

# **interconnect**

**interoperable solutions  
connecting smart homes,  
buildings and grids**

## **WP4 – Smart Grids Framework for an Interoperable Energy System**

D4.3

**Common DSO management and control  
framework for integrating standardized flexibility  
services**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant agreement No 857237

## DOCUMENT INFORMATION

|                         |   |
|-------------------------|---|
| DOCUMENT                | D4.3 – Common DSO management and control framework for integrating standardized flexibility services  |
| TYPE                    | Report  |
| DISTRIBUTION LEVEL      | Public  |
| DUE DELIVERY DATE       | 30/09/2021  |
| DATE OF DELIVERY        | 30/06/2022  |
| VERSION                 | V3.0  |
| DELIVERABLE RESPONSIBLE | Enedis  |
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## DOCUMENT HISTORY

| VERSION | AUTHORS                   | DATE       | CONTENT AND CHANGES          |
|---------|---------------------------|------------|------------------------------|
| 1.0     | Kevin Loussouarn (Enedis) | 30/06/2021 | Initial draft                |
| 2.0     | All authors               | 13/05/2022 | Contributions from authors   |
| 2.1     | All authors               | 01/06/2022 | Corrections and improvements |
| 3.0     | David Rua, Bárbara Maia   | 01/07/2022 | Editorial revision           |

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## EXECUTIVE SUMMARY

Distribution System Operators (DSOs) play a key role in the development of a consumer-centric energy system, enabling new standardized flexibility products for smart homes, buildings, and communities.

InterConnect is about democratization of energy management. The focus of InterConnect WP4 on interoperability of services, also considering a common semantic data understanding, permitted by the SAREF ontology, can create better conditions for replicability of solutions. By having a common data model definition, instead of having multiple solutions for every DSO, services can consume pieces of information in a uniform and predictable way, thus easing service replicability and deployability. It means the services can be used by every DSO under different conditions, such as within another network type, location, or time. This is of importance for companies and utilities since replication bring major benefits for example through a cost-effective application to a larger group of costumers or by reusing proven solutions in a cost-effective way.

WP4 sets the ambition to design and implement a standard DSO interface, which is an API interface that enables and allows the communication between the DSO to market platforms and entities. A common framework and set of tools, which have several functions, provide services, and complement the interface, thereby further enabling DSOs, and other market players, turn the challenges into opportunities, such as the uptake of flexibility mechanisms to solve grid constraints.

This document includes a presentation of input-process-output cycle assessment for each function. This cycle assessment considers: 1) how the network assets, models, and data should be fetched/pushed, from/to a DSO's legacy system in the market to make the most of the resources of the market (assets, players) for optimal operations and 2) the operation phases and ontologies such as SAREF/openAPI communication that are required. This creates a basis for a common framework for the distribution grid management and control system. The framework establishes: 1) the adequate tools and control mechanisms, which facilitate new market mechanisms and 2) services that enable the integration of flexibility as a new network asset in legacy SCADA/DMS systems.

This document also specifies a set of services for implementing distribution services which could be adopted by DSOs outside the InterConnect project and, thereby, contributing to the exploitation of the results from WP4. The replicability will be assured by enabling the incorporation of a range of possibilities to specific inputs. As an example, the observability service 2 associated tool, needs a signal characterisation to incentivise consumption variation as an input. The tool allows this signal input to be a cost tariff, a power limit, an environmental signal for different hours. This possibility allows the use in different contexts (replication) to provide the same service. In fact, this tool will be applied (replicated) to the French, Greek, German and Dutch pilots. The main services described in this deliverable are the following:

- The Distribution grid support for fault location identification (Observability Service 1). It can be mostly used by DSOs and replicated in different member states.
- The quantification of consumer flexibility response (Observability Service 2). It can be used by Retailers, DSOs, aggregators.
- The assessment of grid impact through load type observation (Observability Service 3). It can be mostly used by DSOs but also by aggregators and other planning infrastructure/resources businesses.

- The demand side flexibility forecast and grid congestion forecast. It can be used by DSOs. This is particularly relevant for flexibility services that are offered at the LV/MV levels.
- The network dynamic tariff. It can be used by DSOs.
- The flexibility services for energy management. It can be used by aggregators.

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## ABBREVIATIONS AND ACRONYMS

|              |  |              |  |
|--------------|--|--------------|--|
| <b>ADMS</b>  | Advanced Distribution Management System        | <b>LV</b>    | Low Voltage                              |
| <b>AGG</b>   | Aggregator                                     | <b>MDM</b>   | Meter Data Management                    |
| <b>AMI</b>   | Advanced Metering Infrastructure               | <b>MMS</b>   | Market Management System                 |
| <b>API</b>   | Application Programming Interface              | <b>MV</b>    | Medium Voltage                           |
| <b>BEMS</b>  | Building Energy Management System              | <b>OMS</b>   | Order Management System                  |
| <b>BRP</b>   | Balance Responsible Party                      | <b>OT</b>    | Operational Technology                   |
| <b>CEC</b>   | Citizen Energy Community                       | <b>PV</b>    | Photovoltaic                             |
| <b>CEMS</b>  | Community Energy Management System             | <b>P2P</b>   | Peer to peer                             |
| <b>CEP</b>   | Clean Energy Package                           | <b>REC</b>   | Renewable Energy Community               |
| <b>CIM</b>   | Common Information Model                       | <b>RED</b>   | Renewable Energy Directive               |
| <b>CIS</b>   | Customer Information System                    | <b>RES</b>   | Renewable Energy Sources                 |
| <b>CRM</b>   | Customer Relationship Management               | <b>REST</b>  | Representational State Transfer          |
| <b>DAAC</b>  | Data Acquisition and Control                   | <b>RT</b>    | Real-Time                                |
| <b>DER</b>   | Distributed Energy Resources                   | <b>RTU</b>   | Remote Temporal Unit                     |
| <b>DERMS</b> | Distributed Energy Resources Management System | <b>SAREF</b> | Smart Applications REference             |
| <b>DG</b>    | Distributed Generation                         | <b>SCADA</b> | Supervisory Control and Data Acquisition |
| <b>DMO</b>   | Data Metering Operator                         | <b>SSA</b>   | Service Specific Adapter                 |
| <b>DMS</b>   | Demand Management System                       | <b>TSO</b>   | Transmission System Operator             |
| <b>DNP</b>   | Distributed Network Protocol                   | <b>WFM</b>   | Workforce Management                     |
| <b>DRA</b>   | Demand Response Aggregator                     | <b>WAMS</b>  | Workforce Approval Management System     |
| <b>DSO</b>   | Distribution System Operator                   | <b>WMS</b>   | Warehouse Management System              |
| <b>DSP</b>   | Data Service Provider                          | <b>XML</b>   | Extensible Markup Language               |
| <b>DTC</b>   | Distribution Transformer Controller            |              |  |
| <b>EMS</b>   | Energy Management System                       |              |  |
| <b>ERP</b>   | Enterprise Resource Planning                   |              |  |
| <b>ESB</b>   | Enterprise Service Bus                         |              |  |
| <b>ESP</b>   | Energy Service Provider                        |              |  |
| <b>EV</b>    | Electric Vehicle                               |              |  |
| <b>FTP</b>   | File Transfer Protocol                         |              |  |
| <b>GA</b>    | Generic Adapter                                |              |  |
| <b>GIS</b>   | Geographic Information System                  |              |  |
| <b>HEMS</b>  | Home Energy Management System                  |              |  |
| <b>IC</b>    | InterConnect                                   |              |  |
| <b>ICIF</b>  | InterConnect Interoperability Framework        |              |  |
| <b>ICPP</b>  | Immediate ceiling priority protocol            |              |  |
| <b>IEC</b>   | International Electrotechnical Commission      |              |  |
| <b>IMD</b>   | Internal Market Directive                      |              |  |
| <b>IOT</b>   | Internet of Things                             |              |  |
| <b>IT</b>    | Information Technology                         |              |  |



## 1. INTRODUCTION

The Distribution System Operator (DSO) plays a key role in the development of a consumer-centric energy system, enabling new standardized flexibility products for smart homes, buildings, and communities.

InterConnect is about democratization of energy management. The focus of InterConnect WP4 on interoperability of services, with a common approach permitted by ontology such as SAREF. By having a common data model definition, instead of having multiple solutions for every DSO, services can consume pieces of information in a uniform and predictable way, thus easing service replicability and deployability. It means the services can be used by every DSO under different conditions, such as within another network type, location, or time. This is of importance for companies and utilities since replication bring major benefits for example through a cost-effective application to a larger group of costumers or by reusing proven solutions in a cost-effective way.

A framework helps the DSOs save time by avoiding the duplication of solutions and replicating unnecessary efforts for a common problem. Using common tools facilitates collaboration between the users and its improvement towards more complex solutions and avoid/alert other users for emerging problems. The specific designed tools of the framework are verified by various entities, so assure their reliability.

This deliverable provides a common framework for the distribution grid management and control system. It identifies a set of control strategies/mechanisms and adequate tools to facilitate new flexibility services and at the same time enables the integration of flexibility as a new network asset in legacy SCADA/DMS systems.

The flexibility management typically involves TSOs. However, this deliverable is focused on DSOs and the flexibility platform.

### 1.1 DELIVERABLE D4.3 DEPENDENCIES

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The DSO management and control framework, described in this deliverable, builds on the needs and lessons from previous deliverables (1.1, 2.1, and 4.1).

The services presented in section 4 can be replicated, due to the data process developed through SAREF ontology and under the Interoperability Framework from WP5. The DSO interface specified in D4.2, integrated in the Interoperability Framework, will allow the exchange of information with other semantically interoperable digital services. This is possible due to the existence of Service Specific Adapters - a core development of WP5 - promoting a knowledge interaction of type Ask/React with the service. This goes beyond a standard approach found in a REST API used in simple requests. The work developed in WP5 regarding the Interoperability Framework, can be seen as an example in different stages of the processes of some observability services, where the DSO needs to request information from a data service provider or a third party. Moreover, the services here described will be accessible through the service store developed in 5.2.

This DSO interface depends on the interoperability and proper coordination of different InterConnect digital platforms from WP5 for which it is necessary to define a proper Service Specific Adapter (SSA) for each micro-service of the interface that needs communications happen through the interoperability framework. Namely, flexibility data exchange with aggregators and community energy management systems (EMS), as well as the graph patterns deployed for the observability services. The DSO specifies the API calls of each service/function to be exposed to the interoperability layer by defining the type of knowledge interaction (Ask/Answer or Post/React) together with the relevant graph patterns and communicative acts. On the aggregator or CEMS platforms, there are APIs developed to mirror the functionalities of the DSO interface.

A core development from WP4, explained in this deliverable, is the development of the smart metering platform, which enhances the value of the smart meter. Deliverable D1.1 presents the use cases and explains the opportunity that flexibility unleashes for network service provision (in section 3.1.2. Introduction to Flexibility Markets) and places smart metering at the core of the process. Using D1.1 data flows and time sequences as a starting point, D4.3 details the data parameters and exchanges for the different types of market optimizations available to DSOs. Recognising the hassles related with interacting with smart meters and the value of the data, the metering platform is described in this deliverable as a piece of the management and control framework.

As a core medium to achieve a consumer-centric energy system, through enabling new standardized flexibility services, the role of the DSO is key. The ways for the DSO to enable new consumer-centric services are tackled in the Interconnect D4.1 and D4.2, which are, respectively, the functional and technical specification of the DSO interface. This proposes a system which will enable and allow the communication between DSO, market platforms, service providers, and ultimately to the consumer for enabling new energy services, by integrating new mechanisms for managing flexibility, data sharing and observability, while making use of DSO internal operative systems for metering data availability, grid forecasting and operation. While the DSO interface, as described in D4.1 and D4.2 tackles the need and proposes a system which will allow to make a bridge between the DSO and other external entities, this deliverable will provide complementary guidelines and a framework to perform the link with internal DSO OT systems. This is done, to allow for several system operator to prepare and choose their systems considering the new requirements which are associated to the energy transition, such as flexibility provisioning and acquisition to solve grid constraints. Furthermore, additional tools that benefit the operation and planning of DSOs, such as observability and distributed load analysis, and specified from a utilization and data exchange perspective (black box perspective) in D4.2, and further explained in more detail in this document.

WP4 and this deliverable 4.3, shows the application in the energy sector, at the electricity distribution network level, of the work done regarding interoperability. It demonstrates how a coordinated approach is possible due to a common understanding between different layers. This common understanding is a synergetic requirement for an ever approximation between system operators, facilitating market/business, functional, information, communication, and component level integration.

D4.3 sets the stage for the final deliverable of WP4, D4.4 “Guidelines and Recommendations for the Flexibility Platform and Enhancement of Services.” D4.3 takes the view of the DSO in mind, while D4.4 will focus on the requirements for flexibility service providers and platforms. In brief, the high-level objectives defined in the forthcoming D4.4 include enabling market players to quickly connect to a DSO market; enable a transparent and compliant DSO flexibility market development for all market

agents; and allow energy players to bring their flexibility service platforms into compliance with DSO market requirements and enable bidding of standardized products. To meet these objectives D4.4 will build on the valuable input data authored in D4.3 regarding the common framework for distribution grid management and control systems (in addition to D4.1 and D4.2.) The foreseen DSO tools, control mechanisms, and specifications from D4.3 will provide the information needed to develop guidance for flexibility providers to connect to a DSO flexibility market.

## 1.2 DELIVERABLE OBJECTIVES AND STRUCTURE

---

The objective of this deliverable is to leverage the work realized in T4.1, specifying a DSO flexibility market, enabling new standardized flexibility services provided by aggregators, energy communities and microgrids for distribution grids.

In this deliverable, a common framework for the distribution grid management and control system is proposed, identifying the adequate tools and control mechanisms to facilitate new market mechanisms and services, and, at the same time, enable the integration of flexibility as a new network asset in legacy SCADA/DMS systems.

The document is structured as follows:

- Chapter 1: The objective of Chapter 1 is to introduce the deliverable, the structure, and the objectives.
- Chapter 2: The objective is to describe the DSO reality within InterConnect.
- Chapter 3: The objective is to describe the adequate tools and control mechanisms to facilitate new market mechanisms and services and at the same time enable the integration of flexibility as a new network asset in legacy SCADA/DMS systems.
- Chapter 4: The objective is to describe a common framework to integrate standardized flexibility services into the grid.

## 2. DSO REALITY WITHIN INTERCONNECT

### 2.1 PILOTS WITH GRID INVOLVEMENT

The table below provides an overview of all the InterConnect use cases involving DSOs, where the rightmost column describes the role of the DSO in the individual use case. In the following subchapters the pilot which involves demos will be described. It should be noted that the list only aims to cover the activities within the project and is not exhaustive as per all possible roles for the DSOs.

**TABLE 1: PILOTS WITH GRID INVOLVEMENT**

| DEMO | HLUC   | MAIN SCOPE OF HLUC  | INFORMATION EXCHANGED AND MECHANISM (IF/KE, DSO INTERFACE)   |
|------|--|---|--|
| PT   | HLUC05 - DSO Data Sharing 4 Consumer & Market                                      | <ul style="list-style-type: none"> <li>•Dynamic contracted power limitation</li> <li>•Flexibility mapping (forecast or historical on flex needs)</li> <li>•Smart meter anonymized data for awareness and market participation</li> </ul>  | The DSO is an active participant in the demonstration. The demonstration will involve the mobilization and activation of flexibility, the developing of open data sharing mechanisms for metering and flexibility data, and the enhancement of grid observability through behind the meter appliances.   |
|      | HLUC10 - Flexibility Management for Distribution Grid Support                      | <ul style="list-style-type: none"> <li>•Day-ahead flexibility procurement and mobilization for MV and LV grid support</li> </ul>  |  |
|      | HLUC11 – Enhancing Distribution Grid Observability                                 | <ul style="list-style-type: none"> <li>•Connectivity information of HEMS in a certain geographic area (data service for DSO)</li> <li>•Voltage monitoring</li> <li>•Load diagrams from relevant loads (EV, thermal loads, PV, ...)</li> </ul>   |  |
| DE   | HLUC01 - Maximize utilization of renewable - wind- energy at grid connection point | <ul style="list-style-type: none"> <li>•Dynamic network tariffs (Time of use tariff)</li> <li>•Energy Demand Forecast</li> </ul>  | In the German Pilot the DSO never comes into direct contact with the InterConnect Framework.<br>The data as described is, at least partially, exchanged between KEO (not the DSO) and Fraunhofer via the Knowledge engine.   |
|      | HLUC 2: Maximize utilization of DER energy consumption in premises                 | <ul style="list-style-type: none"> <li>•Active Power limitation</li> <li>•Grid monitoring at connection point (energy, voltage, frequency)</li> </ul>   |  |
|      | HLUC 3: Grid stability via power limitation at grid connection                     | <p><b>HLUC/Primary Use case:</b><br/>Monitoring of GRID connection point, Power Limitation at Grid Connection Point by external set points</p> <p><b>Short description:</b><br/>Certain mid-voltage grid areas are monitored and analyzed via an AI-based state estimation and state forecast. The grid states are then analyzed on possible congestions and possible free capacities are determined. In case of congestions, related active powers set points are communicated to several added-value modules (KEO) where each of them is connected to one hotel which is hosting charging points for electric vehicles. These charging processes can be modified.</p> | <p><b>Information being exchanged:</b> Network model of the power grid, measurements from HV/MV transformers, measurements from intelligent LV substations.</p> <p><b>DSO role and if/how it used the Knowledge engine/ IF or DSO interface:</b><br/>The DSO provides network data and measurements needed for the calculation of power limitations.<br/>The DSO never comes into direct contact with the InterConnect Framework. There is no interface at the DSO that incorporates the InterConnect Framework. The Knowledge engine is used to communicate data between the control unit of the EV chargers und the services that calculates the power limitation.</p> |

|           |   |  |   |
|-----------|---|--|---|
| <b>FR</b> | HLUC1 (Maximize utilization of renewable)<br><br>HLUC 2 – Dynamic tariff  | <ul style="list-style-type: none"> <li>•Dynamic tariff structure</li> <li>•Consumer Smart meter self-consumption mode activation</li> <li>•Smart Meter data management for real-time monitoring</li> </ul>   | <p><b>Information being exchanged:</b> Data from smart meters (Power, consumption, etc.).</p> <p><b>DSO role and if/how it used the Knowledge engine/ IF or DSO interface:</b><br/>The data exchanged by way of InterConnect Semantic Interoperability Framework are used by stakeholders for flexibility services.</p>   |
| <b>BE</b> | Cordium - HLUC 1 – Community Cost optimization – district & building level<br>Thor Park – HLUC 1 – Thor Park. Community cost optimization | <ul style="list-style-type: none"> <li>•Dynamic power limitation</li> <li>•Dynamic tariff structure</li> <li>•Flexibility Forecast</li> <li>•Self-consumption plan and flexibility</li> </ul>  | <p>DSO recognized as an involved indirect actor in the sequence diagram but not a direct participant in the pilots.</p> <p>Interactions in the demonstrator will only be from the Aggregator to end consumers.</p>  |
| <b>IT</b> | HLUC1 Digital Platform for End-User Control and Awareness   | The role of the DSO is to send flexibility request to the aggregator/BSP based on the result of an operational planning of the distribution grid. As the Italian pilot does not have a real DSO, this will be simulated by RSE.                                      | <p>The data exchange between DSO and BSP is based on MQTT messages. Particularly, for the flexibility request the message is in the following form:</p> <pre>{   "timestamp":xxx,   "flexibility":[{     "activation_time":"yyy",     "power":www,     "duration":zzz}] }</pre> <p>activation time is the starting time of the request, while power and duration are the power and the duration of the flexibility as requested by the DSO (eg. 200kW for 1hour starting from 14.30).</p> |
|           | HLUC1 Digital Platform for control and awareness (PUC 3 - Exchange of aggregated flexibility data)  | <ul style="list-style-type: none"> <li>•Flexibility aggregation from residential users to provide ancillary services to the TSO</li> </ul>   |   |
| <b>EL</b> | HLUC – Flexibility Provision.   | <p>This use case describes the process where consumers provide flexibility to the GRID operator.</p> <p>Balance of the energy supply and demand through DR mechanisms and related automated commands' execution, based on consumers' incentivized participation.</p> | <p>Pilot mimics DSO requests.</p> <p>All the interactions will take place through the Knowledge engine/IF.</p>  |
| <b>NL</b> | HLUC1: Optimize sustainability in Smart buildings   | <p>Primary Use Case 8 (PUC8): Dynamic capacity tariffs publication on the connection level to reduce peak load</p> <p>In absence of a DSO in the pilot, a project partner (TNO) will implement in software the System Operator role.</p>                             | <p>The use case allows for a daily publication of grid tariffs based on which flexible demand and flexible supply of buildings are optimized depending on the other forecasts and Primary Use Cases.</p> <p>The Dutch pilot will use the Interoperability Framework of InterConnect to exchange graph patterns of dynamic tariffs with the knowledge engine of ReFlex and the simulated DSO service.</p>  |

## 2.1.1 PILOTS WITH SIMULATED GRID INVOLVEMENT

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### 2.1.1.1 GERMAN PILOT

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The German pilot focuses on three HLUCs. Of these, HLUC 3 is where some of the features of the DSO can be observed. The use case is called: Monitoring of GRID connection point, Power Limitation at Grid Connection Point by external set points, Maximize utilization of renewable -wind- energy at grid connection point.

In this demonstration certain mid-voltage grid areas are monitored and analyzed via an AI-based state estimation and state forecast. The grid states are then analyzed on possible congestions and possible free capacities are determined. In case of congestions, related active power set points are communicated to several added-value modules (KEO) where each of them is connected to one hotel which is hosting charging points for electric vehicles. These charging processes can be modified.

Regarding the DSO role and if/how it used the Knowledge engine/ IF or DSO interface, the DSO provides network data and measurements needed for the calculation of power limitations. However, the DSO never comes into direct contact with the InterConnect Framework. There is no interface at the DSO that incorporates the InterConnect Framework. The Knowledge engine is used to communicate data between the control unit of the EV chargers and the services that calculates the power limitation.

As for the information being exchanged, the network model of the power grid, measurements from HV/MV transformers, measurements from intelligent LV substations, information about renewable energy percentage at connection point

### 2.1.1.2 ITALIAN PILOT

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The role of the DSO is to send flexibility request to the aggregator based on the result of an operational planning of the distribution grid. As we do not have, in the Italian Pilot, a real DSO, this one is simulated by RSE.

In order to have the most accurate and realistic scenario, each flexibility request is related to the result of an operational planning of a synthetic distribution network. The synthetic distribution network is created using a specific tool<sup>1</sup> that will be tailored for the geographical area of the Italian pilot throughout georeferenced libraries.

By the end of the day, the DSO receives the expected aggregated load profiles consumptions of the end users from the aggregator: the estimated baseline consumption and the load profile of the IoT connected devices, which represent, for the Italian pilot extent, the flexible part of the load. Interactions of the simulated DSO with the aggregator is detailed in Figure 1.

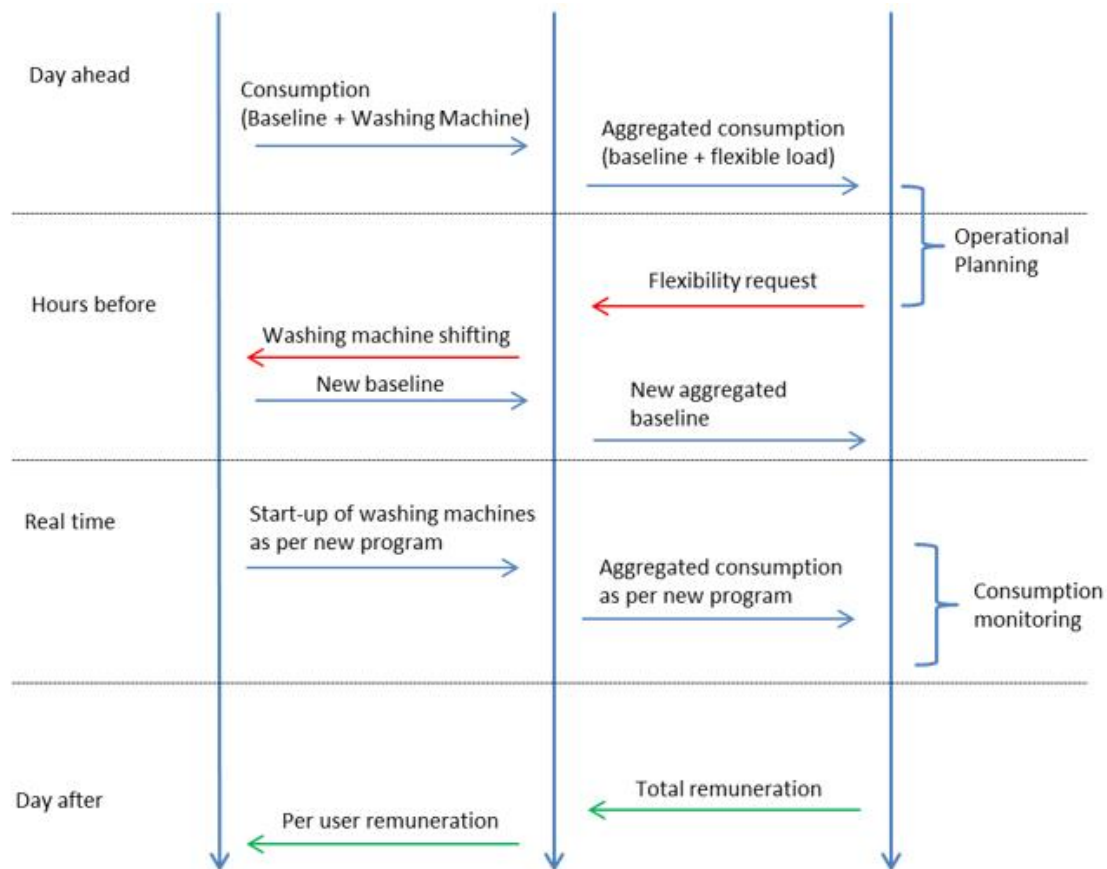
In addition to real data taken from a similar real field, the DSO will leverage on this infield data to conduct an operational planning on the previously created synthetic grid. The result is essentially the

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<sup>1</sup> To be defined.



power flow of the synthetic grid, which can be used to generate a flexibility request in case it is needed (e.g., an in-line power exceeding the maximum value).



**FIGURE 1: THE SIMULATED DSO WORKFLOW IN THE ITALIAN USE CASE**

### 2.1.1.3 GREEK PILOT

The HLUC developed in this pilot will be the dedicated to Flexibility Provision. This use case describes the process where consumers provide flexibility to the GRID operator. Based on the provided flexibility the GRID can respond in high/low consumption periods, balancing the energy demands. Balance of the energy supply and demand through DR mechanisms and related automated commands' execution, based on consumers' incentivised participation, to provide their flexibility schedule and/or their intention to participate in cases of additional reduction is required.

Regarding the information being exchanged, the DSO's requests will be simulated. That means virtual DSO initiates all the DR events by (1) communicating with the DR platform asking for forecasts to detect overloads/underloads, (2) sends a DR request to the DR platform, (3) DR platform sends commands/recommendations to the devices/consumers, (4) DR platform sends feedback to the vDSO about the output of the DR event (successful or not, % of target reached).

All the interactions will take place through the Knowledge engine/IF. We are not aware if these interactions can/should take place through the standardized DSO interface defined/developed in WP4.

#### 2.1.1.4 DUTCH PILOT

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There are several mechanisms such as fixed or fine-grained grid capacity tariffs, dynamic grid capacity tariffs, and market-based solutions that allow a DSO to use the demand side energy flexibility. In the Dutch use case, the main need from the DSO is to prevent demand peaks and supply peaks (the latter one mainly caused by PVs). This can be done by directly controlling flexible assets (by one or more aggregators) which works technically well, but it requires additional actors, and the right business model for them and the DSO. When several consumers are connected to the same grid (as in the Dutch pilot) it is difficult to judge who needs to be rewarded how much for offering their flexibility. dynamic grid capacity tariffs are being applied on the connection level. This use case allows for a daily publication of grid tariffs, however, those tariffs could be the same for every day (to be able to study how effective static tariffs are compared to dynamic tariffs).

The main 'DSO mechanism' that is planned to apply in the Dutch pilot is: a daily publication of grid tariffs, however, those tariffs could be the same for every day (to be able to study how effective static tariffs are compared to dynamic tariffs). The information being exchanged is a quarterly hour capacity tariff, published at least one hour before the active day.

The Dutch pilot makes use of the ReFlex platform (kind of aggregator system) to optimize the energy use and flexibility based on energy tariffs and grid tariffs. Based on various forecasts the flexible demand and supply will be optimized and controlled. The flexible demand (building, batteries, EVs) and flexible supply (PV, batteries) depends on the other Primary Use Cases. In absence of a DSO in the pilot, a project partner (TNO) will simulate in software the System Operator role. The Dutch pilot will use the knowledge engine of InterConnect and graph patterns to exchange data between the simulated DSO service by TNO to get dynamic tariffs via the knowledge engine of ReFlex.

#### 2.1.1.5 BELGIAN PILOT

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The Belgian sub pilots are focused on energy services for communities and can each have a different interaction with a simulated DSO. The main simulated input from DSO perspective comes from flexible or dynamic (forecasted) tariffs which will be used as an additional incentive to virtually valorise the available flexibility in the energy community. Although Fluvius (the DSO for Flanders, Belgium) is not a partner in the InterConnect project, several Belgian partners (Th!nk E, VITO, ThermoVault and others) have close relations with the DSO in earlier projects. The forecasted price incentives are therefore based on realistic data in consultation with Fluvius.

As the current regulatory framework in Belgium is not aimed at peer-to-peer trading or dynamic distribution grid tariffs, the pilot activities stop at aggregation level. The scale of the Belgian pilots is not sufficient to reach the energy markets at TSO level. However, in several of the Belgian sub pilots the DSO is involved to integrate lessons learned in future projects.

Based on the dynamic price signals the sub pilots trigger different use cases. Among them are the peer-to-peer trading where distribution grid tariffs are considered to schedule the optimal timeslot for energy trading. Another use case is the community optimisation of flexible thermal assets (individual water boilers or common heating network) where these thermal assets are controlled to be able to benefit from the dynamic distribution grid tariffs.



## 2.1.2 PILOTS WITH GRID INVOLVEMENT

### 2.1.2.1 PORTUGUESE PILOT

The Portuguese pilot will implement the DSO interface for enabling and operationalise the use cases detailed in 2.1. The DSO interface will act as a gateway between the internal operation of the DSO and the communication with external stakeholders (Flexibility Providers/Aggregators), and ultimately consumers. Besides the implementation of syntactic interoperability mechanisms (i.e., REST APIs) for the enablement of the flexibility purposes, the DSO interface also aims at allowing semantic interoperability through the usage of the Interoperability Framework.

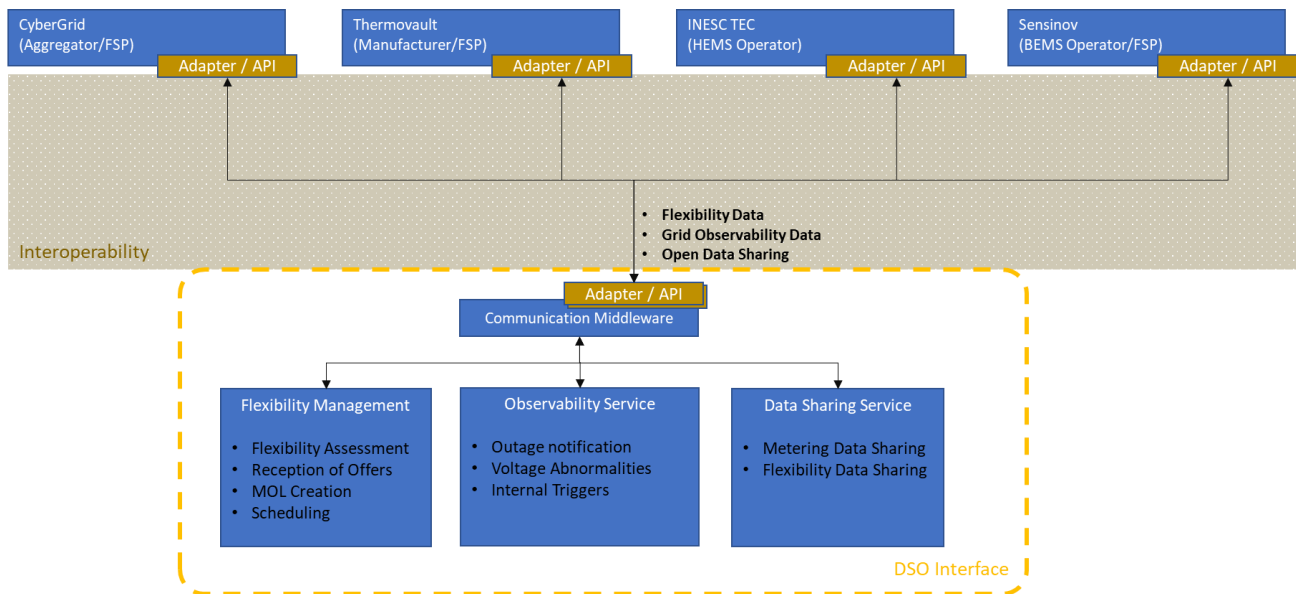


FIGURE 2: PT PILOT DSO PARTICIPATION

The demonstration will directly involve the DSO for the purposes of flexibility mobilisation and activation (HLUC 10) for both commercial and household buildings, leveraging the implemented BEMS, HEMS, and Manufacturers, while enabling the access to consumer and aggregated consumption data to entitled parties (HLUC 5). Furthermore, mechanisms for the enhancement of the grid observability through distributed intelligent appliances (dishwashers, washing machines, dryers, heat pumps, and water heater controllers) will be explored (HLUC 11), with the purpose of automatically identifying abnormalities in the MV/LV grid for the specific areas of the demonstrations.

### 2.1.2.2 FRENCH PILOT: THE DATA METERING PLATFORM

In order to enable the development of dynamic energy services and flexibility of use in the Smart Home, access to customer metering real-time data by all service providers / aggregators is implemented, through the development of a dynamic metering data platform, interoperable and linked to all industrial partners' platforms.

The HLUC1 (Maximize utilization of renewable) and HLUC2 (Dynamic tariff and usage management) are tested. The HLUC5 (DSO data sharing for new energy services) is not directly tested but it allows HLUC1 and HLUC2 to be tested.

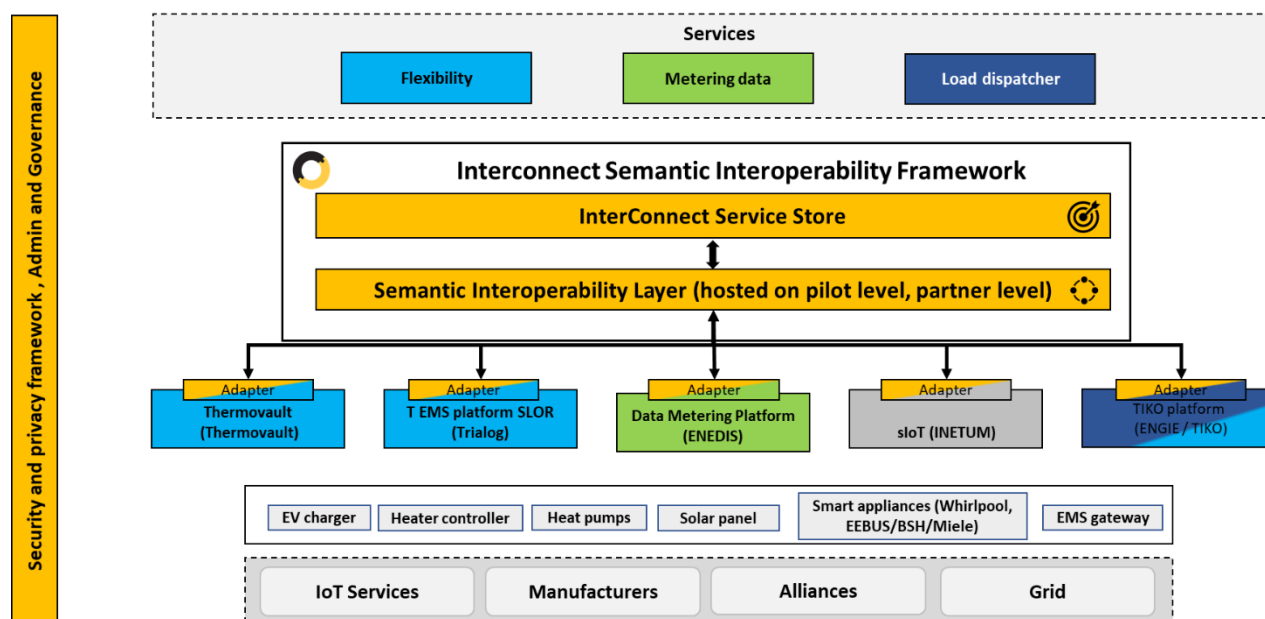


FIGURE 3: FRENCH PILOT MAPPING

As presented in the figure above, the DSO develops and maintains the dynamic metering data platform. The data exchanged by way of InterConnect Semantic Interoperability Framework are used by stakeholders for flexibility services.

## 2.2 INFORMATION EXCHANGE FROM THE GRID POV

The French DSO has developed API that allow some information exchange:

- 3 POST APIs:
  - On the event of a change in subscribed power, the information on the new cut-off power is pushed (data TIC "PCOUP")
  - On event of overrun of subscribed power, the overrun information is pushed (data TIC "STGE"), every 10 seconds as long as there is overrun
  - On a Linky, a smart meter, measuring production, case of collective self-consumption surplus option which must be implemented in the municipality of Le Pradet, the instantaneous power injected is pushed every 30 seconds (data ICT "SINSTI")
- and 1 ANSWER API, which transmits data from the TIC frame as soon as a partner requests it (ASK).

Later in this document, the chapter 3.4.2 describes the technical architecture of the Data Metering Platform. The data and functionalities from smart meters are made available in an interoperable and standardized way enabling service providers to optimise the consumption of Smart Homes and develop new services.

Regarding the use cases to be implemented by the Portuguese Pilot, the following APIs were developed to support the following data exchanges:

### 1. Open Data Sharing

- User Metering Data
- Anonymized Metering Data - Metering data aggregated per grid zone
- Flexibility Data - Historical or forecasted flexibility needs from the system operator per grid zone

## 2. Flexibility

- Flexibility Needs
- Flexibility Offers
- Flexibility Activation Plan

## 3. Observability

- Service Activation/Subscription
- Fault Notification
- HEMS status Request

Besides the technical REST API interface specification, there's also the aim of having interoperable and standardized all these communication through SAREF ontology by leveraging on the work from WP3 and WP5. Therefore, by using SAREF, it can be demonstrated how the semantic interoperability can be leveraged for the interaction with multiple stakeholders, such as FSPs, Aggregators, and Service Providers. From WP3, the methodology for the development of the semantic triplets and SSAs will be followed and applied on the developed REST interfaces for the defined data exchanges by turning, in turn, this developed software component will allow the communication with the Interoperability framework, developed under WP5, through the instantiation and usage of the Generic Adapter.

The referred "SAREF-ization" process, the process to have services interoperable and standardized through SAREF ontology, consists of:

- Describing the existent service and components specification (API);
- Creating the graph pattern triples in relation to semantic interoperability for each component of the service, which turns the implicit knowledge from the REST service into explicit knowledge through the SAREF ontology;
- Designing the compatible Knowledge Interactions as defined in WP5;
- Creating the graph patterns triples for the defined knowledge interactions;
- Developing the SSA for interacting with the Generic Adapter, which maps the existent service into the previously defined knowledge interactions and graph patterns triples;
- Implementing the SSA and GA to make the service available through the IF.

### 3. COMMON FRAMEWORK FOR THE DISTRIBUTION GRID MANAGEMENT AND CONTROL SYSTEM

Distribution grid management and control, needs several tools for monitoring, analysis, control, optimization, planning and training of distribution system operators (DSOs). Advanced Distribution Management System (ADMS) is a comprehensive solution in which all the tools operate homogeneously on a common representation of the complete electricity distribution network. A typical ADMS of a DSO is shown in Figure 4.

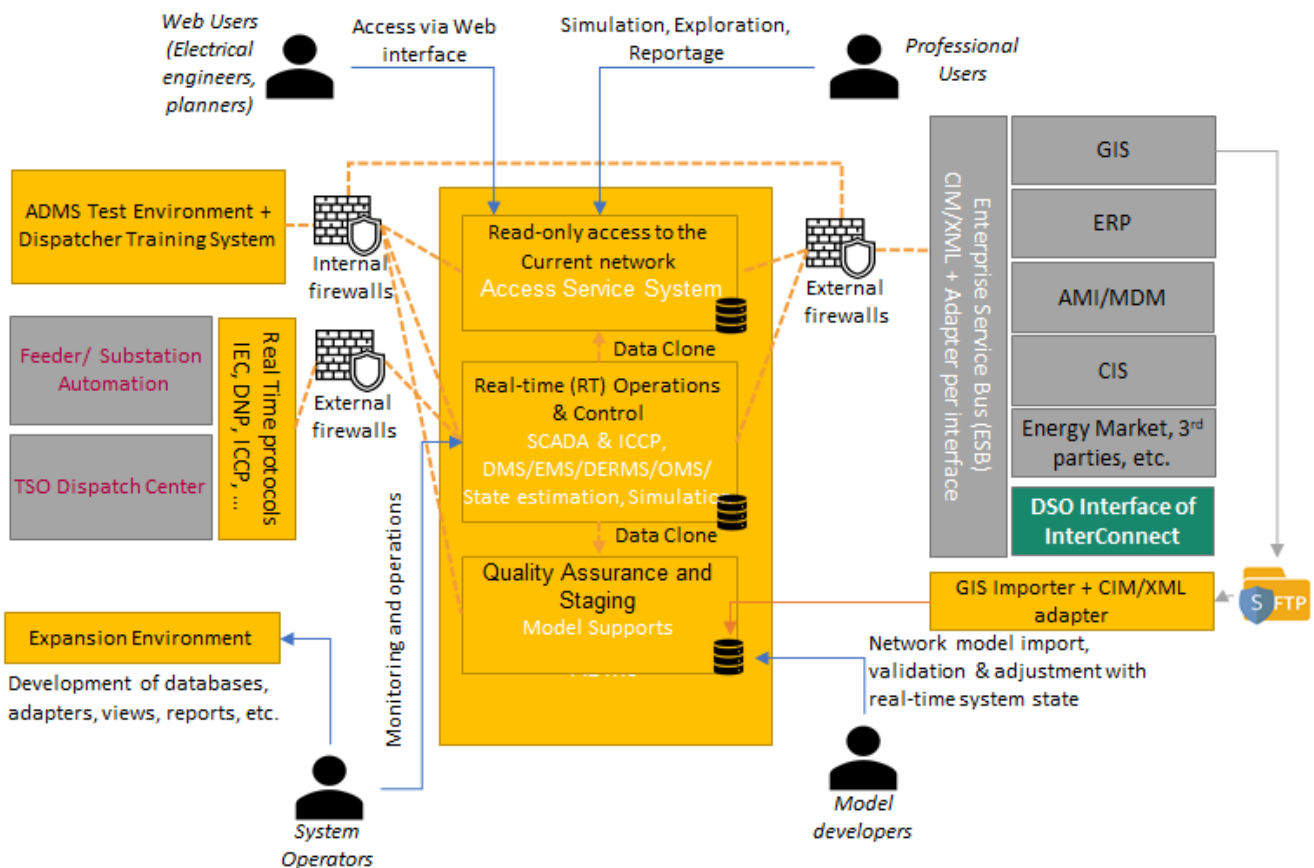


FIGURE 4: DSO INTERFACE OF INTERCONNECT IN A TYPICAL ADMS OF DSO

Operations of DSOs and current ADMS must change dramatically to accommodate variability and unpredictability of DERs. However, active grid-edge assets and systems of customers such as DR assets, DER assets, and microgrid assets and systems, have narrow to no visibility or control as the existing utility SCADA and DMS does not stretch to all service points and customer premises. A platform with new functions in operation and more interfaces for users as well as new measurement, control, and analytics to operate the distribution grid securely and cost-effectively including incentives for prosumers cost minimization could help DSOs.

Advanced grid management is considered as one of the main Smart Grid dimensions of DSOs in parallel with: utilising non-frequency ancillary services; DER, EVs and storage management; Smart metering, remote control, and use of SCADA system control; Regulatory compliance; and DSO-TSO coordination.

To respond effectively to spatio-temporal impact of DER penetration, various tools and functions are recommended for an advanced distribution grid management, such as:

- Optimal Power Flow applications and Load Flow simulation,
- Data Analytic for asset planning and investment strategies,
- Tools for Outage Detection & Prediction,
- Advanced Load & Storage Management, and,
- DER Visualization and Management tools.

In the planning horizon, DSOs need to assess and disseminate the impact of RECs as a non-wire alternative in long-term hosting capacity studies and locational value aligning investment decisions with distribution operational needs. Nevertheless, from the use case analysis of D4.1, focus of DSO operation improvement in IC ecosystem lies on operational planning (day-ahead and intraday) timeframe to integrate emerging enterprises in IT and OT systems and processes of DSO. While big data and IoT technologies are becoming a must-have in the future distributed architecture of distribution systems, but observability and controllability of grid-edge devices and their interoperable operation with DSO management systems are beyond the scopes of analysed use cases (in D4.1) in InterConnect project.

The following section aims to analyse and identify functional and technical needs of DSO interface to address challenges and opportunities of HEMS, BEMS, CEMS, and Aggregator's enterprises integration in distribution grid operations, and consequently, to identify shortcomings of the existing tools, services, and processes in InterConnect ecosystem. The "adequacy of tools and control mechanisms" to manage technical, operational, and economic challenges of interconnected enterprises are derived for transformation of DSO's regular ADMS to the InterConnect-ADMS (Figure 4) with the scopes of:

- Reliability: Distribution constraints management, voltage/reactive management;
- Customer Services: Tariffs and incentives, customer engagement and support (sub-metering, data platform, consumer connection information), P2P trading management;
- Economics: Optimization, forecasting load, renewables, DER, and grid congestions, load modelling and allocation, aggregated modelling, scheduling and dispatch;
- Resiliency: Fault detection and allocation.

### 3.1 AN INTERCONNECT ADMS REALIZATION

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Interfaces of a possible IC-ADMS shall include operator, market, and prosumer interfaces. Based on the roles and responsibilities of distribution grid operator from D4.1 and architecture of the DSO interface from D4.2, IC-ADMS functionalities are divided into:

- IC-DERMS functions: Functional modules for the coordinated scheduling and dispatch of DERs, enhanced individual/aggregate DER management<sup>2</sup>, forecasting, unbalanced load flow and state estimation, sensitivity analysis, loading and voltage constraints management and phase balancing, spatio-temporal resource optimizations<sup>3</sup> and scheduling/bidding/restrictions into DR, DER and markets;

<sup>2</sup> Aggregation of DER capabilities for provision of different products toward grid operational management

<sup>3</sup> Optimization engine should consider fixed schedules, bilateral trades, as well as voluntary bids and offers from marketplace, while respecting resource and distribution grid constraints customized for each analysed scenario.

- IC-SCADA (or DAAC<sup>4</sup>) functions: Detailed modelling of aggregated and individual DER assets; extended observability and controllability from primary distribution equipment to edge devices and customer premises while being integrated in other DSO applications, databases, and systems through the Enterprise Service Bus (ESB); Network topology connectivity service; and Data analytic to handle aggregation of large number of devices and assets;
- Base data storage and management: to maintain base data of registered enterprises, assets, DR programs, tariffs, contracts, etc.;
- Interfaces to local/bulk market platforms: to declare DR/DER Programs and offers, and to delineate grid constraint for RECs e.g., for bilateral market management;
- Portal for registration and qualification of the enterprises: to declare the enterprise type, characteristics and assets, location, planned use cases (markets, DR programs, P2P trading, etc.), user access management, as well as indicators to DSO legacy systems such as to GIS, CIS, flexibility node/zones of Market platform, etc.
- Distribution operations interfaces: for structured and unstructured data exchange with DSO internal ADMS Systems, namely metering and grid data from real-time system and grid model supports of ADMS;
- Performance assessment and settlement: based on the received data AMI/MDM and market data and contractual agreements from the base data management module;

In absence of regulatory and technical provisions, some DSOs may relax or defer parts of the functional requirements. Based on “common” responsibilities of DSOs derived from D4.1’s data exchange clustering, functionalities and required tools of DSO are defined to validate/use flexibility transactions/products for predictive congestion management and voltage support and to increase distribution grid’s observability and controllability toward energy communities.

To keep it simple in this section, functional applications of IC-ADMS are presented for use cases of DSO Interface in the figure below, while considering that, how the network assets and models and data should be fetched/pushed from/to DSO’s legacy systems in market and operation phases for which having interoperable and standardized communication/REST API through SAREF ontology would be required (for external interactions) to be further described in section 3 in more details.

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<sup>4</sup> Data Acquisition And Control

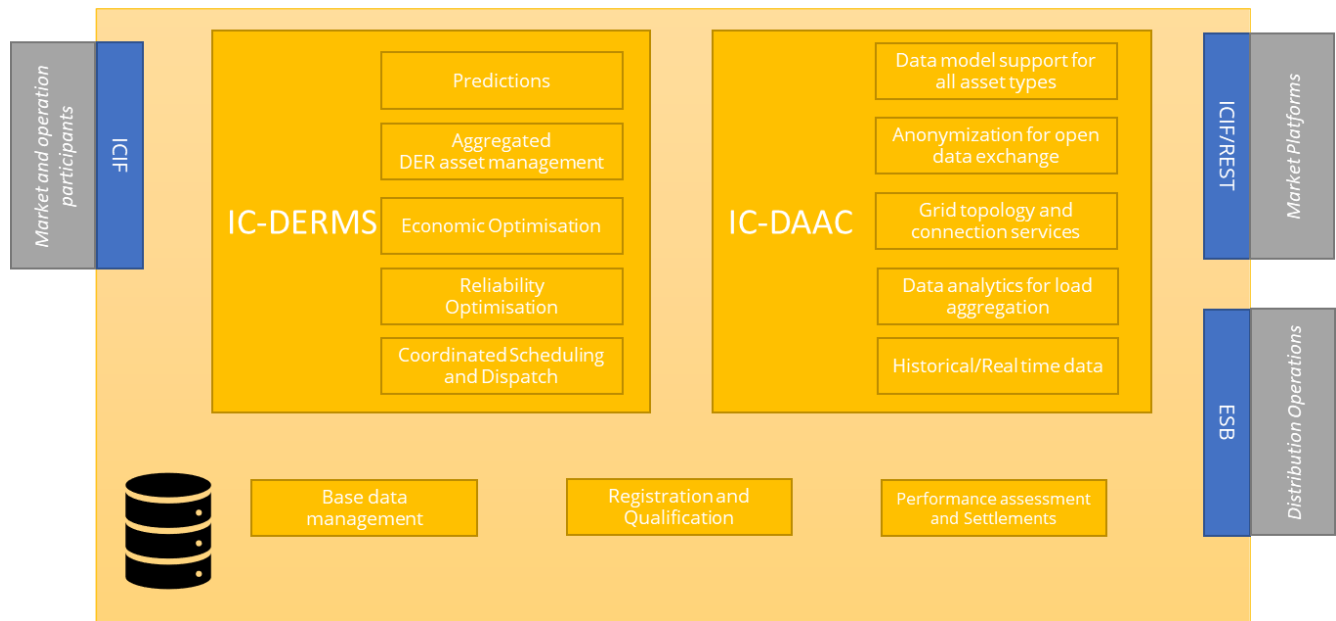


FIGURE 5: THE MAIN FUNCTIONAL MODULES COMPRISING A POSSIBLE IC-ADMS REALIZATION

TABLE 2: DSO INTERFACE USE CASE WITH FUNCTIONAL AND DATA EXCHANGE REQUIREMENTS

| DSO INTERFACE USE CASES                     | IC-ADMS RELATED FUNCTIONALITIES  | DSO/MARKETS/ENTERPRISES RELATED FUNCTIONS  |
|---|--|--|
| Authentication, access and control          | Registration and Qualification function<br>Base data management  | Enterprise type, characteristics and assets, location, planned use cases (markets, DR programs, P2P trading, etc.)<br><br>User access management   |
| Flexibility<br>Procurement<br>Data exchange | Registration and Qualification function<br>Aggregation and prediction functions of DERs, DRs, consumption, and Grid congestions<br><br>Economic Optimization to assess schedules, P2P trades, and voluntary offers for losses minimization <sup>5</sup><br><br>Economic Optimization subject to flexibility resources and network constraints to submit bids and offers<br><br>Reliability Optimization minimising the schedules reduction in emergency conditions | Real time and grid model data from SCADA/ADMS interface<br><br>Real-time telemetry<br><br>Bids/Offer/P2P trades from the market interface<br><br>Non-priced Schedules, P2P trades, and voluntary offers from the enterprises<br><br>Reservation and Activation requests to the Enterprises via ICIF<br><br>Data from AMI/MDM and market result data as well as contractual agreements from the base data management module |

<sup>5</sup> Flexibility services are limited in time. The amount of power, which is not consumed or, at least, reduced at a time, is consumed later at another time.



|   |   |   |
|---|---|---|
|   | <p>Coordinated Scheduling and Dispatch of all assets in real-time operation toward T-D interface management</p> <p>Performance assessment and Settlements</p> <p>Base data management</p> |   |
| Dynamic tariffs data exchange                           | <p>Aggregating and Predicting DRs, DERs, demands, and spot prices</p> <p>Economic optimization to calculate optimal topology and nodal/branch prices</p> <p>Base data management</p>      | <p>SCADA/ADMS for grid model and prevailing operating conditions</p> <p>Prices publishes to the enterprises</p> <p>Publishing tariffs/programs to AMI/MDM</p> <p>Publishing adjusted prosumer plan to ADMS</p>  |
| Topology and consumer connection information management | <p>Registration and Qualification function</p> <p>Data model support for all asset types monitoring</p> <p>Grid topology and connection services</p> <p>Base data management</p>          | <p>Indicators to DSO legacy systems such as GIS, CIS, SCADA/ADMS, AMI/MDM, etc.</p> <p>Flexibility node/zone detection for DER aggregation</p> <p>Mapping network nodes with flexibility zone/area/node from the marketplace and ADMS data support</p> <p>Mapping consumer connection codes and flexibility zones from the marketplace and AMI/MDM data</p> <p>Mapping information from HEMS to observability data of SCADA/ADMS/OMS</p> <p>Real-time telemetry<sup>6</sup></p> |
| Grid constraints data exchange                          | <p>Optimization engine for grid hosting capacity assessment and enhancement studies:</p> <p>Base data management</p>  | <p>AMI/MDM to update constraint</p> <p>The enterprises interface to update constraint</p>   |
| Network observability                                   | <p>Data analytic for load aggregation</p> <p>Base data management</p>   | <p>SCADA/ADMS for observability and power quality data sharing</p> <p>OMS for fault management</p>  |
| Open Data and Analytics data exchange service           | <p>Anonymization and aggregation of load profiles</p> <p>Base data management</p>   | <p>AMI/MDM to fetch data</p> <p>Enterprises interface to deliver requested data</p>   |

<sup>6</sup> As flexibility are set to have a significant effect on the network, such effect must be given to DSO to adjust the load flow computations.

Real-time network monitoring does not suffice. DSO load flow computations combine forecasts, measurements, and real-time analysis of perturbation (weather for renewables and thermal-induced consumption and now flexibility activations).



## 3.2 COMMON FRAMEWORK FOR DSOS FOR MANAGING INTEGRATION OF STANDARDIZED FLEXIBILITY SERVICES

In this chapter, we propose a common framework for DSOs to ensure the participation of DSOs in InterConnect ecosystem and to save time avoiding that every DSO creates its own process to manage standardized flexibility services.

This process is enhanced from a process developed and validated in past EU/National project (Interflex and the French demonstrator Nice Smart Valley). It has been demonstrated, and now used, by Enedis. Furthermore, this framework is considered and adapted to the Portuguese pilot, to provide the guidelines on how to deal with the flexibility processes taking place in the demonstration.

From the process developed and validated in InterFlex, 4 parameters, that are more detailed below in the document, have been added:

- Constraints' inventory and flexibility need identification;
- Topological information & contractual;
- Interactions contracts with flexibility service providers to provide flexibility offers (posting offers, reservations, activation & clearing services);
- Providing data for checking calculations & clearing services to determine if the FSP provided the service it committed to.

### 3.2.1 FLEXIBILITY SERVICE LIFECYCLE

Before deep diving into the common process, figure 6 offers an overview of the flexibility service lifecycle:

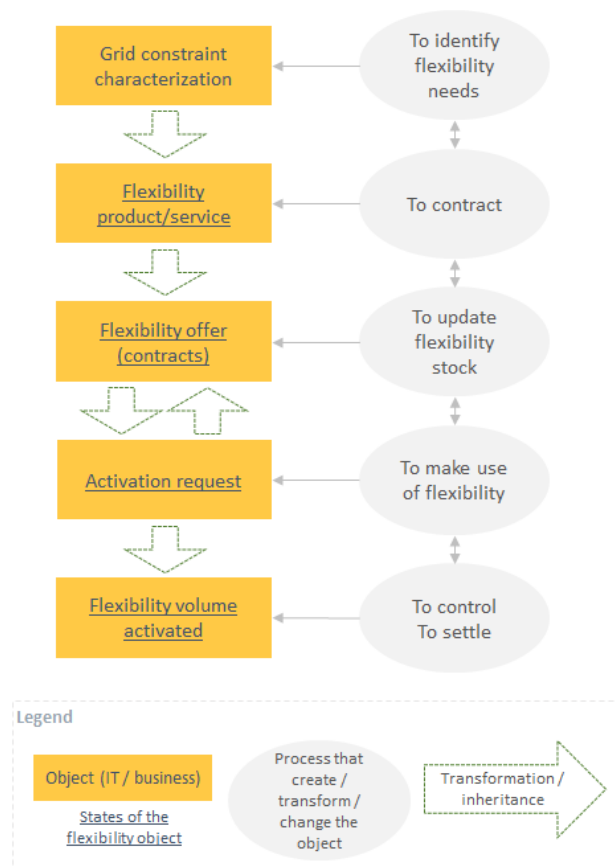


FIGURE 6: FLEXIBILITY SERVICE LIFECYCLE

This lifecycle can be divided into 3 big steps:

- 1.The upstream: before the flexibility service activation
- 2.The activation
- 3.The downstream: after flexibility activation

For each step, the process has been detailed and the recommended information systems that should be involved have been indicated. Their role and an overview of the interactions between the flexibility platform and monitoring/SCADA systems are presented.

### 3.2.2 UPSTREAM: BEFORE FLEXIBILITY ACTIVATION

The full upstream flexibility management process follows two main steps:

- A. Flexibility need identification: before activating flexibility, it is necessary to identify the needs of the grid according to the grid constraints. The process is described in the figure 7.
- B. Contracting between DSO and FSP: Contractualization between DSO and flexibility service provider is necessary before activation. The process is described in the figure 8.

In detail:

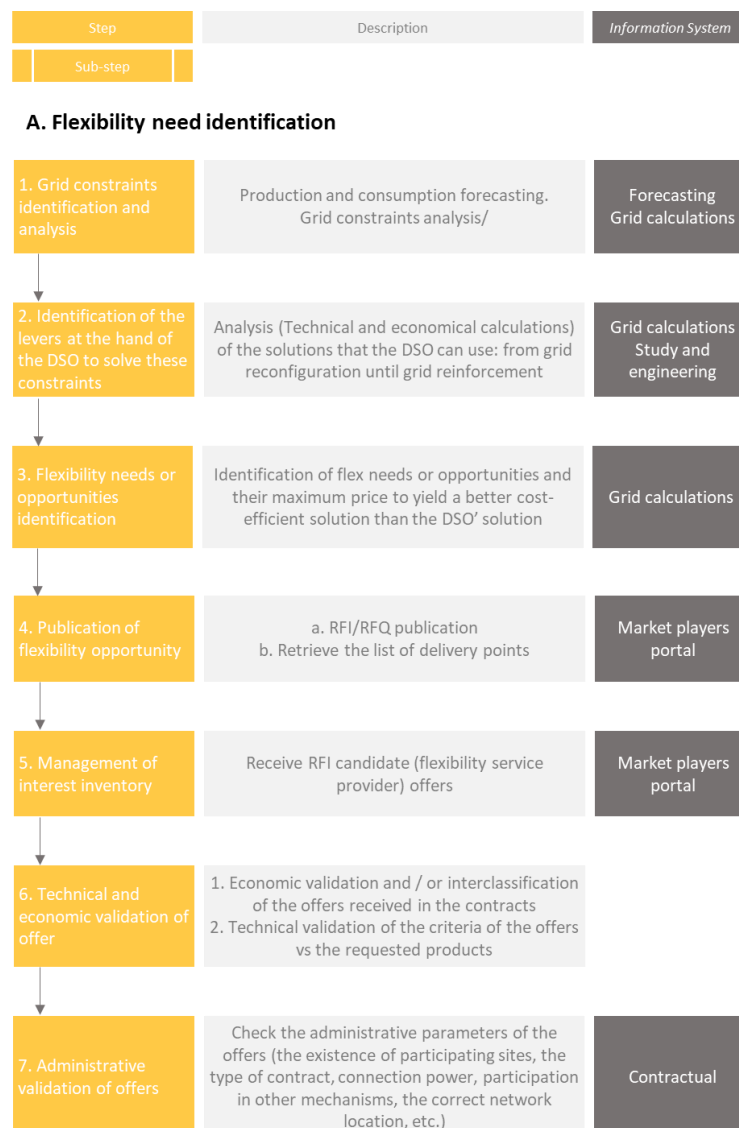


FIGURE 7: UPSTREAM PROCESS: BEFORE FLEXIBILITY ACTIVATION (1/2)

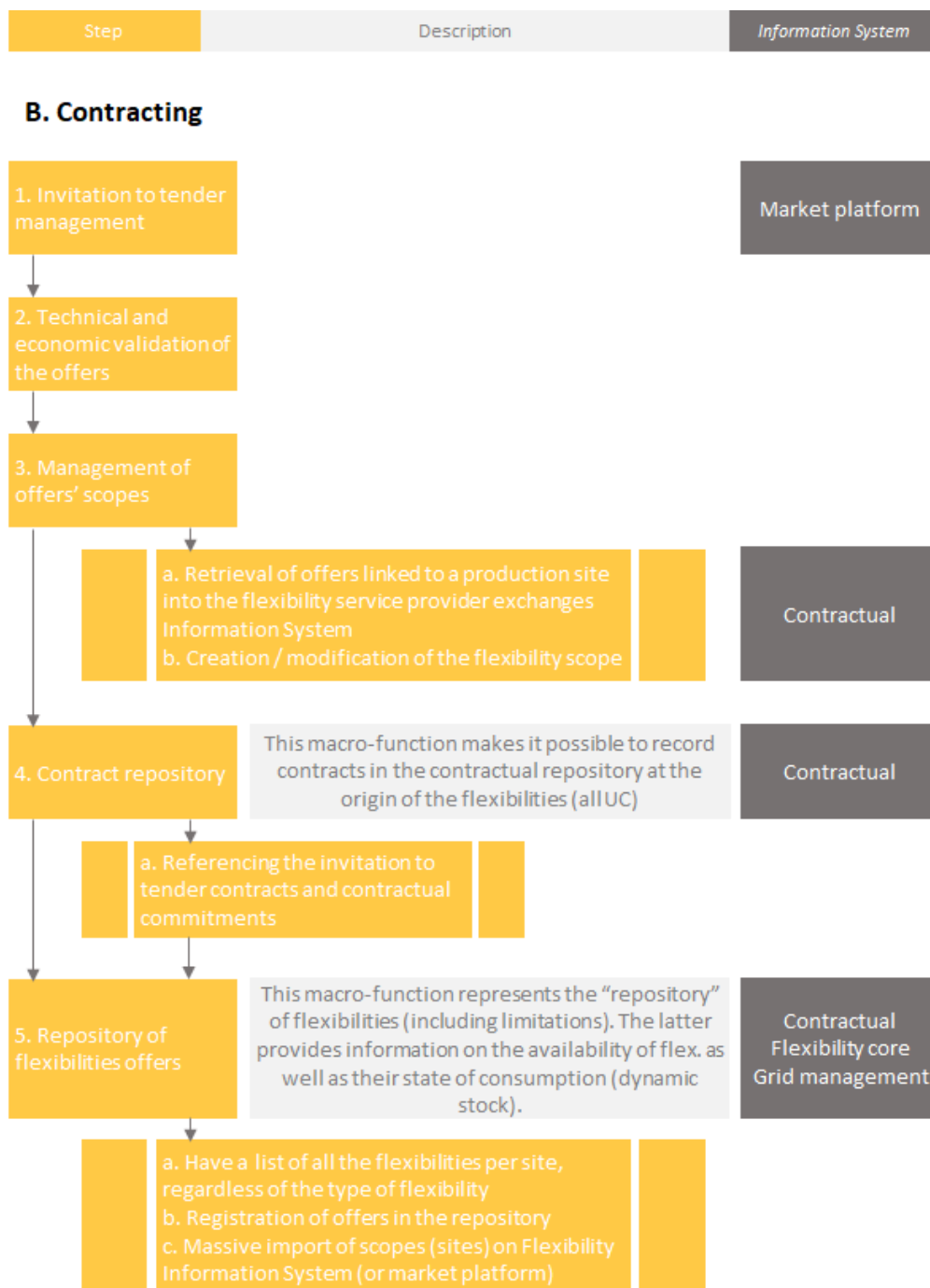


FIGURE 8: UPSTREAM PROCESS: BEFORE FLEXIBILITY ACTIVATION (2/2)

### 3.2.3 FLEXIBILITY ACTIVATION

As soon as a trade is established, the Neutral Market Operator will notify the interested parties: the FSP and the DSO.

After this notification is processed, the activation phase will take place at the defined time:

- The FSP will activate the offered flexibility within the conditions that has been defined during the contracting step;
- As soon as the DSO is notified that flexibility was activated, the DSO can use the flexibility within the previously defined conditions

The process is described in the figure 9.

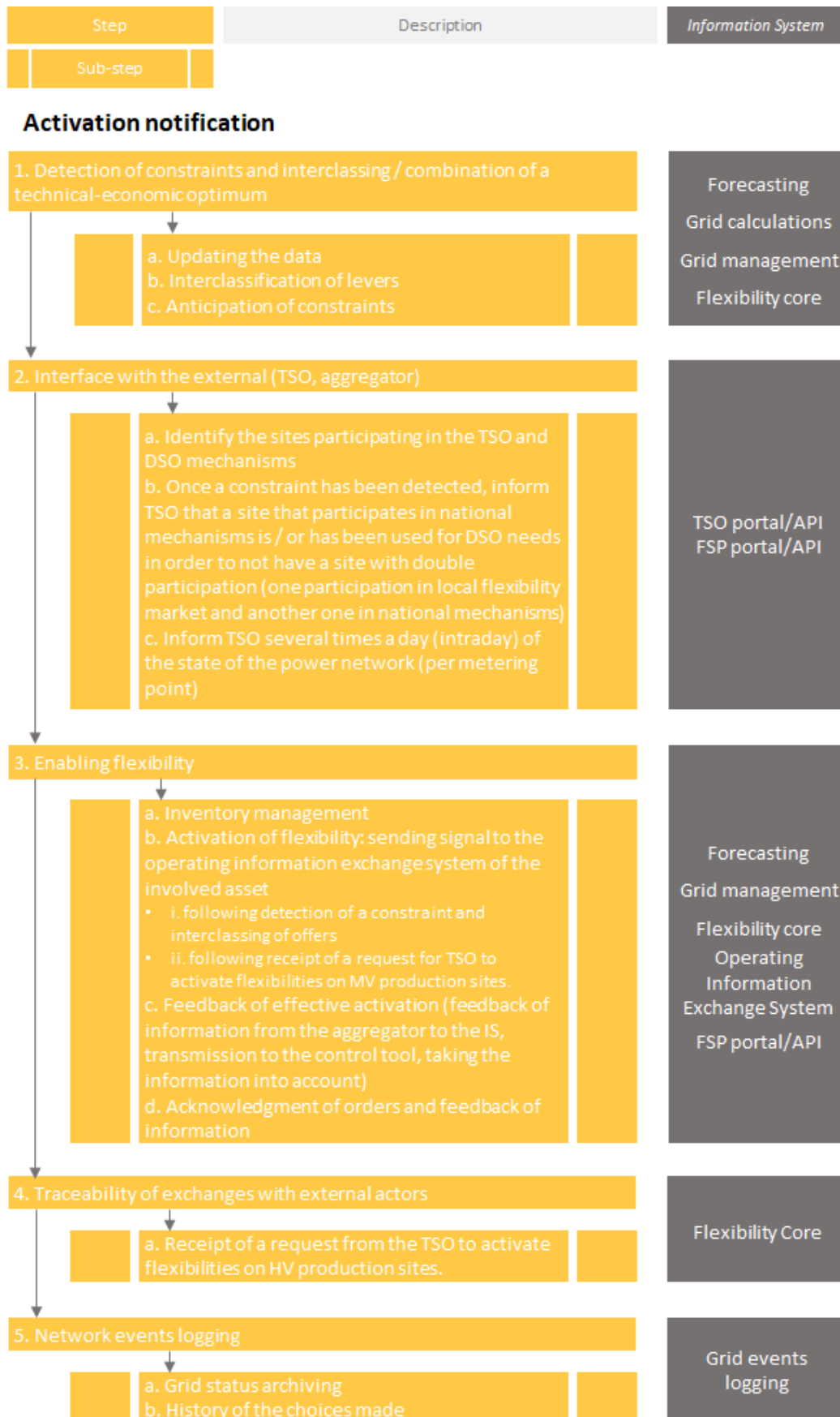


FIGURE 9: FLEXIBILITY ACTIVATION PROCESS

### 3.2.4 DOWNSTREAM: AFTER FLEXIBILITY ACTIVATION

The DSO will measure the delivered flexibility by comparing a baseline (delivered by the FSP) with metering data from each market transaction participant. This information will be shared with the FSP. The FSP will then analyse this information and confirm the transaction. This process is described in Figure 10.



FIGURE 10: DOWNSTREAM PROCESS – AFTER FLEXIBILITY ACTIVATION

### 3.2.5 OFFER STATUS

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There are 4 stages for the flexibility offer:

- Received: The offer is received by the platform.
- Active: The offer has been verified by the DSO. It can be activated.
- Suspended: the offer has been suspended for a period of time because the flexibility service provider has transmitted an inability to respond to an activation over the period.
- Expired: The deadline to activate the offer has passed, the offer can no longer be activated.

### 3.2.6 ACTIVATION NOTIFICATION STATUS AND PROCESS

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There are 3 stages for the activation notification:

- Sent: There is a constraint detected on the grid. The flexibility service provider has been notified.
- Accepted: To reduce or remove the constraint, the flexibility service provider has positively answered to the notification.
- Cancelled: The flexibility service provider has negatively answered to the notification, or the respond delay has expired. The constraint has been removed.

## 3.3 REQUIREMENTS AND INTERACTIONS BETWEEN MONITORING SYSTEM/SCADA SYSTEMS AND FLEX PLATFORM ALIGNED WITH THE USE CASES OF PILOTS (WP1)

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In this chapter, we list these requirements to SCADA and monitoring systems interact with the flexibility platform.

### 3.3.1 SYSTEMS THAT ARE INVOLVED TO MANAGE THE GRID

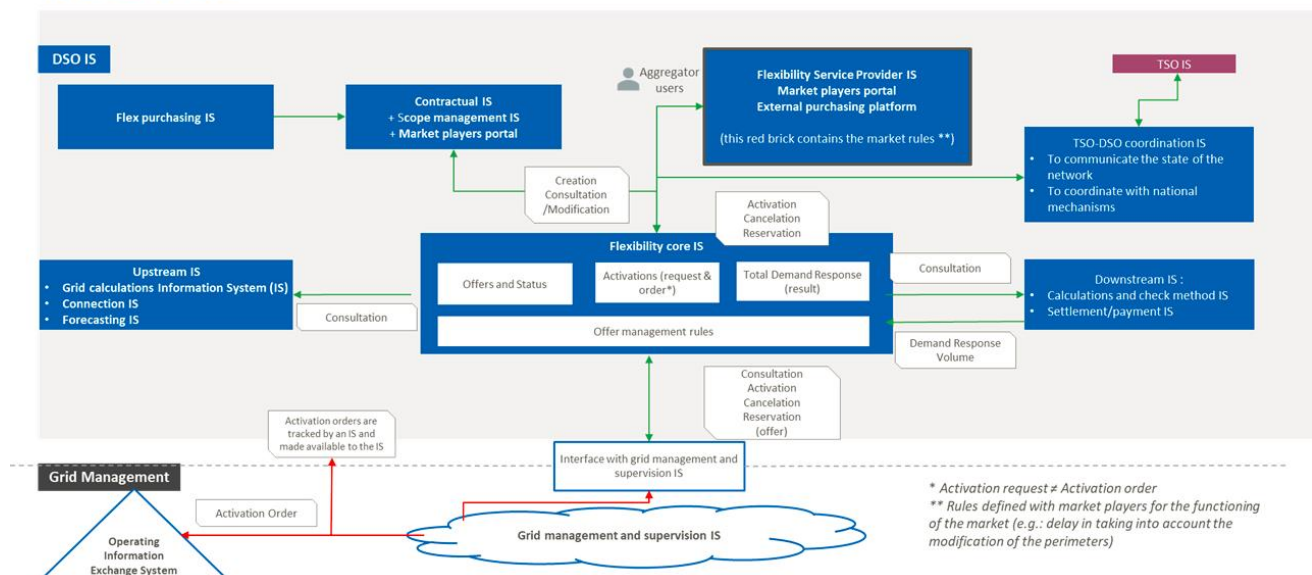
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The information systems (IS) presented in the figures 7, 8, 9 and 10 (in grey in the right column) are listed below. They are involved to manage the grid and to manage flexibility. The figure 11 presents a simplified overview of the interactions between them.

- Upstream IS: Information Systems that are used prior to the activation
  - Grid calculations (IS): IS that manages grid studies
  - Connection IS: IS that manages the connections on the grid
  - Forecasting IS: IS that forecasts the grid behaviour (productions and consumptions)
  - Flex purchasing IS: IS that manages flexibility purchasing
  - Contractual IS: IS that manages contractual aspects
- Scope management IS: IS that manages the scope of the flexibility services.
- Market players portal: Portal to publish grid constraints for market players so that they can propose flexibility offers
- TSO-DSO coordination IS: IS that:
  - communicates the state of the network to other IS
  - coordinates with national mechanisms

- Flexibility core IS: IS that:
  - Requests activation
  - Sends activation order
- Grid management and supervision IS: IS that is responsible to send activation request and order and that supervises the grid and all its events
- Flexibility Service Provider IS: IS(s) owned by FSP to manage flexibility
- Operating Information Exchange System: IS of the asset for which an activation order has been sent
- Downstream IS: IS used after the activation
  - Calculations and verification IS: IS used to calculate the volume that have been activated and to check if this volume matches with the contracted one.
  - Settlement/payment IS: IS that manages the payment of the flexibility provider

## IS overview



**FIGURE 11: INTERACTIONS BETWEEN MONITORING SYSTEM/SCADA SYSTEMS AND FLEX PLATFORM**

As presented in the Figure 11, grid control and management IS are separated from the rest. So, the integration is made by a deposit of the data that are exchanged in an “airlock”. This airlock allows to protect the SCADA systems.

IS must integrate flexibilities by:

- ensuring to maximize the functional synergies of the use cases,
- ensuring the fluidity of the user experience,
- and ensuring cost control while promoting the automation, auditability, and traceability of data flows.

The value created by the flexibility platform will be measured by combining the following KPI:

- Manual gestures costs
- Activated flexibility volume
- Automations costs

### 3.3.2 DSO INTERFACE INTEGRATION WITH LEGACY SYSTEMS

Even though the energy sector is facing an unprecedented digital transformation, it has not always been this way. The critical systems are still mainly supported on legacy systems whose development, due to their criticality, has been carried out in the traditional approach for the way DSOs operate, mainly relying on an OMS/DMS modules supported with an AMI in the last years to start to manage the LV grid.

A typical DSO system architecture will be constituted of the following systems, shown in Figure 12:

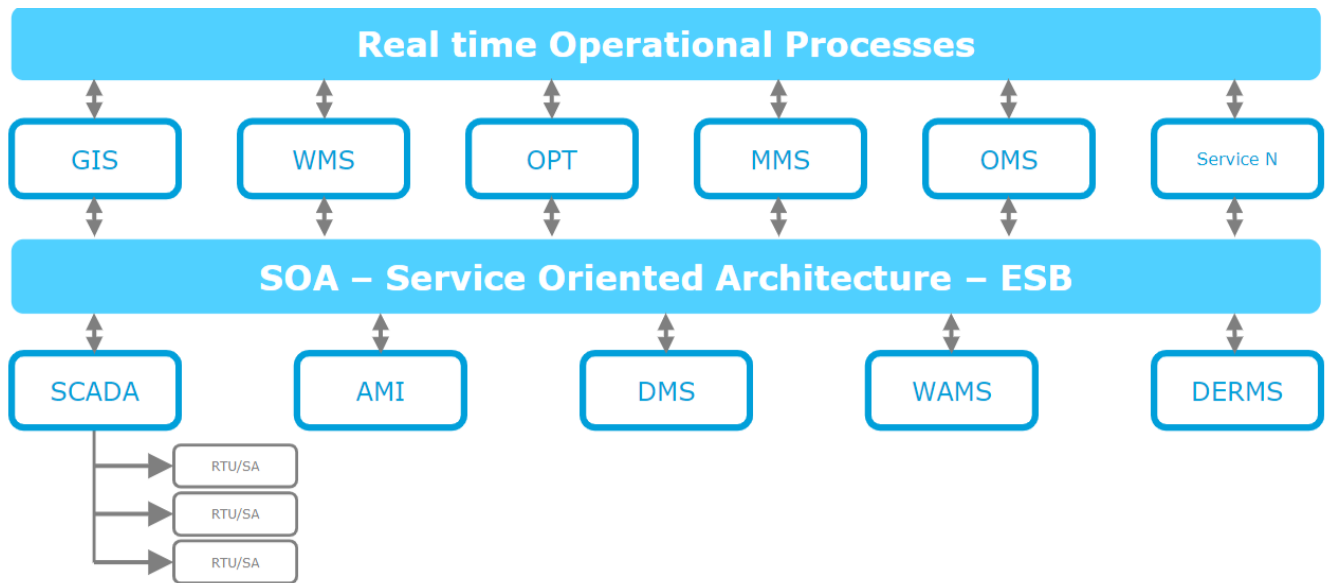


FIGURE 12: DSO SYSTEM ARCHITECTURE

The **DMS/EMS** is typically a SCADA system, complemented with custom functionalities to support a continuous and real time operation of the distribution system. Typically, it combines geographical information with information provided by remote devices installed on the distribution grid (at primary substations, at a few secondary substations, breakers/interrupters installed at overhead lines, among others).

Apart from ensuring a robust and precise interface with the operators, all the actions executed at the DMS (manual manoeuvres executed by the operators, circuit breaker tripping, etc.) are generally reflected automatically on the OMS.

The **Network Planning Tool** integrates grid topology with simulation tools. It is a data-driven tool which aims to improve operations: plan network interventions and contingency scenarios and to optimise the distribution grid: investment analysis, among others. It has power flow calculation capabilities.

The Network Planning tool is "fed" by **forecasting tools**. Forecasting tools use metering data, weather data and other models to feed algorithms that aim at forecasting demand. Hence, forecasting tools are essential for accurate long-term planning.

The **Network Planning Tool** which is nowadays used as a back-office tool will be brought into the spotlight, as it is an essential tool for the long-term planning:



- It will need to integrate forecasting data in an efficient manner and combine it with the workload or load scenarios, to run power flow simulations and calculate the DSO flexibility needs for the long-term;
- Its main output will be the flexibility needs (for the long term), which will be shared with the aggregator;

The **OMS** allows the registration and characterization of any outage. As it combines topological and commercial data, it is an important tool to calculate quality of service indicators.

The degree of complexity of an OMS may vary among DSOs, but generally, it provides the following functionalities:

- Processing of outages communicated by clients.
- Registration and treatment of outages in a consistent manner.
- Workflows to enable process automation.
- Integration between different systems (SCADA, GIS, CRM/CIS, among others).

The **AMI (Advanced Metering Infrastructure)** is the backbone of the smart grid infrastructure:

- It supports communication with smart meters and the concentrators.
- It is the interface which will integrate the metering data with other systems of the DSO.

The AMI is generally composed of two modules:

- A frontend which will ensure the interface with the meters.
- A supervision module which allows you to monitor and control the metering infrastructure in real time.

The calculation of activated flexibility will be executed by the aggregator using data provided by the AMI.

The **CRM /CIS** enables the DSO to manage incoming contacts of clients reporting anomalies on the grid. Typically, it can be used as standalone with an integration to the OMS, or directly in the OMS system. It is a system where a customer reports an anomaly in the electrical grid, namely being in his household, or other grid anomalies he detects (public lighting, hazards, among others).

The **WFM** is a system that allows the DSO to manage the workforce crews that operate in the field. This system usually integrates with the OMS where the operators can have visual information where each team is.

The **GIS** comprises all the core network information and grid topology. It may or not be integrated with the DMS or the OMS.

These legacy core operating systems also make part of the typical ADMS configuration that can be defined:

### ADMS Functional Scope

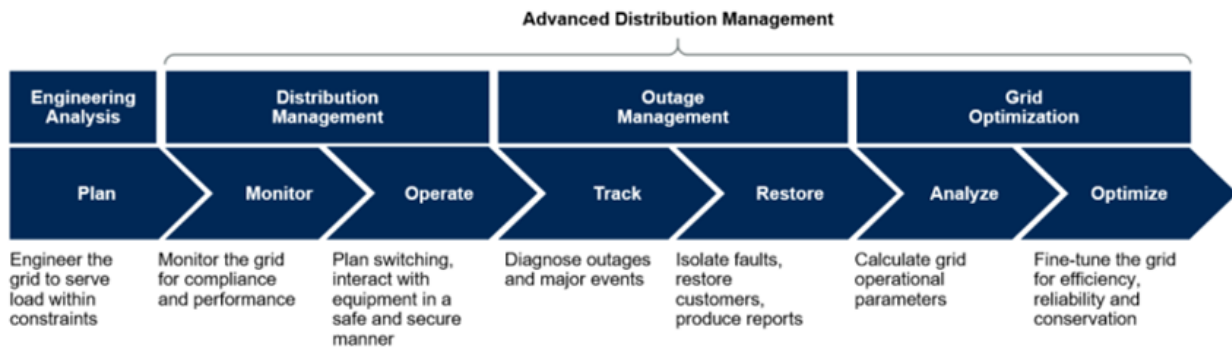


FIGURE 13: ADMS FUNCTIONAL SCOPE

The DSO interface will be a bridge between the DSO systems and an innovative approach to the way the LV grid can be **monitored** and **operated**. It will also help the Grid Optimization scope.

However, the aforementioned legacy systems will need to be adapted to be integrated with this interface and be able to cope with the concept of flexibility.

Depending on the time frame of flexibility activation, the flexibility needs can be identified recurring to different systems:

- **Long term:** flexibility assessment in the context of network investment planning (years ahead);
- **Medium term:** flexibility assessment in the context of maintenance planning (weeks ahead);
- **Near real time:** flexibility assessment in the context of network operation considering outage management.

The following figures display the type of interactions necessary to cope with to activate flexibility.

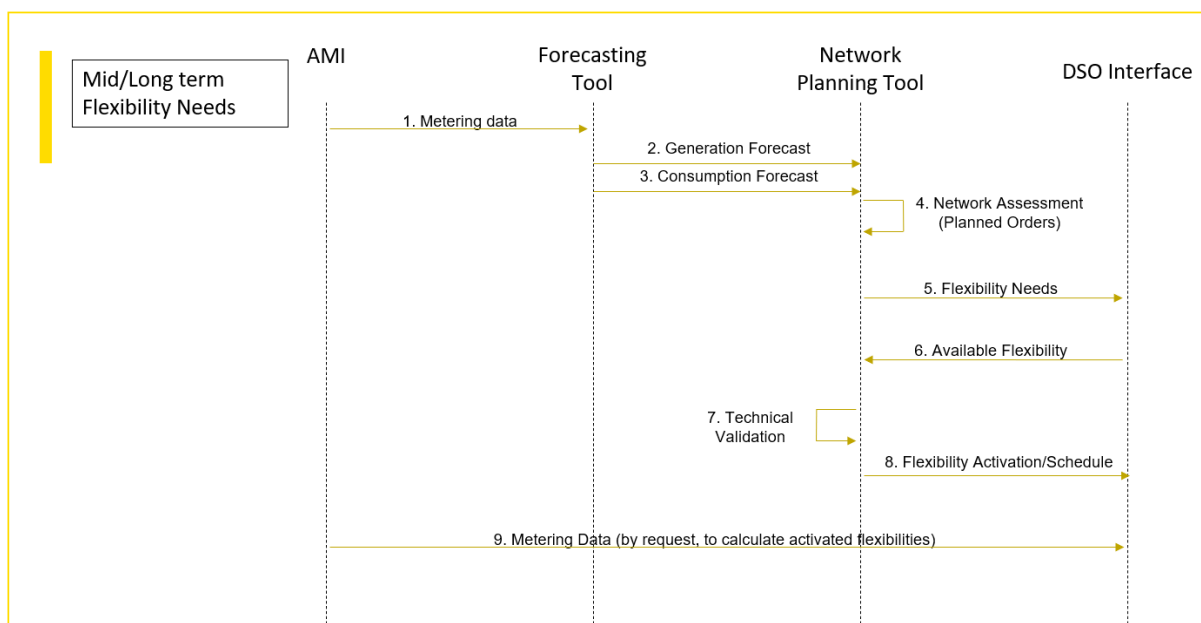
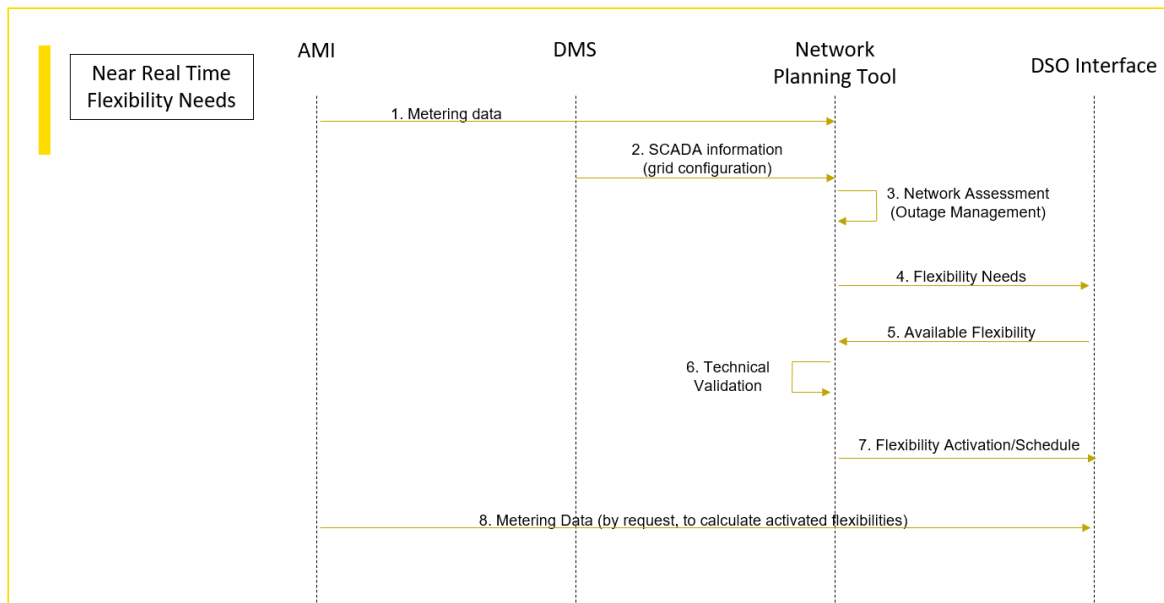


FIGURE 14: EXAMPLE OF NECESSARY INFORMATION EXCHANGE BETWEEN SEVERAL DSO LEGACY SYSTEMS AND THE DSO INTERFACE IN AN OPERATIONAL SCENARIO OF FLEXIBILITY ACTIVATION IN THE MID/LONG TERM

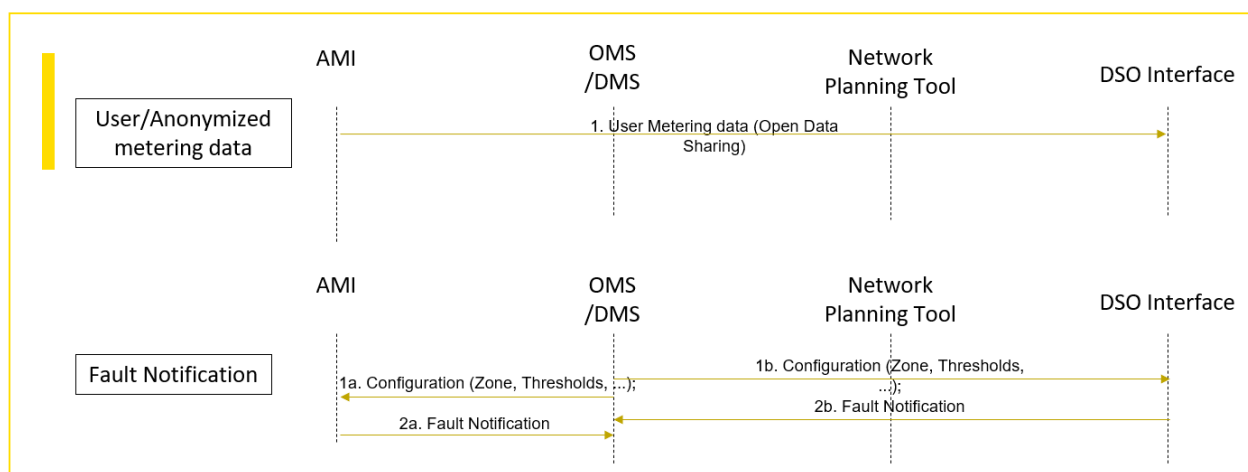
In the Mid/Long Term scenario, the operator will conduct studies to prepare asset investments on the network or prepare maintenance works. In order to do so, the DSO Network Planning Tool must receive forecasts and metering data and use it with the network data to run power flows where you can see the impact of flexibility and how the network will respond to it.

Then, the DSO will send to the DSO Interface the specific flexibility needs, nodes where flexibility is required and the schedule to see the availability. Upon receiving it, the DSO will do a technical validation of the data and send to the DSO Interface the flexibility needed and schedule for the activation.



**FIGURE 15: EXAMPLE OF NECESSARY INFORMATION EXCHANGE BETWEEN SEVERAL DSO LEGACY SYSTEMS AND THE DSO INTERFACE IN AN OPERATIONAL SCENARIO OF FLEXIBILITY ACTIVATION IN NEAR REAL TIME**

In the Real time scenario, the flexibility needs will arise due to an unexpected event on the distribution grid (i.e., the grid is reconfigured). This means that near real time grid configuration will have to be taken into consideration. Although this timeframe is not studied in the Interconnect pilots, it is recommendable to consider it as it enables the DSO to use the flexibility to solve outage problems, and other real time constraints.



**FIGURE 16: EXAMPLE OF NECESSARY INFORMATION EXCHANGE BETWEEN SEVERAL DSO LEGACY SYSTEMS AND THE DSO INTERFACE IN OTHER SCENARIOS**

A full-scale integration of flexibility into DSO operations will require that the aforementioned systems, generally working as silos, are developed considering the possibility of integration with other systems recurring to existing standards. From the DSO side, the AMI, OMS, DMS and Network Planning tool must be developed, to receive and send information to the DSO interface.

The DMS/AMI and Network Planning Tool must have the capability to receive the available flexibility when requested and show it to the operator. Also, there must be a trigger that allows the operator to activate the flexibility. The Network Planning tool must be able to incorporate this data in the power flow calculations.

### 3.4 THE ROLE OF THE DSO INTERFACE

The DSO interface, which is functionally envisaged in D4.1 and technically specified in D4.2, covers the link between the DSO and third-party platforms. This system will act as one solution, which will support multiple scenarios, interactions, and stakeholders for the purposes of flexibility management, data sharing, and enhanced network observability. As such, it's designed as a horizontal scalable system that has the capability to accommodate multiple innovative services, which require the interaction with multiple parties, while using the developed mechanisms to apply syntactic (REST API) and semantic (SAREF) interoperability. Its architecture contains common support modules, such as databases, data analytics, and communication layer, but also service specific modules, which materialize as containerized services inside the DSO interface.

The Interface will allow the DSO to access additional information from the demand side, and with it, new processes and services will allow the DSO to complement its AMI infrastructure to help monitor and detect LV Outages, bringing a more proactive approach to the way the Low Voltage grids are operated, closing the gap to Medium and High Voltage grids. An example of this service will be described later in chapter 4 where the DSO can make use of data directly from customer HEMS to identify fault locations, complementing the data received from DSO smart meters.

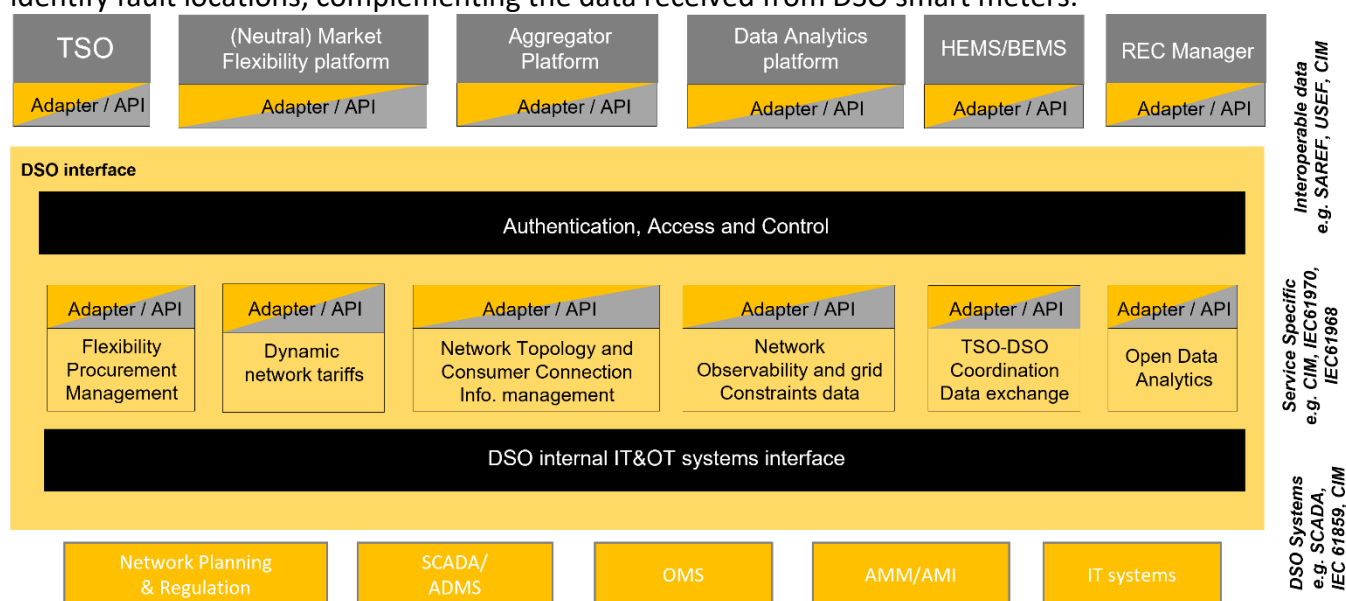


FIGURE 17: DSO INTERFACE BUILDING BLOCKS

As seen in Figure 17, most of the legacy systems used by DSOs are developed bearing in mind a specific key purpose. Hence, these legacy systems, traditionally, haven't been designed to share information among them and with other systems. With the increased diversity of systems that are appearing for

the DSO manage the grid, DSOs will have to reconsider the design of their software architectures to facilitate information sharing, recurring to APIs.

For the DSOs to be able to cope with the fast transformation taking place, these systems will need to become more dynamic, which means that they should be more flexible.

The DSO Interface will serve as a gateway between the DSO and external agents. From the DSO perspective it will require an API connection to the legacy AMI/DMS system, and to the Network Planning Tool (if it is not integrated in the DMS module).

The DSO will need to interact with the Interface to access the data from the costumers' HEMS. For example, with the Observability Service, the DSO will be able to identify potential fault locations. It will then convert that data to the AMI system where it can be confirmed using the DSO smart meter platform and follow the fault process, i.e., dispatch field crews until the problem is solved.

The existence of a solution of this kind will enable the DSO to have a standardized solution that allows it to access data from the costumer side and network operations, changing the way we conduct outages on the Low Voltage grids. The ability to use information and data from the smart meter enables SOs' to have a proactive approach. The operators will have more conclusive data about outages and can compare them with their own AMI structure and dispatch field crews in response to these new alarms. This will increase the quality of service and ultimately help reduce outage durations. Also, for planning maintenance works in the DSO networks, services such as flexibility services, and voltage constraints detection will help maintain the stability of the grid.

By adopting this solution, each DSO will not have to find its own individual solution, which will also help the retailer side to be more competitive. Both sides will benefit from having a solution that does not differ entirely for each DSO. Additionally, this kind of solution will also have an elevated level of reliability since it will rely on various entities to use it and verify it. By using this type of Interface suggested, the DSO will have an easier way to integrate information in their systems, lowering the translations costs between systems. To be able to reach the information needed from the demand side, without a use of a standardized aggregator, the multiplicity of vendors will make it hard to access demand information from too many different systems.

As this system contains transversal components which are reusable across the multiple adopted services, the DSO interface has also the potential to encompass other DSO's solutions which are developed within the InterConnect project, which is the case of the data metering platform. This system can be approach as one module of the DSO interface which makes the link between internal DSO operation and multiple external parties for the purpose of metering data sharing.

### **3.4.1 RECOMMENDATIONS REGARDING CYBERSECURITY AND DATA PRIVACY**

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As in details, step by step described in previous chapters, the identification of desired flexibility to cover the DSO needs should be processed in the SCADA part of the DSO's operational technology (OT), which is the complete system responsible for distribution power network operation supervision. The OT of the DSO is a part of its IT system, which is the matter of highest protection against cyber-attacks, the faults on this software can or will have negative consequences on the power part operation.

The fact is that opening grid operations to IT systems potentially exposes the grid to global cyber-attack. In a context where there is a growing number of cyber breaches resulting in performance degradation and business losses, grid operators clearly need to evaluate the risks of such integration.

As the DSO that implements the platform should already respect the directives and rules regarding cybersecurity, it should integrate the platform respecting the existing cybersecurity governance.

Integrating flexibility services into the grid involves new processes, new information systems (IS) and new data. The DSO should assess the new infrastructure and IS and for each IS the assessment should focus on 4 axes: Availability, Integrity, Confidentiality and Traceability. Depending on the level of impact (minor, high, essential, or capital), an action plan is established.

As an example of cybersecurity and data privacy measures used in InterConnect and in the Data Metering Platform, the endpoints (Store and Knowledge Engine), the delivery point ID sent to POST services are encrypted using an AES\_ENCRYPTION\_KEY.

As part of the Data Metering Platform still, to comply with the GDPR, it is imperative to send the customer a certain amount of information to obtain his consent and in particular:

- the nature of the collected data;
- the purpose of the processing;
- the data retention period;
- to whom are they transmitted (made available);
- the customer's possibility of withdrawing (right of withdrawal).

More details regarding the guidelines of cybersecurity can be found in the deliverable D4.2.

### 3.4.2 DATA METERING PLATFORM

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The main objective of the DSO for the French pilot for InterConnect is to enhance the value of the smart meter Linky by making available its data and functionalities to promote the management of the uses downstream of the meter and to meet the expectations of the consortium on energy communities.

#### The issues:

- **Building an interoperable market:** designing new services for a human-centric energy ecosystem based on a new IOT architecture
- **Set up demonstrators for communities:** identify/test solutions that meet new community needs
- **Integrate the citizen in the creation of new services:** the citizen is both a consumer and a producer of electricity (Prosumer). It is therefore essential to involve the citizen in the development of tomorrow's energy management solutions.

#### Use cases:

The French pilot for Interconnect is poised to make the most of smart meter features and real-time data, and defined two use cases with service providers to optimize end customer consumption:

- **Case 1 - Dynamic Tariff:** implementation of an electricity supplier offer based on spot market prices, allowing the control of consumption of individual customers at the cheapest or least carbon intensive times
- **Case 2 - Maximize local energy exchanges:** maximize local consumption during periods of renewable energy production (collective self-consumption)



## Platform architecture and functionalities:

The European partners aim in this project to interconnect IS platforms and standardize interfaces between platforms according to the SAREF ontology.

A smart meter dynamic data platform is therefore being developed: it aims to provide real-time consumption and production data enabling service providers to optimise the consumption of Smart Homes and develop new services as part of the InterConnect French demonstrator: Some 100 volunteer customers will be offered energy services by InterConnect partners such as: ENGIE and/or THERMOVAULT and/or TRIALOG.

At this stage, Linky's dynamic data can only be accessed locally via its CIS (customer information systems or "TIC") terminal block. To make this dynamic data accessible in an interoperable and standardized way, the French DSO aims to develop an experimental platform where the dynamic data would be made available to all InterConnect service providers.

## Functional diagram of the French demonstrator

*Pilot objective: to facilitate the coordination and interoperability of piloting services within the same household*

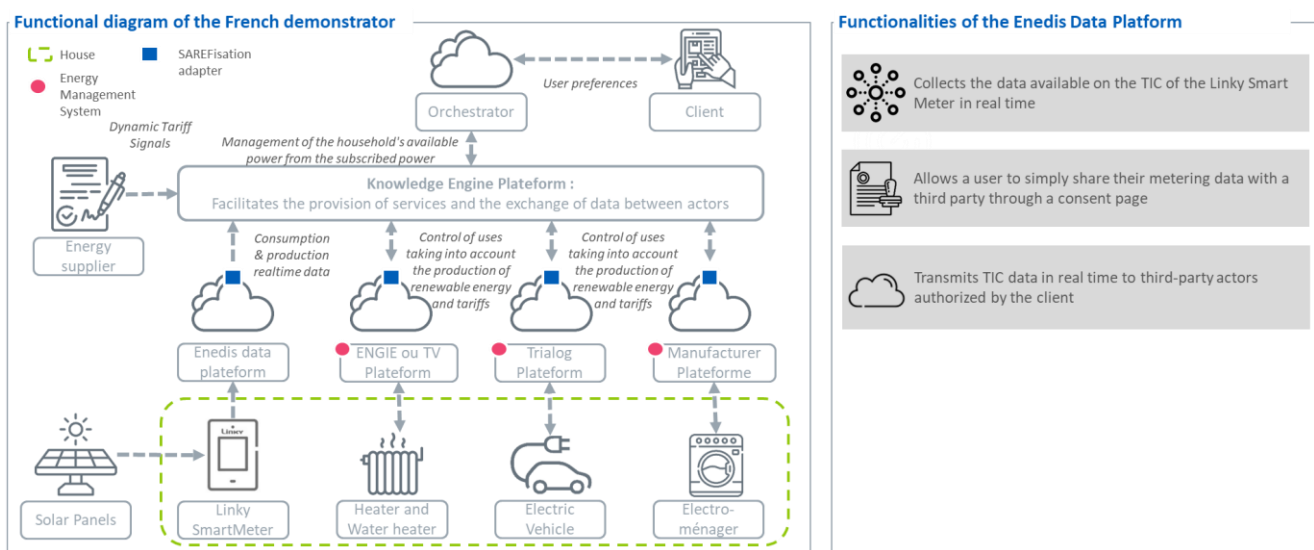


FIGURE 18: FUNCTIONAL DIAGRAM OF THE FRENCH PILOT FOR INTERCONNECT

Figure 18 describes the functional diagram of the French demonstrator: the Smart Home and its equipment delimited by the green dotted rectangle, and above it is the cloud part of the various partners.

The objective within the same household is to control several uses, and there will be several cloud solutions that will enable these uses to be controlled, and therefore several services suppliers.

The problem with having potentially several entities each controlling their own equipment is the risk of exceeding the subscribed power (power limit not to be exceeded otherwise the installation is disconnected), especially if all the uses are switched on at the same time. It is to address this issue that service providers need to have dynamic information from the smart meter to know in real time what

the level of consumption is, to be able to adapt the control of equipment and thus avoid circuit breakers.

In the French demonstration project InterConnect, Enedis is taking on the role of making dynamic metering data available to all players in a neutral, interoperable way, while guaranteeing the integrity of the data.

On this diagram, we can see the KE (Knowledge Engine), which is a connection between the different clouds of the partners. The smart meter data platform transmits its data in a standardized way thanks to intelligent connectors.

The functions of the experimental platform of the French DSO are therefore to collect data from the CIS, to share this information with the various players so that they can enrich their services, while guaranteeing the integrity of the data (cybersecurity) and that the end customer has given his consent to the collection of his data in accordance with the GDPR.

### Enedis platform architecture (detailed in figure 19):

The Linky installed on the customer's site has a local radio transmitter (ERL) connected to the CIS that sends data at the CIS frequency to a gateway (GW) that is installed on the customer's premises and is connected to Wi-Fi. The Wi-Fi connected gateway sends the data to the Enedis InterConnect Cloud, and service providers can get the dynamic information they want through API developments.

At this stage, the partners of the French demonstrator have agreed to send 11 data points to cover the needs of their services (in pink in the figure below). These data are sent following "GET" (when the service provider requests the data) or by "POST" (when there is a change on the data, or according to a predefined frequency). These data are specified in the figure below.

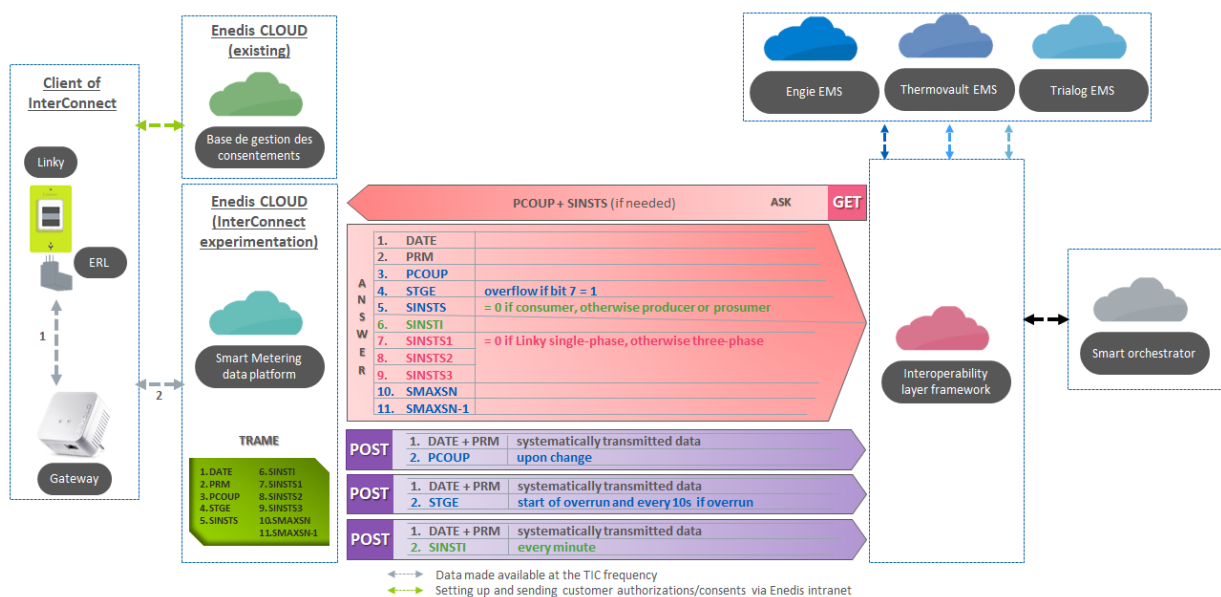
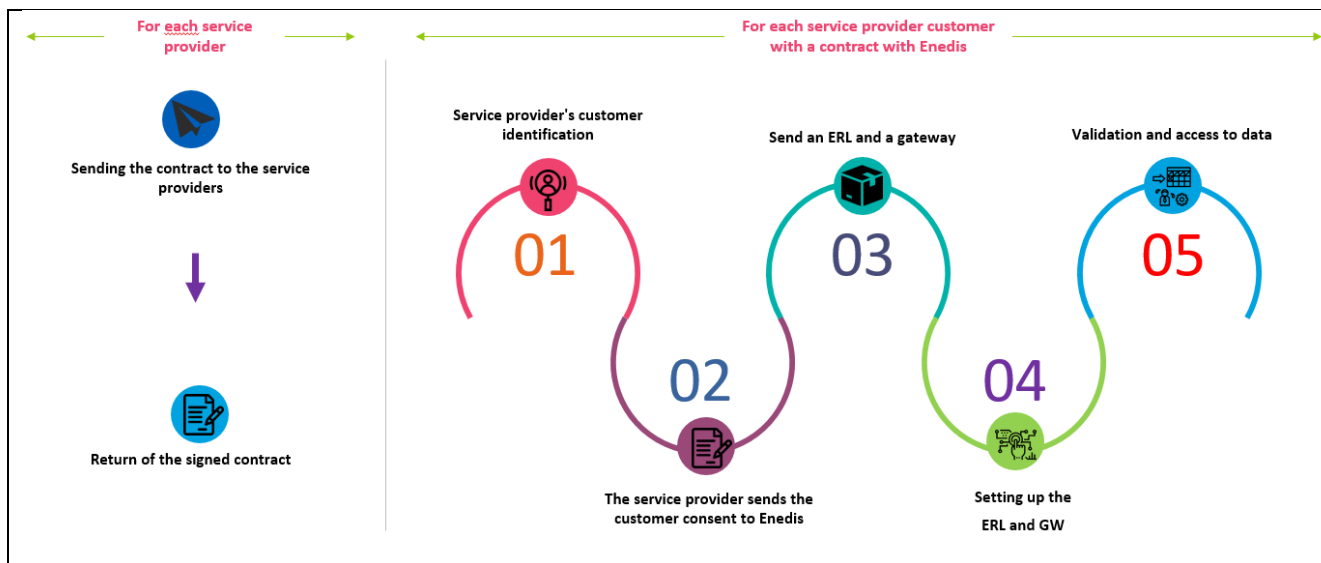


FIGURE 19: ARCHITECTURE OF DATA METERING PLATFORM





**FIGURE 20: SERVICE PROVIDER / CUSTOMER EXPERIENCE**

Figure 20 shows what one of the customer journeys might look like in the French pilot project.

For each service provider:

- Enedis sends a contract to the service providers to describe the real-time DATA they want to access and returns 2 signed copies to Enedis.
- Once the contract is received, Enedis co-signs it and sends a copy back to the service provider.

For each service provider customer with a contract with Enedis:

1. The service provider identifies a customer to implement its service and requests consent.
2. The service provider sends Enedis the consent signed by the customer mentioning their PdL number (smart meter/site reference).
3. Upon receipt of the customer's consent, the ERL and GW devices are sent to the customer.
4. The customer sets its ERL and GW (entering his Wi-Fi connection information + the PdL concerned).
5. After checking the compliance of the PdL, Enedis opens the access to the real time data of its platform to the service provider.

### 3.4.2.1 CYBERSECURITY MANAGEMENT OF THE FRENCH PILOT

#### Security and Privacy Threats for the French pilot:

The table below shows the privacy and security threats identified for the pilot.

**TABLE 3: SECURITY AND PRIVACY THREATS FOR THE FRENCH PILOT**

| STRIDE THREAT CATEGORIES |  |
|--------------------------|--|
| Spoofing                 | Spoofing one service provider, or/and devices on customer premises (T_PX1) |
| Tampering                | Tampering knowledge exchange process, or/and data content(T_PX2)           |
| Repudiation              | Repudiation of data exchange operation, or/and data content(T_PX3)         |

|                           |   |
|---------------------------|---|
| Information disclosure    | Disclosure of data and metadata by eavesdropping interoperability framework and/or for service provider (T_PX4)                     |
| Denial Of Service         | Preventing the interoperability framework instance to operate, and/or service provider(T_PX5)                                       |
| Elevation of privilege    | User of one interoperable service gets access rights to all interoperable services in the pilot, or/and for service provider(T_PX6) |
| LINDDUN threat categories |   |
| Linkability               | Linking Data and meta data transmitted from two different transactions through semantic interoperability layer (T_PX7)              |
| Identifiability           | Identifying user of exchanged data and meta data (T_PX8)  |
| Non-repudiation           | N/A   |
| Detectability             | N/A   |
| Disclosure of information | Disclosure of consent information and privacy preference information  |
| Unawareness               | N/A   |
| Non-compliance            | Consent and privacy preference not handled properly (T_PX10)  |

### Measures for the French PILOT:

The following table lists measures that have been identified to mitigate the identified threats on the InterConnect interoperability framework (the table is based on ISO/IEC 27001 taxonomy of controls). Entries marked N/A are either not relevant or have no identified input. Note that the identified list is indicative. A selection will be made, depending on the needs of pilots.

**TABLE 4: MEASURES TO MITIGATE THE IDENTIFIED THREATS ON THE INTERCONNECT  
INTEROPERABILITY FRAMEWORK**

| CATEGORY                             | SUB-CATEGORIES                              | CONTROL  | DESCRIPTION  |
|--------------------------------------|---|--|--|
| Information security policies        | Management direction.                       | Access policies  | Access policies are at the service level (interoperable services provided by participating stakeholders)   |
|                                      |   | Data management policy   | Interoperability framework does not store data from end users and managed systems  |
| Organization of information security | Internal organisation                       | To be specified in data management plan                                  |  |
| Asset management                     | Responsibility for assets                   | Secure storing of service-related metadata and service docker containers | Metadata of interoperable services registered in service store will be secured as well as uploaded service containers – procedure specified for the service store. |
| Access control                       | Business requirements for access control    | Security and data protection framework                                   | Enforces access to service according to service owner policy and access control rules  |
|                                      | User access management                      | Enforce authorised service access  | Uses security and data protection framework to validate access to a service and enforce authorization levels specified by service provider                         |
|                                      | System and application access control       | Service store web application  | Service store access granted only to registered and authorized users   |
|                                      |   | Interoperability layer   | Interoperability layer access granted only for registered services with interoperability compliance certificate  |
| Cryptography                         | Cryptographic controls                      | Secure exchange  | Secure exchange with service store and semantic interoperability layer   |
| Operation security                   | Operational procedures and responsibilities | Trustworthy interoperability   | Trustworthy exchange capabilities support from services and interoperability framework providers   |
|                                      | Protection from malware                     | Service store protection   | Secure service store from deployment of malware code   |
|                                      | Backup                                      | Service store  | Data replication for backup purposes of the operational data for the service store.  |
|                                      |   | Knowledge directories  | Wherever appropriate, data replication for backup purposes of the operational data for the knowledge directories   |
|                                      | Logging and monitoring                      | Logging behaviour of SIL   | Logging activity of SIL and identify cybersecurity attack patterns, risks, and threats   |
|                                      | Control of operational software             | Certified services   | Services are tested for compliance and receive a certificate necessary for inclusion in the interoperability framework instance                                    |
|                                      | Information systems audit considerations    | Explain decisions  | Provide a log of how the interoperability framework use rules to create outcome  |
| Communication security               | Network security management                 | Secure running instance of service store and knowledge directory         | Rely provider's network security mechanism. Implement additional measures where needed   |

|  |   |   |  |
|--|---|---|--|
|  | Information transfer  | Secure transmission                                   | Secure transmission of data, meta data, knowledge between interoperable endpoints  |
| System acquisition, development and maintenance                | Security requirements of information system                   | Security of interoperable services                    | Each service provider can specify access control and data protection rules for own service   |
|  | Security in development and support processes                 | Privacy by design                                     | Follow privacy by design in developing interoperability framework and its pilot instances  |
|  |   | Secure service lifecycle                              | The development of services follows a lifecycle process where security is integrated   |
|  | Test data   | Testing operation of interoperable services           | Each service provider should prepare test data to test and certify interoperability compliance of a service before inclusion into the interoperability framework instance  |
| Suppliers relationships  | Information security in supplier relationships                | Interoperability framework service level agreement    | Provided by interoperability framework stakeholder(s) to adopters/integrators  |
|  | Supplier service delivery management                          | Interoperability framework service level agreement    | Service level agreement indicates how interoperability framework components are delivered and managed independently  |
| Information security incident management                       | Management of information security incidents and improvements | Service store and knowledge engine logs               | Wherever appropriate, all performance and monitoring logs will be stored in secure manner and used to generate reports for all operational incidents   |
| Information security aspects of business continuity management | Information security continuity                               | Assurance of availability                             | Assurance of service store and semantic interoperability layer availability against DoS  |
|  |   | Monitoring vulnerabilities                            | Periodic analysis of security and privacy risk, and review of vulnerabilities  |
|  | Redundancies  | Add redundant capabilities to avoid denial of service | Examples of measures are the following:<br>Standby service store.<br>Standby interoperability layer enablers.<br>Standby interoperable services (e.g., multiple running instances or Docker container ready to be deployed on demand). |
| Compliance   | Compliance with legal and contractual requirements            | GDPR and cybersecurity compliance verification        | Verification that SIL complies to GDPR regulation and Cybersecurity Act.   |
|  | Information security reviews                                  | Compliance of regular services                        | Verify secure lifecycle of interoperable services  |
|  |   | Compliance of framework services                      | Verify secure lifecycle of interoperability framework services and enablers  |

### 3.4.2.2 RESULTS TO DATE

#### Development of the experimental DSO “Dynamic Data Metering Platform”:

- The architecture of the platform and the data from the Smart Meter to be transmitted to the partners have been defined within partners.
- The scripts of the services (API) and having them interoperable and standardized through SAREF ontology have been delivered.

- The development of the dynamic data platform is launched by iterations; versions are delivered as and when the partners make progress on the graph patterns.
- To date, 3 tests have been conducted with French partners, the tests are satisfactory.

#### ERL and Gateway Development:

At this stage, the hardware and firmware developments of an ERL and a gateway have been carried out. Interface tests between the gateway and our data platform are underway to verify the proper reception of data (integrity and frequency in particular). In the current global context, component shortages have made these device developments difficult.

#### 3.4.2.3 DIFFICULTIES ENCOUNTERED

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- Difficulty to realize the *SAREFization* of services: the DSO is not familiar with the SAREF ontology, and the developers invested a lot of time and effort to become proficient in the subject and to meet the program deadlines.
- The adaptation of the way of coding and developing the data metering platform to satisfy the requirements of SAREF. It was long due to the number of meetings to attend to know how to develop.
- The frequent modifications and evolutions of the KE (knowledge engine) during development and after the test days between the French partners had an impact on the services/bindings of the demonstrator which had to be redeveloped.
- As this is real customer data, the developments, even for a demonstrator, had to consider the requirements of the different partners, particularly in terms of cybersecurity.

#### 3.4.2.4 CONDITIONS FOR REPLICABILITY AND SCALABILITY OF THE DATA METERING PLATFORM

---

The tools and approaches in InterConnect, are developed to consider replicability and scale adjustment. In this case these will depend on several factors.

On the one hand, it must be validated technically: There is currently no platform for making dynamic metering data available and there is still uncertainty about how well it will work, particularly in relation to the novelty for DSOs in using SAREF.

On the other hand, it must be validated functionally: it will be necessary to verify if the dynamic data transmission delays and response times will allow service providers to pilot the flexibility of uses and if the value is indeed there.

The third aspect will concern the removal of legal and regulatory obstacles for the DSO, which is evolving in an environment constrained by the regulations linked to its public service missions.

Finally, the fourth factor will depend on the possible financing of the platforms (development and exploitation) and considering all these criteria, the DSO's decision to industrialize the dynamic data platform.

## 4. TECHNICAL SPECIFICATIONS FOR THE SERVICES TO BE DEVELOPED FOR INTERCONNECT DEMONSTRATIONS

A common approach with a set of tools that are transversal and replicable, which were developed for several use cases, are presented in this section. These tools are considered to be technical enablers for common control and management of the grid. A typical challenge encountered by a DSO includes lack of visibility of the LV grid. These shortcomings present the opportunity to realize the benefits of using HEMS to increase the visibility of the LV grid, new flexibility estimation approaches considering forecast services for load and generation and taking advantage of smart metering as a way to involve consumers in actively energy services. The services assume that the external available data to be collected from the HEMS, is collected by a Data Service Provider (DSP). The actor who will have this role will be responsible for collecting the consumer's approval for their consumption profile to be accessed, processed, and analysed by the DSO, complying with GDPR. The services described in this chapter make use, whenever required, of the InterConnect framework, to ensure interoperability through the use of ontologies or unique references/identifiers. These unique identifiers enable the construction of graph patterns, which are triplet constructions from the inputs and outputs described in this section, understood by the knowledge engine. This feature is what makes these services interoperable, replicable, and scalable, in use and common understanding. The next sub-sections will hence address the following services for wide usage by DSOs and other relevant stakeholders:

- The distribution grid support for fault location identification (Observability Service 1). It can be mostly used by DSOs and replicated in different member states.
- The quantification of consumer flexibility response (Observability Service 2). It can be used by Retailers, DSOs, aggregators.
- The assessment of grid impact through load type observation (Observability Service 3). It can be mostly used by DSOs but also by aggregators and other planning infrastructure/resources businesses.
- The demand side flexibility forecast and grid congestion forecast. It can be used by DSOs. This is particularly relevant for flexibility services that are offered at the LV/MV levels.
- The network dynamic tariff. It can be used by DSOs.
- The flexibility services for energy management. It can be used by aggregators.

In all sub-chapters the tools are introduced and extensively explained regarding its inputs needs and outputs provided. The concepts of the services and the problems they intend to solve are specified and preliminary results based on simulations or examples are shown.

### 4.1 OBSERVABILITY

---

The Observability services were described under the HLUC11 and specified in three primary use cases. These use cases are intended to explore the potential of HEMS/BEMS systems through the data it can provide. It goes beyond an exploratory data analysis activity, as it takes the HEMS data, not only to produce knowledge, but to use it as a valuable tool, from which services can be developed to support the grid. It enhances the grid observability from a bottom-up perspective to some extent, where little, to no visibility, is often verified. Such services are part of the DSO Interface architecture described in

D4.1, which can be called through dedicated SSA or APIs, whose endpoints are described in D4.2. The general technological requirements are transversal, requiring internet connection, HEMS, smart meters (from HAN port) with ID, metering data and the ability to match the HEMS with a specific distribution point of connection. The data input will go through the process of InterConnect (i.e., made it interoperable and standardized through SAREF ontology), where the domain, units and terms are homogenized according to the same ontology. For this a set of graph patterns are specified for each service/request, further explained in each service section. For this process to occur, the variables must be identified, and the type of message and units specified. The API allows several types of interactions as a client, called methods such as get, post, put, delete, options, and trace. Given the nature of the interactions the activation of the services will be done by using mostly the Post/Put, Delete and Get methods.

In terms of data models, the input and output variables are aligned with the information model gaps identified in chapter 5 of D4.1. As mentioned in the same chapter, for this interface, that covers exchange of energy and voltage data from the Smart Meter or MDO, voltage data from the Grid meter, and shortage and submetering data from the HEMS/BEMS, the relevant information models revised in subchapter 5.2.2.5 of D4.1 were: SAREF, IEC CIM, OpenADR, EEBus, DLMS/COSEM, IEC 61850. Following the revision, as recommendations for DSO interface implementation, specifically for the Network observability and grid constraints data exchange in subchapter 5.4, the OpenADR, EEBus, DLMS/COSEM/IEC61850 and Saref were identified and hence, considered in the service conceptualization, tool development and message specification, stated here in JSON format. The correct match of statement of variables, such as MeterID, Time variables and measuring units were hence taken into consideration. In all services, variables always report to the agreed terms in the ontologies, namely the ones added and stated in D2.3 such as flexibility (ic-flex) and Power Limit (ic-pwim), as is the example of Service 2.

Regarding SAREF needs, not all data needs to be made interoperable and standardized through SAREF ontology (semantic interoperability). The principle was easiness of implementation, coherence, security, and interoperability. However, depending on the nature of the interaction only syntactic interoperability (REST API) may be enough. This is typically the case where internal processes and where two defined parties agree on the data format to be exchanged. When unknown third parties are expected to interact with each other, the layer of meaning is required, hence the need to ensure semantic interoperability, which is ensured by referring to Ontologies like Units of Measure (UM) or SAREF. In this sense the following decisions were made for the following services:

- **Observability Service 1** – Fault Location Service - This service will be made interoperable and standardized through ontologies such as SAREF and UM considering data exchange between DSO-Data Service Provider and Third-party requests.
- **Observability Service 2** – This service will be internal to a DSO or to a retailer, hence it is not required to implement ontologies such as SAREF in this case. On the other hand, it should focus on the way the outputs of the service are presented not only with information but with knowledge.
- **Observability Service 3** – This service will be implemented at the DSO level and at this point only data will be exchange via DSO Interface. The internal data (to the DSO) will not make use of ontologies, only the interactions with third parties (DSOs and service requesters and data service providers) will make use of it.

The services will be applied to the following demonstrators shown in Table 5:



**TABLE 5: OBSERVABILITY SERVICES IN THE DIFFERENT DEMONSTRATORS**

| SERVICE   | DEMONSTRATOR                   | NOTE ON IMPLEMENTATION  |
|-----------|--------------------------------|---|
| Service 1 | Portugal                       | The service will be used by the DSO. It identifies an area of observation, and a set of conditions trigger the alert messages. The service is made interoperable and standardized through SAREF ontology as it obtains the information from third parties (HEMS by a DSP) and the communication between the DSO and SP is also made interoperable and standardized through SAREF ontology. The service will be applied using an overall set of commercial and residential users chosen from 5 cities. Each city will have several Grid zones to be observed depending on the size and number of assets available (provided by the DSO).   |
| Service 2 | France, Germany, Greece, Dutch | <p>-In the French pilot the data of the intervention signals will be prices applied to residential consumers. The service can run locally to facilitate data use.</p> <p>-In the German case, the intervention signals are power limitations applied to EV chargers in chosen hotels. Mock data has been shared so far and the service can be run. Historical data however must be gathered.</p> <p>-In the Greek pilot the intervention signals are renewable generation/environmental information about consumption in specific hours. It will be applied to residential buildings.</p> <p>-The Dutch pilot will allow the retrieval of residential and commercial data of consumption with different sets of tariffs. The incentive will hence be price based. The challenge will be the creation of a baseline since the residential building is new.</p> |
| Service 3 | Portugal                       | The DSO will be the main user of the service which runs on its side. The service can be requested by a third party through the DSO interface. It will request analysis from residential areas.  |

The following services are described by focusing on the description of the service itself, the considered inputs, outputs, and the necessary interactions between actors.

#### 4.1.1 OBSERVABILITY SERVICE 1: DISTRIBUTION GRID SUPPORT FOR FAULT LOCATION IDENTIFICATION

This **service refers to** the primary use case 1 and has the following objectives:

- Improve DSO ability to locate faults in MV and LV networks, through services enabled by the data shared through HEMS.
- Will improve network reliability by reducing the duration of service interruption
- Will reduce the need for investing in additional network monitoring equipment.

The DSO, by being able to identify the network areas under analysis, such as secondary substation, corresponding LV feeders or a point of connection, will know exactly the location of the identified fault. This is particularly important in the residential sector, which will be considered in the Portuguese pilot where typically low to no visibility exists.

**Conceptually** this service will be used by the DSO. The data will be collected from a set of specified HEMS through a data service provider, which can run remotely. This data needs to be made interoperable and standardized through SAREF ontology, as shown in Figure 21, since it's an external entity providing it. Both the request and optional settings are done through a Rest API. The HLUC assumes an intermediate actor (Service Provider as the Data Metering Operator) between HEMS and the DSO, and the service response is received through a Post in the API. Due to the nature of the

service, the access to multiple HEMS needs to be permanent, to check its connectivity. There are two activities in this service. The first, this service collects the voltage values and writes it in an Inflow database, the second, monitors this database verifying certain conditions and notifies if abnormal voltages are observed or loss of connectivity. The service can be activated permanently or for specific times due to expected extreme weather conditions, such as high temperatures, high wind speed or expected sporadic events, which may cause a stress operation of a particular area. It may also be requested to monitor a given area constantly, which is expected to have network problems. Once running, if the fault message is triggered, it will keep the notification until the problem is solved. The interaction between the main components and the sequence of actions can be seen in Figure 21:

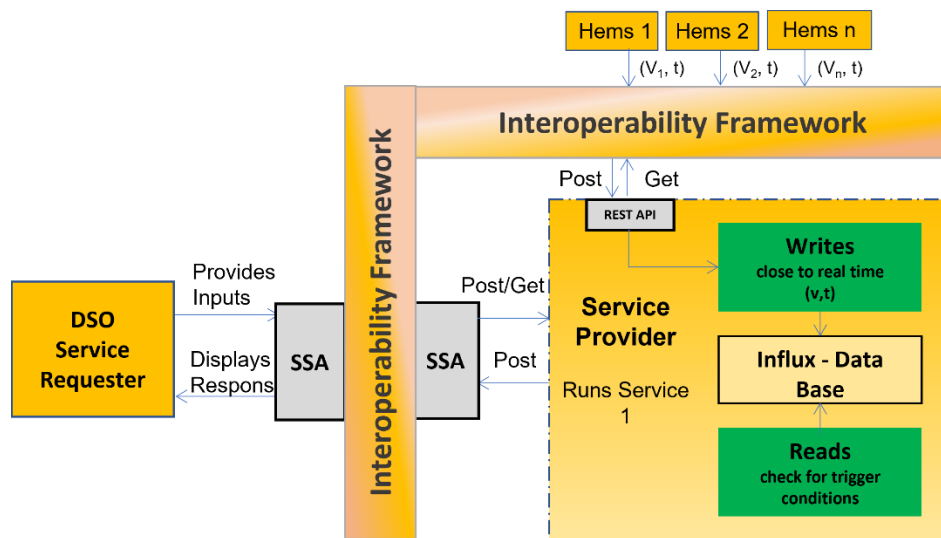


FIGURE 21: ACTION FLOW BETWEEN SERVICE REQUESTER AND SERVICE PROVIDER THROUGH THE SSA

Regarding the **interaction between actors**, the DSO calls the service by defining a Grid Zone, corresponding to the size of a neighbourhood or Postal Code and a set of optional parameters, using the Post method. These parameters are the minimum number of HEMS not communicating, and a second parameter, which is the minimum elapsed time not communicating of those units, to trigger a potential fault alert. These parameters have default values in the algorithm; however, they can be changed. The Service provider can check all the Grid Zones and available points to be monitored under each zone through a GET in the API (in this case SSA). The service checks if the conditions can be met and sends a response message through the SSA with: "Accepted" or "Denied, could not reach Grid Zone or min. nbr. of HEMS". The Service Provider having identified the requested available HEMS in that area, responds with the Voltage readings of the monitored units and the corresponding time stamp. These reading are stored in a database at the service side. The user may use the Get method to find out what is the status of a given HEMS (communicating or voltage reading). If the service detects that the minimum conditions were met to trigger a potential fault message, it does so by posting a response through the SSA to the DSO. The communications between i) the reading at the source and the service provider and ii) the service provider and the DSO go through the interoperability framework, ensuring the interoperability of all parties.

The table below lists the input data and data format required to run the services, which come from both the DSP and the DSO:

**TABLE 6: INPUT DATA AND FORMAT (OBSERVABILITY SERVICE 1)**

| INPUT DATA  | DATA FORMAT  |
|---|--|
| The geographic location to be monitored   | (Location, Grid Zone; strings)                           |
| Define warning thresholds such as minimum time of interruption to trigger the alert (optional). | (Time; seconds; integer)                                 |
| Minimum number of simultaneous disconnections to consider triggering the alert (optional).      | (Number. Of connections; unit: number; integer)          |
| The voltage of the connection points in HEMS  | (Volts; unit:V; integer)                                 |
| Time stamp of voltage records   | (Time step; unit time; date format:dd-mmm-yyyy hh:mm:ss) |
| HEMS ID   | HEMS Identification to differentiate the readings        |

The service requires an identification of a Grid Zone Code and the definition of the minimum number of faulty connections to be considered a fault and the necessary elapsed time to be considered a fault. In each Grid Zone, there will be several HEMS that could be monitored, each will provide the voltage readings, the status of the reading/connection (on or off). If the service can monitor the required minimum number of HEMS which constitute a fault, it accepts the service and provides as outputs the Grid Zone Code where the fault was identified and the total number of potential faulty disconnections. Moreover, it will provide a file with the abnormal voltage readings with its value and corresponding time stamp.

The following JSON representation refer to the inputs required from the service requester:

```
{
  "Fault_Location_Inputs" : [
    {
      "GridZone": "4405-123", (string)
      "Min_nbr_Hems_faulty": "3", (integer)
      "Min_time_of_interruption": "180", (float)
      "Min_time_of_interruption": "seconds"
    },
  ],

  "GridZone":, : [
    {
      "Hems_ID": "ID1234", [
        {
          "timestamp": "2021-12-03T15:11:20Z", (timestamp)
          "Voltage_reading_Status": "On" (boolean)
          "Voltage_from_Hems": "240", (float)
          "Voltage_from_Hems": "volts",
        },
      ]
    }
  ]
}
```

The service is able to notify the DSO automatically whenever there is a fault upon meeting the necessary conditions parametrised. As explained before in order not to overburden the DSO with unnecessary false or negligible alert signals, the service algorithm will filter the warnings according to predefined conditions, such as duration and number of warnings to corroborate this with, validating

it with neighbouring devices (to avoid not having internet connection does not mean there is no electricity service).

The functions or **output** of the service can hence be provided in two ways:

- Notification of potential outage on an identified location (Grid Zone)
- Notification of abnormal voltage reading and time stamp on an identified location (Grid Zone/Hems\_ID)

The fault location does not intend to identify a single consumer fault “per se” but instead an area of the network. However, that particular area may be dedicated to particular customers. For this reason, privacy is not an issue in this service. The voltage observation function is not intended to verify the voltage operational limits compliance. It is intended to check if the voltage magnitude in a group of HEMS is smaller than the nominal value, which may suggest a malfunction.

The Outputs of the service on a JSON representation will be the following:

```
{
  "Fault_Location_Identification" : [
    {
      "GridZone": "4405-123ID", (string)
    },
  ],
  "Voltage_Monitoring" : [
    {
      "Hems_ID": "ID1234"
      "Abnormal_Voltage": Yes (boolean)
      "timestamp": "2021-12-03T15:11:20Z", (timestamp)
      "Voltage_from_Hems": "240", (float)
      "Voltage_from_Hems": "volts",
    },
  ]
}
```

#### 4.1.2 OBSERVABILITY SERVICE 2: QUANTIFICATION OF CONSUMER FLEXIBILITY RESPONSE

This **service refers to** the primary use case 2 and has the following objectives:

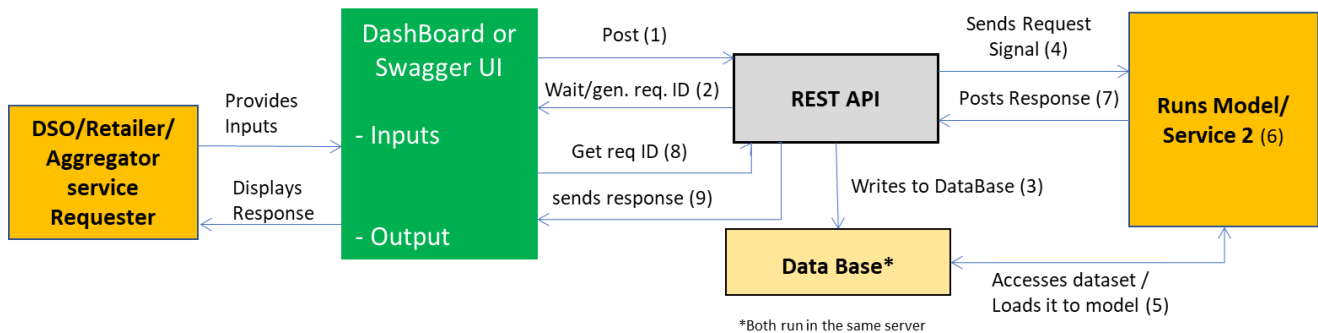
- The service will assess the consumption flexibility of customers or group of customers upon given an intervention signal. An intervention signal is a signal that intends to incentive the customers’ demand side response;
- Will provide ranking of customers according to consumption flexibility response;
- Will allow to identify network areas (or pool of customers) with higher demand response potential.

**Conceptually** the service can be used by the DSOs, Retailers and Aggregators. The data will be collected from the meters and the service will run locally or remotely. This service is being validated in the Greek, French and German pilot, to make use of different intervention signals, exploring the multi-signal recognition capability of the service.

The request of the service is done through a Rest API, which works as a customer/server subscription, with inputs specified by the subscriber and the output is received in a form of a JSON file published in

the API output or displayed graphically. The service is based on a model analysis which focuses on a particular historic time window of observation for a set of clients. Results can be obtained for 1 month (or) by season (or) year. Each of which will provide a different result, as the model depends on consumption behaviours during the analysed time period.

The interaction between the main components and the sequence of actions can be seen in Figure 22:



**FIGURE 22: ACTION FLOW BETWEEN SERVICE REQUESTER AND SERVICE PROVIDER THROUGH THE REST API**

The implementation of the API is to enable the calling of the service and to obtain the response. Figure 22 shows the flow of actions done in the process, being the POST of the dataset required by the service to run the number 1, followed by a waiting notification assigned with a requestID (2). This is necessary because the service may take several minutes to output a response, and this is to safeguard that no failure due to elapsed time is generated. Step 3 is to write the supplied dataset into the server database, which runs in the same machine as the model/service. When this happens it means that there is new data for the model to process, so a signal (4) notifies the model (which is always active/listening) to load the file (5) and runs the model/service (6). Step 7 is the response through a POST in the API. The user must make a GET with the provided requestID (from step 2) to refresh the response field in the API. When it is indeed available, it provides the UI with the response (for example Grafana for graphical representation of results if required, or a JSON output file). The model could work only with a POST of a dataset without having a database. This would work with small datasets. However, the dataset, being a long historical record is likely to result in a large file size (more than 100 MB), hence ensuring all possibilities and more complex analysis, the Database was foreseen. Moreover, the fact that the process may take up several minutes to provide an answer, it means that the process is not synchronous and would result in an error if no response was observed in a short period. For this reason, a database is desirable to allow for this asynchronous response and data size to be treated. Furthermore, a JSON format will be used to send the data, so it can use the http layer with no interruption of communication that could corrupt the file.

The **API input data** coincide with the service inputs and are defined by the subscriber as follows:

**TABLE 7: INPUT DATA AND FORMAT (OBSERVABILITY SERVICE 2)**

| API INPUT DATA                               | DATA FORMAT  |
|--|--|
| Historic time window of analysis: Start Time | (Start Time; unit time; date format:dd-mm-yyyy hh:mm:ss) |
| Historic time window of analysis: End Time   | (End Time; unit time; date format:dd-mm-yyyy hh:mm:ss).  |

|   |  |
|---|--|
| Regular load consumption patterns time series ( $\leq 30$ min time step)  | Timestamp - (Time Series with Time:dd-mm-yyyy hh:mm:ss) and Power; unit: W; type: (float)  |
| Load consumption upon given intervention signals for flexibility participation time series ( $\leq 30$ min time step) | Timestamp - (Time Series with Time:dd-mm-yyyy hh:mm:ss) and Power; unit: W type: (float)   |
| Intervention Signals for flexibility participation time series  | 4 Discrete datatype options (float): Power limit (ic-pwim); Renew. Energy percentage (%/kWh); CO2 Emissions (CO2/kWh); Cost tariff (€/kWh) with Timestamp (Time:dd-mm-yyyy hh:mm:ss) |
| Users ID corresponding to each time series under analysis   | "User4044" (string)  |
| Outside temperature of the location under analysis for every time step (t)  | (unit: C°; float)  |
| Indoor temperature (optional)   | (unit: C°; float))   |
| Occupation rate of the facility (optional)  | "2" (integer)  |
| Note: all Timestamps should be 24-hour system   |  |

The inputs are represented based on the following JSON and submitted through a POST method in the REST API:

```
{
  "user_profile" : [
    {
      "userID": "ID644", (string)
      "timestamp": "2021-04-12T15:11:20Z", (timestamp)
      "customer_consumption": 0.2, (float)
      "customer_consumption_unit": "kW",
      "signal_incentive_Class:Cost: 0.11, (float)
      "signal_incentive_unit": "€/kWh",
      "signal_incentive_Class:CO2_Emissions: 0.11, (float)
      "signal_incentive_unit": "gCO2/kWh",
      "signal_incentive_Class:Renew_Energy_Percentage: 0.11, (float)
      "signal_incentive_unit": "%/kWh",
      "signal_incentive_Class:maximum_power (pi_pwim): 0.11, (float)
      "signal_incentive_unit": "kWh",
      "external_temperature": 19, (float)
      "external_temperature_unit": "degreesCelcius",
      "indoor_temperature_sensor": 24, (float)
      "indoor_temperature_sensor_unit": "degreesCelcius",
      "occupancy_rate": 4.3, (float)
    },
    ...
  ]
}
```

The JSON inputs for the model require the service user to provide user profiles with the indicated fields. It should be noted that there are 4 classes of incentive signals identified in this model (Cost, CO2 emissions, Renewable Energy % and Maximum Power) and one incentive signal data is required for the model to make assessment. These categories of signals enable several demonstrators to use it since it covers several possibilities of incentives. There can be a maximum of 24 incentive signal for the specified category (equal to the number of hours in a day) and the results are represented as i1,

i2 to i24 respectively. For example, an incentive signal category of Cost with three incentive signals (namely high, medium, low) will have results corresponding to i1, i2 and i3.

**The general interaction** between actors is the following: the service subscriber, having obtained the metering and intervention signals (pre and post intervention) send the data to the service. The service is based on a model using linear regression allowing a comparison of the same consumption times when exposed to different signals and without any signals. From the comparison between the consumption changes at the same hours, it is possible to know the willingness and sensitivity to change consumption for a given consumer. This comparison is made possible against a baseline (a pre-intervention period), which is when the consumer had no signals to change its behaviour.

This service assumes that: i) calculation is performed per customer (or for groups of customers); ii) information about intervention signals and ambient temperature is required, as well as metering about electrical energy consumption; iii) customer were subjected to different intervention schemes or trials during the available historical data and have a pre-trial historical record (or in the absence of pre-trial historical data - model requires time periods without and with flexibility participation signals). iv) One type of incentive signal input via API is required for the model to make the assessment. Attributes such as Indoor temperature(t) and occupancy rate(t) (number of persons inside) are optional and can be used if available as they will increase the reliability of the model but are part of the API inputs.

The model is run and provides the following functionalities/**outputs**:

- Time series (24h) with Consumption and Flexibility provided by Customers: (array:data series: kWh)
- Raking customer (%) to identify network areas (or pool of customers) with higher DR potential customer (array, object, float)
- Reliability of DR (flex provision) of each customer for t of a typical day (Percentage, %; float)

The output accuracy will depend on the quality of the input variables, especially the time window defined. The service is implemented in Python, hence it can easily provide the output in standard file formats such as JSON and presents in a graphical manner, for ease of interpretation, the rankings and reliability outputs in Grafana environment, which can be seen in the result example after the JSON representation. The following methods are hence used:

- After the User POST, he is given a Request ID to allow for asynchronous response and is able the retrieve the results using a GET method. The response is only submitted by the Service Provider through a POST method with the JSON structure below:

#### Output:

```
{
  "userID": "ID644",    (string)
  "flexibility_response": [
    {
      "flexibility_hour": 7,    (integer)
      "flexibility_hour_unit": "h",
      "y_PowerD": 2.1,        (float)
      "y_PowerD_unit": "kW",
      "y_lowerD": 1.5,        (float)
    }
  ]
}
```



```

        "y_lowerD_unit": "kW",
        "y_upperD": 2.4,      (float)
        "y_upperD_unit": "kW",
        "y_Power_i1": 2.1,    (float)
        "y_Power_i1_unit": "kW",
        "y_lower_i1": 2.4,    (float)
        "y_lower_i1_unit": "kW",
        "y_upper_i1": 2.4,    (float)
        "y_upper_i1_unit": "kW",
        "y_Power_i2": 2.1,    (float)
        "y_Power_i2_unit": "kW",
        "y_lower_i2": 1.5,    (float)
        "y_lower_i2_unit": "kW",
        "y_upper_i2": 2.4,    (float)
        "y_upper_i2_unit": "kW"
    ... .
    "y_Power_i24": 2.1,      (float)
    "y_Power_i24_unit": "kW",
    "y_lower_i24": 1.5,      (float)
    "y_lower_i24_unit": "kW",
    "y_upper_i24": 2.4,      (float)
    "y_upper_i24_unit": "kW"

    },
    ...
],
"Ranking" : [
    {
        "Ranking_hour": 7,    (integer)
        "Ranking_hour_unit": "h",
        "rank_Flex_i1_Price": 85,    (float)
        "rank_Flex_i1_Price_scale": "%",
        "rank_Flex_i2_Price": 85,    (float)
        "rank_Flex_i2_Price_scale": "%"
    ... .
        "rank_Flex_i24_Price": 85,    (float)
        "rank_Flex_i24_Price_scale": "%"
    },
    ...
],
"Reliability_i1_hours" : [
    {
        "Intervention_hour": 7,    (integer)
        "Intervention_hour_unit": "h",
        "i1_Signal_Power_reliability": 12,    (float)
        "i1_Signal_Power_reliability_scale": "%"
    },
    ...
],
"Reliability_i2_hours" : [
    {
        "Intervention_hour": 7,    (integer)
        "Intervention_hour_unit": "h",
        "i2_Signal_Power_reliability": 23,    (float)
        "i2_Signal_Power_reliability_scale": "%"
    },
    ... .
],
"Reliability_i24_hours" : [
    {
        "Intervention_hour": 7,    (integer)
        "Intervention_hour_unit": "h",
        "i24_Signal_Power_reliability": 17,    (float)
        "i24_Signal_Power_reliability_scale": "%"
    }
]

```

```

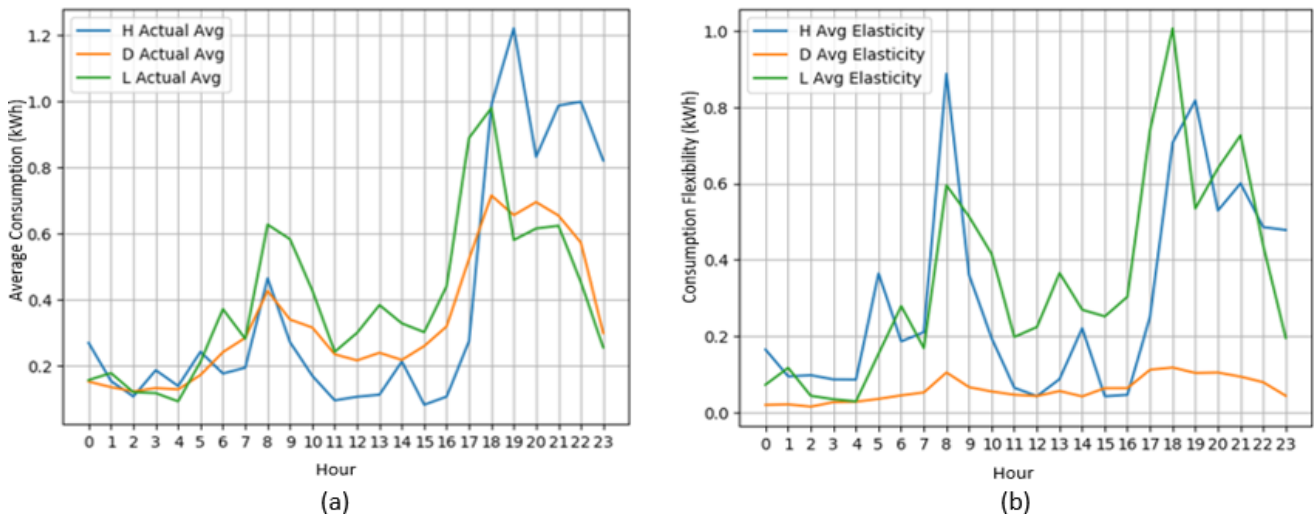
},
...
]
}

```

- Remove the Data Set

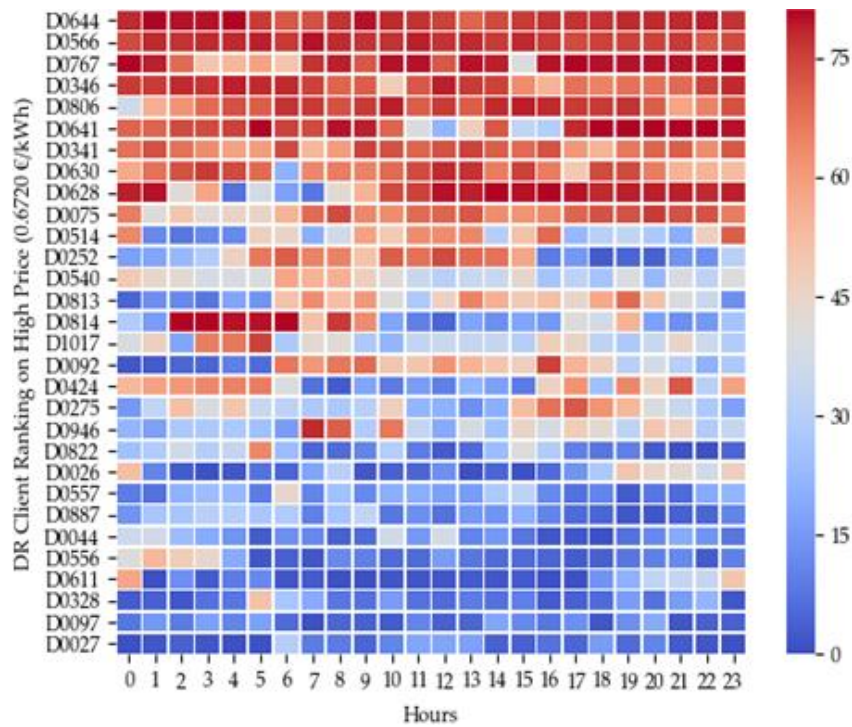
This method removes any record from the database related with the provided req ID or submitted dataset.

An example of the model results (graphical form to be output by Grafana) are shown in Figures 23, 24 and 25 for a dataset with dynamic time-of-use electricity pricing. The dataset contained tariff information, which comprised of three dynamic ToU rates: Default is 0.1176 £/kWh; high is 0.6720 £/kWh; low is 0.0390 £/kWh. The general expectation is for consumers to have higher average consumption for lower price and lower average consumption for higher price periods. This means that, for an ideal client, one would expect a high flexibility and high average consumption for a low price (0.0399 €/kWh) and high flexibility and low average consumption for a high price (0.6720 €/kWh). This could give an insight into how the clients will respond to DR signals, and some periods where the consumers respond poorly for a broader time interval. Thus, the higher the consumption flexibility for the client for those hours, the higher their tendency is to alter consumption for those price signals in those hours. Lower flexibility means that the client is not susceptible to change its consumption in those hours.

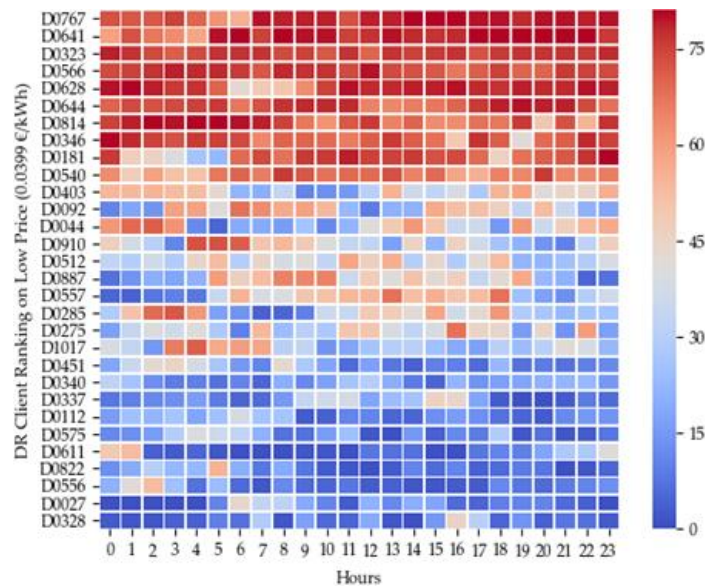


**FIGURE 23: CUSTOMER YY UNDER DEMAND RESPONSE WITH THREE PRICING TARIFFS: (A) ACTUAL AVERAGE CONSUMPTION FROM THE FLEXIBILITY MODEL; (B) AVERAGE CONSUMPTION FLEXIBILITY FROM THE CAUSALITY MODEL (OUTPUT 1)**

The actual average demand (blue, orange, and green lines in Figure 23(a)) gives a sense of the average consumption levels associated to each client for each price signal they experience. When all consumption averages of a client are close to each other, it signifies that the client does not have much flexibility between different price tariffs. Figure 23(b) shows the average flexibility values that were obtained for customer YY and it also indicates which hours are preferred by this client to change its consumption pattern based on the prices experienced. Comparing the average flexibility plot and the average consumption plot, we can clearly see that this client willingly participates in the DR activity, specifically during the morning and evening periods. This client also exhibits low price consumption flexibility during the afternoon.

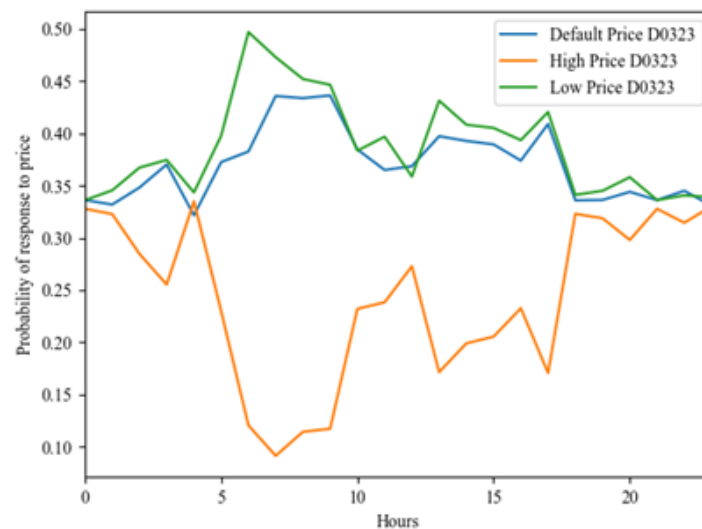


**FIGURE 24: RANKING 30 CUSTOMER FLEXIBILITY FOR HIGH PRICE (OUTPUT 2)**



**FIGURE 25: RANKING 30 CUSTOMER FLEXIBILITY FOR LOW PRICE (OUTPUT 2)**

The ranking output example can be seen in Figures 24 and 25, for the high and low incentive prices respectively. The yy axis refers to each of the clients analysed and the xx axis to the hours. The colour code ranks from high(red) to low (blue) participation or consumption change to the signal for each hour. It is interesting to observe that some consumers have low to no participation in some hours but respond well in others.



**FIGURE 26: CUSTOMER YY'S ESTIMATED PROBABILITY OF RESPONSE TO ALL THREE PRICES FOR EACH HOUR (OUTPUT 3)**

However, analysing the ranking alone may be misleading, and so a third output looks at the reliability those changes in consumption, which can be seen in Figure 26 as an example, showing the probability to react to an incentive, low in green and high in orange, throughout the day. This is particularly interesting for retailers to understand how to design effective tariffs and for Aggregators to understand where to search for participants to include in their portfolios and how to remunerate them.

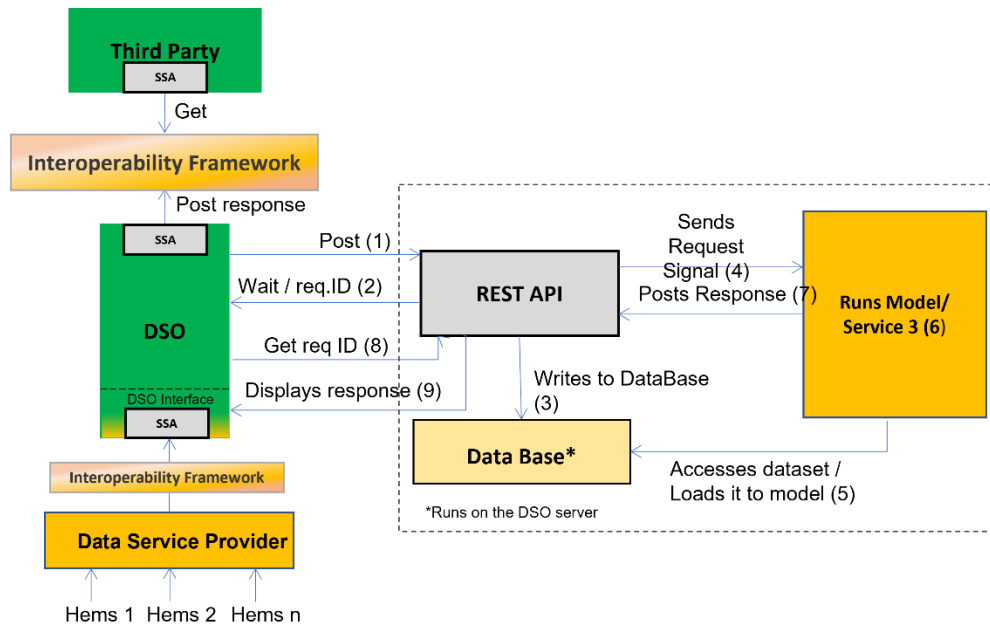
#### 4.1.3 OBSERVABILITY SERVICE 3: ASSESSING GRID IMPACT THROUGH LOAD TYPES OBSERVATION

This **service refers to** the primary use case 3 and has the following objectives:

- The service will allow solving voltage related problems in the networks where monitored devices are connected to, particularly under and over voltage problems, by providing a voltage sensitivity coefficient.
- From the disaggregated load profiles of specific loads from the HEMS it will allow an identification of potential loads which could have a high impact on the voltage operation limits, such as EV, heat pumps or PV systems, and advise on its preferred installation or areas to avoid (EV chargers, PVs...).
- By analysing disaggregated loads, the DSO can estimate, if network voltage violations may be mitigated by acting (through an FSP) on flexible loads, or if the loads are not flexible at all.

**Conceptually** the service will run on the DSO side using historical data that is expected to be updated periodically (e.g., every 24h, 48 h, or weekly). Specifically, the sensitivity factors needed for the voltage analysis functions requires both voltage magnitude and active power injection to be measured for every consumer of a LV, which can be gathered by regular smart meters. Additionally, disaggregated consumption data collected from the HEMS and specific relevant equipment is used to enhance the analysis.

The collection of data from the HEMS will be ensured by a data service provider (DSP), which interacts with the DSO through an SSA. This data needs to be made interoperable and standardized through SAREF ontology and the DSP is the responsible actor for ensuring approval and GDPR compliance of customer data. All outputs are of interest to the DSO, however the third output, can be of particular interest for third parties such as Aggregators, consumers, or other companies interested in finding out the flexibility potential on a given area when considering investments, business opportunities or grid planning (PV, EV chargers, heat pumps etc.). In this case, this third party requests the service to the DSO through a SSA as well with data that are made interoperable and standardized through SAREF ontology. Both these data interactions are identified in Figure 27.



**FIGURE 27: ACTION FLOW BETWEEN SERVICE REQUESTER AND SERVICE PROVIDER THROUGH THE REST API / SSA**

Figure 27 shows the flow of actions observed in the process, being the Post of the dataset required by the service to run the number 1, followed by a waiting notification assigned by a request ID (2). This is necessary because the service may take several minutes to output a response. This this is to safeguard that no failure due to elapsed time is generated. Step 3 action is to write in a database the supplied dataset, which is based in the same machine as the model/service. When this happens it means that there is new data for the model to process, so a signal (4) notifies the model (which is always active/listening) to load the file (5) and runs the model/service (6). Step 7 is the response through a post in the API. The user must make a Get with the provided req.ID (step 2) to refresh the response field in the API. When it is indeed available, it provides the UI with the response. Similarly, as in service 2, the model could work only with a Post of a dataset without having a database. However, the expected file size (up to 100 MB), and the estimated process run time result in an asynchronous match. The same line of thought is pursued regarding the output file format which will be a JSON format, so it can use the http layer to ensure that no interruption of communication exist that could corrupt the file.

#### Tool:

The Sensitivities Engine aims at providing a better understanding of the impacts that different LV consumers may have to the preservation of voltage measurements within the admissible range, with multiple applications to both planning and real-time operation. The core analysis is achieved by means



of sensitivity factors, that portray the effect of changing the active power injection (consumption/generation) of a given consumer on all the voltages of the grid.

Since LV grids can lack an accurate characterization of the topology and electrical parameters in some countries, the calculation of the sensitivity factors was developed to be completely data driven. In other words, the links between consumption and the grid voltage is obtained just using historical measurements of active power injections and voltage magnitudes (typically collected from smart meters and/or HEMSs).

In fact, without the correct model of the grid, becomes impractical for the DSO to run any conventional algorithm for a LV grid. For instance, the flexibility from loads may exist but it is impossible to run an optimal power flow and determine how a flexibility offer will benefit the system.

The following historical data (average values for  $\leq 30$ -min time steps; minimum 3 months) is necessary to build the sensitivity factors. The data from consumers must be considered as a system. All data under the same secondary substation or transformer must be analysed as a network.

In general, the **inputs** for the service coincide with the inputs for the APIs, in this sense below are the methods used and the JSON representations of the requests.

- Remove LV grid

This method removes any record from the database related with the provided grid ID.

- Register LV grid

In order to perform any calculations for a LV grid it is necessary to register it in the internal database. Therefore, this method must be run before trying to update the database with measurements. The structure is the same as the update method described below.

- Update historical data from smart meters

The arrival of a new set of historical measurements triggers the recalculation of the sensitivity factors. Since the data may contain outliers and gaps, the Sensitivities Engine provides several sub-functions to validate data, detect outliers and fill gaps of information. Only then, the new historical data is added to the database. The following JSON snippet illustrates the request body:

```
{
  "historicalFromMeters": [{
    "meter_id": "ytu92099021",
    "master_id": "",
    "info": 0,
    "phase": 0,
    "measurements": [{
      "timestamp": 1287691200,
      "v_measured": 232.034,
      "p_measured": 0.0
    },
    {
      "timestamp": 1287691800,
      "v_measured": 232.334,
      "p_measured": 0.0
    },
    {
      "timestamp": 1287692400,
      "v_measured": 232.129,
      "p_measured": 0.0
    }
  ]
}
```

```
{
  "timestamp": 1287693000,
  "v_measured": 231.971,
  "p_measured": 0.0
}
],
{
  "meter_id": "lkj92099021",
  "master_id": "",
  "info": 0,
  "phase": 0,
  "measurements": [{
    "timestamp": 1287691200,
    "v_measured": 232.034,
    "p_measured": 0.0
  },
  {
    "timestamp": 1287691800,
    "v_measured": 232.334,
    "p_measured": 0.0
  },
  {
    "timestamp": 1287692400,
    "v_measured": 232.129,
    "p_measured": 0.0
  },
  {
    "timestamp": 1287693000,
    "v_measured": 231.971,
    "p_measured": 0.0
  }
]
}
```

The JSON fields are described as follows:

**TABLE 8: JSON FIELDS AND DATA FORMAT**

| FIELDS  |   | DATA FORMAT |
|---|---|-------------|
| <b>meter_id</b> - identifier of any measuring device in the network.  |   | string      |
| <b>master_id</b> – identifier of a device or infrastructure where the measuring device (“meter_id”) belongs to. This can be used to identify and separate a three-phase meter in three single-phase meters. |   | string      |
| <b>info</b> – 0 – regular smart meter; 1 – meter at the MV/LV substation.   |   | integer     |
| <b>phase</b> - only used with meters at the MV/LV substation. 1 - phase R; 2 - phase S; 3 - phase T.  |   | integer     |
| <b>Measurements</b><br>[array]  | <b>timestamp</b> - UNIX timestamp.                        | integer     |
|   | <b>v_measured</b> - estimated voltage magnitude value (V) | double      |
|   | <b>p_measured</b> - estimated active power value (kW)     | double      |

- Perform voltage analysis and load correlation

The user provides disaggregated load profiles from customers whose sensitivity factors are already known and the Sensitivities Engine retrieves correlations between voltage problems and the type of



loads. The analysis considers the statistically more relevant loads per period of a typical day, considering the disaggregated data provided. The following JSON snippet illustrates the request body:

```
{
  "historicalFromAppliances": [{
    "appliance_id": "dsk98",
    "appliance_type": 0
    "meter_id": "ytu92099021",
    "info": 0,
    "measurements": [{
      "timestamp": 1287691200,
      "p_measured": 1.24
    },
    {
      "timestamp": 1287691800,
      "p_measured": 1.43
    },
    {
      "timestamp": 1287692400,
      "p_measured": 2.15
    },
    {
      "timestamp": 1287693000,
      "p_measured": 2.07
    }
  ]
},
{
  "appliance_id": "dsk97",
  "appliance_type": 12
  "meter_id": "ytu92099021",
  "info": 0,
  "measurements": [{
    "timestamp": 1287691200,
    "p_measured": 0.56
  },
  {
    "timestamp": 1287691800,
    "p_measured": 0.89
  },
  {
    "timestamp": 1287692400,
    "p_measured": 0.45
  },
  {
    "timestamp": 1287693000,
    "p_measured": 0.45
  }
  ]
}
]
```

The JSON fields are described as follows:

**TABLE 9: JSON FIELDS AND DATA FORMAT**

| FIELDS  | DATA FORMAT |
|---|-------------|
| <b>appliance_id</b> - identifier of the appliance inside the installation.                              | string      |
| <b>appliance_type</b> - identifier of the type of appliance ( 1 - EV; 2 - Heat pump; 3 - PV; 4 - Other. | integer     |

|   |   |         |
|---|---|---------|
| <b>meter_id</b> – identifier of the meter of the installation where the appliance belongs to. |   | string  |
| <b>info</b> – not used.   |   | integer |
| <b>Measurements</b> [array]   | <b>timestamp</b> - UNIX timestamp.                    | integer |
|   | <b>p_measured</b> - estimated active power value (kW) | double  |

- Identify LV critical nodes and flexibility requirements

The user provides disaggregated load profiles from customers whose sensitivity factors are already known. The following JSON snippet illustrates the request body:

```
{
  "historicalFromAppliances": [{
    "appliance_id": "dsk98",
    "appliance_type": 0
    "meter_id": "ytu92099021",
    "info": 0,
    "measurements": [{
      "timestamp": 1287691200,
      "p_measured": 1.24
    },
    {
      "timestamp": 1287691800,
      "p_measured": 1.43
    },
    {
      "timestamp": 1287692400,
      "p_measured": 2.15
    },
    {
      "timestamp": 1287693000,
      "p_measured": 2.07
    }
  ]
},
{
  "appliance_id": "dsk97",
  "appliance_type": 12
  "meter_id": "ytu92099021",
  "info": 0,
  "measurements": [{
    "timestamp": 1287691200,
    "p_measured": 0.56
  },
  {
    "timestamp": 1287691800,
    "p_measured": 0.89
  },
  {
    "timestamp": 1287692400,
    "p_measured": 0.45
  },
  {
    "timestamp": 1287693000,
    "p_measured": 0.45
  }
]
}]
}
```

The JSON fields are described as follows:

**TABLE 10: JSON FIELDS AND DATA FORMAT**

| FIELDS   |   | DATA FORMAT |
|--|---|-------------|
| <b>appliance_id</b> - identifier of the appliance inside the installation.                             |   | string      |
| <b>appliance_type</b> - identifier of the type of appliance: 1 - EV; 2 - Heat pump; 3 - PV; 4 - Other. |   | integer     |
| <b>meter_id</b> – identifier of the meter of the installation where the appliance belongs to.          |   | string      |
| <b>info</b> – not used.  |   | integer     |
| <b>Measurements</b> [array]  | <b>timestamp</b> - UNIX timestamp.                    | integer     |
|  | <b>p_measured</b> - estimated active power value (kW) | double      |

This service comprises the following distinct functionalities/**Outputs**:

1. **Sensitivity factors calculation**: allows to understand the influence of power injection variations within the LV grid on the voltages. For example, if the consumption of a customer changes, it is possible to determine the voltage change in all the other customers. Likewise, if it is necessary to cause a voltage change in one customer, it is possible to know the customers whose consumption variation would greatly contribute (and by how much).
2. **Voltage analysis & load correlation**: identify customers whose voltage profiles do not comply (or are often close to it) with the technical constraints and correlate these undesirable events with the type of loads that may be causing them. For a given point of interest of the LV grid, the sensitivity factors allow to identify the customers whose consumption/generation have more influence on the voltage of this point. Then, correlations can be established between the disaggregated consumption from these customers and that voltage. Since the consumption patterns vary substantially along a day, this analysis is split into small periods (e.g., every 30 min) of a day.
3. **Identification of LV critical nodes & flexibility requirements**: identifies and ranks consumers whose increased flexibility (e.g., install PVs, charge EVs, charge/discharge storage devices) would contribute to solve voltage violations. The output of this analysis is split into small periods of a day, quantifying for each consumer in the ranking the target amount of flexibility. This information could be shared with third parties (and other sectors like mobility or financial) to highlight opportunities to invest in flexibility resources and demand-side flexibility actions.

Below the JSON structure of each of the three outputs provided by the REST API:

#### **Output 1** - Obtain sensitivity factors response:

Whenever needed, the DSO can ask for the most recent sensitivity factors, which are stored in the internal database of the Sensitivities Engine. The following JSON snippet illustrates the response:

```
{
  "startTime": "2018-09-26T00:00:00Z",
  "endTime": "2018-09-26T01:00:00Z",
  "voltage_sensitivity_points": [{
    "meter_id_V": "ytu92099021",
    "power_injection points": [{
```

```

"meter_id_P": "lkj92099021",
"sensitivity": 0.25
},
{
"meter_id_P": "ytu92099021",
"sensitivity": 0.824
}
]
},
{
"meter_id_V": "lkj92099021",
"power_injection_points": [{
"meter_id_P": "ytu92099021",
"sensitivity": 0.34
}],
{
"meter_id_P": "ytu92099021",
"sensitivity": 0.456
}
]
}
]
}

```

The JSON fields are described as follows:

**TABLE 11: PARAMETER DESCRIPTION OF OUTPUT 1**

| FIELDS  |   | DATA FORMAT   |
|---|---|---|
| <b>startTime</b> - timestamp of the first record (oldest) considered in the calculation of the sensitivity factors.   |   | (Start Time; unit time; date format:dd-mm-yyyy hh:mm:ss)                                      |
| <b>endTime</b> - timestamp of the last record (more recent) considered in the calculation of the sensitivity factors. |   | (End Time; unit time; date format:dd-mm-yyyy hh:mm:ss).                                       |
| <b>voltage_sensitivity_points</b><br>[array]  | <b>meter_id_V</b> - identifier of the meter whose voltage sensitivities are being considered. | string  |
|   | <b>power_injection_points</b><br>[array]  | <b>meter_id_P</b> - identifier of the meter that may affect the voltage of meter_id_V         |
|   |   | <b>sensitivity</b> - impact on voltage of meter_id_V when consumptions of meter_id_P changes. |

**Output 2** -The following JSON snippet illustrates the response to the voltage analysis and load correlation:

```

{
"startTime": "2018-09-26T00:00:00Z",
"endTime": "2018-12-26T01:00:00Z",
"periods": [{
"time": "14h00-16h30",
"average_voltage": 243.98,
"undervoltage": {
"prob_of_occur": 0,
"worst_record": {
"value": 0,
"meter_id": ""
}
},
"customers_causing_problems": []
},
],
"overvoltage": {
"prob_of_occur": 12.1,
"worst_record": {
"value": 252.45,

```

```

"meter_id": "hdg432493"
},
"customers_causing_problems": [{
"meter_id": "opo984443",
"load_type": 5
},
{
"meter_id": "hyi344560",
"load_type": 1
}
],
"Warnings": [
"Consumption is very low considering the high amount of PV generation"
]
},
{
"time": "20h30-21h00",
"average_voltage": 222.78,
"undervoltage": {
"prob_of_occur": 2.3,
"worst_record": {
"value": 215.09,
"meter_id": "hds938929"
}
},
"customers_causing_problems": [{
"meter_id": "hsd989222",
"load_type": 1
},
{
"meter_id": "hyi344560",
"load_type": 1
}
],
"overvoltage": {
"prob_of_occur": 0,
"worst_record": {
"value": 0,
"meter_id": ""
}
},
"customers_causing_problems": []
},
"Warnings": [
"Many EVs are being connected during this period causing a sudden voltage drop"
]
}
]
}

```

The JSON fields are described as follows:

**TABLE 12: PARAMETER DESCRIPTION OF OUTPUT 2**

| FIELDS   |   | DATA FORMAT  |
|--|---|--|
| <b>startTime</b> - timestamp of the first record (oldest) of the disaggregated consumption data.   |   | (Start Time; unit time; date format:dd-mm-yyyy hh:mm:ss) |
| <b>endTime</b> - timestamp of the last record (more recent) of the disaggregated consumption data. |   | (End Time; unit time; date format:dd-mm-yyyy hh:mm:ss).  |
|  | <b>time</b> - one of the 30-min periods | string   |

|  |   |  |  |         |
|--|---|--|--|---------|
| periods - the typical day is divided in 30-min periods [array] | average voltage - average voltage value during this period                                      |  | double   |         |
|  | undervoltage - analysis of the undervoltages during this period                                 | prob_of_occur - probability of occurrence  | double   |         |
|  |   | worst_record - value and meter id of the worst record registered                     | value - voltage value  | double  |
|  |   |  | meter_id   | string  |
|  |   | customers_causing_problems - types of loads and meter id of the installation [array] | meter_id - identifier of the meter   | string  |
|  | appliance_type - identifier of the type of appliance: 1 - EV; 2 - Heat pump; 3 - PV; 4 - Other. |  | integer  |         |
|  | overvoltage - analysis of the overvoltages during this period                                   | prob_of_occur - probability of occurrence  |  | double  |
|  |   | worst_record - value and meter id of the worst record registered                     | value - voltage value  | double  |
|  |   |  | meter_id   | string  |
|  |   | customers_causing_problems - types of loads and meter id of the installation [array] | meter_id - identifier of the meter   | string  |
|  |   |  | appliance_type - identifier of the type of appliance: 1 - EV; 2 - Heat; pump; 3 - PV; 4 - Other. | integer |
| Warnings - interpretation of the analysis                      |   |  | string   |         |

**Output 3** - The following JSON snippet illustrates the response to flexibility requirements:

```
{
  "startTime": "2018-09-26T00:00:00Z",
  "endTime": "2018-12-26T01:00:00Z",
  "periods": [{
    "time": "14h00-14h30",
    "intervention_perimeters": [
      {
        "perimeter_id": "1_1_2",
        "meter_ids": [
          "hdg432493",
          "opo984443"
        ],
        "power_variation_needs": 14.26
      },
      {
        "perimeter_id": "1_2_2",
        "meter_ids": [
          "poe928328",
          "dft991110"
        ],
        "power_variation_needs": 18.87
      }
    ],
    "power_variation_needs": 26.12
  }],
  "periods": [{
    "time": "2_1_1",
    "meter_ids": [
      "hyi344560",
      "qwk734378",
      "iur092992"
    ],
    "power_variation_needs": 26.12
  }],
  "power_variation_needs": 26.12
}
```

```

}}
],
"Potential recommendations": [
"Consumption should increase in several parts of the network.",
"The reduced number of EVs connected during this period may indicate this resource as a possible solution: (4 EVs in perimeter
1_1_2 OR 5 EVs in perimeter 1_2_2) AND 7 EVs in perimeter 2_1_1.",
"Distributed storage devices were not found but could be an alternative to EV charging."
]
},
{
"time": "20h30-21h00",
"intervention_perimeters": [
[{
"perimeter_id": "3_1_1",
"meter_ids": [
"hds938929",
"erd939900",
"pzx002333",
"lop230991"
],
"power_variation_needs": -42.56
}]
],
"Potential recommendations": [
"Consumption is very high in part of the network.",
"The number of EVs connected during this period in perimeter 3_1_1 should decrease by 12.",
"Distributed storage devices were not found but could be used to support EV charging."
]
}
]
}

```

The JSON fields are described as follows:

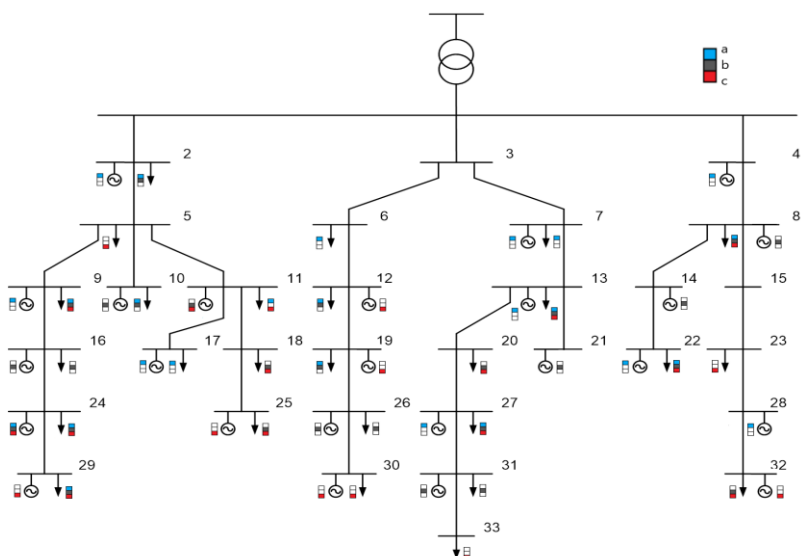
**TABLE 13: PARAMETER DESCRIPTION OF OUTPUT 3**

| FIELDS   |   |   | DATA FORMAT   |
|--|---|---|---|
| <b>startTime</b> - timestamp of the first record (oldest) of the disaggregated consumption data.   |   |   | (Start Time; unit time; date format:dd-mm-yyyy hh:mm:ss). |
| <b>endTime</b> - timestamp of the last record (more recent) of the disaggregated consumption data. |   |   | (End Time; unit time; date format:dd-mm-yyyy hh:mm:ss).   |
| <b>periods</b> - the typical day is divided in 30-min periods<br>[array]                           | <b>time</b> - one of the 30-min periods   |   | string  |
|  | <b>intervention_perimeters</b> - perimeters whose customers would benefit the voltages if they changed their consumption/generation<br>[array of array] - perimeters in the second dimension array are alternatives to solve the same problem | <b>perimeter_id</b> - identifier of the perimeter (inside this file only)                   | string  |
|  |   | <b>meter_ids</b> - identifiers of the meters in the perimeter [array]                       | string  |
|  |   | <b>power_variation_needs</b> - amount of power that should change to solve voltage problems | double  |
|  | <b>Potential recommendations</b> - interpretation of the analysis   |   | string  |



In terms of **actor interactions**, the DSO retrieves the data from the set the smart meters in the area which it intends to monitor. The data can be aggregated to develop the core sensitivity factor matrix. If a more detailed analysis is required by load type (2nd output), the HEMS data is required. This data must be obtained through a Rest API, interacting with a data service provider. It then correlates the load disaggregated data from the consumption profiles, with the voltage variations considered to be problematic by running a machine learning algorithm. The model should be trained periodically for the same area or every time a new area is requested to be analysed. The voltage operational ranges and time it can endure outside operational limits are defined in the service algorithm (or as an option by the requester). These limits can be changed should the service be applied to a MV network level for example. It should be noted that the voltage sensitivity coefficient does not correspond to an isolated event. It changes according to its positioning on the network (distance from feeder, length of cable etc...) and is impacted by neighbouring nodes and loads. It is hence a system analysis instead of a single consumer impact on the grid. This means that, the number of coefficients will be according to the number of consumers (C) to the power of (C). If the service runs data for 10 consumers, the service will provide 100 sensitivity factors. To each consumer, 10 coefficients are provided, corresponding to its impact on its grid voltage and on the impact caused on others if it changes its consumption. The service allows for 150 nodes which covers the expected number of costumers supplied by a given secondary substation. The full network consumption by node (for e.g., under a secondary substation) is required, no partial data can be used, as the model assumes a closed system.

Figure 28 shows an example of a tested network. The single line diagram shows 33 nodes (consumers) with three feeders 2, 3 and 4 below busbar n°1 which is the secondary of the upstream substation. The analysis can be done for the whole network or by feeder, which will result in an easier and faster processing. This is especially important because all node knowledge is required for the analysis. If some consumers data is missing under feeder 3 or 4, the model can still be run for feeder n° 1. Different configurations, phases and a mix of generation and consumption is possible to analysed as shown in the Figure 28. The structural data such as length, location, cables is not necessary since the response will have these characteristics implicit acknowledged.



**FIGURE 28: EXAMPLE OF A SINGLE LINE DIAGRAM FROM A LV NETWORK TESTED**

An example of the sensitivity factors is given in the Table 14, where lines from 1 to 7 can be seen showing the sensitivity coefficient according to nodes (lines) in phase a, b or c and power in each phase

(columns). For the first cell, the following results should be read as: A variation of -0.05674 V is observed in node 1 (Client or set of clients ID) in phase a, due to a variation of 1 kW in node 1 (Client or set of clients ID)

**TABLE 14: SENSITIVITY COEFFICIENTS (OUTPUT 1) EXAMPLE RELATING THE IMPACT OF VOLTAGE ON PER NODE DUE TO 1 KWH VARIATION IN OTHER NODES**

|          | deltaPa1 | deltaPa2 | deltaPa3 | deltaPa4 | deltaPa5 | deltaPa6 | deltaPa7 | n   |
|----------|----------|----------|----------|----------|----------|----------|----------|-----|
| deltaVa1 | -0.05674 | -0.1076  | -0.10367 | -0.06157 | -0.10564 | -0.12363 | -0.12005 | ... |
| deltaVa2 | 0.018599 | -0.19482 | -0.10378 | -0.06158 | -0.10579 | -0.10745 | -0.04516 | ... |
| deltaVa3 | 0.018116 | -0.10779 | -0.21695 | -0.13515 | -0.17983 | -0.1075  | -0.0453  | ... |
| deltaVa4 | 0.01806  | -0.10775 | -0.17767 | -0.22248 | -0.17981 | -0.1075  | -0.04535 | ... |
| deltaVa5 | 0.01887  | -0.1078  | -0.17772 | -0.13513 | -0.36461 | -0.10747 | -0.04519 | ... |
| deltaVa6 | 0.001973 | -0.1078  | -0.10396 | -0.0618  | -0.10603 | -0.43859 | -0.06161 | ... |
| deltaVa7 | -0.05663 | -0.10763 | -0.10368 | -0.06158 | -0.10566 | -0.12365 | -0.13959 | ... |
| deltaVn  | ...      | ...      | ...      | ...      | ...      | ...      | ...      | ... |

#### 4.1.4 API METHODS IDENTIFICATION BETWEEN THE DSO AND THE SERVICES

The interactions between the service requester (e.g., DSO) and the service providers are done through SSAs (for interoperable and standardized services) or, in case the KE is not used, dedicated Rest APIs. These endpoints enter into play whenever a parameter, dataset or request is made to the service. These endpoints (still under development) are described in the D4.2 in more detail, but are here compiled and summarized for the reader in the Table 15.

**TABLE 15: METHODS DESCRIBING THE INTERACTIONS BETWEEN THE DSO AND THE SERVICES**

| INTERACTION DESCRIPTION  | USAGE PURPOSE, INCLUDING USER  | METHOD/GENERIC URL*  | SERVICE |
|--|--|--|---------|
|  | <i>Use by the DSO</i>  |  |         |
| Defines the minimum nbr. of faulty hems to be considered to trigger the fault identification | Specify the parameter min. nbr. of HEMS  | POST<br>https://inesc.interconnect.pt/GridObservability/{HEMS Nbr}       | 1       |
| Defines the minimum elapsed time to be considered to trigger the fault identification        | Specify the parameter min. Elapsed time  | POST<br>https://inesc.interconnect.pt/GridObservability/{HEMS Elps_Time} | 1       |
| Defines the Grid Zone/Postal code in which Hems should be monitored for fault notifications  | Specify monitoring location  | POST<br>https://inesc.interconnect.pt/GridObservability/{Postal Code}    | 1       |
| The DSO inquires the DB (service) communication status of a specified HEMS                   | Understand the communication status of a specified HEMS                            | GET<br>https://inesc.interconnect.pt/GridObservability/{HEMS ID_Status}  | 1       |
| The DSO inquires the DB (service) about the voltage magnitude of the specified HEMS          | Troubleshoot/identify the outage limits by knowing the voltage of a specified Hems | GET<br>https://inesc.interconnect.pt/GridObservability/{HEMS ID_Volt}    | 1       |
| The DSO updates the historical data of a LV grid. This is expected to happen periodically    | Receives a waiting notification and a Req. ID for future Get request               | POST   | 3       |

|   |  |   |   |
|---|--|---|---|
| (e.g., every 24h, 48h, or week), triggering the recalculation of the sensitivity factors.   | processing to account for asynchronous response.   | <a href="http://inesctec.com/api/sensitivityengine/updateHistoricalData/{networkID}">http://inesctec.com/api/sensitivityengine/updateHistoricalData/{networkID}</a>               |   |
| The DSO inserts the dataset to be analysed by the service   | Submit a dataset with specified parameters in the payload. Receives a waiting notification and a request ID to be used in a subsequent Get method to account for asynchronous response.  | POST<br><a href="https://inesc.interconnect.pt/GridObservability/{Elasticity_dataset}">https://inesc.interconnect.pt/GridObservability/{Elasticity_dataset}</a>                   | 2 |
| Having a Req.ID the DSO having stood-by may use a Get method to request the results of the analysis   | Request the data analysis of a previously submitted dataset to which it has received a Req.ID  | GET<br><a href="https://inesc.interconnect.pt/GridObservability/Req_ID/{Elasticity_Results}">https://inesc.interconnect.pt/GridObservability/Req_ID/{Elasticity_Results}</a>      | 2 |
| The service provider posts the results of the sensitivity coefficients  | After running the model the service posts on the REST the results  | POST<br><a href="http://inesctec.com/api/sensitivityengine/getSensitivities/{networkID}">http://inesctec.com/api/sensitivityengine/getSensitivities/{networkID}</a>               | 3 |
| The DSO requests the most recent sensitivity factors with a Req_ID  | The DSO passes an argument to the identifier of the grid/req-ID. The service will return a JSON file with the sensitivity factors.   | GET<br><a href="http://inesctec.com/api/sensitivityengine/getSensitivities/{networkID}">http://inesctec.com/api/sensitivityengine/getSensitivities/{networkID}</a>                | 3 |
| The DSO requests an analysis to the historical voltages of a LV grid. The request specifies the LV grid and is followed by a JSON file containing disaggregated consumption data. | The DSO passes an argument to the identifier of the grid/req-ID. The service will return a JSON file with the sensitivity factors. The user has to wait to allow for asynchronous response   | POST<br><a href="http://inesctec.com/api/sensitivityengine/loadCorrelation/{networkID}">http://inesctec.com/api/sensitivityengine/loadCorrelation/{networkID}</a>                 | 3 |
| The DSO having waited for the model processing, it can request using the Req.ID the response of the model through a GET method  | The response includes a JSON file with data correlating voltage problems with customers and types of loads.  | GET<br><a href="http://inesctec.com/api/sensitivityengine/loadCorrelation/{networkID}">http://inesctec.com/api/sensitivityengine/loadCorrelation/{networkID}</a>                  | 3 |
| The DSO requests recommendations to solve voltage problems in a LV grid, increasing its flexibility .   | Receives a waiting message and a Req_ID for a future GET method to account for asynchronous response.  | POST<br><a href="http://inesctec.com/api/sensitivityengine/flexibilityRequirements/{networkID}">http://inesctec.com/api/sensitivityengine/flexibilityRequirements/{networkID}</a> | 3 |
| The DSO uses the GET method with a Req.ID to obtain the recommendations to solve voltage problems.  | The request specifies the LV grid and is followed by a JSON file containing disaggregated consumption data. The response includes a JSON file with data suggesting areas where increasing flexibility would improve voltage metrics. | GET<br><a href="http://inesctec.com/api/sensitivityengine/flexibilityRequirements/{networkID}">http://inesctec.com/api/sensitivityengine/flexibilityRequirements/{networkID}</a>  | 3 |
| The DSO registers one new LV grid in the Sensitivities Engine   | The DSO receives a req ID for its submission and just needs to pass as argument the identifier of the grid to obtain the response.   | POST<br><a href="http://inesctec.com/api/sensitivityengine/registerGrid/{networkID}">http://inesctec.com/api/sensitivityengine/registerGrid/{networkID}</a>                       | 3 |
| The DSO removes a LV grid from the Sensitivities Engine, deleting all the records in the internal database.   | The DSO passes an argument to the identifier of the grid.  | DELETE<br><a href="http://inesctec.com/api/sensitivityengine/removeGrid/{networkID}">http://inesctec.com/api/sensitivityengine/removeGrid/{networkID}</a>                         | 3 |
| <b>Use by the Service</b>   |  |   |   |

|   |   |   |   |
|---|---|---|---|
| The Service Provider inquires the DSO about the available GridZones and available observable ID_units under each one. | Obtain the GridZone list and get to know the HEMS or observable units to monitor upon request   | GET<br><a href="https://inesc.interconnect.pt/GridObservability/{GridZones}">https://inesc.interconnect.pt/GridObservability/{GridZones}</a>  | 1 |
| The service provider notifies the DSO of potential fault and location   | Used to make the DSO aware of a potential fault in a triggered location. It assumes the DSO has initiated the service and is always "listening" | POST<br><a href="https://inesc.interconnect.pt/GridObservability/{Post Code_Fault}">https://inesc.interconnect.pt/GridObservability/{Post Code_Fault}</a>                                     | 1 |
| The service requester sends a request to delete the dataset previously sent   | Deletes the data set to replace it or to disregard it   | DELETE<br><a href="https://inesc.interconnect.pt/GridObservability/removeDataset/{Elasticity_dataset}">https://inesc.interconnect.pt/GridObservability/removeDataset/{Elasticity_dataset}</a> | 2 |
| The service provider, after having finished its data analysis posts the results                                       | Posts recommendations regarding voltage problems  | POST<br><a href="http://inesctec.com/api/sensitivitiesengine/flexibilityRequirements/{networkID}">http://inesctec.com/api/sensitivitiesengine/flexibilityRequirements/{networkID}</a>         | 3 |
| The service provider, after having finished its data analysis posts the results                                       | Posts the results of the analysis from the received dataset.  | POST<br><a href="http://inesctec.com/api/sensitivitiesengine/loadCorrelation/{networkID}">http://inesctec.com/api/sensitivitiesengine/loadCorrelation/{networkID}</a>                         | 3 |
| The service provider, after having finished its data analysis posts the results                                       | Posts the results of the analysis from the received dataset.  | POST<br><a href="https://inesc.interconnect.pt/GridObservability/Req_ID/{Elasticity_Results}">https://inesc.interconnect.pt/GridObservability/Req_ID/{Elasticity_Results}</a>                 | 2 |

\*The URLs displayed are still under definition and development at this stage. They are identified here to show a generic identification of how they will be referred to.

#### 4.1.5 GDPR COMPLIANCE OF SERVICES

Working with data has never been so delicate, especially when it comes to consumer data. On one hand this is because it is now easier to obtain, with the mass dissemination of power electronics and sensors, and on the other hand, the power to process it, from Deep learning, machine learning, data mining and other AI approaches to create value from it. In the case of electricity services, in particular the provision of flexibility, there is no doubt that without access to consumer's data, for profiling, forecasting, baselining, monitoring just to mention a few, it would not be possible. The General Data Protection Regulation (GDPR) is driven by the notion that consumers in general must be protected, which are most often unaware of what can be done with their data, and what cautious measures can be taken to protect themselves and their interests (personnel data).

The GDPR defines personal data in Art. 4(1) GDPR as: *"Any information relating to an identified or identifiable physical person ('data subject') (i.e. not a legal entity); an identifiable physical person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person."*

The General Data Protection Regulation is not however, an impediment to the use of data, but instead boundaries and rules on how services can be developed, while at the same time keeping track of who has the right to access, copy, process, reshare and store what, from where/who and when. These rules were considered transversely in the Interconnect project and in the development of the services presented in this chapter.

In the case of electricity consumer's data, the main source of data are the smart meters, which can be complemented with other distributed monitoring devices such as Shelly monitors or sensors. At a consumer's home or commercial site this data can then be centralized at a HEMS/BEMS or EMS or communicated at a higher level. It is at this point when the boundaries of the systems are transposed here rules are required. To have access to consumers data, a consent has to be given. This then can be to provide anonymized or non-anonymized data.

There is not an actual definition of anonymization in the GDPR, but the requirements in recital 26 of the GDPR must be met for the data to be considered anonymized. The regulations state the following: *"The principles of data protection should therefore not apply to anonymous information, namely, information which does not relate to an identified or identifiable natural person or to personal data rendered anonymous in such a manner that the data subject is not or no longer identifiable."*

For the development of the observability services presented in this chapter 3, the main principle for GDPR compliance was in fact anonymization of consumers. There are, however, several anonymization techniques suggested by the GDPR that can be used as described below:

- **Randomisation** is a technique which is built on the alteration of the data. The purpose is to cut the link between the individual and the data, without losing the value the controller has of the data. This technique was used when assigning a random UserID or MeterID just for the sake of differentiation when a model is run. This was used in service 2 for the flexibility response, raking and reliability outputs.
- **Generalisation** is an approach to data use, and the purpose of this technique is to reduce the granularity of data, which will have the effect that we disclose lesser data regarding the data subject. By using this type of technique, makes it less likely that a consumer can be singled out. This technique can only work if we store multiple data subjects together. For example, a database storing the HEMS or smart meters from a given Postal Code/Grid Zone and not at a building level would generalise the location category. This was used in services 1 and 3 when choosing an area of observation or gathering of information for a specific geographic area where the grid is being observed. Whenever possible the aggregated data at a level of a secondary substation can also be used, which is another example of generalisation.
- **Masking** is a technique that often works as a supplement to different anonymization techniques. This technique builds on removing any obvious personal identifiers from the data. This was applied to all the services, namely not having the need for connection point code, addresses or names.

The next step tackle after data access is the data processing activity. The Processing is defined in Art. 4(2) GDPR as: *"Any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as collection, recording, organisation, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure or destruction."*

Where exactly the processing takes place, was considered in the design of the services and examples are provided in the next paragraphs. Of the same importance is the storage function (or archiving), which in the GDPR is defined as *"A secured storage of documents/data such that they are rendered inaccessible by authorised users in the ordinary course of business."* Also tackled in the development of the services and mentioned below.

The above-mentioned concerns, anonymization, processing and storing (the right to access, copy, process, share and store) were considered in the design of the services summarized in four approaches always prioritizing the minimization of data transfers and exposure:

- Decide if the service runs remotely or locally;
- Aggregated or disaggregated data usage;
- Distributed/centralized data processing;
- Data storage location.

Service 1 runs remotely and not at the DSO level. The data is queried by a data service provider under a set of triggering conditions (processing). This prevents the data to be transferred unnecessary, lowering the risk of breaches. Only the results of that processing are offered as a service to the DSO, which can store it at their side. Regarding aggregation, in service 1 the main variable under analysis is the voltage, hence it can be considered an aggregated value as no individual use or appliance can be monitored. Even though is it at an individual HEMS level, the triggering of a potential fault is done collectively with at least 3 units. The storage activity is located at the HEMS level.

Service 2 can run totally at the DSO level which mitigates any need to share data with the actual service provider. The DSO has in turn to obtain the data from a data service provider, which has to collect consent forms from the users it monitors. Being this the most individualised service, the interactions are kept only between the source of the data and the one who processes the data (the DSO). The storage of the data will be done at the DSO side as well. All unnecessary information regarding the user is cleared for the datasets/registries.

Service 3 uses disaggregated data in terms of load identification. It obtains the data through a data service provider (in charge of obtaining consents) from a set of HEMS on a given network. The model itself does not need to know the typology of the network, distances in relation to the secondary substation or in relation to other consumers. This service can provide an output, which can be accessed by third parties, such as Retailers, or Aggregators. In this case it will only provide processed data ranking of consumers, informing about opportunities to increase flexibility (promoting the installation of for example PVs, EV chargers, batteries) that could contribute to solve voltage violations. However, the storage of the processed data is at the DSO level.

Complying with the GDPR is not a one-off task. Concepts should be revisited, and the techniques chosen questioned to keep up with the technological advancements and any changes in the organization's practices. It is of the responsibility of each involved participant at each stage, to report any data breaches and to put in place the necessary corrective actions.

## **4.2 FORECASTING**

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This section details a two-fold perspective on the necessary forecasting calculations, which will happen during the execution of the demonstrations, and which directly affect the grid. On one hand, from the system operation perspective, there's the need to calculate the power flows to identify congestions in the time ahead, this is typically made within a couple of days in advance, or within intraday scenarios. On the other side, the Aggregator, acting as an FSP, also needs to consider the several assets which are being considered together for specific zone of the grid and, depending on the requested flexibility needs from the DSO, needs to estimate the available flexibility availability in the specific zone to submit



it to the DSO afterwards. As a couple of hundred of HEMS will be considered for this aggregation, communication mechanisms for the exchanging data with these systems shall happen.

#### 4.2.1 DEMAND SIDE FLEXIBILITY FORECAST

Energy assets can be monetised when forecasting data, such as consumption and/or generation, is calculated by the various service providers and when certain energy assets are actively flexible (e.g., able and ready to reduce load consumption in a time interval).

The new regulatory environment and high energy prices create a need for a smart and innovative ways of finding even smallest, possible flexible energy assets.

Here, the forecasting and being flexible is the key. Without the proper forecasting data, the monetisation cannot be performed in an optimal way.

Flexibility services are created by aggregating a high number of energy assets and their flexibility data. This creates a flexible asset that can then be offered to the following markets: balancing market - TSO, intraday market, or DSO market where flexibility is used to balance the power grid locally.

Flexibility services will be realized within the T7.8 – Overarching use-case, where CyberGRID will develop the SSA adapter, while utilizing the Interconnect framework, to enable flexibility data exchange.

The SSA will include exchange of the following data streams:

- **active power** (consumption or generation from energy asset or sub-aggregation)
- **baseline forecast** (load or generation forecast)
- **flexibility forecast including marginal costs** (available flexibility in positive or negative direction)
- **control signals** (active power continues or scheduled activation signals per energy asset or sub-aggregation)

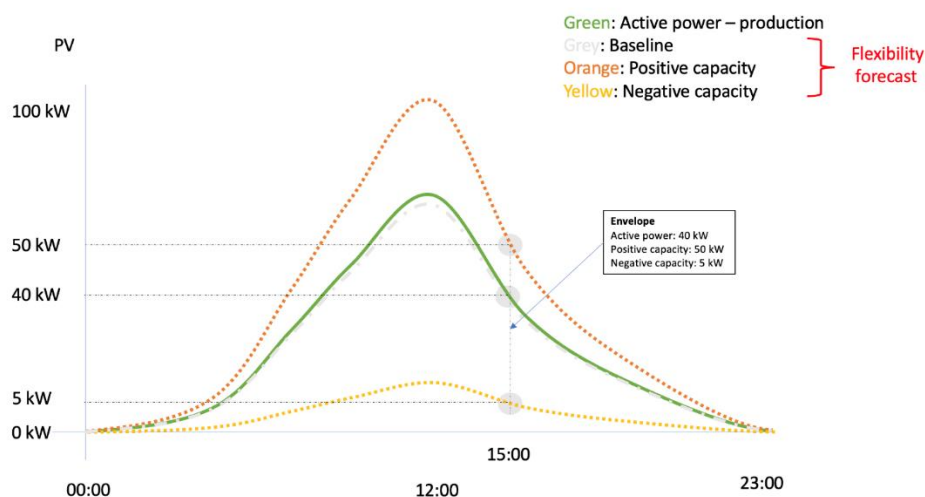
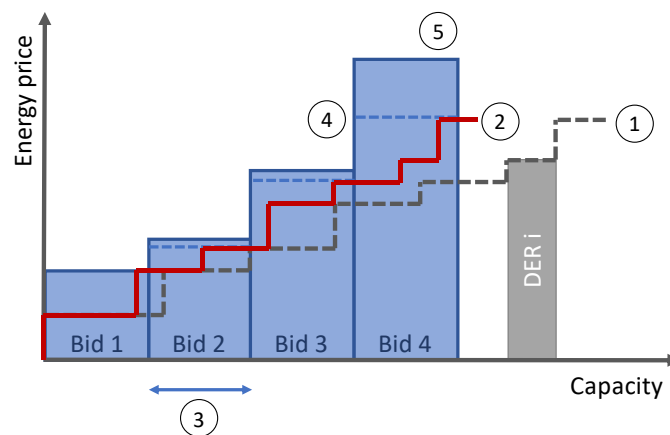


FIGURE 29: FLEXIBILITY SERVICE DATA STREAMS

When flexibilities are aggregated, flexibility offers-bids can more easily meet the market requirements. When cyberNOC (cyberGRID's product for flexibility management) is required to calculate the flexibility bids the following algorithm is performed on the portfolio of energy assets.





**FIGURE 30: FLEXIBILITY BID GENERATION**

The following steps are applied to the bid calculation:

### 1. Flexibility for energy asset

The bid calculation algorithm starts by requesting for the forecasted data for each energy asset

### 2. Reserve algorithm

Reserve algorithm is applied. There are 3 options:

- No reserve: no reserve is allocated
- Reduce capacity by a fixed percentage means to reduce the overall capacity of the group by x %.
- n-y algorithm means to remove the y units with largest capacity from the group

### 3. Sorting

The algorithm sorts the energy assets forecasted flexibilities according to the price (positive ascending, negative descending).

### 4. Bids

Based on the parameters of the algorithm (e.g., bid period is 1 h, bid size is 5 MW) it forms blocks of bids based on the selected rules (e.g., energy price or capacity prices is an average/min/max of the underlying units in the bid)

### 5. Revenue optimisation

As a final step, energy or capacity prices are modified by an algorithm to improve the revenues of the aggregation platform operator. This step depends heavily on the national market rules and behaviour of the other market players. Since the Interconnect demos only assume a simulated market, this step is not a significant aspect for the project.

If the submitted bids were accepted, the bids are put to a scheduler and are activated in the appropriate time automatically or manually (depends on the market requirements).

## 4.2.2 GRID CONGESTION FORECAST

There are different approaches to the grid congestion forecast exercise and a multitude of software to do it. In this section we focus on one approach since the goal is to describe this necessary step of

the flexibility provision process. Within the context of the Portuguese demonstration, 2 different time horizons for the calculation and communication of grid constraints will be tested:

- Day-ahead operation – Calculation of grid constraints for the next day. Calculations are done in advance and published until the 12 a.m. of D-1 and include all time frames for the following day (24h)
- Intraday operation – Periodic assessment of grid constraints. Calculations are done and published at least 6h in advance of the desired time frame.

The calculation of such flexibility needs will happen, as described in 3.3, resorting to the DSO network planning tool, using the topological information of the grid segment under analysis for the demonstrations, which in the case of the PT pilot, will happen in 5 distinct locations.

The network planning tool uses as input:

- Grid topology and network characteristics;
- Load and generation forecast for the timeframe under analysis.

If constraints are identified for the grid segments at the given timeframe, the network planning tool will be capable of calculating the amount of necessary power deviation to solve these constraints, both for congestion management and voltage control, following the form format below, which contains example values:

```
[
  {
    "requestId": "123e4567-e89b-12d3-a456-426614174000",
    "needs": 100,
    "measurementUnit": "kW",
    "direction": "Down",
    "typePower": "Active",
    "startTime": {},
    "endTime": {},
    "HEMSIds": [
      "i1",
      "i2"
    ]
  }
]
```

This information will then be sent to the flexibility management module of DSO interface, to allow for its communication to the respective registered FSPs which contain assets on the analysed grid zone.

## 4.3 NETWORK DYNAMIC TARIFF

There are several dynamic tariff service users, but no provider in the project ecosystem. The need for congestion management is a result of the weakening correlation between wholesale electricity prices and demand, which is caused by further uncertainties from renewables. Distribution Grid Capacity Market and Advanced Capacity Allocation could be alternative options for congestion management with different complexity, value, and risk in comparison with the dynamic network tariffs. Most EU Member States currently have a network tariff based on consumption used. Nevertheless, the consumption-based method may no longer be the relevant one to reflect the real network costs as they are caused by the required peak capacity.

## Distribution Tariffs within the CEP

Active customers, citizen energy communities and energy storage shall be subject to “cost-reflective, transparent and non-discriminatory network charges that account separately for the electricity fed into the grid and the electricity consumed from the grid”. Although there is not a one-size-fits-all distribution tariff model that could be appropriate for all Member States.

## Algorithm

Common types of dynamic tariffs are time-of-use (ToU), real-time pricing (RTP) and critical peak pricing (CPP) and can be defined to reflect network operating conditions. Tiers are used to model different levels within the tariff. There are several possible triggers to switch to another tier:

- Time trigger, changing the prices at certain points in time
- Power trigger, changing prices for specified power limits
- Energy trigger, changing prices for specified energy consumption in a given period (e.g., the first day of the month)

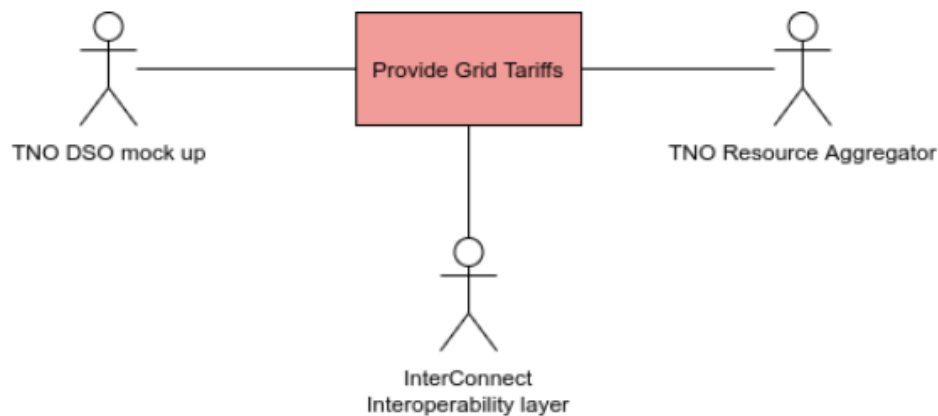
The operating state of the distribution grid is limited by the following operation constraints:

- Voltage limits (voltage quality),
- Thermal limits of cables & transformers,
- MVar bands (interface to TSO), or
- Protection settings.

DSO generates a time and grid-location dependent price for grid usage based on expected nodal consumption levels. The DSO shall forecast the size and the price-responsiveness of the load at threatening grid nodes and calculates the price to optimally reflect the predicted bottleneck problem. EMS of the community will then see a dynamic nodal tariff and an Energy Service Provider energy price to make an optimal schedule with respect to them. Designing dynamic network tariffs may use and designing the locational information associated to the bids the same for estimating future status of the network, forecasting potential technical problems.

1. Based on the learning from smart meters, DSO may build models for the price-elasticity of different demand types in the planning stage which could be updated on a regular basis (related to section 3.2).
2. In the operational planning stage, the predicted demand, grid state and present energy market prices will be employed to calculate appropriate branch prices for distribution grid utilization and is published to subscribers.
3. For settlement the relevant consumption data is gathered by the DSO and the published prices will then be employed to bill the actual grid usage individually.

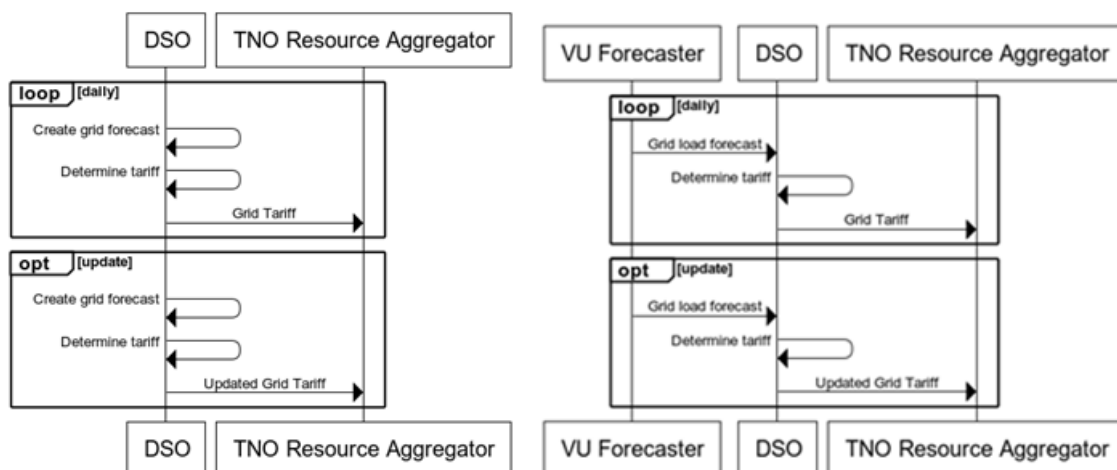
The theoretically optimal network tariff is the lowest tariff that would cause the controllable plus baseline demand to be just lower than network capacity. The Dutch pilot has the only use case of InterConnect in which dynamic grid capacity tariffs will be calculated by the simulated DSO of TNO and published on a daily basis to exploit the implicit flexibility of demand to shave the peak loading of the distribution grid. The diagram of this use case is presented in Figure 31.



**FIGURE 31: USE CASE DIAGRAM OF THE PUC8 (DYNAMIC GRID TARIFFS) IN THE DUTCH PILOT**

Two different scenarios are predicted in this use case for the calculation of Dynamic tariffs by the Simulated DSO as show in Figure 32:

- Grid load Forecast by external forecaster.
- Grid Forecast by the simulated DSO.



**FIGURE 32: DYNAMIC GRID TARIFFS CALCULATION SCENARIOS IN THE DUTCH PILOT**

**TABLE 16 - THE INFORMATION EXCHANGED FOR THE DYNAMIC GRID TARIFFS CALCULATIONS**

|               |                  |   |
|---------------|------------------|---|
| <b>Step 1</b> | Fetch forecast   | The DSO fetches a forecast (either being created by itself or from the forecast PUC, the latter is preferred) |
| <b>Step 2</b> | Determine tariff | Based on a day-ahead forecast, the DSO determines the next day grid capacity tariffs.                         |
| <b>Step 3</b> | Publish tariff   | The DSO publish the tariffs for the next day.   |

In step 1, via the PUC9 (VU forecaster) information are provided about the predicted, dynamic state of the grid, and more specifically, at what time(s) and at what position(s) in the grid are grid problem(s) expected to arise. In PUC10, a fixed power based on contract, but preferably a dynamic value is received from the (mimicked) DSO as a time series of values.

## 4.4 FLEXIBILITY SERVICES

The flexibility service implemented in the DSO interface is materialized into 3 different operational APIs which are used within the Day-ahead and Intraday timeframe, which are detailed in D4.2. This mechanism will provide a central service between the DSO and flexibility providers to facilitate the communication and coordination of all processes related to the mobilisation and procurement of flexibility bids. The APIs are the following:

1. (POST) /Flexibility/Subscribe
  - Enables *DSO -> Service Provider* communication:
    - (POST) Flexibility Needs (1)
    - (POST) Flexibility Activation Plan (3)
2. (DELETE) /Flexibility/Subscribe
  - Disables *DSO -> Service Provider* communication
3. (POST) /Flexibility/Offers (2)

The APIs are meant to be used in the (1)-(2)-(3) order. The first step, after the registration of the service provider, is to subscribe the communication of flexibility needs and activation plan by setting up the appropriate URIs on their side to receive these call back requests.

The APIs serve the following business purposes:

- *Flexibility Needs* (1) | DSO sends flexibility needs to the service provider
- *Flexibility Offers* (2) | Service Provider the flexibility offers to the DSO.
- *Flexibility Activation Plan* (3) | DSO sends activation plan to the service provider

Then, the communications are executed as follows:

- Day-ahead operation
  - *Flexibility Needs* | Periodic request, daily at 12pm - Needs for the 24 hours of the following day
  - *Flexibility Offers* | Until 4pm of D-1
  - *Flexibility Activation Plan* | Until 6pm of D-1
- Intraday operation
  - *Flexibility Needs* | Periodic requests, if needed at [12am, 6am, 12pm, 6pm] - for 12h starting at T+6h
  - *Flexibility Offers* | Until T-3h
  - *Flexibility Activation Plan* | Until T-2h

The DSO interface integration in the Interconnect semantic interoperability layer is accomplished through the development of a Service Specific Adapter, which will translate the previously defined API messages into semantic triplets. The integration with the interoperability framework will allow the interaction with the wider interoperable ecosystem, particularly when assembling the pilot demonstrations. This service specific adapter will then interact with the IC Generic Adapter (entry point into IC Interoperability Framework) to communicate with the semantic interoperability layer.

As depicted in section 2.1.2, within the scope of the Portuguese pilot, the flexibility related communication will happen between the DSO (E-REDES) and 3 different entities:

- **Cybergrid** – Flexibility provisioning from HEMS aggregation (up to 150 real household consumers in 5 locations)
- **Sensinov** – Flexibility provisioning through supermarket BEMS (12 locations)
- **Thermovault** – Aggregation of household dynamic control of water heaters (up to 150 households in 5 locations)

## 5. CONCLUSIONS

Some of the demonstrations within the InterConnect project aim at exploiting the framework and recommendations that are presented in the Chapter 3 of this deliverable and the services that are presented in the Chapter 4.

An example is the case of the Portuguese demonstration (T7.1) in which the DSO will leverage on the proposed improved mechanisms to observe the grid in a dynamic manner, using other devices than the smart meters. By making use of the Interoperability Framework proposed by the InterConnect project, the several connect HEMS can be constantly monitored for appropriate power supply, load levels and voltage levels. Therefore, issues happening on the grid, especially but not exclusively on the LV networks, can be quickly identified and corrected. This type of mechanism will ultimately benefit end customers. For example, in the case of an unexpected power loss, they can have the reposition of the electricity service faster and without triggering manual action on their own. However, specific caution should be taken when dealing with events coming from these data sources. For instance, the creation and testing of algorithms or multi-layered processes which are capable of identifying false positives can be triggered by other kind of events, such as a loss of connection of the internet service provider.

For the observability service 1 (4.1.1), as it is only dependent on data obtained from the HEMS to provide valuable inputs to the DSO, it has the potential to be easily replicable and exploited by other DSOs across Europe. This will be made possible by using the interoperability framework to provide the base communication and connection to the HEMS, which will ultimately allow for the SO to retrieve data in a dynamic manner from the HEMS itself. If successfully implemented, this could lead to an even more reliable and active grid management.

On the other hand, there are services (4.1.2 and 4.1.3) which the demonstrations aim to test but will be hard to convey into seamless replicable processes because they depend on sensitive operational DSO data, such as load consumption or grid topology. For these cases, the tools would still provide an advantage to the operators but the process for communication and deployment is more restrictive, for example, by using on-premises software running in internal systems. However, thereby the InterConnect Interoperability Layer ecosystem remains crucial to provide the means to retrieve HEMS related information and to allow the correlation with DSO internal systems, such as the SCADA and DMS.

As referred to in subchapter 4.4, the flexibility service will be implemented in the PT Pilot to allow for the execution of the processes related to flexibility provisioning to the distribution grid to solve predicted constraints. The flexibility will be provided by the household pilot participants, through home appliances and water heaters but also retail stores which have an active participation in the demonstration. The flexibility service will leverage the mechanisms stated in 4.2 for the calculation of respective grid requirements and availability forecasts in terms of resources.

For the network dynamic tariff service (4.3), there are several dynamic tariff service users, but no provider in the project ecosystem. Dynamic tariffs are not yet a reality for most DSOs and markets, but it is quite interesting to all DSOs and retailers. The dynamic network tariffs method should be implemented before the day-ahead energy bidding process of enterprises (if supported by regulatory provisions), while the flexibility market products could be used after the proposed energy schedules are formulated and congestions are predicted.

The respective dynamic data metering platform service has been tested and now the demonstration aims at validating that the data provided by DSOs on the platform. The goal is to enrich other partners' services and that those services can become useful for the consumer.

The current challenge is to replicate the utilisation of tools and improve scalability, so that they can contribute to a better integration of flexibility services in the system. Those tools will be implemented and enhanced by several demonstrators. They will be integrated into the reflections for guidelines and recommendations for the Flexibility Platform with flexibility enablers and associated constraints defined in D4.4.

## **5.1 CHALLENGES TO THE UPTAKE OF STANDARD/EQUAL SOLUTIONS FOR EUROPEAN DSOS**

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As demonstrated in this paper, the adoption of the DSO interface developed in the InterConnect project can bring various benefit to the DSO operations and enable some of the new roles foreseen for DSOs in the Clean Energy for All European Package (CEP). However, the more than 2000 European DSOs are at very different stages in terms of readiness to take on these new roles. For instance, while it is obligatory for DSOs to roll out the smart meters, some countries struggle to take the first step for instance due to technological issues (legal concerns for privacy) or economic issues (negative CBA for the smart meters at national level) while others are already operating third generation smart meters. This could potentially mean that, despite all possible benefits, achieving standardisation with regards to data requirements based on the smart meter may be challenging within the timeframe of the project.

As explained before, the DSO interface will set the ground for the mobilization and activation of flexibility for solving grid constraints. Amongst the requirements, the built interfaces shall be easy to integrate with to foster the highest number of entities being interested and effectively providing flexibility through connected resources. Even though typical REST API interfaces are currently one of the most streamlined ways to interlink systems, there are some advantages which can be identified if the IFA is leveraged for these specific mechanisms, such as the setup of a standard and commonly understandable way to communicate between parties, which might increase the number of available customers to participate in such processes, but also easily replicate the same process for additional regions/countries.

However, as mentioned in chapter 3, having services available in an interoperable and standardized way from the DSO side is not without challenges. Although not all data needs to be made available in an interoperable and standardized way a notable cost is related to the translation. This owes to the fact that digitalisation is still an ongoing process for DSOs, as for many other stakeholders, and that the expertise to carry out the translation may not exist within DSOs.

Furthermore, it should be taken into consideration that SAREF might not be able to provide added value to all operational fields of DSOs. It rather is an additional language to already existing models that focuses on interoperability with third stakeholders. The uptake of the SAREF based solutions by individual DSOs, especially in the short run, may very well depend on the extend of which SAREF is adopted by their external partners and thereby providing clear advantages in terms of interoperability. However, most actors in the energy system are experiencing the digitalisation in parallel to the DSOs and are as well in the midst of adapting their operations to this transition. Thus, considering that SAREF



was not initially developed for the DSOs, they might prefer to wait and see if the ontology is adopted as expected across the value chain before making the translation themselves.

An additional challenge concerns the implementation of GDPR. While the regulation level to ensure the rights of the consumers applies directly to all EU countries, the implementation of the rules at company differ notably. Changes touching upon such rules represent noticeable costs for DSOs. Therefore, it is important that any result proposed as a common solution also respects concerns related to the impacts on processes in place.

Finally, with respect to interoperability, it should be noted that the last decade has seen an increased interest for digital solutions. These concerns not only DSOs but all parts of the energy system and value chain.

## 5.2 NON-STANDARDIZED AREAS OF DSOS OPERATIONS

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Among the new responsibilities provided by the CEP to DSOs is the provision of flexibility services for managing the grid. As also explained previously in this report, the data from the smart meters will enable DSOs with better observability of their network and the potential to identify zones congestions or voltage violations. While a multitude of projects across Europe are investigating services and products that could respond to such needs of the DSOs, no common specification exists. This means that currently there is no European standard for data requirements to provide flexibility services.

Furthermore, it is assumed that flexibility products will be traded on liberal markets, however, there are no respective developed markets for now. Some countries have open flexibility markets at an experimental level, which might not even be national but rather stem from initiatives by individual DSOs. Consequently, there are no standards for market operations, e.g., bidding, activation and clearing. This trend is likely to lead to a very diverse landscape for both platforms and markets. For those with more advanced and implemented markets, it may be more difficult change to new, harmonized systems yet again.

Because of the missing or very premature state of flexibility markets, also definitions of certain actors and their corresponding responsibilities might have to be adjusted to the changing legislative environment. This is true for aggregators and to some extent for Energy Communities whose operations may even overlap with those performed by a DSO. While both roles are mentioned in the CEP, they are not equally implemented across member states and, in some cases, they are not yet defined in national legislations. Therefore, diversity in the definition of roles and responsibilities in the market will also need to be addressed to ensure the validity of the framework.