D3.5 - Evaluation of preliminary conclusion from demo run

V2.0

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Executive summary

This deliverable, D3.5, presents a post-evaluation[1] of the first demonstration activities carried out in CoordiNet's Spanish demo. It is a sequence to the deliverable "D3.4 Analysis and results of real data from operation (Part 1)" [1] which focuses on the description and results of each test carried out in Demo Run One as well as the calculation of the key performance indicators (KPIs). The present D3.5 aims to discuss the processes carried out in Demo Run One, highlighting the challenges and the lessons learned during the first demonstration activities.

The objective of this deliverable is threefold. Firstly, this deliverable discusses the challenges, successes, and lessons learned from Demo Run One. The objective of this exercise is also to identify possible adjustments that could be made in Demo Run Two and future projects and implementations of the solutions proposed by the CoordiNet project. Secondly, this deliverable presents an analysis of Demo Run One. Three main aspects are focused on, namely the (i) interpretation of KPIs, the (ii) BUC and market implementation and the (iii) customer engagement. Finally, the third objective of this deliverable is to communicate the results from Demo Run One to other CoordiNet tasks using real demonstration data in their respective analyses. This is the case for the overall evaluation of demonstration[2], the scalability and replicability analysis (SRA)[3] of solutions and the cost-benefit analysis (CBA)[4] which will be carried out in Work Package (WP) 6.

In this deliverable, challenges and opportunities identified in Demo Run One of the Spanish demonstration campaigns are reported and discussed. Moreover, a preliminary evaluation of the demonstration is also done based on the KPIs calculated in Demo Run One and ex-post interviews with the demonstration partners.

There were several challenges observed by the system operators (SOs) in implementing the originally designed BUCs. These challenges show the need for further research on important aspects not only for the Spanish demonstration but also for the overall TSO-DSO coordination in Europe. For instance, challenges related to **market design** could be observed, particularly in product definition and cross-border service provision.

The **technical implementation** also presented challenges to the SOs involved in the implementation of the demonstration. For instance, the deployment and integration of the tool Energy Box showed a lack of standards concerning flexibility systems for sFSPs. Another example was the lack of protocol for communicating reactive power and voltage setpoints between the different BUC participants. Although such deployments are expected to be partially done in the context of other emerging businesses (e.g. aggregators, virtual power plants etc.), it is a significant challenge for SOs in the context of Research and Innovation projects. From the perspective of future flexibility use, it also points to the need of creating interoperable solutions, facilitating the development of software and hardware tools. In this context, the

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[1] In Deliverable D3.4, some preliminary conclusions are presented. In this deliverable D3.5, a post-evaluation of the demonstration is carried out having as a basis the results reported in D3.4 and the additional interactions and consultations reported throughout this deliverable.
[2] Task 6.1, within the CoordiNet project structure. Results to be published in deliverable D6.1.
[3] Task 6.4, within the CoordiNet project structure. Results to be published in deliverable D6.4.
[4] Task 6.3, within the CoordiNet project structure. Results to be published in deliverable D6.3.

Spanish demo already provided solutions that could be adopted in the future, such as implementing ICCP in the context of voltage control.

This deliverable also discusses the **stakeholder interactions** among partners and FSPs. An ex-post consultation with the demo partners revealed that the interaction among stakeholders was fruitful and that the parties are aligned in their view of the future use of local flexibility and the need for enhanced coordination. It also showed that the FSPs that agreed to participate in the demonstration were aligned with the objectives of the project and interested in the solutions developed. Nevertheless, the **customer recruitment process** proved to be difficult. From the different types of FSPs contacted, the ones that accepted to participate were mostly distributed generation. These FSPs are already familiar with electricity markets and have their main business in electricity. The types of FSPs that refused to participate often gave the same two main reasons. Firstly, the lack of economic incentives, considering the context of the R&I project. Secondly, the risk that the provision of flexibility could jeopardize their main economic activities. The former can be seen as a direct challenge to R&I projects that show limited attractiveness to potential participants impacting the final results of the work. In the Spanish demo, however, this was partially mitigated by using the Cascading Funds. The latter highlights the difficulty in engaging potential FSPs other than those already involved in electricity markets. While some industries may be inflexible with regards to electricity demand, others could be engaged with stronger economic incentives, aid from new businesses (e.g. aggregators) and enhanced information on the possibilities of flexibility provision.

Finally, this deliverable also analyses the KPIs calculated and discusses the interactions and data exchange between Demo Run One and other Work Packages within the CoordiNet project. The analysis of the KPIs allowed for the identification of several proposals, mostly for future R&I projects, considering that the definition of KPIs for Demo Run Two are already complete and data collection is happening at the time of writing. The exchange of information with other WPs can be divided into pre- and post-Demo Run One. For instance, interactions pre-demonstration led to results that are now being put to practice in the actual demonstration (e.g. definition of market design, grid monitoring, aggregation and information exchange). The KPIs and other conclusions produced by Demo Run One will serve tasks 6.1, 6.3, 6.4 and 6.6 in different ways. Firstly, it provides real-world data that can be used as the base case for both qualitative and qualitative studies (e.g. the CBA in T6.3). Secondly, it reveals the main challenges faced by the demo, which can be helpful in defining simulation scenarios (e.g. in T6.4) or initial hypothesis in the case of customer engagement for further investigation (T6.6). Thirdly, the KPIs and conclusions from Demo Run One will also be integrated into the overall analysis of the CoordiNet demonstrations (T6.1).

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Notations, abbreviations and acronyms

Table 1: Acronyms list

Acronym	Definition
ASIDI	Average System Interruption Duration Index
BaU	Business-as-Usual
BUC	Business Use Case
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CECRE	Control Centre of Renewable Energies
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DFIG	Doubly Fed Induction Generator
DSO	Distribution System Operator
EEE	Energía Eólica del Estrecho
EGP	Enel Green Power
EV	Electric Vehicle
FSP	Flexibility Service Provider
HVAC	Heating, Ventilation, and Air Conditioning
ICCP	Inter-Control Centre Communications Protocol
IT	Information Technology
KPI	Key Performance Indicators
LV	Low Voltage
mFRR	Manual Frequency Restoration Reserves
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
PDBF	Day-Ahead Baseline Program, according to the Spanish acronym
PEESA	Planta Eólica Europea, S.A
PESUR	Parque Eólico del SUR
R&I	Research and Innovation
REE	Red Eléctrica de España
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

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 aims 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 centered on three key objectives:

1. To demonstrate to which extent coordination between TSO/DSO will lead to a cheaper, more reliable and more environmentally friendly electricity supply to the consumers through the implementation of three demonstrations at large scale, in cooperation with 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 necessary building blocks 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 are carried out in three different countries, namely Spain, Sweden and Greece. In each demo activity, different products are tested, in different time frames and relying on the provision of flexibility by different types of Distributed Energy Resources (DERs). Figure 1 presents an approach to identify (standardised) products, system services, and coordination schemes to incorporate them into the future CoordiNet platform for the realisation of the planned demo activities.

Figure 1: Overall CoordiNet approach: Services, timeframes, coordination schemes and products that will be demonstrated in different countries (Spain in pink, Sweden in yellow, and Greece in grey)

1.2. The Spanish Demonstration

The Spanish demonstration campaign of the CoordiNet project aims at demonstrating the feasibility of procuring several system services by means of different coordination schemes between DSOs and the TSO. In particular:

- Congestion Management is solved at high (HV), medium (MV) and low-voltage (LV) levels by using different market arrangements. At high and medium voltage, a Common Congestion Management Market has been set up, so that the requirements of both the TSO and the DSO can be taken into account while dispatching flexible units. At low-voltage, units below 1 MW can be used by the DSO to solve congestion issues through a Local Congestion Management Market.
- Balancing service is procured through a central coordination scheme, where DSOs will be able to set limitations to the activation signals sent by the TSO to the flexibility providers located in their distribution grid.
- Voltage Control is provided by units connected at high and medium voltage to solve voltage issues, regardless of whether they affect the TSO or the DSO, through a Common Voltage Control Market.
- Controlled Islanding is also provided by units located in distribution grids through a Local Market.

An overview of the Spanish demonstrator is presented in Figure 2, which shows the locations and the Flexibility Service Providers (FSPs) of each pilot site, the DSO of each location and the services, products and coordination schemes tested. More details are provided in the following tables.

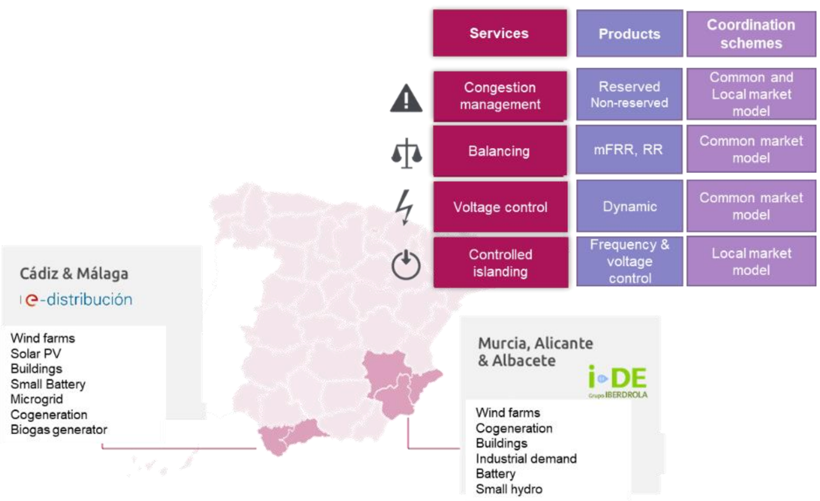

Figure 2: Map of the Spanish demonstrator areas.

For the purpose of testing these coordination schemes, two demonstration phases have been organized, Demo Run One and Demo Run Two, which include four Business User Cases (BUCs). Demo Run One is focused on testing the coordination schemes for BUC ES1a: Common Congestion Management, BUC ES2: Balancing and BUC ES4: Controlled Islanding. Demo Run Two is focused on testing the coordination schemes for BUC ES1b: Local Congestion Management and BUC ES3: Voltage Control. The overview of the timeline is given in Figure 3.

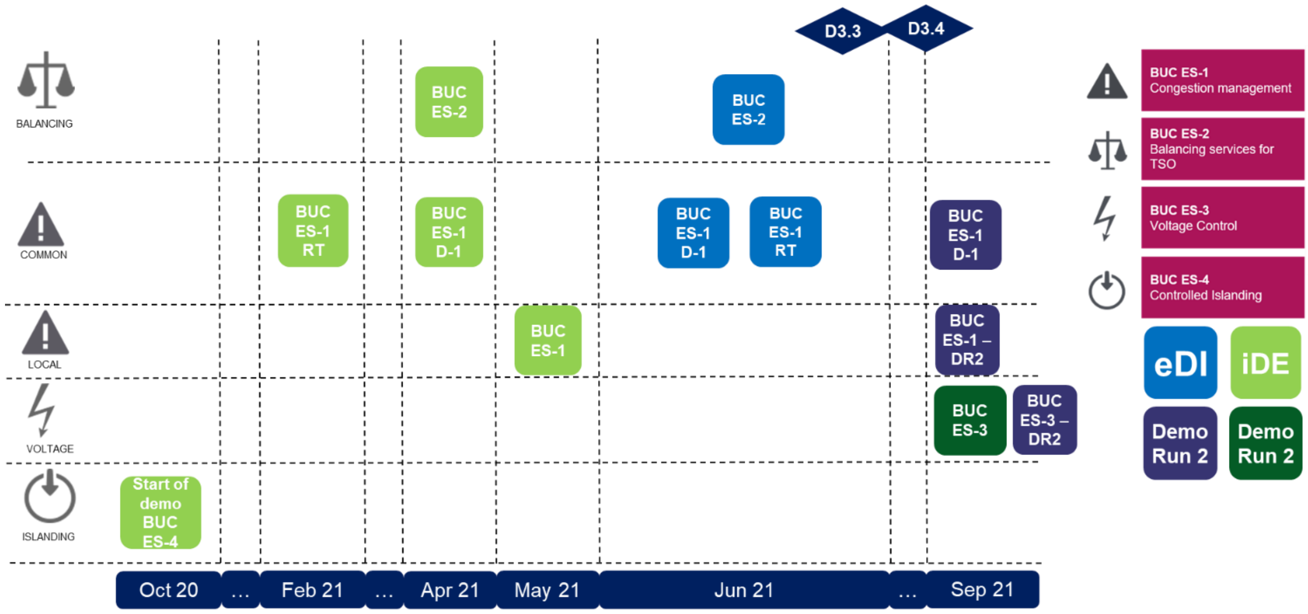

Figure 3 Demo Run Timeline. Source: [1]

This deliverable aims to describe all tests that have been performed as part of Demo Run One. It defines the test procedures for BUC ES1, BUC ES2 and BUC ES4 in detail, followed by the results from the performed tests. The summary of the tests can be found in Table 2:

Table 2 - Summary of Demo Run One tests. Source: [1]

Demonstration site owner	Test type	Test process	Demonstration site	Actors involved
	Prequalification	Prequalification of FSP units for the execution of demo.	Cadiz	REE and Enel Green Power (EGP)
		Communication tests between e-distribución platform and CoordiNet Common platform.	Cadiz	e-distribución and REE
e-distribucion	Communication	Communication tests between Aggregator and CoordiNet Common Platform, Aggregator and Local Platform, Aggregator and FSPs.	Malaga	TECNALIA, N-SIDE and e-distribucion
	BUC	BUC ES1a: Common Congestion Management, BUC ES2: Balancing.	Cadiz	IREC, e-distribucion, REE and EGP

i-DE	Prequalification	Prequalification of FSP units for the execution of demo.	Murcia	i-DE
	Communication	Communication tests between i-DE platform and REE platforms.	Albacete and Murcia	i-DE and REE
	BUC	BUC ES1a: Common Congestion Management, BUC ES2: Balancing, BUC ES4: Controlled Islanding.	Albacete and Murcia	i-DE and REE

1.3. Scope of the document

This deliverable, D3.5, presents a post-evaluation of the first demonstration activities carried out in Spain. The deliverable is a sequence to the deliverable "D3.4 Analysis and results of real data from operation (Part 1)" [1]. While the D3.4 focuses on the description and results of each test carried out in Demo Run One as well as the calculation of the key performance indicators (KPIs), this D3.5 aims to discuss the processes carried out in Demo Run One, highlighting the challenges and the lessons learned during the first demonstration activities.

The objective of this deliverable is threefold. Firstly, it aims at providing a discussion on the challenges, successes and lessons learned from Demo Run One. The objective of this exercise is also to identify possible adjustments that could be made for Demo Run Two, as well as for future projects and implementations of the solutions proposed by the CoordiNet project. Secondly, this deliverable presents an analysis of the Demo Run One focused on three main aspects, namely the (i) interpretation of KPIs, the (ii) BUC and market implementation and the (iii) customer engagement. Finally, the third objective of this deliverable is to communicate the results from Demo Run One to other CoordiNet tasks using real demonstration data in their respective analyses. This is the case for the overall evaluation of demonstration[5], the scalability and replicability analysis (SRA)[6] of solutions and the cost-benefit analysis (CBA)[7].

Figure 4 presents a representation of the main objectives and overall workflow of task 3.5.

[5] Task 6.1, within the CoordiNet project structure. Results to be published by deliverable D6.1.
[6] Task 6.4, within the CoordiNet project structure. Results to be published by deliverable D6.4.
[7] Task 6.3, within the CoordiNet project structure. Results to be published by deliverable D6.3.

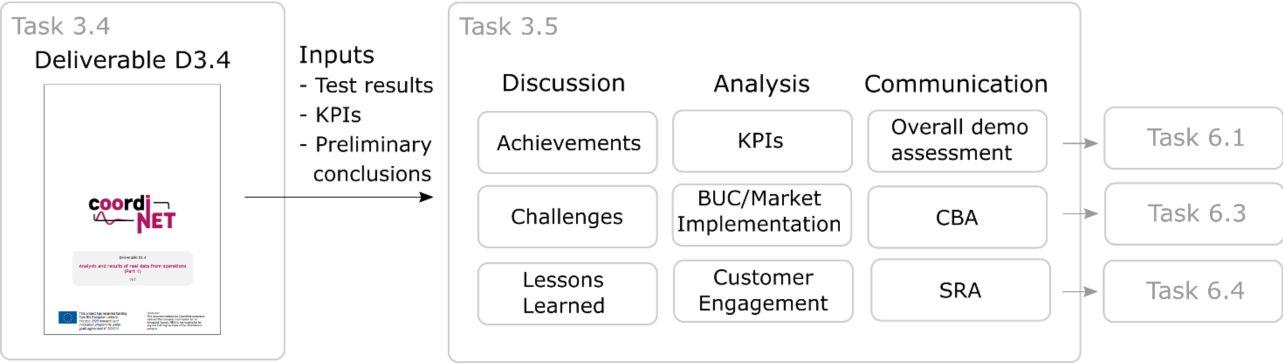

Figure 4: Overall objectives of Deliverable D3.5

1.4. Document structure

This deliverable is organised according to its three main objectives. Therefore, Chapter 2 provides the discussion of the Demo Run One implementation. The chapter is divided per System Operator (SO), where the two DSOs and the TSO present their views on the achievements and shortcomings of Demo Run One. Chapter 3 reports the interaction with the remaining tasks in the CoordiNet project in the effort to communicate results from the Demo Run One. Chapter 4 is devoted to the analysis of the three key aspects, namely the BUC implementation, customer engagement and the KPIs. Finally, chapter 5 concludes the document.

2. Demo Run One: Lessons Learned

In this chapter, a discussion is provided on the different challenges, successes and lessons learned in Demo Run One of the Spanish demonstration. The chapter is divided per SO involved in the demo and BUC, in which each DSO and the TSO report discuss and conclude their experiences during the demonstration campaign conducted until the time of writing. The experiences of the DSOs have not been summarized in one combined section, as both of them have defined and performed their tests separately. This has resulted in different outcomes for each of them, which is why they are documented in individual sections.

2.1. e-Distribución (DSO)

This subchapter is dedicated to the analysis of the first demo run in the e-distribucion pilots and will address conditions and hindrances, both technical issues and regulatory challenges, faced with the aim to improve the performance of the next demo run and future similar projects. Section 2.1.1 presents a summary of the demos performed at Demo Run One, in which the BUC-1a Common Congestion Management and the BUC-2 Balancing are included. Furthermore, Section 2.1.3 describes the challenges faced from the DSO perspective in relation to each of the services tested described in the CoordiNet deliverable D3.1.

It must be noted that Section 2.1.1 as well includes the BUC ES-1b Local Congestion Management and BUC ES-3 Voltage Control. Although the demos have not been executed for such services during Demo Run One, work has been carried out regarding definitions and preparation.

2.1.1. Summary of the Demonstrations Performed in Demo Run One

This section briefly summarises the different demos performed during Demo Run One in which the BUC ES1-a (Common Congestion Management) and BUC ES-2 (Balancing) are covered. A more detailed description of each demo can be found in Table 3.

2.1.1.1. BUC ES-1a: Common Congestion Management

2.1.1.1.1. Day-Ahead timeframe

BUC ES-1a: Use Case 1- Bundle’s Upper Limitation Requested by DSO

The objective of this use case is to fix problems of over-loading throughout the capacity of the available generation. To this end, a simulation of a congestion at the substation **Pinar del Rey** in which the capacity of the transformers TF4 and TF5 is limited below the nominal value is applied. This congestion is solved by reducing the generation of PESUR, PE ESA and Guadarranque units.

BUC ES-1a: Use Case 2- Multiple Physical Unit Lower-Limitation Requested by DSO

The objective of this use case is to test a lower-limitation requested by the DSO, to the FSPs PE SUR and PEESA, individually. The application of the demo case is carried out by simulating an Operations and Maintenance (O&M) intervention in the power line which connects Fresno substation and Estrecho substation, and such conditions might bring a congestion in the power line which connects Estrecho substation with Menacha substation. As a consequence, the DSO requests a lower-limitation to the units of PESUR and PEESA in order to avoid the congestion.

BUC ES-1a: Use Case 3 - TSO Lower-Limitation and DSO Upper-Limitation on the Same Individual Physical Unit (Conflicting)

The objective of this case is to test the communication and coordination when different FSP limitations are requested by both DSO and TSO at CoordiNet Common Platform. To this end, a congestion in Pinar del Rey substation will be simulated by reducing the capacity of transformers TF4 and TF5. Consequently, the DSO requests an upper limitation to Guadarranque solar plant. Simultaneously, the TSO requests a lower limitation to Guadarranque wind farm. This creates a conflict between the requests, which must be solved through the coordination between system operators of both TSO and DSO.

2.1.1.1.2. Real-time timeframe

BUC ES-1a: Use Case 4 – Individual Physical Unit Upper-Limitation Requested by DSO

The objective of this demo case is to fix problems of over-loading throughout the capacity of the available generation. To this end, a real-time congestion at the **Puerto de la Cruz substation** is simulated, in which the capacity of the main transformer is limited below the nominal value. This congestion is reduced or solved by reducing the generation of the EEE wind farm.

BUC ES-1a: Use Case 5 – Individual Physical Unit Upper-Limitation Requested by DSO

The objective of this demo case is to fix problems of over-loading throughout the capacity of the available generation, in real-time. To this end, a congestion at the substation Pinar del Rey is simulated in which the capacity of the transformers TF4 and TF5 is limited below the nominal value. This congestion is reduced or solved by reducing the generation of PESUR wind farm.

BUC ES-1a: Use Case 6 – DSO and TSO Upper-Limitation on the Same Units (Not Conflicting)

The objective of this case is to fix problems of over-loading at Puerto de la Cruz substation through the capacity of the available generation: Los Lances and EEE wind farm. But for this case, both DSO and TSO request the generation curtailment in real-time. In order to simulate this congestion, the capacity of the transformer of the substation Puerto de la Cruz is reduced, forcing the grid limitation.

The DSO requests to reduce both Los Lances and EEE (with an upper-limitation congestion bundle) and sends the request to CoordiNet Common Platform, while the TSO requests only the reduction of EEE wind farm (individual physical unit upper-limitation). As neither of the limitations are not in conflict, CoordiNet Common Platform is able to optimize the limitations and both are accepted.

2.1.1.2. BUC ES-2: Balancing

BUC ES-2: Use Case 1 – Individual Physical Unit Upper-Limitation Requested by DSO

The objective of this demo is to coordinate between TSO and DSO when the DSO requests, in real-time, an individual physical unit upper-limitation, to ensure a safe operation at **Pinar del Rey substation**. The limitation is requested for PESUR wind farm, and it applies for the Manual Frequency Restoration Reserves (mFRR) process.

2.1.2. Summary of the Demonstrations Performed In Demo Run One and an Overview of the Ones to Come in Demo Run Two

Demo Run One started in M22 with the tests for BUC ES4 from i-DE. From M26 to M29, i-DE performed the remaining planned tests from BUC ES1 and BUC ES2 for Demo Run One. The tests on BUC ES1 and BUC ES2 from e-Distribución were carried out in M30.

Both e-Distribución and i-DE performed the tests for BUC ES1 in the Day-Ahead and Near Real-Time timeframe. The Demo Run One was concluded in M30 with the BUC ES1 tests in the Near Real-Time timeframe.

The tests for Demo Run Two are planned to start in M33. The schedule and the results of this demo run will be documented in D3.6.

2.1.3. Challenges and Opportunities from the Point of View of the DSO

2.1.3.1. Introduction

From what was initially proposed within the definition of the CoordiNet Project, several challenges have been found, which called for some adaptations that are still ongoing. This section analyses the main challenges, difficulties and adjustments carried out during the course of Demo Run One, from the perspective of the e-Distribucion campaign, following the BUC specification.

2.1.3.2. BUC ES1: Balancing

During the test of the BUC ES2 Balancing the limitations sent from the DSO were only applied under the scope of the mFRR market process and not in the Replacement Reserves (RR – TERRE Platform) market process. This is because in such demos, when the DSO aims to limit an FSP unit under the balancing scope, the bids sent by the FSP must be previously cleared in the market. As the TERRE platform is a cross-border EU platform (where the Spanish TSO REE participates), the implementation was more complex to perform in TERRE and therefore the demos were only performed at the mFRR balancing process, which is nationally controlled by Red Eléctrica de España (REE).

Additionally, the demos were performed at CoordiNet Common Platform ‘testing environment’ and therefore, the redispatches generated were not applied in real operation. This condition leaves the door open for future testing the demos in the ‘real environment’ of the platform.

2.1.3.3. BUC ES2a: Common Congestion Management

The FSPs is one of the main actors in the flexibility markets. As FSPs may vary in nature, in the CoordiNet project, they are sorted into two types: FSP and **small FSP (sFSP)**.

In the scope of Malaga’s pilot, the sFSPs are made up by small units such as buildings with demand response and photovoltaic systems or small microgrids with some batteries and flexible demand. As they are not yet prepared to straightforwardly support the grid with their flexibility, **this kind of sFSPs presents several difficulties to assure their controllability and monitoring**.

As a first step, **getting the permissions** needed to visit the buildings of the sFSPs, **collecting the electrical circuits** or **installing certain sensoring or remote control units** (Energy Box[8]) is a long process, which can take from weeks to months, depending on the sFSP owner. Additionally, the electrical circuits themselves are not always in a condition to facilitate the controllability of the demand or other flexible assets. For instance, there have been cases in which the single line diagram is missing, or it has not been recently updated, making it more time consuming and in consequence more costly to implement the remote control of the different assets.

Figure 5 Energy Box installed at Málaga scenario

Moreover, the controllability of the units varies significantly since **different brands and equipment models** are installed in each of the buildings. This means that the optimal configuration cannot be expected for each unit, and they will need to be evaluated individually. Therefore, to reach the desired level of monitoring and control of the building, several resources are needed in terms of equipment and personnel, which increases the investment need.

Another hindrance found is **the lack of interoperability to set the protocols needed for the Energy Box communications**. Depending on the asset, different communication protocols have been set, which makes the process more challenging and therefore more time-consuming. Standardization of the communication protocols is seen as an opportunity to improve the monitoring and controllability of the sFSPs during the performance of the demos.

However, it is important to notice that these difficulties relate mostly to the implementation of the demonstration activities. In the case of a commercial implementation, these difficulties are expected to be

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[8] The Energy Box is a multi-purpose concentrator product prototype for the operation in various scenarios of advanced electrical networks. With versatile communication capabilities, it contains an embedded computer that provides computing and processing capacity to implement distributed computing: collection and storage of information, execution of algorithms and control of the sFSPs among others. More information can be found at Coordinet Deliverable 3.1.

shared or borne by the aggregators and not by the DSOs. In fact, the current Spanish regulation allows for the aggregator to freely define their communication protocol with the aggregated Distributed Energy Resources (DER), as long as the frequency of the information exchange between aggregator and DSO is within what is established in the regulation [2].

Considering the above, along with the fact that CoordiNet is a project focused on platform development and coordination that does not offer remuneration to the sFSPs involved, the participation of the sFSP units has proven to be complicated. Therefore **higher incentives** must be studied to **foster higher sFSP participation.**

In any case, it is worth noting that all the sFSP preparation process previously described is not expected to be carried by the DSO. In practice, it must be the aggregator, the one in charge of ensuring that the sFSPs are ready for their participation in the different services. Nevertheless, since CoordiNet is a pilot based project led by the DSO, the DSO itself assumed the task.

Additionally, during Demo Run Two in the Malaga pilot for the Common Congestion Management BUC, one of the main limitations found is that **demand physical units cannot participate as a congestion bundle** when the DSO or TSO send a limitation as the actual regulatory framework is not fully developed. This restriction **limits the role of the aggregator,** which computes the bids sent to the market but cannot manage their units in an optimal way, considering their baselines. Regulatory frameworks could be updated to solve this in a way that the flexibility solutions follow a technology-agnostic approach between generation, consumption and storage[9].

In relation to the demos performed during Demo Run One in the Cadiz scenario when performing real-time (Intraday time frame) tests, it must be noted the fact that there are **FSP units (mostly renewable units, such as wind farms) which are naturally intermittent and sometimes generate above or below the PDVP (Programa Diario Viable Provisional)[10] programme** (or last intra-hour programme). This challenges the DSO ability to identify and understand the behaviour of such FSPs and keep an eye on them in real-time operation in those cases in which real-time congestion has been identified in its grid.

2.1.3.4. BUC ES2b: Local Congestion Management

Aside from the difficulties described in Section 2.1.3.3 regarding sFSP monitoring and controllability, the main challenge faced during the preparation and performance of the demos was the limited amount of data that is currently available from the LV grid. In order to solve this, sensors were deployed at the low voltage side of the secondary substation's transformers for the demo to be able to better monitor LV grids and identify potential flexibility needs. In this phase, several difficulties related to installation, data collection and processing were found, which made the process slower. Additionally, the local market BUC requires some adjustments in the DSO platform in order to can read all this data correctly.

[9] Demand response participation in service markets is rather recent in Spain. Participation in balancing markets was introduced in 2019 [3]. Nevertheless, limitations on minimum bid size exist. Also, according to the new regulation, aggregated demand, generation or storage will be allowed to offer balancing, but in a separated fashion. In other words, demand and generation could not be aggregated together, as shown in [4].

[10] It is the daily program, with an hourly breakdown, which incorporates the modifications introduced in the PDBF programme once the congestion management market is executed.

In e-distribucion Malaga's scenario, a total of three LV sensor providers are being tested and this condition requires coordination between them and the DSO for the data and protocols standardisation, as well as centralisation of the LV measurements obtained in the same database. This need for coordination again makes the process slower, but it provides an opportunity for e-distribucion to learn what the most appropriate technology provider for future LV sensoring projects is.

2.1.3.5. BUC ES3: Voltage Control

In the definition phase of Voltage Control BUC at Cadiz scenario, initially, a total of five units were considered to evaluate their participation at the demos. Among the five, only one unit[11] is qualified to participate: PESUR. The FSP unit of EEE (with DFIG technology as PESUR) was also under analysis for its participation, but after some local tests, it was decided to dismiss it due to two main reasons:

- There was no budget available for the power plant's retrofit.
- EEE FSP unit is placed downstream to Puerto de la Cruz substation, sharing a busbar with the FSP unit of Los Lances. Such a condition limited the voltage control at EEE because the increase of reactive power in EEE caused overvoltage at Los Lances that set off the protection devices.

With respect to the first reason, depending on the technology, the problem can be solved by updating the power plant controls in the actual wind plants, but this requires a high investment. During the CoordiNet project, this was partially solved thanks to the Cascading Funds mechanism, which allowed to retrofit the unit of PESUR. With respect to the second reason for EEE participation cancellation, it is worth mentioning that for future service implementation, the interaction between power plants in shared networks must be taken into account.

Considering all this, the main lesson learnt is that currently, many FSPs are not prepared to participate in the service due to the lack of voltage controllability or singularities at their grid connection. In order to avoid these expenses during future flexibility projects, more updated units and better grid conditions must be considered when selecting the FSPs. Likewise, with the aim of the demo being to incentivise the participation of as many FSP units as possible, the remuneration of their services must be enough to make up for the required investment needed to allow such participation.

With regard to the prequalification of the units, it was noticed during local tests that when the unit of PESUR was forced to its maximum reactive power injection (capacitive range), the overcurrent protections of PESUR's primary station were automatically activated. This activation led to the FSP being impeded from reaching their maximum reactive power capacity. In order to solve this, it was needed to hire an external company that performed an overcurrent/overvoltage analysis at the substation. This, however, delayed the demos and meant higher expenses.

Once this problem was solved, after performing new tests, a new challenge was found, this time related to the grid characteristics. Again, when testing the capacitive range of the power plant (injection of reactive power, voltage increment), the voltage at the HV side of PESUR's substation (66/22kV) was higher than

[11] The prequalification of a unit for the voltage control requires implementing important updates in the power plant control as in Coordinet we are testing a voltage control service was not required in the commissioning of PGM. Nowadays, Royal Decree 647/2020 and Order TED/749/2020 require this operation control modes.

expected (rounding 68.5kV), and after the reactive power injection, it took an increased amount of values of 70kV in total. For self-protection, the wind turbines automatically reduced the provision of active power, which made the test invalid. This behaviour is represented in Figure 6 and Figure 7.

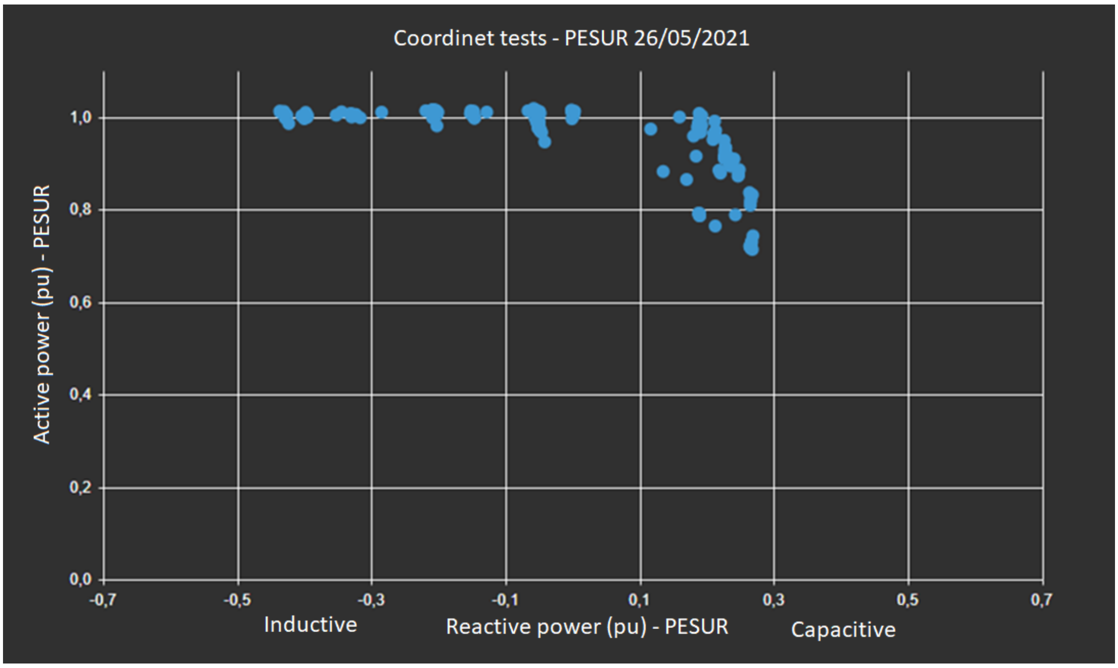


Figure 6 PQ curve generated at local test on 26/05/2021

Figure 7 Active (blue) and reactive power (orange) generated at local test on 26/05/2021

In order to solve this limitation of the active power,, with the coordination between the DSO and TSO, a new scenario was performed in which the power line of 66kV, connecting Puerto de la Cruz substation and PESUR substation, was closed. In this way, the initial voltage at the HV side of PESUR substation was decreased and allowed a higher capacity of reactive power injection to be reached, as can be seen in Figure 8 and Figure 9.

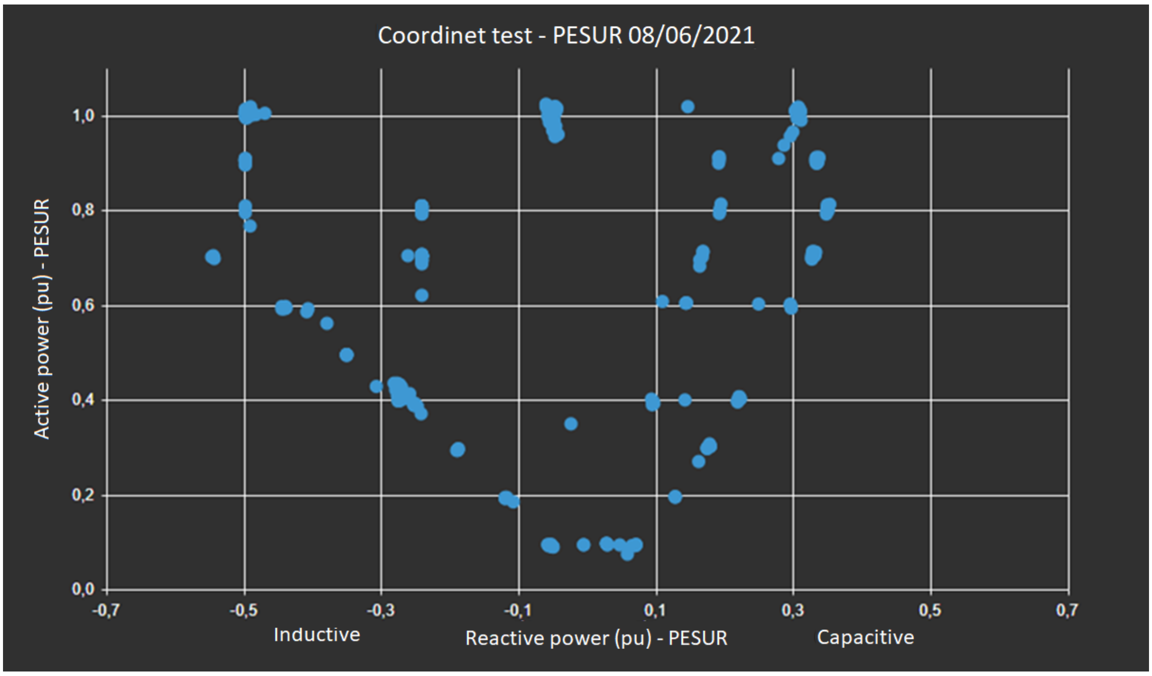


Figure 8 PQ curve at local test on 08/06/2021

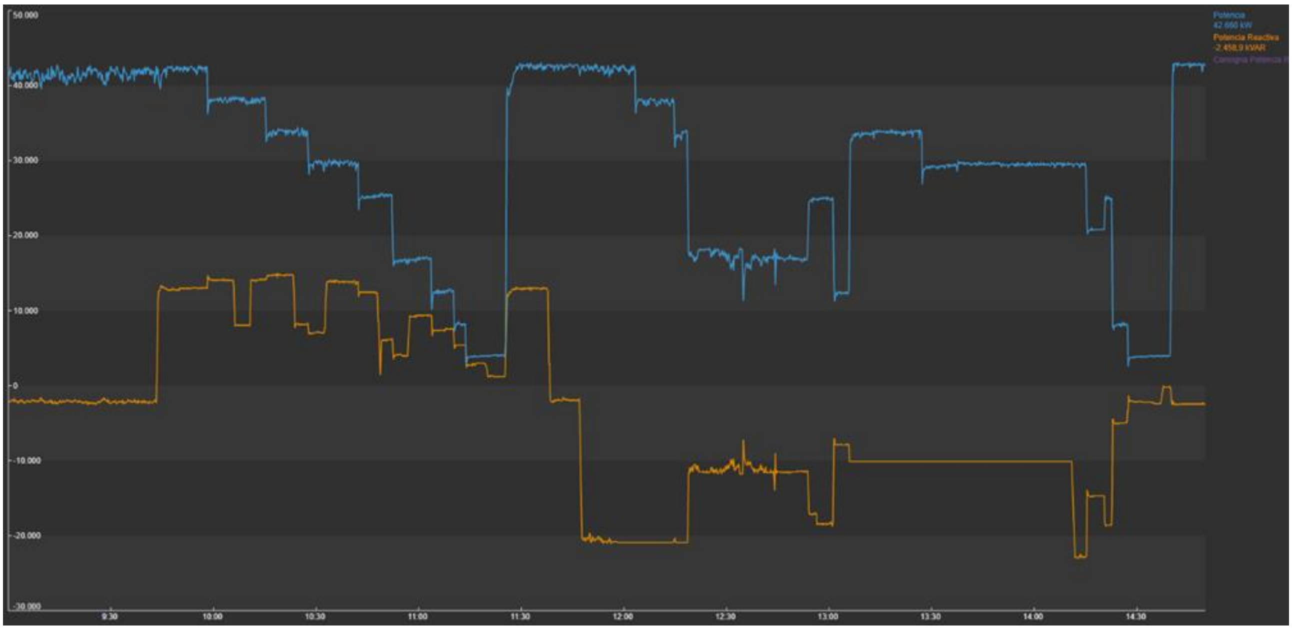


Figure 9 Active (blue) and reactive power (orange) generated at local test on 08/06/2021

As a conclusion of the tests performed, it has been identified 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. This forces scheduling the prequalification tests looking for conditions in those moments that are expected to be more favourable. Alternative methods must be analysed to complete the pre-qualification in cases in which the grid conditions are not optimal.

Moreover, the FSP unit participating in this BUC was not prepared to participate in the market unexpectedly. This is due to the fact that the FSP unit needs an on-site manual configuration to change from the reactive power compulsory capacity limits to the maximum reactive power capabilities shown in Figure 8, and this condition forces to foresee the participation of the unit in a reactive power market. Therefore there is an opportunity for a future voltage control market to select power plants that are automatically prepared for their participation in the service. As an alternative, there is a possibility for older FSPs to assume the extra cost and perform the necessary retrofit for participation in the service.

Lastly, it was found that there is no communication protocol previously established for the communication of reactive power and voltage setpoints between the different BUC participants: DSO, TSO, Market Agent and FSP. This was a challenge that was solved by implementing an ICCP (Inter Control Centre Communications Protocol) protocol among them.

2.1.3.6. DSO Platform

As general learning, it must be mentioned that developing the DSO platform is a very lengthy process as the platform is a completely new tool. It requires the preparation of many modules that need customised Power Flow (PF) and Optimal Power Flow (OPF) algorithms for every product and market timeframe, as well as platform architecture development and management of a high amount of measurement data. In this context, the OPF does not use historical data from large FSPs as input data but the scheduled program from the market settlement. This provides significantly more accurate outcomes.

Furthermore, the e-distribución grid modelling requires a high level of detail as well as the modelling of many different network elements with a high level of difficulty. For instance, with regard to the OPF algorithms, it has been a challenge to build the algorithms for the BUC ES2b: Local Congestion Management, mostly in relation with the active power needs creation because such an output is not a classical value obtained in an OPF, and therefore adaptations have been implemented. Similarly, in the BUC ES3: Voltage Control, the optimal power flow algorithms built for the generation of the reactive power needs also require a high level of design.

In the development of the DSO platform, another limitation faced concerns the need for a detailed definition of each test case in order to customise each algorithm with the conditions agreed for each of the services. In addition, there is a need for data or information from other platforms which are under development through the CoordiNet project, as is the case of the CoordiNet Local Market Platform developed by N-SIDE or the updated performed at CoordiNet Common Platform.

2.2. i-DE (DSO)

In the i-DE demo, during Demo Run One the implementation was done for services related to three use cases: Congestion Management (both in real-time and day-ahead), Controlled Islanding and Balancing. Lessons learned from all three use cases were collected. Furthermore, some general conclusions were drawn, especially with regard to platforms. This section is therefore divided into four subsections: one dedicated to the global challenges of the project from the i-DE point of view, one dedicated to the use case of controlled islanding, one dedicated to the Common Congestion Management Platform and the last one dedicated to the balancing test.

2.2.1. Challenges for the pilot

The specific challenges of i-DE pilot have been many, as the pilot has tried to cover a wide range of network situations, services and coordination schemes. The initial ambition was to perform some testing, even if the testing was minimal, at each voltage level and in each of the services considered in the project. In this way, we could test the common platform and the local platform. Three aspects have been particularly relevant to be able to carry out the tests; first, the development of the platforms and their functionalities, secondly the customer engagement and third, the coordination with other stakeholders.

2.2.1.1. Platforms and functionalities

The platform designed in i-DE is an important achievement of the demonstration campaign. To this end, it has been necessary to align the needs of various departments of the company with the emphasis on the operation control centre. The result is a platform that interacts with all the systems that manage any data that is necessary for the processes designed for the use cases.

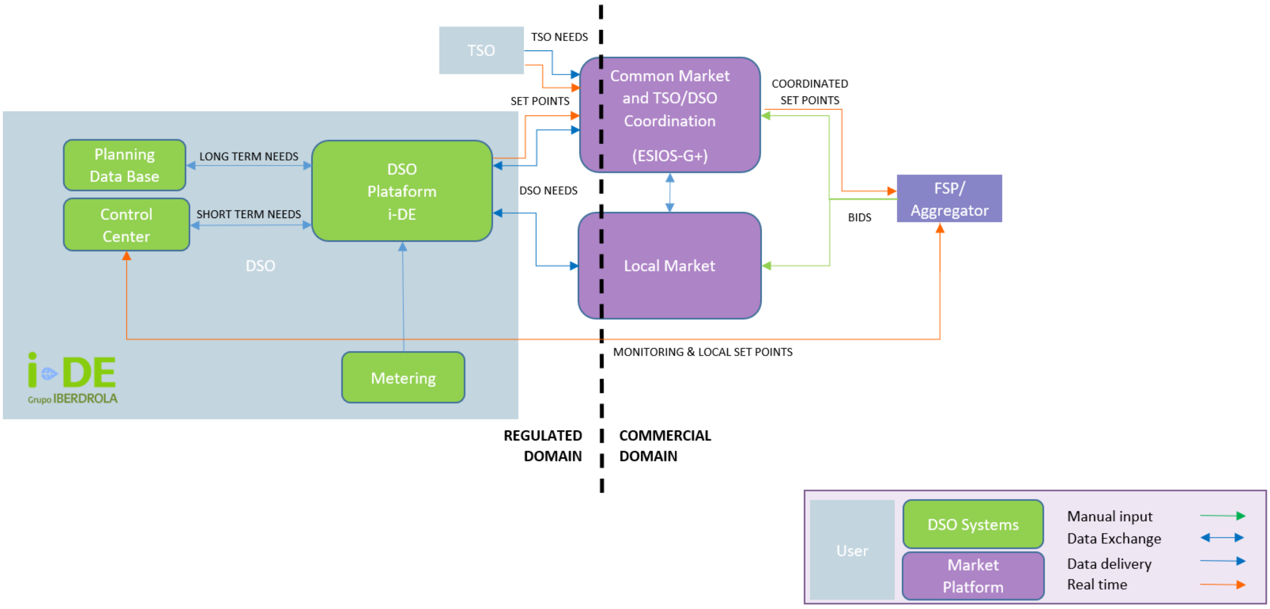


Figure 10 i-DE Flexibility Platform

To develop the i-DE Flexibility Platform, the normal prototyping processes had to be carried out, but some steps were particularly challenging:

- Selection of the platform supplier: in order to make a relevant development, it was necessary to choose a collaborating company with sufficient guarantees and knowledge of the existing systems. In some systems, such as real-time systems, it is not straightforward to integrate functionalities from different manufacturers without compromising operability.

- Links with other systems: Selecting the systems which interact, what data should be exchanged and how often. With the prototype format, links to existing platforms cannot compromise normal operations. For example, with access to smart meters data, it was necessary to limit the number of accesses.

- Security: Compliance with cybersecurity requirements to be able to develop a system that interacts with the most sensitive processes and systems, such as operation and measurement, with all the guarantees. These requirements have not been static throughout the project and it has been necessary to redesign access from the cloud to the company's internal systems several times.

- Communication channels and protocols for links with other systems: Due to cybersecurity requirements, it has not been possible to have real-time data as quickly as it could have been desired. However, data refresh times of 5 to 15 minutes have been achieved, which are acceptable for carrying out the pilot.

- Sending setpoints: Although this functionality is only used in the voltage control use case, it has been designed during the first stage. Calculating the data based on our monitoring and managing to send the setpoint through the information channels in real-time has required some additional developments.

This i-DE platform pilot developed in CoordiNet is the window used by the control centre operator to use the flexible tools. In it, the short and long term needs of the network are registered. Long-term needs must correspond to the network needs to be processed in the planning database, and short-term needs are registered directly by the operator. Long-term needs are translated into short-term operations by the control centre.

The platform is interconnected with the SCADA[12], so it obtains the monitoring data in real-time both from FSPs and the grid. It is interconnected with the smart meters for forecasts and also obtaining real-time data, and interconnected with the market platforms. Therefore, all the information necessary to manage the service is on the platform.

The potential candidate FSPs to solve requirements are entered into the i-DE platform together with each service requirement and are selected automatically from a determined grid configuration.

In its interaction with the market platforms, it receives feedback from the FSPs chosen for each service. Then, activation monitoring can be done in it as well. Only in the voltage control use case sending of setpoints by the platform during service activation is tested. These are calculated automatically following the requirements registered by the operator.

While the challenges have been significant, the flexibility platform has been a major achievement in the project. Not only because it achieved the most ambitious scope we had designed, achieving links to all the expected systems internally, but also because it has made it easier for us to demonstrate. As an example, the design of the services is customisable and allows us to design new services.

2.2.1.2. Customer engagement

The project began with the commitment of a significant number of generators provided by other companies in the Iberdrola group. Around 1GW of installed generation capacity could contribute its flexibility to the different services for TSO and DSO that could be tested. However, a large part of this generation (675MW) is connected directly to the transmission grid, and another significant part is connected to the 132kV sub-transmission grid (190MW). Therefore, although there was a lot of power available, there was very little diversity in terms of network, as many are in the same voltage level. Therefore, from the beginning of the project, an attempt was made to involve flexibility providers connected to lower voltage grids and demand-based flexibility at any level. To this end, contact was made with five strategic sectors situated in the

[12] Supervisory Control and Data Acquisition

CoordiNet deployment area to try to involve them in the project. These five sectors are described individually in the following subsections.

2.2.1.2.1. Ceramic tile industry

The tile industry in the Castellón region is one of the most mature in terms of combining its main process with energy solutions that condition the sizing of the distribution network. When planning in this area it is always necessary to consider higher and lower generation scenarios compared to higher and lower demand scenarios with special attention. Specifically, distributed generation in the form of cogeneration associated with the thermal process of the tile furnaces has been a key actor of the networks for many years. Therefore, one of the most important companies in the field and the industry association were contacted. Although they found the solution technically very interesting, the main thermal process that conditions the production of both electricity and its main process is not likely to be constrained by the grid's needs. The economic impact of even a partial loss of production is not affordable for these tile manufacturers. Therefore, offering any service associated with active power management is not possible due to the "inflexibility" of demand. Exclusively participation in reactive services could have been considered, but it is a very big limitation, and other solutions were chosen.

2.2.1.2.2. Hotel industry

The hotel tourism sector in the province of Alicante has a very important specific weight in the economy. Moreover, it is a sector that makes intensive use of assets during specific times; the summer months and Easter. In other words, in this part of the distribution network, it is possible to foresee that congestions in the distribution network occur only a few times a year (and in a specific period). Therefore, in this situation, a flexibility solution could be more competitive than a reinforcement of the network, as the number of activations would be lower. To this end, an association of hoteliers with a strong representation in the province was contacted. However, after explaining the details of the project, there was no interest from potential flexibility providers, again due to the impact it may have on the core process. For the hotel sector, the priority is the comfort of the customers, and their main electricity consumption comes from air conditioning and kitchens. In neither case, do they have the capacity to reduce power in the expected peak demand that might occur on a Saturday in August. Perhaps battery storage could help to cover this function in these cases. But at the moment there are no batteries for this purpose and these customers usage of electricity in demand peak hours is critical. Therefore, there was no possibility to address this sector in the pilot.

2.2.1.2.3. Water distribution

Water distribution companies could be excellent candidates to provide flexibility to the network, and they are also large consumers of energy due to the need to power the water pumping stations that exist all over the country. Moreover, in some cases, they have the possibility of storage, with more or less efficiency, but technically possible. For this reason, two very relevant organisations in the sector were contacted, but in both cases, it was not possible to obtain their participation due to the lack of economic incentive in the project. In Alicante, Albacete and Murcia, the rivers are not very flowing. However, water consumption is very important, which is why there is a transfer of water from another part of the country. A transfer that affects the entire distribution of water in the area, where there are also several desalination plants. For this reason, the expected flexibility was greater. After several contacts and invitations and explaining the project's objectives, it was not possible to recruit new resources in this sector.

2.2.1.2.4. Local authorities

Unlike the sector referred to in the previous section, the most relevant local authorities in the area do have innovation departments that are very interested in the impact of the energy transition. They are particularly concerned with the new electrification of electric mobility and air conditioning. In this way, some local organisations were contacted, and a positive response was obtained from Murcia City Council. The City of Murcia has actively collaborated from the beginning of the project to carry out the congestion test on the local platform. Two buildings whose air conditioning can be controlled from the City Council's systems could participate, and thanks to the incentives provided by the Cascading Funds, it has been possible to make the proposal possible. The priority for municipalities is the comfort of their citizens, but they are also sensitive to the development of new infrastructures. Therefore, the possibility of avoiding new investments seemed to be a sufficient incentive for them to want to do some testing. This compromise allowed us to address the lower voltage levels of the network: MV and LV.

2.2.1.2.5. Large consumers

In addition to looking for diversity at different voltage levels, the major flexibility providers available to the project were generators. So there was also a need to find FSPs with demand-side participation to allow for testing these flexibility services throughout the project. To this end, some large customers were contacted. In general, the response was similar to the previous cases. The sensitivity with the main process and the lack of economic incentive did not help to convince this kind of customer to participate in the pilot. Finally, after much insistence, the interest of a cement factory in the area was obtained. In addition, as in the previous case, the cascading funds helped to achieve this challenge. This client had experience in providing this type of service as it had experience in the interruptibility service that could be offered to the TSO. This participation allowed to test the demand for the balance services offered by the TSO.

2.2.2. Challenges of the Demonstrations Performed in Demo Run One

This section addresses the issues related to the use cases in Demo Run One, which are Controlled Islanding, Congestions in the CoordiNet Common Platform (both real-time and day-ahead) and Balancing.

2.2.2.1. Controlled Islanding

One of the main challenges of the Controlled Island service is defining the necessary control and monitoring through the platform so that a third party can deliver such a critical service without any problem. The DSO has the grid visibility, and the FSP has control of the island during the delivery of the service. Therefore if there are any quality of service problems during the island mode, the DSO is ultimately responsible for them (even if it does not have the control at that moment). In a testing environment such as the one described in this document, those problems are unlikely to arise. But they should somehow be considered when scaling up the service to real life, not only technically but also to define the proper settlement of the service.

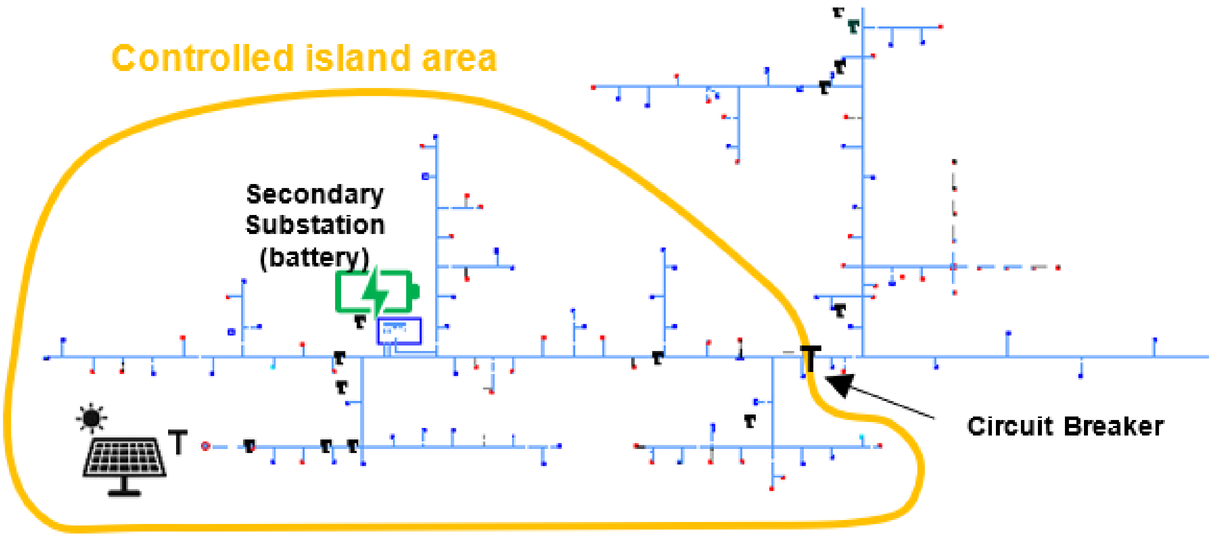


Figure 11 Part of the grid dimensioned to be controlled with the service.

Another challenge identified during this trial was specifying the attributes to pre-qualify this service. Again, given the criticality and uniqueness of this service, the pre-qualification phase is very important because once the FSP attributes are validated by the DSO, the DSO will count on this FSP to ensure the quality of supply. The lack of liquidity from FSPs to offer this service in a location where it is needed would probably oblige the DSO to sign a long-term agreement with the FSP after pre-qualifying the FSP. This peculiarity makes this service more likely to be resolved through bilateral contracts rather than local markets.

In this BUC, the storage unit used to deliver the service belongs to i-DE. This approach is linked to some regulatory obstacles as to determining the conditions to allow the DSO to own and operate storage facilities whose main purpose is to solve grid problems. Nevertheless, the test could have been performed by a third party owned battery with minor changes to its execution.

2.2.2.2. Congestions in Common TSO-DSO Platform

The tests in the common platform were divided into two: Real-Time and Day-Ahead, as the treatment was different, although both followed the same process as shown in Figure 12.

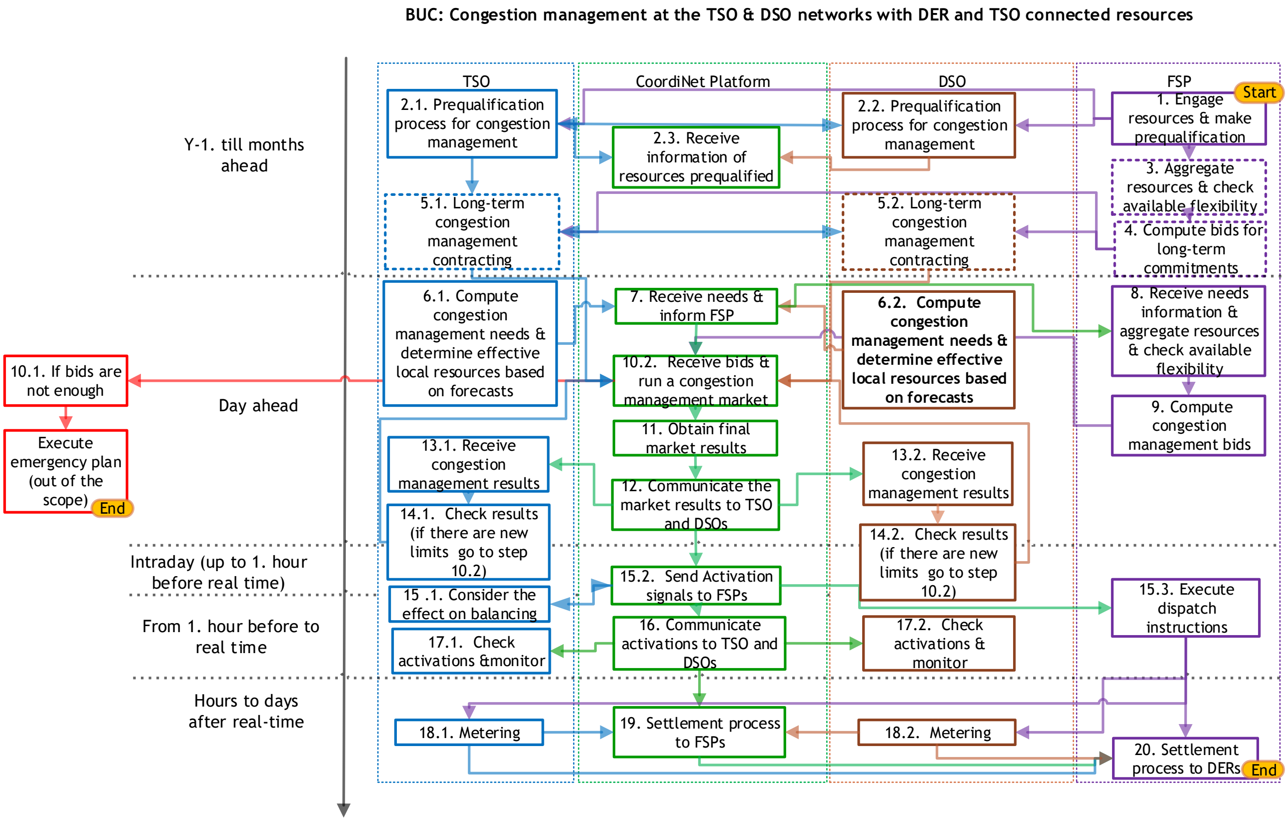


Figure 12 Flowchart for congestion management in Common Platform

2.2.2.2.1. Real-Time

These tests were conducted using REE's GeMas platform. This platform allows the participation of renewable generation in real-time adjustments. The first improvement of this service would be to open the solution to demand-side participation and other types of generation.

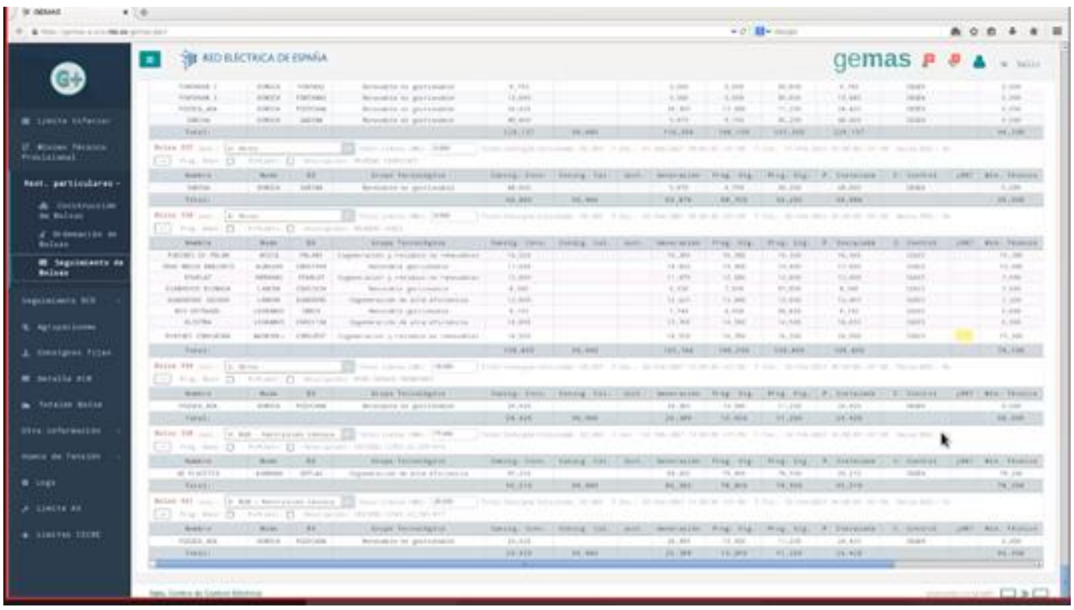


Figure 13 Gemas platform during i-DE pilot tests.

In this case, the algorithm for coordinating TSO and DSO needs is straightforward, with the CoordiNet Common Platform taking the largest constraint as valid. This solution has proven to be useful, simple and easily scalable.

Another relevant point is that the DSO can set constraints for the next hour but cannot set constraints for the next minute through the system. However, this functionality is anyway available as it can be done through the TSO operator. So for the operation, and for the demo itself, it is just a small but unnecessary delay. An improvement could be to allow the DSO to update their constraints more frequently.

Regarding the availability of the FSPs, it must be taken into account that due to the time of the year when the tests took place, it was not possible to count on hydro generation. Therefore, the tests were carried out with wind generators and cogeneration.

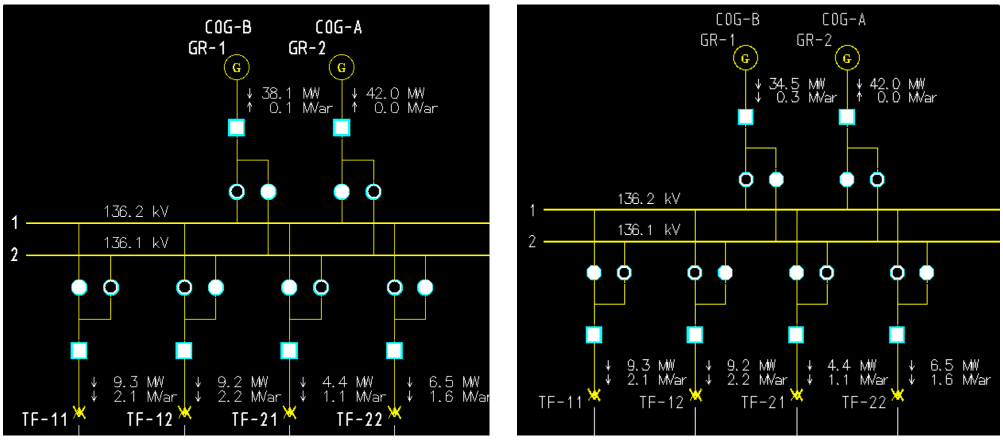


Figure 14 Co-generation power reduction during tests

2.2.2.2.2. Day Ahead

During the congestion test on day-ahead in the CoordiNet Common Platform, it was possible to count on other generators that do not regularly participate in the Gemas platform, as the CoordiNet Common Platform used was eSIOS. These limitations of day-ahead are simpler than the previous one, and the result was fully successful. Nevertheless, several points were detected that could be conclusions of the test:

Firstly, the limitations applied for the whole day. Therefore, it was not possible to set the limitations for some hours. This is easy to improve and necessary to adapt the tools used in the demo in case of definitive implementation of the common platform for congestion management. Even the quarter-hour granularity is more interesting to adjust the requirements further and not to generate unnecessary redispatches.

Secondly, all day-ahead constraints must be sent in the same message. This obliges the DSO to update his entire order every time he detects a requirement during the previous day. This is not a major functional problem, but it places an unnecessary operational burden on the DSO. For a potential definitive implementation of the common platform for congestion management, it would be interesting if the TSO could receive the constraints independently during the period allowed for this purpose.

Thirdly, the physical units are already previously defined per generating group. As this is the code needed to exchange information between TSO and DSO, the DSO systems must name the resource sets in a homogeneous way with that of the TSO. This is not a big problem, but it has to be considered.

Finally, because the i-DE platform was designed to interface with the eSIOS production platform and the development platform was used during testing, it was necessary to redirect the DSO-TSO link, which required allocating some extra time to be spent on the test.

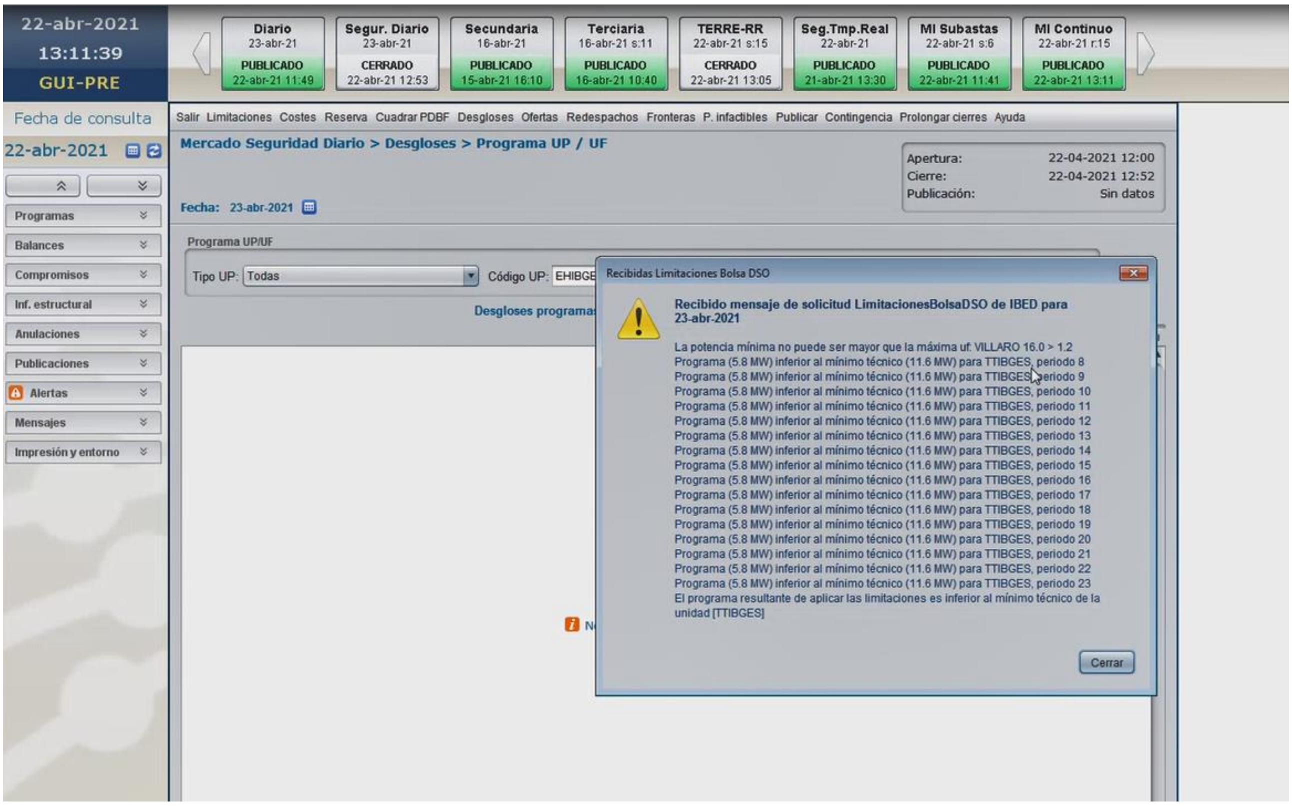


Figure 15 eSIOS platform during i-DE congestion management in Day Ahead tests

Although they were not the subject of these tests, it is interesting to note that day-ahead constraints also allow a minimum limit to be defined in the same way a maximum limit is defined. This may be useful occasionally, although it is not likely that there will be a regular need for this type of constraint for the DSO. It could be useful on an occasional basis to carry out scheduled jobs on the network.

2.2.2.3. Balancing use case

The Balancing case tests proved to be of little use to the DSO. After all, it was a question of registering limitations on the power reserved to deliver these services. It is unusual for the DSO to limit the capacity of providers of services such as mFRR or RR. In some situations where it is necessary to limit the power of a generator, such a limitation is normally expected to be done with the congestion management service. Nevertheless, as it may occur sporadically and for innovative purposes to see the result in practice and draw theoretical conclusions, a test of this capacity limitation was carried out.

These tests also allowed for the use of generation and demand. However, in the case of the i-DE test, only generation resources were used.

A point of improvement for this use case could be to increase transparency for the DSO. Since once the constraint has been submitted, the DSO does not know whether the impact has been on the mFRR service or on the RR service, but it is not relevant information for the DSO.

2.3. REE (TSO)

From what was initially raised at the CoordiNet Project, several challenges have been found, which have needed some adaptations in the TSO existing platforms and the development of new ones. This section analyses the main challenges, difficulties, and adjustments carried out during Demo Run One.

2.3.1. Challenges and Opportunities From the Point of View of The SOs (TSO)

2.3.1.1. TSO existing platforms (eSIOS and GEMAS+)

In the Spanish Electrical System, the current coordination between TSO and DSOs is quite well developed. As a result, there exist different platforms to manage the interactions between them.

One of the most important is the eSIOS platform, developed by the Spanish TSO REE to perform the tasks of information and processes management specifically related to the electricity market, allowing, among other functions, to communicate with market actors who buy or sell energy.

Another essential platform is GEMAS+ which accesses the real-time information received in the Control Centre of Renewable Energies (CECRE) and uses it to determine whether the present generation scenario is admissible for the system.

These platforms were the starting point to create the CoordiNet Common Platform, a platform used by TSO and DSOs to exchange information and improve even further the existing TSO-DSO coordination. The Coordinate platform includes an upgraded version of eSIOS and GEMAS+, below are described the main new features developed for them:

GEMAS+:

- Real-time FSPs congestion management by the DSOs: Currently, GEMAS+ is run by the TSO CECRE dispatcher, who set the limits to the FSP generation units in real-time, DSO can ask for limitations to the CECRE dispatcher if some FSPs are affecting their grid.
- With this new version, DSOs can themselves manage these congestions in GEMAS+. In fact, DSOs can create bundles of FSPs, set limits for these bundles, and manage them (modify the period validation, remove etc.). This new functionality implies a fast response to solve the congestions occurring in the DSO grids and, therefore, an improvement of the system security.
- Enhanced TSO-DSO coordination: this functionality automatically solves incompatibilities of grid congestion affecting both TSO and DSOs. If the congestion cannot be solved automatically, GEMAS launched a warning to both grid operators.

eSIOS:

- Day-Ahead FSPs congestion management by DSOs: Currently, in the Day-Ahead, DSOs can set limits to the FSPs causing congestion in their grid. This management is carried out manually (by phone communication between TSO -DSO dispatcher). With this new functionality, DSOs can insert directly in eSIOS the limits to solve the congestions generated for the FSPs connected to their grid.
- Data exchange: according to the KORRR regulation, DSOs have the right to retrieve information regarding the limits and redispatches applied to the FSPs.

Additionally, several upgrades were performed in eSIOS platform to adapt all the subsystems (i.e. Redispatching algorithm).

All of these upgrades in the existing platforms have represented a big challenge for the IT systems of the Spanish TSO. The reasons are listed below.

- GEMAS+ and eSIOS are critical platforms that are under real-time operation. Any change in these tools requires exhaustive checks to avoid malfunctioning, which could endanger the system.
- Even the changes in these platforms are related to a single part of the whole system. There are many subsystems that had to be modified and retested in order to guarantee well functioning.

Besides the TSO platforms, the CoordiNet project has also used new coordination procedures. Currently, the new procedure regarding TSO-DSOs information exchange is under regulatory approval. This guideline includes rules for the exchange of structural information and real-time information among TSO-DSOs and the FSPs in Spain. During the BUCs in Demo Run One (both Balancing and Common Congestion Management), DSOs were informed about the redispatches and limits applied to the FSP affecting their grid by the new functionalities implemented in eSIOS platform. This new feature allowed DSOs to use the information for their grid analysis.

Concerning the missing aspects, the coming Demo Run Two will serve to improve the overall results. One of the most important is the demand participation in both balancing and congestion management processes. The participation of demand in the Spanish balancing markets is described in the document "Condiciones relativas al Balance" recently approved by the Spanish National Regulatory Agency (NRA)[13]. To participate in the balancing markets, these new participants have to pass some tests in order to demonstrate to the Spanish OS that they are capable of activating the energy in the condition fixed in the regulation.

During the Demo Run One, the demand unit participating in CoordiNet, could not start this pre-qualification process as the required structural information wasn't provided to the TSO. In Demo Run Two, it is expected that this information will be presented, and the unit will be able to start the pre-qualification process. Once this stage has finished, the second target of the BUC is the real participation of these units in the real balancing market.

The second target for Demo Run Two is related to the demand participation in Phase 1 of the day ahead congestion management process. This participation is not in the current national grid code. For these reasons, the tests will be simulated using an eSIOS.

Finally, regarding demand participation, the only missing point is related to participation in the real-time congestion management process. Although this case was analysed during the definition phase of the project, the necessary changes in the GEMAS+ platform were far beyond the project and affected too deeply a critical tool for the TSO.

1... [13] *Resolución de 11 de diciembre de 2019, de la Comisión Nacional de los Mercados y la Competencia, por la que se aprueban las condiciones relativas al balance para los proveedores de servicios de balance y los sujetos de liquidación responsables del balance en el sistema eléctrico peninsular español* and available at https://www.boe.es/diario_boe/txt.php?id=BOE-A-2019-18423

2.3.1.2. Voltage control

Directive (EU) 2019/944 defines voltage control as a non-frequency ancillary service that shall be used by TSOs to ensure operational security. In particular, the Spanish electrical system has evolved over the last decade, becoming more capacitive, especially during off-peak periods. The voltage conditions of the transmission system in Spain are quite changeable due mainly to the variability of renewable generation and power transfers with other TSOs. Therefore, REE has designed a new voltage control based on real-time set points instead of the current methodology based on fixed ones.

The voltage control service can be provided through several modalities based on voltage, reactive power and power factor setpoints. The grid manager can select the modality that better fits system needs between the ones available in real-time. The coordination between TSO and DSOs is defined through a set of control measures to be applied in their frontiers according to the voltage profile in the transmission network to control the reactive power flow through these frontiers.

VOLTAIREE is the automatic scheme used by REE to control the voltage of the transmission network and validate the service providers' participation. It comprises an Optimised Voltage Regulation (OVR) and a Secondary Voltage Regulation (SVR) which operates in adjacent timescales to improve its performance and stability when facing system perturbances. The main purpose of the OVR is to maintain pilot nodes' voltage profiles in an appropriate range. Therefore, an OPF computes a short-term forecast of optimal voltage and reactive power considering the current network state estimation.

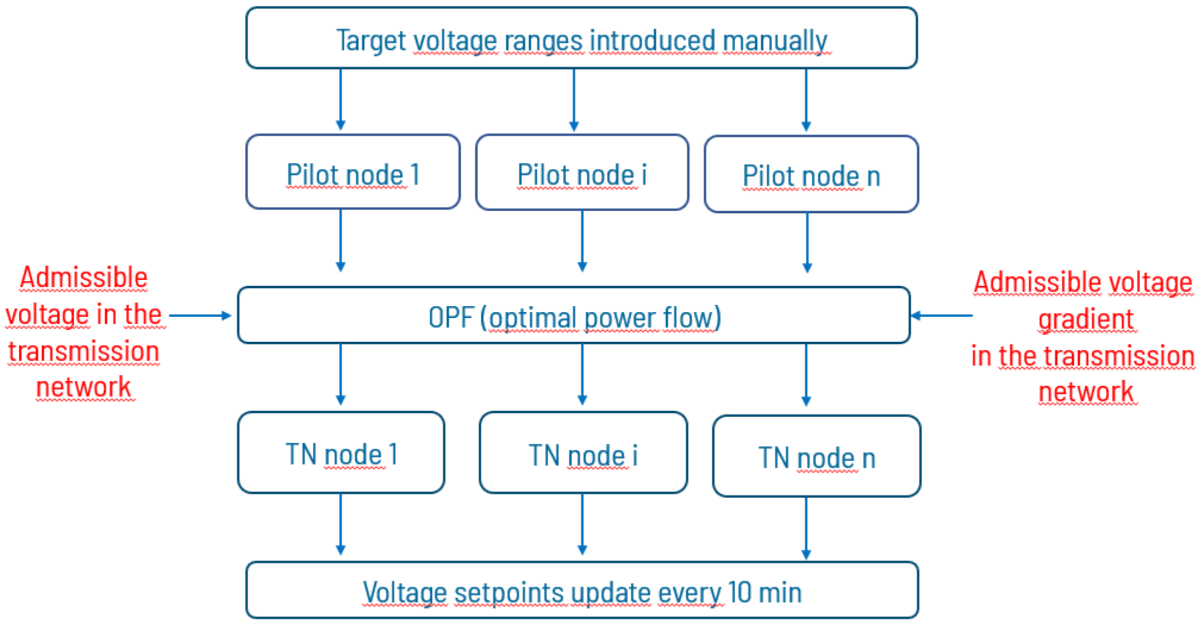
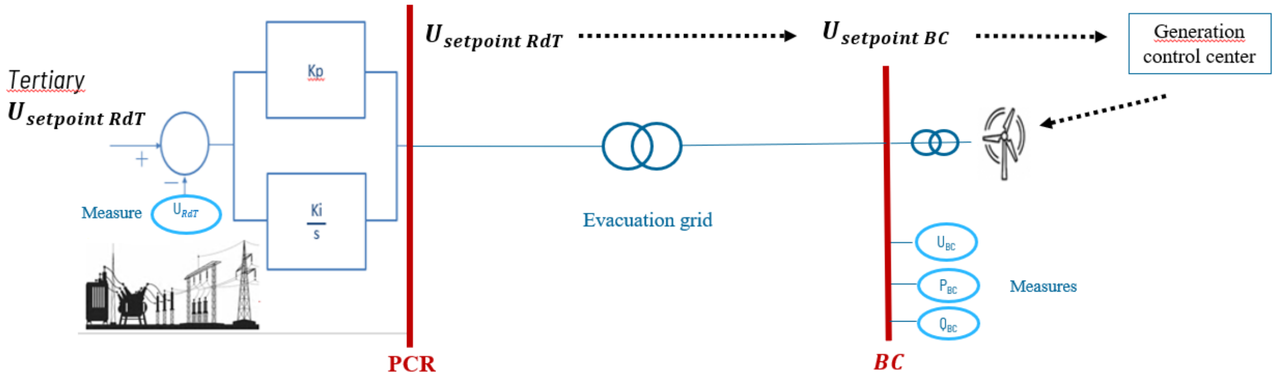


Figure 16 Optimised Voltage Regulation Algorithm[14]

[14] TN: Transmission Network

The SVR automatically sends setpoints in real-time to service providers to minimise the difference between the voltage setpoint calculated by the OVR and the voltage measurement of the point of interconnection between the service provider and the transmission network.



$$Translation\ from\ PCR\ to\ BC: \quad U_{setpoint\ BC}[kV] = U_{setpoint\ RdT}\ [pu] \cdot U_{nominal\ BC}$$

$$Q_{setpointBC}[Mvar] = \frac{(U_{setpointBC} - U_{BC})}{U_{nominal\ BC}} \cdot K_v \cdot Q_{oblig\ max}$$

$$fdp_{setpointBC} = \frac{P_{BC}}{\sqrt{P_{BC}^2 + Q_{setpointBC}^2}}$$

Figure 2 Secondary Voltage Regulation Algorithm

To make available and useful the potential additional reactive capabilities of service providers, new reactive capacity zonal markets have been designed. Weekly auctions guarantee the necessary reactive capacity for each zone through a transparent, non-discriminatory and market-based process.

Every provider larger than 1 MW can participate in the market. It just has to pass a pre-qualification process in which the grid manager shall validate their additional reactive capabilities and time responses. The tests shall be repeated for various active power values. Each test will have several phases for both reactive power generation and absorption: stabilisation, fulfilment of voltage setpoint and saturation instructions. The test result for each FSP is its additional capacity of reactive power and its time of response to modification of setpoint. The test results of the six wind farms participating in the transmission network demonstration are summarised in the following figures and tables[15].

[15] In order to preserve the anonymity of results, the wind farms connected at the the i-DE's netwrok are identified by their identifiers, following the same approach as in the CoordiNet deliverable D3.1 [5].

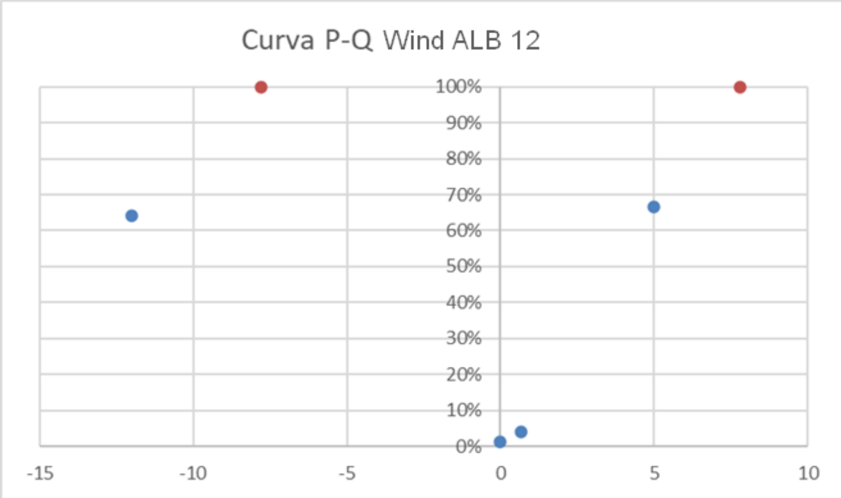


Figure 17: P-Q Curve for Wind ALB 12

Table 4: Wind ALB 12 I pre-qualification test

	fdp setpoint	HOUR	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	7,8	
	Compulsory Consumption			100%	-7,8	
P high	Maximum Consumption		25	64%	-12	134
	Maximum Generation		26	67%	5	135
P low	Maximum Consumption		0,44	1%	-0,01	136
	Maximum Generation		1,61	4%	0,66	135

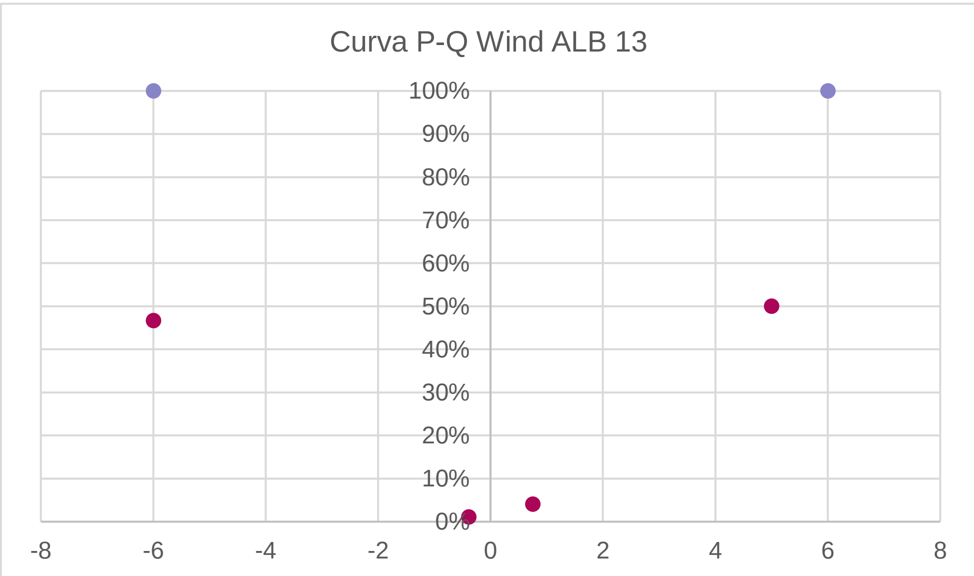


Figure 18: P-Q Curve for Wind ALB 13

Table 5: Wind ALB 13 pre-qualification test

	fdp setpoint	HORA	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	6	
	Compulsory Consumption			100%	-6	
P high	Maximum Consumption		14	47%	-6	134
	Maximum Generation		15	50%	5	135
P low	Maximum Consumption		0,32	1%	-0,39	136
	Maximum Generation		1,21	4%	0,75	135

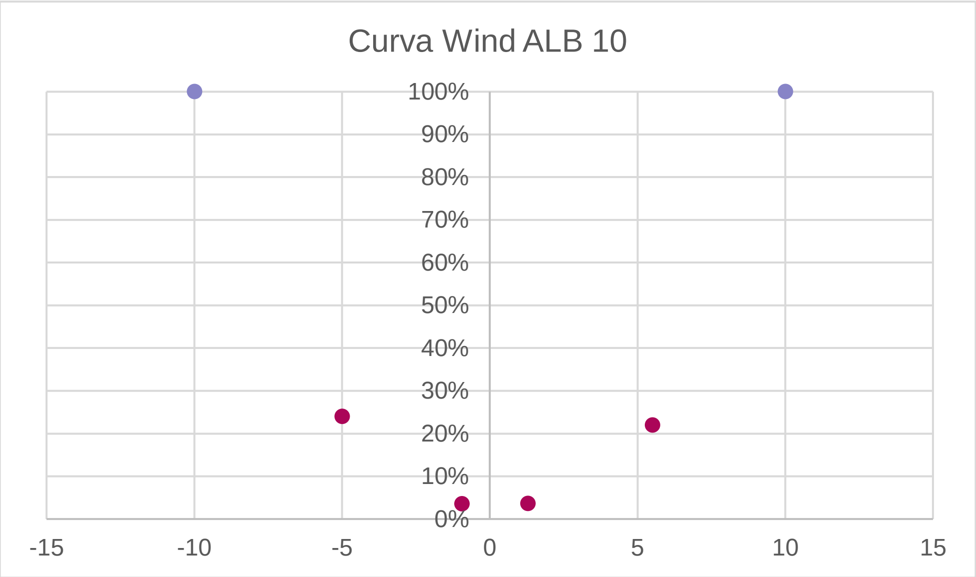


Figure 19: P-Q Curve for Wind ALB 10

Table 6: Wind ALB 10 pre-qualification test

	fdp setpoint	HORA	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	10	
	Compulsory Consumption			100%	-10	
P high	Maximum Consumption		12	24%	-5	134
	Maximum Generation		11	22%	5,5	135
P low	Maximum Consumption		1,78	4%	-0,94	137
	Maximum Generation		1,81	4%	1,29	137

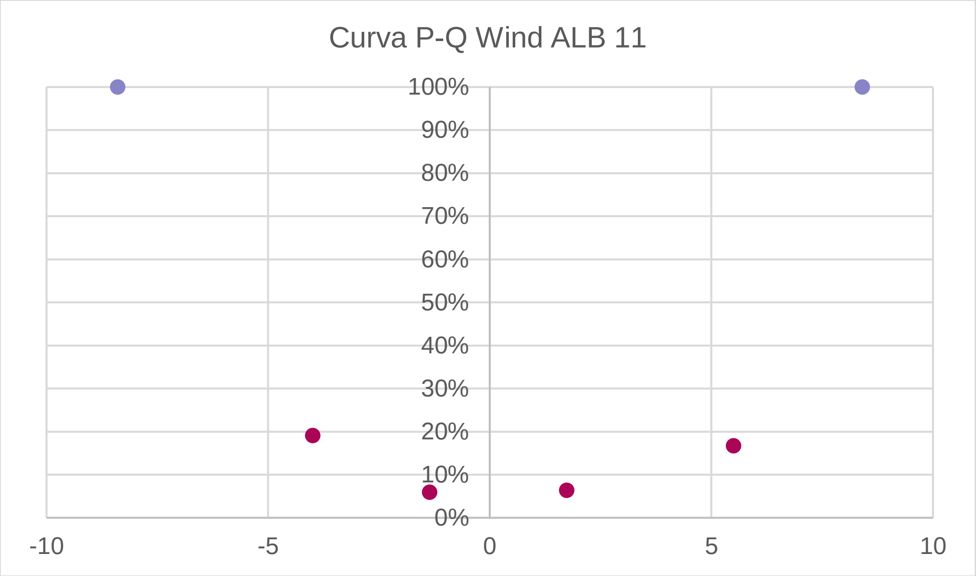


Figure 20: P-Q Curve for Wind ALB 11

Table 7: Wind ALB 11 pre-qualification test

	fdp setpoint	HORA	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	8,4	
	Compulsory Consumption			100%	-8,4	
P high	Maximum Consumption		8	19%	-4	134
	Maximum Generation		9	17%	5,5	135
P low	Maximum Consumption		2,48	6%	-1,36	137
	Maximum Generation		2,67	6%	1,73	136

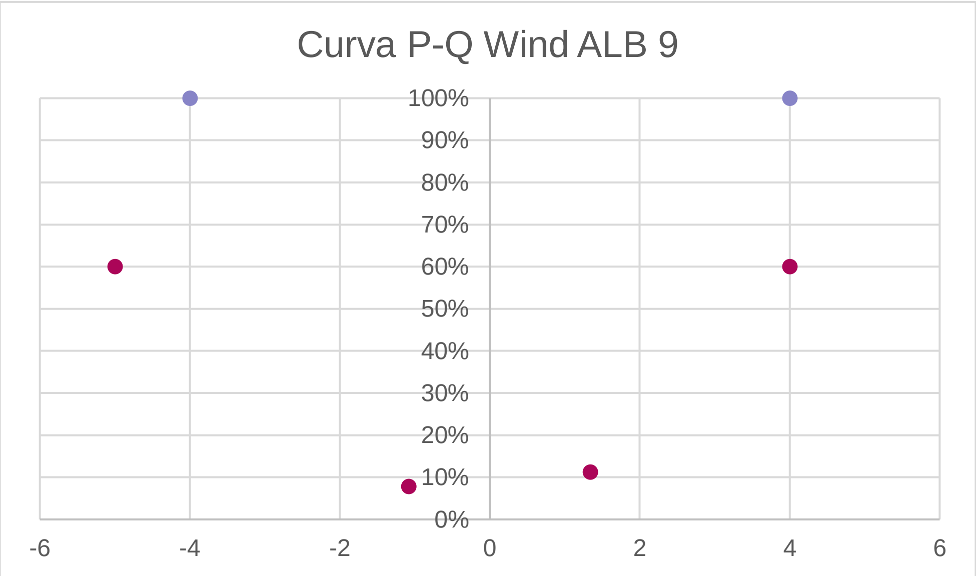


Figure 21: P-Q Curve for Wind ALB 9

Table 8: Wind ALB 9 pre-qualification test

	fdp setpoint	HORA	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	4	
	Compulsory Consumption			100%	-4	
P high	Maximum Consumption		12	60%	-5	133
	Maximum Generation		12	60%	4	136
P low	Maximum Consumption		1,56	8%	-1,08	136
	Maximum Generation		2,25	11%	1,34	136

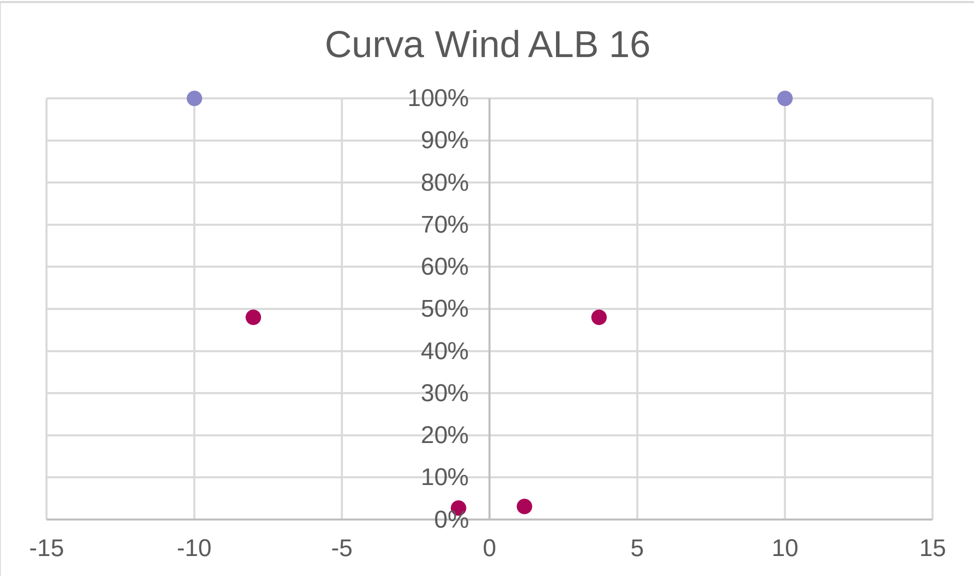


Figure 22: P-Q Curve for Wind ALB 16

Table 9: Wind ALB 16pre-qualification test

	fdp setpoint	HORA	P [MW]	P [%]	Q [Mvar]	U [kV]
	Compulsory Generation			100%	10	
	Compulsory Consumption			100%	-10	
P high	Maximum Consumption		24	48%	-8	133
	Maximum Generation		24	48%	3,7	136
P low	Maximum Consumption		1,36	3%	-1,05	136
	Maximum Generation		1,57	3%	1,18	137

We can conclude that the wind farms tested have an additional reactive capacity for the entire range of active power production. However, along with the low active power range, additional reactive capacity is minimal. Even if only a few points of the PQ curve were collected, it is understood that it is not necessary to carry out further qualification tests because the rest of the points of the P-Q curve will emerge throughout the voltage control use case.

3. Inputs to WP2 and WP6

The major goal of CoordiNet is to demonstrate the procurement of system services and, hence, the demonstration WPs (WP3, WP4 and WP5) have had a close collaboration with the rest of the WPs from the very beginning. Since WP1 launched the activities in the first months of the project, the closest collaboration during the first demo run of WP3 has been with WP2, and the main results will be used by WP6, as shown in Figure 23. This chapter summarises such collaborations.

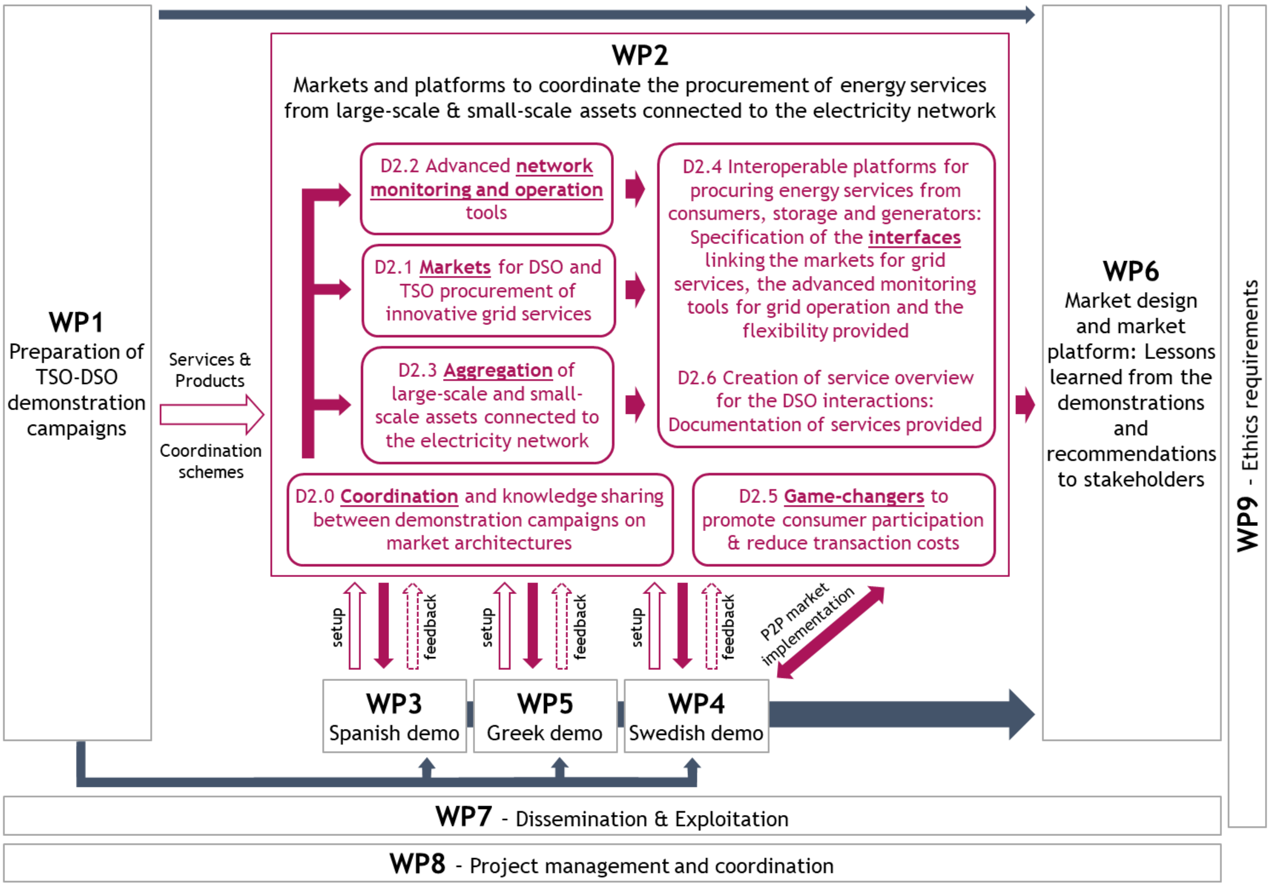


Figure 23: Main interactions and links of WP2 deliverables with the other WPs of the CoordiNet project

The cooperation between WP3 and WP2 focused on four main areas: market setup (task 2.2, D2.1 [6]); grid monitoring and operation tools (task 2.3, D2.2); DER characteristics, aggregation and disaggregation (task 2.4, D2.3 [7]) and information exchanges (tasks 2.1, D2.0 [8] and task 2.5, D2.4 [9] and D2.6[16]). Additionally, some generic information was provided in advance.

As first input, the Spanish demonstrator provided some basic information about the demonstration campaign, including locations, units that will provide flexibility, BUCs, etc. Based on this information, and through an iterative process, the business case analysis and activity graphs were created in D1.5 [10]. Those activity graphs were afterwards updated (e.g. to include the local market, which was not included in the

[16] Upcoming deliverable

first version) and extended, so that simplified representations of the component layer of the Smart Grid Architecture Model (SGAM) diagrams could be created in D2.0 [8]. In addition, in preparation for the rest of the activities in WP2, a review of existing platforms in the Spanish demonstrator and how they were expected to be updated/extended within the demonstration campaign was provided and included in D2.0 [8].

When defining the market setup, D2.1 [6] described the market design dimensions and principles, and WP3 provided information about how those principles were used in practice and how the overall system architecture was defined in the Spanish demonstrator. Moreover, the current market organisation was provided, together with a proposal on how to integrate the flexibility markets implemented in CoordiNet within existing frameworks, in terms of timing, balancing responsibility allocation (for demand, generation and storage) and aggregation requirements. In WP2, the potential baselining methodologies for congestion management were analysed and the Spanish demonstrator provided the required information so that the most suitable methodology for the Spanish case was identified. As a final input, the Spanish demonstrator also identified the market tools, together with their associated functionalities and requirements, which are needed to address the objective of the business use cases.

The grid monitoring and operation tool analysis was performed in D2.2 [11], by identifying the generic functionalities and requirements that such tools should perform. For that purpose, the Spanish demonstrator identified, first, the functionalities required to address the BUCs in Spain, afterwards the tools that could deliver them and, finally, the generic requirements of those tools. This procedure was iterative, as new functionalities and requirements were identified during the progress of the demonstration.

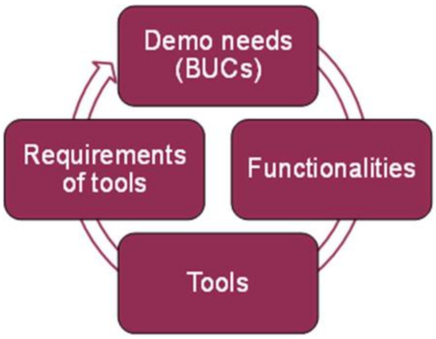


Figure 24: Methodology followed to identify the functionalities and requirements of the tools (D2.2, [11])

The inputs of the different demonstrators allowed WP2 to identify the common functionalities, tools and requirements, as well as the general requirements that had to be met by all tools in each demonstrator and the specific functionalities, tools and requirements of each demonstrator. Likewise, for each requirement, a rationale of the requirement, the acceptance criteria and the priority of the requirement could also be identified. Requirements were classified as general, functional & data, operational, security, legal and architecture requirements. As a result of this identification of all generic functionalities and requirements, the necessary data exchange between the tools was also identified.

To account for DER characteristics, aggregation and disaggregation in D2.3 [7], the Spanish demonstrator provided information about the DER units involved in the demonstration campaign, together with market deployment aspects. In this case, the objective was to identify the types of units to be considered, as well as the market dimensions which could affect the aggregation activity, to propose appropriate aggregation and disaggregation methods, which could then be used by the demonstrators. This way, the proposed aggregation and disaggregation methods are suitable for, among others, the units identified in the demonstrators, i.e. district heating installations, small to medium-sized conventional generators, small to medium-sized combined heat and power (CHP) units, small to medium-sized renewable generators, charging points of electric vehicles (EV), energy storage systems and Heating, Ventilation and Air Conditioning (HVAC) systems (large renewable generation plants are also part of demonstrators, but they do not need to be aggregated as for the rest of small to medium-sized DER). Likewise, the market aspects to be considered included 1) the time between the bidding phase and the actual delivery phase, 2) capacity vs. energy markets, and 3) aggregation level. As a final contribution from the Spanish demonstrator, the functionalities and requirements that aggregation tools should meet were also identified, so that D2.3 could compile the generic functionalities, tools and requirements needed to properly aggregate and disaggregate flexibility resources.

In this case, the information flowed, first, from the demonstrator to WP2 but, then, it was taken back to the Spanish demonstrator since TECNALIA used the aggregation method proposed in D2.3 as the basis for building the aggregation platform used in the demonstration in Málaga.

As described above, the activity about gathering insights information exchanges started in the early stages of both WP2 and the Spanish demonstrator and was included in D2.0 [8]. Then, after the functionalities, tools and requirements for the three main blocks of the information exchange architecture (market, grid operation & monitoring and aggregation & disaggregation) were identified, a service catalogue for the different BUCs was created in D2.4 [12]. For that purpose, the information gathered from the different demonstration campaigns was updated. The service catalogue provided a detailed analysis of how the stakeholder exchanges the information within the specific BUCs. The service catalogue also makes clear what role the CoordiNet market platform plays and how it is integrated into the information flow between DSO, TSO and other market players. Besides the description of the methodology and the elaboration of the service catalogue, the required standards, common interfaces and the requirements for information exchange were also presented in D2.4 [12]. This service catalogue was further extended in D2.6 by including information about KPIs, the Technology Readiness Level (TRL), the quality levels and access rights so that the overall architecture and the requirements for information exchange are meaningfully concluded.

After the completion of the first demo run, the results will be mostly used in WP6, whose overall objective is to assess and evaluate the results of the demonstration campaigns and provide recommendations for an adapted market design at the EU level and needed policies to support this, to enable TSOs and DSOs across Europe to procure standardized products for grid services in a coordinated manner. WP6 is structured in seven tasks (see Figure 25).

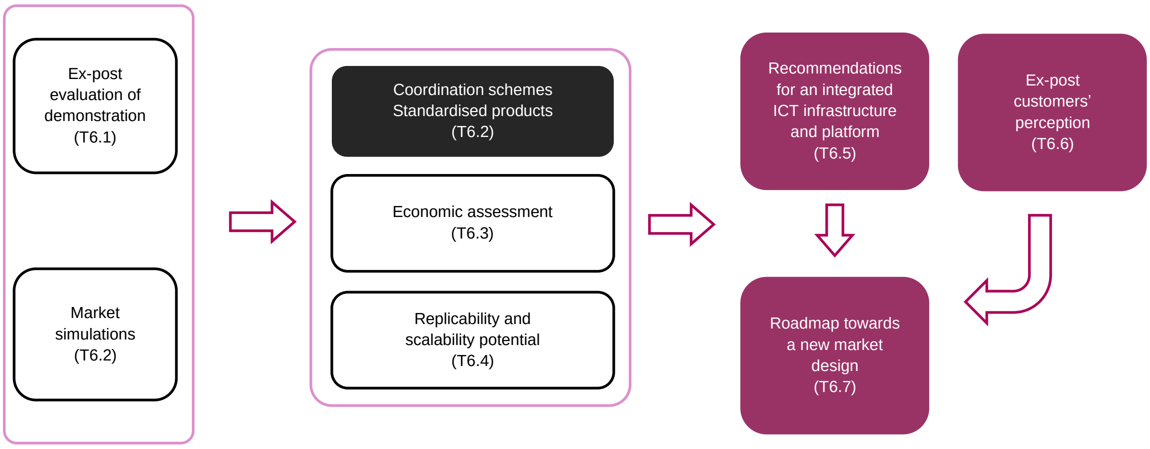


Figure 25: WP6 main structure.

As far as the interaction between WP 6 and the Spanish demonstrator in the effort to communicate results from the first demo run is concerned, most of the information is exchanged through task 6.1, although some direct information is also provided to tasks 6.3, 6.4 and 6.6, taking advantage that those tasks are led by partners in the Spanish demonstrator (TECNALIA, Comillas and ONE, respectively).

The aim of task 6.1 is to analyse the results of the different demonstrations in Spain, Sweden and Greece and draw conclusions based on their outcomes. For this objective, an iterative process has been defined to analyse the KPIs obtained in the first demo runs, in the case of Spain, in Demo Run One [1]. After gathering the demonstrator characteristics, the KPIs obtained by the demonstrator have been collected. In the Spanish case, the KPIs of the first demo run can be found in deliverable 3.4 [1]. These KPIs have been analysed by task 6.1 partners. Each partner was in charge of analysing specific KPIs, so all the KPIs had a responsible for their review and analysis. After a first round, some doubts and questions arose, which were collected into a spreadsheet. Based on this spreadsheet, several meetings have been held with the Spanish DSOs and TSO in the demonstrator, i.e. e-distribución, i-DE and REE, until all doubts and issues raised in the review process were solved. To make the meetings as efficient as possible, a bilateral format has been used between each DSO or TSO and one of the Spanish partners (e-Di/IREC, TECNALIA and Comillas, respectively). In this sense, the continuous support of the industrial partners has been of key importance for technological partners to perform a proper KPIs analysis. As a reference, 30 KPIs were analysed for the Spanish demonstrator.

In addition to this general data gathering from the demonstrators, the Spanish demonstrator has taken a relevant role in defining the scope of the analysis in task 6.3. The main objective of this task is the economic assessment of the proposed coordination schemes and products for system services. This analysis takes input from the replicability and scalability analysis in task 6.4 (see below) and from the KPI analysis in task 6.1, especially regarding ICT costs (both CAPEX and OPEX). Instead of performing a classical cost-benefit analysis, e-distribución proposed to follow a more innovative approach so that the regulatory implications of the use of flexibility could be taken into account. For that purpose, weekly meetings have been established between e-distribución and TECNALIA (where Comillas, as task 6.4 leader, also contributes) to analyse and propose a regulatory scheme that ensures that market agents (aggregators, FSPs) see a positive business case, whereas roles performed by regulated agents (TSO, DSO, flexibility market operator) receive a regulated remuneration which, on the one hand, ensures the right incentives for them to operate flexibility markets, while, on the other, ensures to do so only in the cases where the use of flexibility is more economically-efficient than other alternatives (e.g. grid reinforcement).

In task 6.4, the Scalability and Replicability Analysis (SRA) of the BUCs proposed by the CoordiNet project is conducted. In this task, the base scenario is established at the current networks, with the FSPs participating in the demos. From there, simulations are conducted testing different sensitivities over the different characteristics of the network and the FSPs, for instance. Replicability scenarios are also investigated, simulating different types of DER as FSPs and different market models. Therefore, the current D3.5 allows for the T6.4 to identify characteristics that could be relevant when setting up the SRA scenarios. For instance, different types of FSPs that finally did not participate in the demo can be simulated. Additionally, simulations could provide results for a longer time horizon, as it was shown that this is a limitation for the calculation of some of the proposed KPIs.

Task 6.6 evaluates the ex-post customer perception of the CoordiNet demonstration activities. In this context, this deliverable D3.5 provide valuable inputs for the definition of the initial hypothesis with regards to Spanish customers. On on hand, section 2.2.1.2 describe the difficulties found in the customer recruitment process. On the other hand, section 4.2 conducted a consultation with the demo stakeholders, revealing their perceptions on customer involvement and engagement, as well as the over interactions among stakeholders in the demonstration.

4. Demo Run One Analysis

In this chapter, a preliminary assessment of the Spanish Demo Run One is presented. Three aspects are analysed, namely the implementation of the BUCs and markets, the customer engagement, and the KPIs from Demo Run One. This assessment aims at providing interim conclusions from the Spanish demonstration, which is conducting the Demo Run Two as of writing.

4.1. BUC and Market Implementation

The Spanish Demo Run One implemented and demonstrated three BUCs, namely (i) Common Congestion Management (ES-1a), (ii) Balancing (ES-2), and (iii) Controlled Islanding (ES-4). In this section, the original BUC definitions presented in deliverables D1.5 [10] and D3.1 [5] are revisited, and an assessment of the overall BUC and market implementation is made.

The focus of the tests for the Common Congestion Management BUC – ES-1a - were to test the provision of flexibility by FSPs connected at the distribution networks participating in the common congestion management market organised and cleared by the TSO. The FSPs participating in the demo are already participating in the actual congestion management markets of the TSO. These units are connected at the high-voltage distribution grids, as in Spain, the DSOs operate networks up to 132kV [13].

As identified in the preliminary regulatory overview presented in CoordiNet deliverable D1.1 [14], a regulatory mechanism already existed at the beginning of the project, allowing the DSO to evaluate the impact of the activation of FSPs connected to the distribution grid and set limitations in the congestion management market of the TSO. This regulatory option, however, was not commonly used, and the coordination mechanisms available to the TSO and the DSOs for this interaction were limited. Therefore, the CoordiNet project actively contributed to the development of the necessary tools for both TSO and DSOs to enable this coordination. On the DSO side, the DSO Platform provided the necessary tools for the evaluation of potential flexibility needs [15]. On the TSO side, adaptations of the existing systems and interfaces for the DSO were developed with the CoordiNet Platform concept [16]. This platform enabled the DSO to be seamless communicate and monitor the flexibility needs of the TSO platform.

With regards to the market implementation, ES-1a was based on the already existing congestion management in Spain. Being this a common market model, the TSO is responsible for organising and clearing the market. Therefore, congestions in the distribution grid are identified as well as the units that have an impact on the congestion, the needs for change in the dispatch are sent from the DSO to the TSO who accesses the bids and calculates the necessary redispatch to ensure solving the detected constraints. The limited units by the DSO would be remunerated according to the market rules, also applicable to the generators connected at the transmission grid [14].

The BUC ES-2, particularly the provision of balancing services by DER, followed a similar approach to the ES-1a implementation. The balancing market, too, is a market operated by the TSO in which FSPs connected at the distribution grid may participate, which characterises a common market model [17]. The implementation of this BUC leverages another regulatory provision, allowing the DSO to verify the impact of balancing activations in the distribution grid and eventually limit them. More specifically, Article 182(5) of the System Operation Guideline establishes that "*each reserve connecting DSO and each intermediate DSO shall have the right, in cooperation with the TSO, to set, before the activation of reserves, temporary limits to the delivery of active power reserves located in its distribution system. The respective TSOs shall agree with their reserve connecting DSOs and intermediate DSOs on the applicable procedures.*" [18]. The implementation of the BUC ES-2 contributed precisely to the definition of such procedures, to the development of the necessary tools for this mechanism to be in place, and to the demonstration of their technical feasibility. From a market perspective, this BUC too benefited from the already existing balancing market, considering that FSPs participating in the demonstration are already participating in this market.

The ES-4 was the BUC from Demo Run One that tested a completely new service. The controlled islanding tested in Demo Run One established the service characteristics and tested the technical feasibility of their implementation. As shown in the KPI analysis of section 4.3, the tests for this BUC could successfully demonstrate the controlled islanding service is technically possible. Moreover, it also identified important aspects of the islanding operation. For example, the presence of a storage system was critical, as it provided “local balancing” during the islanding state. Given the novelty of this BUC, the tests were focused more on the technical aspects of the BUC rather than on its market setting. Therefore, market-related questions such as the liquidity of an islanding product or the need for long-term procurement by the DSO to ensure the service provider when needed, especially in the “outage islanding” case, are still open.

4.2. Stakeholder Interaction

In order to understand the development of communications between stakeholders in the Spanish Demo and given the hierarchy of system operation and commercial development, a series of interviews were arranged with the main representatives of the TSO, Red Eléctrica de España; and the two DSOs present in WP3, namely e-DI and i-DE. However, it is important to note that the opinions presented in this section do not represent the institutional view of these organizations but only the individual views of the interviewees.

It is worth noting that it was agreed not to capture the feedback from the FSPs and Aggregators at this time since these will be part of a broader analysis in WP6. The aim of this consultation was to capture the experience of the SOs in the process of interacting with potential FSPs and other stakeholders during Demo Run One of the Spanish demonstration.

The following is a summary of those discussions between the SOs, laying down the main take-aways, ideas and experiences from these players. The authors thank them for their openness and high level of detail during these interviews.

4.2.1. Stakeholders

First, the SOs were asked who their main stakeholders were during the demos, and it had been an encouraging surprise to understand that all of them had interactions at all levels. In general terms, the TSO had more interactions with the DSOs, while the DSOs concentrated the interactions with the aggregators and with the DER or FSPs. Although, of course, the main interactions were with the levels immediately above or below, there were significant and meaningful interactions beyond the ‘closest’ stakeholder. For instance, as a result of the conversations in WP3, at least one FSP had direct exchanges with Red Eléctrica de España, and this not only to enhance their participation in the demos but also with the objective to explore the opportunity to keep providing services even after the end of the demo and CoordiNet.

4.2.2. Quality of dialogue

The SOs were asked regarding the quality of the dialogue across the chain and this on various levels: Technical, Commercial and Problem-solving.

In general, the overall technical understanding amongst SOs was deemed very high, with respondents highlighting the high quality of the technical discussions and stressing how CoordiNet served as ‘another’ forum where ideas were worked on since there are numerous European and National programmes that 'touch' or deal with similar topics at different stages of development. Therefore, one could assert that system operators (both transmission and distribution) in the Spanish demo were in sync, technically speaking.

Respondents also spoke very highly of the technical understanding of the aggregators. Stating dialogues was always easy, and whenever a technical complexity or detail was overlooked by them, the dialogues were efficient, causing no delays in the process.

Coming to the individual flexibility service providers, the dialogues were also exalted. Interviewees referred to them, both industrials, administrations, and renewable generation companies, as highly committed to the project and willing to bring to the project personnel with high technical capabilities to ensure a smooth, seamless communication across all levels. As said by one interviewed responsible: "Sometimes the first person appointed from a company to participate to these calls is not the most technically skilled or does not even have to know everything. Our job was to assist them in navigating these complexities to ensure a good outcome for the demo and the company itself".

Regarding the requirements for information exchange and Information Technology (IT) set-up, it is interesting to note that in all interviews, the topic of the communication systems was raised. IT protocols, were expressed to play an important role in communication, but to be worthless if they are not secure. Hence, from their foundation, IT infrastructure and protocols are built in very robust and fault-free structures, which are often not the most user-friendly, which brought up some conversations in the development of the Spanish Demo.

However, acknowledging the gap to be bridged, all respondents welcomed the 'flexible attitude' from all parties. Parties agreed to 'ease' and to be more flexible in their procedures. Therefore, respondents defined the communications in their platforms as hassle-free. The stakeholders shared the view that the demo would be a failure if it would not set a direction that led to the actual implementation and use of it in the near future.

An interesting reflection from one of the respondents is that a great enabler for a good understanding and communication has been the periodical meetings carried out within the demo, which ensured that any issue was dealt with in time and efficiently.

It is very important to point out that to define the pilot, the platforms, the services, the exchange of information between the different agents, it was necessary to bring together all the different actors: TSO, DSO, customers, aggregators, generators, operators, planners, researchers and technologists. All of them were part of the same team in order to carry out the pilot. Despite coming from very different activities and with different, sometimes conflicting, interests, it has been possible to meet the project milestones in a fruitful way thanks to the willingness to work as a team.

Figure 26 Spanish team

4.2.3. Transition to implementation

The SOs interviewed always had in mind the forthcoming transition into a more efficient system operation model and their need to adapt and develop new capabilities and business models to cope and to draw opportunities from it. They were asked about the main challenges that will be faced at the transposition of the ideas and models explored in CoordiNet under the Spanish Demo into the Spanish System as it stands today. Their answers included that:

- All SO representatives[17] stressed the sentiment that CoordiNet has provided them with a great opportunity to dialogue and test their ideas and that this was reinforced by a number of other national and supra-national programmes with similar or related goals. They all mentioned that giving an answer to how to make this transition possible and developing the required skills has become their job description and their DNA over the last years. In other words, their vision, objectives, and mindset have **already shifted** in this direction. There are numerous activities, investments and working groups fostering the digitalisation of the system, which is quite complete in the transmission level. Now, they meant that the next challenge is to do the same at the distribution level where the challenges are numerous due to the taxonomy of the grid at the distribution level.All interviewees signalled **communication** as one barrier to overcome if we want to handle the transition process efficiently. Here we refer to the digital information transfer between stakeholders on two levels. Today's platforms are built in very robust ways, which are the only way to operate transmission systems. However, the proliferation of distribution-level services raises an

[17] As mentioned above, these views express the position of the interviwees only, and not the overall position of their organizations.

opportunity (and responsibility) to build more user-friendly platforms and processes for aggregators and flexibility service providers.

- An interesting point made by most respondents was whether these changes shall be orchestrated and organised from the perspective that the system requires resilience and security, which is a top-down approach trying to find the compromises to achieve the least mininmum IT requirements in order to open for the participation of mass scale participants; or as an opportunity for all market participants to provide their flexibility in a transparent, efficient and non-discriminatory way, i.e. a bottom-up approach that starts with an economic incentive as the first step and therefore a deeper change in market design. 'Setting **the right priority** might prove crucial in making the transition a smooth process' said one respondent.
- Some respondents highlighted the role of the **intrinsic culture** in consumption participants, meaning that for some consumers, energy is only a "right", and do not see the opportunity and benefits of flexibility. According to numerous studies and deliverables within CoordiNet, there is significant potential flexibility already in the system. Flexibility that not only is dormant, untapped, and require ways and mechanisms to be exploited, but also, and perhaps, first of all, requires acknowledgement that one's flexibility has value to the system and therefore should also have value for the owner him/herself.
- Another point raised by the respondents was, besides the convenience of projects such as CoordiNet, the necessity to orchestrate more opportunities to develop pilots or **sandboxes** to explore into further detail actual constrains and limits in real applications into daily operations.
- An additional interesting point was made regarding **renewable generators**. These technologies are the main cause for imbalances in the generation forecast. However, their technologies, capabilities and management are constantly improving. Coupled with their finer data granularity (compared to consumers), they were pointed to as a greatly understated flexibility solution. Indeed, renewable assets are scattered across geographies, but their ownership/management is in far fewer hands (in Spain there are no more than 30 habilitated control centres for renewable generators), making their participation in flexibility mechanisms a possibility already.
- Giving **knowledge** regarding the importance of flexibility was also seen as an important action to work towards. Not all the FSPs understand the technical concepts of flexibility as their core business is not related to energy. The lack of comprehension makes it also difficult for the potential FSP to understand the benefits of the role, which leads to them being less engaged. It was discussed where this education should come from, and one idea is for it to come from the policymakers or governments to the citizens and companies. The public administration could educate citizens and other companies in this future market.
- Additionally, **economic incentives** from the public administration would also motivate consumers to participate in this transition towards flexibility.
- Last but not least, **policy-making and regulation**, as regulation tends to lag behind technical and business solutions. Therefore, a fertile regulatory environment would be necessary to foster the implementation of CoordiNet's solutions. Respondents highlighted the good dialogues they have with the policymakers. Still, a number of decisions have to be made around market design and market structure (e.g. economic incentives for flexibility procurement, product definition, coordination scheme in the TSO-DSO context)[18]. The general consensus is that a one-size-fits-all

[18] At the time of writing, these aspects are being further explored in the context of the WP6 of the CoordiNet project. The results shall be presented in deliverables D6.6 and D6.7.

market design for flexibility procurement is difficult to be achieved and that different solutions could co-exist.

Considering the interviews carried out and the discussion above, it can be concluded that stakeholder interaction did not find meaningful obstacles in the course of the Spanish Demo Run One in CoordiNet. There is a rooted alignment amongst SOs who see an opportunity (even a need) to develop the paradigm of active system operation to the new reality. The responsibilities are dispersed, but it became clear as a result of the interviews that there are also different levels of understanding of where we are and where we have to go. Whereas system operators are already marching their way along with the energy transition, it is the lower voltage levels of consumers (and/or their aggregators) who need a 'push' from either regulation or communication.

4.3. KPIs

The Demo Run One of the Spanish demonstration has focused on the implementation of three BUCs, out of the five BUCs defined for the whole demonstration campaign in this demo country. The Common Congestion Management, Balancing and Controlled Islanding BUCs have been tested in the Demo Run One phase, while the Local Congestion Management and the Voltage Control BUCs are tested in the Demo Run Two phase.

The definition of the BUCs being tested by the Spanish demo was firstly presented in the CoordiNet deliverable D1.5 [10]. Additionally, the KPIs to evaluate these BUCs were also defined at the beginning of the project in the CoordiNet deliverable D1.6 [19]. Following the initial set-up of the Spanish demonstration, both BUCs and the associated KPIs were revisited and reached their final definition in the deliverable D3.1 [5]. Therefore, in this section, the BUCs and KPIs considered are the ones in D3.1.

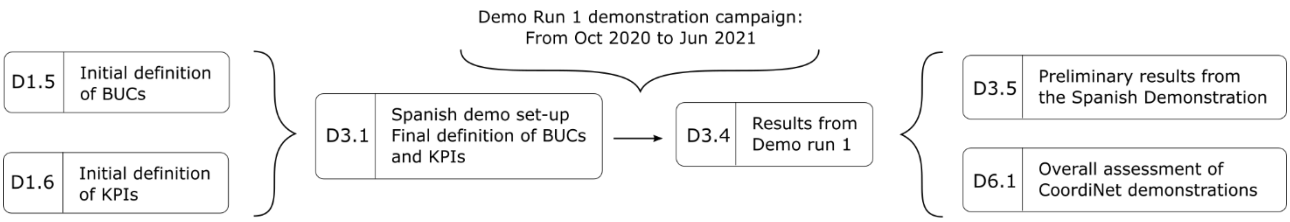


Figure 27: Definition, calculation and analysis of KPIs within the Demo Run One

In this section, the KPIs calculated within Demo Run One are analysed to provide a first evaluation of the first demonstration campaign. This preliminary analysis is based mainly on the results published in the CoordiNet deliverable D3.4. The goal of this analysis is to have a first evaluation of the overall pilot concept, and the solutions developed. Nevertheless, the KPIs calculated within the Spanish demo are also analysed in the CoordiNet deliverable D6.1[19]. Figure 27 illustrates the documents related to the KPI definition, calculation and analysis.

[19] Not published at the time of writing.

4.3.1. Overview of the KPIs

According to D1.6 and D3.1, a total of 34 KPIs[20] have been defined for the Spanish demonstration. In Demo Run One, 29 of the KPIs were calculated and reported in D3.4[21]. In D3.1, the KPIs are also categorised into Economic, Environmental, Social and Technical KPIs. Considering the 29 KPIs in Demo Run One, the majority (17) are technical, while 8 are economic, 3 are social and 1 is environmental.

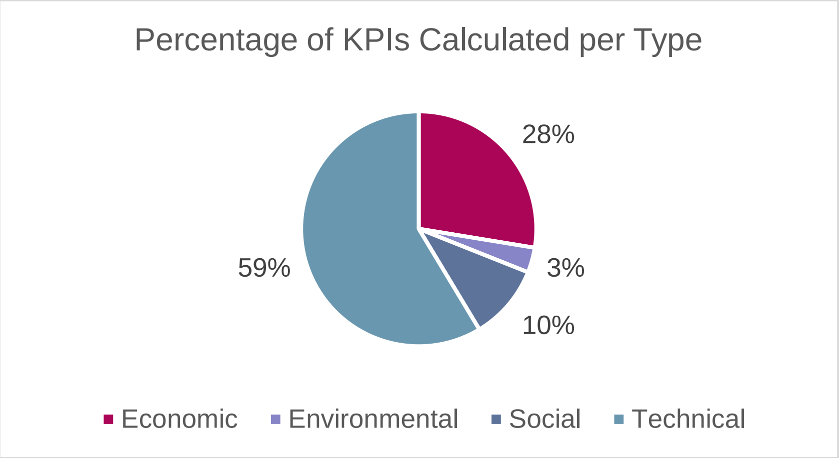


Figure 28: Proportion of KPIs per type in the Demo Run One

Most of the KPIs calculated are not BUC-specific but rather concern all the BUCs in the demo run, or all the BUC of the Spanish demonstration. Among the KPIs that do focus on one BUC, four are related to controlled islanding and one on balancing, as shown in Table 10.

Table 10: KPI-BUC mapping

KPI	Type	BUC Specific?	ES-1a	ES-2	ES-4	Common to all
KPI_1 - Cost of counteractions needed based on the activated flexibility	Econ.	No				x
KPI_2[22] - Cost of R&I solution vs. grid alternative solution	Econ.	No				x
KPI_4 - OPEX - Operational Expenditures	Econ.	No				x
KPI_5 - OPEX for service procurement	Econ.	No	x			
KPI_6 - Average cost per service for the examined period	Econ.	No	x			
KPI_7 - Increase RES and DER hosting capacity	Tech.	No				x
KPI_8 - Reduction in RES curtailment	Envir.	No				x
KPI_10 - Accuracy of RES production forecast calculated 1 hour in advance	Tech.	No				x
KPI_11 - Accuracy of RES production forecast calculated 24 hours in advance	Tech.	No				x

[20] In deliverable D1.6, it is mentioned that 33 KPIs are defined by the Spanish demo. Nevertheless, one extra KPI is calculated in Demo Run One, namely KPI_24.
[21] The remaining KPIs will be calculated in the Demo Run Two, as they are related to BUCs not tested in Demo Run One, namely ES-1b and ES-3.
[22] In deliverable D1.6, this KPI is identified as KPI_3, while in D3.4 it is KPI_2. In this D3.5 we maintain the ideintification of D3.4.

KPI_13 - Criticalities Reduction Index	Tech.	No				x
KPI_14 - Islanding duration	Tech.	Yes			x	
KPI_15 - TIEPI - Equivalent interruption time related to the installed capacity	Tech.	Yes			x	
KPI_16 - Potential offered flexibility	Tech.	No	x	x		
KPI_17 - Increase in the amount of load capacity participating in DR	Social	No	x			
KPI_18 - Volume of transactions	Econ.	No	x	x		
KPI_19 - Number of transactions	Econ.	No	x	x		
KPI_20 - ICT cost	Econ.	No				x
KPI_21 - Deviation between market activated and actual activated mFRR	Tech.	Yes		x		
KPI_22 - Requested flexibility	Tech.	No	x	x		
KPI_24 - Accuracy of load forecast calculated 1 hour in advance	Tech.	No				x
KPI_25 - Accuracy of load forecast calculated 24 hours in advance	Tech.	No				x
KPI_31 - Total activation time of a product	Tech.	No	x	x		
KPI_32 - Delivered energy in controlled island	Tech.	Yes			x	
KPI_33 - Maximum power (non-transient) in controlled island	Tech.	Yes			x	
KPI_34 - Percentage of tested products per demo	Tech.	No				x
KPI_36 - Participant recruitment	Social	No				x
KPI_37 - Active participation	Social	No				x
KPI_38 - Type of flexibility providers per demo	Tech.	No				x
KPI_39 - Total computational runtime	Tech.	No				x

4.3.2. Economic KPIs

All the eight economic KPIs are calculated in Demo Run One. They can be summarised into two categories, namely (i) CAPEX-OPEX for SOs and (ii) flexibility market indicators. Within the first category, five KPIs aim at capturing what would be the Capital Expenditure (CAPEX) and the Operating Expenditure (OPEX) involved in the implementation of the demonstration solutions to the SOs procuring and using flexibility. More specifically, two KPIs [2 and 20] focus on the CAPEX items, while three KPIs [1, 4 and 5] analyse the OPEX components of flexibility usage in the context of the demo. On the market implementation side, two KPIs [18 and 19] look at the volume and number of transactions, respectively.

The CAPEX KPIs consider, on the one hand, the cost of a Business-as-Usual scenario (BaU) and the CAPEX involved in the implementation of the Research and Innovation (R&I) solutions [*KPI_2 - Cost of R&I solution vs. grid alternative solution*]. With regards to the latter, the biggest cost item is the necessary ICT developments, which are reported in KPI_20 [*ICT cost*]. Considering that most tests in Demo Run One tested the hypothesis of DER being activated without creating problems in the distribution grid, the BaU would constitute a reinforcement of the potentially congested assets against the alternative solution of procuring and activating DER in flexibility markets. Comparing the CAPEX involved in the two solutions, it is observed that R&I CAPEX is considerably lower than the BaU scenario. The ratio between R&I and BaU CAPEX ranges from 2% to 16%, depending on the network selected for the demonstration by the SOs. These results show that, on the one hand, the BaU items are mostly network-dependent, as they include transformers or lines to be reinforced. On the other hand, the R&I solution could be expected to be scalable, as cost items are mostly related to the ICT development for the flexibility procurement and activation. The comparison between the CAPEX costs of the two alternatives, however, cannot be directly used for economic comparison of alternatives, as the OPEX of both solutions is not considered in the abovementioned KPIs. This type of cost component is captured in KPIs 1, 4 and 20.

The KPI 1 aims at capturing the eventual cost of redispatch created by the error derived by the flexibility procurement and activation mechanisms. It is to say that activation of a flexibility mechanism could lead to new congestions not initially foreseen and which would require a remedial redispatch. This type of redispatch was not observed in the demo, and therefore the value of this KPI is zero. Partially this can be attributed to the controlled environment of the demonstration. However, it is worth mentioning that on the design of the BUCs, steps were included to minimise the risk of these situations. Figure 29 illustrates the steps included in the Spanish BUC to avoid remedial redispatches caused by flexibility activation.

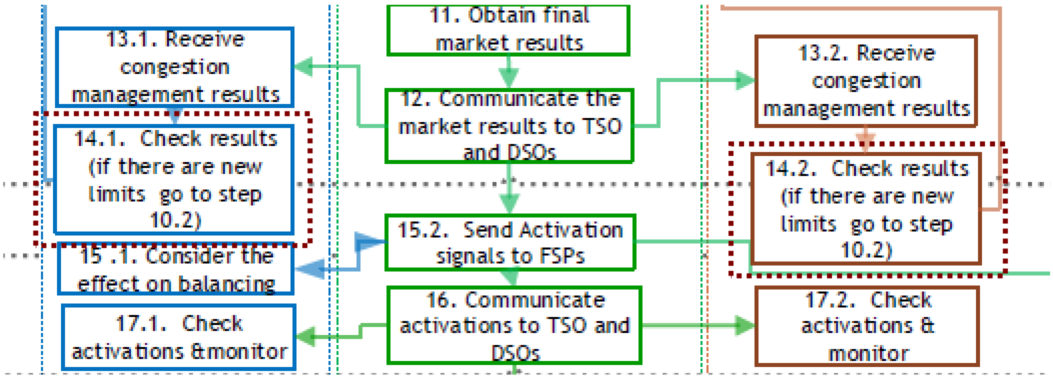


Figure 29: Checks by both TSO and DSO to avoid remedial redispatches. Adpated from [5].

The KPIs 4 and 5 aim at calculating specifically what the cost of procuring the flexibility for the different BUCs would be. The Operations & Maintenance (O&M) cost of the R&I scenario is computed in KPI_4, while the price paid to the flexibility providers is estimated. The computation of these KPIs, defined in yearly terms, presents the challenge of reaching an annual value based on a demonstration with a short duration. Therefore, assumptions were necessary, potentially reducing the accuracy of the KPI. Among those, firstly, is the fact that the total number of activations necessary [KPIs 4 and 5] throughout the year is unknown based on the testing carried out in the demonstration alone[23]. Secondly, the exact cost for the flexibility procurement [*KPI_5 - OPEX for service procurement*] is also difficult to estimate. With regards to the latter, it is worth mentioning that demonstrations focused mostly on the technical aspects of the communications and activation of the flexibility. For some BUCs, an actual market clearing and settling would be needed to ensure the necessary liquidity and economic incentives so that FSPs can provide bids in a competitive environment, revealing to the SOs a market-based cost of flexibility procurement.

Nevertheless, these KPIs still provide valuable information that could be used in a preliminary CBA of the R&I solutions. This exercise is exemplified for the BUC ES-1a in the Cadiz demo site. Firstly, considering the information provided by KPI_2, it is possible to calculate the annuity of the reinforcement considered. For this purpose, in addition to the cost of the transformer reported in Table 74 of the D3.4, a weighted average cost of capital (WACC) of 5.58% [20] and an asset life of 40 years [21] are considered. With such parameters, the annuity is computed in 99,679 €/year, as shown in Table 11.

[23] Simulations in other CoordiNet task are estimating these values though, in particular Task 6.4, in which the scalability and replicability of sultions is being tested.

Table 11: Annuity of the BaU scenario for ES-1a in Cadiz

Business as Usual Scenario	
Reinforcement cost	€1,582,800
WACC	5.58%
Asset Life	40 years
Annuity	**99,679 €/y**

Considering the KPIs 2, 4 and 5, it is possible to calculate the average annual cost for the R&I solution according to the assumptions used in the D3.4. Note that (i) O&M per year is taken directly from KPI_4, that (ii) the flexibility cost per year is a direct summation of KPI_5 (Table 76 from D3.4), and that (iii) the annuity of the R&I CAPEX considers the CAPEX from KPI_2, a WACC of 5.58% and an asset life of 12 years[24].

Table 12: Anual cost of the R&I scenario for ES-1a in Cadiz

R&I Solution	
O&M per year	28,650 €/y
Flexibility Cost / Year	59,506 €/y
Annuity CAPEX R&I	10,424 €/y
Total per year	**98,580 €/y**

A comparison between the annual values of the R&I solution and the BaU solution under the KPIs calculated and reported in D3.4 suggest that the R&I solution is slightly more beneficial, as R&I – BaU = 1,099 €/year. This result, however, embeds assumptions made during the calculation of the KPIs. To assess the impact of these assumptions, they can be then subject to sensitivity analyses to understand which scenarios could make the R&I economically more efficient and the opposite. This exercise is done in Table 12 as it presents a sensitivity over the average price of flexibility and the average energy per activation.

Note that the average cost for flexibility (9.97 €/MWh) for the base case is obtained directly from KPI_6, as the weighted average of the units, considering their redispatched energy. The base case numbers are marked as * in Table 12. Similarly, the average energy per activation of the base case (75MWh) is obtained by dividing the total energy redispatched (summation in KPI_5) by 80, which is an assumption made on the number of activations required in a year for the ES-1a[25].

Table 12 shows that for a wide range of scenarios, the R&I would be economically more interesting than the BaU solution. The base case is slightly positive, as mentioned above. However, a scenario that considers an average of 10 MWh of average energy activated per congestion event (marked as ** in Table 12) is significantly more beneficial, considering the average price of 9.97 €/MWh and the 80 activations per year. These parameters are chosen in reference to the test “CADIZ - CCM CASE 1”, described in D3.4, in which the FSPs were required to reduce 10.5 MW for one hour. In other tests, reductions are even lower, suggesting the average flexibility activation per congestion event could be lower.

[24] According to the Spanish regulation [21], software would have an asset life of 5, while smart grid components of 12 and metering infrastructure of 15 years. In this exemples the value of 12 is chosen as a simplification, considering that the ICT involved would be a mix among the different types of assets.
[25] The assumption of 80 activations per year is made by the DSO i-DE, and not e-DI, to which the Cadiz network belongs. Nevertheless, this number is used as a starting point for the sensitivity analysis.

On the other hand, some scenarios in which the average price of flexibility is higher than the initial assumptions make the R&I less beneficial than the BaU. This could indicate that under certain market conditions (e.g. different types of FSPs with different costs or bidding strategies) this could jeopardise the efficiency of R&I solution.

Table 12 below presents the results for the sensitivity exercise. The results shown are for the “R&I – BaU” comparison. Green cells (and therefore positive results) indicate a scenario in which the R&I is more beneficial than the BaU one. A red cell (negative results) expresses the opposite.

Table 13: Sensitivity over the average price of flexibility and the average energy per activation. Results in €/year for the R&I - BaU.

Results show the “R&I minus BaU” comparison in €/year.		*Average flexibility price (€/MWh)*							
		5	**9.97***	15	20	30	40	50	70
Energy per activation (in MWh)	**10****	56,605	**52,632**	48,605	44,605	36,605	28,605	20,605	4,605
	20	52,605	44,658	36,605	28,605	12,605	-3,395	-19,395	-51,395
	30	48,605	36,685	24,605	12,605	-11,395	-35,395	-59,395	-107,395
	40	44,605	28,712	12,605	-3,395	-35,395	-67,395	-99,395	-163,395
	50	40,605	20,738	605	-19,395	-59,395	-99,395	-139,395	-219,395
	60	36,605	12,765	-11,395	-35,395	-83,395	-131,395	-179,395	-275,395
	70	32,605	4,792	-23,395	-51,395	-107,395	-163,395	-219,395	-331,395
	75*	30,753	**1,099**	-28,952	-58,805	-118,510	-178,215	-237,920	-357,330
	80	28,605	-3,182	-35,395	-67,395	-131,395	-195,395	-259,395	-387,395
	90	24,605	-11,155	-47,395	-83,395	-155,395	-227,395	-299,395	-443,395

This analysis aims solely to illustrate that the economic KPIs already calculated for Demo Run One can already be used to preliminarily assess the economic viability of the R&I solutions being tested. For the completeness of the analysis, assumptions would have to be checked and other parameters added to the computations. In fact, such analyses are being done in other WPs of the CoordiNet project. For example, Deliverable D6.4 investigates the scalability and replicability aspects of the different BUCs, shedding light on the question abovementioned (e.g. how the different types of FSPs may change the results BUC for the different actors).

Another lesson learned is that a KPI calculating the benefit of the solution proposed against the BaU of the innovation project could be added, even if assumptions have to be made. Such KPI could be adopted in future R&I projects.

4.3.3. Technical KPIs

As shown in Figure 28, most of the KPIs calculated by the Spanish demonstration are associated with technical aspects of the solutions proposed. This is also in line with the focus of the tests conducted within Demo Run One, which prioritised the communication, activation and monitoring of the flexibility for the different BUCs. From the 17 technical KPIs, five are BUC-specific, including ES-2 and ES-4.

The balancing BUC ES-2 has one specific KPI, namely KPI_21, which calculates the deviations in mFRR markets caused by flexibility modelling errors and/or flexibility forecasting errors. Considering that the activations were made in the environment test, the values for this KPI considered the actual deviations in mFRR of the different FSPs. Although these values may not capture the effects of the complete ES-2 implementation, they signal that deviations (mostly positive) do exist for wind farms. Such deviations should be considered, especially by DSOs, when considering the implementation of flexibility mechanisms for congestion management.

The BUC ES-4 – controlled islanding – has four KPIs exclusively calculated for this BUC. The KPIs 14 and 32 present the duration of the islanding and the delivered energy, respectively. These two KPIs present the fulfilment of the islanding energy needs in terms of duration and volume. With regards to the former, the islanding achieved the totality of the requested duration in the different tests (both programmed and outage cases). With regards to the energy provided, the whole electrical island could be maintained by the FSPs, namely a PV generator and a battery. It is worth mentioning that the battery played the crucial role of balancing the energy locally, maintaining stability within the island. The tests of BUC ES-4 demonstrated the technical feasibility of the islanding mode, maintaining the supply within technical limits, and ultimately providing maximum power in the controlled island of 945 kW [*KPI_33 – Maximum power (non-transient) in controlled island*], which represents 77% of the peak demand of the grid considered.

The KPI_15 calculated the TIEPI indicator for the islanding BUC in 0.10835 minutes, meaning that, under a real use, the islanding operation would have avoided an impact in the DSO's TIEPI of approximately 0.11 minutes. The TIEPI is an indicator of continuity of supply. It is an acronym in Spanish: *Tiempo de Interrupción Equivalente de la Potencia Instalada*. It is in practice similar to the Average System Interruption Duration Index (ASIDI) defined by the IEEE standard 1366-2003, although instead of using the kVA served, the MV/LV transformation capacity and the power contracted by MV consumers are considered as weighting factors. Thus, any fault affecting the LV grid exclusively would not be included in these reliability indicators.

Besides being a technical indicator of continuity of supply, the TIEPI also has economic implications. The DSOs in Spain are subject to an economic incentive mechanism over the TIEPI and the NIEPI[26]. These indicators are calculated separately every year for four different types of areas: urban, semi-urban, concentrated rural and scattered rural. The incentive is a symmetric bonus/malus scheme. The total annual incentive/penalty for a DSO i is capped to +2%/-3% of the base DSO remuneration (without incentives) in the previous year. Therefore, KPI_15 is also useful as an input for a potential CBA of the ES-4.

Among the remaining technical KPIs calculated, 12 of them are not BUC-specific, although some are calculated only to two BUCs, and others apply to all three BUCs tested in the Demo Run One. Among those, four KPIs are devoted to verifying the forecasting error of both load and RES production.

Four different KPIs are devoted to the calculation of RES and load forecasting errors for two forecasting horizons, namely 24h and 1h in advance. With regards to the RES forecasting, almost all FSPs considered are wind farms, except for a cogeneration unit in Murcia. The individual forecasting results are in line with the typical range of forecast accuracy for individual wind farms, as illustrated in Figure 30[27].

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[26] *Número de Interrupciones Equivalente de la Potencia Instalada:* The NIEPI measures the frequency of interruptions, similary to the ASIFI defined by the IEEE standard 1366-2003.

[27] The source of the figure is that from 2009 and therefore the current state-of-the-art reference values could be different. Additionally, the typical range shown is generalized, and does not take into account the location of the wind farms.

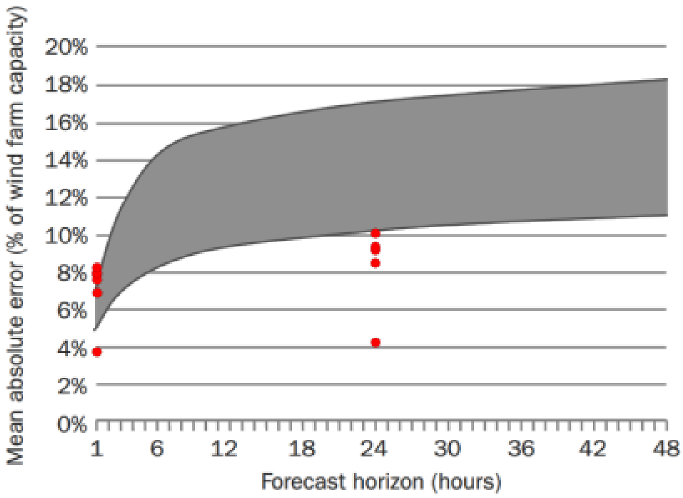

Figure 30: Typical range of forecast accuracy for individual wind farms and individual FSPs in Demo Run One (in red). Source: Adapted from [22].

With regards to the demand forecasting [KPIs 24 and 25], outliers were observed in both the 24h and 1h in advance forecasts for the DSO. The detailing of these deviations is presented in Deliverable 3.3 [15]. However, excluding the outliers, the Mean Absolute Percentage Error of both day-ahead and intraday load forecasting is considered appropriate, at 9.45% and 3.73%, respectively.

The KPI_7 [*Increase RES and DER hosting capacity*] aims at calculating if the R&I solution proposed by the demonstration could lead to an increase in hosting capacity for RES and DER. However, it was observed the hosting capacity for the considered buses has already reached its limits, considering that it is calculated based not only on the steady-state capacity but also dynamic capacity and short circuit level. This shows some limitations to consider flexibility usage in the increase of hosting capacity. The hosting capacity calculation is precisely defined in the Spanish regulation, and the three criteria defined (steady-state, dynamic capacity and short-circuit level) do not foresee the consideration of flexibility. In this sense, this KPI also points to a potential regulatory barrier, as flexibility solutions cannot be considered in the hosting capacity calculations considering the current procedures.

The KPI_16 [*Potential offered flexibility*] calculates the potential flexibility available to the SOs in the different BUCs. For this KPI, data from the actual congestion management and the balancing markets are used. The FSPs considered (mostly wind power plants) could potentially offer all their downward capability to flexibility mechanisms together with the existing congestion management markets. In balancing markets, these units also participate in such a way that the potential flexibility can also be verified. Similarly, the requested flexibility in KPI_22 and the total activation time in KPI_31 also consider the flexibility from the actual markets (congestion management and balancing). The fact that this data can already be gathered from the actual markets is since Demo Run One focused on the demo areas of high-voltage networks managed by the DSO. In these networks, the connected FSPs are already participating in the TSO markets.

The KPI_13's objective was to calculate the reduction in criticalities in terms of overvoltage and overcurrent. For this KPI, the Spanish demo partners verified what was the historical number of criticalities observed in the demo networks and estimated what the CoordiNet solutions could contribute to their reduction. It was estimated the BUCs developed and tested in Demo Run One could reduce the number of criticalities in the distribution networks by 20%. One challenge regarding the calculation of this KPI is the need for data over a longer period (one year at least), which surpasses the period of demonstration. Therefore, an estimation was needed based on a reduced period of the demonstration testing.

From the perspective of the number of products in the demo, all products originally foreseen were finally tested [*KPI_34 - Percentage of tested products per demo*]. Nevertheless, some considerations should be made. In terms of balancing, it is worth mentioning that tests were made in the CoordiNet Common Platform 'testing environment', as not to endanger the security of supply. These results can be considered valid for both mFRR and RR products. Similarly, the black start product was tested in a controlled environment, as no actual outages occurred in the period of demonstration.

4.3.4. Social and Environmental KPIs

Four different KPIs are devoted to social and environmental aspects of the demonstration, three being related to the former and one to the latter. The environmental KPI_8 computes the reduction of RES curtailment due to the implementation of the R&I solutions. For this KPI, a similar approach to KPI_13 [*Criticalities Reduction Index*] was adopted. Firstly, the past RES curtailment for the demo areas was observed. Secondly, an estimation was made for what would be the reduction, considering the tools and solutions developed in the project. Also, similarly to KPI_13, KPI_8 [*Reduction in RES curtailment*] would require a longer sample of observations from the R&I solution to calculate the actual reduction in RES curtailment.

The three social KPIs in Demo Run One aim at calculating the (i) increase in the amount of load capacity participating in demand response (DR) [*KPI_17 - Increase in the amount of load capacity participating in DR*], the (ii) participant recruitment [*KPI_36 - Participant recruitment*], and (iv) active participation of FSPs [*KPI_37 - Active participation*]. With regards to the increase of the amount of DR capacity, it is worth mentioning that for the two DSOs, no previous demand response existed before the CoordiNet project in the demo areas considered. The KPIs 36 and 37 calculated the total of customers that first accepted to participate in the demo [KPI_36] and from those, the ones that actively participated in the demonstration [KPI_37]. For the computation of these KPIs, it is possible to observe that some difficulty exists in the engagement of customers, as not all contacted FSPs accepted to participate, and not all participants actively contributed to the demonstration. Together with KPI_38 [*Type of flexibility providers per demo*], these KPIs quantify the challenges in terms of customer recruitment described in section 2.2.1.2.

4.3.5. Lessons learned

Based on the assessment above, several lessons learned can be identified. These lessons learned could serve to both KPI calculations in Demo Run Two, as well as for when defining KPIs in future R&I projects.

- Several KPIs would benefit from a larger sample, specifically from a longer period of observations. Several economic and technical KPIs had to rely on the best assumptions made by the demonstration partners as not enough data was available. This potentially reduces the accuracy of the computed KPIs. In future projects, a longer period of demonstration could be considered. Alternatively, and possible more realistically, KPI formulas for those KPIs that require annual values should also propose how the demo data can be extrapolated to allow for the KPI calculation.
- When designing KPIs, it is important to consider that some products or services can only be tested in controlled or simulated environments. For instance, congestions or a complete outage (in the case of islanding) may not be expected in reality and therefore have to be simulated. Similarly, balancing services have to be tested in a controlled "testing environment", as failing in providing these services could compromise the security of supply.
- With regards to economic KPIs, several of them compute CAPEX and OPEX items of the demonstration and compare them with the BaU solutions. The preliminary analysis illustrated that a KPI integrating this economic information could be possible, reaching a preliminary CBA of the demonstration. Nevertheless, such calculations, if adopted in future projects, should be considered as a preliminary assessment to be enhanced and confirmed by other research activities in the R&I project.

- Some of the BUC-specific KPIs shed light on challenges and opportunities for the different BUCs tested in the demonstration. For example, the BUC ES-4 had four BUC-specific KPIs, which allowed for important findings concerning that product (e.g. the participation of batteries are crucial to offering “local balancing” during islanding). In future projects, more BUC-specific KPIs could be foreseen, aiming at capturing particularities in the products and services tested.
- For one KPI, a potential regulatory barrier was found for its calculation. More specifically, the Spanish regulation that sets the methodology for the calculation of hosting capacity does not consider flexibility mechanisms. A theoretical calculation of hosting capacity increase could be possible. This could also lead to a regulatory proposal on how the current hosting capacity methodology could be adapted to incorporate the benefits from flexibility solutions.
- In general, a large proportion of KPIs are technical and economical, and a minority is environmental or social. Although this is in line with the scope of the demonstration, a higher number of social KPIs could help understand and quantify challenges in terms of customer engagement. KPIs based on surveys with participants could be an alternative to enhance visibility over difficulties in engaging active participants to the demonstration.

5. Conclusions

In this deliverable, challenges and opportunities identified in Demo Run One of the Spanish demonstration campaign are reported and discussed. Moreover, a preliminary evaluation of the demonstration is also done based on the KPIs calculated in Demo Run One and ex-post interviews with the demonstration partners.

Several challenges were observed by the SOs in the implementation of the originally designed BUCs. These challenges unveil the need for further research on aspects that are important not only for the Spanish demonstration but for the overall TSO-DSO coordination in Europe. For instance, some challenges related to **market design** could be observed. When demonstrating the limitation of FSPs by DSOs in the balancing markets (BUC ES-2), the TSO and the DSOs could establish and demonstrate the appropriate coordination mechanisms for the products being operated nationally (mFRR). However, when considering the same for the cross-border RR product (through the TERRE platform), incompatibilities were observed. In this particular case, it was observed that the use of FSPs connected at the distribution grid for cross-border balancing products could pose more challenges than the nationally defined ones.

The **technical implementation** also presented challenges to the SOs involved in the implementation of the demonstration. For instance, the deployment and integration of the Energy Box showed that there is a lack of standards about flexibility systems for sFSPs. Another example was the lack of a communication protocol for the communication of reactive power and voltage setpoints between the different BUC participants. Although such deployments are expected to be partially done in the context of other emerging businesses (e.g. aggregators, virtual power plants etc.), it is a significant challenge for SOs in the context of R&I projects. From the perspective of future flexibility use, it also points to the need of creating interoperable solutions, facilitating the development of software and hardware tools. In this context, the Spanish demo already provided solutions that could be adopted in the future, such as the implementation of ICCP in the context of voltage control.

This deliverable also discussed the **stakeholder interactions** among partners and FSPs. An ex-post consultation with the demo partners revealed that the interaction among stakeholders was fruitful and that parties are aligned in their view of the future use of local flexibility and the need for enhanced coordination. Based on the results obtained and the interviews conducted, it is possible to conclude that the interaction among the three SOs was very positive, leading to the desired coordination, particularly in terms of platform implementation, integration and real-time activation of distributed flexibility. It also showed that the FSPs that agreed to participate in the demonstration were also aligned with the objectives of the project and interested in the solutions developed. Nevertheless, the **customer recruitment process** proved to be difficult. From the different types of potential FSPs contacted, the ones that accepted to participate were mostly distributed generation. These FSPs are already familiarized with electricity markets and have their main business in electricity. The other types that refused to participate often mention two main reasons. Firstly, the lack of economic incentives, considering the context of the R&I project. Secondly, the provision of flexibility could jeopardize their main economic activities, and therefore they could not provide flexibility. The former can be seen as a direct challenge to R&I projects that show limited attractiveness to potential participants. In the Spanish demo, however, this was partially mitigated by the use of the Cascading Funds. The latter sheds light on the difficulty in engaging potential FSPs other than the ones already involved in electricity markets. While it is possible that some industries are inflexible demands, others could be engaged with economic incentives, aid from new businesses and enhanced information on the possibilities of flexibility provision. These conclusions were also identified in the interviews conducted with the project stakeholders and discussed in section 4.2.

Finally, this deliverable also analysed the KPIs calculated and discussed the interactions and data exchange between Demo Run One and other Work Packages within the CoordiNet project. The analysis of the KPIs allowed for the identification of several proposals, mostly for future R&I projects, considering that the definition of KPIs for Demo Run Two are already complete and data collection is happening at the time of writing. The KPIs and other conclusions produced by Demo Run One will also be used in different activities within the CoordiNet project. Firstly, it provides real-world data that can be used as the base case for both qualitative and qualitative studies (e.g. the CBA in T6.3). Secondly, it reveals the main challenges faced by the demo, which can be helpful in defining simulation scenarios (e.g. in T6.4) or initial hypotheses in the case of customer engagement for further investigation (T6.6). Finally, the KPIs and conclusions from Demo Run One will also be integrated into the overall analysis of the CoordiNet demonstrations (T6.1).

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