI**– Andrej Čampa
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	17/04/2023

Service testing summary

Functional and KPIs testing

Table 109. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
SLOVENIA	SLOVENIA_3.1_JSI_FT.1	Data ingestion	●	JSI	
	SLOVENIA_3.1_JSI_FT.2	LV/MV modelling	●	JSI	
	SLOVENIA_3.1_JSI_FT.3	Analyse results through UI	●	JSI	
	SLOVENIA_3.1_JSI_FT.4	Results export	●	JSI	
	SLOVENIA_3.1_JSI_KPI.1	KPIs	●	JSI	
TURKEY	TURKEY_3.1_JSI_FT.1	Data ingestion	●	JSI	
	TURKEY _3.1_JSI_FT.2	LV/MV modelling	●	JSI	
	TURKEY_3.1_JSI_FT.3	Analyse results through UI	●	JSI	
	TURKEY _3.1_JSI_FT.4	Results export	●	JSI	
	TURKEY _3.1_JSI_KPI.1	KPIs	●	JSI	

Usability testing

Table 110. Usability testing

UI Critical errors
Log-in error /
Graph display /

UI Non-critical errors
Font size /
Limit axis /

UI Recommendations
/

1. Service Functional and KPIs Testing Actions

Table 111. 3.1_JSI_FT.1 Data ingestion

Functional Test Description	Test Actions	Pilot	Check
1.Data ingestion	Make sure the data from the pilot is correctly ingested for the service.	ELCE	●
		OEDAS	●
	Check if the Results tab shows initial values	ELCE	●
		OEDAS	●

Table 112. 3.1_JSI_FT.2 LV/MV modelling

Functional Test Description	Test Actions	Pilot	Check
2.LV/MV modelling	Check if 'Selected nodes' shows the list of all simulated nodes.	ELCE	●
		OEDAS	●
	Select nodes and observe the initial values and optimize values graphs if they change.	ELCE	●
		OEDAS	●
	Histograms of the optimized values should be closer to the nominal value (1) compared to the initial values.	ELCE	●
		OEDAS	●

Table 113. 3.1_JSI_FT.3 Analyse results through UI

Functional Test Description	Test Actions	Pilot	Check
3.Analyse results through UI	Check if plots are generated by selecting the nodes	ELCE	●
		OEDAS	●
	Check if grid topology is the same as described in GIS	ELCE	●
		OEDAS	●
	Check if all contracts are listed	ELCE	●
		OEDAS	●
		ELCE	●

	Check if selecting the contract shows the results of the right contract	OEDAS	●

Table 114. 3.1_JSI_FT.4 Results export

Functional Test Description	Test Actions	Pilot	Check
4.Results export	Verify '*Download initial values*' button function. [Downloads the .csv file of the initial state.]	ELCE	●
		OEDAS	●
	Verify 'Download optimized values' button function. [Downloads the .csv file of optimized state and report file pdf]	ELCE	●
		OEDAS	●

Table 115. 3.1_JSI_KPI.1 KPIs

Functional Test Description	Test Actions	Pilot	Check
5.KPIs	KPI for selected nodes is shown. It should be lower <1 for worst-case nodes.	ELCE	●
		OEDAS	●

2.Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 116. UI critical errors

Critical errors	Screen shots and description	Reporter
Type of error (login….)	/	

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 117. UI non-critical errors

Non-critical errors	Screen shots
Font size	/
Limit axis	/

UI Recommendations

Provide recommendations for improving the front-end UI

Table 118. UI recommendations

Recommendations	Screen shots
Recommendation 1	/
Recommendation 2	/

JSI approach: Fraud patterns detection

Service	**S4.2 - Non Technical Losses**
Algorithm provider	**JSI** – Dušan Gabrijelčič
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	21/11/2023

Service testing summary

Functional and KPIs testing

Table 119. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	ELCE_4.2_JSI_FT.1	Create data contract	●	ELCE	
	ELCE_4.2_JSI_FT.2	Activate data contract	●	JSI	
	ELCE_4.2_JSI_FT.3	Create service contract	●	ELCE	
	ELCE_4.2_JSI_FT.4	Activate service contract	●	JSI	
	ELCE_4.2_JSI_FT.5	Service execution and results	●	ELCE	
Spain	EyPESA_4.2_JSI_FT.1	Create data contract	●	EyPESA	
	EyPESA_4.2_JSI_FT.2	Activate data contract	●	JSI	
	EyPESA_4.2_JSI_FT.3	Create service contract	●	EyPESA	
	EyPESA_4.2_JSI_FT.4	Activate service contract	●	JSI	
	EyPESA_4.2_JSI_FT.5	Service execution and results	●	EyPESA	

Usability testing

Table 120. Usability testing

UI Critical errors
/

UI Non-critical errors
/

UI Recommendations
/

1.Service Functional and KPIs Testing Actions

Pilot: Slovenian

Table 121. ELCE_4.2_JSI_FT.1 Functional test task 1

Functional Test Description	Test Actions	Check
1.Create data contract	Search for the data set "Fraud pattern detection (NTL) input data" on Marketplace. Click on "See more" and "Contract data". 	●
	Enter business parameters and click "Submit"	●

Table 122. ELCE_4.2_JSI_FT.2 Functional test task 2

Functional Test Description	Test Actions	Check
2.Activate data contract	Approve the data contract from functional task 1 - data contract structure and parameters are okay	●
	Activate the data contract - data contract can now be used in service contracts	●

Table 123. ELCE_4.2_JSI_FT.3 Functional test task 3

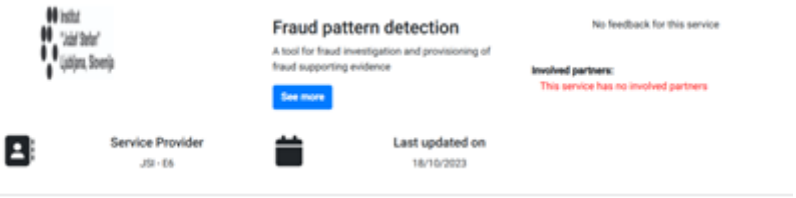
Functional Test Description	Test Actions	Check
3.Create service contract	Search for the "Fraud pattern detection" service on the Marketplace. Click on "See more" and then "Request new service". 	●
	Enter business parameters	●
	Select the corresponding service parameters: 	●
	Select data contract created in functional task 1 and activated in functional task 2	●
	Click on "Yes" for "Enable immediate execution"	●
	Click on "Request service" to send the service contract	●

Table 124. ELCE_4.2_JSI_FT.4 Functional test task 4

Functional Test Description	Test Actions	Check
4.Activate service contract	Approve the service contract from functional task 3 - contract structure, business and technical parameters are okay, data contract selected and immediate execution enabled	●
	Activate the service contract - this will make an instance of the service	●
	ASM invoked	●
	Data accessed through the data lake	● *Comment: Data has been uploaded in service Docker image*

	Read technical parameters and run the service	

Table 125. ELCE_4.2_JSI_FT.5 Functional test task 5

Functional Test Description	Test Actions	Check
5.Service execution and results	Upon activation of service contract, click on "Go to service" button for the corresponding service contract, found in the "Service requests" table on "My Services" page for "Service User": 	●
	UI accessed after clicking "Go to service button"	●
	Notebook executed - service no longer in "Services" -> "Running" tab	●
	Click on service ID in "Services" -> "History" tab to fetch report	●

2. Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 126. UI critical errors

Critical errors	Screen shots and description	Reporter
/		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 127. UI non-critical errors

Non-critical errors	Screen shots
/	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 128. UI recommendations

Recommendations	Screen shots
/	

S5.1 – Flexibility Forecast

UPC approach: Flexibility forecast

Service	**S5.1 FLEXIBILITY FORECAST**
Algorithm provider	**UPC** – Rafaela Ribeiro / Arthur Pasquet
Solution provider	**ICOM**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	30/11/2023

Service testing summary

Functional and KPIs testing

Table 129. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	SLOVENIA_5.1_UPC_FT.1	History	●		
	SLOVENIA_5.1_UPC_FT.2	Data Selection	●		
	SLOVENIA_5.1_UPC_FT.3	Training model results	●		The model fails to be trained
	SLOVENIA_5.1_UPC_FT.4	Forecast results	●		The model doesn't forecast
	SLOVENIA_5.1_UPC_KPI.1	KPIs	●		No KPIs
	SLOVENIA_5.1_UPC_EXEC	Execution times pilot	●		No execution

Usability testing

Table 130. Usability testing

UI Non-critical errors
Font size
Limit axis

UI Recommendations
Include selection of "Positive Flexibility" or "Negative Flexibility"

1. Service Functional and KPIs Testing Actions

Pilot: Slovenia

Table 131. SLOVENIA_5.1_UPC_FT.1 History

Functional Test Description	Test Actions	Check
7.History	List of previous runs can be observed	●
	"Model Info" and "Forecast" buttons return corresponding information	●
	Within "Model Info" functions as verified in Table 9.	●
	Within "Forecast" functions as verified in Table 10.	●

Table 132. SLOVENIA_5.1_UPC_FT.2 Data selection

Functional Test Description	Test Actions	Check
8.Data selection	Selection of "EV" and/or "HP" from droplist	●
	Selection of either "Positive Flexibility" or "Negative Flexibility"	●
	Date selection is more than 1 year and it exists on dataset	●
	If time resolution is lower than present in the data, the time resolution of the data is used.	●
	The last 7 days of data exist.	●
	The user can consult previous runs.	●

Table 133. SLOVENIA_5.1_UPC_FT.3 Training model results

Functional Test Description	Test Actions	Check
9.Training model results	Summary of Data Selection correctly presented	●
	Table presents model results and real data comparison with correct units and title	●
	Plot presents the model results and real data comparison with correct units and title	●
	Selection of training line or input values on plot	●
	Interaction with plot lines is available	●
	Data download button delivers the file	●

Table 134. SLOVENIA_5.1_UPC_FT.4 Forecast results

Functional Test Description	Test Actions	Check
10.Forecast results	Summary of Data Selection correctly presented	●
	Table presents the forecasted flexibility values for all times of the day with correct units and title	●
	Plot presents the forecasted flexibility values for all times of the day with correct units and title	●
	Interaction with plot line is available	●
	Metrics shown should be bigger or equal to zero	●

Table 135. SLOVENIA_5.1_UPC_KPI.1 Forecast results

Functional Test Description	Test Actions	Check
11.KPI	Use case 1 - Total flexibility value: 872.65/> 0	●
	Use case 1 - Average flexibility value: 51.33/>0	●
	Use case 1 - Average flexibility availability: 0.19/[0-100%]	●
	Use case 1 - Mean Absolute Percentage Error: 242.46/[0-100%]	●
	Use case 2 - Total flexibility value: 872.65/> 0	●
	Use case 2 - Average flexibility value: 51.33/>0	●
	Use case 2 - Average flexibility availability: 0.19/[0-100%]	●
	Use case 2 - Mean Absolute Percentage Error: 242.46/[0-100%]	●

Table 136. SLOVENIA_5.1_UPC_EXEC Functional Test Task 4

Functional Test Description	Test Actions	Execution time local/front-end	Check
12.Execution time	Training + Executing algorithm for Use Case 1	28 min/ 60 s	●

2.Usability testing

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

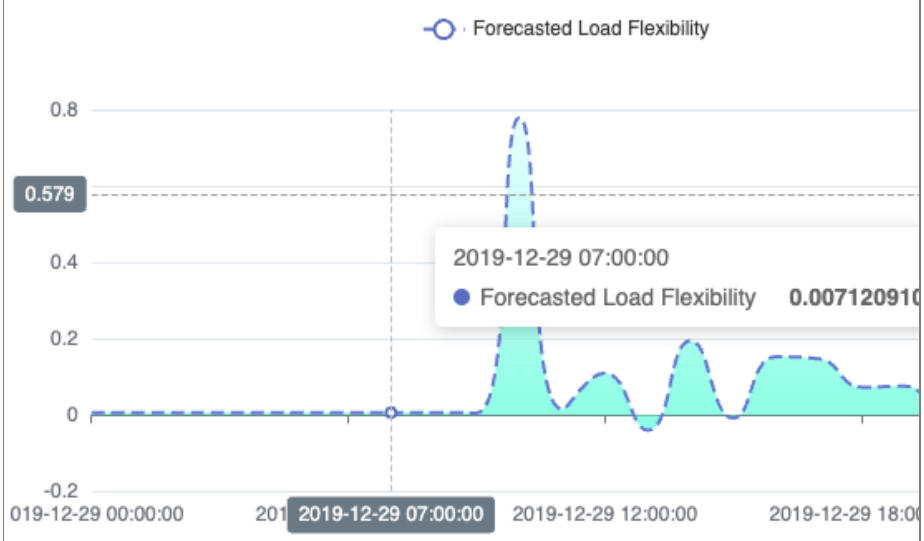
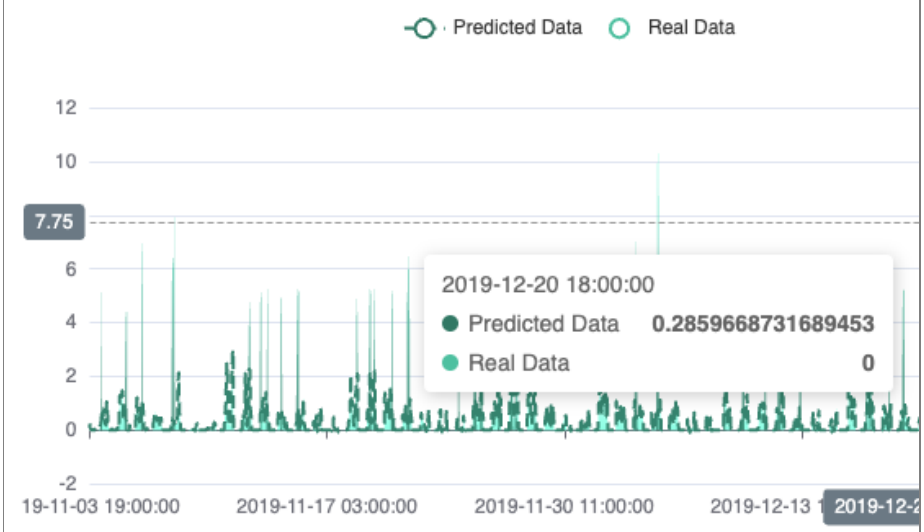
Table 137. UI non-critical errors

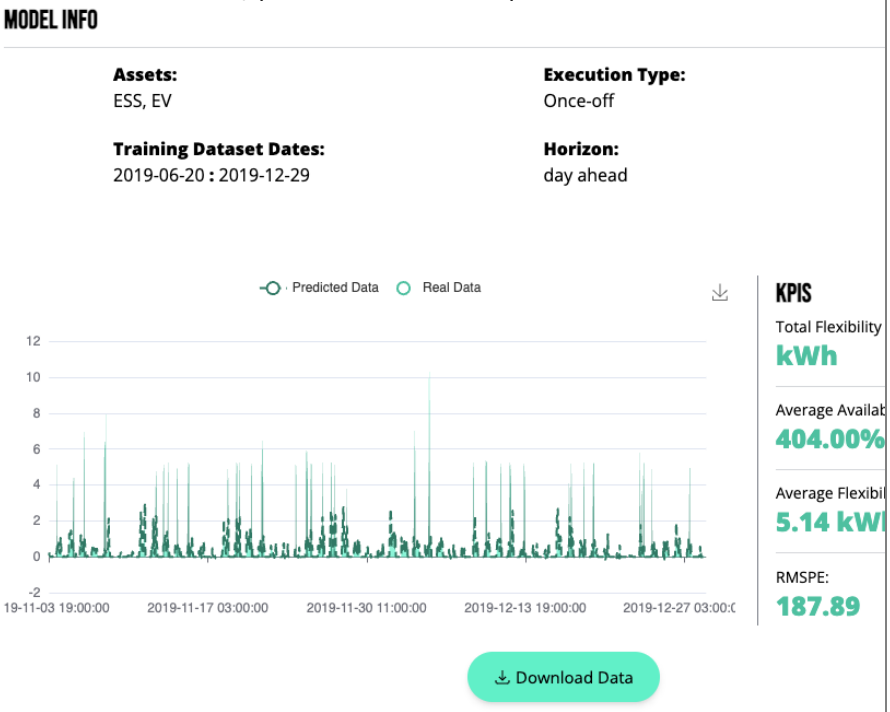
Non-critical errors	Screen shots
Font size	Nothing to declare.
Limit axis	Nothing to declare.

UI Recommendations

Provide recommendations for improving the front-end UI

Table 138. UI recommendations

Recommendations	Screen shots
Recommendation 1	For forecast  Add the unit on the Y axis
Recommendation 2	For model training the same 

Recommendations	Screen shots
Recommendation 3	En model and forecast, put the name of the pilot 
Recommendation 4	

3.Annex - Use cases

Pilot: Slovenia

Use case 1: single asset

Assets: EV, positive flexibility
Dates: 2019/01/01 to 2022/07/03 correlation not found, dates used were 2019/01/01 to 2020/01/04; time resolution set to 1 hour

Use case 2: aggregation

Assets: EV + HP, positive flexibility
Dates: 2019/01/01 to 2022/07/04 (2019/01/01 to 2022/07/03 + 2019/01/01 to 2022/07/04, respectively) correlation not found, dates used were ; 1 hour time resolution
Dates: 2022/05/01 to 2022/06/16; 15 minutes resolution

JSI approach: Flexibility forecast

Service	**S5.1 - Flexibility Forecast Based On Price Signals**
Algorithm provider	**JSI** – Dušan Gabrijelčič
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	21/11/2023

Service testing summary

Functional and KPIs testing

Table 139. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	ELCE_5.1_JSI_FT.1	Create data contract	●	ELCE	
	ELCE_5.1_JSI_FT.2	Activate data contract	●	JSI	
	ELCE_5.1_JSI_FT.3	Create service contract	●	ELCE	
	ELCE_5.1_JSI_FT.4	Activate service contract	●	JSI	
	ELCE_5.1_JSI_FT.5	Service execution and results	●	ELCE	

Usability testing

Table 140. Usability testing

UI Critical errors
/

UI Non-critical errors
/

UI Recommendations
/

1.Service Functional and KPIs Testing Actions

Pilot: Slovenian

Table 141. ELCE_5.1_JSI_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
1.Create data contract	Search for the data set "Flexibility forecast input data" on Marketplace. Click on "See more" and "Contract data". 	●
	Enter business parameters and click "Submit"	●

Table 142. ELCE_5.1_JSI_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.Activate data contract	Approve the data contract from functional task 1 - data contract structure and parameters are okay	●
	Activate the data contract - data contract can now be used in service contracts	●

Table 143. ELCE_5.1_JSI_FT.3 Functional Test Task 3

Functional Test Description	Test Actions	Check
3.Create service contract	Search for the "Flexibility forecast based on price signals" service on the Marketplace. Click on "See more" and then "Request new service". 	●
	Enter business parameters	●
	Select the corresponding service parameters:	●

		
	Select data contract created in functional task 1 and activated in functional task 2	●
	Click on "Yes" for "Enable immediate execution"	●
	Click on "Request service" to send the service contract	●

Table 144. ELCE_5.1_JSI_FT.4 Functional Test Task 4

Functional Test Description	Test Actions	Check
4.Activate service contract	Approve the service contract from functional task 3 - contract structure, business and technical parameters are okay, data contract selected and immediate execution enabled	●
	Activate the service contract - this will make an instance of the service	●
	ASM invoked	●
	Data accessed through the data lake	● *Comment: Data has been uploaded in service Docker image*
	Read technical parameters and run the service	

Table 145. ELCE_5.1_JSI_FT.5 Functional Test Task 5

Functional Test Description	Test Actions	Check
5.Service execution	Upon activation of service contract, click on "Go to service" button for the corresponding service contract, found in the "Service requests" table on "My Services" page for "Service User":	●

and results		
	UI accessed after clicking "Go to service button"	●
	Notebook executed - service no longer in "Services" -> "Running" tab	●
	Click on service ID in "Services" -> "History" tab to fetch report	●

2.Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 146. UI critical errors

Critical errors	Screen shots and description	Reporter
/		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 147. UI non-critical errors

Non-critical errors	Screen shots
/	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 148. UI recommendations

Recommendations	Screen shots
/	

S5.3 – Flexibility aggregated services for DSOs

UPC approach: Flexibility-based AC OPF

Service	**S5.3 Flexibility Agg Services for DSOs**
Algorithm provider	**UPC** – Alejandro Hernandez
Solution provider	**ICOM**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	27/07/2023

Service testing summary

Functional and KPIs testing

Table 149. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	SLOVENIA _X.X_PARTNER_FT.X	Functional Test Task 1	●	Alejandro Hernandez	
	SLOVENIA _X.X_PARTNER_FT.X	Functional Test Task 2	●	Alejandro Hernandez	
	SLOVENIA _X.X_PARTNER_FT.X	Functional Test Task 3	●	Alejandro Hernandez	
	SLOVENIA _X.X_PARTNER_KPI.X	KPIs Task *n*	●	Alejandro Hernandez	
	SLOVENIA _X.X_PARTNER_EXEC	Execution times pilot 2	●	Alejandro Hernandez	

Usability testing

Table 150. Usability testing

UI Non-critical errors
Font color
Axis label

UI Recommendations
Recommendations such as more informative messages for the user to understand some features of the interface should be considered. Darker tone of some fonts.

1.Service Functional and KPIs Testing Actions

Pilot: Slovenia

Table 151. SLOVENIA_S5.3_UPC_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
1.Data Ingestion	Make sure the data from the pilot is correctly ingested for the service.	●
	Verify the data from the service S3.1 is correctly received	●
	Verify there are no NaN values	●

Table 152. SLOVENIA _S5.3_UPC_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.Review daily results	Check Summary values shown. All of the values should be coherent and appropriate. Comment: There is no value that appears for most congested lines.	●

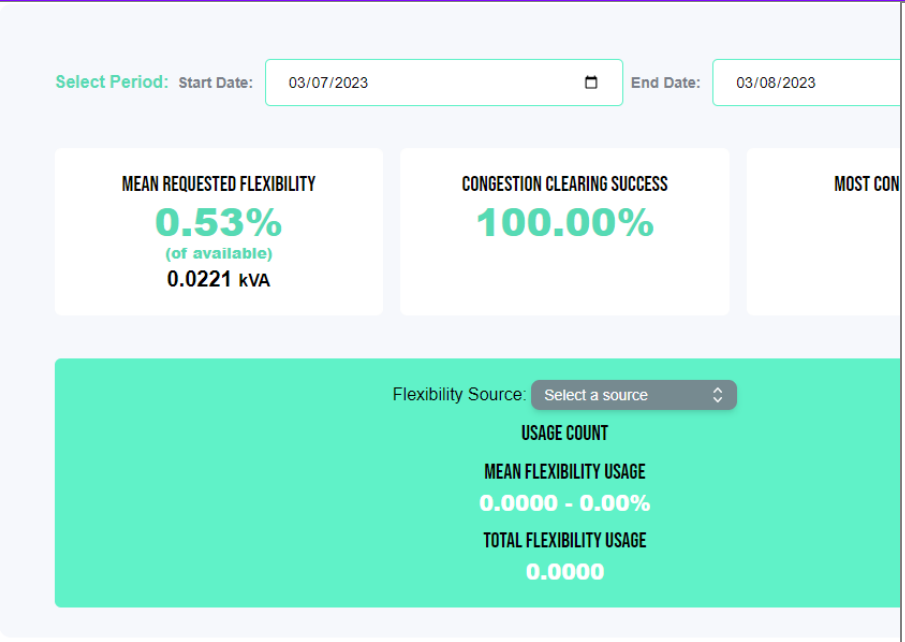
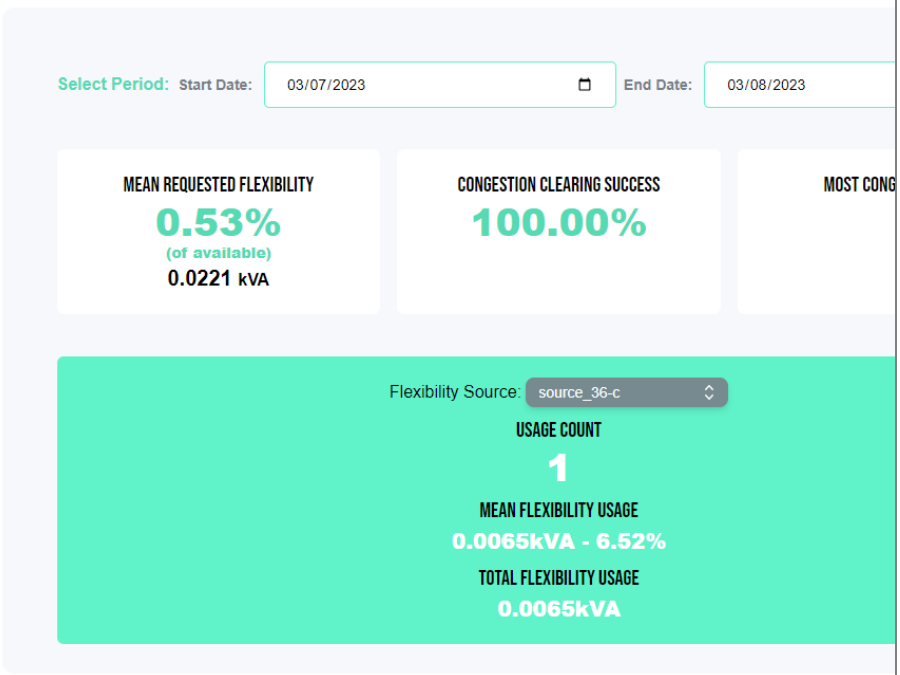
Functional Test Description	Test Actions	Check
		
	Explore different selection of flexibility sources. Try two and make sure the values change. Comment: the term *Usage Count* could be benefited from an explanation (for example a submark or info icon where it says it refers to hours)	●
		
	Check the values shown for different dates selection. Choose at least two available dates and make sure the values change.	●

Table 153. SLOVENIA _S5.3_UPC_FT.3 Functional Test Task 3

Functional Test Description	Test Actions	Check
3.Evaluate visualization	Select different times of the day, confirm the plots change	●
	Download figures for the most congested time of the day	●
	Confirm the images open correctly	●

Table 154. SLOVENIA _S5.3_UPC_FT.4Functional Test Task 4

Functional Test Description	Test Actions	Check
4.Preview of data	Select different buses IDs and explore their behaviour	●
	Download the data in excel form Comment: the data never appears in the table form or excel form to download.	●
	Confirm the downloaded dataset opens correctly	●

Table 155. SLOVENIA _S5.3_UPC_FT.4Functional Test Task 5

Functional Test Description	Test Actions	Check
5.Execute Use Case 1	Compare results given the set	●

Table 156. SLOVENIA _S5.3_UPC_KPI.5Functional Test Task 6

Functional Test Description	Test Actions	Check
6.KPI	KPI benchmark/range comparison Requested Flexibility in range of 20 to 50%	●
	KPI benchmark/range comparison congestion clearing in range of 80 to 100%	●

2.Usability testing

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 157. UI non-critical errors

Non-critical errors	Screen shots

Font color	
Limit axis	This plot should have a label on the y-axis "P-MW"

UI Recommendations

Provide recommendations for improving the front-end UI

Table 158. UI recommendations

Recommendations	Screen shots
Recommendation 1	If possible, change FR for "Flexibility Request" for clarity.
Recommendation 2	More recommendations have been given through this document.

JSI approach: Flexibility services for DSOs based on neural networks

Service	**S5.3 - Flexibility Services For DSOs**
Algorithm provider	**JSI** – Dušan Gabrijelčič
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	22/11/2023

Service testing summary

Functional and KPIs testing

Table 159. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
Slovenia	ELCE_5.3_JSI_FT.1	Create data contract	●	ELCE	
	ELCE_5.3_JSI_FT.2	Activate data contract	●	JSI	
	ELCE_5.3_JSI_FT.3	Create service contract	●	ELCE	
	ELCE_5.3_JSI_FT.4	Activate service contract	●	JSI	
	ELCE_5.3_JSI_FT.5	Service execution and results	●	ELCE	

Usability testing

Table 160. Usability testing

UI Critical errors
/

UI Non-critical errors
/

UI Recommendations
/

1.Service Functional and KPIs Testing Actions

Pilot: Slovenian

Table 161. ELCE_5.3_JSI_FT.1 Functional Test Task 1

Functional Test Description	Test Actions	Check
	Search for the data set "Flexibility service for DSOs input data" on Marketplace. Click on "See more" and "Contract data".	●

1.Create data contract		
	Enter business parameters and click "Submit"	●

Table 162. ELCE_5.3_JSI_FT.2 Functional Test Task 2

Functional Test Description	Test Actions	Check
2.Activate data contract	Approve the data contract from functional task 1 - data contract structure and parameters are okay	●
	Activate the data contract - data contract can now be used in service contracts	●

Table 163. ELCE_5.3_JSI_FT.3 Functional Test Task 3

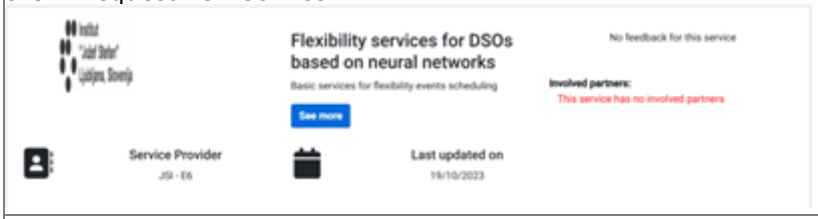
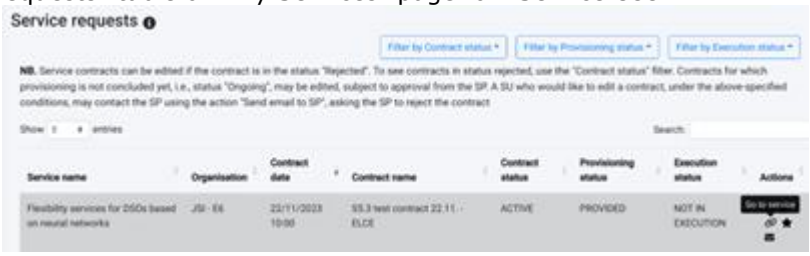
Functional Test Description	Test Actions	Check
3.Create service contract	Search for the "Flexibility services for DSOs based on neural networks" service on the Marketplace. Click on "See more" and then "Request new service". 	●
	Enter business parameters	●
	Select the corresponding service parameters: 	●
	Select data contract created in functional task 1 and activated in functional task 2	●
	Click on "Yes" for "Enable immediate execution"	●
	Click on "Request service" to send the service contract	●

Table 164. ELCE_5.3_JSI_FT.4 Functional Test Task 4

Functional Test Description	Test Actions	Check
4.Activate service contract	Approve the service contract from functional task 3 - contract structure, business and technical parameters are okay, data contract selected and immediate execution enabled	●
	Activate the service contract - this will make an instance of the service	●
	ASM invoked	●
	Data accessed through the data lake	● *Comment: Data has been uploaded in service Docker image*
	Read technical parameters and run the service	

Table 165. ELCE_5.3_JSI_FT.5 Functional Test Task 5

Functional Test Description	Test Actions	Check
5.Service execution and results	Upon activation of service contract, click on "Go to service" button for the corresponding service contract, found in the "Service requests" table on "My Services" page for "Service User": 	●
	UI accessed after clicking "Go to service button"	●
	Notebook executed - service no longer in "Services" -> "Running" tab	●
	Click on service ID in "Services" -> "History" tab to fetch report	●

2.Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 166. UI critical errors

Critical errors	Screen shots and description	Reporter
/		

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 167. UI non-critical errors

Non-critical errors	Screen shots
/	

UI Recommendations

Provide recommendations for improving the front-end UI

Table 168. UI recommendations

Recommendations	Screen shots
/	

S6.1 – Energy management at household or at community level & S6.2 – Energy forecasting

Service	**S6.1&S6.2 Energy management at household or community level**
Algorithm provider	**JSI**– Andrej Čampa
Solution provider	**JSI**
	Good performance ●
	Non-critical error ●
	Error detected ●
Release date	17/04/2023

Service testing summary

Functional and KPIs testing

Table 169. Testing summary table

Pilot	Functional Test ID	Functional Test	Check	Test responsible	Comments
SLOVENIA	SLOVENIA_6.1&6.2_JSI_FT.1	Data ingestion	●	JSI	Ingestion from edge computer - SM not datalake
	SLOVENIA_6.1&6.2_FT.2	Training of the model	●	JSI	In some cases, household asset was (e.g. type of HVAC) changed during testing period, which influenced the model accuracy
	SLOVENIA_6.1&6.2_FT.3	Forecasting	●	JSI	
	SLOVENIA_6.1&6.2_JSI_FT.4	Schedule	●	JSI	
	SLOVENIA_6.1&6.2_KPI.1	KPIs	●	JSI	

Usability testing

Table 170. Usability testing

UI Critical errors
Log-in error /
Graph display /

UI Non-critical errors
Font size /
Limit axis /

UI Recommendations
Ability to add/delete the end-user

1.Service Functional and KPIs Testing Actions

Table 171. 3.1_JSI_FT.1 Data ingestion

Functional Test Description	Test Actions	Pilot	Check
1.Data ingestion	By selecting the start and end date, the weather data should be plotted for that period	ELCE	●
	Tick "get data" to read the SM data (it might take some time if a long time window is selected, due to the amount of data)	ELCE	●
	Use the drop-down menu "Select SM" to select different prosumers, the data should change accordingly.	ELCE	●

Table 172. 3.1_JSI_FT.2 Training of the model

Functional Test Description	Test Actions	Pilot	Check
2.Training of the model	Select the time window on the left and check the SM and weather data on which the training needs to be performed.	ELCE	●
	Once the data is obtained, the train button will appear. Execute it for the training.	ELCE	●
	Training <1min for a month of data	ELCE	●
	Save the model to use the latest model for future forecasting	ELCE	●

Table 173. 3.1_JSI_FT.3 Forecasting

Functional Test Description	Test Actions	Pilot	Check
3.Forecasting	Move to the forecast tab to see the graphs of the forecasted SM for the selected SM using the model.	ELCE	●

Table 174. 3.1_JSI_FT.4 Schedule

Functional Test Description	Test Actions	Pilot	Check
4.Schedule	Select different optimization criteria	ELCE	●
	Table with schedule correctly presented	ELCE	●

Table 175. 3.1_JSI_KPI.1 KPIs

Functional Test Description	Test Actions	Pilot	Check
5.KPIs	At least one asset is activated.	ELCE	●

2.Usability testing

UI Critical errors

Errors that affect the tangible/numeric results: graphs display, login error, etc.

Table 176. UI critical errors

Critical errors	Screen shots and description	Reporter
Type of error (login….)	/	

UI Non-critical errors

Errors that do not affect the tangible/numeric results: font sizes, colors of graphs, limits of the axis, etc.

Table 177. UI non-critical errors

Non-critical errors	Screen shots
Font size	/
Limit axis	/

UI Recommendations

Provide recommendations for improving the front-end UI

Table 178. UI recommendations

Recommendations	Screen shots
/	

9 References

[1] D7.1 "Large Scale pilots' methodology"

[2] Annual Report of Elektro Celje for 2022, accessible at: https://www.elektro-celje.si/si/elektro-celje/letna-porocila

[3] D4.3 "Tools for observability"

[4] D7.2 "Pilot 1 – Spanish pilot description and results"

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