D3.7 - Final Spanish Demo report Results and Analysis of the Full-scale Demonstration

V1.0

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Author(s)	

José Pablo Chaves Ávila-Comillas
Luis Olmos Camacho-Comillas
Leandro Lind- Comillas
Anzhelika Ivanova – IREC
Jordi Farré - IREC
Miguel Pardo – e-Distribución
Daniel Davi – e-Distribución
Fernando David Martin – iDE
Carlos Ojeda – iDE
Oihane Barreiro - iDE
Alberto Gil – REE
Juan Julian Peiró - REE
Carlos Madina – Tecnalia
Maider Santos – Tecnalia
Nerea Ruiz – Tecnalia

Mattia Barbero – Bamboo Energy
Guillaume Leclercq – N-SIDE
Arnaud Debray – N-SIDE
Victoria Benjumeda- ONE

Reviewers

Epameinondas Floros– IPTO
Marios Sousounis- IPTO
Nicholas Etherden– Vattenfall

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Executive summary

This report presents the main results of the Spanish demonstrator of the CoordiNet project. The demonstrator consisted in paving the way to procure flexibility services using different alternative coordination schemes between Distribution System Operators (DSO) and Transmission System Operator (TSO). In particular, four main services were investigated: balancing, congestion management (both at TSO and DSO networks), voltage control (both at TSO and DSO networks) and controlled islanding (at DSO network).

Two demonstrator phases were developed to implement the ambitions of the project and the theoretical developments. Demo Run 1 was focused on testing the coordination schemes for BUC ES1a: Common Congestion Management, BUC ES2: Balancing for generation units and BUC ES4: Controlled Islanding. Demo Run 2 was focused on testing the coordination schemes for BUC ES1b: Local Congestion Management, BUC ES3: Voltage Control and BUC ES2: Balancing for demand units.

This deliverable aims at providing the main results and conclusions from both demonstrator phases, in particular on Demonstrator Run 2.

In the Spanish demonstrator, four system services, namely congestion management, balancing, voltage control and controlled islanding were tested. The services were tested under different coordination schemes. The congestion management was tested under the common and local market models, the balancing services under the central market model, the voltage control under the common market model and the controlled islanding under the local market model. Energy products were considered for congestion management and balancing, while both, energy and capacity products, were considered for voltage control and controlled islanding.

The FSPs in the Spanish demonstrator include distributed generation, demand response, and storage systems. The predominant type of FSP varies according to BUC and voltage level. When testing the common balancing and congestion management BUCs, wind farms, small hydropower plants and cogeneration were the main types of FSPs, as these BUCs focused on resources connected to HV levels. For BUCs tested in lower voltage levels, demand response, micrograds and storage systems were also used. That is the case of the islanding BUC, which used a combination of PV panels and a battery. The local congestion management market was composed primarily of micro-grid and demand response. About 300 MW and 20 FSPs were considered in the two demo runs of the Spanish demonstration.

To perform the demonstration, different platforms were developed and adapted as described below and presented in the Figure below.

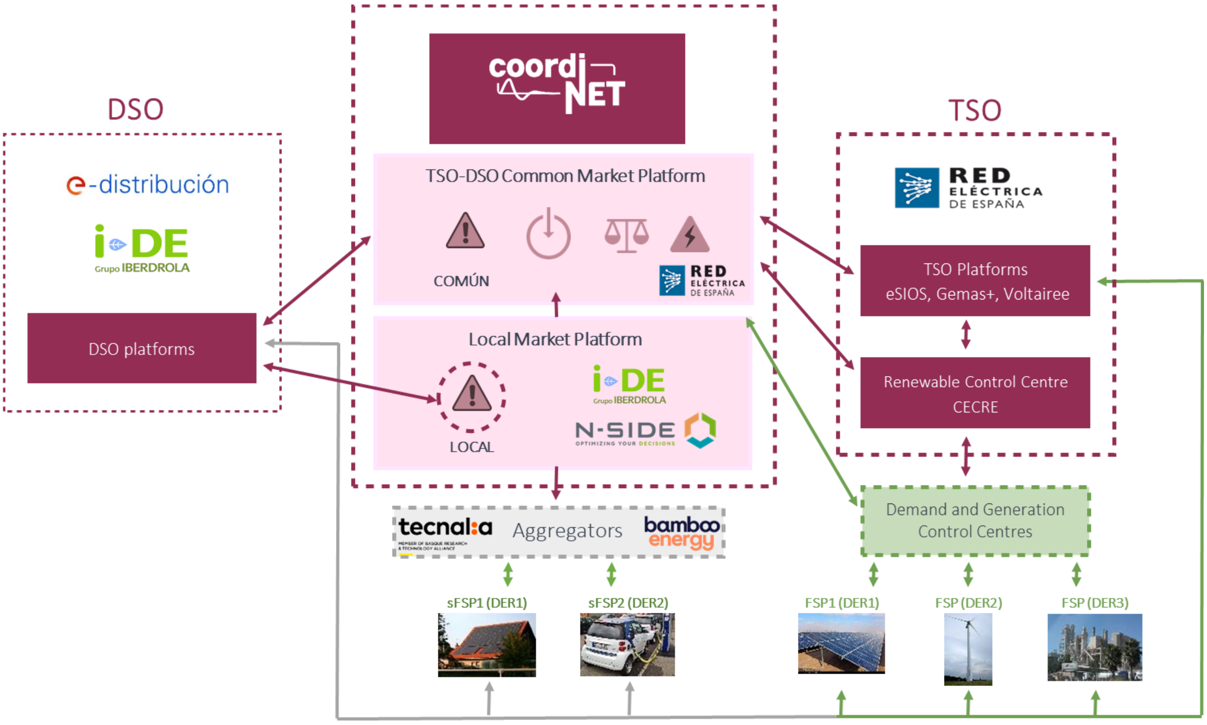

Figure 1 Platforms developed and adapted for the CoordiNet Spanish demonstrator

Adaptation of TSO platforms (part of the Common Market Platform):

- GEMAS+: this platform accounts for both congestions or balancing constraints. In CoordiNet, the platform was developed to allow the DSOs to input the network constraints and create a portfolio of units which solve congestions.
- e.SIOS: this platform performs the tasks of information and process management. It was updated to allow units providing demand response services to participate in the balancing markets. eSIOS platform was upgraded to deal with demand FSPs during the day-ahead Congestion Management Process.
- VOLTAIREE: this platform sends real-time setpoints to the providers connected to the transmission grid through their GCCs. DSOs can send their setpoints also to the GCCs or use VOLTAIREE as a gateway. VOLTAIREE receives from e.SIOS the reactive power capacity assigned to each provider in the market, validates each provider's compliance and sends to e.SIOS the penalties for imbalances.

New DSO platforms

- E-distribución
- Observability module: includes the forecasting, metering and checking of activation functionalities, which are essential for the correct operation of the Market module.

  Day-ahead DSO: sends the needs of distribution networks to different platforms. The platform also allows registering manual requirements or inputs from other DSO tools other than the observability module.

  Intraday DSO: checks the results computed in the market clearing, where the flexibility services can be traded.

  The communication module establishes all communications between the Local Platform, Common Platform, DSO tool, and market agents.

- I-DE

  Onesait Flexibility platform: aims to control and monitor FSPs which provide the long-term and short-term needs of the DSO

  Local market platform: simulates the local market clearing in the i-DE environment

New aggregators platforms:

- Tecnalia AggreFlex: implements the required functionalities to allow an aggregator of small-scale DERs to participate in common and local congestion management markets.
- Bamboo: offers a scalable and versatile platform for independent aggregators and retailers to efficiently manage distributed energy resources.

Local market platform: includes bid registration, registration of DSO needs, optimal market clearing without network constraints violations and publication of the matched trades.

The Spanish demonstration activities led to important conclusions with regards to the BUCs proposed and the tools implemented. The local flexibility market, for instance, proved to be effective in solving congestions for the DSO in a market way, procuring the flexibility from the assets in the network, clearly and transparently. The overall conclusion of the Demo Run 2 test results is that the proposed TSO-DSO coordination schemes for 'BUC ES1a Common Congestion Management', 'BUC ES1b: Local Congestion Management' and 'BUC ES3: Voltage Control' have proven to be suitable for the effective procurement of these flexibility services.

The development of the CoordiNet Spanish demonstrator also provides key insights for the steps ahead on different key topics to enable the provision of flexibility services by any asset connected to either transmission or distribution networks. These steps are: (i) TSO-DSO coordination schemes, (ii) new flexibility markets, (iii) new roles and activities, (iv) information exchange, and (v) entry barriers to markets. Figure 2 summarizes the different recommendations on those topics.

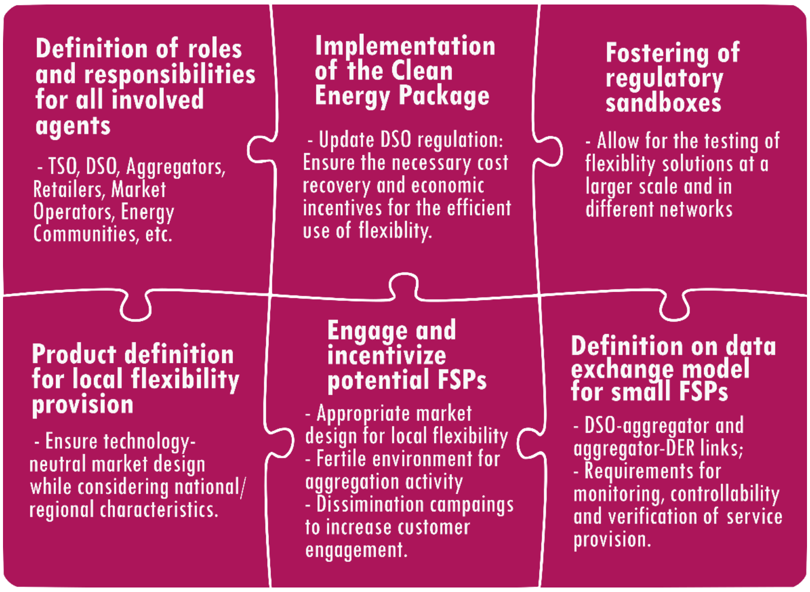

Figure 2: Spanish demonstration policy recommendations

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Notations, abbreviations and acronyms

Table 1: Acronyms list

Acronym	Definition
ASIDI	Average System Interruption Duration Index
API	Application Programming Interface
BaU	Business-as-Usual
BUC	Business Use Case
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CCM	Common Congestion Management
CECRE	Control Centre of Renewable Energies
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DFIG	Doubly Fed Induction Generator
DSO	Distribution System Operator
EB	Energy Box
EEE	Energía Eólica del Estrecho
EGP	Enel Green Power
EV	Electric Vehicle
FSP	Flexibility Service Provider
GCC	Generation Control Centre
GCT	Gate Closure Time
HVAC	Heating, Ventilation, and Air Conditioning
ICCP	Inter-Control Centre Communications Protocol
IREC	Catalonia Institute for Energy Research
IT	Information Technology
KPI	Key Performance Indicators
LV	Low Voltage
MARI	Manually Activated Reserves Initiative
mFRR	Manual Frequency Restoration Reserves
MQTT	Message Queuing Telemetry Transport
MV	Medium Voltage
NECP	National Energy and Climate Plans
NIEPI	Number of interruptions equivalent to power, according to the Spanish acronym
NRA	National Regulatory Authority
O&M	Operations & Maintenance
OPEX	Operating Expenditure

OPF	Optimal Power Flow
OVR	Optimised Voltage Regulation
P	Active Power
PCR	Point of Connection of the Resource to the network
PDBF	Day-Ahead Baseline Program, according to the Spanish acronym
PDVP	Day-Ahead Viable Program, according to the Spanish acronym
PEESA	Planta Eólica Europea, S.A
PESUR	Parque Eólico del SUR
PICASSO	Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PLC	Power Line Communication
Q	Reactive Power
REST	Representational State Transfer
R&I	Research and Innovation
REE	Red Eléctrica de España, Spanish TSO
SCADA	Supervisory Control and Data Acquisition
sFSP	Small Flexibility Service Provider
SGAM	Smart Grid Architecture Model
SO	System Operator
SRA	Scalability and Replicability Analysis
SVR	Secondary Voltage Regulation
TERRE	Trans European Replacement Reserves Exchange
TIEPI	Time of interruption equivalent to power, according to the Spanish acronym
TRL	Technology Readiness Level
TSO	Transmission System Operator
WACC	Weighted Average Cost of Capital
WP	Work Package
WS	Web Service

1. Introduction

1.1. The CoordiNet project

The CoordiNet project is a response to the call LC-SC3-ES-5-2018-2020, entitled "TSO – DSO – Consumer: Large-scale demonstrations of innovative system services through demand response, storage and small-scale generation" of the Horizon 2020 programme. The project is aimed at demonstrating how Distribution System Operators (DSO) and Transmission System Operators (TSO) shall act in a coordinated manner to procure and activate system services in the most reliable and efficient way through the implementation of three large-scale demonstrations. The CoordiNet project is centred on three key objectives:

1. To demonstrate to which extent the coordination between the TSO and the DSOs will lead to a cheaper, more reliable and more environmentally friendly electricity supply. This takes place through the implementation of three demonstrations at a large scale in cooperation with the market participants.
2. To define and test a set of standardised products and the related key parameters for system services, including the reservation and activation process for the use of the assets and, finally, the settlement process.
3. To specify and develop a TSO-DSO-Consumers cooperation platform, starting with the building blocks that are necessary for the demonstration sites. These components will pave the way for the interoperable development of a pan-European market that will allow all market participants to provide energy services, and opens up new revenue streams for consumers providing system services.

In total, ten demo activities were carried out in three different countries, namely Spain, Sweden and Greece. In each demo activity, specific products are tested in specific time frames and rely on the provision of flexibility by specific types of Distributed Energy Resources (DERs). Figure 3 describes an approach to identify (standardised) products, system services, and coordination schemes to incorporate them into the CoordiNet platform for the undertaking of the planned demo activities.

Figure 3: Overall CoordiNet approach: Services, timeframes, coordination schemes and products that are demonstrated in three countries (Spain in pink, Sweden in yellow, and Greece in grey)

1.2. Scope of the document

This deliverable, D3.7, assesses ex-post the second set of demonstration activities carried out in Spain and provides the conclusions and policy recommendations derived from the Spanish demonstration in the CoordiNet project[1]. This deliverable is a continuation of deliverable "D3.6 Analysis and results of real data from operation (Part 2)" (Ivanova et al. 2022). While D3.6 focuses on the description and results of each test carried out in Demo Run Two, as well as the calculation of the key performance indicators (KPIs), D3.7 discusses the processes carried out in Demo Run Two, highlighting the challenges ahead and the lessons learned during the second set of demonstration activities.

1.3. Document structure

This deliverable is organised around three main pillars of the Spanish demonstration, namely the (i) customer engagement aspects of the demo (ii) platforms developed, and (iii) the markets implemented.

Following this introduction, Chapter 2 provides a brief overview of the Spanish demonstration, focusing on the Demo Run 2 activities. Chapter 3 presents the main drivers and barriers of customer engagement in the Demo. Chapter 4 provides the final description of the platforms developed and used in the whole Spanish demo, including the local market and aggregation platforms first tested in Demo Run 2. Chapter 5 describes and discusses the markets developed and implemented through the demo, including both Demo Runs. Finally, Chapter 6 provides the main conclusions drawn from the demonstration activities and relevant policy recommendations from the Spanish demonstration perspective.

[1] For more information on the results and the analysis of the Demo Run 1, the reader is referred to CoordiNet Deliverables D3.4 and D3.5, respectively (Ivanova et al. 2021; Lind et al. 2022).

2. Spanish demonstrator and demo runs

This section briefly describes the demo tests that have been carried out by the Spanish demonstrator. It identifies the different demonstration sites, the resources available in each site, the flexibility products considered, and provides a brief description of the Business Use Cases, the platforms developed and used and the developments necessary to conduct the Spanish demo.

Renewable generation units considered are connected at the e-distribución, I-DE and REE networks at high, medium and low voltage levels. Demand-side resources considered are connected at the low and medium voltage networks at e-distribución in Malaga and the i-DE's ones in Alicante and Murcia. Cádiz and Albacete demo sites feature renewable generation, mainly wind power. In both locations, Voltage Control, Common Congestion Management and Balancing BUCs have been conducted. Given that most of the units of these types of resources already participate in markets, few specific developments need to be implemented to conduct the demos. However, voltage control is a new service for which the products and the market framework have been defined and agreed upon between the TSO and DSO recently. Figure 4 shows the locations, flexibility technologies, services, products and coordination schemes considered in the Spanish demo.

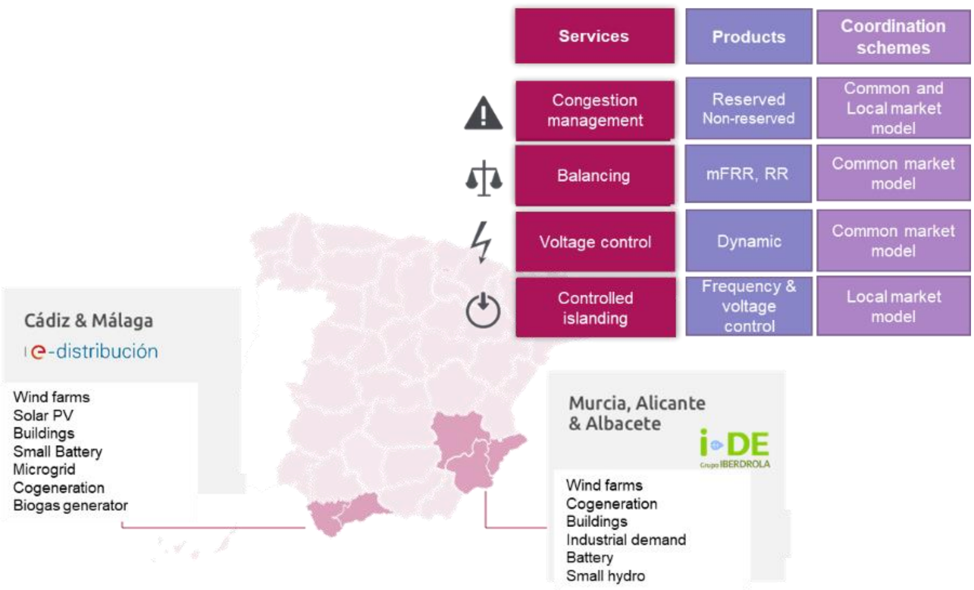


Figure 4 Spanish Demonstration Regions and Services

For each of the demo areas, the resources participating in the demonstration have been identified. This is the result of collaborative work to engage a significant number of FSPs in the project. The FSPs involved have performed tests and analyses to estimate the amount of flexibility they can provide and identify their requirements (e.g. controllability, communication) to provide services to the TSO and/or the DSOs in a coordinated manner, either directly or through aggregators. This task was constantly updated to reflect the changing circumstances and the constraints of each type affecting their participation in these markets that were not foreseen. Besides, the networks of the different demonstration locations are described here, including the location of resources, their topology, and their electrical characteristics.

Table 2 presents an overview of the FSPs participating in the two demo runs of the Spanish demonstration campaign.

Table 2: Number and size of FSPs per demo site

Demo site	Demo run 1		Demo run 2	
	Number of units	Capacity	Number of units	Capacity
Cadiz	5	103 MW	1	42 MW
Malaga	7	14.5 MW	8	15 MW
Albacete	7	143 MW	7	126 MW
Murcia	1	90 MW	2	90.8 MW

The systems and components employed also play an important role in enabling the testing of the CoordiNet solutions. In this regard, on the DSOs side, control systems were developed and a hardware device was deployed to monitor and control those flexibility providers that are connected to distribution networks. On the TSO side, some adaptations of the existing market platforms were carried out to facilitate, or even enable, the participation of the new types of DER (e.g. demand response), the provision of the products, and the implementation of the processes being demonstrated. In addition, the "CoordiNet Platform", as presented in CoordiNet deliverable D1.5 (Gürses et al., n.d.) had to be developed. This platform comprises two systems, one on the TSO side, namely the Common Platform, and the other on the distribution side, named the Local Platform.

The Products and services delivered in the Spanish demonstration have also been specified in D3.1 (Chaves Ávila et al., 2020). In Deliverable D1.3, a preliminary, theoretical, assessment of the possible products and services to be delivered is provided (Delnooz et al. 2019). The Local Congestion Management service had to be developed from scratch in the Spanish demonstration since this is not currently in place. All the steps described within the definition of the Business Use Cases for each of the actors involved (TSO, DSO, FSP and aggregators) had to be followed, as well. The local platform had to be implemented as well, including its clearing algorithms and its interaction channels with the actors. This platform should be used to handle both Local Congestion Management at the e-distribución and i-DE grids, as well as controlled islanding on i-DE's grid. Since e-distribución and i-DE had different needs, two separate local platforms were implemented: one developed by e-distribución and another by i-DE. Both platforms exchange data with the common platform, owned by the TSO.

A description of the main objectives of each BUC follows:

- BUC ES1a: Common Congestion Management. The main objective of this BUC is to procure flexibility, made available by FSPs connected to both the TSO and DSO networks, in a coordinated manner to solve temporary congestions that can occur in both networks. This BUC is tested in the demo sites in Cádiz, Málaga, Albacete, Alicante and Murcia, throughout the two demonstration phases.

- BUC ES1b: Local Congestion Management. The main objective of this BUC is to procure flexibility, made available by the resources connected to the DSO LV networks, to solve temporary congestions that can occur at the DSO LV networks. This BUC is tested in the demo sites in Malaga and Murcia. It is of main importance due to:
  - The local nature of the congestion in the network is addressed, given that the DSO may not have the full observability and monitoring capabilities of the grids affected.
  - Small flexibility service providers (sFSP) may face an entry barrier to participating in this service through the Common Congestion Management platform.
  - The proposed product is less complex, and has a shorter response time and a longer activation period if structural congestion, maintenance works and outages in the local network occur.

- BUC ES2: Balancing. The main objective of this BUC is to reduce the balancing cost (TSO perspective), while avoiding unforeseen technical problems (congestion or voltage) at the distribution level. This BUC is tested in the demo sites of Cadiz, Albacete and Alicante.

- BUC ES3: Voltage Control. The main objective of this BUC is to test a new product for voltage control aimed at solving voltage problems that occur in the TSO and DSO networks. This BUC will be tested in Cadiz, Albacete, Alicante and Murcia.

- BUC ES4: Controlled Islanding. The objective of this BUC is to assess the ability of the system to operate part of the distribution network in islanding mode during outages or programmed maintenance services. This BUC has been tested in Murcia.

Within the Spanish demonstration campaign, two demonstration phases have been organized: Demo Run 1 and Demo Run 2, while four Business Use Cases (BUCs), already mentioned, have been considered. Demo Run 1 focused on testing the coordination schemes for 'BUC ES1a: Common Congestion Management', 'BUC ES2: Balancing', and 'BUC ES4: Controlled Islanding'. Demo Run 2 focused on testing the coordination schemes for 'BUC ES1b: Local Congestion Management' and 'BUC ES3: Voltage Control'. In addition, it includes those tests for 'BUC ES1a: Common Congestion Management' that took place at the Malaga demonstration site.

The overview of the timeline of the Demo Runs 1[2] and 2 are given in Figure 5 and Figure 6, respectively. The figures below show when the different BUCs were tested, including which product was being tested in each period (day-ahead: D-1; RT: Real-time). Additionally, some BUCs were demonstrated in different periods (marked as Part 1, 2 and 3).

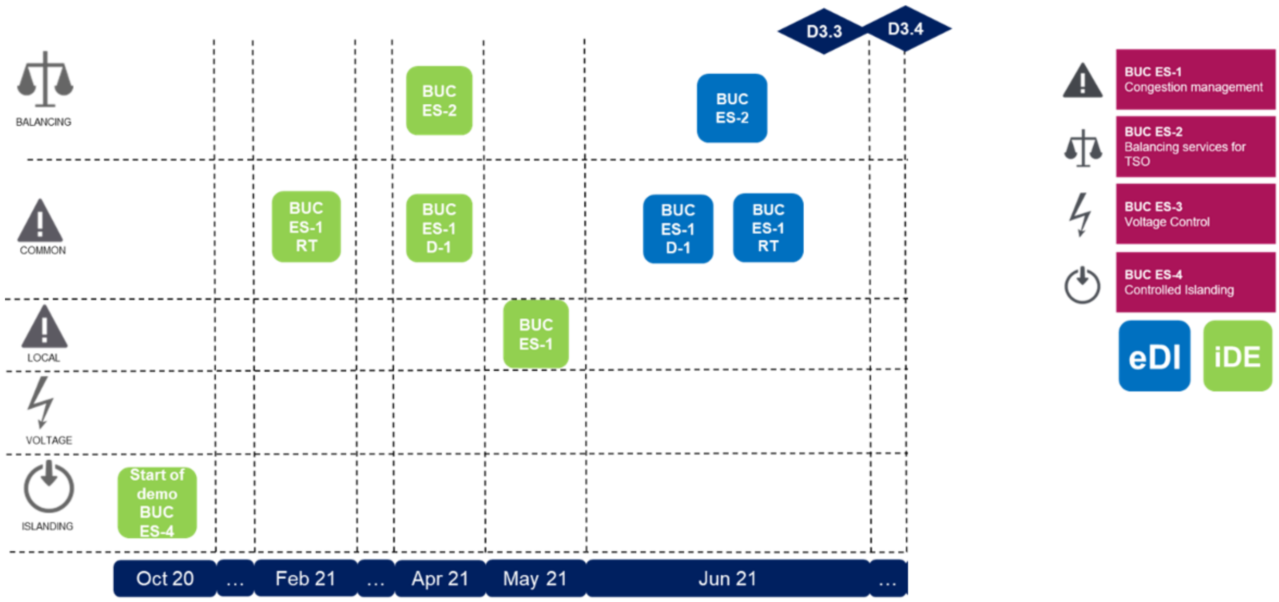


Figure 5: Demo run 1 timeline. Adapted from CoordiNet D3.4 (Ivanova et al. 2021).

[2] For more information on the results and the analysis of the Demo Run 1, the reader is referred to CoordiNet Deliverables D3.4 and D3.5, respectively (Ivanova et al. 2021; Lind et al. 2022).

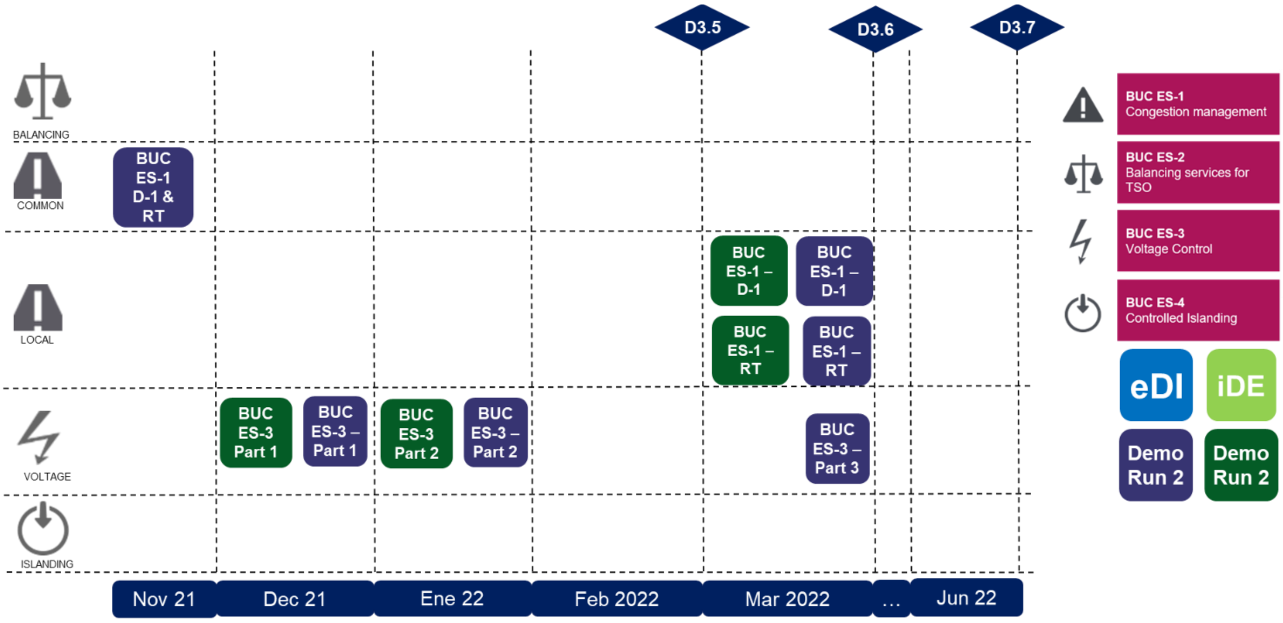


Figure 6 Demo Run 2 Timeline

The main focus of this deliverable is Demo Run 2, which started with preparations in M30. The first tests of this Demo Run were performed in M35 and concerned BUC ES1a, managed by e-distribución on the demonstration site in Malaga. These tests covered both the day-ahead and the near-real-time market timeframes. The main results from Demo Run 1 are presented in CoordiNet Deliverable 3.4 and 3.5 (Ivanova et al. 2021; Lind et al. 2022).

From M36 to M38, the BUC ES3 tests were carried out by e-distribución and i-DE on the demonstration sites in Cadiz, Albacete and Murcia, respectively.

The last tests carried out were the BUC ES1b tests, undertaken by both e-distribución and i-DE in M40 (April 2022).

3. Customer engagement

The FSPs involved in the Spanish demonstration are both CoordiNet project partners and external stakeholders. The project partner FSPs were mostly distributed generation, while the external stakeholders were primarily demand-side resources. Involving FSPs who were not project partners was foreseen as a challenge from the beginning of the project. To make their participation in balancing and congestion management markets possible, technical prequalification requirements had to be established. The main engagement strategy that took place in the Spanish demonstrations was to include the option for FSPs to apply to the CoordiNet project's Cascading Funds. This way, the FSPs would be able to upgrade their current infrastructure to fulfil the technical prequalification requirements, which enabled their participation in the demonstrations. This turned out to be one of the most important incentives for FSPs to participate in the demonstration.

The sites in Cadiz and Albacete already involved RES, mainly wind power, and therefore test voltage control, common congestion management and balancing BUCs. Most of the generation units currently already participate in markets, which reduces the amount of required specific developments to be able to participate in the Spanish CoordiNet demonstrations. Yet, voltage control is a new service which was developed through Coordinet, but is yet not an existing market, thus needed to be developed by the TSO and DSO within the project. Moreover, FSPs with generation resources applied for the Cascading Funds. The CoordiNet call for expression of interest was published on the CoordiNet website (https://coordinet-project.eu/) on May 15th, 2020 and closed on October 30th, 2020. A total of 6 eligible proposals from 5 FSPs were received for this call. These proposals would receive funding for a total amount of 142 000 EUR.

The FSPs who received cascading funding are placed in five different locations:

- Malaga: Customers connected to MV or LV grid in the areas Centre of Malaga, Industrial Park Guadalhorce, Cadiz Road District and Campanillas.
- Cadiz: Customers connected to MV grid in the province of Cadiz.
- Alicante: Customers connected to 132kV >1MW in the province of Alicante.
- Murcia: Buildings connected to MV or LV grid located around Abenarabi Street in Murcia City, or buildings connected to LV around Plano de San Francisco Street in Murcia City or large-scale cogeneration near La Aljorra (Murcia).
- Albacete: Renewable generation or cogeneration in the province of Albacete

The FSPs involved have performed tests and analyses to estimate the amount of flexibility they can provide and identify their requirements (e.g. controllability, communication) to provide services to the TSO and/or the DSOs in a coordinated manner, either directly or through aggregators.

3.1. Participating stakeholders

Interviews with the FSPs that participated in the demonstration were conducted. A deep analysis of the interviews and their outcomes is provided in deliverable D6.6, and some key points are highlighted here, as follows.

The potential flexibility of some resources participating in the demonstration were contacted at the beginning of the project, finally formalizing their participation at the early stages of the project (also considering that some FSPs were supported by the Cascading Funds). The resources considered in the Spanish demo include both generation and demand, such as wind projects, solar power generators, cogeneration plants, biogas, storage, and demand-responsive loads. The demand-side resources considered are connected to the low and medium voltage networks belonging to e-Distribución, in Malaga, and to i-DE in Alicante and Murcia.

Several types of barriers emerged in FSPs' participation in flexibility markets, including technical and regulatory barriers, internal barriers, and communication barriers. Regarding the regulation and the type of FSP (e.g. demand-response, distributed generation), FSPs encountered barriers related to the fact that the type of FSP was not able to participate in the flexibility market due to the current regulation. For instance, current regulation in Spain does not allow for certain types of FSPs (e.g. small demand-response units) to participate in Balancing, Congestion Management, and Voltage Control Additionally, for units that can participate (e.g. distributed generation), certain communication and control devices are required, meaning that upfront investments are necessary.

The internal barriers are mostly barriers related to the lack of commitment shown by the FSPs to provide flexibility, as well as to the roles involved in the development of flexibility provision capabilities in their organization. These barriers are a result of the FSP´s lack of knowledge about the flexibility markets' advantages. Understanding the value of flexibility is a complex task if the core business of the company is not the energy sector. There are not enough resources dedicated to understanding and communicating the economic advantages of providing flexibility.

The FSPs largely complained about the fact that there is no clear communication from the market on when the market timing for each service. Also, participants seemed to be risk-averse regarding flexibility provision, especially the high intensive energy consumers, due to their dependence on the volume of energy consumed for their core businesses.

Regarding the strategies followed for customer engagement throughout the project, the Spanish demo wanted to put focus on including demand-side resources on common and local platforms. Therefore, the main engagement strategy implemented in the Spanish demonstrations for FSPs to participate and strengthen their engagement was including the option for FSPs to apply to the CoordiNet project's Cascading Funds.

In this way, the FSPs would be able to upgrade their current installations to fulfil the technical prequalification requirements, which also enabled their participation in the demonstrations, which was deemed to be one of the most important incentives provided to the FSPs when defining the customer engagement strategy at the beginning of the project.

The sites in Cadiz and Albacete already host some RES generation, mainly wind power. This facilitates the process of testing within the voltage control, common congestion management and balancing BUCs. Currently, most of the generation units participate in markets, which reduces the amount of required specific developments to implement the concerned BUC. Yet, voltage control is a new service for which there is a need by the TSO and the DSO to still design the product and the market necessary. Therefore, also those FSPs with generation resources applied for the Cascading Funds.

Through the interviews held, the FSPs have provided recommendations on the market design, based on their experiences in the demonstrations. For example, regarding the technical aspects, they stressed the importance of improving the monitoring and measurement processes to facilitate their participation in the flexibility markets. The FSPs interviewed expressed their view that it would be valuable for the potential service providers to know more about the service in advance. Besides, some FSPs expressed the view that third-party service providers, which are responsible for the integral management of the energy facilities, would help develop the flexibility market.

Several more recommendations were given by the FSPs to improve the market and the future pilot projects. As aforementioned, these are discussed in deliverable D.6.6.

3.2. External stakeholders' interactions

To obtain relevant feedback on the soundness of the design of the flexibility market considered in the project, an FSP workshop was organized in Madrid in March 2022. In this event, FSP associations and other FSPs were invited to participate. The results from the Spanish demos were shared with the audience, and discussions were held to report their input. More information regarding this event, the questions addressed to the external FSPs and the points raised by them are available in CoordiNet Deliverable D6.6.

The insights from these interactions are summarized below.

As many as 63% of the FSPs (9 in total) knew about the CoordiNet project. Most of them, 67,7%, learnt about it through references from other professionals.

As many as 75% had participated in flexibility projects before, such as HESTIA, Flexiciency, Flexderms Posytif, Demand response, and projects internally in their company.

About 75% expressed the intention to participate in a flexibility market in the future. From these, 40% answered that they would participate in balancing services and local markets-DSO. Only 20% answered they would consider participating in common TSO-DSO congestion management markets.

As many as 67% said that they could offer demand response services, while 22% could offer flexibility in generation, and the remaining external FSPs could deliver flexibility with batteries.

As many as 83% expressed they could offer more than 5 MW of flexibility, which shows most of them are large consumers and generators. Only 17% could offer less than 100 kW.

Regarding the main drivers for participating in the flexibility market:

- As many as 87% of the respondents stated that economic benefits were the main driver for their participation in the market. Besides, 71,4 % of them expressed that it would be beneficial for them to earn payments both for activation and availability.
- Over 62% stated that incrementing their knowledge about the flexibility markets is one of the main drivers of their participation. Specifically, assessing the amount of flexibility provided is seen to be a challenge.
- Only 25% stated that environmental awareness and contributing to the energy transition was the main driver of their participation in the market.

Regarding the main barriers that hinder the participation of FSPs in flexibility markets, the main feedback received follows:

- As many as 62,5 % of the FSPs stated that high entry barriers (e.g. high initial investment) were one of the main obstacles to entering the market. About 50% of the external FSPs indicated that their participation in flexibility markets could impact their main business activity, and the complex prequalification process was the main barrier.
- More than 37% stated that regulatory restrictions were a relevant barrier.
- Also, lack of knowledge about the market and price volatility were mentioned as relevant barriers.

Regarding the changes that could be made to the flexibility markets to improve their functioning, different proposals were made. They include lowering the regulatory requirements to participate in the market, lowering the entry costs, making the monitoring and control of buildings compulsory, providing these markets with stronger institutional support, and defining and implementing a strong economic signal related to the provision of flexibility in markets. Specifically, it was brought up that industrial demand has a high potential to provide flexibility. However, further encouraging these consumers to participate in flexibility markets requires providing them with the means to ensure that their participation does not negatively affect their main business activity.

Overall, the FSPs indicated they had limited knowledge about the products traded in the flexibility markets. This shows that the flexibility of markets and products are not sufficiently explained.

- About 50% of the FSPs were familiar with the local congestion management services and products.
- Only about 37,5% of them were familiar with the products related to voltage control and technical restrictions not involving the provision of power reserve.
- Only 25% of them knew about the controlled islanding services and products.

4. Platform development

This section presents the platforms developed in CoordiNet Spanish demonstrator and the interactions and adaptation with existing platforms. To perform the demonstration, different platforms were developed and adapted as described below and presented in Figure 7.

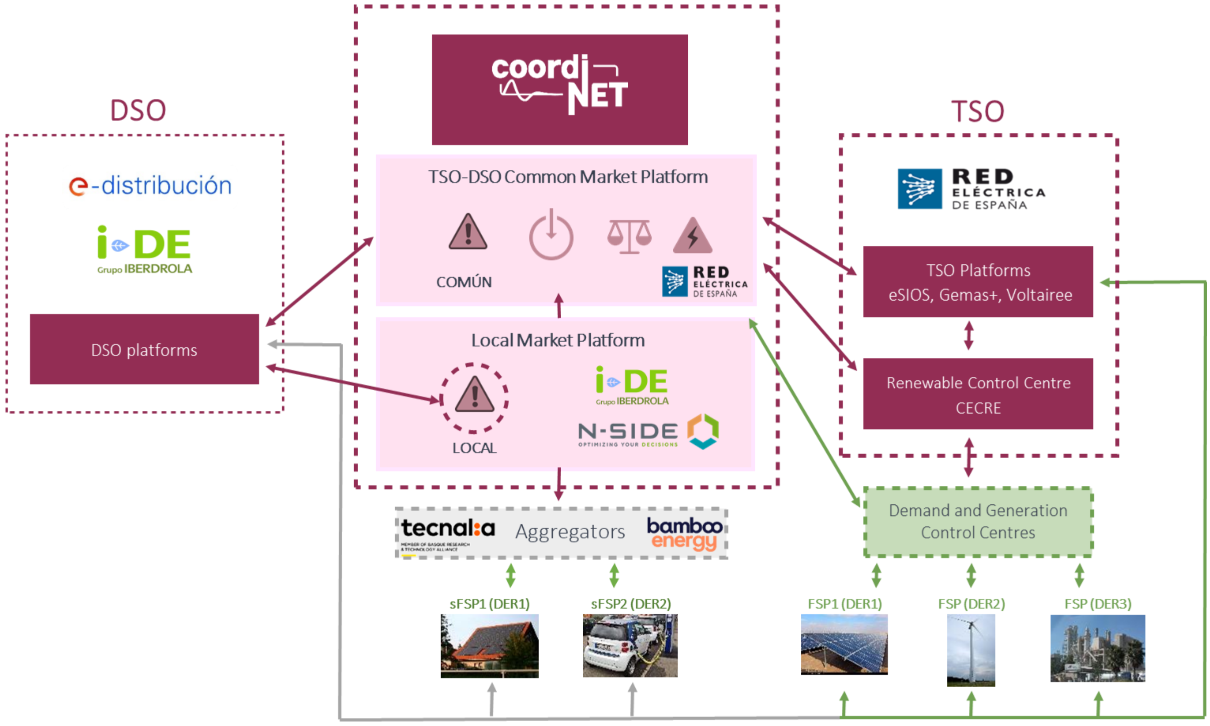


Figure 7: Platforms developed and adapted for the CoordiNet Spanish demonstrator

4.1. DSOs platforms

4.1.1. e-Distribución

4.1.1.1. Overview of the DSO Platform

e-distribución built a DSO Platform which has four main modules: i) Day-ahead DSO, ii) Intraday Operation DSO, iii) Observability and iv) Communication, as depicted in Figure 8.

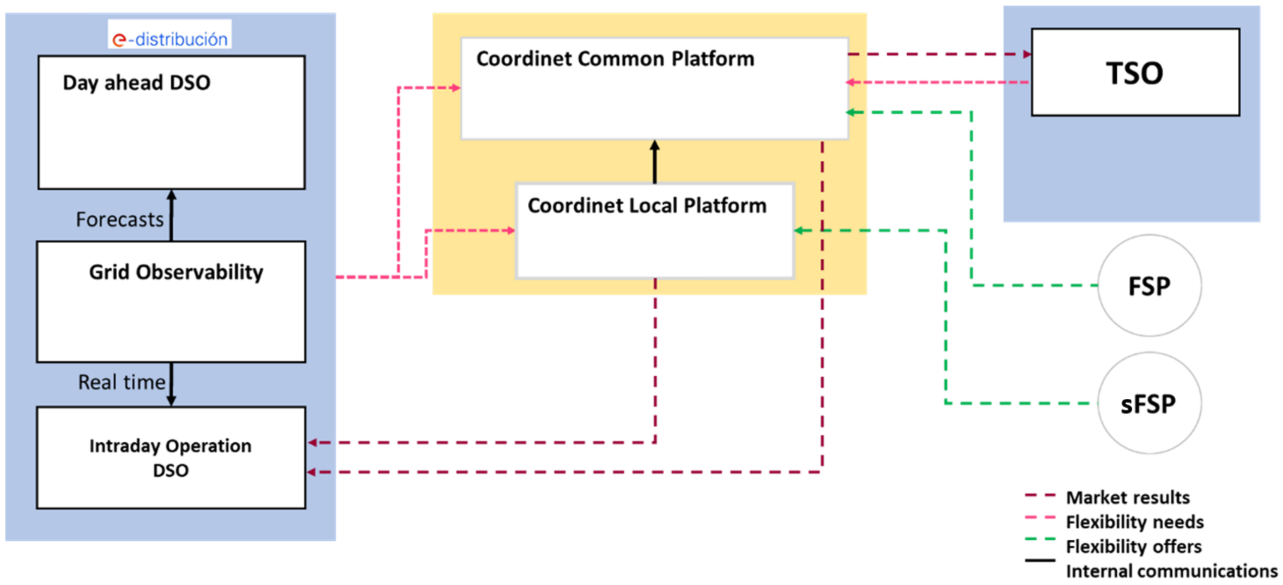


Figure 8. Schematic view of the different agents

The main modules developed in the framework of the CoordiNet project are briefly described in Table 3.

Table 3. DSO (e-distribución) tool. Brief description

Tool name	Brief Description	New	Adapted
Day-ahead DSO	This module is in charge of sending the needs of distribution networks to different platforms. The platform also allows registering manual requirements or inputs from other DSO tools other than the observability module (described below).	x	
Intraday DSO	The Intraday Operation module is in charge of checking the results computed in the market clearing, where the flexibility services can be traded.	x	
Observability	This module is related to the grid's operation. It includes the forecasting, metering and checking of activation functionalities, which are essential for the correct operation of the Market module.	x	
Communication	This module is responsible for establishing all communications between the Local Platform, Common Platform and the DSO tool.	x	

The description of these modules is briefly described below (a detailed description of the modules can be found in CoordiNet Deliverable D3.2:

1. Day-ahead DSO: This module is in charge of estimating the needs of the distribution network for the different BUCs and sending these needs to the different platforms (CoordiNet Common Platform and CoordiNet Local Platform). Different submodules will be operating depending on the BUC. Four submodules will be used: i) Common Congestion Management module, ii) Local

Congestion Management module, iii) Security Check Balancing module and iv) Local Voltage Control Module. Figure 9 shows an overview of the module inputs and outputs.

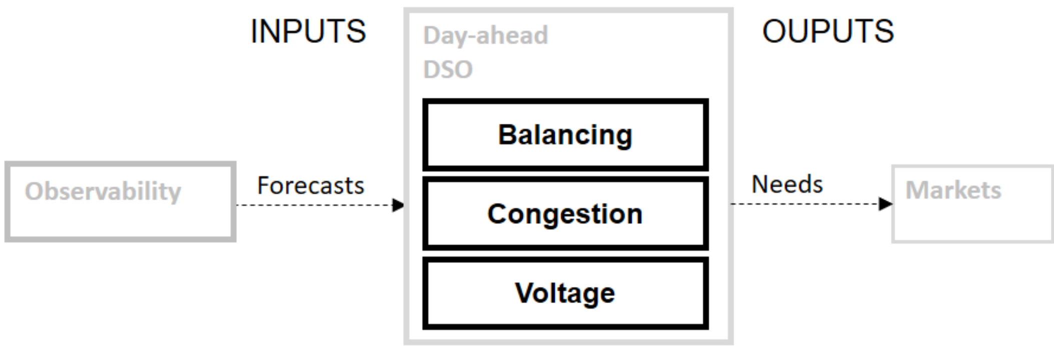


Figure 9. Day-ahead module structure in the DSO tool developed by e-distribución

2. Intraday Operation DSO: The Intraday Operation module receives the results computed in the day-ahead market clearing and sends new needs to the intraday markets. This module is shared by four functionalities: "Local Congestion Management", "Common Congestion Management", "Local Voltage Control", and "Security Check Balancing". An overview of the module inputs and outputs can be seen in Figure 10.

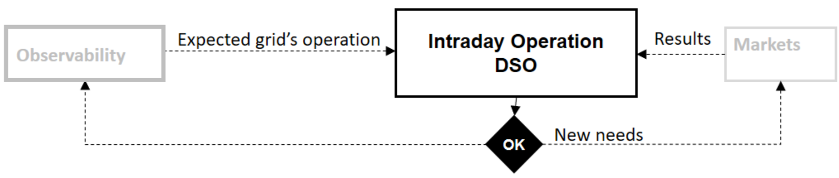


Figure 10. Intraday module structure in the DSO tool developed by e-distribución

3. Observability: This module is related to the grid operation. It includes the forecasting, metering and checking of activation functionalities, which are essential for the correct operation of the Market module, as depicted in Figure 11. To estimate the expected grid operation and the amount of flexibility that needs to be activated, two forecast models have been developed: one related to generation, and another related to consumption. This functionality is in charge of executing all forecasting models. The consumption of the participants in the Local and Common Platforms is not forecasted by the Observability module, but participants must send their consumption baselines before presenting a bid. These consumption baselines are received from Common and Local Platforms, together with the market results. These baselines are used as forecasts by the Observability module. However, the total consumption of the grid includes the consumption of clients who do not participate in the Local and Common Platforms or do not send valid forecasts, for which consumption must be forecasted. To do these forecasts, the network's measurements (active and reactive power) are retrieved from the e-distribución database and stored in the DSO Platform. Forecasts are done using historical data.

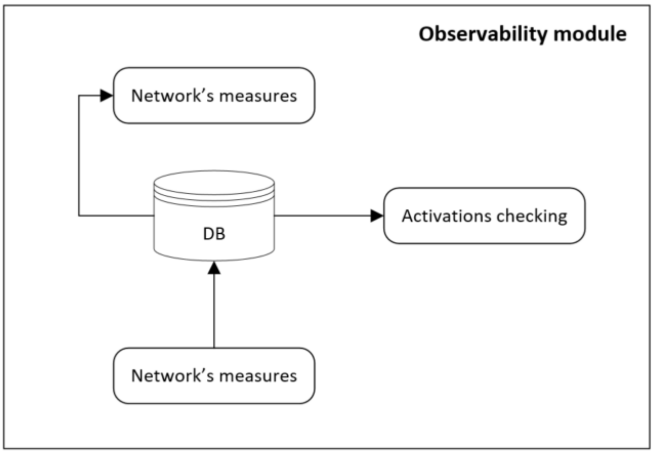


Figure 11. Observability module structure in the DSO tool developed by e-distribución

4. Communication: This module is responsible for establishing all communications between the Local Platform, the Common Platform, the DSO Platform and e-distribución's Control Centre:
   a. Communications with the Local Platform: This module is in charge of communicating with the CoordiNet Local Platform. The communication with the CoordiNet Local Platform should be able to deal with the following actions:
      i. Add/edit/remove the network representation in the database (for the DSO).
      ii. Add/edit/remove bids from the database (for DSO and the aggregator).
      iii. Launch a clearing market process (for the market operator).
      iv. Ask for the market-clearing result (for the DSO, the aggregator, the Common Platform and the market operator).
   b. Communications with the Common Platform: This module is in charge of the communications with the CoordiNet Common Platform. The communication with the CoordiNet Common Platform should be able to deal with the following actions:
      i. Add/edit/remove congestion bundles to the CoordiNet Common Platform.
      ii. Get the confirmation of acceptance/modification of the congestion bundles.
      iii. Add limitations to the FSPs to the CoordiNet Common Platform.
      iv. Add/edit sensitivities of the FSPs to the CoordiNet Common Platform.
      v. Add/edit voltage limits.
      vi. Send voltage setpoints to the FSPs connected to the DSO network.
      vii. Ask for the market-clearing result (Market programs (PDBF, PDVP…)).
   c. Communications with e-distribución's Control Centre: There is a need to communicate with the e-distribución Control Centre to gather real-time data measurements (active and reactive power, voltage and current) of the Málaga and Cádiz demonstrators.
   d. Communications with the DSO Platform: In addition to the "computer-to-computer" communication interfaces described above, a graphical representation, "computer-to-human" interface, has been developed (dashboards). An interactive GUI has been developed to allow the DSO Platform operator to visualise the operation and change the configuration parameters and start/stop some of the modules of the DSO Platform.

The details of the tests performed can be found in CoordiNet D3.6.

4.1.1.2. Obtained results

4.1.1.2.1. Demo run 1

COMMUNICATION TEST

CADIZ

BUC ES1A: COMMON CONGESTION MANAGEMENT

The deployed communications between the DSO and the TSO (CoordiNet Common Platform) worked properly to allow the participation of both in the BUC ES1A: COMMON CONGESTION MANAGEMENT, since all the required messages were correctly exchanged.

BUC ES2: BALANCING

The deployed communications between the DSO and the TSO (CoordiNet Common Platform) worked properly to allow their participation in the BUC ES2: BALANCING, since all the required messages were correctly exchanged.

MÁLAGA

BUC ES1A: COMMON CONGESTION MANAGEMENT

The deployed communications between the different stakeholders listed next worked properly to allow their participation in the BUC ES1A: COMMON CONGESTION MANAGEMENT, since all the required messages were correctly exchanged:

- DSO and TSO (CoordiNet Common Platform)
- Aggregator and TSO (CoordiNet Common Platform).
- AGGREGATOR and FSPs.

BUC ES1B: LOCAL CONGESTION MANAGEMENT

The deployed communications between the different stakeholders listed next worked properly to allow their participation in the BUC ES1B: LOCAL Congestion Management, since all the required messages were correctly exchanged:

- Aggregator and CoordiNet Local platform.

PREQUALIFICATION TEST

Regarding the 'BUC ES1a: Common Congestion Management' and the 'BUC ES2: Balancing' in the Cádiz scenario, the FSP units had already been prequalified by the SO, since they already participate in the provision of these services. Therefore, no prequalification process is needed to perform the BUCs tests.

BUC TESTS

CADIZ

BUC ES-1A: COMMON CONGESTION MANAGEMENT

The Common Congestion Management demos have been correctly performed in Cadiz. The developments and modifications in the DSO Platform and the CoordiNet Common Platform needed to perform the demos in this BUC have been correctly deployed. For this BUC, in the 6 demos performed it has been demonstrated that the DSO can define and apply limitations on the FSPs generation or consumption level in coordination with the TSO, to solve congestion in the distribution network. The figures below show an example of one of the demos performed: the congestion detection by the DSO; the definition of the FSP's limits by the DSO;

the application of this limitation on the FSP by the SO; and the application by the FSP of this limitation on the resources it manages.

Figure 12 shows the DSO Platform where the DSO detects congestions.

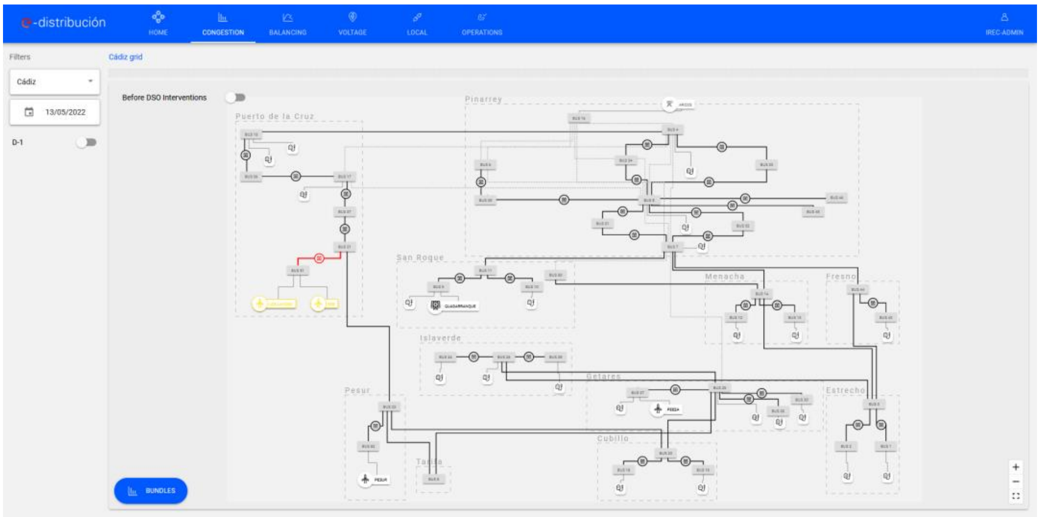


Figure 12 DSO Platform capture of the congestion in the Puerto de la Cruz Substation - CADIZ CCM CASE 4

Figure 13 shows a capture of the DSO Platform of the RT bundle creation (FSP Limitation sent to the Coordinet Common Platform).

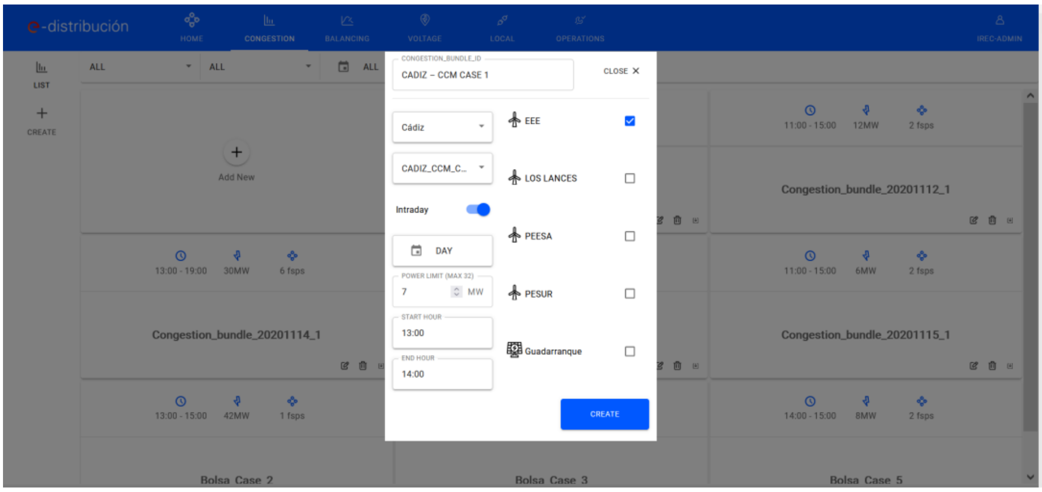
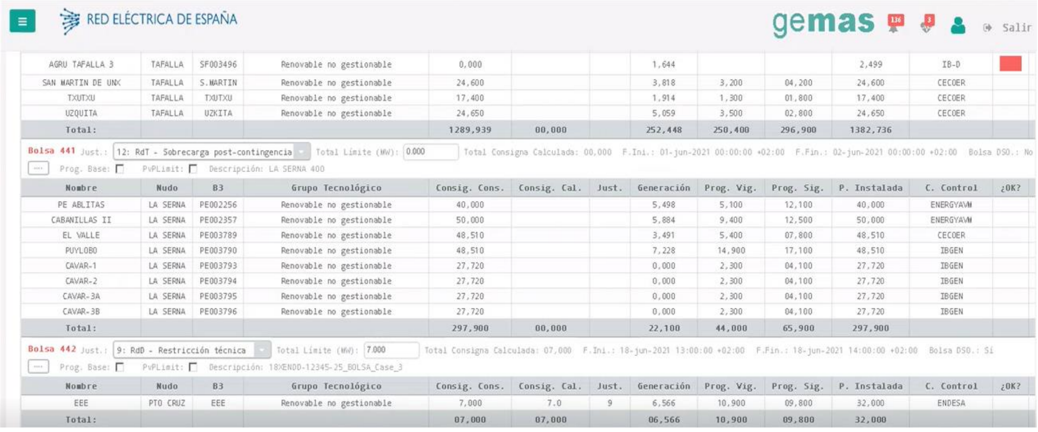


Figure 13 DSO Platform capture of the RT bundle creation - CADIZ CCM CASE 4

Figure 14 shows a capture of the GEMAS Platform (Coordinet Common Platform) where it can be seen that the bundle created by the DSO Platform has been correctly received and taken into account in the RT technical constraints process run by the SO. The limitation created by the DSO is sent to the FSP in RT.



RED ELÉCTRICA DE ESPAÑA — gemas — Salir

AGRU TAFALLA 3	TAFALLA	SF003496	Renovable no gestionable	0,000			1,644			2,499	IB-D	
SAN MARTIN DE UNX	TAFALLA	S.MARTIN	Renovable no gestionable	24,600			3,818	3,200	04,200	24,600	CECOER	
TXUTXU	TAFALLA	TXUTXU	Renovable no gestionable	17,400			1,914	1,300	01,800	17,400	CECOER	
UZQUITA	TAFALLA	UZKITA	Renovable no gestionable	24,650			5,059	3,500	02,800	24,650	CECOER	
Total:				1289,939	00,000		252,448	250,400	296,900	1382,736		

Bolsa 441 Just.: 12: RdT - Sobrecarga post-contingencia Total Límite (MW): 0.000 Total Consigna Calculada: 00,000 F.Ini.: 01-jun-2021 00:00:00 +02:00 F.Fin.: 02-jun-2021 00:00:00 +02:00 Bolsa DSO.: No
Prog. Base: PvPLimit: Descripción: LA SERNA 400

Nombre	Nudo	B3	Grupo Tecnológico	Consig. Cons.	Consig. Cal.	Just.	Generación	Prog. Vig.	Prog. Sig.	P. Instalada	C. Control	¿OK?
PE ABLITAS	LA SERNA	PE002256	Renovable no gestionable	40,000			5,498	5,100	12,100	40,000	ENERGYAVM	
CABANILLAS II	LA SERNA	PE002357	Renovable no gestionable	50,000			5,884	9,400	12,500	50,000	ENERGYAVM	
EL VALLE	LA SERNA	PE003789	Renovable no gestionable	48,510			3,491	5,400	07,800	48,510	CECOER	
PUYLOBO	LA SERNA	PE003790	Renovable no gestionable	48,510			7,228	14,900	17,100	48,510	IBGEN	
CAVAR-1	LA SERNA	PE003793	Renovable no gestionable	27,720			0,000	2,300	04,100	27,720	IBGEN	
CAVAR-2	LA SERNA	PE003794	Renovable no gestionable	27,720			0,000	2,300	04,100	27,720	IBGEN	
CAVAR-3A	LA SERNA	PE003795	Renovable no gestionable	27,720			0,000	2,300	04,100	27,720	IBGEN	
CAVAR-3B	LA SERNA	PE003796	Renovable no gestionable	27,720			0,000	2,300	04,100	27,720	IBGEN	
Total:				297,900	00,000		22,100	44,000	65,900	297,900		

Bolsa 442 Just.: 9: RdD - Restricción técnica Total Límite (MW): 7.000 Total Consigna Calculada: 07,000 F.Ini.: 18-jun-2021 13:00:00 +02:00 F.Fin.: 18-jun-2021 14:00:00 +02:00 Bolsa DSO.: Sí
Prog. Base: PvPLimit: Descripción: 18XENDD-12345-25_BOLSA_Case_3

Nombre	Nudo	B3	Grupo Tecnológico	Consig. Cons.	Consig. Cal.	Just.	Generación	Prog. Vig.	Prog. Sig.	P. Instalada	C. Control	¿OK?
EEE	PTO CRUZ	EEE	Renovable no gestionable	7,000	7.0	9	6,566	10,900	09,800	32,000	ENDESA	
Total:				07,000	07,000		06,566	10,900	09,800	32,000		

Figure 14 Congestion bundles screen in GEMAS (CoordiNet Common Platform) - CADIZ CCM CASE 4

Figure 15 depicts the EEE supervision screen of the SCADA in the FSP Control Center. In this figure, it can be seen the limit sent by the SO (orange line) and how the FSP applies this limit (blue line).

Figure 15 EEE supervision screen of the SCADA in the FSP Control Center for the EGP - CADIZ CCM CASE 4

BUC ES-2: BALANCING

One demo has been performed in the balancing scenario. The objective of this demo was to coordinate the actions implemented by the TSO and the DSO when the DSO requests, in real-time, the application of an individual physical unit upper-limitation, in this case, to ensure the safe operation of the **Pinar del Rey substation**. The limitation was requested to be applied on the PESUR wind farm, and it has been applied for the mFRR process.

This demo was successfully performed. It has been demonstrated that the DSO can submit limitation requests (send minimum or maximum limitations) to the FSPs (Connected to the distribution network), in coordination with the TSO, to avoid congestion in the distribution network (as shown in Figure 16). The TSO takes these limitations into account when performing the mFRR balancing reserve clearing. The FSP market agent takes into consideration the physical unit limitations imposed by the DSO and the TSO when disaggregating the programming units' cleared bids.

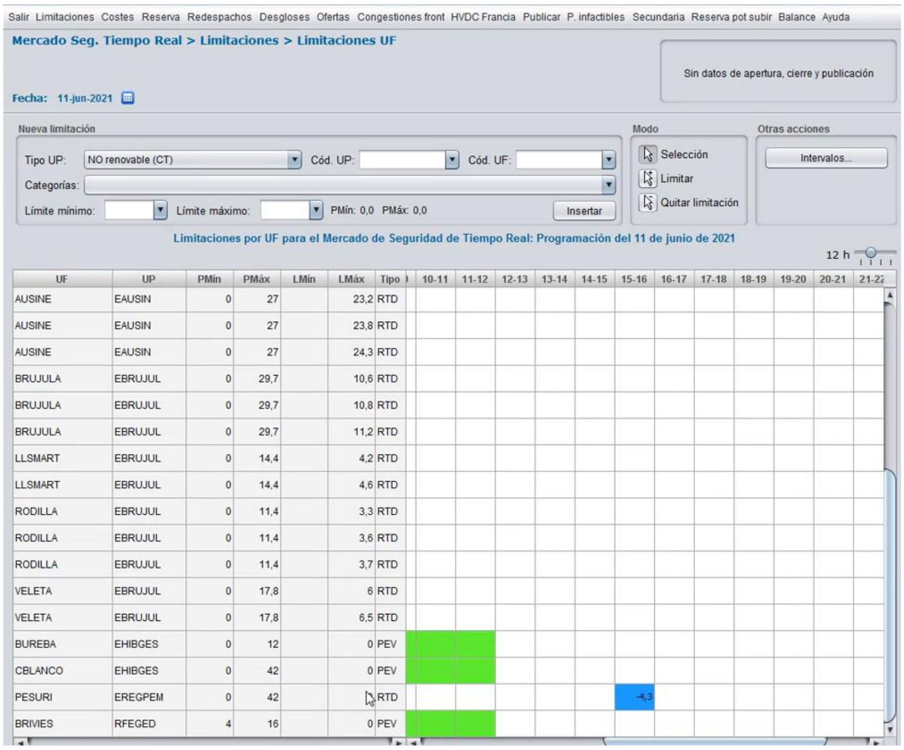


Figure 16 Physical unit redispatch generated by the CoordiNet Common Platform - CADIZ Balancing CASE 1

4.1.1.2.2. Demo run 2

COMMUNICATION TEST

CADIZ

BUC ES-3: VOLTAGE CONTROL

The objective of this test was to check the ability to control the reactive power output of the power plant PESUR by having the DSO send different reactive power control setpoints, with the SO acting as a gateway using the ICCP protocol. The control modalities tested include the voltage setpoint (Modality A), the reactive power setpoint (Modality B) and the power factor setpoint (Modality C). In every modality, both the ability to have the plant producing or consuming reactive power (inductive and capacitive behaviour) was checked. The test provided successful results. The reactive power production of the FSP was controlled by the DSO in all three modalities.

Figure 17 shows an instance of the PESUR FSP Remote Terminal Unit during the communication tests. In this instance, the setpoint from the SO has been correctly received (marked in yellow on top) and how it has been correctly applied by the RTU (marked in orange).

Figure 17 PESUR FSP Remote Terminal Unit screenshot voltage setpoint (CADIZ - Voltage Control Communication Test 1)

MÁLAGA

BUC ES1A: COMMON CONGESTION MANAGEMENT

The deployed communications between the different stakeholders listed next worked properly, allowing their participation in the BUC ES1A: COMMON CONGESTION MANAGEMENT. All the required messages were correctly exchanged:

- DSO and TSO (CoordiNet Common Platform)

- Aggregator and TSO (CoordiNet Common Platform).

- AGGREGATOR and FSPs.

BUC ES1B: LOCAL CONGESTION MANAGEMENT

The deployed communications between the different stakeholders listed next worked properly, allowing their participation in the BUC ES1B: LOCAL Congestion Management, since all the required messages were correctly exchanged:

- Aggregator and CoordiNet Local Market Platform.

- DSO and CoordiNet Local Market Platform

PREQUALIFICATION TEST

CADIZ

BUC ES-3: VOLTAGE CONTROL

The FSP PESUR has been correctly prequalified. The DSO, in coordination with the SO, has prequalified the unit of PESUR to participate in the voltage control BUC, for the modality C. Since the communication test for the modality A and B had already been done with successful results, the determination of the PQ curve of the plant is prequalified for the three modalities.

In the prequalification test, the PQ curve of the power plant has been determined taking into consideration the network's technical limitations (overcurrent protection, etc). The PQ curve obtained from the prequalification test is depicted in Figure 18.

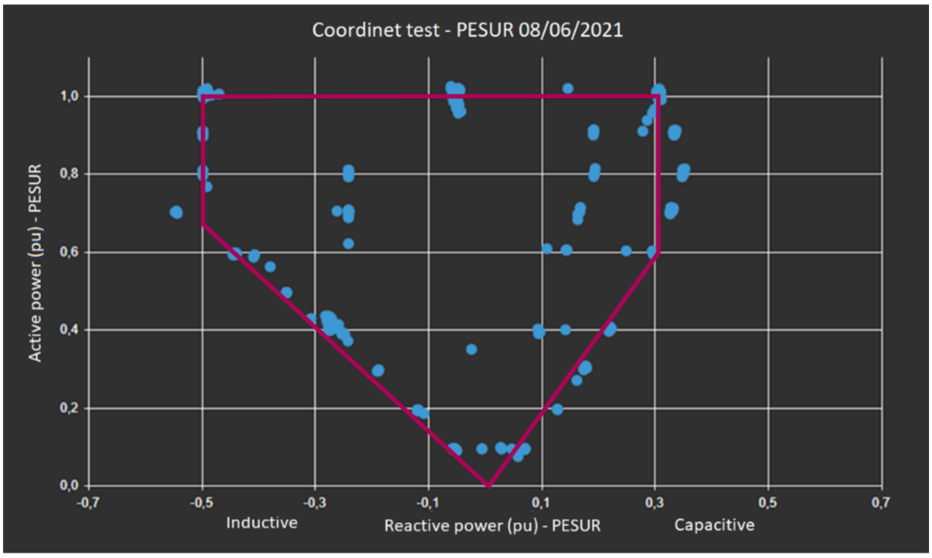


Figure 18 PQ curve obtained prequalification parameters (CADIZ - Voltage Control Prequalification Test 1)

BUC TESTS

CADIZ

BUC ES-3: VOLTAGE CONTROL

In the voltage demo performed, both the functioning of the voltage market mechanism and the management of the voltage had been successfully tested.

Regarding the voltage market mechanism, the DSO was able to submit the relevant information on the reactive power needs to the CoordiNet Common Platform. The FSP unit of PESUR, through their market agent, was able to send the corresponding reactive power bids. Then, the voltage market cleared correctly.

Concerning the network operation, the DSO has been able to avoid voltage deviations by the use of the reactive power regulation capabilities of the FSP PESUR connected at the distribution level. The DSO has been able to control the FSP PESUR by sending voltage and reactive power setpoints through the CoordiNet Common Platform. In Figure 19, the reactive power setpoints computed by the DSO Platform and sent to the PESUR FSP are depicted. Figure 20 shows the PESUR FSP reactive power measures registered in the EGP SCADA.

Figure 19 shows the DSO Platform the following values of the PESUR FSP are represented: active power (yellow), maximum capacitive reactive power capability (orange), maximum inductive reactive power capability (red), reactive setpoint computed by the DSO Platform (green) and reactive power measure (blue).

Figure **19** PESUR reactive power setpoints DSO Platform (CADIZ – Voltage Control CASE 1)

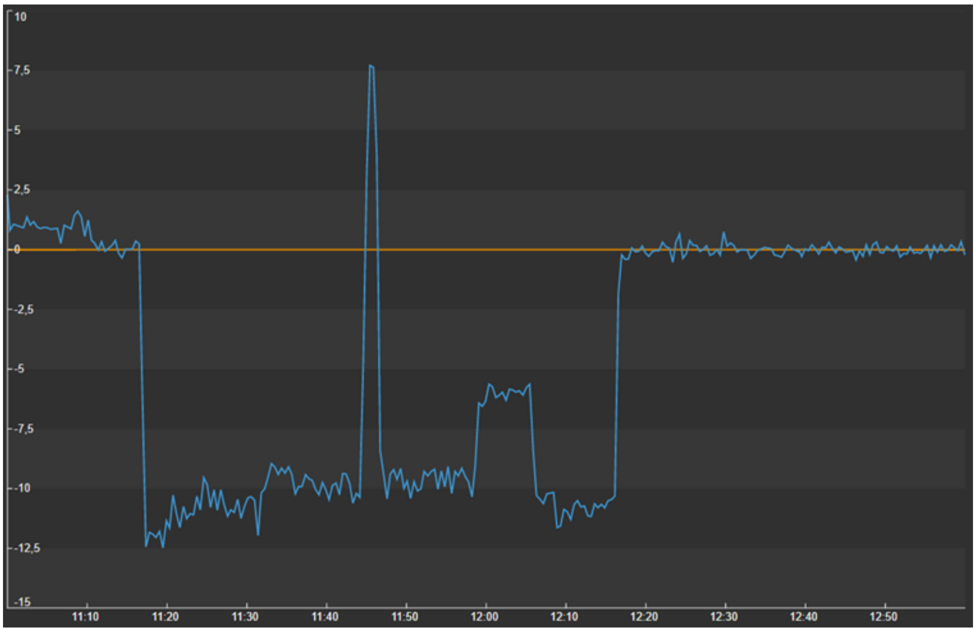


Figure **20** PESUR BC reactive power output measures (MVAr) EGP SCADA (Modality 3) (CADIZ – Voltage Control CASE 1)

Figure 21 shows the voltages measured at power plant busbars from EGP SCADA and how the reactive power consumption by the FSP helps to reduce the voltage (around 2kV) at the node.

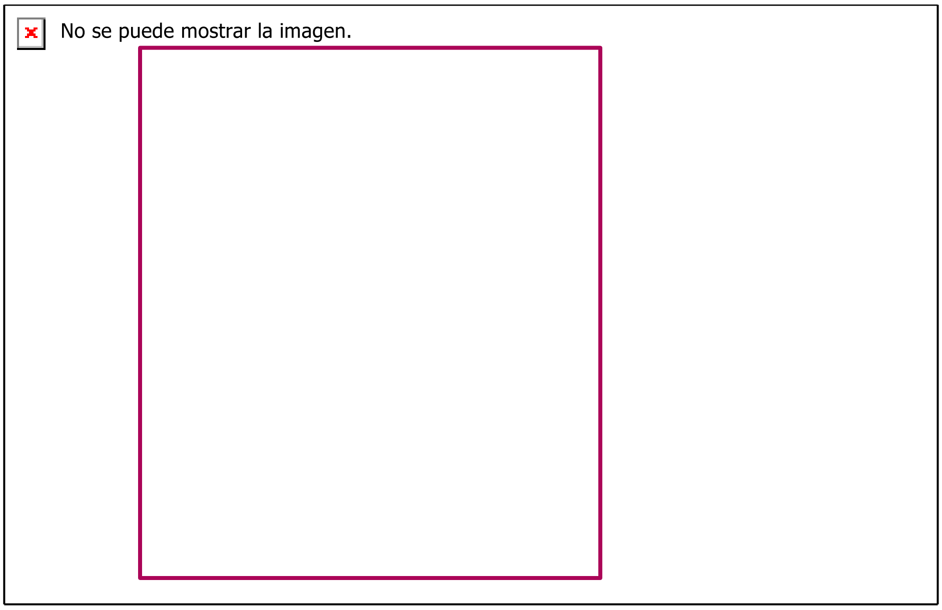


Figure 21 PESUR BC voltage measures (kV) EGP SCADA (Mode 1) (CADIZ - Voltage Control CASE 1)

MALAGA

BUC ES-1A: COMMON CONGESTION MANAGEMENT

The Common Congestion Management demos were correctly performed in Malaga. For this BUC, in the 5 demos performed it has been demonstrated that the DSO can submit limitation requests to the FSPs in coordination with the TSO to solve congestion in the distribution network. The figure below shows, as an example, the application of a limitation by the FSP for the demo CASE 5 - INDIVIDUAL PHYSICAL UNIT UPPER-LIMITATION (REAL TIME).

Figure 22 shows the setpoint reception from the SO and application by the EMASA's SCADA system (marked in garnet in the SCADA capture).

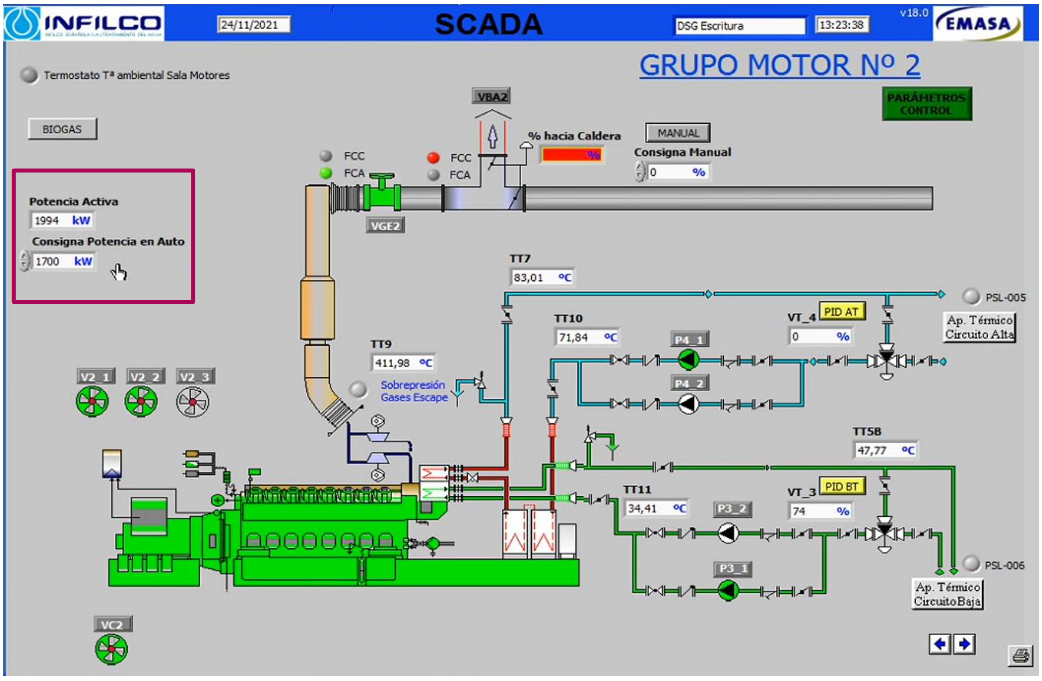


Figure 22 Gas engine active power reduction at EMASA's SCADA system (MALAGA – CCM CASE 5)

BUC ES1B: LOCAL CONGESTION MANAGEMENT

For this BUC, a total of 5 demos have been performed, within which demos 1 and 2 concerned the day-ahead timeframe, while demos 3, 4 and 5 concerned the Intraday timeframe.

The demos proved the ability of the DSO to satisfy its active power needs through the mobilization of the flexibility provided through the aggregator bids submitted on the Local Market, thus reducing the power line congestion simulated.

In Figure 23 and Figure 24, the activation of two sFSP bids to solve the management of congestion in the DSO grid in the MALAGA – LCM CASE 5 is depicted.

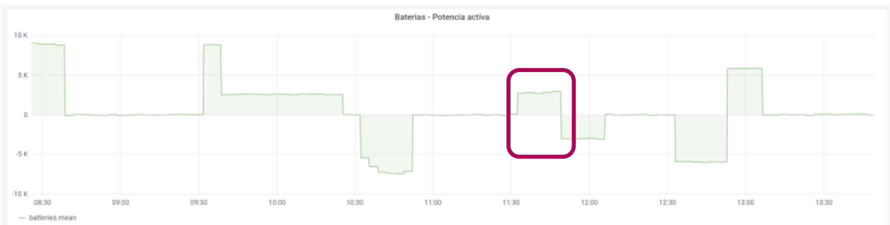


Figure 23 Battery Inverter activation sent by Tecnalia to Tabacalera Microgrid sFSP (MALAGA – LCM CASE 5)

Figure **24** PV Inverter active power activation sent by the Tecnalia to Tabacalera Microgrid sFSP (MALAGA – LCM CASE 5)

4.1.1.3. Conclusions, lessons learnt and next steps

DEMO RUN 1

The main contributions of the Demo Run 1 phase include the detailed definition of the BUC tests for 'BUC ES1a: Common Congestion Management' and 'BUC ES2: Balancing', the undertaking of the prequalification and on-site communication tests and the results, or information, produced in these tests, the undertaking of the BUC tests, and the calculation of the initial KPIs.

All those units participating in 'BUC ES1a: Common Congestion Management' and 'BUC ES2: Balancing' had already been prequalified for these services and did not have to undergo an additional prequalification process. Communication tests had been conducted before for all actors. However, these previous tests had been carried out in laboratory conditions. Before the BUC tests, additional on-site communication tests have been performed by e-Distribución, REE, Tecnalia, N-SIDE and IREC, to make sure the BUC tests run smoothly. All these tests were a success.

The overall conclusion of the Demo Run 1 test results is that the proposed TSO-DSO coordination schemes for 'BUC ES1a Common Congestion Management' and 'BUC ES2: Balancing' have proven to be suitable for the effective procurement of these flexibility services. All the processes considered were implemented successfully. These ranged from the implementation of limitations of the output of FSP units submitted by the DSOs and the TSO to the Common CoordiNet Platform to addressing different congestion management and balancing needs by modifying the output of the FSPs, in both the day-ahead and the Real-Time timeframes.

DEMO RUN 2

The main contributions of the second demo run phase include the detailed definition of the BUC tests for 'BUC ES1b: Local Congestion Management' and 'BUC ES3: Voltage Control', the undertaking of the prequalification and on-site communication tests, and the results, or information, produced in these tests, the undertaking of the BUC tests, and the calculation of the second demo run KPIs.

The units participating in 'BUC ES1a: Common Congestion Management' had already been prequalified for the services and did not have to undergo an additional prequalification process. In the case of 'BUC ES1b: 'BUC ES1b: Local Congestion Management' and 'BUC ES3: Voltage Control', the units have undergone prequalification tests before the implementation of the BUCs. Before the BUC tests, additional on-site communication tests have been performed by e-Distribución, REE, Tecnalia, Bamboo, N-SIDE and IREC, to make sure the BUC tests run smoothly. These tests were performed with no major issues.

The overall conclusion of the Demo Run 2 test results is that the proposed TSO-DSO coordination schemes for 'BUC ES1a Common Congestion Management', 'BUC ES1b: Local Congestion Management' and 'BUC ES3:

Voltage Control' have proven to be suitable for the effective procurement of these flexibility services. All the processes considered were implemented successfully. These ranged from the implementation of limitations of the output of the FSP units submitted by the DSOs and the TSO to the Common CoordiNet Platform, and the DSOs to the Local Market Platform, to addressing different congestion management and voltage control needs by modifying the output of the FSPs, in both the day-ahead and the near-real-time timeframes.

4.1.2. i-DE

4.1.2.1. DSO Platform concept

The DSO Platform, from the i-DE perspective, is a sub-system used by the control centre to manage flexible resources. The short and long-term needs of the network are registered in the DSO platform. The long-term needs must correspond to the network needs defined in the planning database, and the short-term needs are registered directly by the operator. The long-term needs trigger short-term operations aimed at serving the former. This is carried out by the control centre.

The platform is interconnected with the SCADA. Thus, it collects the monitoring data in real time both from FSPs and the grid. It is also interconnected with the smart meters, to collect forecasts and also real-time data. Lastly, the DSO platform is interconnected with the market platforms. Therefore, all the information necessary to manage the flexibility services required is available on the platform.

The list of potential candidate FSPs to meet each service requirement, which is selected automatically according to the grid configuration, is uploaded onto the i-DE platform together with the information on each service requirement.

In its interaction with the market platforms, the DSO platform receives information on the FSPs chosen for each service. Then, the monitoring of the activation of these FSPs can be done through the platform as well. Only in the voltage control use case, the DSO sends the setpoints to the FSPs through the platform during the service activation. These are calculated automatically according to the requirements defined and submitted by the operator.

In the case of the i-DE Demo, the local market was simulated within the same platform to avoid connection problems with the N-SIDE local platform. Figure 25 shows the concept that was designed for the project.

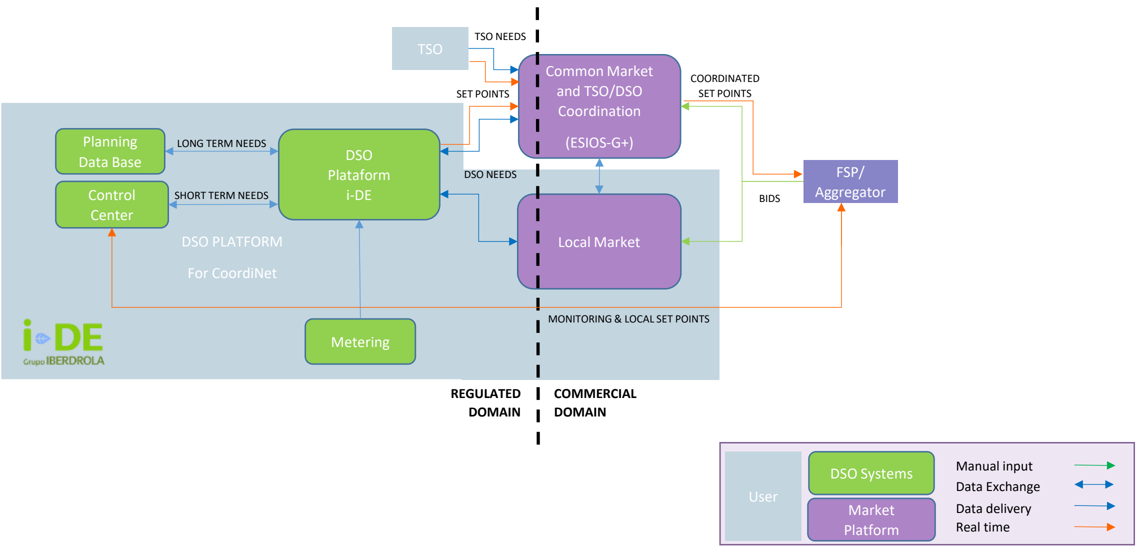


Figure 25 i-DE Platform concept

The i-DE platform is based on a solution from Minsait (Indra Group) called Onesait Flexibility. This platform aims to manage the long-term and short-term needs of the DSO as shown in Figure 26.

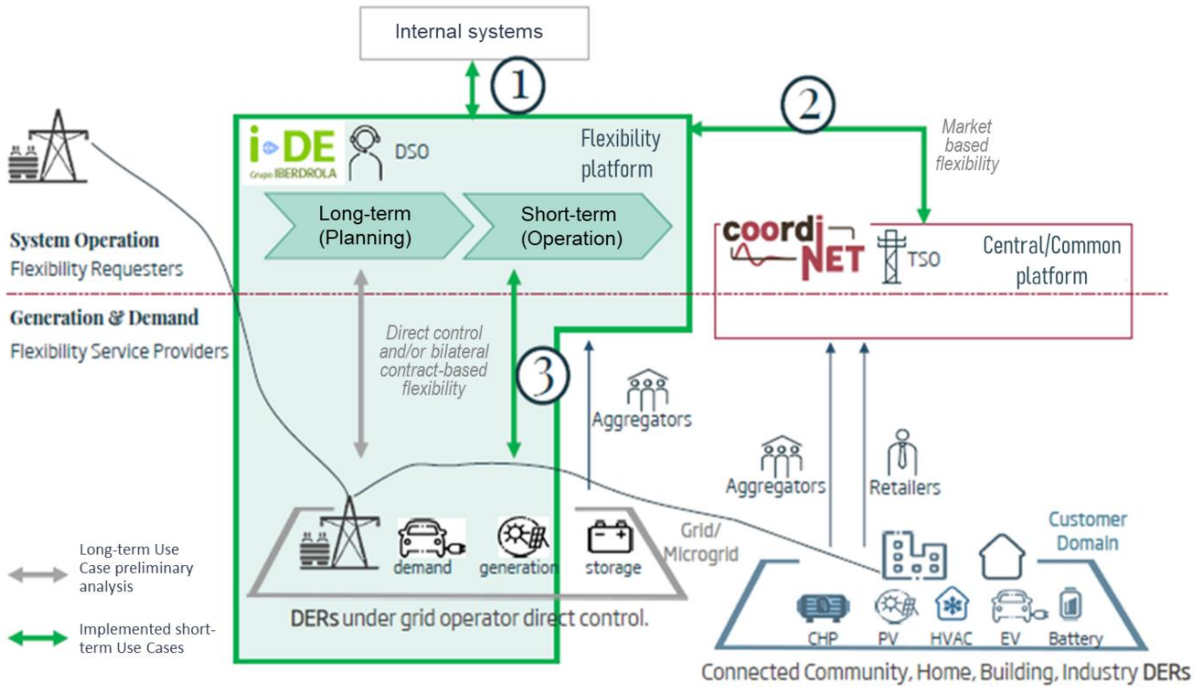


Figure 26 Minsait solution for the i-DE Platform

The i-DE DSO tool aims to facilitate the provision of solutions addressing the needs of the network both in short term, which is needed to achieve a safe operation, and in long term, as identified in the long-term planning. The solutions considered include those different from the traditional ones and that sooner or later will appear in the regulatory scenario. This platform is conceived to manage the network needs related to the quality of supply, the outages occurring, the programmed maintenance works, and those aimed at postponing, or even avoiding, certain investments. The solutions implemented through the platform are a complement to the network investment plan and one more tool for the control centre to operate the network. In addition, the tool aims to serve as a formal communication channel between the operation and planning processes to share the needs detected in the network.

The i-DE DSO tool should be able to make efficient management of the flexibility services in all the phases of the process of delivery of these services: from the prequalification process to settlement. This includes the detection of the system needs and allocation of resources to address them, interaction with the common and local markets, forecast of relevant system variables and other data, programmed or agreed monitoring of the network state, activation of flexibility services (including the submission of setpoints), validation of the service delivery and finally the settlement of system provision including the application of penalties when needed. Additionally, collecting measurements from smart meters, as well as the measurement from the LV monitoring devices and SCADA data are necessary. This is a long process for which it was only possible to develop some functionalities in a simulated environment, as listed below.

- There were some developments made directly by i-DE, including the following:
    - Integration of the i-DE systems: Control, monitoring and measurement systems
    - Integration in the CoordiNet platform: extension of REE systems
    - Attributes identification for the services.

- Solution parameterization: master data and signals

- And other functionalities were developed based on the Onesait flexibility solution
  - Monitoring functionality
  - Hierarchical organization of assets
  - Modelling of flexibility services
  - Subscription of FSPs' services
  - Network needs registration
  - Management of flexibility operations
  - Monitoring and Auditing

4.1.2.2. Infrastructure

At the time of the installation of the infrastructure and the deployment of the solution, some tasks were carried out following the guidelines defined within Iberdrola's security areas, including:

- Documentation of the security measures implemented in the product
- At *the application* level: password encryption, Spring validation, application of good practices in authentication, use of certificates, vulnerability check from "continuous integration and continuous delivery" deployments.
- At the infrastructure level: bastions of machines and internal communication among private IPs.
- Maintenance: scheduled shutdowns of the environment, analysis of Bastion Machine usage

The conceptual scheme of communication channels implemented is shown in Figure 27. All the interactions with the i-DE internal system took place through a VPN connection, and all the interactions with the common platform used the https protocol.

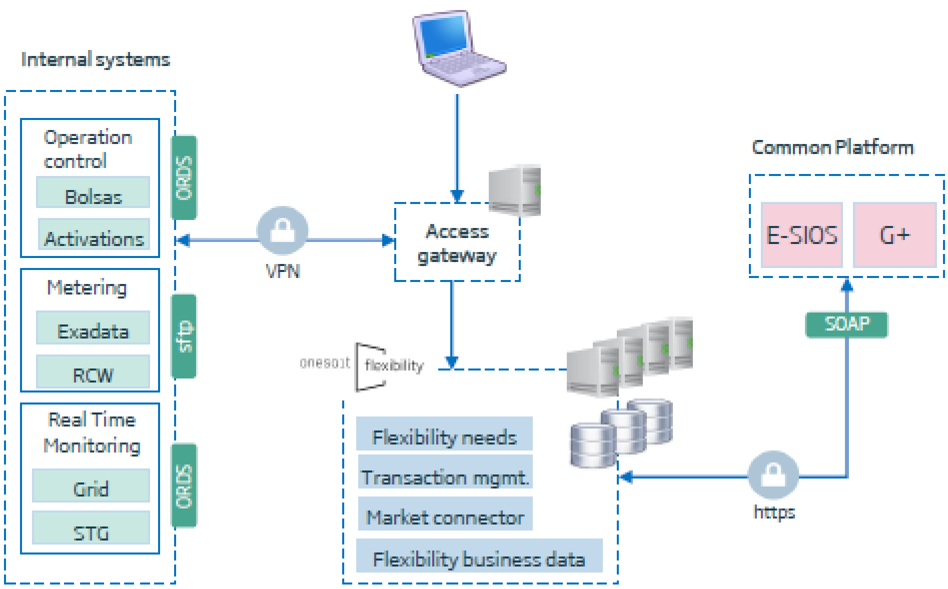


Figure 27 Communications scheme for the i-DE Platform

4.1.2.3. Principles for the platform deployment

This is a wide-ranging-purpose platform for managing the flexibility processes that is built on 4 principles that allow the stakeholders to accelerate the implementation of the use cases:

- Flexible and scalable modular architecture

The solution is based on a modular architecture that provides flexibility in its deployment and use, adapting to the needs of each user, reducing infrastructure costs, and ensuring its adequate future scalability.

- Broad functional coverage of use cases and actors

The platform has a multi-service and multi-actor approach. Given the immaturity of the market and the regulatory uncertainties, the use cases are implemented by parameterizing (i.e. selecting attributes) the existing functionalities and degrees of freedom that ensure their extensibility.

- Open to third-party algorithms

Open to algorithms of high added value employed by third parties or the client himself, deploying and/or executing models making use of own architecture. While the product (platform) can make use of its intelligence, this is considered a critical function that can be delegated.

- Designed to be integrated with external platforms and systems

The platform is designed to take advantage of the extensive integration capabilities of vertical asset platforms, third-party systems or market platforms. *Cloud2cloud* and *edge integration possibilities can be implemented in it*.

Processes and technical components are standardized, but we also consider the implementation of specialized functions to reduce the deployment costs and accelerate the development of new use cases.

Onesait Flexibility manages the monitoring and control of distributed resources and demand, generation and storage assets, through a unified *IoT* solution for the participation of these in Flexibility Services. This product aims to be able to cover *end-to-end* processes, from the registration of a need to the pre-settlement of the services addressing it.

This platform allows the DSO to deal with distributed energy resource portfolios (DERs), including large individually participating clients (FSPs), in an integrated manner, usually through bilateral contracts, or in an aggregate manner. Besides, this platform facilitates contracting flexible capacity through local market platforms. In this way, the DSO has an alternative to investing in network repowering, contributing to increasing its ability to manage the increasing variability of the demand and the congestion in the network.

4.1.2.4. General Functionalities

Some functionalities were created generically for all pilots and use cases, these include the following:

- Analysis panels. Different kinds of panels could be customized to suit specific needs. Both smart meter data and SCADA data are used for monitoring and analyzing measurements.

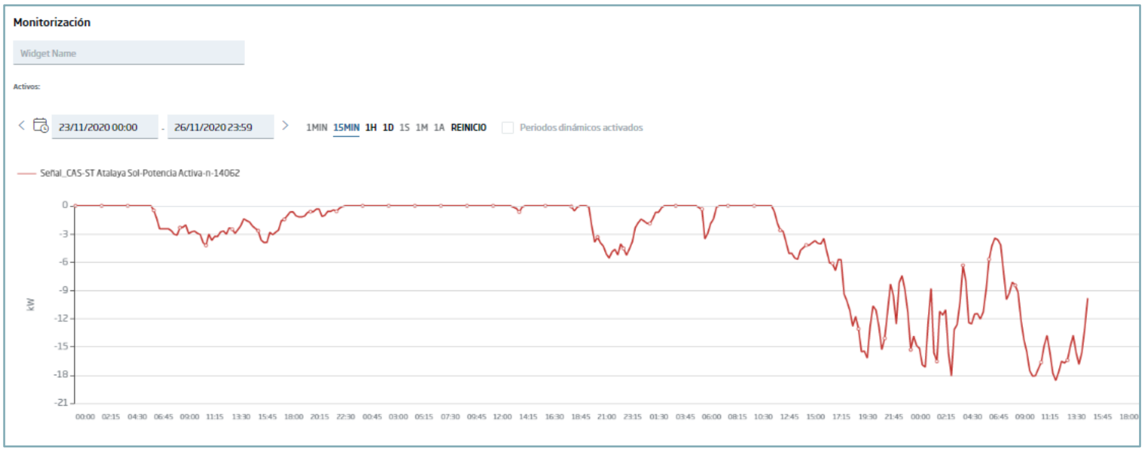


Figure 28 Analysis panels: Measurements from smart meters and SCADA can be monitored. The active power of an FSP is shown. (Onesait Flexibility Platform by Minsait)

- Flexibility: This functionality allows the DSO to manage the long-term needs envisaged by the "Needs" mode, and manage the operation in the "Operations" mode. Figure 29 shows the panel of the long-term needs.

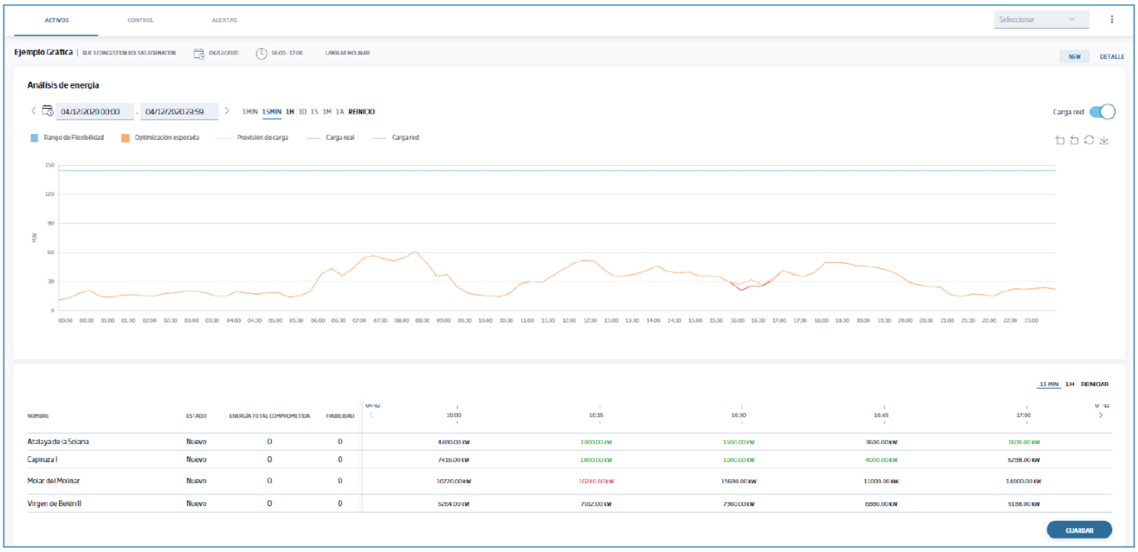


Figure 29 Flexibility needs in the Onesait Flexibility platform. Active power limits are programmed for different time ranges and different FSPs. (Onesait Flexibility Platform by Minsait)

- Configuration: different possible uses of the platform have been defined, including the resources management, the hierarchical representation of the network as an asset tree for the control centre operator to find the resources easily, and the management of the users, including their profiles. Some users are allowed to create needs, other operators are allowed to manage them by operations, and some others will have the profile for specific steps in the workflows. This allows the companies to specify the role of the users and the services to provide, to design the attributes of each service (as shown in Figure 30).

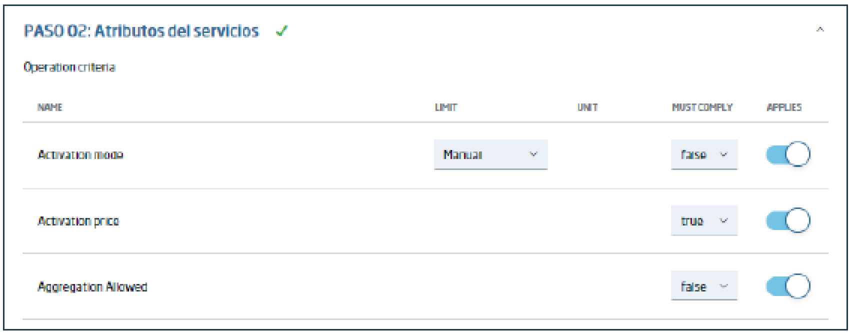


Figure 30 Service attributes (Onesait Flexibility Platform by Minsait)

The parameterization of the service is a critical aspect of the use case. Each resource is registered as a DER with its features to be monitored or controlled, as shown in Figure 31.

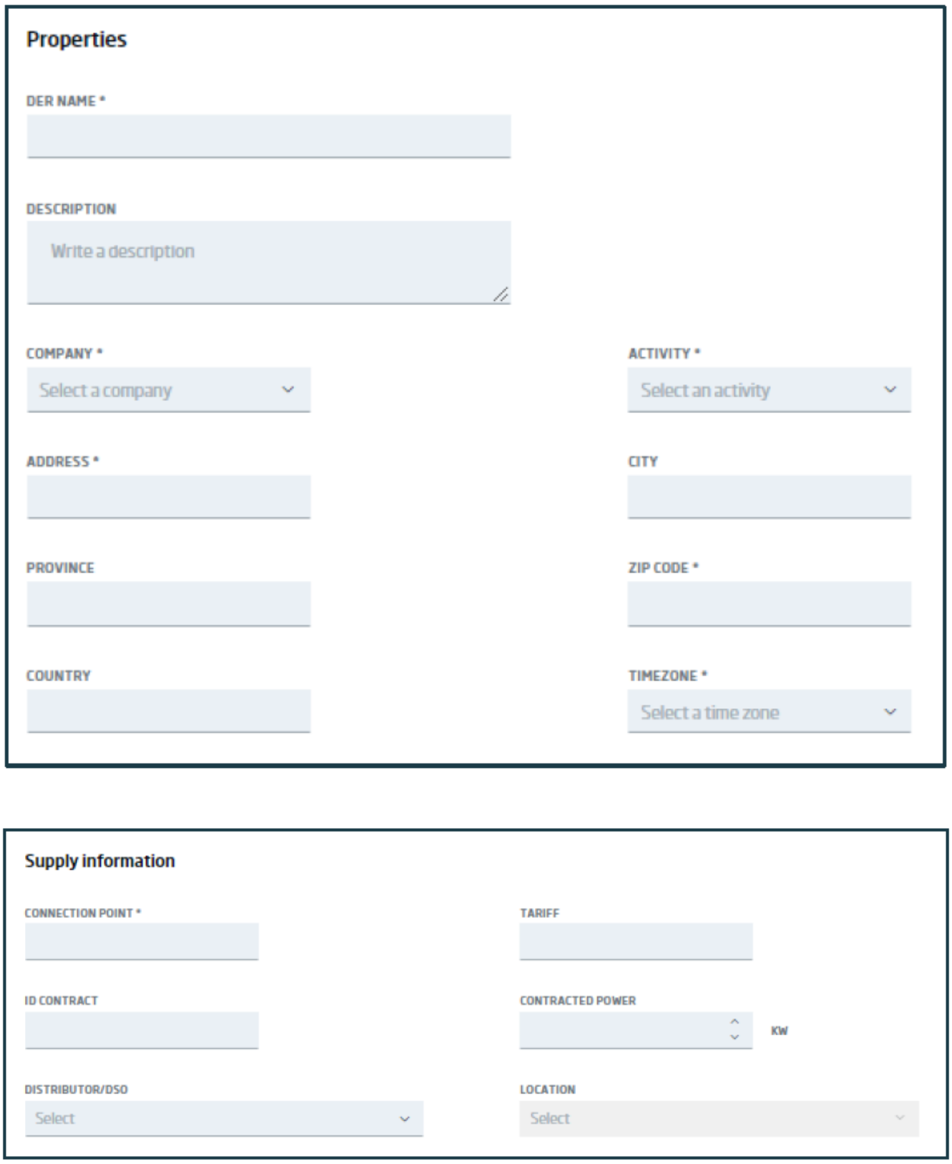


Figure 31 DER attributes in the Onesait Flexiblity Platform (Onesait Flexibility Platform by Minsait)

In addition to the configuration modules described above and existing or used in CoordiNet, the platform currently has additional functionalities:

- Roles and permissions: Enhanced security management with the ability for an administrator user to define roles, which in turn can be assigned various combinations of permissions (creation, editing, querying, deleting system entities).
- Configuration Services: the ability to adapt the general information managed, the signal type, the unit of measurement and the granularity to the needs and features of the use case, as the adaptation of the functionality to the use case on control voltages. Also, timer processes are added to the existing input, output and save processes.
- Contracts: manages the evolution of contracts to form a complete economic module
- Asset management (DERs): the option is enabled for the user to create customized attribute templates for the assets, providing these attributes for each DER, which can be used for registration of the identifiers of external systems: UP, UF, B1, B2, B3, etc. Also at the level of each RED, it is possible to record its unavailability, so that the flexibility of this RED cannot be used, or it is not required to participate in flexibility services.

4.1.2.5. Integration in the CoordiNet ecosystem

The communication of the DSO platform with that run by REE aims to facilitate the coordination of the system operators regarding their respective domains of responsibility. The following is a list of the most relevant data to be exchanged among them:

- BolsaGemas: Message sent by the DSOs for them to manage groups of FSPs (“*Bolsas*”) in the Gemas+ application to define and enforce Real-Time restrictions on the generation of FSPs in their distribution network.
- LimitacionesDSO: Message including the information that the DSOs send to the SO to impose limitations on individual physical units of their network of influence.
- LimitacionesBolsaDSO: Message including the information sent by the DSOs to set an upper limit to the output of a group of physical units of their network of influence.
- LimitacionesSujeto: Message published by the SO including the individual power limits set by the SO, for security reasons, per programming unit or physical unit in the day ahead.
- ReqCapReactivaAdicional: Message including the information sent by the DSOs on the reactive power requirements for each of the sessions (inductive and capacitive) for their distribution network and the selected DEMO.
- AsigCapReactivaAdicional: Message published by the SO including the results of all the auctions of a week. It includes all the offers, matched in the market or not, the area they refer to and the price offered.
- ProgramasUPCLP: For the local market use case, this involves sending to the eSIOS platform (CoordiNet common platform) a file including the final program of the programming units as a result of the limits that are established in the local market.

4.1.2.5.1. Use Cases in the platform

The following diagram describes the full spectrum of use cases that are ultimately implemented on the i-DE Flexibility platform.

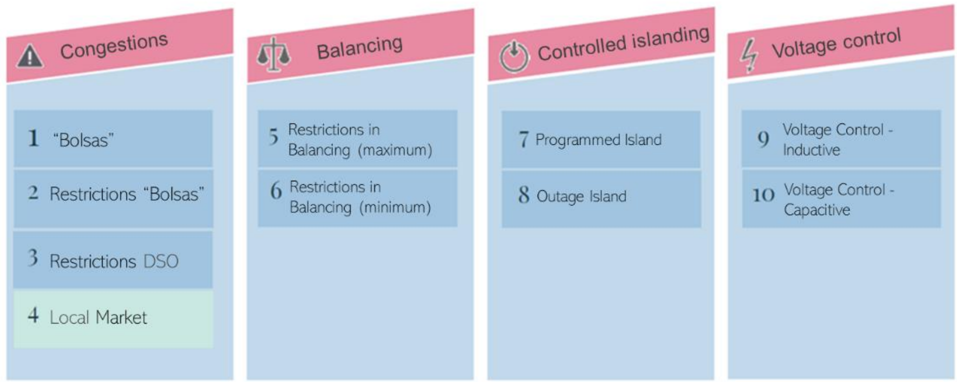


Figure 32 Solutions for each use case in the i-DE platform

Building on the versatility offered by the platform, several use cases were created based on the definitions of the services designed in the WP1 of the CoordiNet project. Below is the specific design for each of them.

CONGESTION USE CASES ES-1A AND ES-1B

This configuration applies to the ES-1a use cases. Its workflow must allow the management of congestion through the common platform, both in real-time and in the day ahead. In essence, the platform works by sending restrictions of the individual FSP or "bolsas" (groups of FSPs) to REE, the way they were defined by operation. This is either accepted or rejected by REE and allocated and programmed for the FSPs that were matched in the market. This information is sent back to the i-DE platform which feeds the internal systems, so it is taken into account in operation. Its workflow is shown in Figure 33.

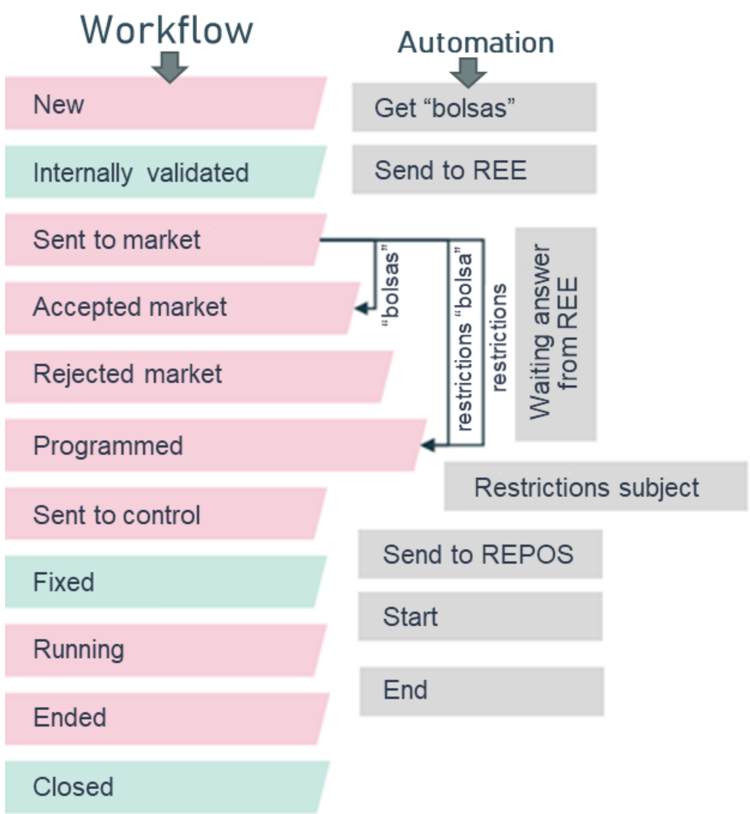


Figure 33 Workflow for the management of congestion in the common platform

Following some steps, internal processes were triggered within the platform.

The functioning of Local Markets addressed the ES-1b use case, which focuses on congestion managed through the local platform, and follows a different workflow. The local market use case addresses small congestion in the grid (< 1 MW) by managing aggregated demand resources. Figure 34 shows the workflow of actions taken in the platform to manage congestion in the local market. In this case, the DSO interacts with the TSO to send the programs of resources, as well as with the aggregator for it to access the market managed through the DSO platform. The aggregator can send the baseline information and the bids. As explained in the workflow, the DSO creates a new requirement of congestion management in the platform, to which the FSPs that can resolve this congestion place their offers. Market matching is done in the platform and according to this, the accepted bids are allocated to the FSPs and this new program is communicated to REE. When the operation time comes, the FSP run according to those programs.

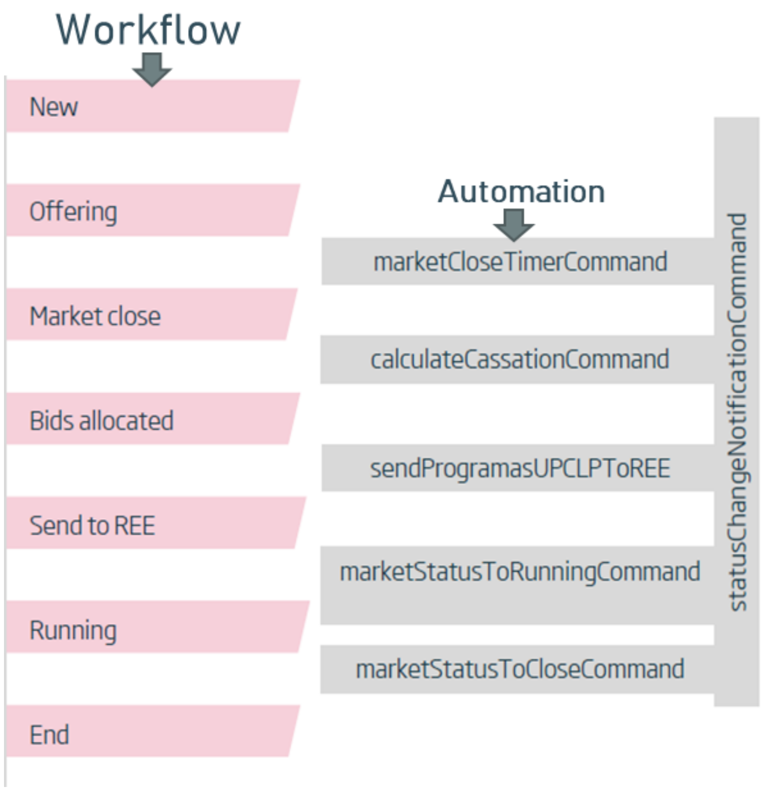


Figure 34 Workflow for the management of local congestion through the local platform

BALANCE USE CASE ES-2

This use case allows the DSO to set limits on the generation in coordination with the TSO. The TSO considers these limits for the management of frequency control services such as mFRR and RR. In this case, the workflow is relatively simple (Figure 35), since it involves submitting information on limits that are enforced by the TSO, and REE.

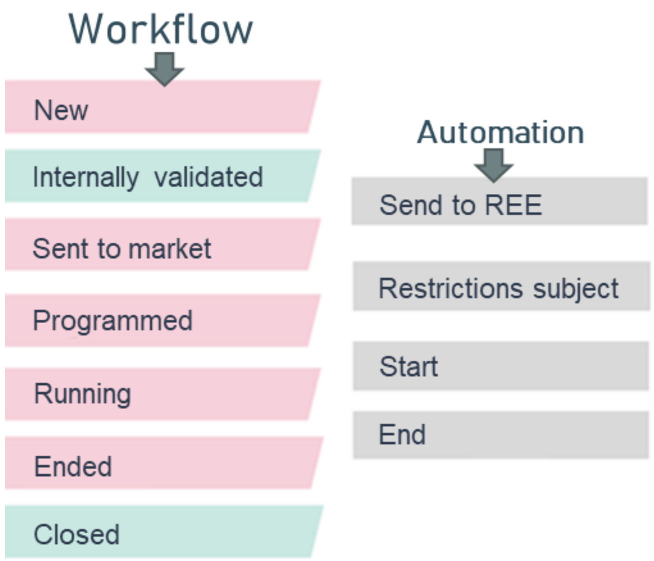


Figure 35 Balancing limitations workflow

VOLTAGE CONTROL USE CASE ES-3

This use case is managed through a common market model. Therefore, it also requires coordination between the DSO and the TSO. The service provided requires the calculation of the required PQ area, which is the parameter defined in the bids traded in the market, and setpoints within the selected areas for the participating resources. Next, the main steps in the corresponding workflow are discussed (Figure 36):

- The required PQ area, defined based on the reactive power needed in the weekly horizon market session, is calculated according to static and known technical characteristics of the available areas of the resources that can offer the voltage control service.
- The communication with REE is established, sending the corresponding request.
- Based on the offers received from the physical units, in the market matching is carried out and areas are assigned.
- Within these areas, and depending on the level of desired reactivation in closer time horizons already during the execution of the service, the power factor is calculated according to an order of priority, respecting the technical characteristics of the resources. This means the DSO calculates in near real-time the power factor that is needed to correct the voltage in each moment and establishes a priority of FSPs (for example considering the effectiveness of each resource due to its proximity to the area where the voltage problem occurs) so that they are activated according to it.
- Communication with control systems is established to transfer information on the setpoint to REE via the ICCP link, for it to send it, in turn, to the resources.

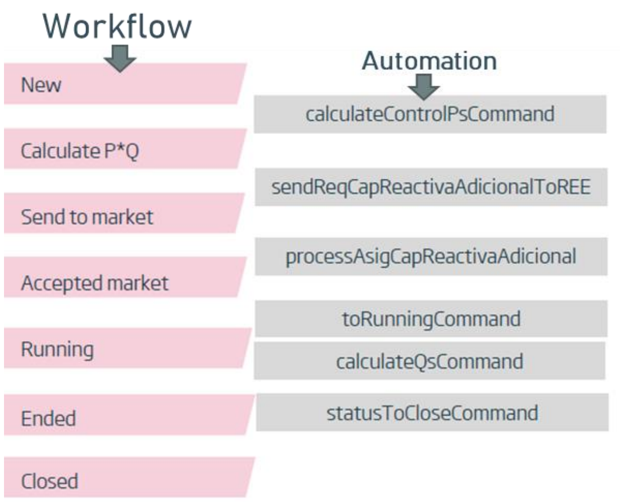


Figure 36 Voltage control workflow

CONTROLLED ISLANDING USE CASE ES-4

In this use case, the aim is to isolate a section of the distribution network by maintaining supply with local generation and storage resources. This use case was conceived as a service agreed with the FSPs. No automated processes were triggered in this case, since the interaction of the FSP with the DSO was already fully automated. The platform is, anyway, ready to define and submit data on the setpoints and signals if this solution is further deployed.

There are 2 services involved in the use case: one for Programmed Maintenance and another for Outages. In the case of Programmed Maintenance, information on the need of the control centre in this regard is provided beforehand. In the case of unprogrammed outages, an operation is registered directly. The communication of the requirement to the FSP and the setting up of the island could be carried out, but it was not necessary for the demo.

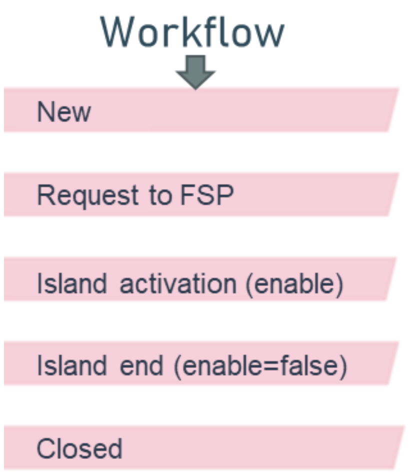


Figure 37 Controlled islanding workflow

4.2. TSO platforms

The Spanish TSO REE has developed and hosted the TSO-DSO Common Market platform within the CoordiNet Platform concept. The main objectives of this platform are:

- Serve as an interface that manages different interactions between TSO, DSOs and FSPs.
- Coordinate the different functions necessary to carry out the developments and analyses for each one of the use cases.

The common platform is composed of the already existing systems at REE (see Table 4): eSIOS and GEMAS+ (all of them specifically adapted for the project), and the new ones developed to perform the developments and analyses for some BUCs, such as VOLTAIREE for voltage control.

This chapter provides an overview of each of them including the main technical developments for their implementation, the tests carried out to validate their functionalities, and finally, the main conclusions, and lessons learnt.

Table 4 REE platforms used in CoordiNet

Tool name	Brief Description	New	Adapted
eSIOS	Market platform used by the Spanish TSO, to exchange information and to manage the different markets operated by the TSO.		x
GEMAS+	The tool used in the CECRE control centre to control the RCR generation.		x
VOLTAIREE	The voltage control platform was developed to apply the new voltage control service that will be implemented in Spain.	x	

4.2.1. GEMAS+

GEMAS+ is the main tool used by the CECRE's (control centre of renewable energies) operator to carry out the control of renewable generation, CHP and biogas plants in Spain. This platform accesses the real-time information received in CECRE and uses it to determine whether the present generation scenario is admissible for the system taking into account the congestions or then balancing issues which occur during normal operation (both real-time or day-ahead).

GEMAS+ has been designed considering that the operator must be able to create, manage and activate a portfolio of generation units rapidly (generation bundle should be understood as a set of units to which setpoints are sent by the TSO to limit their global production), as some situations may arise in which it may be necessary to return the system to a balanced, N-1 secure state as soon as possible. Currently, DSOs can set limits to the output of this generation (only to those generation units which affect their grids), but this process is carried out manually (typically by phone or e-mail). The CoordiNet common platform allows DSOs to manage the congestion in their distribution grids in the same way the REE dispatcher does i.e. using a direct communication machine-machine (without the need to use emails). Thus, the following management options for DSOs have been implemented:

- Bundle generation setting: DSO dispatcher can create a generation bundle containing those units which are connected to its grid and cause congestion if the total generation output is higher or lower than a certain value.
- Bundle generation modification: DSO dispatcher can also modify the composition of the generation bundle:
    - Include new units in the generation bundle
    - Remove units in the bundle.
    - Modify the limit set (value of the output limit, duration of the limit etc.).
- Bundle generation removal. DSO dispatcher can remove the generation bundle if the congestion is no longer affecting its grid.

The tests performed to validate the functioning of these new functions are described in section 4.2.1.1.

Additionally, the new functionalities also included the publication of relevant information for the DSOs such as the list of FSPs, on which new limits were applied concerning their functioning, the values and ranges of these limits, etc. Right now, DSOs do not receive this information (they only receive the final program for each programming unit). Therefore, it was necessary to develop a set of xml files to make all of this information accessible to the DSOs.

Finally, the core algorithm of GEMAS+ was modified to allow coordination between TSO and DSOs. With this new functionality, GEMAS+ checks that the TSO and DSOs limits are fully compatible, and, if not, informs both the TSOs and DSOs about the existing incompatibility.

4.2.1.1. Tests performed

The internal tests carried out to demonstrate the functionalities described above were part of Demo Run 1 only. Next, these tests are described:

- Test 1a: Generation bundle set and removal.
  The DSO will send a set bundle message which includes several generation units in a one-hour horizon. As it is stated in the process rules for this type of message, these communications must be set 10 minutes before the starting time of the enforcement of the generation bundle.
- Test 1b: Generation Bundle set, modification and removal.
  The DSO will send a set bundle message which includes several generation units in a one-hour horizon. After that, the DSO sends two new messages: one modifying the output limit of the generation bundle, and another one modifying the validity period of the bundle.
  Then, the DSO will send two additional messages to modify the bundle. However, in this test case, these messages contain several errors regarding the physical units (UFs, for its Spanish acronym) belonging to the bundle and the validity period. In this situation, GEMAS+ will reject the messages.
- Test 1c: Generation Bundle set and removal (Two-Generation Bundles).
  In this test, the DSO will send a message to create two-generation bundles. The messages are correct, so GEMAS+ accepts the bundles and sends back an ACK message.

4.2.1.2. Conclusions, lessons learned and next steps

The results of each of the BUCs performed during the DEMO Run 1 and DEMO run 2 have shown that the GEMAS+ platform with the above-mentioned new functionalities, is a fundamental tool not only to operate securely the system but also to allow proper coordination between TSO and DSOs. GEMAS+ allows both TSO and DSOS to set rapidly limits to their affecting units with the certainty that these limits will be fully compatible with the existing ones.

Taking into account the criticality of the GEMAS+ platform for the secure and reliable system operation, the implementation of all of these new functionalities has represented an important challenge for the Spanish TSO. First of all, for cyber-security reasons, the core of the GEMAS+ platform is not accessible from other external platforms, so it was necessary to use a by-pass platform to transfer securely the information exchanged between the TSO and DSOs, and between TSOs and FSP control centres.

In addition, the timing in which these new functionalities have had to be implemented has been an additional challenge, since, in the meantime, the TSOs have had to develop new functionalities and platforms to comply with the Spanish and European regulations (quarter-hourly programming, balancing platforms –MARI, PICASSO, TERRE, IGCC, etc.).

Regarding the next steps, these will be focused on allowing the control in real-time of the demand via GEMAS+. The new Spanish regulation allows demand units to participate in balancing markets and it is foreseeable that they cause congestion in the grid. The implementation of this functionality is highly complex because it involves a deep change in the core GEMAS+ algorithm.

The next steps and new functionalities regarding this platform are listed below:

- Allow GEMAS+ to manage FSPs and aggregators with a lower installed capacity (>1MW), currently, the threshold is 5MW.
- Modify GEMAS+ to allow the control of demand FSPs, this is a huge challenge because this new functionality implies a deep change in the algorithm and it will be necessary to check all the existing functions and procedures.

4.2.2. eSIOS

eSIOS is the platform developed by REE to perform the tasks of information and process management specifically related to the electricity market. eSIOS allows REE, among other functions, to communicate with market agents who bid in the Spanish electricity market, to notify the acceptance or rejection of the bids transparently and confidentially, and to publish the results of the different markets and schedules.

In the same way, the GEMAS+ platform was updated to allow DSOs to set limits to the FSP causing congestion in their grid in real time, the eSIOS platform has been updated to allow this same functionality to be implemented in the day-ahead congestion management.

The eSIOS platform regularly exchanges information with other market participants. Due to this, the new required functionalities were less critical to implement than in the GEMAS+ platform. In any case, it was necessary to modify the congestion optimization module within eSIOS, a critical module which calculates the limits and redispatch of the programing units. The following functionalities are implemented within eSIOS:

- Processing of the DSOs limits sent via the CoordiNet common platform. The processing of these limits needs to be coordinated to detect and manage the possible incompatibilities between the TSO and the DSOs limits.
- Limits and re-dispatching calculation for demand units.

Parallel to the development of the CoordiNet Project, the eSIOS platform was updated to allow demand units to participate in the balancing markets. These developments were used during the demo run 2 when a demand FSP (CEMEX) started a prequalification process to participate in RR and mFRR markets.

Finally, the eSIOS platform was upgraded to deal with demand FSPs during the Day-ahead Congestion Management Process. However, the participation of demand units in this congestion process is not included in the current operational procedures, due to this reason, the BUC agreement was carried out in a test environment.

4.2.2.1. Tests performed

The internal tests carried out to demonstrate the functionalities described above were carried out during both DEMO Run periods:

- Test 1a: FSP Limitation set by the DSO in the day-ahead common congestion management process.

  This test aims to ensure the correct reception of the DSO limit file, and its later processing during the optimization congestion management process in the day-ahead horizon.

- Test 1b: Incompatible FSP Limitation by DSO in the day-ahead common congestion management process.

  This test aims to ensure that the algorithm detects and informs the dispatcher about the possible incompatibilities in the DSO limits. These possible incompatibilities may be due to the FSPs which have been limited (it is necessary to check whether each FSP belongs to the DSO grid), or due to the total amount of output limit value, or even due to the horizon that applies to the limit. In all of these cases, the algorithm has to detect the error and send a message to the dispatcher including the reason for the error.

- Test 1c: Incompatible FSP limit by DSO and TSO in the day-ahead common congestion management process.
- This test aims to detect possible incompatibilities between the limits set by the TSO, and the limits set by the DSO, indeed it is not unusual that both operators require different output values for the FSPs, and these differences can affect dramatically the grid of the other operator. The algorithm checks all the limits, and in case it detects limits inserted by both operators, it has to decide whether they are compatible (then setting the most restrictive one), or are incompatible, in this case, the algorithm will send a popup message to the TSO dispatcher telling him to contact the DSO operator.
- Test 1d: FSP Limitation by DSO in the Day ahead Common Congestion Management Process before the Gate Closure Time (GCT).
- This test aims to detect possible errors regarding the reception of limits before the GCT, the algorithm has to detect these situations and inform DSOs.
- Test 2d: Demand FSP Limitation by DSO in the Day ahead Common Congestion Management Process before the GCT.
- This test aims to ensure the good performance of all eSIOS functions and modules when a demand FSP limit is received from the DSOs platform.

4.2.2.2. Conclusions, lessons learned and next steps

The results of each of the BUCs performed during both demo runs showed that the eSIOS platform with the above-mentioned new functionalities is a fundamental tool for data exchange between TSO and DSOs, which also improve the coordination between them.

On the other hand, the implementation of a demand module for the day ahead congestion management in a test environment is the first step to allowing demand FSPs in this new service, of course, it will require regulatory approval, but at least technically, the TSO systems are ready.

4.2.3. VOLTAIREE

VOLTAIREE is a real-time application integrated into the Siemens Scada-EMS Spectrum 3.11 in a multisite peer-to-peer configuration. It is also coordinated with other applications from REE, DSOs and Generation Control Centers (GCCs). Each GCC must have technical characteristics of the units and real-time measures of its service providers to the grid manager during the commissioning phase. VOLTAIREE sends real-time setpoints to the providers connected to the transmission grid through their GCCs. DSOs can send their setpoints also to the GCCs or use VOLTAIREE as a gateway. VOLTAIREE receives from e·sios© the reactive power capacity assigned to each provider in the market, validates each provider's compliance and sends to e·sios© the penalty counters [Mvar/h] both for the mandatory or/and the additional service if applicable.

VOLTAIREE runs in parallel and independently in two independent and redundant control systems. A signal is sent to the GCCs to indicate which system is the master at the moment. There are periodic execution programs with configurable execution times. The secondary control loop is implemented according to the scheme shown in **Figure 38**.

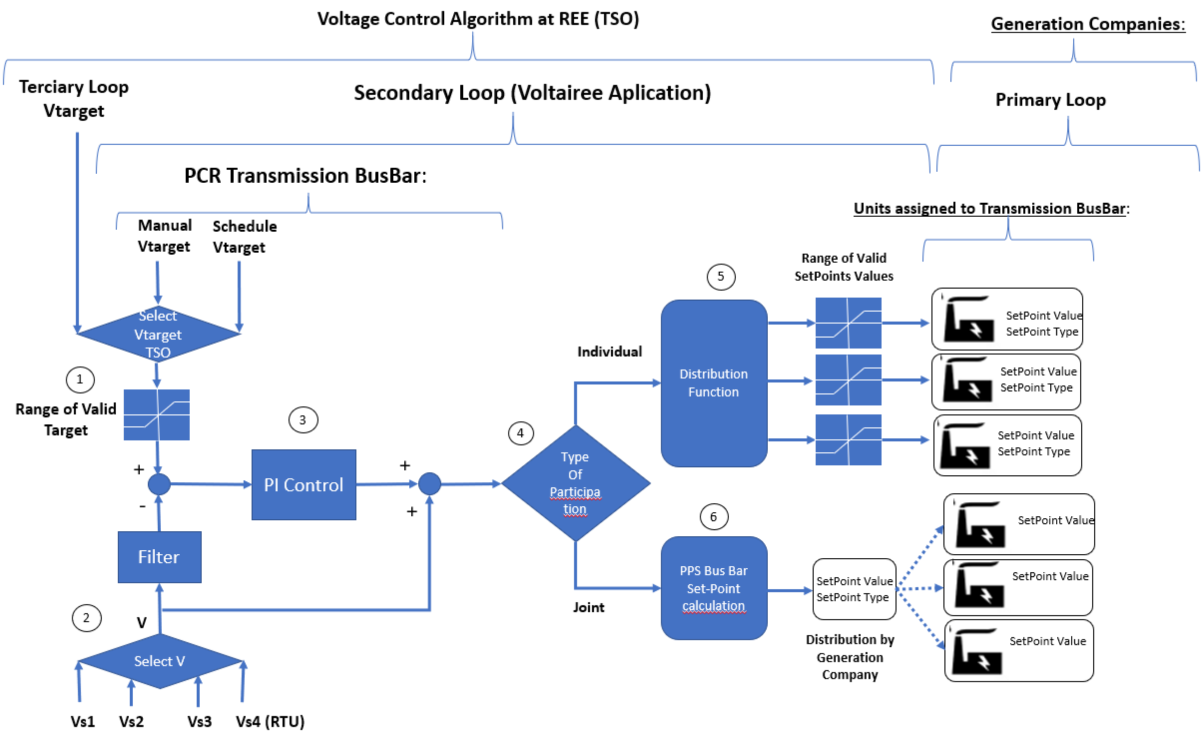


Figure 38 Additional reactive capacity example of an existing renewable generator

The secondary control loop can receive the Point of Connection of the Resource (PCR) to the network voltage setpoint either from the tertiary loop, from a predefined schedule or the operator can select it manually (1). The PCR voltage input is automatically selected from several measures according to a qualitative prioritization; however, the operator can also manually select the most appropriate measure regarding the substation topology in real-time. In any case, a low pass filter removes high-frequency components of the selected PCR voltage measure (2).

A proportional-integral control minimizes the error between PCR voltage setpoint and voltage measure. The proportional and integral gains are adjusted to avoid undesirable interactions with other secondary controls or/and transformers automatic tap changers. The integral component has an anti-windup mechanism to limit the excessive growth of the output in case of persistent errors (3). A distribution function converts the PCR voltage setpoint into BC (individual participation) or PPS (aggregated participation) (4). In both cases, the operator can select the mode between the ones available and the · K_v value per provider in modes B and C (5, 6).

VOLTAIREE analyses providers' responses every execution cycle comparing the reactive power required by the setpoint with the reactive power measure in BC and/or PPS. If the error exceeds an established threshold, VOLTAIREE checks if the provider has reached its compulsory and/or additional reactive capacity using its P-Q and U-Q curves, its voltage and active power measures and additional reactive capacity received from e·sios©.

When the provider is not saturated, VOLTAIREE accumulates in a penalty counter the reactive power not provided. These penalty counters are sent back to e·sios© for the settlement of the service if it was not provided properly for more than de 25% of the execution cycles of the hour. Figure 39 shows the VOLTAIREE flowchart, execution cycle periodicities regarding validation, penalty counters and secondary loop calculation are settable independently (step1, step 2 and step3).

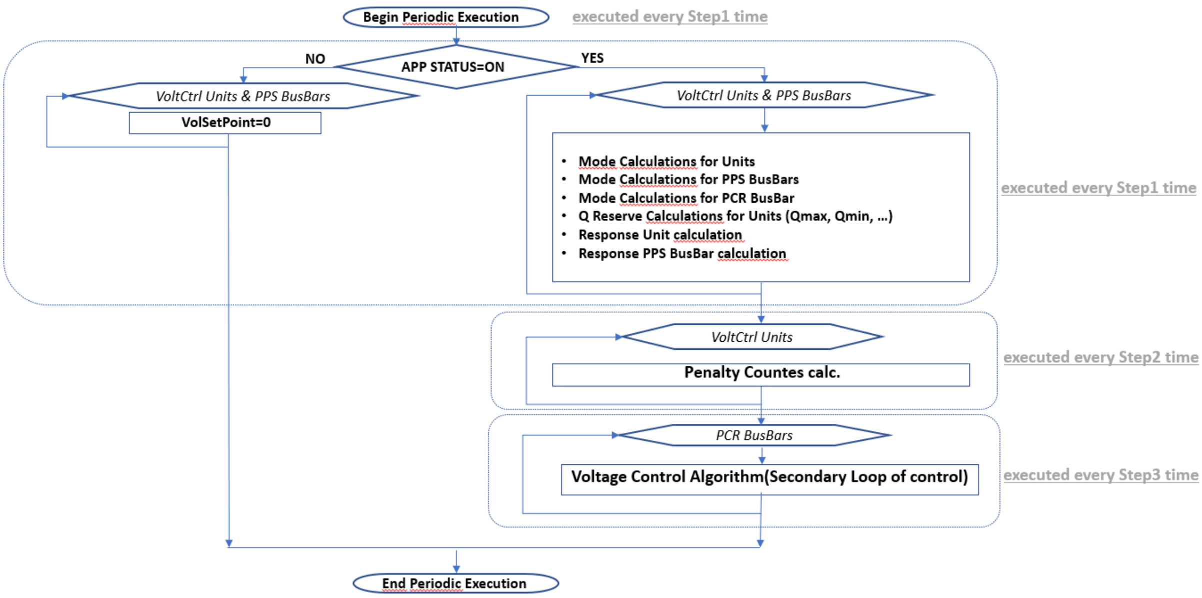


Figure 39 VOLTAIREE flow chart

4.3. Aggregation platforms

Within the CoordiNet project, two aggregation platforms have been developed:

- Tecnalia AggreFlex platform
- Bamboo Energy Aggregation platform

The objective of these platforms is to allow the aggregation of small-scale DERs to participate in Common and Local Markets. Their main functionalities include the estimation of the available flexibility of the aggregated DERs, computation of the bids to be sent to the markets and finally, operation of the DERs in real-time to fulfil market assignments.

This chapter provides an overview of each of them including the main technical developments for their implementation, the tests carried out to validate their functionalities, and finally, the main conclusions, and lessons learnt from the demonstration test cases.

4.3.1. Tecnalia AggreFlex platform

4.3.1.1. Overview of the aggregation platform

Tecnalia AggreFlex platform implements all the required functionalities to allow an aggregator of small-scale DERs to participate in common and local congestion management markets operated by the TSO and the DSO, respectively. The design of the aggregation platform is based on a component-based architecture, where each component is as independent of others as possible, and where communications among components are managed utilizing persistent database storage systems. It includes interfaces with the DERs to be aggregated, with the different Market Platforms (common/local) and with external service providers (e.g., weather forecasting service) that supply the required information for the calculation of the flexibility bids. Figure 40 shows the main components of the platform, together with the technologies used for its implementation and deployment. The main implemented modules are the following: 1) monitoring and control of DERs (DER Management module), 2) computation of the flexibility bids to be sent to the market (Market Optimization module), 3) communications with DERs (DER Communications module), 4) communication with local and common markets (Market Communications module), 5) databases to share information among the different components (Databases module), 6) communication with external service providers such as weather information supplier (Auxiliary Data Communications module) and 7) auxiliary components including price forecasting and DER model calibration functionalities in charge of adjusting the values of the parameters of the DER models based on historical measurement data using regression techniques (Auxiliary Components module). All these components are described in detail in D3.2 "Report of Hardware and Software tools developed for the DSO, TSO, market and aggregator".

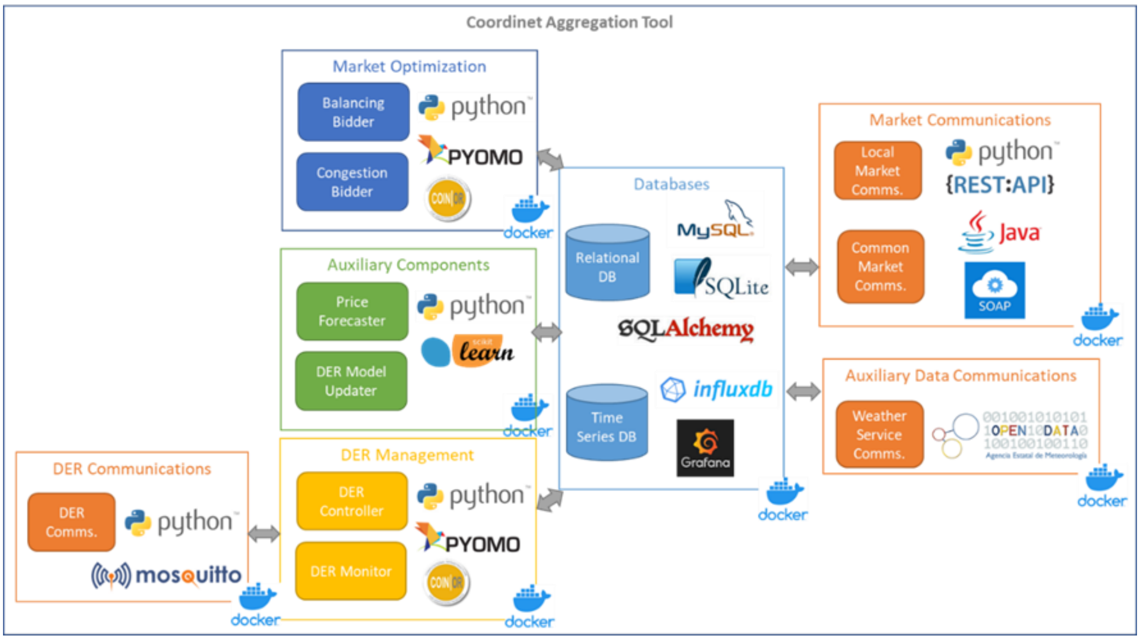


Figure 40 Tecnalia AggreFlex platform implementation

The bidding strategy implemented within the Market Optimization module is intended to maximize the economic benefits of the aggregator when participating in the mentioned markets (common/local congestion management markets). The bidding algorithm, which is based on a mixed integer linear programming model (MILP), determines the amount of flexibility made available by the aggregated DERs and the price to be bided for it. In addition, the individual control actions to be implemented on the DERs to mobilize this flexibility are also calculated. Inputs to the algorithm include the prosumers' comfort preferences and the technical parameters and constraints of the controlled devices, together with the weather and price forecasts. The novelty of this algorithm lies in the fact that it considers that the payback produced by the control of the DERs during the congestion period is traded in conventional intraday energy markets. That is, the energy shifted from the congestion period to the previous and/or the subsequent ones when providing upwards flexibility, or from the non-congestion periods to the congestion period when providing downwards flexibility, is bought/sold by the aggregator in conventional intra-day energy market sessions. In this way, the aggregator can optimize the supplied flexibility during the congestion period while ensuring that the costs of the energy deviations incurred during the provision of that service are compensated. A detailed description of this optimization algorithm is provided in D2.3 “Aggregation of large-scale and small-scale assets connected to the electricity network” (Joseba Jimeno et al. 2021).

4.3.1.2. Tests performed

The tests carried out to demonstrate the feasibility of the implementation of the developed aggregation platform and its correct functioning have been divided into two phases: Demo Run 1 and Demo Run 2.

4.3.1.2.1. Demo run 1

The objective of the Demo Run 1 was to test the functioning of the communications deployed for the participation of the Aggregator in common and local congestion management markets. It has been tested that these communications work properly. To this end, three different test cases were defined and conducted.

1) Test 1: Communication between the Aggregator and the CoordiNet Common Platform:

This test has focused on assessing the interactions between the Aggregator and the CoordiNet Common Platform “testing environment” for the participation of the former in the day-ahead common congestion management market. The test comprised the following steps:

- On the day D-1, the aggregator sends the baseline message to the common platform including the breakdown per physical unit of the program accepted for the Programming Unit in the day-ahead energy market;
- the Aggregator receives a message from the CoordiNet Common Platform including the PDBF;
- the Aggregator sends to the common platform a message including the definition of the flexibility bid for the congestion period; and, finally,
- the Aggregator receives the messages including the results of the clearing process (PDVP message, limitations and redispatch orders).

2) Test 2: Communication between the Aggregator and the CoordiNet Local Platform:

This test has focused on assessing the interactions between the Aggregator and the CoordiNet Local Market Platform (developed by N-SIDE) for the participation of the former in both, the day-ahead and the intraday local congestion management markets. The steps followed for the participation of the Aggregator in the day-ahead local congestion management market are the following:

- in the day ahead, the aggregator sends the baseline message to the local platform;
- the aggregator receives the DSO flexibility needs messages from the local platform;
- the aggregator submits the congestion management bids; and, finally,
- the aggregator receives the clearing results.

The interactions for the participation of the Aggregator in the intra-day local congestion management market, which have also been tested, are similar to the previous ones, but they take place during day D, that is, in the intraday market that opens 30 minutes before the congestion period starts.

3) Test 3: Communication between the Aggregator and the FSPs (real-time monitoring)

This test has focused on assessing the real-time monitoring of the FSPs by the Aggregator. This information is essential for the Aggregator to estimate the available flexibility to be offered in the common/local congestion management markets, as well as to decide the real-time set-points for the DERs that fulfil the market assignments. For the test, the following FSPs located in Malaga have been considered: TABACALERA POLO DIGITAL (Heat, Ventilation and Air Conditioning system (HVAC)), TABACALERA MICROGRID (Photovoltaic (PV) and Batteries), TABACALERA SHOWROOM (PV) and PASEO MARÍTIMO (PV and Batteries). During the tests, it has been checked that the required information about the monitored variables (e.g., active power consumption/production, internal temperatures, etc.) is received by the aggregator, with a time resolution of 10-15 seconds, and that these measurements are correctly stored in the aggregator's database.

4.3.1.2.2. Demo Run 2

Demo Run 2 has focused on BUC tests. The objective of these tests has been to validate the actual participation of the aggregator in both the common congestion management market (BUC ES-1a), and the local congestion management market (BUC ES-1b). The steps taken from the point of view of the Aggregator, for both BUCs are similar, including:

- sending information on the baseline;
- receiving the DSO flexibility needs;
- estimating the available flexibility and calculating the flexibility bids to be submitted by the aggregator;
- receiving the outcome of the market-clearing process, and finally,
- delivering the control signals to the FSPs to fulfil the market assignments (the real activation of the FSPs was carried out only in several test cases as described below).

The tests have been carried out in two different demonstration sites: Malaga (e-Distribución) and Murcia (e-DI) (see deliverable D3.6 “Analysis and results of real data from operations” for more information). Next, the test cases conducted for each BUC in each demonstration site are described.

Malaga demonstration site

<u>BUC ES-1a: Common Congestion Management</u>:

Three different test cases have been conducted to validate the ability of the aggregator to participate in the day-ahead common congestion management market. All of these cases have been conducted using the CoordiNet Common Platform ‘testing environment’. Consequently, the limitations (and, therefore, the redispatches in the baselines of the units) have not been applied in the real system operation.

- **Multiple physical unit upper-limitation (demand) (Day-ahead):** The objective of this demo case has been to check if the mobilization of the flexibility of demand connected to a grid node could contribute to fixing problems of over-loading at the substation level. To this end, congestion occurring from 10:00 to 11:00 on day D has been simulated at the substation San Sebastian, where the capacity of one of the transformers has been limited below the nominal value. This congestion should be eased, or solved, by setting a consumption multiple physical unit upper-limitation, formed by demand units of TABACALERA MICROGRID and TABACALERA POLO DIGITAL. The aggregator is expected to aggregate the flexibility provided by both FSPs to create an upwards flexibility bid (to reduce the power consumption) during the congestion period and to submit this bid to the common market platform.

- **Multiple physical unit upper-limitation (demand) and lower limitation (generation)**: The objective of this demo case has been to fix certain over-loading problems by limiting the capacity of the available generation and demand. This congestion, occurring from 9:00 to 10:00 on the day D is eased, or solved, by setting an individual physical unit lower-limitation to the generation unit of EMASA; and a multiple physical unit upper-limitation to the demand units, formed by TABACALERA MICROGRID and POLO DIGITAL. The aggregator is expected to aggregate the flexibility of TABACALERA MICROGRID AND POLO DIGITAL to create an upwards flexibility bid (to reduce the power consumption) during the congestion period and to submit this bid to the common market platform.
- **Multiple physical unit lower-limitation (demand):** The objective of this demo case has been to check if the use of demand connected to a grid node can contribute to fixing the problems of over-loading at a substation level. To this end, congestion at the substation POLIGONO is simulated. The capacity of one of the transformers in this substation is limited to 10.4 MVA, which forces to compensate for the power demand flowing downstream of this transformer. The congestion occurs on day D from 20:00 to 21:00. This condition is addressed by a multiple physical unit lower-limitation, formed by the demand units of TABACALERA SHOWROOM, TABACALERA MICROGRID and TABACALERA POLO DIGITAL. This increases their demand to relieve the use of this transformer. The aggregator is expected to aggregate the flexibility provided by the aforementioned FSPs to build an upwards flexibility bid (increase power consumption) for the congestion period.

BUC ES-1b: Local Congestion Management:

Three different test cases have been defined and addressed to test the participation of the aggregator in the local congestion management market. The first one focused on its participation in the day-ahead market, and the second and third ones on its participation in the intra-day market. The intra-day tests include also the activation of the flexibility of the FSPs according to the market-clearing results to demonstrate the capability of the aggregator to send control set-points to the FSPs in real-time to deliver the committed flexibility.

- **Market clearing with no real activation (Day-ahead): The** objective of the demo case is to test the functioning of the Local Market and its interaction (through the communication channels) with the DSO Platform and Tecnalia AggreFlex Platform. To this end, in D-1, the DSO sends information to the Local Market Platform.
- **Market clearing with real activation (Intraday-1):** The objective of this demo case has been to check the functioning of the Local Market and its interaction (through the communication channels) with the DSO Platform and Tecnalia AggreFlex Platform, in real-time. The activation of the flexibility of the FSPs according to market-clearing results is also performed to demonstrate the control capabilities of the aggregator over the FSPs. To this end, the DSO sends to the Local Market Platform information on upward flexibility need in the grid node CD80159 (line PACIFICO) from 11:30-11:45 on day D. The aggregator is expected to generate upwards flexibility bids for the FSPs MICROGRID SMARTCITY, TABACALERA POLO DIGITAL and TABACALERA MICROGRID and send them to the Local Market Platform.
- **Market clearing with real activation (Intraday-2):** The objective of this demo case has been to check the functioning of the Local Market and its interaction (through the appropriate communication channels) with the DSO Platform and the Tecnalia AggreFlex Platform, in real-time. The activation of the flexibility of the FSPs according to market-clearing results is also performed to demonstrate the control capabilities of the aggregator over the FSPs. To this end, the DSO sends to the Local Market Platform information on downward flexibility need in the grid node CD80159 (line PACIFICO) from 12:30-12:45 on day D. The aggregator is expected to generate downwards flexibility bids for the FSPs MICROGRID SMARTCITY, TABACALERA MICROGRID and TABACALERA SHOWROOM and send them to the Local Market Platform.

Murcia demonstration site

BUC ES-1b: Local Congestion Management:

- **Case 1 - Market clearing involving the activation of FSPs in Murcia city (Day-ahead):** The objective of this demo case has been to check the functioning of the i-DE Local Market Platform and its interaction (through the communication channels) with the DSO Platform and Tecnalia AggreFlex Platform. To this aim, the demo has tested the participation of the aggregator in a day-ahead local congestion management market to solve congestions detected in an MV line. In real-time, the flexibility of the corresponding resource (heat air conditioning of the city hall building) is activated to deliver the service.

A detailed description of all tests carried out in Demo Run 2 is provided in CoordiNet D3.6 “Analysis and results of real data from operations”.

4.3.1.3. Obtained results

The main results from the Demo Run 1 are:

- The deployed communications between the Aggregator and the CoordiNet Common Platform worked properly to allow the participation of the Aggregator in the Day-ahead common congestion management market since all the required messages were correctly exchanged between them.
- The deployed communications between the Aggregator and the CoordiNet Local Platform (developed by N-SIDE) worked properly to allow the participation of the Aggregator in both the day-ahead and the intra-day local congestion management markets since all the required messages were correctly exchanged between them. An issue related to the clearing of the bids by the Local Market Platform was detected that was solved for Demo Run 2.
- The communication technologies deployed for the monitoring of the FSPs can receive real-time measurement data every 10-15 seconds. Initially, it was detected that, in some cases, communications were interrupted during certain periods and for some FSPs. This issue has been analysed and partially avoided in the second demonstration phase. **Figure 41** shows, as an example, a screenshot of the information displayed for the user interface developed for the monitoring of the FSP TABACALERA-POLO DIGITAL. The period considered lasted from the 11th to the 18th of June 2021. This figure displays the active power consumption, the reactive power, the reactive energy, the current, and the voltage and power factor of the HVAC system installed on that site.

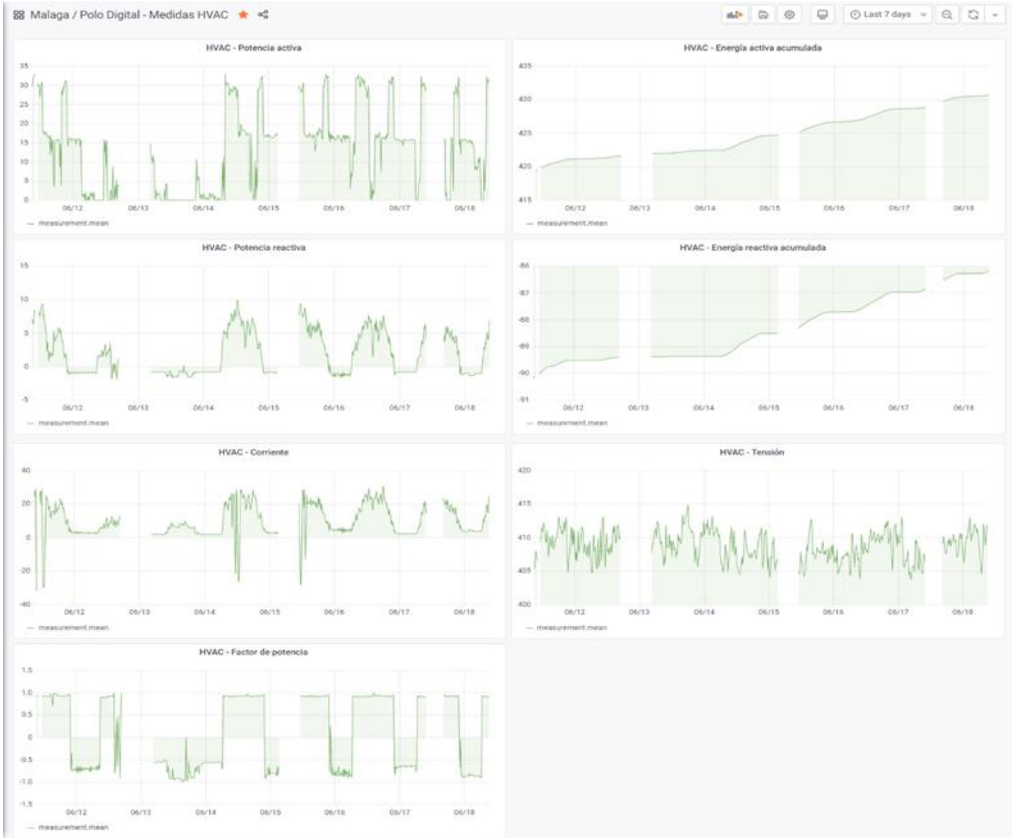


Figure 41. Screenshot of the monitoring of "TABACALERA – POLO DIGITAL" – HVAC system

A detailed description of the tests carried out during demo run 1 and the results obtained are provided in the deliverable D3.4 "Analysis and results of real data from operations (Part 1)" of the CoordiNet project.

The main results from demo run 2 are discussed next.

BUC ES-1a: Common Congestion Management:

- The AggreFlex platform allows the participation of the aggregator in the day-ahead Common Congestion Management Markets (BUC ES-1a). The test cases carried out in Malaga have demonstrated the capability of the developed aggregation platform to aggregate the available flexibility from the FSPs, generate upwards/downwards flexibility bids according to the requirements of the TSO, and exchange information with the common market platform to participate in the mentioned market.
- As the output of test cases 1 and 2, the DSO sends a request to the FSPs TABACALERA POLO DIGITAL and TABACALERA MICROGRID to reduce their power consumption by 0.1 MW. In test case 4, the DSO sends a request to TABACALERA POLO DIGITAL and TABACALERA MICROGRID to increase their power consumption during the congestion period by 0.2 and 0.1 MW, respectively. The results of these test cases have shown that the amount of flexible demand is not enough to address the congestion alone, but it contributes to the congestion relief.

BUC ES-1b: Local Congestion Management:

- The AggreFlex platform allows the actual participation of the aggregator in both the day-ahead and the intraday Local Congestion Management markets (BUC ES-1b). Similarly, for the common congestion management market, the aggregation platform can generate the required flexibility bids and exchange information with the local market platform developed by N-SIDE to participate in the aforementioned markets. Two sample messages from the day-ahead local congestion management market test case are provided in the following figures. **Figure 42** shows a screenshot of the XML message sent by the Aggregator to the Local Market Platform with the upwards flexibility bid corresponding to Tabacalera - Polo Digital (UPNSIDE2). Figure 43 shows the clearing results sent by the Local Market Platform to the Aggregator for such sFSP.


```
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- <SimpleBid>
    <BidID>Tecnalia_NSIDE_1063_DA-2022-03-17t13:00:00-00:00</BidID>
    <Timestamp>2022-03-17T10:24:42Z</Timestamp>
    <DsoNeed>false</DsoNeed>
    <Direction>upward</Direction>
  - <Location>
      <NodeID>1063</NodeID>
    </Location>
    <ProgrammingUnit>UPNSIDE2</ProgrammingUnit>
    <SenderID>TECNALIA</SenderID>
  - <ListOfSimplePeriods>
      <PeriodNumber>49</PeriodNumber>
      <Price>54.413605</Price>
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    </ListOfSimplePeriods>
  - <ListOfSimplePeriods>
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    </ListOfSimplePeriods>
  - <ListOfSimplePeriods>
      <PeriodNumber>52</PeriodNumber>
      <Price>54.413605</Price>
      <Volume>0.023560889</Volume>
    </ListOfSimplePeriods>
    <SessionID>DA-2022-03-17t13:00:00-00:00</SessionID>
</SimpleBid>
```


Figure **42** Upwards flexibility bid (UPNSIDE2 -Tabacalera-Polo Digital)


```
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- <ListOfResults>
  - <ListOfBidResults>
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    - <Location>
        <NodeID>1063</NodeID>
      </Location>
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      </Periods>
      <ProgrammingUnit>UPNSIDE2</ProgrammingUnit>
      <SenderID>TECNALIA</SenderID>
      <SessionID>DA-2022-03-17t13:00:00-00:00</SessionID>
      <Timestamp>2022-03-17T13:36:11.232501Z</Timestamp>
  </ListOfBidResults>
```


Figure **43** Upwards flexibility bids clearing results (UPNSIDE2-Tabacalera-Polo Digital)

- The test case that focuses on the participation of the aggregator in the intraday local congestion management market has also demonstrated the ability of the aggregator to remotely control the FSPs to provide the committed flexibility by sending the required control signals to the EnergyBox. In particular, the following control actions have been sent to the FSPs in Malaga to deliver the flexibility dispatched to the aggregator in the intraday market lasting from 11:30 to 11:45 (upwards flexibility):
- TABACALERA POLO DIGITAL sets the set-point temperature of the HVAC system to 20.5°C and disconnects the heat recovery units.
- TABACALERA MICROGRID: discharge 3.3 kW during 15 minutes the batteries

Figure 44 shows the activation of the HVAC in the TABACALERA-POLO DIGITAL consisting of turning off partially the HVAC system (switching off the heat recovery units). From 11:30 to 12:00 it can be seen that the power consumption of the HVAC system is zero, reducing as a consequence its power consumption by 22 kW during the congestion period.

Figure 44 HVAC control activation signal sent by the aggregator to Tabacalera Polo Digital sFSP

Figure 45 shows the reduction of the temperature setpoint from 21.5°C to 20.5°C of the HVAC in TABACALERA-POLO DIGITAL (orange line).

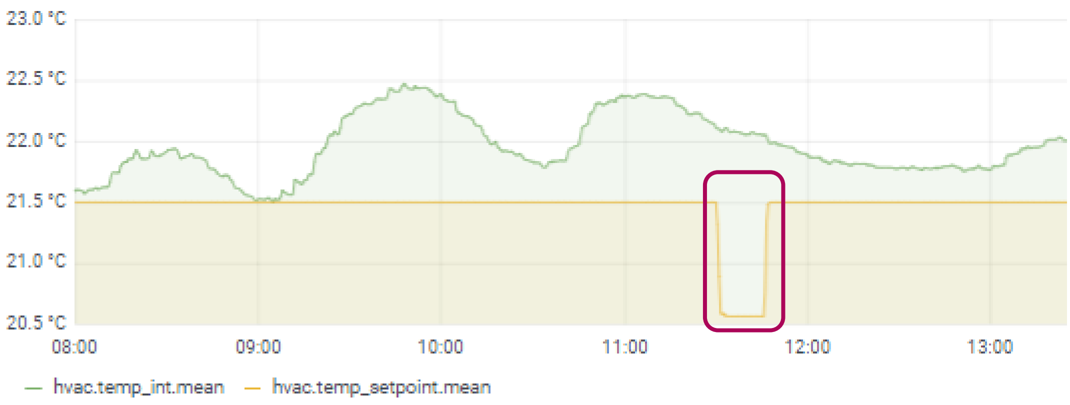

Figure 45 Temperature setpoint activation signal sent by the Tecnalia to Polo Digital sFSP

Finally, in Figure 46 it can be seen the activation signal sent to TABACALERA-MICROGRID corresponds to a discharging setpoint (-3.3kW during 15 minutes) to the Battery Inverter from 11:30 to 11:45.

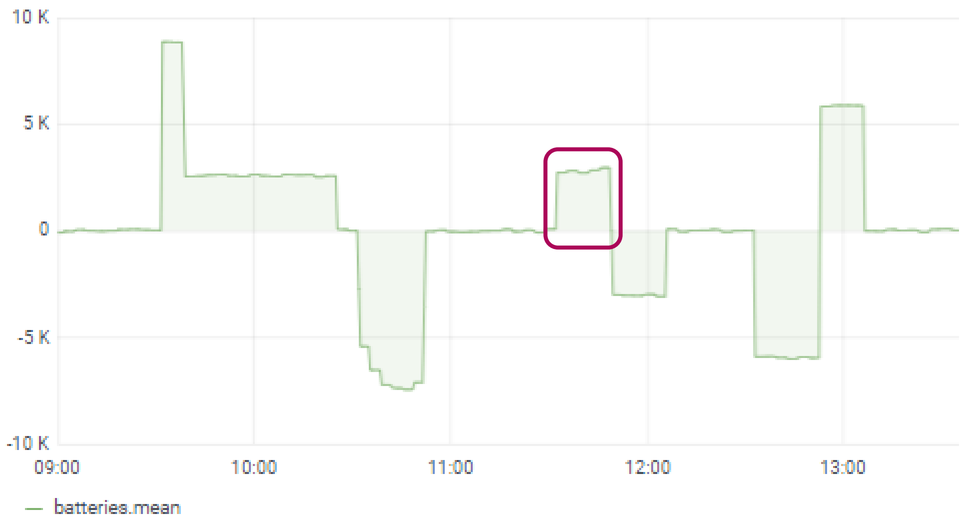

Figure 46 Battery active power activation sent by the Tecnalia to Tabacalera Microgrid sFSP

As it can be seen in the previous figures, the control set-points are correctly received and the corresponding control variables are appropriately adjusted by the FSPs, thus contributing to addressing the congestion detected by the DSO. At 11:45h, the activation period ends and the aggregator adjusts the set-point for the FSPs to return to their previous states and submits this information to the FSPs, as can be also seen in the previous figures.

Similar conclusions have been obtained for the second intraday market lasting from 12:30 to 12:45 (downwards flexibility) in which the following activation orders were delivered by the aggregator to the FSPS:

- TABACALERA SHOWROOM: cut off the PV production
- TABACALERA MICROGRID: charge 6 kW of the batteries and cut off the PV production

The test case conducted in Murcia showed that the aggregator is also able to communicate with the local market platform developed by iDE to participate in the day-ahead local congestion management market and, afterwards, control the output of the FSP in real-time to deliver the service. Specifically, the control action implemented has involved reducing the power consumption of the city hall building of Murcia by turning off the air conditioning system (with three units of 200 kW nominal power each) for 1 hour. The amount of flexibility finally delivered is less than expected, due to the high temperature in the city on the day of the test. However, the full process of the participation of the aggregator in the mentioned market through the activation of the FSP has been validated.

The detailed description of the outputs of the test of the demo run 2 can be found in CoordiNet D3.6 “Analysis and results of real data from operations (Part 2)”.

4.3.1.4. Conclusions, lessons learned and next steps

The demos conducted to test the Tecnalia AggreFlex platform are divided into two main phases. The first one has focused on testing the exchange of information between the platform and the common and local markets, as well as the FSPs (real-time monitoring of DERs). The second phase has assessed the ability of the aggregator to participate fully in both the common congestion management market (BUC ES-1a), and the local congestion management market (BUC ES-1b). The results of the demos have demonstrated the technical ability of the developed aggregation platform to allow an aggregator of distributed flexible energy resources to participate in common and local congestion management markets in different timeframes (day-ahead and intraday). In particular, through the platform, the aggregator can:

- Monitor the output of the flexible units in the Malaga demonstration site
- Estimate their flexibility
- Bid this flexibility in the common and local markets, operated by the TSO and the DSO, respectively
- Receive the market-clearing results
- Decide which units are best placed to be dispatched
- Control the response of these flexible units

4.3.2. Bamboo Energy Aggregation platform

4.3.2.1. Overview of the aggregation platform

Created in July 2020, Bamboo Energy S.L. is a spin-off of the Catalan Energy Research Institute (IREC) created, precisely, to enable the provision of flexibility on the energy demand side. The technology behind the Bamboo flexibility platform has been developed by professionals with more than 10 years of experience working in the Catalonia Institute of Energy Research (IREC). The IREC work is recognized by the scientific community. In these years, the group has produced 47 scientific publications and participated in more than 25 European, national and industrial projects. The company offers a scalable and versatile platform for independent aggregators and retailers to efficiently manage distributed energy resources.

The platform, under the name Bamboo, is based on a combination of cutting-edge technologies such as a very scalable cloud serverless architecture and an advanced time-series database. The platform uses the best cyber security practices for user authentification and data encryption and is also integrated with a blockchain platform for data exchange decentralization. Self-trained Machine Learning algorithms are used to estimate the flexibility of the client portfolio and predict the market conditions, and robust mathematical modelling and combinatorial optimization algorithms are used to compute the optimal management of the electricity demand and its analysis.

Bamboo Energy's platform is an agnostic system that can be connected to all the types of flexibility asset communication systems, to manage a wide variety of flexibility assets from different sectors. Thanks to its modular architecture, it allows the existing modules to be updated and can easily incorporate new functionalities.

The main characteristics of the solution proposed are:

- Due to the use of artificial intelligence, this platform is fully automated.
- It manages flexibility assets of different types at the same time, maximizing the value of the flexibility mobilized through it.
- It is easily adaptable to different market requirements thanks to its completely parametrizable optimization models to build the market offers.
- It automatically manages real-time flexibility trading operations
- The algorithms employed within the platform are placed in the cloud, and the software is hardware agnostic.

4.3.2.2. Tests performed

During the project, two demos were carried out to prove the ability of the Bamboo platform to manage the participation of distributed flexibility resources in local markets to solve the grid congestion.

The objective of the first demo was to test the functioning of the Local Market platform and the exchange of information between it and the DSO Platform through Bamboo. To this end, during the day ahead of real-time operation, Bamboo sends the power consumption forecast, also called baseline, of the "Centro de Sciencia y Tecnología" and the "Greenray" buildings' to the Local Market platform. In parallel, during the day ahead, the DSO sends to the Local Market platform the request for a certain amount of downward flexibility needed at the grid node where the building "Centro de Sciencia y Tecnología" is placed, considering the baseline previously sent. Once the Local Market receives the information on the DSO needs, this information is available for the flexibility services provider to download, as shown in the next caption.


```
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<SessionID>DA-2022-03-11t13:00:00-00:00</SessionID>
```


Figure 47 Caption of the DSO needs downloaded during the first demo

After this, Bamboo forecasts the amount of flexibility available to be mobilized on the next day and builds and submits to the Local Market Platform a DOWNWARD flexibility offer (an increase of consumption) for the demand for the building of the "Centro de Sciencia y Tecnología", which is located in Node 126. This building, during the periods when the DSO has some flexibility needs, has about 60 kW of flexibility available to be mobilized from the chillers installed in the building. Finally, Bamboo submits the data on the amount and type of available flexibility to the Local Market platform, where the clearing process takes place.

The objective of the second demo case is to check the functioning of the Local Market and the exchange of information between this and the DSO Platform and the Bamboo Energy Aggregation platform, in real-time while managing grid congestion and mobilizing the flexibility available from the demand.

To this end, first, BambooEnergy sends, during the day ahead, the expected consumption of the "greenray" building to the Local Market platform. The congestion of the grid is simulated at the power line placed just upstream of the grid where the "greenray" building is located. Related to this, the DSO sends in real-time its flexibility needs to the Local Market platform. This congestion is expected to be eased or solved by addressing the DSO needs by mobilizing the UPWARD flexibility provided by an aggregator. Indeed, Bamboo receives from the Local Market the data on the DSO needs. Then, this platform estimates the flexibility available within the building (about 4 kW) to reduce its consumption. Finally, the platform builds and submits, to the Local Market platform, a flexibility offer for the demand in NODE 66, as shown in the next piece of code.

```xml
<SimpleBid>
    <BidID>Bamboo_CD004863_20220208_123098</BidID>
    <Timestamp>2022-03-24t11:30:00-00:00</Timestamp>
    <DsoNeed>false</DsoNeed>
    <Direction>upward</Direction>
    <Location>
        <NodeID>66</NodeID>
    </Location>
    <ProgrammingUnit>BambooProgrammingUnit</ProgrammingUnit>
    <SenderID>bambooenergy</SenderID>
    <ListOfSimplePeriods>
        <PeriodNumber>1</PeriodNumber>
        <Price>400</Price>
        <Volume>0.005</Volume>
    </ListOfSimplePeriods>
    <SessionID>ID-2022-03-24t11:30:00-00:00</SessionID>
</SimpleBid>
```


Figure 48 Bamboo's upward flexibility offer at Node 66[3]

After this, when the market-clearing is performed, Bamboo and the DSO download the market results from the Local Market platform to verify that the flexibility offered has been cleared correctly. In the demo run, the offer built and submitted by Bamboo is accepted, which means that the DSO relies on a consumption reduction to take place at Node 66 during the period when the flexibility need has been identified and reported.

Finally, Bamboo sends the consumption set point, resulting from the mobilization of flexibility, to all the 10 flexible devices of the "greenray" building to reach the new consumption level set. The change in the consumption level is verified by the Bamboo front end. Then, the demo is finished.

4.3.2.3. Obtained results

The main results of the demo 1 are listed next:

- Describing and displaying the structure of the aggregator platform, including all the buildings whose consumption is monitored by the Bamboo Platform, both in an aggregated and disaggregated way.

[3] It can be seen on the image a volume offered of 0.005 while the flexibility offered by the FSP was actually 4kW. This is due to the rounding algorithm of the market platform. For a further implementation it was suggested to define the bid as kW for small FSPs instead of MW.

Figure 10 Aggregated and disaggregated consumption from the 10 buildings monitored by the Bamboo Platform

- Demonstrating the ability of the Bamboo platform, the DSO and the Local Market platform to send, receive and clear day ahead flexibility offers and needs. Besides, the reliability of these platforms in conducting the aforementioned activities is checked. The flexibility offer built and submitted for period 76 is cleared correctly. The price offered by the FSP is -150 €/MWh, meaning that the FSP expects to receive at least 150 € per MWh of downward energy cleared, in return for increasing its consumption level. The bid offered by the FSP, in this case, is illustrative, considering that as of today, FSPs do not know what is the value of their flexibility. The volume of DOWNWARD power offered amounts to 60 kW. Considering these, the FSP earns 2.2 € for a quarter of an hour of full activation of this amount of energy.
- Determining the accuracy of the day-ahead baseline forecast algorithm of the Bamboo Platform. This has reached a level of 93.5 % considering only data for a few days.

The main results of the demo 2 are listed next:

- Demonstrating the ability of the Bamboo, DSO and Local Market platforms to send, receive and clear day ahead flexibility offers and needs reliably.
- Assessing the accuracy of the day-ahead baseline forecast algorithm of the “Greenray” building. This has reached an accuracy level of 85.7 % considering only a few days of data.
- Assessing the accuracy of the intraday flexibility forecast algorithm of Bamboo for the “Greenray” building. This has predicted that the flexible load available within the building during the concerned period, when the DSO requested some flexibility to be delivered, amounts to 4kW. This is provided by the HVAC installed in the building. During the flexibility activation period, the consumption of the flexible equipment within the building is reduced by 4.2 kW. This corresponds to an accuracy of the flexibility forecast algorithm of 95 %.
- This demo has also validated the correct functioning of the exchange of information processes taking place between the Bamboo Platform and the Energy box installed in the building.
- Proving the load of this building can be controlled remotely by the aggregation platform to solve grid congestion. This has also been shown during the flexibility activation period. Showing the correct functioning of the aforementioned processes, the flexibility offer for the building has been cleared correctly in the intraday market session ID “ID-2022-03-24t11:30:00-00:00”. The SP has offered a price of 400 €/MWh, meaning that the FSP expects to receive at least 400 € per MWh of UPWARD energy cleared, corresponding to a decrease in its consumption. The flexibility offered

amounts to 4 kW. This involves that the FSP earns 0.4 € for a quarter of an hour of full activation of this amount of energy.

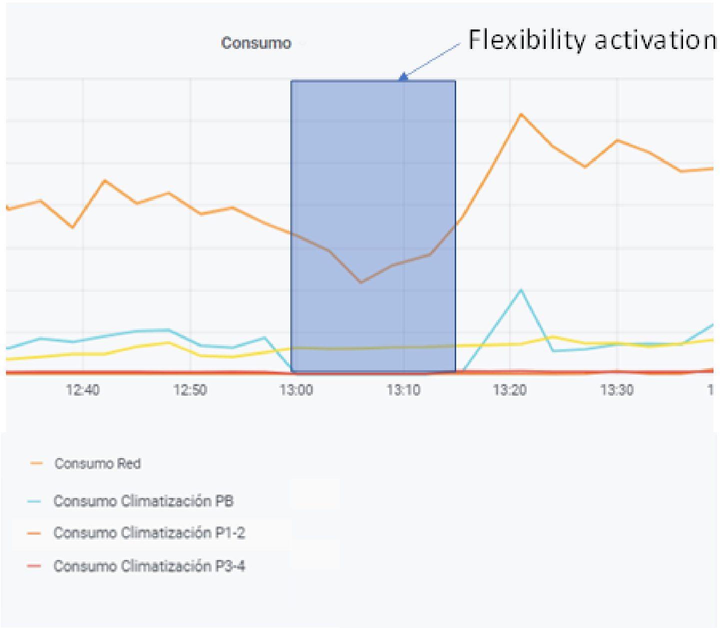

Figure 49 Consumption behaviour (orange and blue line) during a flexibility activation

4.3.2.4. Conclusions, lessons learned and next steps

The demo in Malaga previously described and analysed demonstrated the technical feasibility of the distributed flexible energy resources participation in local markets to solve grid congestion. Also, the integration of the Bamboo Flexibility platform with the Local Market platform, built by N-Side paves the way for a larger-scale implementation of the solution here assessed, to enable the participation in the flexibility market of distributed energy resources.

4.4. Local market platforms

4.4.1. Overview of the N-SIDE local market platform

The N-SIDE local market platform implements all the required processes to allow a smooth run of the market according to the agreed market design (see Coordinet Deliverable D3.2). This includes bid registration aspects, registration of DSO needs, optimal market clearing avoiding network constraints violations, and publication of the matched trade, i.e. accepted order and quantities, as well as market prices (see Figure 50).

N-SIDE's core business resides in developing advanced clearing algorithms and being able to consider in the market platform more advanced biddings products, such as block orders, that allow FSPs to reflect in their bids more accurately the features of their assets and their constraint (see Figure 50). Such an auction tool also allows considering a variety of grid constraints, explicitly taking into account the market clearing optimization algorithm (see Figure 50).

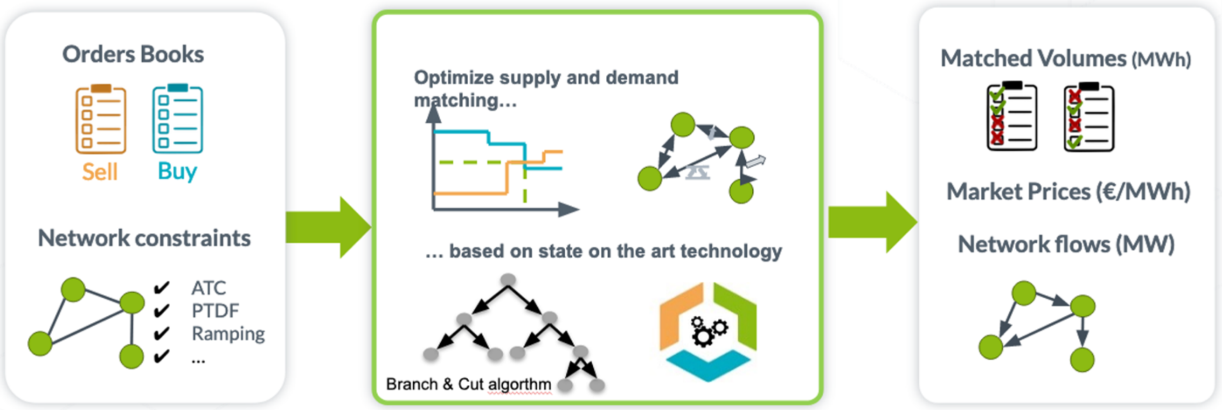

Figure 50 Conceptual explanation of the N-SIDE Power Matching algorithm used in the local market platform

The very first information that needs to be uploaded on the market platform is the grid topology and characteristics. The DSO is expected to do so using a REST service (see Figure 51). Networks are modelled through a list of nodes and arcs, the latter representing the lines. Each arc is connecting two nodes and has a maximum capacity parameter. The network topology input can be updated every time it is needed but this input is expected to be rather static. The network topology input does not need to be the real detailed topology but can be an equivalent model of the distribution grid, as the DSO sees fit, with a detail on the lines which are likely to be congested.

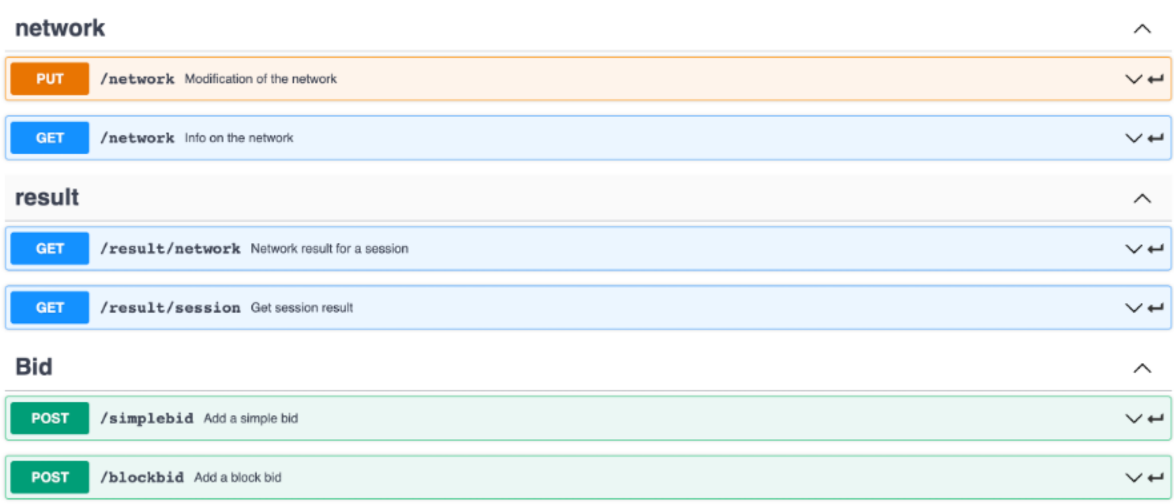

Figure 51 Subset of REST API functions to exchange information with the N-SIDE local market platform

The second step of the process is for both FSPs and DSO to place their orders on the platform. FSP offer the flexibility they have available to mobilize from local assets, while the DSO sends a bid representing the flexibility need to solve a congestion. Every bid must refer to (a) a specific location in the grid (i.e. a node), (b) a specific timestamp, (c) and a specific session (i.e. day-ahead or intra-day). Each bid must also be assigned a bid price, a volume, and a direction (referring to either upward or downward flexibility).

Following a predefined schedule (see details in Coordinet Deliverable D3.2) for the day-ahead and intra-day market auctions, the platform clears the market, i.e. it determines the matching of flexibility offer bids to flexibility needs bids that maximize some objective (see Figure 50). In this use case, the maximum social value is achieved when solving all the congestions in the grid at the lowest possible cost. Computing this optimum requires solving a mixed-integer linear programming problem. The day-ahead market is cleared every day at 2 pm CET/CEST. After this, an intraday session is run every 15 minutes throughout the day (for delivery 30min later), where the DSO can update/refresh his flexibility needs closer to real-time. In this setup as well, the local market clearing algorithm selects the accepted volumes and determines the market prices which minimize the cost. The pricing scheme considered in this demo is pay-as-clear.

The last step simply involves publishing the results of the clearing. For this purpose, users can fetch the matched trades, which are saved in the database using a rest API.

This service is hosted as a SaaS solution on a dedicated server in the cloud (see Figure 52). It comprises an HTTP server that handles the API service, a data layer that takes care of all the data manipulation and storage, and a core engine that performs the actual market clearing. This engine is based on the N-SIDE Power Matching Algorithm solution, which is a standard product from N-SIDE which is running in operation on large-scale real markets for various customers. Every new feature of the product undergoes intensive testing to ensure everything is working correctly. The input and output data are stored in a separate database in the cloud that is accessed by the data layer of the tool.

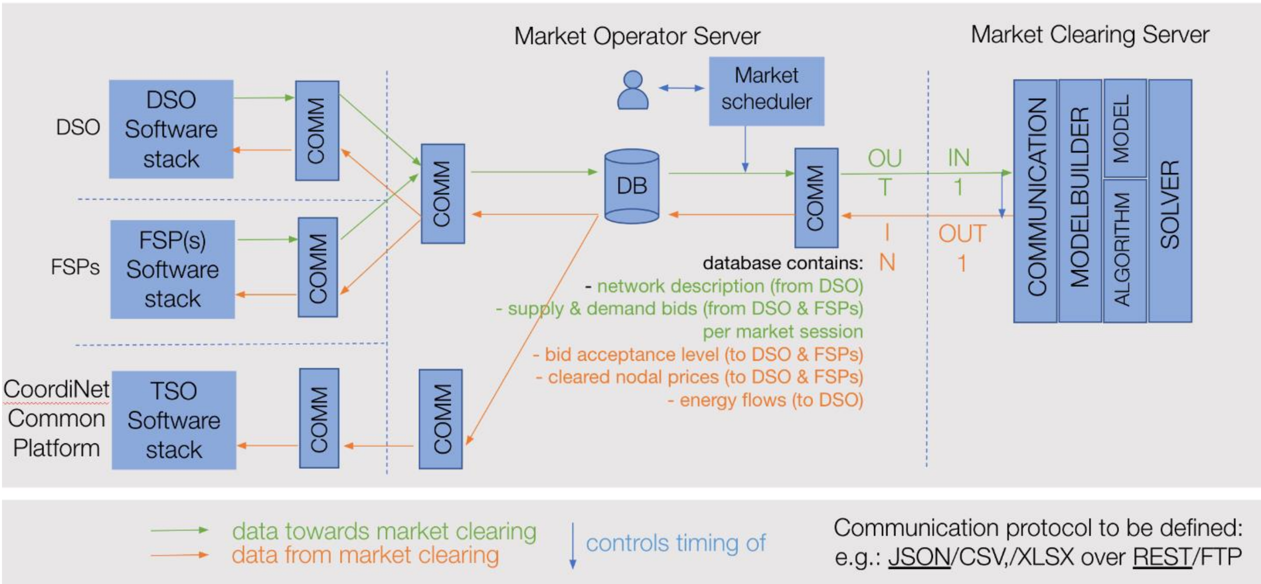

Figure 52 N-SIDE local market platform architecture and interactions with DSO, FSP and Common platforms

4.4.2. Tests performed

All tests have been described in the DSO section (see section 3.1.1.2) and FSP sections (see section 3.3.1.2 and section 3.3.2.2).

Internal tests (unit tests, functional tests, performance tests) have been performed extensively to test the functionalities of the local market platform, extending the high-level standard N-SIDE applies for its Power Matching Solution (for instance used in operations by IEX, the largest power exchange in India).

4.4.3. Obtained results

Results of the internal tests have been satisfying and otherwise, the local market platform has been working as expected, providing results in line with the expected outputs, given the inputs described in the tests in the local congestion management in CoordiNet Deliverable 3.6.

4.4.4. Conclusion

N-SIDE has developed a local market platform fit for the project, with a communication layer based on REST API and its own power matching algorithm product. This algorithm can consider several of the coordination schemes developed in CoordiNet and was here configured for the local market setting.

The local market platform was a central platform and results showed that it is indeed feasible to solve congestions for the DSO in a market way, procuring the flexibility from the assets in the network, clearly and transparently, i.e. based on clear market rules and optimization formulation of the market products and grid constraints.

4.5. Summary of communication implementations in the Spanish demonstrator

The ICT architecture of the Spanish Demo is presented in Figure 53. The figure shows the main platforms described later on in this section. Although the Local Platform was envisioned to be unique and be used by any existing DSO, due to practical reasons, i-DE determines the resources to be activated, while e-distribución interacts with the local market platform developed by N-SIDE.

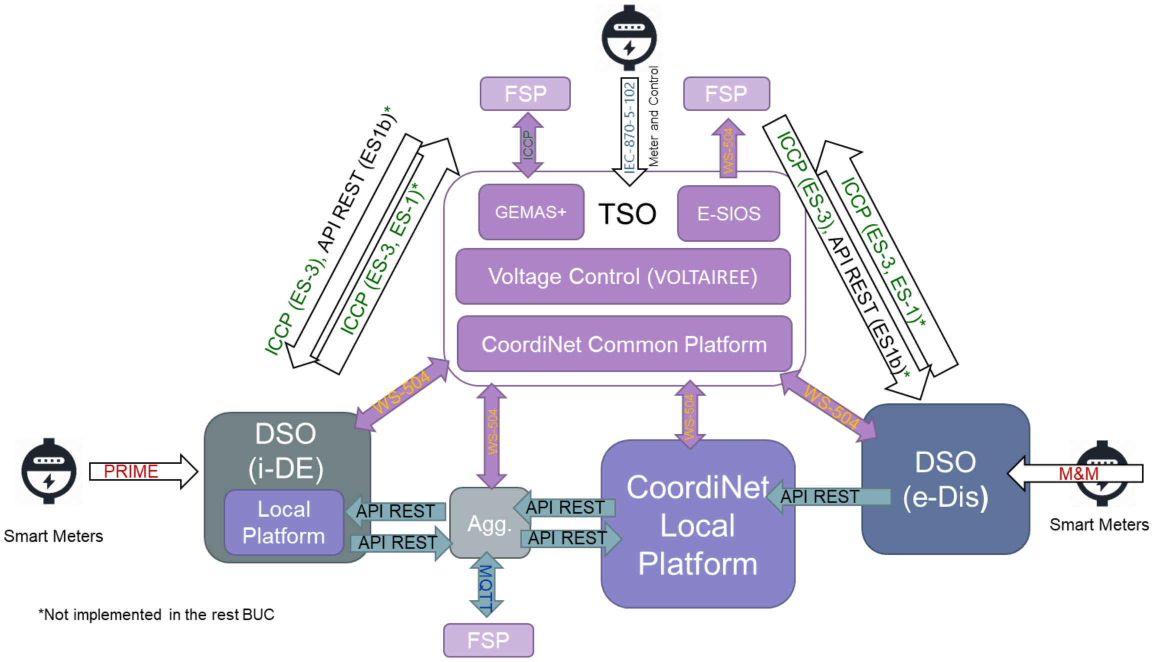

Figure 53.- ICT Architecture implemented in the Spanish Demo. Communication between FSPs and the two DSOs is identical, the figure only shows one for clarity reasons.

As shown in Figure 53, each actor in the system has several specific interfaces that need to be used when communicating with it. The Local Platform can be contacted using the REST API to communicate the bids from the market supply (FSPs) and demand (DSO). Similarly, the local platform communicates the Congestion Management Needs and Market Results to the FSP aggregator.

Communication with CoordiNet's Common Platform is done using the WS-504 protocol. The Local Platform communicates the Market Results while DSOs provide the network constraints and needs. The Common Platform uses the WS-504 protocol to broadcast the Market Results to the DSOs and aggregator. Additionally, the aggregator indicates baselines and bids to the Common Platform using this same technology.

The Common Platform (more precisely, GEMAS+) uses ICCP as a real-time communication protocol to set real-time limits to the FSP generation corresponding to the generation of bundles from the DSOs. In addition to the previous, ICCP is also used in the Voltage Control use case.

Finally, FSPs communicate their flexibility to the aggregator using the MQTT protocol, given its asynchronous behaviour. FSPs inform the aggregator about measurements taken in the DERs and the aggregators indicate the corresponding setpoints

Client-Server protocols are used in situations wherever there is a need to retrieve data or command the start of process execution. This kind of usage is coherent with the idiosyncrasy of such protocols. Nevertheless, each one of the used client-server protocols has its specific features.

In the case of WS-504, as mentioned before, it´s a more robust and less flexible protocol which has higher processing needs (compared to REST-API). Its usage to interact with the Common Platform is justified since this interface will be dealing with devices that probably will have few processing restrictions (i.e. mainframe machines or servers), such as the ones in the DSOs' premises or the Local Platform.

A clear contrast with the WS-504 is the REST-API used when communicating with the Local Platform. In this case, the most valuable feature is easier connectivity (due to a simpler protocol), so that any kind of device (not only those not limited by its processing capabilities) could connect. A REST-API covers this requirement, which validates its selection for this interface.

Finally, the last Client-Server protocol is ICCP, which is used in interfaces which need a real-time communication performance. This is the case of the setpoints communications to the FSPs through the GEMAS+ module.

The CoordiNet Spanish Demo also uses communication protocols intended for asynchronous behaviour (i.e. occurring at random instants). This is the case of the FSP units sending their status and setpoints at any moment in time. As described previously, FSP sends updates to an MQTT broker which, in turn, publishes the information to the actors that previously subscribed to the corresponding fields. Given the uncertain (i.e. asynchronous) nature of the change in the FSP unit's variables, MQTT is a very popular technology used in similar IoT environments.

Finally, there is the case of the Smart Meter devices providing information about consumption to the DSOs. In this situation, some form of Power Line Communication technology is used: Meters&More in the case of e-Distribución and PRIME in the case of i-DE, since these are the technologies both utilities are using in their corresponding deployments. This communication technology is chosen as the Spanish Demo is placed in mid/high-densely populated areas where PLC behaves reasonably well thanks to moderate attenuations.

5. Market developments and implementations

This section describes the most relevant contribution and achievements of the CoordiNet Spanish demonstrator. The section refers to the main relevant KPIs obtained in the demonstrator runs and describes existing challenges and barriers detected in the Spanish context.

5.1. Balancing

5.1.1. Main achievements and contributions within CoordiNet

Improvement of the TSO-DSO coordination

The main achievement of the Balancing BUC has been improving the Coordination between the TSO and the DSOs in the balancing processes.

The balancing processes comprise a set of real-time markets (some of them carried out through common European platforms) through which the FSPs provide services to restore the system balance. System balancing is a task exclusively assigned to the TSO; however, DSOs can set limits on those units which may cause congestion in the DSO grid. This is stated in the forthcoming regulation SO GL 182 and Spanish Operating Procedure 3.1[4]. This BUC tries to improve the management of imbalances according to the following actions:

- Automation of the process whereby the DSO sets limits on those FSPs affecting their grid. Before CoordiNet, this process was carried out manually. Then, this new functionality reduces constraints setting times, which, in turn, leads to an improvement in the system operation.
- Assessment of the compatibility of the limits established by the TSO and the DSO. Quite often, the limits set by the TSO impact the DSO's grids, and vice versa. This functionality analyses the levels of all the limits set. Then through this same functionality, the platform aims to find the value to apply to strike a reasonable trade-off. If this is not possible, the two operators are informed of the situation and encouraged to negotiate a solution that is appropriate for both.
- Improvement of the TSO-DSO data exchange process: According to both national and European regulations, the TSOs have to share the relevant information with the DSOs. This information includes the information about the technical characteristics of the units, and the programs and re-dispatches applied. In the BUCs carried out, the TSO made available part of this information to the DSOs.

Due to the complexity of the balancing processes, and to be able to allocate the provision of flexibility to some of the FSPs participating in Coordinet, it was decided to carry out the BUCs in a testing environment. Through this strategy, it was possible to monitor the performance of all the tasks and subtasks and track the management actions affecting the offers submitted by the stakeholders (offers and limits assigned, compatibility problems raised, etc.). Additionally, some BUCs were carried out off-line since the service offered by FSPs is not covered by the Spanish grid codes.

[4] https://www.ree.es/en/activities/operation-of-the-electricity-system/operating-procedures

Participation of demand FSP in the balancing process

One of the most important goals of the European regulation addressing the ecological transition is removing the barriers to the entrance of new participants, among others the Demand Side Response. Related to this target, the CoordiNet project has defined a BUC to verify the technical capacity of the demand FSP units to meet the requirements set to participate in the balancing markets. This BUC has also tried to show the potential of this technology to contribute to system security.

This BUC was carried out during demo run 2. It involved testing the capability of the demand FSP (CEMEX) to participate in the Spanish balancing markets, i.e. passing the prequalification tests, which are a set of procedures designed by the Spanish TSO and published in the document "Guía para el cumplimiento del requisito de Información Estructural". This document sets the steps that follow to qualify a demand unit:

- Submitting the technical characteristics of the units. This information includes the grid connection bus, the maximum consumption rates, the capacity of the transformer etc.
- Implementing a communication channel between the FSP and the SO (ICCP link) for the latter to receive the telemetry of the consumption of the FSP.
- Registering new demand programming units to allow them to participate in the Spanish Balancing Markets through the eSIOS platform.
- Performing the prequalification tests, which are described in the national grid code 3.8. This involves adopting a consumption profile close to the outcome printed in Figure 54.

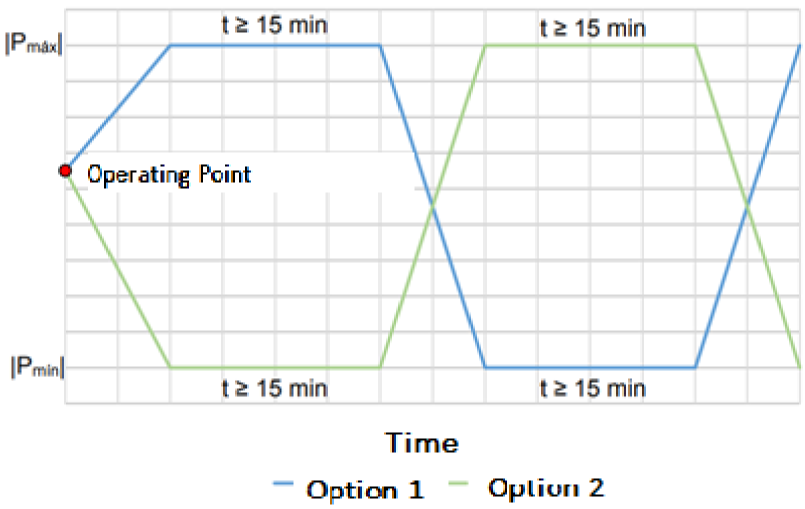

Figure 54 Consumption profile for demand prequalification process to participate in the Spanish Balancing Markets

The demand FSP CEMEX meets all the previous requirements except for the ability to register new demand program units. This requirement is essential to be able to participate in the balancing markets, since, without this program unit, the eSIOS market platform could not assign the bids in the market to a specific player. Then, the FSP cannot be fully qualified. Consequently, the scope of the BUC has been reduced to just assessing the capacity of the FSP to participate in the market. However, the real participation of the FSP in the balancing market has not been implemented.

The main results of the ramp test of the FSP CEMEX, within the prequalification test carried out on March 21st, are listed below:

- Upward ramp Power variation in 15 minutes: 7,31 MW.

- Downward ramp Power variation in 15 minutes: 7,86 MW.
- Upward ramp Power variation in 30 minutes: 8 MW.
- Downward ramp Power variation in 15 minutes: 8 MW.

Graphically, the response, corresponding to the results of the ramp tests reported above, is depicted in Figure 55.

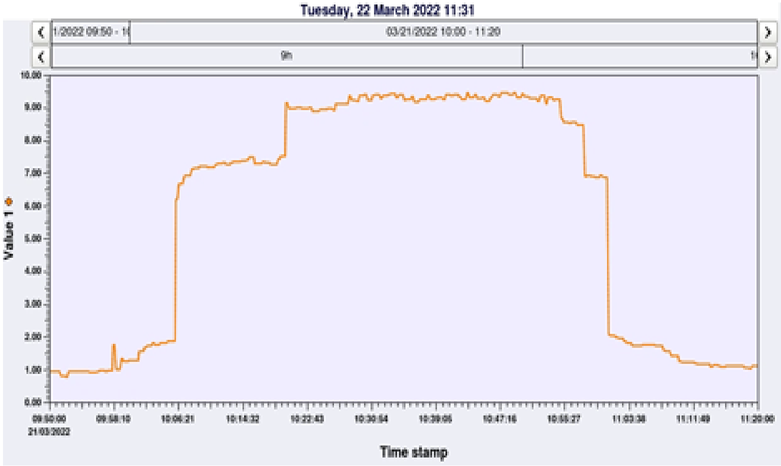

Figure 55 FSP Consumption during the CoordiNet demonstration

Verifying that the technical capabilities of this particular FSP demand unit meet the requirements to participate in the balancing markets represents a huge achievement. This is not only because it shows the potential of these FSPs, but also because it opens the door to the full participation of this new type of technology in the balancing markets, which could have a significant positive impact on the ecological transition. Indeed, one of the most important goals of the European regulation is to remove the barriers to the entrance of these new participants.

5.1.2. Main KPIs

The following KPIs are relevant for balancing Use Case.

Table 5 Main balancing BUC KPIs

KPI	Value	Comments
KPI_33- Total Activation time of a product	9 260 h	This value represents the total amount of hours where the Spanish electrical system needed balancing energy in the first half-year of 2021.[5]

[5] The value considers both mFRR and RR products, and both upward and downward hours, reason why the number of hours is higher than 8760 h.

KPI_22- Requested flexibility	1 848 707 MWh	This value represents the total energy required by the Spanish electrical system to maintain the balance during the first half-year of 2021.

5.1.3. Challenges and barriers

The main challenge faced by the TSO was related to the fact that the new functionalities listed above required the upgrade of one of the most critical platforms, eSIOS. Indeed, any change in its algorithm could produce the malfunction of other processes carried out by this platform.

When demonstrating the limitation by the DSOs of the output of FSPs by DSOs in the balancing market, the TSO and the DSOs could interact according to the appropriate coordination mechanisms for those products being delivered nationally (mFRR). However, when considering the same for the cross-border RR product (through the TERRE platform), some incompatibilities among the required interaction processes were observed. In this particular case, it was observed that the use of FSPs connected to the distribution grid for the provision of cross-border balancing products could pose more challenges than the nationally defined balancing products.

Regarding the demand for FSP participation in the balancing services, the following barriers were found:

- Need to facilitate the Demand FSP market registration process, including the ability to register new demand program units.
- Provide information to potential demand FSPs about the balancing markets and their operation.

5.2. Common congestion management

5.2.1. Main achievements and contributions within CoordiNet

During demo run 2, the Common congestion BUC was redefined and their relevance increased by testing the capability of demand FSPs to participate in the Spanish Day-ahead Congestion Management Process. This BUC involves exchanging information on limits on several demand units in the area of Malaga utilizing the e-di (limitation exchange process carried out automatically through the CoordiNet Common Platform).

Contrary to the balancing market, the participation of demand in congestion management markets is not supported by current national regulations. Due to this, it was impossible to carry out this BUC using the online eSIOS market platform. Instead, it was carried out using an offline testing version of eSIOS. Nevertheless, the platform and its functionalities are the same as the online eSIOS. The only reason for conducting the demonstration on the offline version is that the current regulation would not allow the real activation of the CoordiNet FSPs, as no regulatory sandbox exists for that matter. However, undertaking this BUC in this way has led to the same conclusions as making use of the real eSIOS platform, as the platform (e.g. data exchange functionalities, algorithms used) are the same.

5.2.2. Main KPIs

Table 6 shows the main KPIs to evaluate the success of the implementation of ES-1a on common congestion management.

Congestion management requires counteractions to rebalance the system after solving congestions, this cost could be relevant as should in Table 6.

By comparing the KPI_4 and KPI_5, the OPEX of the current equipment used is higher than the one of a single unit that is represented in KPI_5 for Malaga's FSPs. The OPEX for service procurement includes both the aggregator's and physical unit cost to provide the service (€/MWh) multiplied by the total amount of MWh provided at the market during the demos, and the OPEX for the installation of the software necessary for monitoring and control the FSPs, which is equal for each FSP considered. Additionally, the cost per FSP related to the aggregation platform development is included. To make a fair comparison, the use of the FSP's flexiblity in different markets would be needed.

Table 6 Main common congestion management BUC KPIs

KPI	Value	Comments
KPI_1 – Cost of counteractions needed based on the activated flexibility	510.88 €	The costs of these counteractions are due to the need to maintain the balance in the system.
KPI_4 – Operational Expenditures (OPEX)	42 880 €	This indicator calculates the recurrent costs that are required to operate and maintain the installed equipment. It is assumed that each congested equipment would require 80 services a year.
KPI_5 - OPEX for service procurement	32 242 €- 32 423 € (Malaga FSPs)	This indicator includes both the aggregator's and physical unit cost to provide the service (€/MWh) multiplied by the total amount of MWh.

5.2.3. Main challenges and barriers

To achieve the actual participation of the aggregator platform in the common congestion management markets, there are still several technical, economic and regulatory challenges that have to be addressed, including the following:

- The minimum trading volume required to be allowed to participate in the existing common markets is too large for the aggregators of small-scale DER. In Spain, the minimum power allowed for participating in the global market is 0.1 MW (100 kW), with the same granularity. This means that: 1) Every FSP (aggregator or individual FSP) must be able to offer at least 100 kW to participate, 2) Every FSP can offer only any multiple of 100 kW (100, 200, 300… kW), 2) If the installed power is not an exact multiple of 0.1 MW (e.g. 160 kW), some capacity can be lost. This limit should be reduced to allow most aggregators to participate in the common congestion management market.
- The costs for the aggregator to deploy the communications with the TSO common platform are very high. In Spain, the common market requires the monitoring and control of the FSPs by ICCP protocol (IEC 60870-6 TASE.2). As part of Spanish critical infrastructure, the communication shall be redundant among systems. This implies the installation of a duplicated dedicated line between the TSO and every FSP and the implementation of the mentioned communication protocol. These

requirements can make inviable from an economical point of view the participation of the aggregator in the common congestion market.

- In the case of the day-ahead timeframe, the corresponding process had to be implemented through the Common CoordiNet Platform 'testing environment' and the limitations could not be applied directly to the FSPs. This is a consequence of the fact that the everyday operations of the TSO cannot be bypassed to carry out a demonstration test.

The following challenges are shared by the common and local congestion management markets:

- Having real-time monitoring and control capabilities of the flexible resources is fundamental for the aggregator to be able to participate in these markets. However, this is not an easy task, as demonstrated in Malaga. In some cases, the equipment available was too old to enable the external control of the resources, while, in others, the existence of proprietary control software did not allow the easy control of the equipment.
- Computing accurate enough estimates of the flexibility that can be delivered by DERs is essential for the aggregator to minimize the deviations incurred. This requires developing and deploying aggregation models that accurately represent the behaviour of the DERs under the different possible control actions. This represents a challenge for the aggregator since the flexibility that can be mobilized depends on many factors, several of them subject to a high degree of uncertainty (e.g. end-users behaviour, weather conditions, etc.).
- Defining the real-time control actions to be carried out on the DERs to comply with the market dispatch is another important requirement to be met by the aggregator. The aggregator should apply techniques (e.g. MPC – Model Predictive Control) allowing him to recompute in real-time the setpoints to be defined for the DERs, and applied to them, considering their real-time behaviour, as well as the short and medium-term system forecasts to minimize the deviations from their trading position.
- Managing in an efficient way the economic payback produced in the previous and the following time intervals of the congestion period is needed to avoid deviations concerning the scheduled consumption/production. This issue has been addressed within the bidding algorithm developed by considering that the changes made to the amount of energy produced or consumed when managing the grid congestion are traded in intra-day market sessions.

5.3. Local congestion management

5.3.1. e-distribucion

5.3.1.1. Contributions and achievements

The main objective of this BUC was to procure flexibility from resources connected to the DSO LV networks to solve temporary congestion that can occur at the DSO LV networks. This BUC is of great importance due to:

- The local nature of the congestion in a network where the DSO may not have full observability and monitoring capabilities.
- The small flexibility service providers (sFSP) may face an entry barrier to participating in processes run on the common congestion management platform.
- The proposed product is less complex, has a shorter response time and a longer activation time than other similar ones in the case of structural congestion, maintenance and outages on local networks

In the case of e-distribucion, the tests took place in Malaga and there was a total of four actors involved. Those are:

- The DSO: the grid owner and is in charge of submitting information on the local congestion needs per node to the market.

- Aggregators (2): participate in this service, depending on the specific area and assets: Tecnalia and Bamboo Energy. They were in charge of monitoring the performance of the sFSPs, as well as building and sending the flexibility bids to the Local Market Platform.
- Market Operator: this platform is owned by the fourth actor, N-SIDE, which took on the Market Operator role.

The Local Market Platform is a welfare maximization independent platform that runs the market clearing process taking into account the network status and the flexibility bids received. The pricing scheme implemented was of a pay-as-cleared type, which means there was a uniform price applied per bidding area of the network. In other words, for each market period t, every cleared bid of a given bidding area was applied the same price, which corresponds to the highest cleared bid (€/MWh).

The monitoring and control of the loads were carried out through an Energy Box (EB). The EB is a solution for micro-grid management developed by CIRCE. It is a multi-purpose concentrator to manage the operation in various scenarios involving advanced electrical networks and smart grids. In addition to its versatile communication capabilities, it contains an embedded computer that provides computing and processing capacity to implement distributed computing. The processes run on this computer include the collection and storage of information, the execution of algorithms and the control of the installation among others.

Furthermore, increasing the observability of the LV distribution grid is crucial to monitor the grid status and improve the process of detection and solving of local congestion. To this end, 108 MV/LV secondary substations (including more than 130 transformers) have been updated by installing sensors at the LV side of the transformers, facilitating the correct management of the local network congestion tested in Malaga.

Before starting the demos, the correct functioning of the several interactions between the different partners involved in the Local Congestion BUC was tested, which is also critical to assess the capability of the systems developed to manage local congestion. This included the communication processes taking place between the DSO, the Aggregators, their platforms and the Local Market Platform. Within the main demo tests, there were five cases tested, corresponding to two in the day-ahead timeframe and 3 in the intraday timeframe, with both aggregator platforms. All the tests were performed successfully and showed that the common coordination schemes developed to provide an effective solution for the management of local congestion.

5.3.1.2. Relevant KPIs

There are several KPIs that are relevant for Local Congestion Management. Some of them are specifically calculated for local congestion management, while some others are common to all the cases within the second demo run. The list of KPIs, together with their level for the BUC, and the key points on the assessment of these levels are given in Table 7.

Table **7** - KPIs relevant for Local Congestion Management, e-distribución

KPI	Value of KPI	Comments
KPI_1 – Cost of counteractions needed based on the activated flexibility	0 €	As the amount of power delivered per demo was under the threshold of 0.1 MW, no counteractions have been necessary and, therefore, their cost amounts to 0€.
KPI_4 – Total Expenditures	147 406.50 €	This amount corresponds to all the business use cases tested at CoordiNet as well as both demo sites. This cost contains

		the cost of development and deployment of the DSO Platform and the cost of the EB development and installation.
KPI_5 - OPEX for service procurement	161 941.08 €	These include the costs incurred in the tests conducted using both aggregators: Technalia and Bamboo Energy. This cost contains the cost to provide the service, the aggregation platform maintenance cost and the EB maintenance cost.
KPI_6 - Average cost per service for the examined period	161 941.80 €	The calculations in KPI_5 consider the average cost of the examined period and the costs for the maintenance of the platforms. At the same time, the EBs are fixed regardless of the examined period. Thus, the average costs over all the services equal the OPEX values calculated in KPI_5.
KPI_11 - Inaccuracy of the RES production forecast calculated 24 hours in advance	5525	Normalized Mean Absolute Percentage Error (MAPE) In this case the KPI is normalized (divided by the FSP Capacity in MW).
KPI_16 - Potential flexibility offered	0.214 MWh	Total volume for all demo tests.
KPI_17 - Increase in the amount of load capacity participating in DR	0.488 MW	The total increase in the amount of load capacity participating in DR in all the tests
KPI_18 - Volume of transactions	0.396 MWh	The total volume of the transactions taking place. It is the sum of offered volumes before market clearing and the cleared and dispatched volumes.
KPI_19 - Number of transactions	12	
KPI_20 - ICT cost	551 410 €	Includes the costs of the DSO platform, both Aggregator platforms and the Local Market platform.
KPI_22 - Requested flexibility	0.182 MWh	The total amount of flexibility requested for all the demo tests.
KPI_24 - Accuracy of the load forecast calculated 1 hour in advance	3.73 %.	Mean Absolute Percentage Error (MAPE)
KPI_25 - Accuracy of the load forecast calculated 24 hours in advance	9.45 %	Mean Absolute Percentage Error (MAPE)
KPI_31 - Total activation time of a product	2.75 h	The market time unit considered was 15 min.

KPI_34 - Percentage of tested products per demo	100 %	The demos covered one product, local congestion management
KPI_36 - Participant recruitment	100 %	Four actors recruited
KPI_37 - Active participation	100 %	Four actors participated
KPI_38 - Type of flexibility providers per demo	83 %	Five out of the six considered technologies were available and provided flexibility[6].

5.3.1.3. Challenges and barriers

In the case of local congestion management, the biggest challenge was the installation of the monitoring and control devices for the FSPs and the LV network. The process of installing the Energy Box was lengthy and customized for every FSP. This resulted in a reduction in the amount of flexibility that one of the sFSP made available and the withdrawal of the participation of another sFSP in the final BUC tests. In addition, some delays were incurred in the installation of the sensors.

KPIs show high entry costs for aggregators, therefore the higher the number of transactions traded the faster the activity can be potentially profitable. This depends on the flexibility needs and the value stacking from different markets.

The process of installing the 16 Energy Box was lengthy and customized for every FSP. This resulted in a reduction in the flexibility available to be mobilized by one FSP and the withdrawal of the participation of another sFSP in the final BUC tests.

Before reaching the commercial phase, some adjustments should be made to the regulation applicable and the communication layer:

- The granularity of the product to be traded should be finer: Since the granularity of the bids allowed in the Local Market platform is too coarse, the first offer submitted has not been accepted by the Local Market platform. Then, the Bamboo platform has had to artificially increase the amount of flexibility available within the building. Without modifying this, the offer submitted for the building would not have been considered in the clearing process, since, during the demo, the amount of flexibility made available by one of the buildings has amounted to just some kWs. We suggest changing the unit of the offer from MW to kW to allow small assets to participate in the market.
- The Flexibility market timeline should also be adjusted. To avoid speculation, the flexibility offers should be submitted only after the baseline for the FSP is published, and, subsequently, the DSO publishes the needs to be met. Then possibility for speculative offers would be reduced.
- Adjustments to the Measurement&Validation process: The definition of the measurement and validation process is paramount to building an effective business model. These aspects are out of

[6] From what is reported in Deliverable 3.4, a modification to the original number of technologies defined in D1.6 is included: no EV is under the scope of the demos. Considering this, in Demo Run 2 a total of five technologies are available at this region: renewables (PV and wind), conventional generators connected to the distribution system, aggregator, consumers, storage.

the scope of the project. However, the DSO needs to understand the flexibility delivered by the FSP, and for the FSP to accurately build the flexibility offer and deliver accordingly.

- The data exchange process should also be improved: The hardware installed at the site where the flexibility is delivered should ensure the excellent quality of the data in terms of connection reliability and data resolution. During the demo, Bamboo had some problems in harvesting data, due to internet connection problems. In a commercial phase, the hardware installed should ensure a higher reliability level. At the same time, the frequency of receiving some of the data has been reduced to adapt it to the hardware characteristics and enable the management of multiple flexibility assets. In a commercial phase, the hardware installed should be adapted to increase the quality of the connection and the granularity of the data exchanged.

5.3.2. I-DE

5.3.2.1. Main achievements and contributions

A local market pilot was conducted with the same purpose of assessing the ability of the market and platform developments carried out, and the coordination schemes designed and implemented, to mobilize the flexibility of small FSPs in the i-DE distribution network. This included assessing the value of the flexibility provided. For this, and thanks to the Cascading Funds, it was possible to collaborate with the City of Murcia. A study was carried out focused on assessing the possibilities created through the management of the supplies of the City Council. Two buildings were selected to be part of the pilot. These two buildings could make flexible use of energy, and that in one of them could be monitored by the SCADA system. Tecnalia acted as an aggregator for the pilot.

The test has turned out to be especially interesting to check the feasibility of creating a network need and managing the provision of flexibility from a provider to address this need. The facilities involved were office buildings and municipal services, and flexibility could be obtained from the management of the air conditioning demand, i.e. Demand Response in LV and MV grids. Regarding the local market itself, given the difficulty of implementing the interconnection with the local market developed by N-SIDE, it was decided to make use of the market matching within the functionalities of the i-DE platform. This should have the same effect on the test as the use of the N- SIDE market and was easier to implement.

As for the implementation of the project approach, and in the same way that happened in the e-distribución demo, the installation of one Energy Box (EB) for the control of the load by the aggregator has turned out to be very complicated. The programming of the device so that it could interact with the SCADA of the City Council was not simple and required the intervention of the developer of the software of the City Council itself.

Regarding the visibility of the network, it was required to install devices of various kinds to have real-time information on the network and the consumption of the buildings, both in the MV network and the LV network. In MV a whole switchgear was fully automated in the junction to one building´s connection. In LV sensors at the LV side of the transformers and LV feeders were installed in the secondary substation where the other building is connected.

On the other hand, from the point of view of the provision of flexibility, the importance of making reliable predictions of the amount of flexible capacity that can be mobilized is noteworthy. In the pre-qualification tests, the amount of flexible power that was deemed to be available was significant. However, when conducting the demo, the amount of flexible power available was significantly lower because the ambient temperature was less extreme. The dependence of flexibility on external parameters, such as the ambient temperature, must be taken into account when calculating the short-term and long-term flexibility needs and resources available.

5.3.2.2. Relevant KPIs

The list of relevant KPIs, the levels computed for these in the demo, and the key points for the interpretation of these results are provided in Table 8. These KPIs refer to the Local congestion management service.

Table 8 - KPIs relevant for Local Congestion Management in i-DE demonstrator

KPI	Value	Comments
KPI_4 – Operational Expenditures	14 472 €	Considering each local congestion situation would require providing 54 services a year.
KPI_5 - OPEX for service procurement	0,50 €	The estimation provided by the aggregator for the local market has been considered. It considers the price requested by the aggregator in €/MWh. The maintenance of the platform is not considered.
KPI_6 - Average cost per service for the examined period	25 €/MWh	The estimation provided by the aggregator for the local market has been considered.
KPI_11 - Accuracy of the RES production forecast calculated 24 hours in advance	5,3 %	Normalized Mean Absolute Percentage Error (MAPE)
KPI_16 - Potential Offered flexibility	0.2 MWh	Calculated as the flexible amount of energy (MWh) offered during the test.
KPI_17 - Increase in the amount of load capacity participating in DR	0.40 MW	The total increase in the amount of load capacity participating in DR
KPI_18 - Volume of transactions	0.02 MWh	The total volume of transactions in the demo tests.
KPI_19 - Number of transactions	1	
KPI_20 - ICT cost	265 000 €	Includes the costs of the DSO platform, both Aggregator platforms and the Local Market platform.
KPI_22 - Requested flexibility	0.3 MW	Amount of flexible power required.

KPI_31 - Total activation time of a product	1 h	The provision of flexibility requirement was made for 1 hour.
KPI_34 - Percentage of tested products per demo	100 %	One targeted product (local congestion management) was tested.
KPI_36 - Participant recruitment	100 %	One customer accepted to participate.
KPI_37 - Active participation	100 %	One customer actively participated.
KPI_38 - Type of flexibility providers per demo	12.5 %	One out of eight technologies listed in D1.6 participated in this use case.

5.3.2.3. Challenges and barriers

In the case of local congestion management making use of the local platform, the main challenges have been the development of the platform itself and the implementation of the corresponding links with the different actors. This situation has been overcome by developing an API (Application Programming Interface) that allows the interaction with the aggregator and the submission of http messages to the common platform to take place. The difficulties of implementing a link to the local market developed for the e-distribution demo were overcome by making use of the internal market matching functionality existing in the i-DE platform, considering the same logic already existing for it. This required a slight extension of the scope of the analyses, but a very simple logic has been chosen for this algorithm. The accuracy of the forecast of the amount of available flexibility. Due to the type of demand being managed, the amount of flexibility available in this case is very sensitive to the ambient temperature. It is, therefore, necessary to highlight the role of the aggregator in computing this accurate forecast of the amount of flexibility available, which can be used to determine the flexibility available to the DSO.

Interactions with the assets' technological developers become a barrier to automating the controllability of the resources.

5.4. Voltage control

5.4.1. Main Contributions

Current Spanish voltage control currently is based on fixed instructions that grid managers issue by phone, email or even regular mail. This Voltage control demo proposes a voltage control scheme based on real-time setpoints calculated, in the case of the TSO, thanks to the tertiary and secondary loops to optimize the voltage profile of the transmission network pilot nodes to solve the new challenges of the Spanish electrical system. The DSOs have also sent voltage, reactive power and power factor setpoints, either directly or through VOLTAIREE, to the FSPs connected to their networks to optimize their voltage profile.

This demo also proposes a new zonal market design intended to encourage providers to offer their whole available capacity in addition to the mandatory one. Since voltage control is local, each network manager must define zones of electrical influence and establish an additional reactive capacity requirement per zone.

5.4.2. Main KPIs

The main KPI for ES-3 voltage control BUC is the estimation of the increment of reactive power flexibility for the network operators, however, these values depend on the operating conditions of the power plants as reported in CoordiNet D3.6 (Ivanova et al. 2022).

Voltage control OPEX depends if, to provide the service, it affects the active power which the FSP cannot provide to the grid due to the reactive power injection or absorption. Given the conditions of the FSP and the network itself, for the inductive case, no variations in the active power are found in the case of Cadiz to absorb reactive power from the grid and therefore there is no cost related to this product. In contrast, for the capacitive case, several difficulties were found to maintain the active power stable while injecting reactive power into the grid and therefore such a situation might cause related costs to the FSP. Nevertheless, considering the network conditions where the FSP of PESUR is connected (in which the voltage at the power plant busbars is higher than the nominal value), the only service which the FSP provides is the inductive reactive power or reactive power absorption and consequently, no costs are considered. The complete list of KPIs is included in Deliverable 3.6.

Table 9 - KPIs relevant for Voltage control BUC

KPI	Value	Comments
KPI_2 – Estimation of the increment of reactive power flexibility for the network operators (TSO and DSO)	There is no single value it depends on the operating points of units	The estimation of the increment of reactive power flexibility was done using the PQ curve obtained during the prequalification tests.
KPI_4 – Operational Expenditures (OPEX)	268 €	It’s assumed that voltage control with reactive power would require 1 service a year. This is expected to be required in programmed maintenance.
KPI_5 - OPEX for service procurement	0€	Referred to PESUR installation.

5.4.3. Challenges and barriers

The procurement of additional capacity to the mandatory requirements for generation units to manage voltage control is a new service which has not been remunerated separately from the congestion management market. Although an initial market design proposal has been established, the functioning of that market mechanism is still to be tested in the system. The lack of experience in providing the service and the evolution of the system requirements provide uncertainties in the evolution of the service. Furthermore, local arrangements and quantifying the effects of local grids which belong to different developers add complexity to the procurement.

Future research should also analyse the effect of reactive power penalizations to guarantee that the new scheme provides efficient incentives and a level playing field for demand-side resources.

One of the lessons learnt that should be taken into account in the future voltage market design is that currently, many FSPs are not prepared to participate in the service due to the lack of voltage controllability or singularities in their grid connection. The costs related to the retrofit of the existing FSP that would allow these units to provide the service should be further analysed with the OEMs. Consequently, the remuneration of the future voltage services must be enough to make up for the required investment needed to allow such participation.

From the test performed some other challenges and barriers were identified. One of the challenges identified is the fact that the FSP's capacity to be prequalified for the Voltage Control service is highly dependent on the grid conditions. So, depending on the grid conditions, the FSP would not be able to prequalify all its reactive power additional capacity. Alternative methods must be analysed to complete the pre-qualification in cases in which the grid conditions are not optimal.

Another challenge that is worth mentioning and must be taken into account for future service implementation is the interaction between power plants in shared networks. The supply of reactive power varying the voltage can affect other FSPs that are close to the one that is providing the service, causing e.g. the tripping of the FSP electrical protections.

5.5. Controlled islanding

5.5.1. Main achievements and contributions

This test was carried out in a rural 20kV radial line fed from a substation (66/20kV) in Murcia. There are several automatic circuit breakers along the line, which allow generating smaller or bigger load islands. The considered island area comprises a total length of 116km of overhead lines, where 1179 customers are connected (6092kVAs of installed power) and the peak load is 1,23MW. Apart from the FSP, the battery of 1,25MW/2MWh, there is a PV plant of 1500kWp within the island area, which allow islands to last longer (if they take place in daytime). The battery was the FSP responsible for maintaining the controlled island (frequency and voltage) as a grid forming inverter, no matter where the power is actually generated.

The main objective of this BUC was to test the prequalification process of potential providers and activation of the corresponding resources for the Controlled Islanding service . The main contributions in the process were:

- The definition of the specific attributes that apply to each of the products (Programmed Island and Outage Island) to be able to simplify the requirements and reduce the entry barriers for a service that is very specific by itself.
- The specification of the information and commands to exchange between the local platform and the FSP to create the island keeping the quality of service, at least when no sudden events occur while the system is in the island mode.
- The implementation of the whole process on a local platform.

5.5.2. Main KPIs

The list of KPIs that apply for the Controlled Islanding service is listed in Table 10. Its relevance is discussed in the comments column.

Table 10 - KPIs relevant for Local Congestion Management, i-DE

KPI	Value	Comments
KPI_4 - Operational Expenditures	268 €	Controlled islanding will only be needed very few times a year (once a year was considered). The KPI does not include any investment or energy cost for delivering the service.
KPI_14 - Islanding duration	100 %	The island should last as long as required, which is easier in a testing environment. It represents the percentage of time where the controlled island can provide the service. This KPI is important to measure for settlement purposes. The energy required for the islanding duration was delivered all the time (1.5 hours)
KPI_15 - Equivalent interruption time related to the installed capacity	0.108 min	The TIEPI avoided is a useful indicator to calculate how the service could potentially be remunerated, as it represents the value of this service for the grid operator and, consequently, for the grid users.
KPI_32 - Delivered energy on controlled island	0.012 MWh	The energy delivered to an island is an important indicator to calculate how the service could potentially be remunerated since it represents the energy that the FSP could not use for other purposes.
KPI_33 - Maximum power (non-transient) in controlled island	0.945 MW	The maximum power of the island indicates the load that could be supplied within the island. It is also needed for the settlement. As the battery did not provide energy, the power demanded in the controlled island load was the difference between the power generated by the photovoltaic generator minus the power absorbed by the battery.
KPI_38 - Type of flexibility providers per demo	12.5 %	One resource (battery storage) out of eight technologies listed in D.16. participated in this use case.

5.5.3. Challenges and barriers

The main challenges of the Controlled Island BUC are summarized as follows:

- The service itself is so specific in terms of location, and in terms of the necessary attributes to provide by a third-party FSP, that it is unlikely to have a competitive market for this service in the future. This peculiarity makes this service more likely to be delivered through bilateral contracts rather than local organized markets.
- No “near real-time” communication system was implemented between the FSP and the local platform. The communication frequency was enough to deliver the service because no unexpected

event occurred while being in the island mode. It must be taken into account that the FSPs operation mode was known to i-DE. However, for any other FSP that may not be the case Therefore, the control of the island operation should be somehow kept in the hands of the grid operator, even if the energy could be provided by the FSP, given it is a service that may be used few times per year.

6. Conclusions and policy recommendations

The Spanish demonstration of the CoordiNet project has implemented five different BUCs covering four different services for the TSO and the DSO. The two demonstration campaigns could successfully test the proposed solutions for a variety of actors, including the SOs, aggregators and FSPs. Apart from the results and KPIs and test results presented and discussed in the previous sections, the demonstration activities could shed light on the challenges faced by the different actors, and the next steps to be taken both in terms of future research as well as the exploitation of the CoordiNet results. In this section, the main conclusions and discussion points are highlighted. They cover five main topics, namely (i) TSO-DSO coordination schemes, (ii) new flexibility markets, (iii) new roles and activities, (iv) information exchange and platform development, and (v) entry barriers to markets.

6.1. TSO-DSO coordination schemes

The CoordiNet project has tested several different market models. In the Spanish demo, three of them were implemented, namely the central (BUC ES-2), the common (BUC ES-1a) and the local (BUC ES-1b and ES-4) market models or coordination schemes. Also, several studies were conducted, from a theoretical perspective, on the economic and technical efficacy of the various coordination schemes proposed (e.g. CoordiNet deliverables D6.2, D6.3, D6.4). Based on the practical implementation of coordination schemes, the Spanish experience during demonstrations has shown that the fitness of a market model could be also influenced by three main factors. They are: (i) the service being procured, (ii) the topology of the network, and (iii) the voltage level operated by SOs. The combination of these three factors will play an important role in determining the impact on transmission and distribution grids of procuring and mobilizing distributed flexibility. In principle, flexibility at lower voltage levels will have a lower impact on the transmission networks, suggesting that the local market model could be an appropriate tool for solving problems at MV and LV levels with limited needs for coordination. The topology of the network also influences how flexibility can be procured and used. Stronger coordination is required in meshed grids (e.g. several TSO-DSO interconnection points) compared to that required in radial networks. Finally, the type of service provided should also affect the selection of the coordination scheme. It was shown, for instance, that the best model for the provision of voltage control differs depending on the voltage levels and the network characteristics. Therefore, the choice of a coordination scheme should be considered on a case-by-case basis.

6.2. New flexibility markets

Among the different markets tested in CoordiNet, some were already established before the beginning of the CoordiNet project, namely the balancing and common congestion management markets. Still, for the BUCs demonstrating these markets, important adaptations of these markets were made to incorporate distributed flexibility in the context of TSO-DSO coordination. Other markets, however, are completely new. This is the case for local flexibility markets and voltage control markets.

Local flexibility markets proved to be an effective tool to solve problems close to where they occur. The local markets (focused on the MV and LV levels) are compatible with the participation of small FSPs that are not able to participate in other types of flexibility markets (e.g. common congestion management). It is worth mentioning that, even when aggregated, certain requirements may prevent the participation of small FSPs in central markets (need for communication channels with the flexibility providing unit). Therefore, not only local markets are effective in solving the DSOs' needs, but they also facilitate the participation of small FSPs. Hence, local flexibility markets have the advantage of adapting better to the reality of smaller FSPs. Prequalification processes and minimum bid sizes can be made compatible with the capability of FSPs. Additionally, the communication and monitoring requirements can potentially be more flexible and accessible for these providers. Finally, local flexibility markets have the advantage of causing less impact on the transmission grid, reducing the need for information exchange when compared to markets at the HV and transmission grids.

The market for voltage control services, as proposed in CoordiNet, is also new. Although voltage control services are already provided, they are mainly a mandatory requirement. No market exists for the procurement of standardized products. The tests in the Spanish demonstration showed the technical efficiency of this solution. However, barriers for certain types of providers, such as RES units, may still exist. Some of them might require retrofitting for control of active power setpoints, which could represent an entry barrier to voltage control markets. Nevertheless, the creation of voltage control markets had the advantage of providing locational signals for investments in reactive power capabilities. For the still unknown aspects of these markets (e.g. entry barriers for the different technologies), pilot projects and regulatory sandboxes could be used to further inform regulation on the actual best implementations of voltage control markets.

6.3. New roles and activities

The new markets will have to be placed within the market sequence already in place, including the wholesale energy markets and the existing service markets (e.g. balancing, and central congestion management). In CoordiNet, the three different demonstrations adopted different locations for the newly created markets. In Sweden, for instance, the local markets are placed before the DA markets, while in Spain and Greece they are cleared after. From the Spanish demonstration perspective, having the local flexibility market after the wholesale energy markets proved to be beneficial, given that, in this way, both TSO and DSO know the day-ahead schedule of the different agents when the local market is called and cleared. This allows the TSO and the DSO to better forecast their flexibility needs. Nevertheless, this approach may be more challenging for FSPs, as they have less time to prepare offers.

The design of products has to be inclusive as well so that FSPs in all forms (e.g. independently or aggregated; small or large) can participate in technology-neutral markets. While providing a level-playing field to all potential market participants, product design will have to consider the characteristics of every country or region, in terms of networks and resources available. In this regard, regulatory sandboxes can also provide a relevant tool for product feature discovery, so that regulators can define which are the most appropriate products.

6.4. Information exchange and platform development

Data exchange will also require further definitions and refinements. Firstly, local markets should be set in a way so that they provide the right signals to market agents while ensuring market results are technically sound. One solution adopted in the Spanish demonstration is the use of sensitivity factors for the local market formulation. Secondly, the provision of flexibility by small FSPs will call for the exchange of data regarding their electricity usage in some form, so that flexibility provision can be verified and settled. One solution to facilitate this data exchange for flexibility purposes is the use of independent monitoring devices by aggregators, such as the EnergyBox deployed in the Spanish demonstration. This way, the burden on the small FSPs can be reduced, and requirements for their participation can be made less strict. This would also allow the aggregator and/or DER to freely choose the communication protocols for their link, which would enable competition in this field and the development of more efficient alternatives. Additionally, the communication between the SO and DER would be simplified, as the latter would be aggregated, reducing the communication links involving the SO.

6.5. Entry barriers to markets

Adequately designed products and markets are one important enabler of the participation of FSPs in flexibility markets, but it is not the only one. To engage customers, several other actions are still needed. Aggregators, for instance, are expected to play an important role in unlocking the potential flexibility of DER. Therefore, a fertile environment for this business model is desirable, including a complete regulatory framework setting their role, responsibilities and coordination needs with other agents (e.g. the customer's BRP). Moreover, it is important to notice that local flexibility markets are incipient and will go through a development phase before they reach their full maturity. In this context, regulation should consider that certain designs may provide stronger incentives for participation, which could be useful to foster market development, such as the use of capacity products instead of activation-only products.

On top of the incentives and fertile market conditions abovementioned, public knowledge and engagement is also a key component of the success of flexibility solutions. One challenge faced by the Spanish demonstration was the lack of early customer engagement. Although part of the lack of engagement was due to the lack of enough financial incentives (apart from the cascading funds granted to some FSPs), part was also due to the lack of knowledge they have on the possibilities and potential of providing flexibility services to SOs. Therefore, communication campaigns at an early project stage should be considered within an integrated strategy to foster the development of local flexibility solutions.

From the perspective of the SOs, the ones procuring flexibility services, it is also clear that regulatory changes are needed so that the use of flexibility can become a reality. Firstly, the national regulatory framework in Spain still does not recognize the use of local flexibility by DSOs. Consequently, the current economic regulation in place does not provide the necessary conditions for DSOs to use flexibility as an alternative to the CAPEX solutions. For that to happen, DSOs need to have the cost of procuring and mobilizing flexibility recognized in their remuneration schemes, and, potentially, some economic incentives to opt for the flexibility solution when this is more efficient. Also, depending on the coordination scheme in place, an appropriate mechanism for cost-sharing among the SOs involved should be implemented.

6.6. Summary of Recommendations

The Spanish demonstration in CoordiNet has been able to successfully contribute to the development and adaptation of platforms and markets so that both the TSO and the DSOs could use flexibility in an efficient and coordinated manner. The FSP too had the opportunity to start providing flexibility through new platforms and aggregation solutions. Innovative markets for new services (e.g. local congestion management, islanding operation and voltage control) were implemented. Nevertheless, the Spanish demonstration has proved that several aspects are still to be improved, or addressed so that the solutions demonstrated can be exploited up to their full potential. Then, more projects should be further investigated and address the recommendations provided here. Figure 56 summarizes these recommendations.

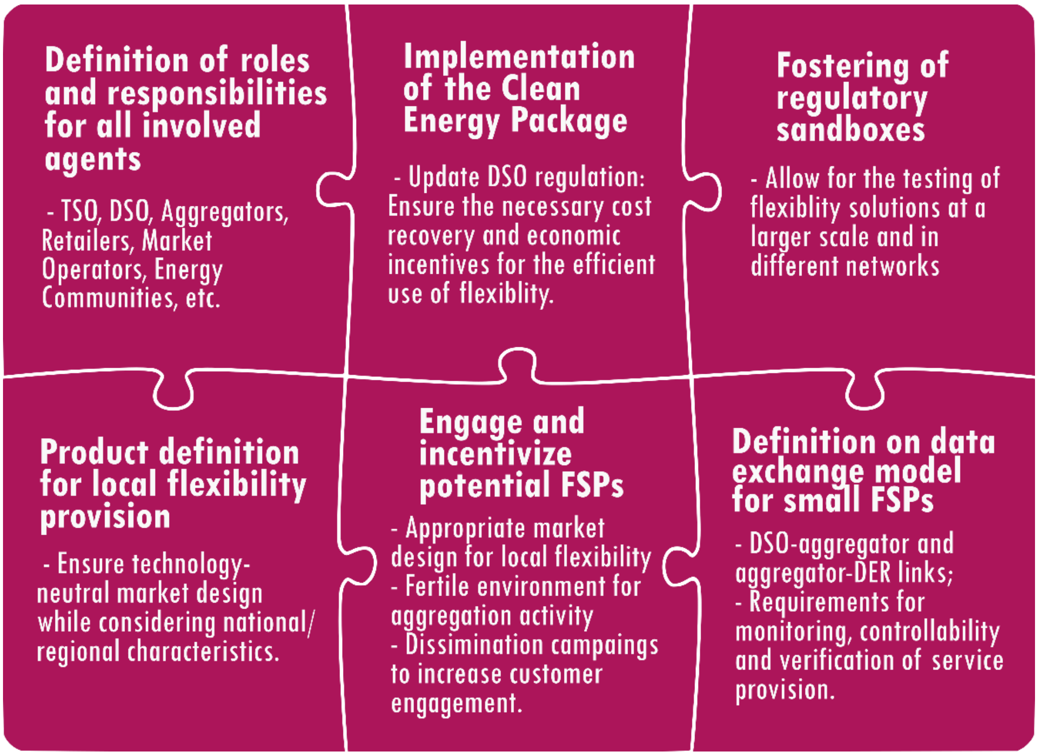

Figure 56: Spanish demonstration policy recommendations

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