Demo results assessment and data collection report

Portugal

D9.5

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Dissemination Level	Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Issue Record

Planned delivery date	30/9/2023
Actual date of delivery	31/1/2024
Version	V1.0

Version	Date	Author(s)	Notes
0.0	2022-09-23	REN	First ToC outline
0.1	2022-10-10	NESTER	Align with D9.6 and D9.7
0.2	2022-10-20	NESTER	Refinement of the ToC
0.3	2024-01-12	REN, E-REDES, NESTER, INESC-TEC	Full draft version
0.4	2022-09-23	REN	First ToC outline

About OneNet

The project OneNet (One Network for Europe) will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

OneNet is funded through the EU's eighth Framework Programme Horizon 2020, "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future".

As the electrical grid moves from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. The project brings together a consortium of over seventy partners, including key IT players, leading research institutions and the two most relevant associations for grid operators.

The key elements of the project are:

- Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
- Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
- Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
API	Application Programming Interface
ASM	Active System Management
AWS	Amazon Web Services
BUC	Business Use Case
DDEP	DSO's Data Exchange Platform
DEP	Data Exchange Platform
DPlan	E-Redes operational planning tool
DSO	Distribution System Operator
EHV	Extra High Voltage
EVs	Electric Vehicles
FSP	Flexibility Service Provider
GUI	Graphical User Interface
HV	High Voltage
ICT	Information and Communication Technologies
IT	Information Technology
JRC	Joint Research Centre
KPI	Key Performance Indicator
MV	Medium Voltage
MW	Megawatt
NATS	Connective Technology for Adaptive Edge & Distributed Systems
NECP	National Energy and Climate Plan
NTS	National Transmission System
PDIRD	National Electricity Distribution Network Development and Investment Plan
PDIRT	National Electricity Transmission Network Development and Investment Plan
PREDIS	Generation and consumption forecasts DSO tool
PSS/E	Power System Simulator for Engineering
PV	Photovoltaics
RES	Renewable Energy Sources
RESP	Public Service Electricity Network
RMSA	Security of Supply Monitoring Report for the National Electric System
RND	National Electricity Distribution Network
RNT	National Transmission Network
RRT	Transmission Network Regulation
SOs	System Operators
SPUs	Small Production Units

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SUC	System Use case
TDEP	TSO’s Data Exchange Platform
TSO	Transmission Distribution Operator
UC	Use Case
TYNDP	The 10-year network development plan
VAR	Voltage Ampere Reactive
WECL	Western Cluster
WP	Work Package

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Executive Summary

This deliverable presents the assessment of the demonstration results and reports the data collection of the Portuguese demonstrator implementation. It also provides a set of recommendations and evaluation of the achievements regarding the prequalification and flexibility forecast procedures/framework, operational planning activities and development of communication infrastructure within the Portuguese demonstrations carried out in OneNet project.

The Portuguese demonstrator has focused on providing developments and contributions concerning the definition of flexibility products, namely the information exchange between transmission system operators (TSOs), distribution system operators (DSOs) and Aggregators (of supermarkets) regarding congestion management services and concerning operational planning activities with respect to maintenance plans, load and generation forecast and TSO/DSO short-circuit currents. All the information exchanged between the involved partners resorted to dedicated cloud-based data exchange platforms (DEPs) created in the scope of the project. In parallel the usage of the OneNet Connector solution to exchange flexibility needs and offers between TSO and Aggregator was also tested.

Throughout the demonstrator, some significant challenges were encountered. The lack of participation from Flexibility Service Providers (FSPs) limited the number of real consumers' data, impacting the quality of the flexibility potential assessment, particularly for critical sectors such as supermarkets and industrial consumers. This fact has a reasonable explanation in the lack of consumer awareness that still exists in Portugal in which the flexibility concept and how consumers can actively contribute to the energy system is still an area under development. Another challenge worthy to highlight is related with data quality concerns during the demonstrator wherein some demo sites there were substantial variances between DSO and TSO forecasts and considerable discrepancies between some grid models and reality, spotlighting the need for enhanced coordination between operators and in defining common observability areas. Regarding the integration with the OneNet system the cybersecurity requirements of the OneNet Connector led to implementation challenges for regulated entities like TSOs and DSOs.

Finally, the achievements, learnings and impact of the Portuguese demonstrator can be summarized in three domains:

- New tools and methodologies:
    - Data Exchange Platforms Proficient Operation through the implemented DEPs ensuring effective bidirectional data transmission across various use cases, facilitating coordination and integration with existing internal systems and tools.
    - Successful Integration of OneNet Connector enabling efficient information exchange regarding flexibility needs and potentials between the TSO and the Aggregator. The challenges

regarding the connector requirements were surpassed resorting to dedicated cloud-serves off premises in the TSO case.

- Flexibility estimation methodology defined in which the Aggregator developed a tool that allows the identification of the foreseen flexibility potential of one or more FSP. From the results of the demonstrator a total average value around 70kW of available flexibility during flexible hours, for supermarkets can be expected. From the TSO side, also a flexibility needs and FSP provision simulation tool was developed and evaluates the flexibility requirements of any network and offers FSPs optimal flexibility dispatch solutions to address potential network constraints.

- Improvement of technical TSO-DSO coordination:
    - Facilitate the coordination regarding maintenance plans due to the successful exchange of annual and monthly/weekly maintenance plans and updates via the DEP.
    - Enhancement of load and generation forecast is shown in the demonstrator. It shows the importance and improvement of the load and different type of generation forecast through the jointly assessment between TSO/DSO of their individual forecasts.
    - Improvement of short-circuit forecast in TSO/DSO interface. The coordination process implemented to the exchange of the short-circuit currents between system operators was successfully tested and the results highlight the importance of joint contributions assessment for optimizing grid asset planning and enhancing operational activities.
- Consumer engagement:
    - Organization of a workshop to increase consumer awareness regarding flexibility provision processes: Enhanced understanding among more than 60 participants, representing various stakeholders, regarding the process, benefits, and participation in upcoming flexibility markets.

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1. Introduction

Europe's electricity landscape is transforming significantly. It is moving from a traditional, centralized model to a more distributed and connected framework. This emerging setup is characterized by a substantial amount of variable electricity generation and a greater role for consumer participation. This evolution necessitates changes in how network management is approached, especially in terms of enhanced collaboration between TSOs and DSOs to ensure the system's efficient functioning.

A key aspect of this transformation involves improving the ways in which SOs exchange information. This step is vital for boosting the network's efficiency, dependability, and its capacity to integrate a larger share of renewable energy sources. A tangible instance of such initiatives is the OneNet Portuguese demonstrator that focuses on establishing a novel data sharing mechanism between the Portuguese TSO and DSO, aiming to optimize network planning and operations, and which results are documented and analysed in the present document.

1.1. Task 9.2

This deliverable presents the results of the Portuguese demonstration of the OneNet project that fits within the Work Package (WP) 9, that includes the demonstrators of the Western Cluster (Portugal, Spain, France). WP9 is segmented into six different tasks:

- Task 9.1, that established the initial alignment and set-up of the three demonstrators of the Western Cluster.
- Task 9.2, Task 9.3 and Task 9.4 that focus on the demo implementation for the Portuguese, Spanish and French demos, respectively.
- Task 9.5 that focused on the generic analysis and comparison of results from the demos within the Western Cluster, including the success metric analysis.
- Task 9.6 identified the main lessons learnt and performed the scalability and replicability analysis of the demo solutions.

This document is the last of two deliverables of Task 9.2, related to the Portuguese demonstration. The task is divided into three different sub-tasks, concerning the set-up, alignment and integration of solutions (Sub-Task 9.2.1); the demonstration and test (Sub-Task 9.2.2) and the data collection (Sub-Task 9.2.3), with this deliverable addressing the last two. Under the second sub-task are the actual demonstration activities, namely concerning the exchange of the data related to flexibility provision and for operational planning purposes between the TSO and DSO, by resorting to both DEPs deployed. The demonstration was divided into two different phases, a first phase that occurred in August 2023, and a second in end of November and mid December 2023. The decision to carry out two demonstration phases resulted not only from the need to optimize the results gathered using the tools in development, but also to have a bigger sample of results, with more locations addressed. That being

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said, the first demonstration phase was carried out for all the SUCs (SUC01, SUC02, SUC06, SUC07, SUC08), addressing two substations (Pocinho and Batalha), while the second demonstration phase was carried out for the SUCs 07 and 08 for five substations (Pocinho, Batalha, Zêzere, Portimão and Mourisca), since these were the SUCs that could be improved through the use of operational planning tools that were still under finalization during the first demo phase. The second demonstration phase also allowed to complement the results from SUC02, for which no current needs were identified, and to present an analysis of the future needs for the DSO and TSO aligned with the main trends and targets for the electricity sector in Portugal.

The third and last sub-task relates to the computation of the Key Performance Indicators (KPIs) for both demonstration phases, which were previously defined within Task 2.4 of OneNet, and does the compilation and analysis of these KPIs, allowing the results to be compared to the objectives of the Portuguese demonstration. This sub-task is complemented with other tasks within the OneNet project both internal and external to the WP9.Whereas this sub-task focuses on the KPI results for the Portuguese demo, these results are then used and analyzed from the perspective of the entire Western Cluster within the Tasks 9.5 and 9.6. An even wider analysis is done within Task 11.1, that captures the KPI results from all the clusters within OneNet. The remaining tasks within WP11 also make use of the results captured within the demonstration, either for Scalability and Replicability Analysis purposes (T11.4), for Business Model analysis (T11.5) or to gather general learnings for recommendations the work developed under the remaining tasks.

Task 9.2 is also related to Task 2.3 and Task 5.1, since it demonstrates the Business Use Cases (BUCs) and SUCs described in both tasks, respectively. Apart from this, the main recommendations from Task 3.1 and WP4 were also considered in the solutions developed.

Lastly the Portuguese demonstration also makes use of the OneNet Connector within SUC02, using it as an alternative means to exchange data between the TSO and the Aggregator on the flexibility offers, linking this task with the WP6 developments.

Figure 1.1 portrays these interactions, both within and outside WP9.

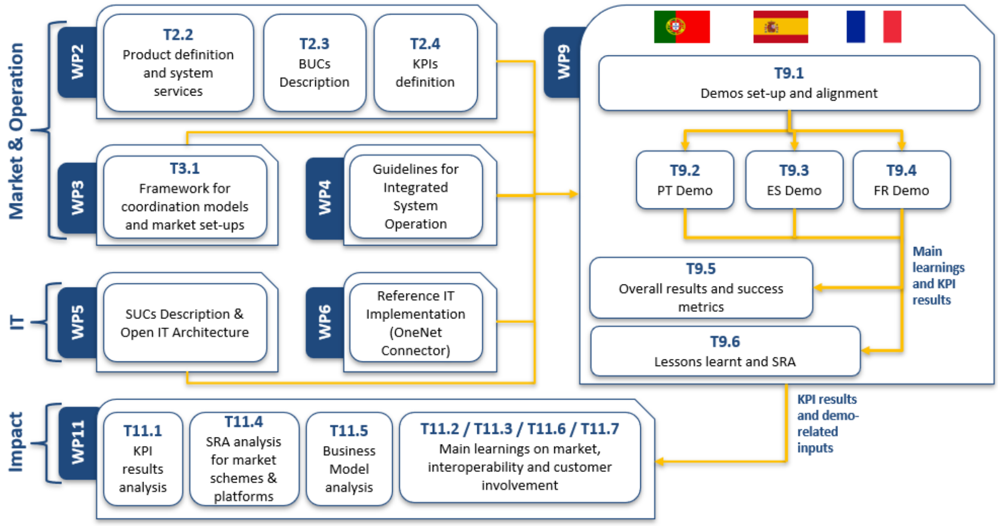

Figure 1.1 - Interconnection between the OneNet Task 9.2 with other tasks and work packages in the OneNet project.

1.2. Outline of the Deliverable

The structure of the deliverable is presented in Figure 1.2. Chapter 1 is the introductory section of the document, including the objectives and the context of the activities carried out in Task 9.2, also describing the role of the task within the major structure of the OneNet project and of WP9. Chapter 2 presents a summary of the BUCs and SUCs analyzed and tested within the Portuguese demonstration as well as the description of the KPIs used to evaluate the demo, including both: (1) demo level KPIs, that are specifically framed to fit the objectives of the demo; and (2) common KPIs, that are common to several OneNet demonstrators and that allow a comparison between them.

Chapter 3 presents the description of the demonstration environment, namely the architecture of the DEPs and a generic description of the backend and frontend for the TSO, DSO and Aggregator, including the main interactions that exist between the different components within the DEPs architecture, as well as tools and methodologies developed to deliver the results of the SUCs. Chapter 4 presents the evaluation of the demonstrators, including a description and main characteristics of the demo sites selected and the methodology, input data, samples of the results and the analysis of KPI results for each SUC. Chapter 5 describes the main achievements and challenges faced both within the developments and during the two demonstration phases, including an identification of the main actions adopted for mitigation purposes. Lastly, both the main conclusions and the expected actions to be taken for exploitation of the results are presented in Chapter 6, giving the TSO and DSO perspective of the demo performed.

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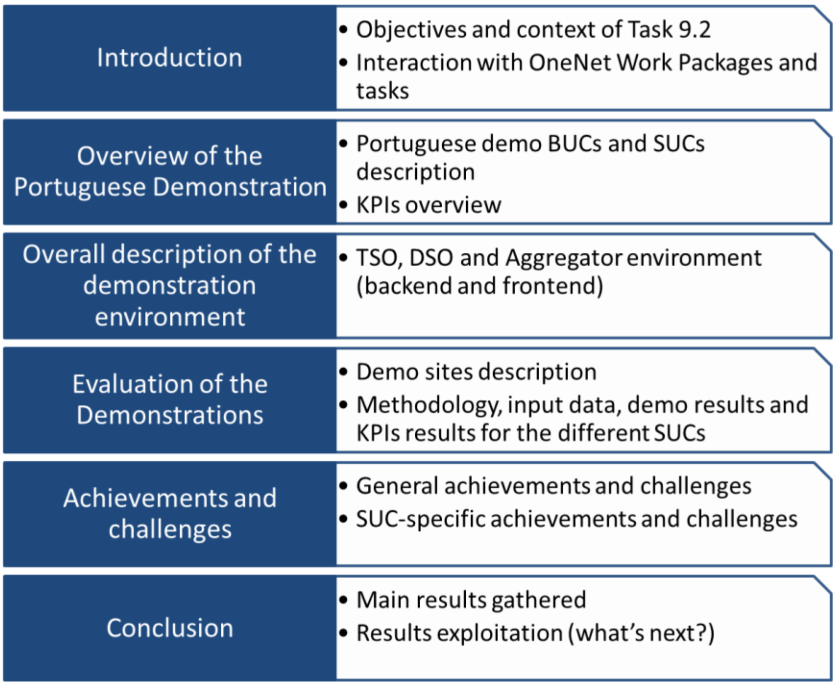

Figure 1.2 - Outline of OneNet Deliverable 9.5.

1.3. How to read this document

This document should be read together with D9.2 [1], as both address different stages of the demonstration. Namely, D9.2 describes the detail behind the DEPs architecture, together with the API specification and the processes behind each SUC. D9.2 also delivers on preliminary demonstration results, that give an initial glance to the potential outcomes of the demonstration and provides a description of the KPIs that were used to evaluate the demonstration. D9.5's essential goal is to present the final results of the demonstration, having all the developments been realized, analyzing the KPIs and the demonstration and to present the key learnings gathered from the demonstration. The results presented within this document are also further analyzed and compared throughout different demos within OneNet in D9.8 [2], D9.9 [3] and D11.1 [4].

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2. Overview of Portuguese Demonstration

The primary objective of the OneNet Portuguese demonstrator is to formulate solutions for the flexibility provision, focusing on the FSP pre-qualification and forecast phases, and to create operational planning synergies between TSO and DSO. This demonstrator involved the collaboration of the Portuguese TSO (REN), Portuguese DSO (E-REDES) and two Portuguese R&D research centers (R&D NESTER and INESC TEC). R&D NESTER and REN, play jointly the TSO role during the demonstrations, while INESC-TEC plays the role of Aggregator. Five different use cases were demonstrated, two of them related with the flexibility provision and the other three associated with the operational planning activities. The UCs encompass 4 distinct areas for testing, one in the Northeast of Portugal (Pocinho), one in Coastal Beira of Portugal (Mourisca), two in the center of Portugal (Zêzere and Batalha) and also one in the South of Portugal (Portimão). The demonstration involves FSPs data, namely supermarkets and industrial consumers, and real data from the planning departments of the Portuguese SOs.

The Table 2.1 shows the overview of the Portuguese demonstrator, including the domain of the UCs, the services considered, the products, BUCs and SUCs. The demonstrator aims also to provide solutions for predictive congestion management. For predictive congestion management, long-term and short-term solutions are envisioned. For operational planning purposes it was addressed the short and long-term horizons, although with more focus in the day-ahead operations.

Table 2.1 - Overview of the Portuguese demonstration

<table>
<tr><th>Domain</th><th>Service</th><th>Product</th><th>BUC</th><th>SUC</th></tr>
<tr><td rowspan="3">Flexibility</td><td rowspan="3">Predictive active power for congestion management</td><td rowspan="2">Predictive short-term local active</td><td rowspan="2">WECL-PT-01: Exchange of Information for Congestion Management – Short Term</td><td>SUC-PT-01: Evaluation of the Product & Grid pre-qualification requirements</td></tr>
<tr><td>SUC-PT-02: Day-Ahead & Intraday Flexibility needs</td></tr>
<tr><td>Predictive long-term local active</td><td>WECL-PT-02: Exchange of Information for Congestion Management – Long Term</td><td>SUC-PT-01: Evaluation of the Product & Grid pre-qualification requirements</td></tr>
<tr><td rowspan="3">Operational planning</td><td colspan="2" rowspan="3">Short Term and Long-Term information exchange</td><td rowspan="3">WECL-PT-03: Exchange of Information for Operational Planning</td><td>SUC-PT-06: Maintenance plans information exchange</td></tr>
<tr><td>SUC-PT-07: Consumption and generation forecast information exchange</td></tr>
<tr><td>SUC-PT-08: Short-circuit levels information exchange</td></tr>
</table>

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2.1. Portuguese Demo Business Use Cases (BUCs)

As described in D9.1 [5] and D9.2 [1], the Portuguese demonstrator specifies the exchanges of information between SOs to enable flexibility provision and to improve the operational planning activities. For the BUCs concerning flexibility, the Active System Management (ASM) report [6] stages were considered, namely, the necessary steps in defining the process upon which TSO and DSO should coordinate. Given that the goal is to focus on the information exchange, all the stages, except for the settlement process, were considered. For the BUC concerning operational planning, the operational processes of the SOs that can be improved with the exchange of information between network operations are taken into account.

2.1.1. WECL-PT-01 - Exchange of Information for Congestion Management – Short Term

This BUC focuses on describing in detail each process phase of the ASM report, mentioning what kind of information shall be exchanged and what rules shall be established between the DSO and TSO in order to procure congestion management products for short-term, in intraday and day-ahead time periods.

The main objectives of this BUC are to:

1.1 Design the process phases of the ASM report, so that it can serve as a basis for future developments.

2.1 Coordinate the usage of flexibility for different voltage levels.

3.1 Identify what information should be shared between DSO and TSO for each of the flexibility procurement process phases for short terms congestion management, including for the technical selection and validation of the bids by the relevant SO.

4.1 Construct information exchange mechanisms to enable market-based procurement of flexibility products.

2.1.2. WECL-PT-02 - Exchange of Information for Congestion Management – Long Term

This BUC focuses on describing in detail each process phase of the ASM report, mentioning what kind of information shall be exchanged and what rules shall be established between the DSO and TSO in order to procure congestion management products for long-term (more than 1 year time step).

The main objectives of this BUC are to:

1. Design the process phases of the ASM report, so that it can serve as a basis for future developments.
2. Coordinate the usage of flexibility for different voltage levels.
3. Identify what information should be shared between DSO and TSO for each of the flexibility procurement process phases for long term congestion management, including for the technical selection and validation of the bids by the relevant SO.
4. Construct information exchange mechanisms to enable market-based procurement of flexibility products.

2.1.3. WECL-PT-03 - Exchange of Information for Operational Planning

This BUC is centred at defining and describing the TSO and DSO information exchange, with the aim to improve and facilitate long-term to short-term operational planning for both networks.

The main goals of this BUC are to:

1. Identify the scheduled/forecasted information exchanged between the SOs, with the aim to improve the programming of the DSO and TSO operations.
2. Anticipate and solve constraints in the distribution and transmission grids.
3. Develop information exchange tools to share the identified information.

2.2. Portuguese Demo System Use Cases (SUCs)

For each of the BUCs described in chapter 2.1, more concrete SUCs were identified. Table 2.2 shows the designation of the SUCs considered for the Portuguese demonstrator and their correspondence with the respective BUC.

Table 2.2 - Summary of SUCs from the Portuguese demo and corresponding BUCs.

SUCs Nº	SUC Designation	Ref. BUC
SUC-PT-01	Evaluation of the Product & Grid pre-qualification requirements	WECL-PT-01 and WECL-PT-02
SUC-PT-02	Day-Ahead & Intraday Flexibility needs	WECL-PT-01
SUC-PT-03	Long-term Flexibility needs	WECL-PT-02
SUC-PT-04	Selection of Bids	WECL-PT-01 and WECL-PT-02
SUC-PT-05	Evaluate Grid Constrains	WECL-PT-01 and WECL-PT-02
SUC-PT-06	Maintenance plans information exchange	WECL-PT-03
SUC-PT-07	Consumption and generation forecast information exchange	WECL-PT-03
SUC-PT-08	Short-circuit levels information exchange	WECL-PT-03

Even though eight SUCs were identified in the Portuguese demonstrator, only five were tested, namely SUC01, SUC02, SUC06, SUC07, SUC08, being the ones addressed throughout the remainder of this deliverable. The choice of these SUCs took into account the ASM report phases related to Preparation/Pre-qualification and Planning/Forecast, leaving the Market Phase/Monitoring and Activation out of the scope of the Portuguese demonstrator. Note that at the initial stage of the SUC definition, the more specific development requirements were still to be specified, hence, a selection of the SUCs for the testing under the Portuguese demonstration was carried out, having a better knowledge of such requirements, aiming to optimise the result and quality of the demonstration. A more in-depth explanation on this selection process and on the SUCs analysed and tested under the Portuguese demonstration can be found in D9.2 [1].

The five SUCs in the scope of this deliverable are described below.

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2.2.1. SUC01 - Evaluation of the Product & Grid pre-qualification requirements

The interactions and actions of the DSO and TSO for prequalification purposes are described and tested in this SUC, including interactions between the two SOs and actions taken by each before the interaction point. This comprises identifying and exchanging the requirements for products (product prequalification), as well as conducting a grid impact assessment and analysing the results (grid prequalification). Further on, this SUC is referred to as SUC01.

2.2.2. SUC02 - Day-Ahead & Intraday Flexibility needs

This SUC focuses on the information sharing between the DSO and TSO addressing the requirements for short-term flexibility from both the SOs, including the steps taken by each to identify these requirements. This interaction seeks to stop future congestion caused by activating flexibilities to meet both SOs' needs. Under the terms of this SUC, two distinct methods are used to verify the communication between the two DEPs – TSO Data Exchange Platform (TDEP) and DSO Data Exchange Platform (DDEP): For the remaining SUCs, there are two options: 1) Directly through the APIs included into both platforms, which is the solution used for the remaining SUCs; or 2) Using the OneNet Connector for the exchange. Further on, this SUC is referred to as SUC02.

2.2.3. SUC06 - Maintenance plans information exchange

This SUC addresses the information exchange between the DSO and TSO concerning maintenance plans from both SOs in multiple time horizons. This includes not only the exchange of annual maintenance plans (long-term), but also the update and track record of the works closer to the real-time (medium-term to real-time). This SUC will further on be referred to as SUC06.

2.2.4. SUC07 - Consumption and generation forecast information exchange

This SUC focuses on the exchange of information between the DSO and TSO concerning consumption and generation forecasts computed at the TSO/DSO interface and disaggregated by technology type, including procedures taken to obtain these values. This interaction is expected to occur in day-ahead, in accordance with market clearing results. Further on, this SUC is named SUC07.

2.2.5. SUC08 - Short-circuit levels information exchange

This SUC is based on the information exchange between the DSO and TSO regarding short-circuit currents forecasts determined at the TSO/DSO interface, including the procedures used to compute these values, that may be used for operational planning purposes. Only the three-phase symmetrical short-circuit is under the scope of this SUC. Further on, this SUC is referred to as SUC08.

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2.3. KPIs overview

This chapter presents a summary of the KPIs that are used for the assessment of the Portuguese demonstration taking into account its scope and main objectives of the different BUCs and SUCs, which description was introduced in the previous sub-chapters. Common KPIs that are horizontal to several demos within OneNet are also presented within this chapter. A more detailed description of these KPIs can be found in Chapter A.1.

2.3.1. Demo KPIs

Table 2.3 presents a summary of the demo KPIs applicable to the Portuguese demonstration of OneNet.

Table 2.3 - Demo KPIs applicable to the Portuguese demonstration.

ID	Name	Description	Unit	BUC/SUC
KPI_H04	ICT costs	The term ICT cost comprises the communications and information technologies directly related to the implementation of the communication infrastructures between DSO and TSO.	k€	BUC01, BUC02, BUC03
KPI_N34	Successful ending of Prequalification Process	This indicator measures the percentage of prequalification processes that were successfully deployed from an ICT point of view.	%	SUC01
KPI_N46	Number of prequalification process that needs additional information	This indicator measures the percentage of prequalification processes that require additional information, considering all the fields considered in the data model.	%	SUC01
KPI_H05	Reduction in RES curtailment	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.	MWh	SUC02
KPI_H15A	Requested flexibility	This indicator measures the amount of flexibility requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio.	MW	SUC02
KPI_N27	Total power of avoided congestions through flexibility activation	The difference of the total amount of power of the congestions (overloaded elements) in the grid for all periods of observation between the scenarios without flexibility activation (before SUC implementation) and the ones with flexibility activation (after SUC implementation).	kW	SUC02
KPI_N31	Number of congestions/violations on DSO network	Anticipate distribution grids constraints because of scheduled maintenance actions. By exchanging information of maintenance works between the TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology	%	SUC06

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ID	Name	Description	Unit	BUC/SUC
		reconfiguration, flexibility activation or even maintenance works reschedule. This KPI will evaluate the effectiveness of this information exchange to avoid congestions.		
KPI_N32	Number of congestions/violations on TSO network	Anticipate transmission grids constraints because of scheduled maintenance actions. By exchanging information of maintenance works information between the TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works reschedule. This KPI will evaluate the effectiveness of this information exchange to avoid congestions.	%	SUC06
KPI_H20A	Error of the RES production forecast calculated 24 hours in advance	Evaluate the forecast quality after the information exchange between the DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.	%	SUC07
KPI_H20B	Error of load forecast calculated 24 hours in advance	Evaluate the forecast quality after the information exchange between the DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.	%	SUC07
KPI_H28	Maximum ratio of false-positive and negative congestion forecasts	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.	%	SUC07
KPI_H21B	Share of false positive and negative congestion forecasts	The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.	%	SUC07
KPI_N33	Improvement of the Forecast	This indicator measures the improvement of forecast value after the information exchange. The TSO currently has generation and load forecasts, and short circuit currents which include embedded generation for which it does not have visibility. With this information exchange the TSO has a better dataset as it is complemented with data from the DSO regarding the distribution grid outside of the TSO/DSO observability area. It is expected that these extra data contribute to a better forecast.	%	SUC07, SUC08
KPI_N25	Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value	Deviation between the maximum planning estimated value of Isc (short-circuit current) (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.	A	SUC08

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ID	Name	Description	Unit	BUC/SUC
	registered for the series under analysis			
KPI_N30	Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	Deviation between the maximum planning estimated value of Isc (short-circuit current) (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.	A	SUC08

2.3.2. Common KPIs

Table 2.4 presents a summary of the demo common KPIs applicable to the Portuguese demonstration of OneNet, which consist in KPIs designed by OneNet horizontal WPs to compare the performance across the different Cluster Demos in the project.

Table 2.4 - Demo KPIs applicable to the Portuguese demonstration.

ID	Name	Description	Unit	BUC/SUC
KPI_H01	Number of FSPs	This SUC aims to decrease the entry barriers for flexibility provision by simplifying the process for FSPs. Overall progress of this aim can be measured by the number of FSPs considered and involved in the demo for testing the prequalification interactions.	-	SUC01, SUC02
KPI_H02	Active Participation	This indicator measures the percentage of customers actively participating in the demo, meaning, the ones that responded to our survey aimed at evaluating the flexibility potential at MV level, with respect to the total customers that accepted the participation, meaning, the ones that actually provided the necessary data. This indicator will be used to evaluate the customer engagement plan.	%	SUC01, SUC02
KPI_H09B	Volume of transactions (Power)	This indicator measures the volume (in kW) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.	kW	SUC02
KPI_H09A	Volume of transactions – cleared bids (P or Q Availability)	This indicator measures the volume (in kW) of the available flexibilities to solve grid congestions identified during the examined period T.	kW	SUC02
KPI_H09D	Volume of transactions – cleared bids (P	This indicator measures the volume (in MWh) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.	MWh	SUC02

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ID	Name	Description	Unit	BUC/SUC
	or Q Activation) (Energy)			
KPI_H14A	Available Flexibility	Ratio between the flexible power that can be used for congestion management and the forecasted total power demand.	%	SUC02
KPI_H12	Number of avoided technical restrictions	Ratio between the number of avoided congestions (overloaded elements) in the grid for all periods of observation scenarios with flexibility activation (after SUC implementation) by the DSO and/or TSO action and the total number of expected restrictions.	%	SUC02

3. Overall description of the demonstration technical environment

The Portuguese demonstrator developed platforms and procedures to exchange information and provide cooperation among the Portuguese DSO (E-REDES), TSO (REN) and aggregators. For the context of the demonstrator, INESC TEC took the role of an Aggregator, while R&D NESTER supported REN on its developments and jointly took the role of TSO. Hence, the Portuguese demo presents three different perspectives matching the three represented actors, fulfilling distinct needs, which are here explored. A comprehensive description of the Portuguese architecture environment developed in the scope of OneNet was already provided in the deliverable D9.2 [1], in this chapter the idea is just to provide to the reader an overall description of the demonstration environment that was deployed for the Portuguese OneNet demonstrations.

3.1. TSO environment

From the TSO's point of view, the value it takes from coordination in the selected use cases includes: visibility enhancement of the grid to improve operation mechanisms, Improvement of operational planning capabilities such as short circuit calculation, maintenance, generation and consumption forecasts at the transmission level, and one merged process for evaluation of the product and grid prequalification for flexibility provision. Beyond the use cases demonstrated, TSOs could leverage on the coordination to improve other activities such as:

a) Grid Balancing: TSOs are responsible for balancing electricity supply and demand on a broader scale. Information shared by DSOs and Aggregators can be used to optimize the use of transmission lines, generation resources, and interconnectors. By coordinating with other stakeholders, TSOs ensure the overall stability and reliability of the transmission grid.

b) Cross-Border Cooperation: In case of interconnected grids, TSOs collaborate with their counterparts in neighboring countries to exchange information on power flows, generation capacity, and reserve resources. This helps optimize cross-border electricity trading and enhances grid resilience.

c) Ancillary Services: TSOs rely on FSPs and Aggregators to provide ancillary services like frequency regulation, reserves, and ramping support. By sharing data on system requirements and market signals, TSOs enable aggregators to offer these services efficiently.

d) Capacity Planning: TSOs use shared information on expected changes in generation capacities and demand patterns to plan and expand the transmission infrastructure effectively. This helps anticipate future grid requirements and avoids bottlenecks.

In the scope of the OneNet Portuguese demonstration, REN and R&D NESTER collaboratively worked in order to design and develop a dedicated infrastructure that can easily and efficiently be integrated with internal tools

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and databases. In order to demonstrate the planned use cases, real data from the TSO should feed the infrastructure with the final goal of exchanging this information with external stakeholders (DSO, Aggregators, etc.) following the agreed data structures. A detailed description of the TSO environment including tools and APIs is presented in the Deliverable D9.2 [1].

The TSO environment architecture is depicted in the Figure 3.1.

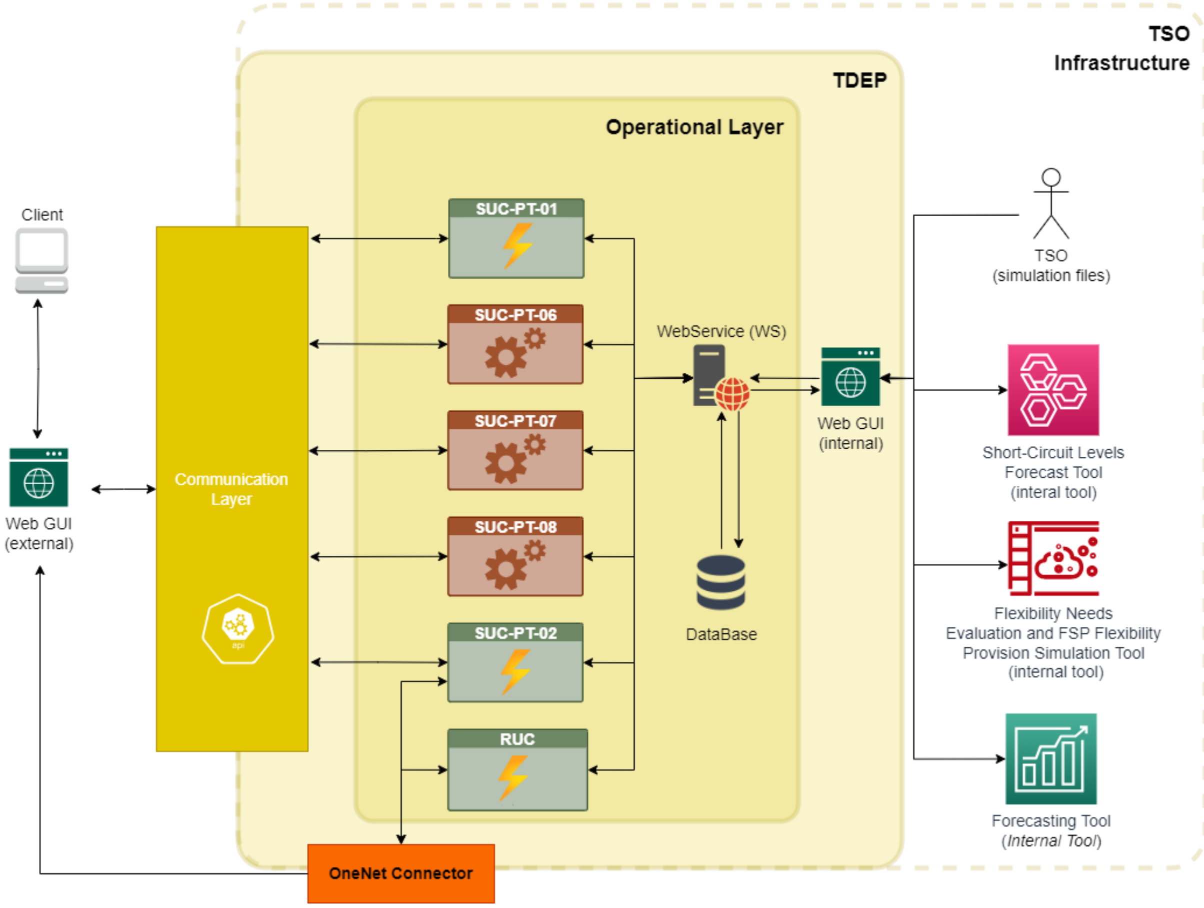

Figure 3.1 - TSO demonstration environment architecture.

3.1.1. Backend

The information exchange occurs through an application-programming interface (API). The TSO, as well as the DSO, developed a cloud-based data exchange platform system that serves as a gateway between the internal systems of the TSO with other possible external entities. The Amazon Web Services (AWS) cloud systems provide the essential IT infrastructure, including servers and databases, to deploy the developed software components. This configuration enables the fulfillment of UCs requirements and their respective APIs through modules and information exchange mechanisms within a cloud environment.

As part of the operational layer, in the backend the API has several endpoints created for the multiple SUCs in order to facilitate the dedicated information exchange between the different actors and the internal tools.

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Some of the endpoints are exclusive for internal use of the TSO and others are open after creating a user account and consequently approved by the TSO. The list of the publicly available endpoints for all the SUCs was presented in deliverable D9.2 [1].

The different UCs require data that originates from internal processes of REN (TSO). Therefore, it was crucial to integrate with these operational processes in a practical and as automated manner as possible. This ensures that files containing market results, maintenance plans, load and generation forecasts, among other information, are integrated into the various UCs and internal tools developed within the scope of the project.

Two tools were specially created for the Portuguese demonstration, the Flexibility Needs Evaluation and FSP Flexibility Provision Simulation Tool (for SUC02) and the Short Circuit Currents Forecast Tool (for SUC08).

The TSO Flexibility Needs Evaluation and FSP Flexibility Provision Simulation Tool, a Python/Matlab script, empowers users to evaluate the flexibility requirements of any network and offer Flexible Service Provider (FSP) flexibility dispatch solutions to address potential network constraints. In the SUC02 demonstration, the tool showed its capabilities by being applied to the Extra High Voltage (EHV) Portuguese transmission network owned by the TSO. This tool comprises two essential modules. The first module computes TSO nodal flexibility needs in the TSO/DSO transformers (EHV/HV), contributing to a comprehensive understanding of the active and reactive requirements within the overall system. The second module provides optimal dispatch strategies for FSPs, offering effective solutions to meet the identified TSO flexibility needs. This modular approach ensures a systematic assessment and response to network constraints. Moreover, the tool can be employed for both single and multi-period studies, offering a dynamic perspective on flexibility requirements. Additionally, the tool supports stochastic analysis, enhancing its applicability to scenarios with varying uncertainties and complexities. The tool's workflow involves initiating a grid analysis, primarily addressing the active and reactive requirements of the entire system (first module). Subsequently, based on the grid status for each period, the tool forecasts the optimal FSP planning for multiple periods (second module), thereby contributing to a proactive and strategic approach in addressing flexibility needs within the network.

The Short-Circuit Currents Forecast Tool is a Python script designed to facilitate short-circuit calculations using the Power System Simulator for Engineering software (PSS/E). The script automates the process of opening and configuring PSS/E, running simulations, and extracting results. Utilizing the Python subprocess module, the script launches PSS/E and executes specific commands within the software. These commands involve opening an initial power flow data file in RAW format, defining parameters for PSS/E power flow and short-circuit calculations to ensure accurate simulation according to REN procedures. The script then performs Automatic Sequencing Fault Calculation, repeating this process 48 times for all files provided by the Portuguese TSO, with a granularity of 30 minutes, covering a full day, thus, delivering in this manner a day-ahead forecast of the short-circuit currents in the EHV/HV substations.

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The forecasting tool presented in Figure 3.1 corresponds to the internal tool that REN uses in their processes to provide load and generation forecast.

All of these tools are linked with the cloud-based data exchange platform through the deployed endpoints and the information related with the different SUCs is stored in the database connected to the TSO web-services.

3.1.2. Frontend

A Graphical User Interface (GUI) platform was created in order to allow users to interact with the TSO data exchange platform. The GUI is designed to make the interaction between users and the TDEP more intuitive and user-friendly by visually representing the UCs results and demonstration information. Allowed users can manipulate and submit information regarding the different UCs demonstrated. As shown in Figure 3.1, GUI can be used both for interacting with TSO's internal tools and procedures, as well as serving as an interface for external users who wish to interact with and/or query TDEP.

This frontend was initially designed by NESTER and then was materialized by Watt-IS, through the launched Open Call Project "WISeGrid – Electrical Grid Web-based optimization services" [7]. The implemented User Interface Platform, delivering a Web Application using a stack of Ruby on Rails[1] web framework and ReactJS[2]. To fetch requisite data for the Web Application, Watt-Is has implemented an API client designed to access diverse endpoints provided by NESTER through the TDEP. User authentication processes are also facilitated over this API. Consequently, the backend infrastructure of the GUI Platform is streamlined, as a substantial portion of backend operations is delegated to the TDEP API. This encompasses database management, user authentication procedures, initiation of data exchanges, and related functionalities.

The frontend pages before and after login are shown in Figure 3.2 and Figure 3.3, respectively.

[1] Ruby on Rails, often simply referred to as Rails, is an open-source web application framework written in the Ruby programming language. It follows the Model-View-Controller (MVC) architectural pattern, which helps in organizing code and separating concerns in a web application.

[2] ReactJS, commonly referred to as React, is an open-source JavaScript library used for building user interfaces (UI) or user interface components, particularly for single-page applications where UI updates are frequent.

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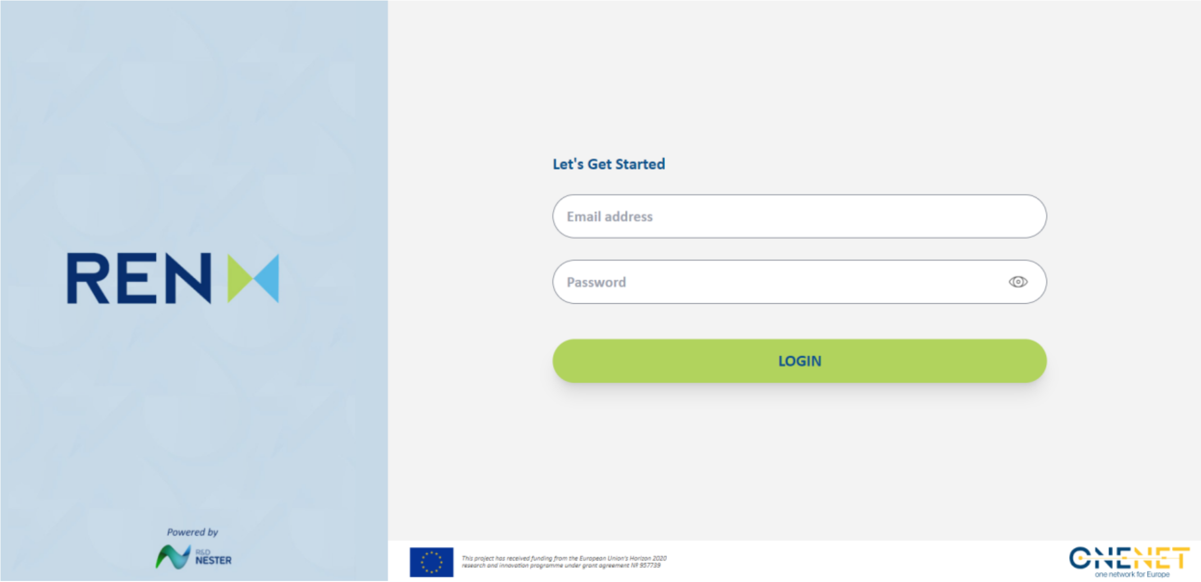

Figure 3.2 - TSO login page.

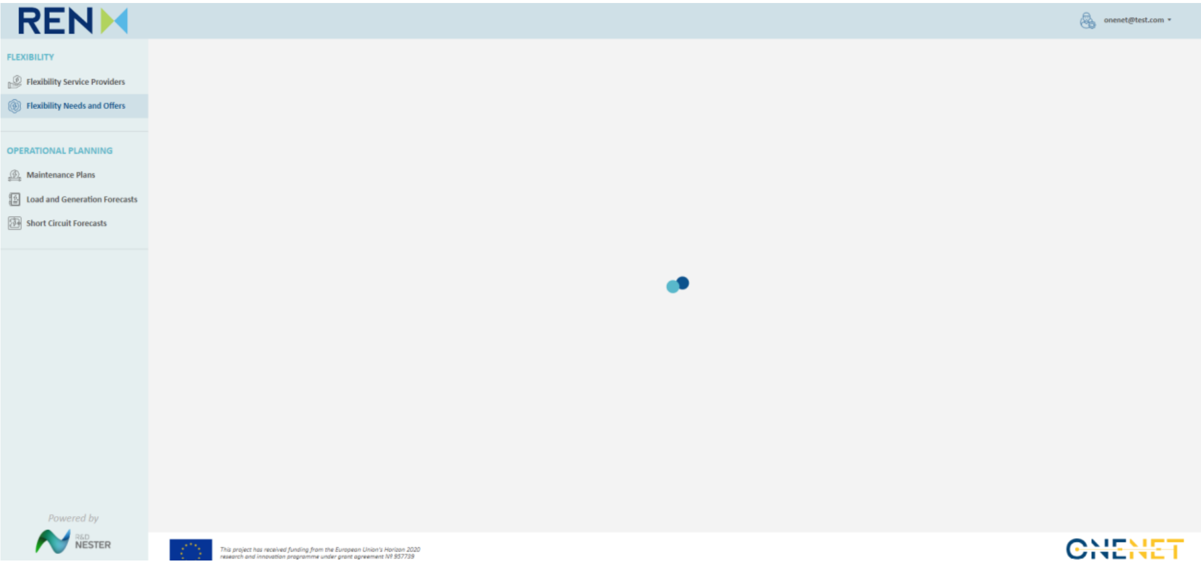

Figure 3.3 - TSO initial page after the login.

At the left tabbed section of the TSO initial page (Figure 3.3) it is possible to see the five SUCs demonstrated listed, representing each of them a button to access to the respective demo results page, which is presented in more detail in the chapter 4.

3.2. DSO environment

From the point of view of the DSO, cooperation enables sharing not only the availability of flexible connected assets but also the flexibility needs and activations that might have impact to the TSO. This cooperation will improve the overall management of congestion issues and avoidance of any unexpected congestions originated by flexibility activations, maximizing the flexibility potential and increasing the market size and liquidity/volume. It also improves operational planning activities capabilities, with a higher focus on maintenance alignment and both generation and consumption forecasts at the distribution level. By defining a harmonized process for evaluation of the product and grid prequalification for flexibility provision, in alignment with the one implemented by the TSO, will provide for higher transparency and efficiency in the process, given the roles and processes are clearly defined and agreed by the two parties. Another value brought by the DSOs is higher sensitivity in discovering potential flexibility assets/providers, since they are more prone to benefit from the location factor and closer to the end consumer itself. Beyond the use cases (UCs) the DSOs could further leverage this coordination on the following activities:

a) Grid Stability: DSOs are responsible for managing the distribution grid, which includes a significant amount of renewable energy sources, distributed generation, and energy storage systems. Coordinating with other system operators, both among DSOs and between DSOs and TSOs, they can contribute to maintaining grid stability by ensuring that distributed energy resources (DERs) are properly integrated and synchronized with the rest of the grid.

b) Demand-Side Management: DSOs collaborate with other operators to implement demand-side management strategies. This involves incentivizing consumers to adjust their energy consumption patterns to match supply availability. By sharing information on demand forecasts and generation capacities, DSOs can optimize grid operations and reduce the need for costly grid upgrades. This could also mean cross border cooperation with other DSOs such as demonstrated in the Western regional use case.

c) Flexibility Provision: DSOs can identify localized grid constraints and bottlenecks. By collaborating with flexibility aggregators and TSOs, they can leverage flexible resources (such as demand response, energy storage, or distributed generation) to eliminate grid congestion and enhance grid reliability.

d) Voltage and Power Quality Management: DSOs need to maintain voltage and power quality within acceptable limits. They can utilize flexibility services to manage voltage fluctuations and grid imbalances efficiently, reducing the risk of power disruptions and equipment damage.

Similarly to the infrastructure implemented by REN and R&D NESTER, the DDEP was also developed in a way to efficiently integrate the tools managed by the DSO and that will be used to feed in the data to the DDEP's database through a set of internal APIs, and following the agreed data models [1]. This data is subsequently displayed in the Web GUI from the DDEP and exchanged with the TDEP, also making use of dedicated APIs. These processes and interactions, namely the exchanges between the DDEP and TDEP will diverge depending on the SUC and are further detailed in D9.2 [1].

The DSO environment architecture is depicted in the Figure 3.4.

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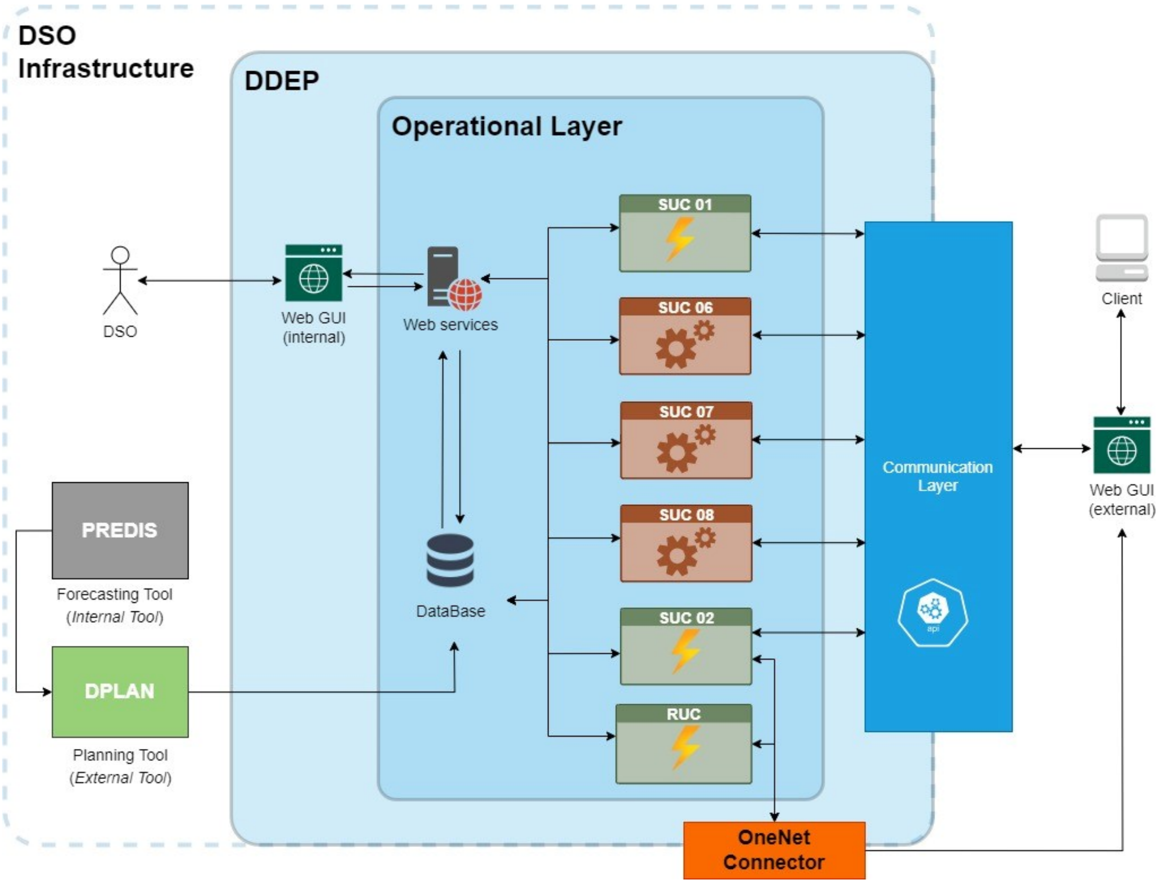

Figure 3.4 - DSO demonstration environment architecture.

3.2.1. Backend

The backend of the DDEP comprises all components from the internal APIs that interact with the DSO tools, to the operational layer that includes the database for storing the data and the web services, as well as the communication layer, composed of all the APIs that allow the communication between the DDEP and external clients, in this case, the TSO, through the TDEP. Thus, the DDEP serves as a gateway between the internal systems of the DSO and external entities that aim to interact with the DSO within the scope of the use cases developed in the demonstration. Similarly to the TDEP, the DDEP is also cloud-based, and resorts to Azure cloud systems for the provision of the necessary infrastructure to deploy the components developed within the demonstration.

The APIs that compose the communication layer include endpoints specific for the different SUCs. Some of the endpoints created point to the DDEP, foreseeing the upload of the necessary data to the DDEP database, for example, originating from the DSO tools used, while others point to the TDEP, foreseeing the exchange of the data with the TSO. The characteristics of these endpoints can be found in D9.2 [1].

The level of automation of the interactions between the user and the DDEP depends on the SUC. Two of the SUCs (SUC01 and SUC06) involve a more manual interaction through the GUI of the DDEP, where the information from the FSPs and the maintenance plans (both the annual and the update) are directly inserted in the frontend,

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where specific fields have been created for that purpose. For SUCs 02, 07 and 08 this interaction is automated and happens in pre-defined timings through a predefined flow of internal processes, starting with the generation of the generation and demand forecast data through the PREDIS tool from E-REDES to the feeding in DPlan that calculates the flexibility needs, the disaggregated demand and generation forecasts and the short-circuit forecasts and sends them to the DDEP through the internal APIs. More information on these tools can be found in D9.2 [1].

3.2.2. Frontend

The DDEP also includes a GUI that allows the interaction between the users, in this case the DSO, with the platform. The GUI was designed to be intuitive to the user, segmenting the information between the UCs and representing visually the main results of the UCs, including the status of the interactions, and providing enough and systematized data to allow a fast and easy decision and response by the user.

In the case of the DSO, two GUIs were developed by two separate entities to demonstrate replicability of the solution implemented. One of the GUIs was developed by a sub-contracted party, Link Consulting, and addressed SUCs 01 and 02, while the second GUI was developed by Watt-IS, through the launched Open Call Project "WISeGrid – Electrical Grid Web-based optimization services" [7], addressing SUCs 06, 07 and 08. Both GUIs follow the exact same structure. However, while the GUI developed by Watt-IS delivers a Web Application using a stack of Ruby on Rails web framework and ReactJS, as was implemented for the TDEP GUI, the GUI developed by Link Consulting uses the VueJS framework, which is an open-source development framework for developing interfaces in JavaScript.

The frontend pages before and after login are shown in Figure 3.5 to Figure 3.8, respectively and for both GUIs.

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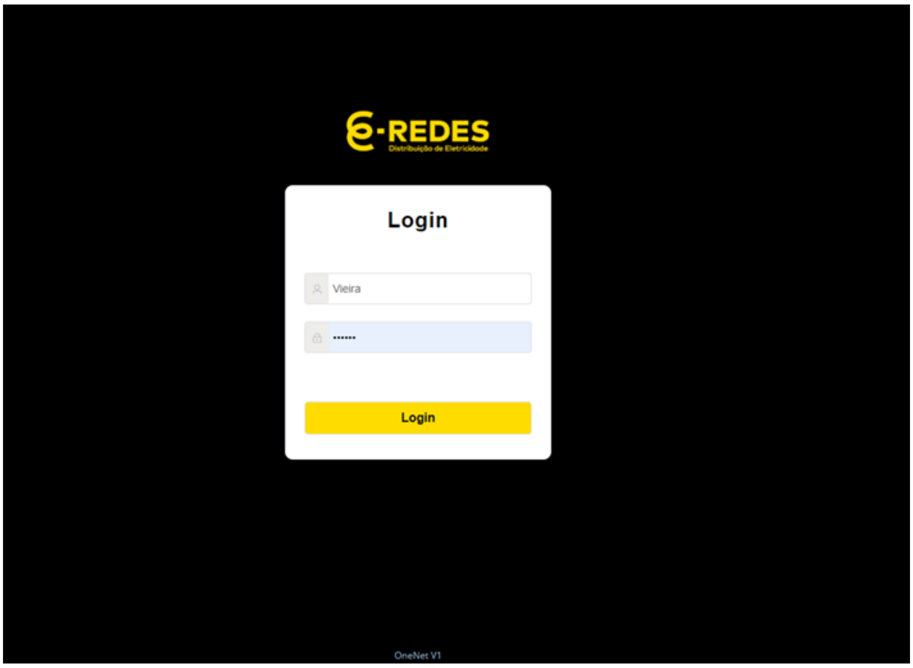

Figure 3.5 - DSO login page – Frontend developed for SUC01 and SUC02.

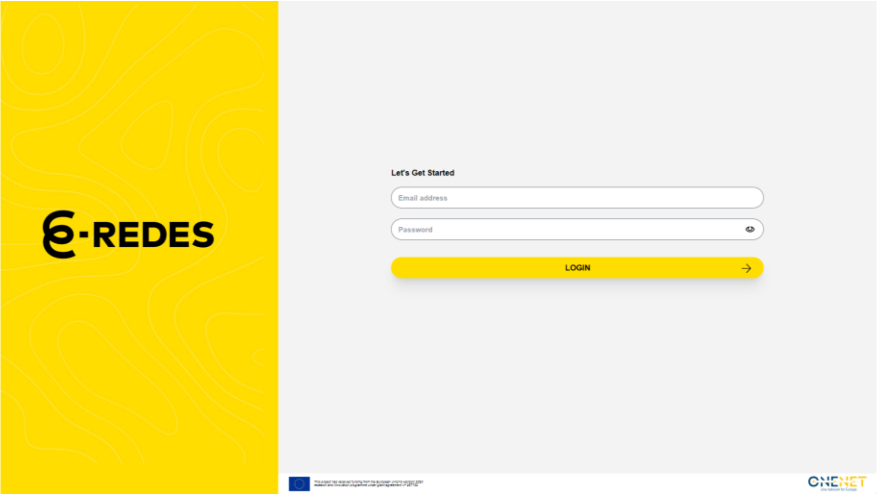

Figure 3.6 - DSO login page – Frontend for SUC06, SUC07 and SUC08.

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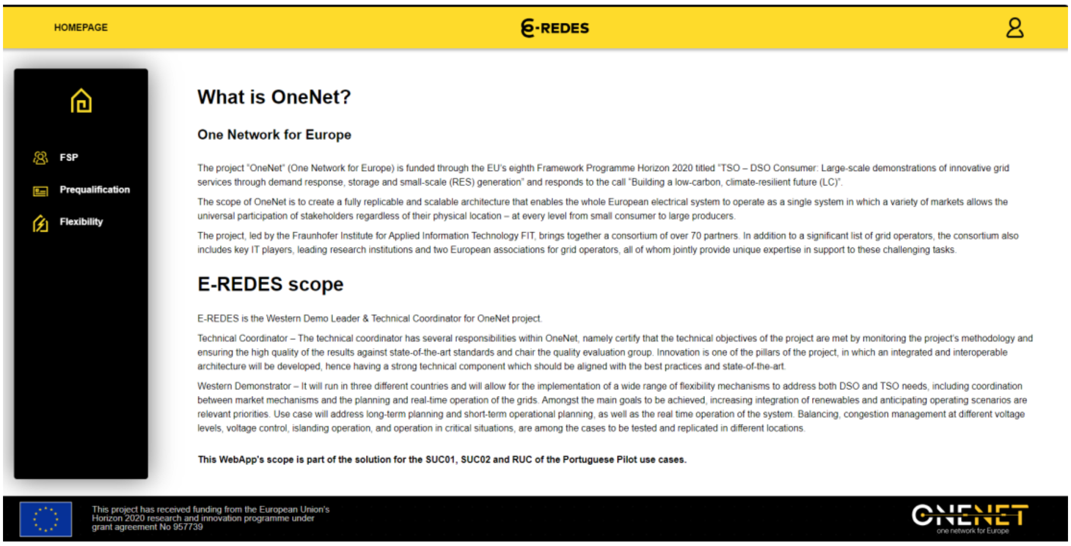

Figure 3.7 - DSO initial page after the login – Frontend for SUC01 and SUC02.

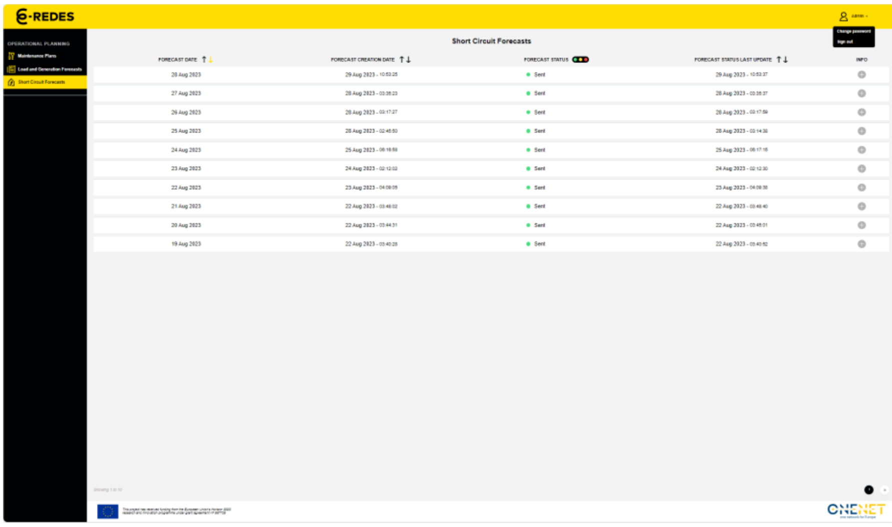

Figure 3.8 - DSO initial page after the login – Frontend for SUC06, SUC07 and SUC08.

At the left-hand section of the DSO initial page (Figure 3.7 and Figure 3.8) it is possible to see the SUCs listed. By clicking in each of them, it is possible to access to the respective demo results page, which is presented in more detail in the Chapter 4.

3.3. Aggregator environment

The Aggregator benefits from having a single point to report flexibility availability, in which the connection point ID is shared between system operators, ID provider and bid ID, facilitating the bid process. In the Portuguese demo, two grid zones were considered for the SUC02 demonstration, covered by Pocinho and Batalha demo sites. The ease of posting the flexibility availability means that the focus can be put on the asset

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location and its modelling. The methodology applied was the one presented in D9.2 [1]. Further coordination of SO would promote the activities of the Aggregators namely in:

a) Resource Optimization: Flexibility aggregators gather data from distributed energy resources, demand response providers, and energy storage systems. By sharing this information with DSOs and TSOs, they facilitate the optimal use of flexible resources to meet system needs.

b) Market Participation: Aggregators use shared grid operation data to participate in energy markets, providing flexibility services and responding to market signals. This helps balance supply and demand, support grid stability, and monetize the value of flexibility.

c) System Visibility: Aggregators contribute to system visibility by sharing real-time data on available flexibility with grid operators. This information is essential for grid planning and operation, as it allows operators to understand the available resources and make informed decisions.

The Portuguese Demo ran for two weeks from 14th of August to 28th of August 2023. Specific hours were defined for the message exchange by the defined Rest API requests, for example 16h each day to post information such as flexibility availabilities for each of the substations by InescTec for SUC02. The log files were retrieved by the platforms in order to calculate the KPIs at a later stage.

3.3.1. Backend

As an acting Aggregator, InescTec POSTED its availability according to the methodology published in D9.2 [1], into the TSO platform (TDEP platform). The tool used for the flexibility estimation does not have a front end by itself but can be seen in the TDEP front end. The main steps of the methodology are here summarized:

1. Clustering – Acknowledging the fact that different types of behaviors can be identified amongst the flexibility resources aggregated, i.e., the supermarkets, a clustering exercise was performed for each day of the year; This resulted in clusters corresponding to small, medium and large supermarkets.

2. Create representative profiles with uncertainty – Since clusters are composed of several observations, to have a representative profile, the median or mean value can be used. However, this could result in a high error of interpretation. For that reason, the uncertainty was considered using a statistical distribution for each of the 15-minute observation.

3. Identification of the operational profiles - A deduction of the base consumption to the representative profiles was done to extract only the operational load profiles potentially subject to flexibility provision.

4. List of main typical loads of the supermarkets – Main loads in terms of length of operation and power demand were listed.

5. Classification regarding their flexibility ability - Three categories were defined for the assets regarding their ability to be I) variable and shiftable; ii) not variable but shiftable; iii) nor variable or shiftable. For the assets in

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the first two categories, for the sake of simplification, they were grouped into larger asset nomenclature of I) Illumination/Lighting; ii) Refrigeration; iii) Climatization ad Ventilation.

6. Event driven consumption stratification - Considering the Percentile 50 of each 15-minute observation of each cluster, which is a representative load diagram day of each of the supermarket (cluster) and based on the operating hours and stratification of the grouped nomenclature, a percentage of power was assigned to each of those groups and used in the other supermarket sizes (clusters).

7. Define constraints: A percentage of that power of arbitrarily identified as flexibility available, not considered as disruptive for the potential supermarket users present at that moment. A set of restrictions during the representative day for each cluster was defined, capturing elements such as no lighting during night hours available, or the need for the refrigeration chambers to defrosting cycles where no flexibility would be available or that these chambers could shift from eco mode to normal mode to boost mode operation.

8. Availability for each time interval - With the flexible power estimated for each 15-minute time step for a day.

9. Number of supermarkets in a grid zone - The area of the substation is identified through google maps, and the number of each supermarket cluster in the map is considered as a multiplication factor of the flexibility estimated so far.

10. Monte Carlo simulation - Since the value of flexibility has a statistical distribution implicitly assigned, a thousand iterations are run, to find out the statistical distribution of the output.

11. Risk assessment - Based on the output, and since there is an aggregation error associated, in order not to take the risk of incurring an imbalance, the 75th percentile of each flexibility value was considered (can be other).

12. A final array (up to 96 entries) is presented as the available flexibility to be offered with a specified message content.

The tool runs with Crystal Ball[3] add-in to Excel and uses a Python script to run an API POST request into the TDEP platform. Two POST requests were made per day, corresponding to the availability for each demo site (Batalha and Pocinho). The Demo for SUC02 ran from 14th to the 25th of August. The python script for that effect ran automatically every 16h (GMT+1) and is provided in Figure 3.9 for Pocinho Substation as an example for the 18th of August, while Figure 3.10 shows an example of the response log file.

[3] Crystal Ball (standard edition) is the easiest way to perform Monte Carlo simulations in your Excel spreadsheets and models. Crystal Ball automatically calculates thousands of different "what if" cases, saving the inputs and results of each calculation as individual scenarios.

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```
# 1- Authentication in TDEP

import requests
import sys
import base64
from datetime import datetime
import os
import datetime
import pandas as pd
import json
import csv

# Login information for passing to Nester

url = "http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/login/access-token"
headers = { 'accept': 'application/json', 'Content-Type': 'application/x-www-form-urlencoded', }
data = { 'grant_type': '', 'username': 'xxxxxxxxxxxx @onenet.com', 'password': 'xxxxxx', 'scope': '', 'client_id': '',
'client_secret': '', }
response = requests.post( url, headers=headers, data=data)

# Performs login at Nester and receives jwt access token

print('\n', url)
auth_String = response.json()['token_type'] + ' ' + response.json()['access_token']
print(auth_String)

# 2- Calls the file by the name of the day. The automatic algorithm at 16h every day, checked #the current date
#day, and called the file of the corresponding day saved locally

now = datetime.datetime.now()
from time import gmtime, strftime
now=strftime("%Y-%m-%d", gmtime())
now1=str(now)+ ".csv" #File structure name is for example: 09-08-2023.csv
now1
df1 = pd.read_csv(now1, header=None, encoding='ISO-8859-1', sep=";")
df1.head()

# 3- Flexibility posting for Batalha SE (example)

# Open the CSV with the name of the day and reads in the data

with open(now1) as f: #open ex: '10-07-2023.csv'
   reader = csv.reader(f, delimiter=';')
   data = [[] for _ in range(96)]
   for row in reader:
      for i in range(96):
         data[i].append(row[i])
```

```
new_list = []

for row in data:
#The Power is converter from kW to MW dividing by 1000
   new_dict = {"node_id": "B6014", "active_power_quantity": float(row[1])/1000, "reactive_power_quantity":
float(row[2])/1000,
            "period_from": row[3], "period_to": row[4]}
   new_list.append(new_dict)

new_list
parsed_data = new_list

# Create a new dictionary with the desired structure
new_data = {
   "sender_source": 2,
   "grid_nodes": parsed_data,
   "created_at": datetime.now().isoformat(),
   "flex_type": 1
}

# Convert the new dictionary to JSON format with integer values
new_data_json = json.dumps(new_data, indent=4, default=int)

# # Make the post in Nester Endpoint

# define the URL endpoint where you want to send the POST request from Nester
url = "http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/flexibility/needs/offers"

# send the POST request with the JSON data and headers
response = requests.post(url, headers={"Authorization": auth_String}, data=new_data_json)

# print the response status code and content
print(response.status_code)
print(response.content)

#4- Storing a log file locally
if response.status_code == 200:
# Define the file path where you want to save the content for response
   file_path_response = r"C:\Users\inesctec\Desktop\response.txt"

# Open the file in append mode and save the content
   with open(file_path_response, 'a') as file:
# Write the content to the file
      file.write(str(response.status_code) + '\n')
      file.write(response.content.decode() + '\n')
```

Figure 3.9 - Python script example to automatically POST the flexibility availabilities.

200
b'{"sender_source":2,"grid_nodes":[{"node_id":"B6014","active_power_quantity":0.0,"reactive_power_quantity":0.0,"period_from":"01/08/2023 00:15","period_to":"01/08/2023 00:30"},{"node_id":"B6014","active_power_quantity":0.0,"reactive_power_quantity":0.0,"period_from":"01/08/2023 00:30","period_to":"01/08/2023 00:45"},

(.......interrupted for size......){"node_id":"B6014","active_power_quantity":0.0,"reactive_power_quantity":0.0,"period_from":"01/08/2023 23:45","period_to":"02/08/2023 00:00"},{"node_id":"B6014","active_power_quantity":0.0,"reactive_power_quantity":0.0,"period_from":"02/08/2023 00:00","period_to":"01/08/2023 00:15"}],"created_at":"2023-07-24T21:49:54.723835","flex_type":1,"id":94}'

Figure 3.10 - Example of the Response logged.

The full script to POST the availabilities of flexibility during the Demo can be found in Appendix A.2 of this document.

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4. Evaluation of the Demonstrations

This section evaluates the Portuguese demonstrator regarding the 5 different SUCs defined, during the two demonstration phases (1st demo phase - 14/08/2023 – 28/08/2023 and 2nd demo phase - 27/11/2023 – 22/12/2023).

4.1. Demo Sites

The 5 demo sites selected were distributed in the continental Portugal with one in the Northeast of Portugal (Pocinho), one in Coastal Beira of Portugal (Mourisca), two in the center of Portugal (Zêzere and Batalha) and also one in the South of Portugal (Portimão). The choice of these demo sites was not only due to geographically location but also due to diversity in the energy mix.

Figure 4.1 - Demo sites location.

In the Figure 4.1 it is presented the geographical distribution of all the demo sites and in Table 4.1 you can find the main characteristics of the 5 demo sites. Note that the generation installed capacity at the distribution side is the aggregate value of assets connected at the HV and MV levels and from the transmission side corresponds to the aggregated value from the private lines connected to the HV bay from which only the TSO has visibility.

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Table 4.1 - The 5 demo sites details.

<table>
<tr><th>Demo Site</th><th colspan="3">Connected resources</th><th>Total</th></tr>
<tr><td rowspan="11">Pocinho</td><td rowspan="2">Lines</td><td colspan="2">EHV</td><td>8 lines</td></tr>
<tr><td colspan="2">HV</td><td>5 lines</td></tr>
<tr><td rowspan="2">EHV/HV Transformers</td><td colspan="2">Number</td><td>2</td></tr>
<tr><td colspan="2">Power</td><td>120 MVA + 126 MVA</td></tr>
<tr><td rowspan="4">Generation</td><td>TSO (HV)</td><td>Hydro</td><td>36 MVA</td></tr>
<tr><td rowspan="3">DSO (HV and MV)</td><td>Hydro</td><td>152 MVA</td></tr>
<tr><td>Wind</td><td>8 MVA</td></tr>
<tr><td>PV</td><td>10 MVA</td></tr>
<tr><td rowspan="2">Circuit Breakers</td><td colspan="2">DSO</td><td>25 kA</td></tr>
<tr><td colspan="2">TSO</td><td>31.5 kA</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td rowspan="15">Mourisca</td><td rowspan="2">Lines</td><td colspan="2">EHV</td><td>4 lines</td></tr>
<tr><td colspan="2">HV</td><td>6 lines (1 Private)</td></tr>
<tr><td rowspan="2">EHV/HV Transformers</td><td colspan="2">Number</td><td>3</td></tr>
<tr><td colspan="2">Power</td><td>170 MVA + 120 MVA + 126 MVA</td></tr>
<tr><td rowspan="9">Generation</td><td>TSO (HV)</td><td>Hydro</td><td>8.53 MVA</td></tr>
<tr><td rowspan="8">DSO (HV and MV)</td><td>Wind</td><td>34.4 MVA</td></tr>
<tr><td>PV</td><td>31.4 MVA</td></tr>
<tr><td>Hydro</td><td>17.7 MVA</td></tr>
<tr><td>Biomass</td><td>14.7 MVA</td></tr>
<tr><td>Biogas</td><td>5.0 MVA</td></tr>
<tr><td>Cogeneration (RES)</td><td>35.8 MVA</td></tr>
<tr><td>Cogeneration (non-RES)</td><td>8.6 MVA</td></tr>
<tr><td rowspan="2">Circuit breakers</td><td colspan="2">DSO</td><td>25 kA</td></tr>
<tr><td colspan="2">TSO</td><td>31.5 kA</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">Batalha</td><td rowspan="2">Lines</td><td colspan="2">EHV</td><td>4 lines</td></tr>
<tr><td colspan="2">HV</td><td>8 lines (1 private)</td></tr>
<tr><td></td><td colspan="2">Number</td><td>3</td></tr>
</table>

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Demo Site	Connected resources			Total
	EHV/HV Transformers	Power		3 x 170 MVA
	Generation	TSO (HV)	Wind	118.14 MVA
		DSO (HV and MV)	Wind	42.2 MVA
			PV	37.3 MVA
			Cogeneration (non-RES)	6.5 MVA
			Biogas	4.3 MVA
	Circuit Breakers	DSO		25 kA
		TSO		31.5 kA
Portimão	Lines	EHV		8 lines
		HV		5 lines
	EHV/HV Transformers	Number		2
		Power		2 x 170 MVA
	Generation	DSO (HV and MV)	Wind	135.6 MVA
			PV	45.6 MVA
			Cogeneration (non-RES)	5.3 MVA
			Hydro	2.3 MVA
			Biogas	1.8 MVA
	Circuit breakers	DSO		25 kA
		TSO		31.5 kA
Zêzere	Lines	EHV		6 lines
		HV		9 lines
	EHV/HV Transformers	Number		3
		Power		3 x 170 MVA
	Generation	DSO (HV and MV)	Hydro	110.1 MVA
			Wind	32.4 MVA
			PV	39.6 MVA

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Demo Site	Connected resources			Total
			Biomass	19.6 MVA
			Biogas	1.7 MVA
			Cogeneration (RES)	23.4 MVA
			Cogeneration (non-RES)	8.2 MVA
	Circuit Breakers	DSO		25 kA
		TSO		31.5 kA

4.2. System Use Case 01 (SUC01) demo

4.2.1. Methodology

This SUC aims to test the prequalification process, namely the interactions between the DSO and TSO, targeting two inner steps within the overall process, the product and grid prequalification processes, under two different scenarios. The first being when the FSPs connected to the distribution grid aim to deliver services to the TSO (Scenario 1), and the second when the FSPs connected to the transmission grid, aim to deliver services to the DSO (Scenario 2). The process is quite simple, it starts with a pre-agreement of the prequalification requirements, followed by a product prequalification by the SO to which the FSP will provide the service, followed by a grid prequalification by the SO where the FSP is connected and a notification of the result. A detailed description of the SUC and of the different scenarios covered can be found in D9.2 [1]. Hence, in summary, the objectives of this SUC are the following:

- Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe.
- Enable FSPs and their resources for flexibility markets, since the prequalification phase is necessary for the following phases that will approach.
- Define the list of requirements for product prequalification for DSO and TSO.
- Ensure coordination between system operators for all scenarios.
- Receive and send data between system operators in a secure manner.

The SUC makes use of both DEPs for the interactions and the success of the SUC is related with the successful exchange of prequalification data. Thus, the outcome of the SUC is the effectiveness of the entire process.

4.2.2. Input data from the demo sites

Since this SUC focuses on the ex-ante prequalification process, it is not limited regionally as the remaining SUCs are, thus, the demo site is the entire EHV, HV and MV networks from mainland of Portugal. The data

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gathered within this SUC mainly relates to the characteristics of the FSPs, including: a) FSPs connected at the EHV level, which refer to the 20 FSPs that have participated in the ancillary services market for the TSO; b) FSPs connected at the MV level, consisting of the 230 installations from one supermarket chain that have answered to a survey for interest gathering and that have agreed to share their data for the Portuguese demonstration. Table 4.2 presents the data gathered for SUC01, for the two categories of FSPs addressed. As these FSPs didn't actually participate in the demonstration, the field values were assumed to be the same within one entire category. A full description of the fields and the data model can be found in D9.2 [1].

Table 4.2 - Data gathered for SUC01

Data gathered	EHV connected FSPs	MV connected FSPs
FSP name	Name of the FSP (industries)	Name of the FSP from the supermarket chain
Type of resource	4 -> Industrial DR	5 -> Retail DR
Mode of activation	1 -> Manual	3 -> Both
Flexibility direction	3 -> Both	2 -> Down
Location data	Coordinates of the industry	Coordinates of the supermarket
Type of portfolio	0 -> Single	0 -> Single
SO connected	1 -> TSO	0 -> DSO
Maximum full activation time	Not available	Not available
Result of product PQ	0 -> Accepted	0 -> Accepted
Result of grid PQ	0 -> Accepted	0 -> Accepted
RUC	0 -> No	0 -> No
Reasoning	Nothing to declare	Nothing to declare

4.2.3. Demo Results

Since the core focus of SUC01 is the exchange of prequalification data between the DSO and the TSO, the main results to highlight are related to the data exchanged, namely the JSON messages exchanged between both parties, aggregating information on the FSPs considered. The JSON message follows the data model and schema defined within D9.2, consisting of 13 data entries for each FSP, 5 of which are required to be filled in and 8 are optional.

Below is the JSON message exchanged between the DSO and the TSO, comprising prequalification data on one of the 20 FSPs considered, connected at the EHV level. Note that the message refers to the last iteration of the process, already including the result of the product and grid prequalification phases, which have been both been accepted, therefore presenting the value 0, which stands for "accepted".

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```json
{
  "m_id": "TSO_FSP#1",
  "name": "Solvay Portugal, S.A.",
  "resource_type": 4,
  "mode_activation": 1,
  "flexibility_direction": 3,
  "location_info": "38.855076594104204, -9.067504515344847",
  "portfolio_type": 0,
  "so_connected": 1,
  "max_full_activation_time": "NA",
  "product_prequalification_result": 0,
  "grid_prequalification_result": 0,
  "is_RUC": 0,
  "reasoning": "Nothing to declare"
}
```

The same schema and data model was applied for the FSPs connected at the MV level. Below is the JSON message exchanged between the DSO and the TSO, comprising prequalification data on one of the 230 FSPs considered, connected at the MV level.

```json
{
    "m_id": "DSO_FSP#1",
    "name": "Continente Bom Dia Fátima",
    "resource_type": 5,
    "mode_activation": 3,
    "flexibility_direction": 2,
    "location_info": "39.375075524644705, -8.3950507943052062",
    "portfolio_type": 0,
    "so_connected": 0,
    "max_full_activation_time": "NA",
    "product_prequalification_result": 0,
    "grid_prequalification_result": 0,
    "reasoning": "Nothing to declare"
  }
```

Note, however, that these messages characterize not only the form how both DEPs interact with one another, but also how both platforms read the data provided within the frontend, where the interaction with the user is done, meaning that the user (DSO and TSO) do not use the JSON messages for the exchange of data, but the frontend to upload this same data. Figure 4.2 and Figure 4.3 show the frontend for both TDEP and DDEP for SUC01, respectively.

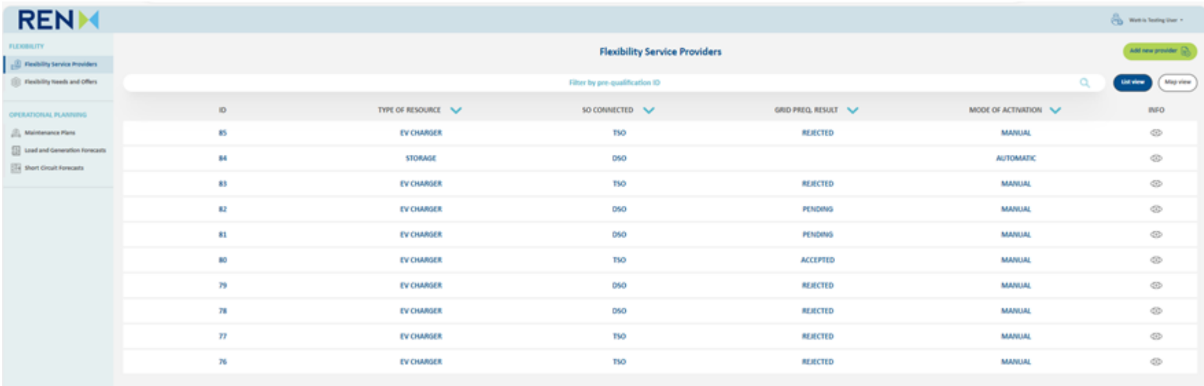

Figure 4.2 - TDEP frontend for SUC01.

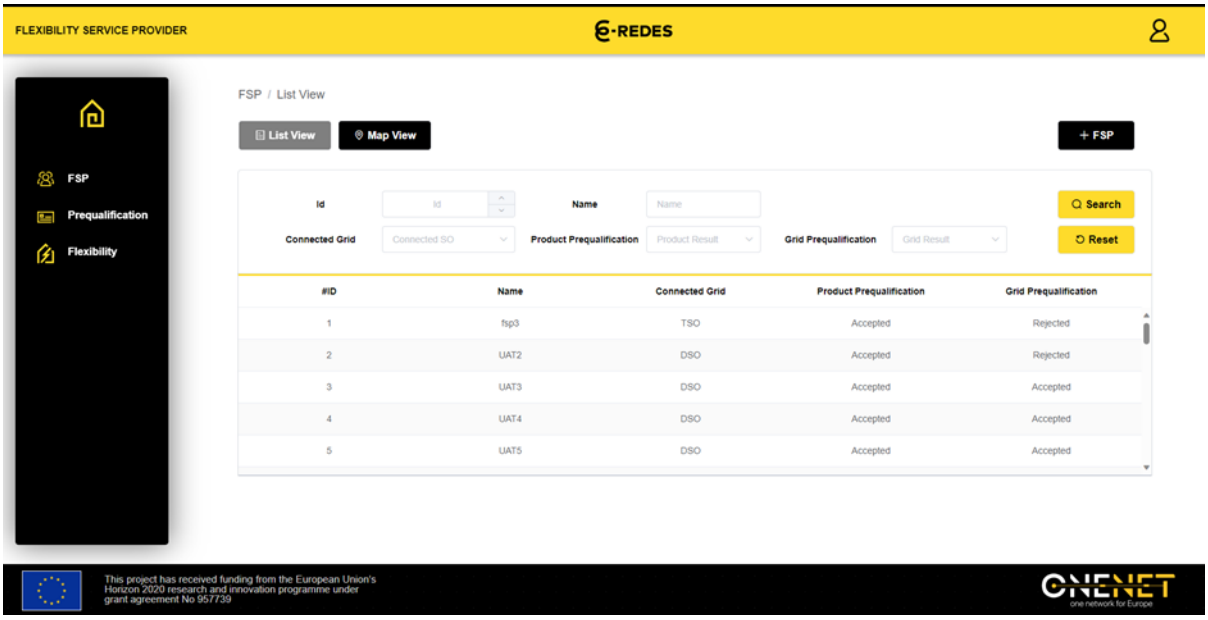

Figure 4.3 - DDEP frontend for SUC01.

The upload of FSP data by the user is done through a separate WebApp created for that purpose. Figure 4.4 and Figure 4.5 show this WebApp for both TDEP and DDEP, respectively.

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Figure 4.4 - TDEP frontend for SUC01 – add new FSP.

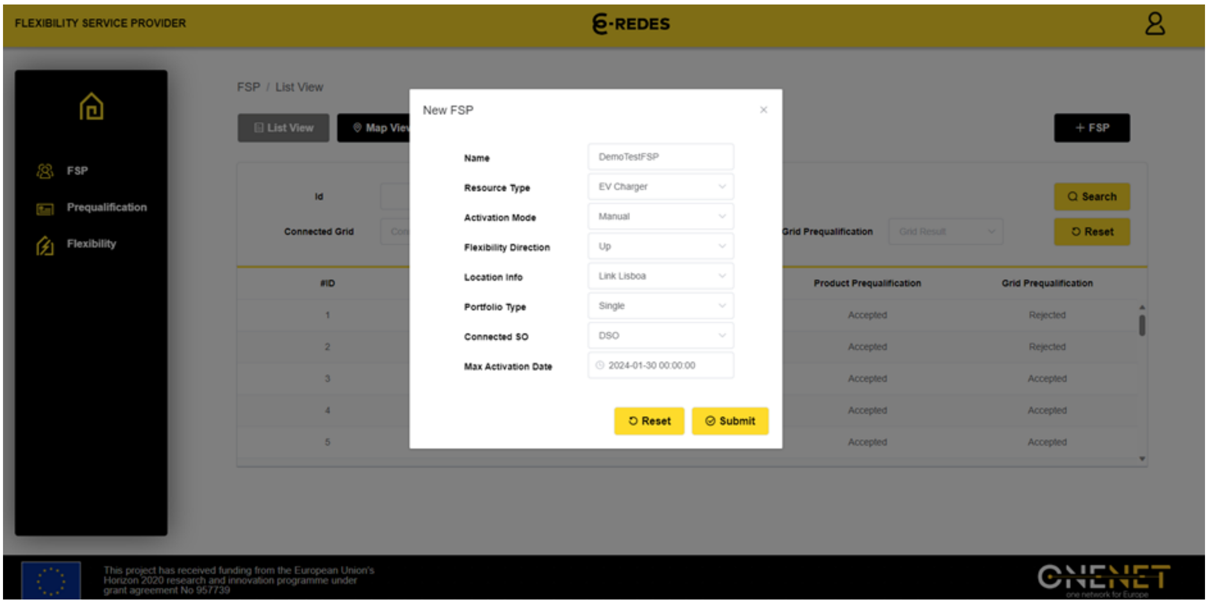

Figure 4.5 - DDEP frontend for SUC01 – add new FSP.

4.2.4. KPI computation

Five KPIs were computed for SUC01, two that are specific to the use case (KPI_N34: Successful ending of Prequalification Process; KPI_N46: Number of prequalification process that needs additional information) and

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three that are common amongst several demonstrators of OneNet (KPI_H01: Number of FSPs; KPI_H02: Active Participation; KPI_H04: ICT costs). A summary and analysis of the KPI results can be found below.

4.2.4.1. Demo KPIs applicable to SUC01

A summary of the demo KPI results applicable to SUC01 can be found in Table 4.3.

Table 4.3 - Computation of demo KPIs applicable to SUC01

KPI name	KPI ID	Target value	Final value
Successful ending of Prequalification Process	KPI_N34	100%	100%
Number of prequalification process that needs additional information	KPI_N46	0%	100%

Regarding KPI_N34, and considering the prequalification steps covered within the demonstration, all the FSPs were able to be prequalified. However, it is important to highlight that issues related to the actual ICT capabilities from the FSP point of view were not taken into account, which should be considered in a prior step in the prequalification process which is the FSP prequalification. And in fact, looking into the actual FSPs that have participated in the ancillary services market, there was 1, that wasn't able to enter the market, due to ICT issues – thus, if considered this first step, the real value for this KPI would in fact be 99.6%. This is indeed a point for improvement, to also take into account this first step to assess the ICT capabilities of the FSP, which is possible to introduce in a scenario with real FSPs participating.

As for KPI_N46, since the information required to be exchanged in the prequalification process is a requirement on its own for the process to successfully finish, this KPI takes into account not only the required fields but also the optional fields. Since the information exchanged was the one that could be extracted from the FSPs data, the missing fields are the same for all FSPs and, in this case, only information of Full Activation Time was not able to be determined. This leads to having at least one optional field missing per FSP/process.

4.2.4.2. Common KPIs applicable to SUC01

A summary of the demo KPI results applicable to SUC01 can be found in Table 4.4.

Table 4.4 - Computation of common KPIs applicable to SUC01

KPI name	KPI ID	Input value	Target value	Final value
Number of FSPs	KPI_H01	230 (DSO) + 20 (TSO)	At least 230	250

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Active Participation	KPI_H02	250/250	100%	100%
ICT costs[4]	KPI_H04		-	184 150 EUR

Regarding KPI_H01, the total number of FSPs connected to the distribution level include all the 230 supermarkets for Mainland Portugal that were used for the flexibility potential analysis. Adding to this, are 20 FSPs that participate in the ancillary services market (Replacement Reserve market) and are connected to the transmission network. However, it is important to note that the demonstration didn't actually take into account the direct participation of the FSPs in the prequalification process, meaning that only the data available to the SOs regarding the FSPs was considered for prequalification purposes. The only interaction with FSPs made was in a previous step, through a survey submitted to several customers connected at the distribution level, to have their agreement on the use of the data, from which was got the 230 participants at MV level.

Replacement Reserves market) and are connected to the transmission network. However, it is important to note that the demonstration didn't actually take into account for the direct participation of the FSPs in the prequalification process, meaning that only the data available to the SOs regarding the FSPs was considered for prequalification purposes. The only interaction with FSPs made was in a previous step, through a survey submitted to several customers connected at the distribution level, to have their agreement on the use of the data, from which was got the 230 participants at MV level.

Since the demonstration is focused on the interaction between the DSO and TSO, the active participation from the FSP point of view (KPI_H02), is considered from the point of view of data used. And, given that all the FSPs from which was got data were considered in this SUC, the value is 100%.

The ICT costs (KPI_H04) represent the system development and management required to allow the DEPs to be up and running. Since there are no such systems deployed in real operations, the value is compared to a baseline of zero. Note that as assumption for the demonstration purposes, the costs for the Azure (from DSO side) and AWS (from TSO side) systems are only foreseen by the end of the year. So, in case of roll-out of the solution, these costs need will increase. It is important to highlight that this KPI is the only one that is horizontal to all SUCs, since it covers all the developments, resources and IT infrastructure needed, hence, this analysis is applicable to the remaining SUCs.

[4] This KPI is common and has the same value for all the SUCs.

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4.3. System Use Case 02 (SUC02) demo

4.3.1. Methodology

This SUC focuses on the information exchange between the Aggregator, DSO and TSO regarding flexibility needs from both sides for a short-term timeframe (day-ahead), including procedures taken by each to determine these needs. Nester developed a tool to help the TSO (REN) in order to identify the day-ahead flexibility needs in the TSO/DSO interfaces (EHV/HV substations) and that can also provide the FSPs optimal dispatch to solve the TSO flexibility needs. The tool can be used for single or multi-period studies and can run a stochastic analysis.

This interaction aims at preventing further congestions derived from activation of flexibilities to cover the needs from both actors. The communication between the two DEPs (TDEP and DDEP) is tested via the APIs implemented in both platforms. This SUC includes as well as a scenario in which the information exchange occurs between the Aggregator and the TSO, regarding the exchange of day-ahead available flexibility. The Aggregator computes the aggregated available flexibility connected in each TSO/DSO interface and sends the respective offers to the TSO (do not have price associated, just the power offered up or down). The information exchange in this scenario is performed using the TDEP but also through the OneNet Connector. For more details is recommended the read of the D9.2 [1].

For the second demonstration phase a different study was performed. The TSOs and DSOs undertook comprehensive planning studies to assess and anticipate the dynamic changes in the energy landscape. With a particular focus on the expected increase in photovoltaic (PV) generation, the proliferation of electric vehicles (EVs) and the implementation of Demand Side Response (DSR), new challenges will arouse. The studies in the second demo phase focus in identifying potential congestions within the transmission grid in future network scenarios defined according to the goals and forecasts presented in Plano de Desenvolvimento e Investimento da Rede Nacional de Transporte (PDIRT) [8], Relatório de Monitorização da Segurança de Abastecimento do Sistema Eléctrico Nacional (RMSA) 2022 [9], National Energy and Climate Plan (NECP) [10], ENTSO-E's 10-year network development plan (TYNDP) [11] and devising strategies to ensure the grid's robustness in the face of evolving energy consumption patterns. As for the distribution network, the analysis took into account the targets and projections from the Portuguese NECP, RMSA 2022 and PDIRD-E 2023-2025 [12], focusing on the main variables affecting the operation of the distribution network and an initial analysis on flexibility use cases, namely on the identified needs, addressed in the internal FIRMe flexibility pilot project [13].

4.3.2. Input data from the demo sites

Regarding the SUC02, the data needed for the 2 demo phases differs due to the fact that 2 different analyses were made. In the 1st demo phase real data was exchanged in order to compute the flexibility needs and flexibility potential during the 2 weeks of the 1st demo phase (14/08/2023 – 28/08/2023). For the 2nd demo phase a planning study was carried in order to assess the future needs in the transmission and distribution grids.

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4.3.2.1. 1st Demo Phase

The input data needed for the TSO demonstration:

1. TSO day-ahead grid topology - refers to the representation of the transmission network structure and its expected operating conditions for the following day. This information is used by TSOs to plan and optimize the operation of the grid, ensuring that it can safely and reliably deliver electricity to meet demand;
2. TSO day-ahead load forecast - refers to an estimate of the electricity demand for the following day;
3. Electricity spot market closure results - refers to the final prices and volumes of electricity traded in a spot market for the following day;
4. Power Flow simulation files (.raw) including all the previous information - are data files that store the configuration and operating conditions of an electrical power system. These files are used as input for the "TSO Flexibility Needs Evaluation and FSP flexibility provision simulation" tool.

The input data needed for the DSO demonstration:

1. Complete HV and MV network model – refers to the representation of the HV (60 kV) and MV (30 and 15 kV) network where the DSO has visibility, including the distributed generation;
2. Generation and consumption short-term forecasts computed by an internal DSO tool (PREDIS) –this data is then sent to the DPlan (E-REDES operational planning tool), which then automatically sends the aggregated forecasts to the DDEP;
3. Calculated constraints – the potential constraints are determined after running the network optimization.

The input data needed for the Aggregator demonstration:

1. The location of the substation – This input is required to estimate the grid zone which is the area of influence of the substation. Once the positioning is known, the methodology for flexibility estimation, further described in D9.2 step (9), computes the influence area based on the report by the JRC from the DSO Observatory [14];
2. The location of the flexible assets or installations – Based on these locations and knowing the area of influence estimated in the previous input, it is possible to know which and how many facilities fall within that are to be considered for flexibility availability offers;
3. Load diagrams of the supermarkets/flexibility resources – Historical load diagrams are necessary in order to run the algorithm for flexibility estimation. It is based on these that, the disaggregation, cycles, operating hours and clusters can be identified;
4. Facility activity description with asset identification and asset flexibility classification;
5. Delivery Point Code (CPE) or Client ID for each activation point;

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6. Message exchange format and endpoints to share flexibility availability with SO.

4.3.2.2. 2nd Demo Phase

The input data needed for the TSO demonstration in the 2nd demo phase:

1. Gather relevant information regarding the load and generation trends for future grid scenarios;
2. Identify the developments and investment plans for the transmission grid in the upcoming years;
3. Create the future transmission grid model (.raw);
4. Develop relevant planning scenarios for simulation to assess the future needs in the transmission network.

The input data needed for the DSO demonstration in the 2nd demo phase:

1. Gather relevant information regarding the load and generation trends for future grid scenarios;
2. Gather the relevant flexibility use cases that will be considered in the distribution network development and investment plan (PDIRD-E 2025 [12]), that will comprise the period 2026-2030;
3. Gather the flexibility needs identified for those use cases.

4.3.3. Demo Results

The results of the demonstrator are presented in two sub-sections, where the first sub-section showcases the outcomes related to the information exchange concerning the identification of day-ahead aggregated flexibility needs from both TSO and DSO and the day-ahead flexibility potential from Aggregator. In the second sub-section, the results of the network planning studies are presented based on the goals and trends for 2030.

4.3.3.1. 1st Demo Phase

The main focus of the SUC02 is to TSO and DSO exchange the information regarding the identified the flexibility needs for the next day, aggregated at TSO/DSO interface, in another words, the amount of flexibility they will need to obtain to solve their needs and constraints. The flexibility potential available for the next day is assessed and published by the Aggregator.

4.3.3.1.1. TSO and DSO flex needs

During the 1st demo phase (14th to 28th of August 2023) the TSO computed every day the day-ahead flexibility needs basing on the real data from REN and resorting to the NESTER developed “TSO Flexibility Needs Evaluation” tool.

Below is part of a JSON message exchanged between the TSO and the DSO, comprising the transmission flexibility needs data for one of the demo sites (Pocinho- B6007).

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```
  {
  "sender_source": 1,
  "grid_nodes": [
    {
      "node_id": "B6007",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "2023-08-18T00:00:00+00:00",
      "period_to": "2023-08-18T01:00:00+00:00"
    },
    {
      "node_id": "B6007",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "2023-08-18T01:00:00+00:00",
      "period_to": "2023-08-18T02:00:00+00:00"
    },
    (…)
    {
      "node_id": "B6007",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "2023-08-18T22:00:00+00:00",
      "period_to": "2023-08-18T23:00:00+00:00"
    },
    {
      "node_id": "B6007",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "2023-08-18T23:00:00+00:00",
      "period_to": "2023-08-19T00:00:00+00:00"
    }
  ],
  "created_at": "2023-08-17T16:22:21.544201Z",
  "flex_type": 0
}
```

The message above is stored in the TDEP database and sent to the DDEP where is also stored. The profile of the transmission and distribution flexibility needs are presented in the Figure 4.6 and Figure 4.7, respectively. Once both DEP have the message, it becomes available in the GUI of each DEP, the time-series and the corresponding graphical representation of the flexibility needs, as shown in Figure 4.8 and Figure 4.9 for the TDEP and DDEP, respectively.

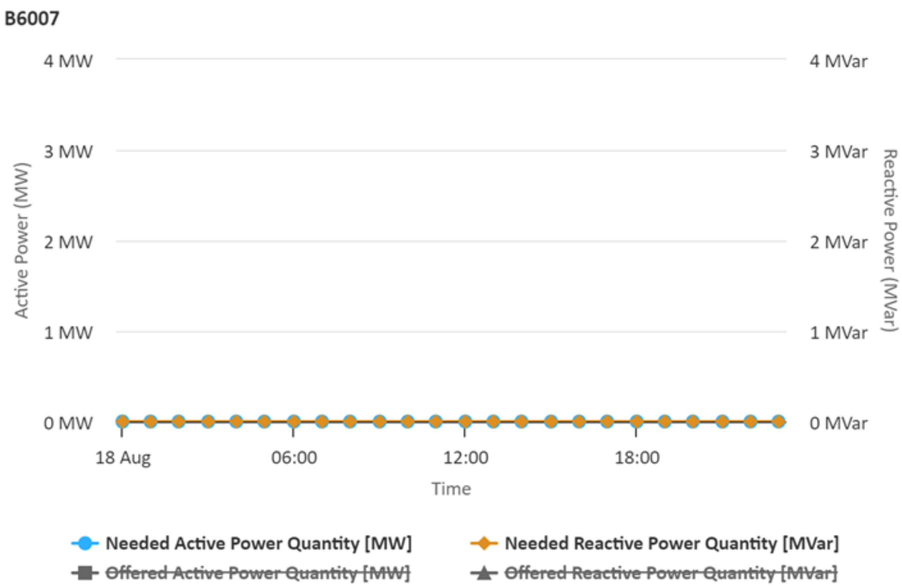

Figure 4.6 - Foreseen TSO flexibility needs at B6007 (Pocinho) demo site for 18th August 2023

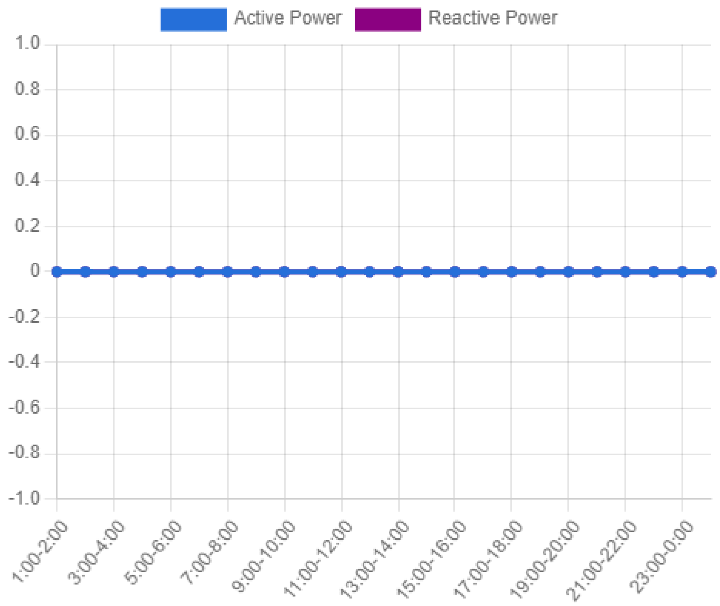

Figure 4.7 – Foreseen DSO flexibility needs at B6007 (Pocinho) demo site for 18th August 2023.

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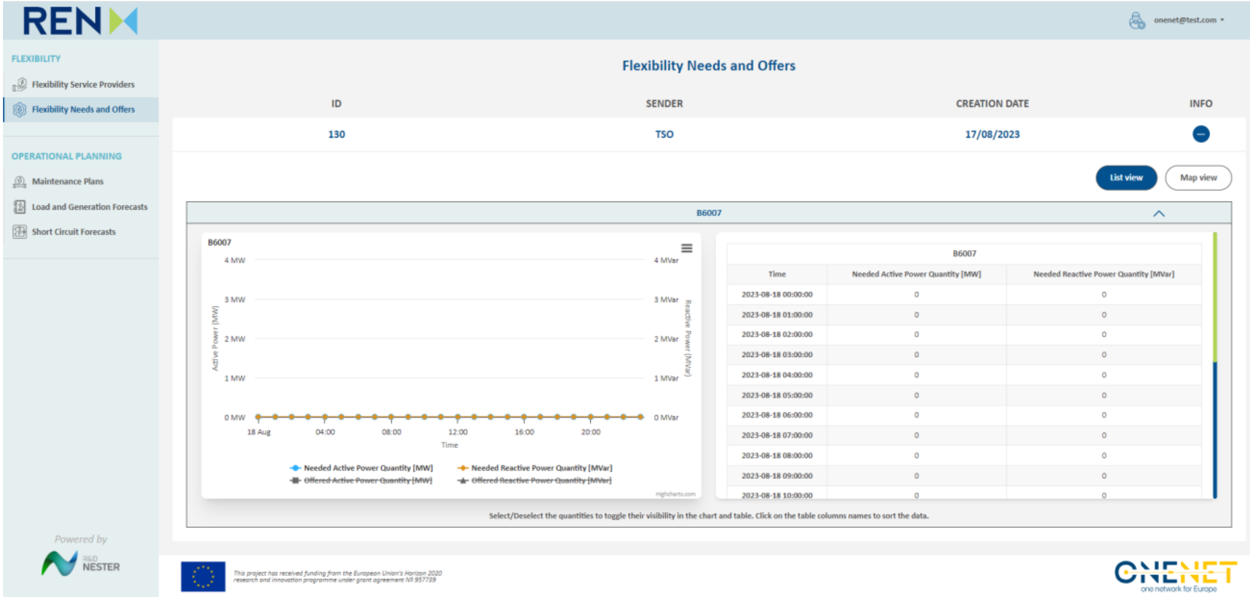

Figure 4.8 - TDEP frontend for the SUC02

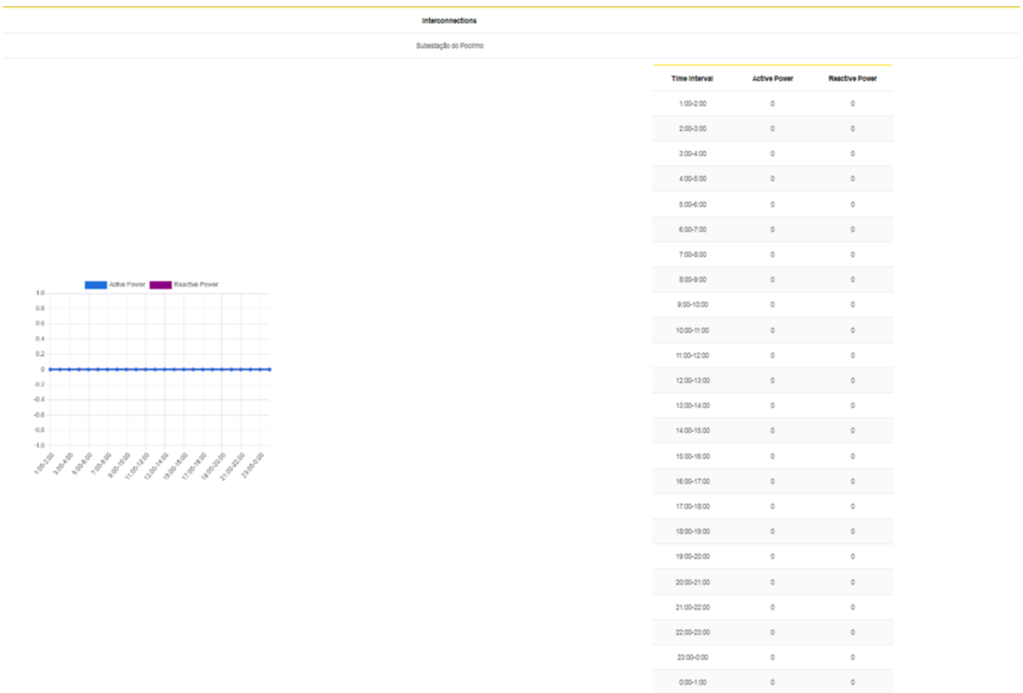

Figure 4.9 - DDEP frontend for the SUC02

During the 1st demo phase no congestion were found in the transmission network during the 2 weeks demonstration period, which results in the absence of TSO flexibility needs for both demo sites under analysis. From the point of view of the information exchange between the internal procedures of the TSO and ultimately the submission of the TSO flexibility needs to the DSO was implemented successfully and the system processes efficiently and within the expected timeframe. The "TSO Flexibility Needs Evaluation and FSP flexibility provision simulation" tool was successfully used and correctly identified potential network constraints. As already mentioned, no congestions were verified in the transmission grid during the entire demonstration period, since the TSO network is planned in a way to avoid congestions, under different scenarios, and TSO can resort to re-dispatching and topology change in order to avoid congestions before activating flexibility units. Apart from that, it is important to highlight that the demonstration took place in August, a period where several industrial loads are not consuming, and hydro power plants are not producing – two types of resources that are predominant in the two substations.

Without any congestions, the need for both flexibility and curtailment are null, meaning that no flexibilities are selected to serve their purpose. This situation leaves several KPIs under this SUC with a null value (as presented in the next sub-section). It is important to note that, although there are no congestions foreseen nowadays (having as basis the 1st demo phase results), they are foreseen to happen increasingly within these next years with increased DER penetration, justifying the need for TSO/DSO coordination in flexibility needs assessment. This is especially true with the increasing integration of non-firm connections into the network that is expected in the coming years.

4.3.3.1.2. Aggregator flexibility potential

The flexibility estimation output is a sum of each supermarket category available flexibility, multiplied by the number of similar supermarkets in each category. The result of the algorithm is a time series with 15-minute intervals and the corresponding active power in each time step. The result is then converted into JSON format in Python and Posted in the TSO's endpoint. Below is an example of the structure sent to the TDEP platform on the 18th of August, during the demonstration:


```
{"sender_source":2,
"grid_nodes
[{"node_id":"B6007",
"active_power_quantity":0.0,
"reactive_power_quantity":0.0,
"period_from":"18/08/2023 00:15",
"period_to":"18/08/2023 00:30"},
{"node_id":"B6007",
"active_power_quantity":0.0,
"reactive_power_quantity":0.0,
"period_from":"18/08/2023 00:30",
"period_to":"18/08/2023 00:45"},
....
```


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An example of the output from the flexibility availability estimation tool is provided in Figure 4.10 for the 18th of August of the Portuguese Demonstration for the Pocinho Substation. Each Post in the System Operator's platform was done automatically at 16h (GMT), signaling a successful Post with a 200, a 400 "Bad Request Error" or 500 "Unable to reach server" error. No errors were verified during the Demo. Each API Post request would generate a log file locally in a txt format, so that the results could be verified if needed.

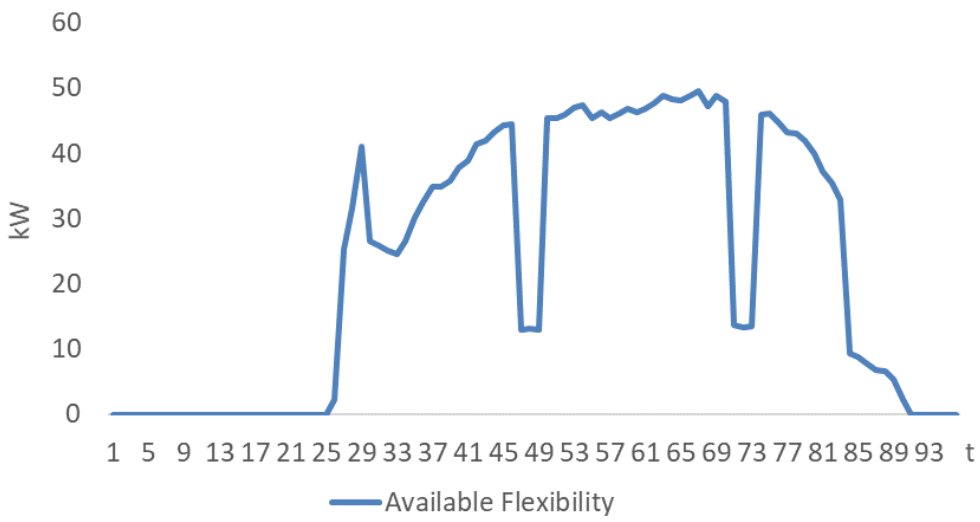

Figure 4.10 - Flexibility estimation example for Pocinho Substation on the 18th of August 2023

From the TDEP side, once the submission of the flexibility availability is successfully received, it is promptly presented in the GUI has shown in the Figure 4.11.

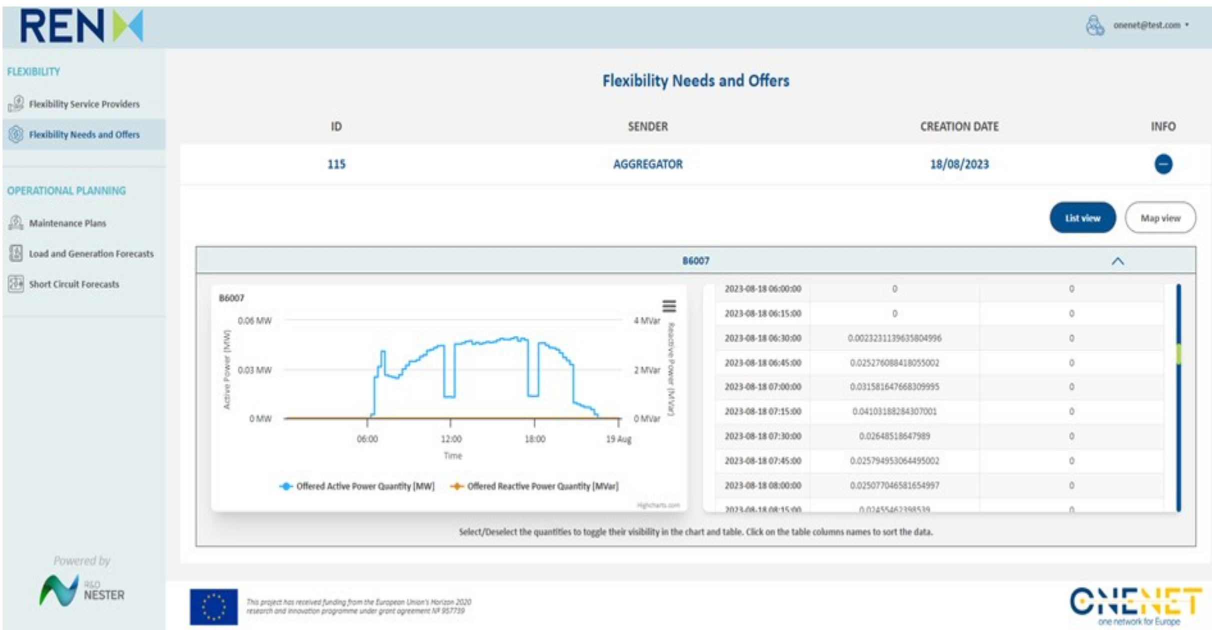

Figure 4.11 - TDEP visualization of flexibility estimation (offers) sent by Aggregator for Pocinho demo site on the 18th of August 2023

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4.3.3.2. 2nd Demo Phase

Regarding what as mentioned in the previous sub-section, the PT demo decided to include an assessment of future planning scenarios in which was emulated possible congestions caused due to the increase or distributed generation and EVs in the grid.

In order to perform this study and to base them on the real expected trends and goals for Portuguese electrical system, the planning scenarios that are analyzed are based on the latest versions of the TYNDP, RMSA, NECP and PDIRT (National Electricity Transmission Network Development and Investment Plan) documents.

Future landscape of the Portuguese electricity system

In July 2020, the Portuguese government approved in the Council of Ministers, the National Energy and Climate Plan for 2030 (NECP 2030) [10], defining the country's climate ambition and setting ambitious targets for GHG emissions, efficiency, and RES integration for the upcoming decade[5]. The Portuguese NECP defines a clear objective of achieving a 47% RES integration in the final consumption (translating in 80% RES incorporation in electricity), alongside a 35% decrease in the primary energy consumption for 2030, that together contribute to the achievement of a GHG emission reduction target of 45-55% compared to 2005 values. One important figure to highlight is that the decrease in the gross final energy demand will happen through a shift to more efficient energy uses, resulting, in most cases in an electrification of demand (e.g., through EV and heat pumps adoption), therefore, to an overall increase of the electricity demand.

To meet these targets, a strong reinforcement of the installed capacity from RES needs to be achieved, and the plan defines a clear route, envisaging an increase of the RES installed capacity by more than 60% (11 GW), comparing to 2022 year-end values, and an overall generation capacity increase by 34% (8 GW). Figure 4.12 portrays the expected evolution of the installed capacity according the Portuguese NECP, together with the electricity demand evolution foreseen by the RMSA-E 2022[6], which is expected to increase by 29% in comparison to 2022 end of the year values.

[5] This analysis considers the current official NECP. A revision of the NECP is to be published to align with the increased FF55 and REPowerEU targets. The draft version of the new NECP sets higher targets, namely, a GHG reduction target of 55% and a 49% target for RES integration.
[6] The RMSA-E 2022 analysis different demand scenarios: central conservative, central ambition and superior ambition. For this report the central ambition scenario was chosen.

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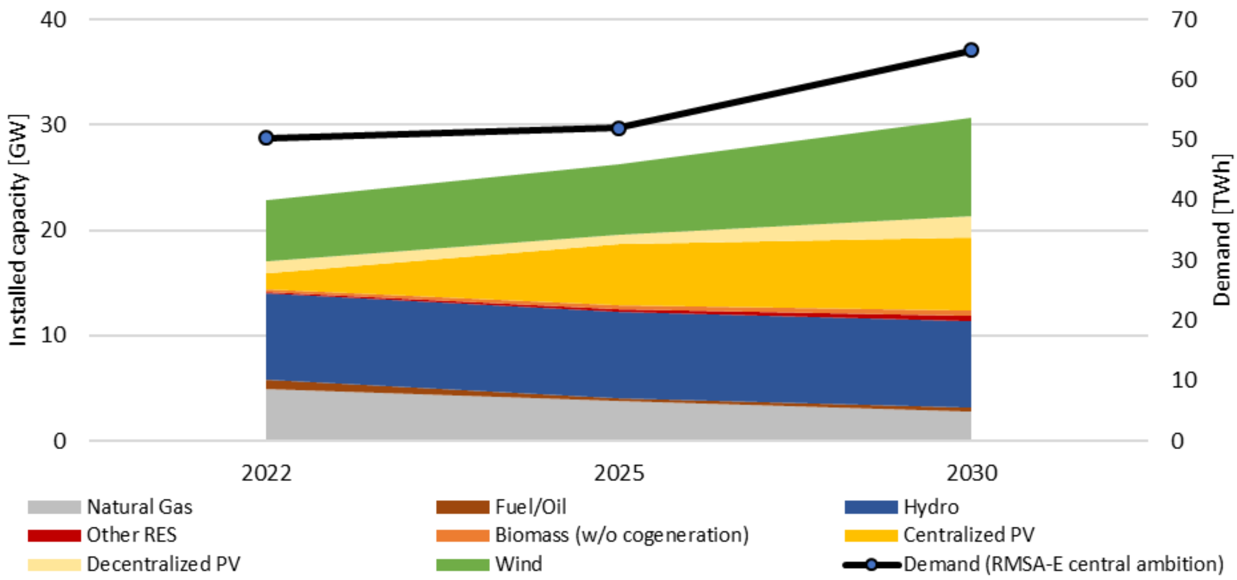

Figure 4.12 - Expected installed capacity by source 2022-2030 according to NECP 2030 and evolution of electricity demand according to RMSA-E 2022.

This landscape, namely the increase in demand, together with the increased penetration of variable RES in the electricity system, solidify the need to increase the flexibility of the overall energy system, allowing both generation and demand to adapt depending on the system's needs. This aspect has been reflected in the national legislation for the electricity system, which has introduced the possibility of allocating injection capacity reserves in the public service electricity network with restrictions (flexible connections), thus promoting the shift from a network planning and management model to an innovative and active management model, in a dynamic, adaptive and flexible way. Complementary to this provision, the cost efficiency of the network development options, both for transmission and distribution networks, have to be investigated, through a cost and benefit analysis, where the need to build new network infrastructure needs to be compared to other viable alternatives, namely the acquisition of flexibility in the market.

In light of these developments and the findings from the first demonstration phase, it is clear that there is a need to analyze the future flexibility requirements of both TSO and DSO in Portugal. Currently, the network planning in Portugal is aimed at preventing congestion, a strategy that has proven effective to date. However, it is anticipated that this scenario will likely evolve in the future, necessitating a forward-looking approach to managing network flexibility. The following sections will dive into this analysis for the TSO and DSO, respectively.

Analysis of future TSO needs

The development of the PDIRT, with a ten-year horizon, must take into consideration, notably, the characterization of the NTS (National Transmission System), the Security of Supply Monitoring Report for the National Electric System (RMSA-E), the safety standards for NTS planning outlined in the Transmission Network Regulation (RRT), requests for capacity enhancement and connection panels formulated by the operator of the

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National Electricity Distribution Network (RND), and the production licenses granted. For the purpose of verifying the adequacy of the transmission network to the demand and forecasting potential necessary investments, the latest PDIRT (2022-2030) uses the more moderate evolution (Central scenario), corresponding to an average annual growth rate of 1.5%. This rate represents a consumption growth, reversing the declining trend recorded in the last two years (-2.1%).

The expected allocation of approximately 1.5 GVA of power for the interconnection of Small Production Units (SPUs), which are units with a capacity of up to 1 megawatt (MW) injecting their entire production into the Public Service Electricity Network (RESP), and whose interconnection is established with the RND, results in a significant increase of inverse energy flows within numerous substations of the National Transmission Network (RNT). This means an increase of oriented flows from the RND to the RNT, orchestrating the transference of energy from areas within the RND characterized by diminished consumption and heightened production to regions where consumption surpasses production. Over time, contingent upon the consumption and production dynamics at each delivery point within the RNT, this interplay can assume diverse manifestations, with the predominant flow direction being from the RND to the RNT in several substations.

The commissioning of this new connected power within the RND imposes an additional burden on the existing EHV/HV substations due to their installed power. In specific substations, the available capacity becomes insufficient, jeopardizing N-1 security concerning the supply of consumptions and potentially fostering overloads within the meshed structure of the VHV network. From the latest PDIRT [8], a reinforcement of the installed transformation power is anticipated in eight of the current substations of the RNT, along with the construction of two new 400 kV transmission lines.

The study carried in this section goes beyond the analysis done by the Portuguese TSO in the scope of the PDIRT, including more ambitious scenarios regarding the demand and distributed generation, with particular focus in the potential impact of solar generation, EVs and SPUs in transmission network. For the mentioned study, the reinforcement of the network is disregarded in favor of the utilization of flexibility potentially available. The main objective of the study is to understand if, in more ambitious planning scenarios, the transmission network is ready to incorporate the challenges caused by the new consumption and production dynamics due to the increasing DERs and EVs, for example.

Table 4.5 - Planning Scenarios tested in the 2nd demo phase for the transmission network

#	Season	Load Regime	Hydro Production	Thermal Production	Wind Production	Solar Production	EVs Regime	Exchange balance
1	Winter	Peak	High	Medium	High	Null	EV 60-40	Export
2	Summer	Intermedium	Low	Low	Low	High	EV 60-40	Export

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Two planning scenarios were built, having as baseline the information published in PDIRT and the goals/forecasts defined in the RMSA-E and NECP. The two scenarios are presented in the Table 4.5.

The charging strategies entail diverse implications at the peak level of the electrical system due to their representation of distinct daily charging profiles. The daily charging profiles considered have two different charging strategies: Direct Charging, where charging is conducted whenever necessary and Valley Charging, where off-peak periods are prioritized for electric EV charging.

For the characterization of peak consumption from the EVs, the two charging strategies were combined to represent two distinct plausible hypotheses regarding the EV behavior:

- EV 20-80: where 20% of light passenger vehicles adopt a Direct Recharging strategy and 80% adopt Valley Recharging. The remaining segments adhere to a similar charging strategy.
- EV 60-40: where 60% of light passenger vehicles adopt a Direct Recharging strategy and 40% adopt Valley Recharging. The remaining segments maintain the charging strategy of 20% Direct Recharging and 80% Valley Recharging.

The penetration of electric vehicles remains a significant growth driver in the demand forecast and impacts the potential growth of peak consumption. This is attributed not only to the expected increase in the electric vehicle stock but also to the charging strategy adopted by consumers and technological advancements observed in the sector.

In the RMSA-E 2022, noteworthy is the consideration of the increment in battery capacity and available charging powers in the market. Within the horizon of 2030, and under a strategy with a greater prevalence of Direct Recharging by light Battery Electric Vehicle + Plug-in Hybrid Electric Vehicle, this situation may contribute an additional 1,600 MW to the peak of the electrical system, according to the Ambition scenario.

The Table 4.6 summarizes the main planning scenarios generation characteristics settled in the simulation environment and the load values considered from the Superior Ambition Scenario set in RMSA-E 2022, for 2030.

Table 4.6 - Load and Generation profile of the 2 simulated scenarios

Scenario	Load [MW]	Hydro Production [MW]	Thermal Production [MW]	Wind Production [MW]	Solar Production [MW]	EVs Regime [MW]
1 – Winter Peak	11490	7924.07	1236.05	5128.80	0	1600
2 – Summer noon	8010	2796.73	1086.30	1206.78	4681.95	1600

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The scenario 1 corresponds to a winter peak scenario for 2030 in which the hydro and wind generation are very high corresponding to 85% of the respective installed capacity of each technology. The thermal production is composed by gas and biomass (cogeneration) units. The scenario 2 correspond to a summer noon scenario for 2030 in which the solar production is high and around the 70% of the solar installed capacity in service.

The study performed consisted in a power flow analysis in order to identify grid constraints caused by the increase of load and generation in the Portuguese TSO network for a superior ambition scenario. The grid model was updated according to the public information existent in the latest PDIRT document.

From the simulation carried for the scenario 1 the results shown that for such an ambitious scenario regarding peak load, the Portuguese grid system would face some issues regarding the reactive power and consequently voltage. The power flow was not able to converge for the scenario presented and since the scope of the Portuguese demonstration is the predictive active power for congestion management this scenario turned out of scope. Nevertheless, it is worthy to mention that the absence of sufficient reactive power injection in transmission grids presents significant challenges to the stability and efficiency of the power system. Reactive power is crucial for maintaining voltage levels, without adequate reactive power support, issues such as voltage instability, increased line losses, and the risk of voltage collapse may arise. The increased integration of renewable energy sources, which may not consistently provide reactive power support due to operation with higher power factor, also contributes to the problem. To address the lack of reactive power, various solutions can be implemented. Installing compensating devices like synchronous condensers, shunt reactors, and static VAR compensators enhances the injection of reactive power into the grid.

From the scenario 2 analysis were identified some grid congestions in branches located in the south of Portugal. All the congestions are mainly caused due to high penetration of solar generation in that area, highlighting the need to curtailment, reinforce the grid or use flexibility available in the area. In the next figures are presented the congestions faced in an anonymized manner in order to not disclose critical information from the Portuguese TSO.

The congestions shown in the Figure 4.13 (Congestion A), the Figure 4.14 (Congestion B) and the Figure 4.15 (Congestion C) have different levels of severity and for those reason different recommended solutions.

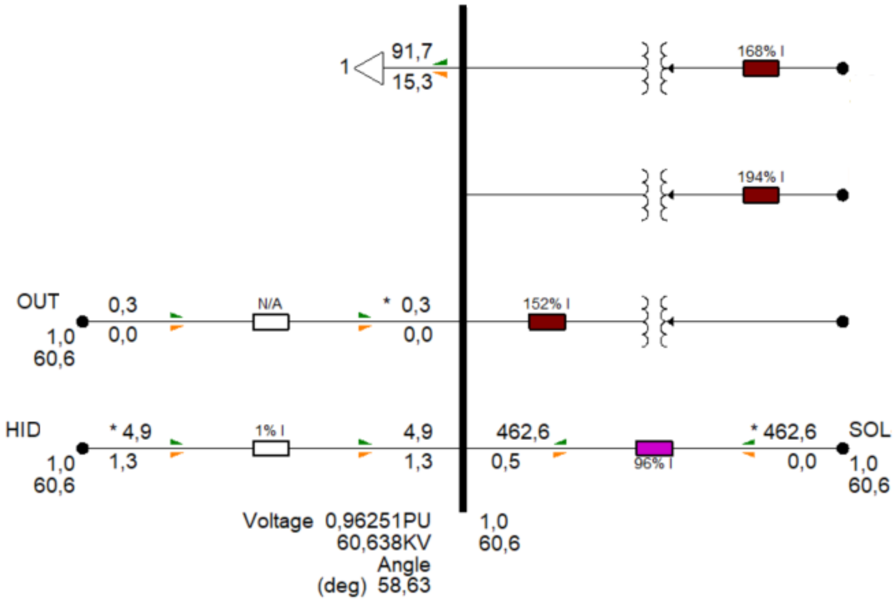

Figure 4.13 - Scenario 2 – Congestion A

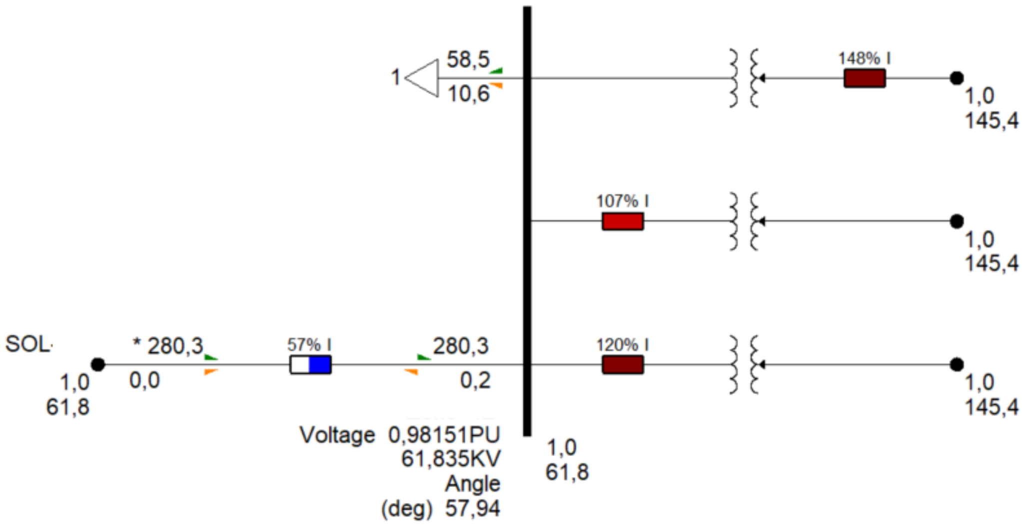

Figure 4.14 - Scenario 2 – Congestion B

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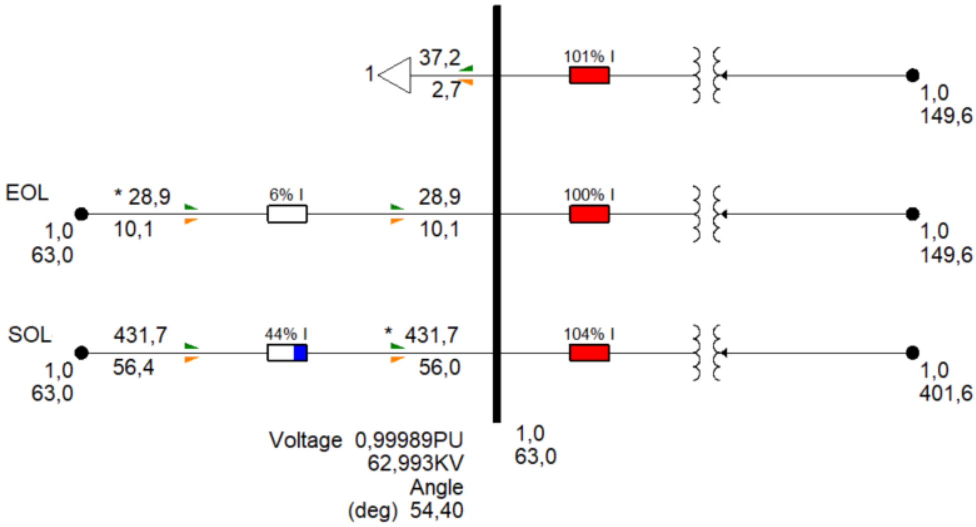

Figure 4.15 - Scenario 2 – Congestion C

In the Congestion scenario A, the overload in one of the transformers of the substation reaches almost 200% of its rated capacity. In this case, the best option to solve this type of congestion is to redispatch/curtail generation or to reinforce the substation with the acquisition of another transformer. For the Congestions B and C since the overloads are smaller, resorting to the "TSO Flexibility Needs Evaluation and FSP flexibility provision simulation" tool is possible to do the exercise of identifying what are the flexibility needs to solve each of the known congestions. In the Figure 4.16 and Figure 4.17 is presented by the "FP" load, the amount of aggregated flexibility required in the 63kV to overcome the Congestion scenarios B and C, respectively.

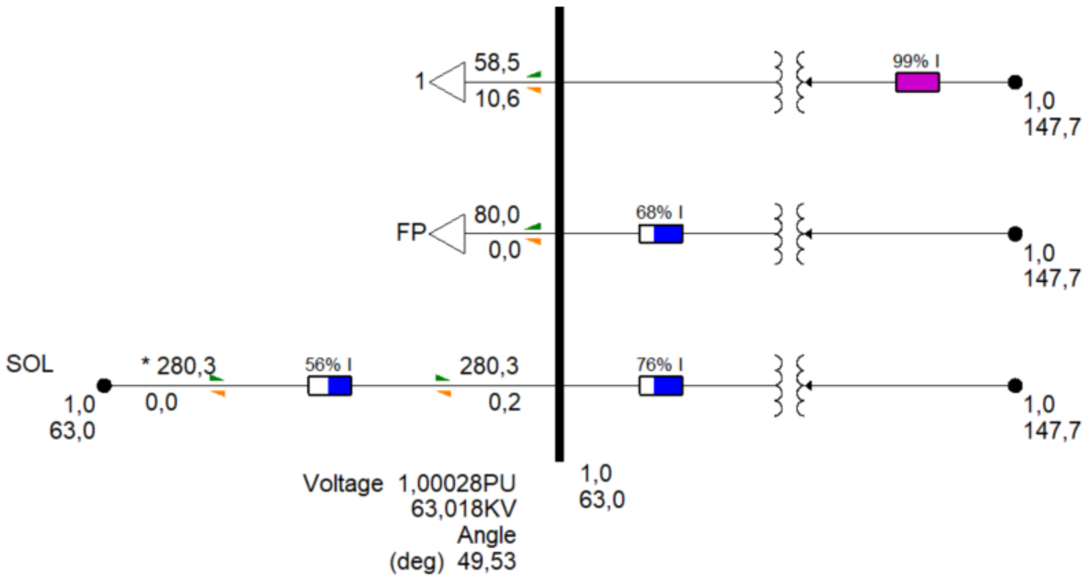

Figure 4.16 - Scenario 2 – Flexibility needed to avoid the Congestion B

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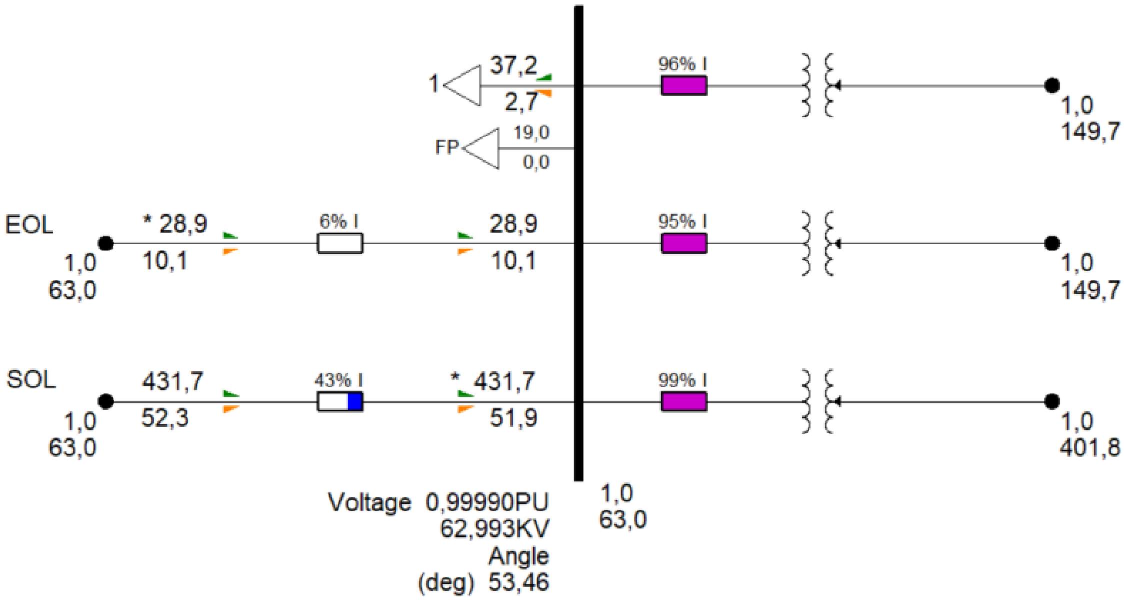

Figure 4.17 - Scenario 2 – Flexibility needed to avoid the Congestion C

From the result for the Congestion scenario B, it would be needed to have 80 MW active power being offered at the 63kV busbar in order to overcome the congestions at the presented substation, caused by the high solar penetration. This value might look considerable high although as stated previously is expected that in 2030, the EVs can contribute to the peak consumption with 1.6 GW, in the ambition scenario. Said that 80 MW of flexibility could probably be offer by an aggregation of multiple EV charging station and in that way provide resilience and reliability to the substation under analysis, avoiding the need of reinforcement or curtailment. For the Congestion scenario C the narrative is exactly the same and even more possible since the flexibility needed is only of 19 MW, for the scenario under analysis.

In conclusion, the planning study conducted for the 2030 TSO network has provided valuable insights into the potential challenges arising from increased load, distributed generation, and the proliferation of EVs. As it is anticipated a surge in demand and a significant rise in renewable energy sources, particularly solar generation, it becomes evident that potential grid congestion is a looming concern.

The identified scenario (Scenario 2) where congestion arises due to the excess of solar generation underscores the importance of proactively addressing these challenges. The traditional grid infrastructure, while robust, may face limitations in accommodating the evolving dynamics of energy consumption and generation. However, our study indicates a promising solution might lie in leveraging the flexibility inherent in EVs and other distributed energy resources.

In summary, our planning study for the 2030 TSO network emphasizes the necessity of proactive measures to address potential congestion, especially in scenarios dominated by excess solar generation, in which are expected some needs of flexibility in the interface TSO/DSO.

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Analysis of future DSO needs

The changes that will occur in the Portuguese national electricity system will be particularly reflective in the distribution network, due to the increasing shift from a centralized energy system to a decentralized one, with increased penetration of distributed energy resources. According to the Connecting the Dots report [15], 70% of the new installed capacity in Europe will be connected to distribution grids. With this assumption and resorting to the historic values for DER installed capacities presented in the PDIRD-E [12], it can be concluded that more than 10 GW (>35%) of the total RES installed capacity will be originated from the distribution network. This shift will happen alongside a change in the demand patterns, with the dual integration of self-consumption installations and EVs, trends that can be observed in Figure 4.18.

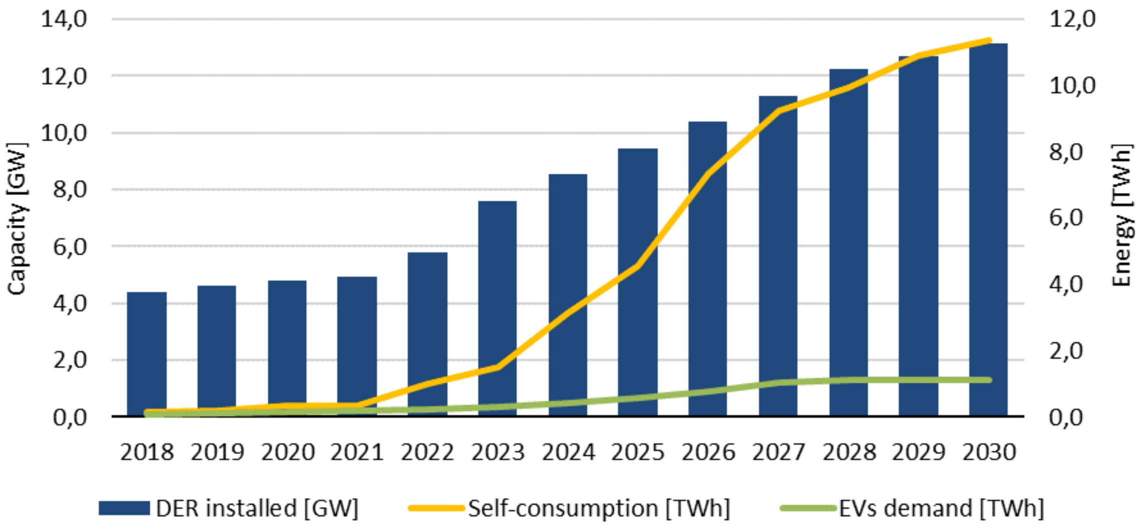

Figure 4.18 - Expected evolution of DER installed capacity, self-consumption and EV demand in the distribution network.

These changes will undoubtedly bring higher complexity to the management and operation of distribution networks since the dynamics of both production and consumption will be harder to predict. Apart from this, the increased electrification of the demand originating from the shift from carbon-based technologies to more efficient and cleaner ones (e.g., EVs and heat pumps) will increase the electricity demand. Resorting to the PDIRD-E demand and synchronous peak demand forecasts for 2027, it is possible to obtain approximate values for 2030, where an increase in both variables is foreseen: the demand and the synchronous peak demand both to increase by ~10% compared to 2022 values (Figure 4.19). Note that the synchronous peak demand increased significantly in 2021 due to a cold wave occurring during January 2021, while the decrease in 2020 was related to the shutdown of several consumers, such as industries and supermarkets, during the pandemic.

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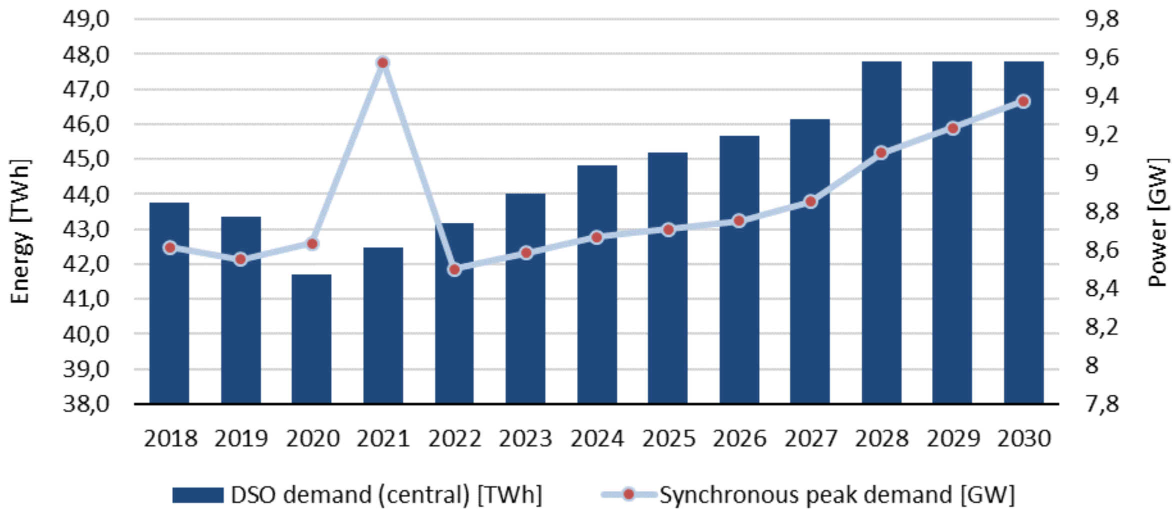

Figure 4.19 - Expected evolution of the electricity demand and the synchronous peak demand in the distribution network.

Thus, it is crucial not only to increase the smartness of the networks, so that a more active management is possible, but to boost the flexibility of the system, adjusting the production and/or consumption to meet the system needs and allow for a more efficient operation. The need to adopt these non-conventional solutions, that can be seen as a way to postpone investments in the physical networks or even to allow more customers to connect to the network until reinforcements are not deployed, is already acknowledged in the PDIRD-E 2023-2025.

In the most recent update of the PDIRD-E, E-REDES aims to explore flexibility solutions, backed by innovative planning methodologies that ensure the system's security and reliability remain uncompromised. Since these solutions are still considered a novel concept with very limited experience worldwide, E-REDES is adopting a bottom-up approach with regular interactions with the national authorities and regulators to define the best track for the cost-effective implementation of these solutions. In that sense, the PDIRD-E anticipates the development of pilot projects to test and validate specific "use cases" already identified, which are crucial for gradually integrating these concepts into the broader scope of the industry.

Answering to the requirement set by the Portuguese legislation to evaluate the cost-benefit of these solutions, in comparison to conventional ones, the forthcoming PDIRD-E will include the results of the cost-benefit analysis for selected use cases. An initial set of use cases has been selected for the first pilot of flexibility in Portugal, which had its first auction and pre-qualification phases in 2023, with the dual goal of both testing the concept with the involvement of FSPs and also to develop internal know-how and capabilities. Note that this pilot derives from an internal E-REDES project (FIRMe) supported by Piclo. These use cases reflect services of which E-REDES sees as relevant to cope with potential faults resulting, for example, from storms, with a request

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from a customer that may overload the system or even with situations where a maintenance work needs to be carried out.

Hence, the following products were considered:

- Restore – answers to events of fault in the system;
- Dynamic – answers to constraints arising during programmed unavailability related to maintenance works of distribution network assets;
- Secure – manages peak demand under normal network operation, allowing the connection of new customers while network reinforcements are not deployed.

Considering these three selected use cases, the required capacity (flexibility needs) that was auctioned summed 55,3 MW for a total of eight locations. The locations selected were the following: São Martinho do Campo, Tondela, Paredes de Coura, Bragança, Bombardeira, Vila Nova de Milfontes, Beja and Marinha Grande. A total of 21 FSPs have made offers to E-REDES, comprising demand side response (mainly industries), producers, aggregators and storage systems. Table 4.7 summarizes the amount of flexibility requested and the total offered by the FSPs for the three different use cases.

Table 4.7 - Flexibility request by E-REDES in the FIRMe pilot for the three selected use cases

Use case / Product	Flexibility requested (needs)	Flexibility offered
Restore	47,7 MW	18,0 MW
Dynamic	5,5 MW	16,0 MW
Secure	2,1 MW	1,9 MW

E-REDES crossed the flexibility offered with its needs, and from the 36 MW offered, 30 MW (82%) will be accepted. It is important to emphasize that both the dynamic and restore products have low probability of being activated, considering that the network has enough redundancy to cope with such events. However, the DSO recognizes that in a situation where this redundancy (the N-1 standard) is compromised or not available, these flexibilities can play a crucial role in maintaining the stability and reliability of the electricity distribution network.

This is analysis is just a first step in the evaluation of the potential and real necessity for the adoption of such flexibility solutions, and the upcoming editions of the PDIRD-E will further explore these solutions to build up the DSO's knowledge on this matter. This approach is particularly relevant when there is substantial uncertainty and unpredictability over the future behavior of the distribution system.

4.3.4. KPI computation

4.3.4.1. 1st Demo Phase

The demo KPIs results for the first demo phase applicable to SUC02 for Pocinho (B6007) substation are presented in Table 4.8.

Table 4.8 - Demo KPI results applicable to SUC02 for Pocinho (B6007) substation.

KPI name	KPI ID	Target Value	Final Value
Reduction in RES curtailment	KPI_H05	0 MWh	0 MWh
Volume of transactions – cleared bids (P or Q Availability)	KPI_H09A	> 10 kW	31,8 kW
Volume of transactions (Power)	KPI_H09B	0 kW	0 kW
Volume of transactions – cleared bids (P or Q Activation) (Energy)	KPI_H09D	0 MWh	0 MWh
Number of avoided technical restrictions	KPI_H12	0 %	0 %
Available Flexibility	KPI_H14A	> 0,1%	0,27 %
Requested flexibility	KPI_H15A	0 MW	0 kW
Total power of avoided congestions through flexibility activation	KPI_N27	0 kW	0 kW

The demo KPIs for the first demo phase applicable to SUC02 for Batalha (B6014) substation are presented in Table 4.9.

Table 4.9 - Demo KPI results applicable to SUC02 for Batalha (B6014) substation.

KPI name	KPI ID	Target Value	Final Value
Reduction in RES curtailment	KPI_H05	0 MWh	0 MWh
Volume of transactions – cleared bids (P or Q Availability)	KPI_H09A	> 10 kW	70,7 kW
Volume of transactions (Power)	KPI_H09B	0 kW	0 kW
Volume of transactions – cleared bids (P or Q Activation) (Energy)	KPI_H09D	0 MWh	0 MWh
Number of avoided technical restrictions	KPI_H12	0 %	0 %
Available Flexibility	KPI_H14A	> 0,01 %	0,04 %
Requested flexibility	KPI_H15A	0 MW	0 MW
Total power of avoided congestions through flexibility activation	KPI_N27	0 kW	0 kW

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For both demo sites (B6007 and B6014), the KPIs computed matched the target values, although most of them are negative due to the lack of congestions in the transmission and distribution network during the 1st demonstration phase period.

The KPI_H09A and KPI_H14A are the one that can be analyzed more in depth, and both are related with the flexibility available from the supermarkets that participated in the study namely the ones connected to the two demo sites mentioned. The KPI_H09A results assess the volume (in kW) of the available flexibility to solve potential grid congestions in Batalha and Pocinho demo sites, during the 2 weeks of the 1st demo phase, and the daily mean value achieved were 70,7kW and 31,8 kW, respectively. The KPI_H14A gives the ratio between the flexible power that can be used for congestion management and the forecasted total power demand. During the 2 weeks of the 1st demo phase, for the Batalha demo site a total of 17,24 MWh was available for flexibility activation and for the Pocinho demo site a total of 7,75 MWh was available.

4.4. System Use Case 06 (SUC06) demo

4.4.1. Methodology

This SUC defines and tests the information exchange between the DSO and TSO regarding maintenance plans from both sides. This involves the exchange of annual maintenance plans (long-term) but also the update and track record of the works closer to real-time (medium-term to real-time). This SUC provides a major improvement in the actual proceedings of the Portuguese SOs in which the communication exchange is done through email in order to share and update the maintenance plans.

TSOs and DSOs must work together to develop maintenance plans that ensure the optimal performance of the energy grid, which is increasingly important due to the integration of renewable energy sources and smart grid technologies. An accurate definition of the maintenance plans is crucial for the operational activities of different stakeholders from consumers to grid operators. This SUC has as the objective to keep track of the maintenance works scheduled and update them when needed, by exchanging more detailed information during different timeframes.

Two scenarios are considered: Year-ahead works programming and Monthly/Weekly/on-event update of maintenance plans. As their names suggest, processes for creating year-long maintenance plans and for close-to-date updates were proposed. Detailed steps are found in D9.2 [1].

4.4.2. Input data from the demo sites

For this SUC, the demo sites considered were both Batalha and Pocinho. In those substations, coordinated maintenance works reduce the unavailability of assets that might impact the performance and security in the operation of the system. Real maintenance plans from 2023 were used in the demonstration period. An initial assessment was required to adapt the information provided by the TSO and DSO into the proposed data model.

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A complete description of the data model is available in D9.2 [1]. However, an initial adaptation of the original information into the proposed data model is seen in the following xml example.


```xml
<UniqueID>MP2023-D-2</UniqueID>
      <WorkDetailsArray>
        <Element-ID>LN60-6233</Element-ID>
        <Owner>0</Owner>
        <Type>3</Type>
        <Last-Update-By>0</Last-Update-By>
        <Voltage-Level>5</Voltage-Level>
        <Long-Name>LN60 6233 SÃO JORGE - MACEIRA - BATALHA (REN)</Long-Name>
        <Case-Type>1</Case-Type>
        <Date-From>2023-04-30</Date-From>
        <Date-To>2023-04-30</Date-To>
        <Time-From>2023-04-30T06:00:00+00:00</Time-From>
        <Time-To>2023-04-30T20:00:00+00:00</Time-To>
        <Work-Period>3</Work-Period>
        <Daily-Replacement>0</Daily-Replacement>
        <Restitution-Time-Working-Days>20:00:00</Restitution-Time-Working-Days>
        <Restitution-Time-Out-of-Working-Days>20:00:00</Restitution-Time-Out-of-Working-Day
s>
        <Cause-of-Request>CB Maintenance</Cause-of-Request>
        <Special-Condition>Line disconnected, isolated and blocked, and earthed at the ends
</Special-Condition>
        <Remarks>Nothing to declare</Remarks>
        <Person-in-Charge>HV South Dispatch TEL:+351XXXXXXXXX</Person-in-Charge>
        <Coordination-Status>2</Coordination-Status>
        <Case-ID-REN>ND</Case-ID-REN>
        <Case-ID-E-REDES>OC204/23</Case-ID-E-REDES>
        <Unavailable-Capacity>0</Unavailable-Capacity>
        <Date-of-Last-Change>2022-01-01T19:40:00+00:00</Date-of-Last-Change>
        <Remarks-from-Receiver>Nothing to declare</Remarks-from-Receiver>
        <Asked-by>ND TEL:+351XXXXXXXXX</Asked-by>
        <Authorization-Sender>ND TEL:+351XXXXXXXXX</Authorization-Sender>
        <Authorization-Receiver>ND TEL:+351XXXXXXXXX</Authorization-Receiver>
      </WorkDetailsArray>
```


After the acceptance of the proposed data model, the TSO and DSO adapted their maintenance plans to it and collected them inside a single csv file for each company.

4.4.3. Demo Results

Inside the TDEP, the corresponding home page is seen in Figure 4.20. From the TSO point of view, the interface covers all the expected functionalities, namely: navigation through all the available maintenance plans in the database, and submission of annual plan and the corresponding validated annual plan containing the contributions from both TSO and DSO.

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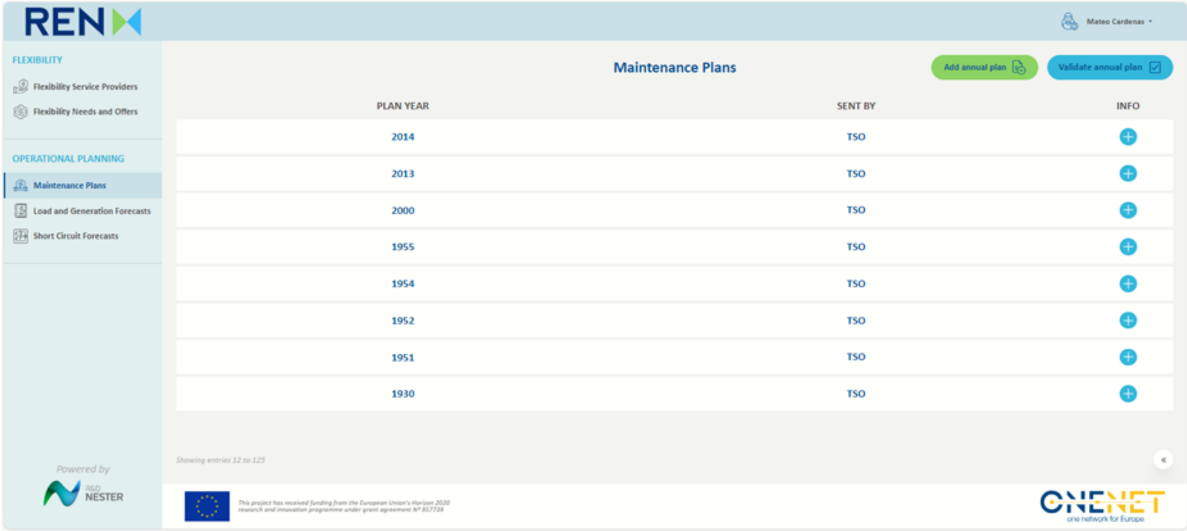

Figure 4.20 - Annual plans submitted to the TDEP (testing environment)

From the DSO point of view, the home page for this SUC is presented in Figure 4.21. All the functionalities described for the TDEP are also available in the DDEP, except the submission of the validated annual plan. The DDEP has a traffic light system to immediately inform the user/operator of the status of each maintenance plan.

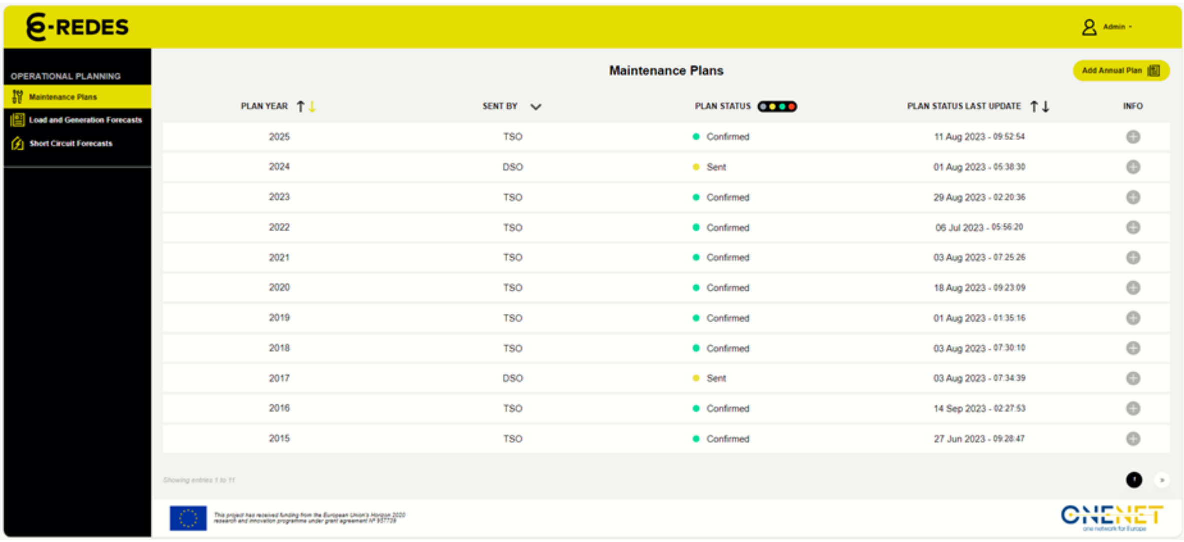

Figure 4.21 - Annual plans submitted to the DDEP (testing environment)

After one of the maintenance plans is selected in either DEP, a Gant view of the content is displayed as presented in Figure 4.22 in the case of the TDEP. This functionality is also foreseen in the DDEP and is presented in Figure 4.23. This view presents all the works inside a maintenance plan, their status, the owner of the asset, last party that updated the work and an eye button that displays a pop-up window with further details as seen in Figure 4.24. In addition, it is possible to update a plan, include a new work in the plan or update an existing work within that plan as shown in Figure 4.24 for the TDEP and Figure 4.25 for the DDEP.

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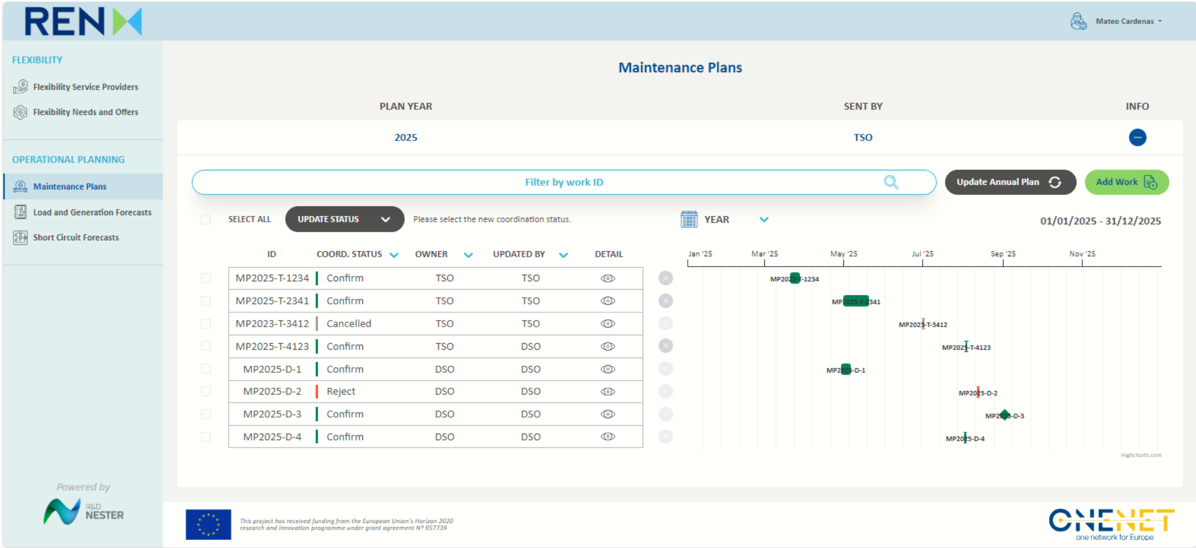

Figure 4.22 - TDEP visualization of all the works included in a certain annual maintenance plan.

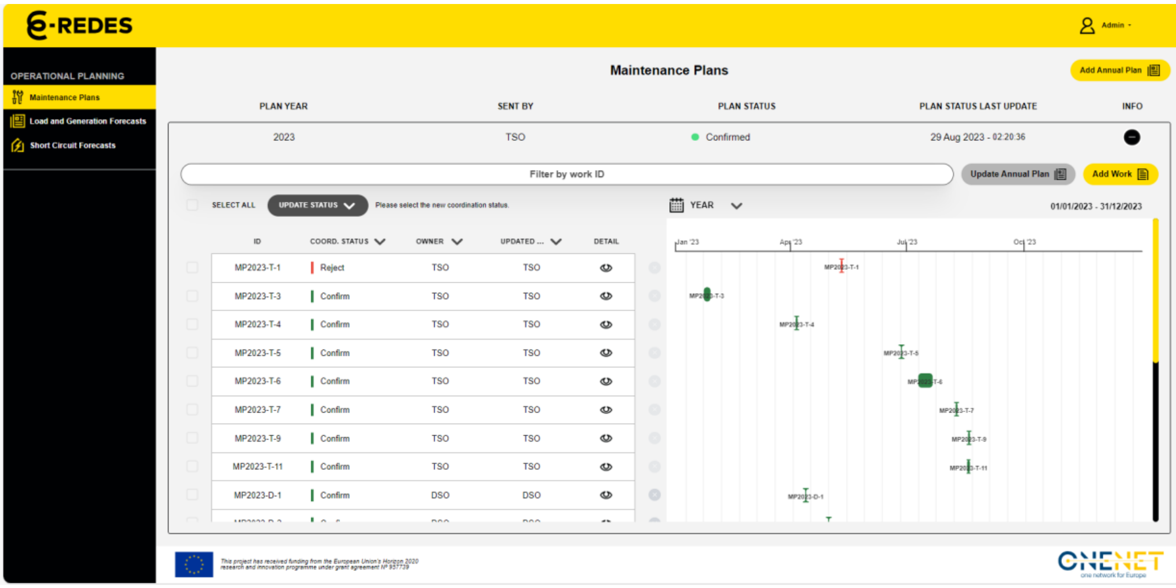

Figure 4.23 - DDEP visualization of all the works included in a certain annual maintenance plan.

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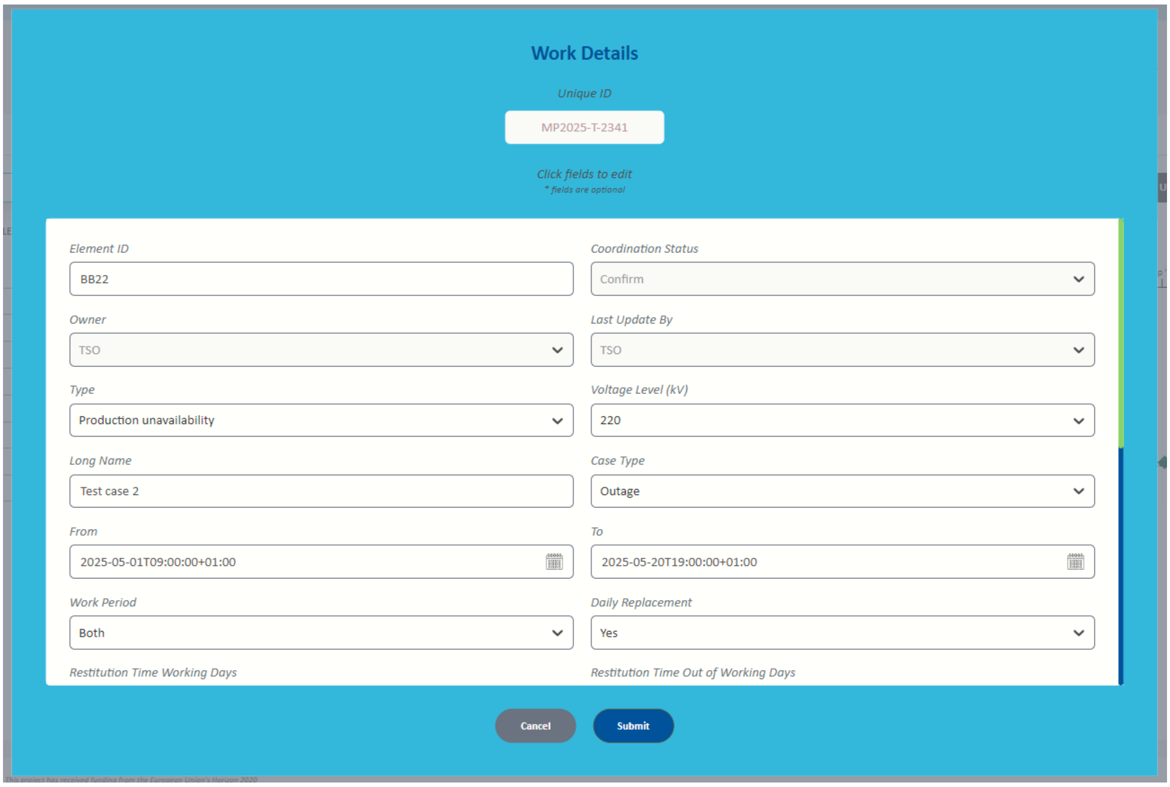

Figure 4.24 - TDEP window to check/change the details of each planned maintenance work.

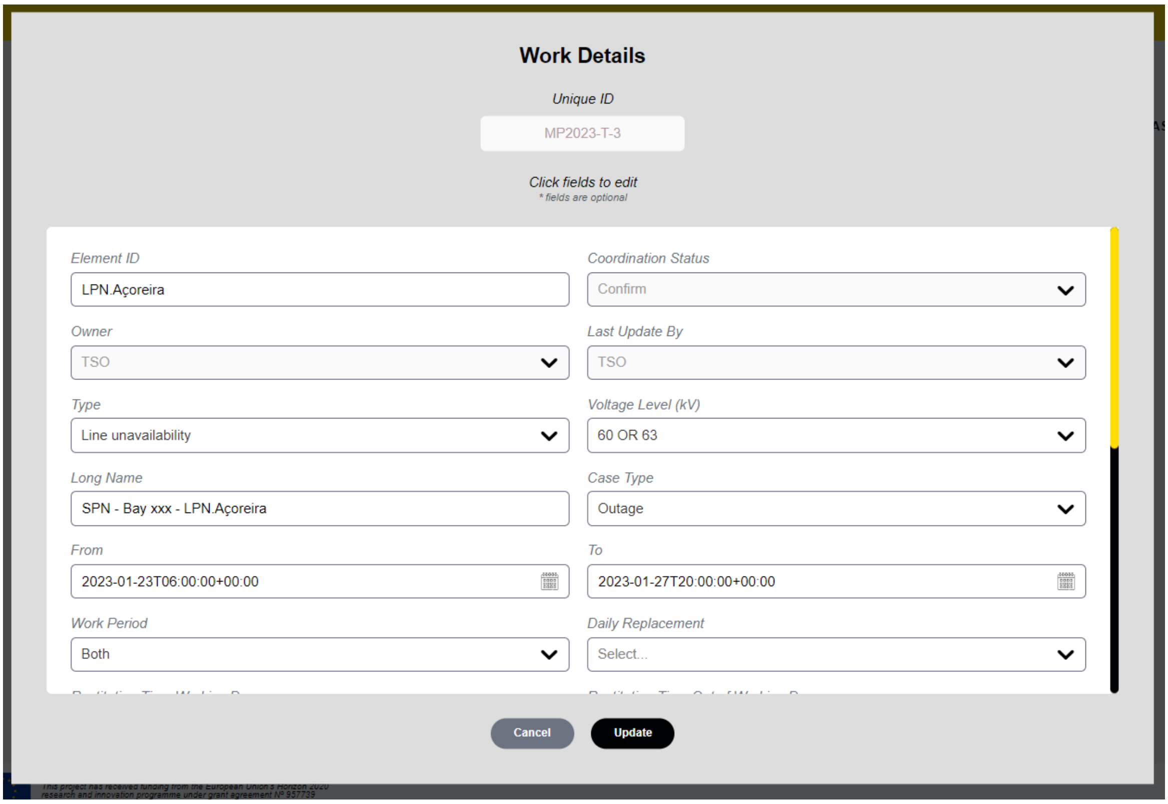

Figure 4.25 - DDEP window to check/change the details of each planned maintenance work.

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After presenting the platforms to be used and considering the csv files described in section 4.4.2, it was possible to develop the scenarios created for this SUC. The previous was defined on a testing procedure describing the whole interactions to be made. The testing procedure is detailed in Appendix SUC06 Functional testing procedure. The presented steps were performed in between the Portuguese TSO (REN) and DSO (E-REDES) with the IT cooperation of R&D NESTER. Every step in the interactions was achieved successfully for both scenarios included in the SUC.

4.4.4. KPI computation

After completing the demonstration described in the previous subsection, it was possible to compute the Demo KPIs applicable to SUC06, which are presented in Table 4.10.

Table 4.10 - Demo KPI results applicable to SUC06

KPI name	KPI ID	Target Value	Final Value
Number of congestions/violations on DSO network	KPI_N31	0	0
Number of congestions/violations on TSO network	KPI_N32	0	0

The yearly maintenance plans were successfully exchanged through both DEPs and the annual maintenance plan was retrieved, including the 2023 works that are relevant for both SOs. For instance, local maintenance works with no repercussion to the connected SO were not communicated. Changes and additions to the existing annual plan were also possible to introduce, directly through the DEPs. There were no technical restrictions identified resulting from the works carried out. For example, from the distribution network point of view, due to the high redundancy of the network, the maintenance works deployed didn't cause any restriction. At the transmission level the maintenance works deployed didn't cause any restriction either.

4.5. System Use Case 07 (SUC07) demo

4.5.1. Methodology

This SUC aims to exchange the consumption and generation aggregated forecasts in the TSO/DSO interface nodes. The forecasts are exchanged from the DSO to the TSO every 24 hours on a day-ahead basis, considering the market clearance results. The data should include the forecast for the next 72 hours, with a 15-minute granularity.

Both the TSO and DSO create their respective generation and consumption forecasts after the market clearance results arrive. Subsequently, the DSO publishes the forecasts files at the DDEP, that will then be posted on the TDEP, so that the TSO is able to compute the error between both forecasts (TSO's and DSO's). A detailed

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description of the SUC and of the different scenarios covered can be found in D9.2 [1]. Hence, in summary, the objectives of this SUC are the following:

- Demonstrate that it is feasible to implement these system processes efficiently and within the expected timeframe.
- Improve TSO and DSO forecast processes by taking into account each other's generation and load forecasts.
- Improve programming of TSO and DSO operation activities.
- Contribute to the improvement of the forecast of technical constraints.
- Receive and send data between system operators in a secure manner.

Hence, the main outcome of this SUC is the improvement of the generation and consumption forecasts, considering the disaggregated forecasts for distribution level resources shared by the DSO on a daily basis.

4.5.2. Input data from the demo sites

This SUC envisages the exchange of consumption and generation 72h-ahead forecasts from the DSO to the TSO. To obtain these output data, the following input data was required during the two demonstration phases:

- Complete HV and MV network model – refers to the representation of the HV (60 kV) and MV (30 and 15 kV) network where the DSO has visibility;
- Generation and consumption forecasts computed by internal DSO tool (PREDIS) –this data is then sent to the DPlan (E-REDES operational planning tool), which then automatically sends the aggregated forecasts to the DDEP.

4.5.3. Demo Results

4.5.3.1. 1st Demo Phase

The SUC07 is essentially focused on the exchanged of disaggregated generation and consumption forecasts from the DSO to the TSO for the following three days, to allow an overall improvement of the forecast from the TSO side. The data is exchanged through XML messages exchanged between the DDEP and the TDEP. An example of this message for the Pocinho substation (B6007) is presented below.


```xml
<Consumption>
  <Time-of-creation>2023-08-23T15:00:00+00:00</Time-of-creation>
  <Start-time-of-data>2023-08-24T00:00:00+00:00</Start-time-of-data>
  <End-time-of-data>2023-08-26T23:45:00+00:00</End-time-of-data>
  <START-TIME-ARRAY>
    <Start-Time-of-Forecast>2023-08-24T00:00:00+00:00</Start-Time-of-Forecast>
    <BUS-ID-ARRAY>
      <BusID>B6007</BusID>
      <GENERATION-LOAD-ARRAY>
```

```
        <Generation-Load-Type>1</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>2</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>3</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>4</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>5</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>6</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>7</Generation-Load-Type>
        <Forecasted-Value>9627</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
      <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>8</Generation-Load-Type>
        <Forecasted-Value>0</Forecasted-Value>
        <SI-Prefix>6</SI-Prefix>
      </GENERATION-LOAD-ARRAY>
    </BUS-ID-ARRAY>
    <BUS-ID-ARRAY>
  </START-TIME-ARRAY>
</Consumption>
```


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The message above is stored in the DDEP database and sent to the TDEP where it is also stored. Both the generation and consumption profiles are presented in the GUI of both DEPs once stored in the databases, as presented in Figure 4.26 and Figure 4.27.

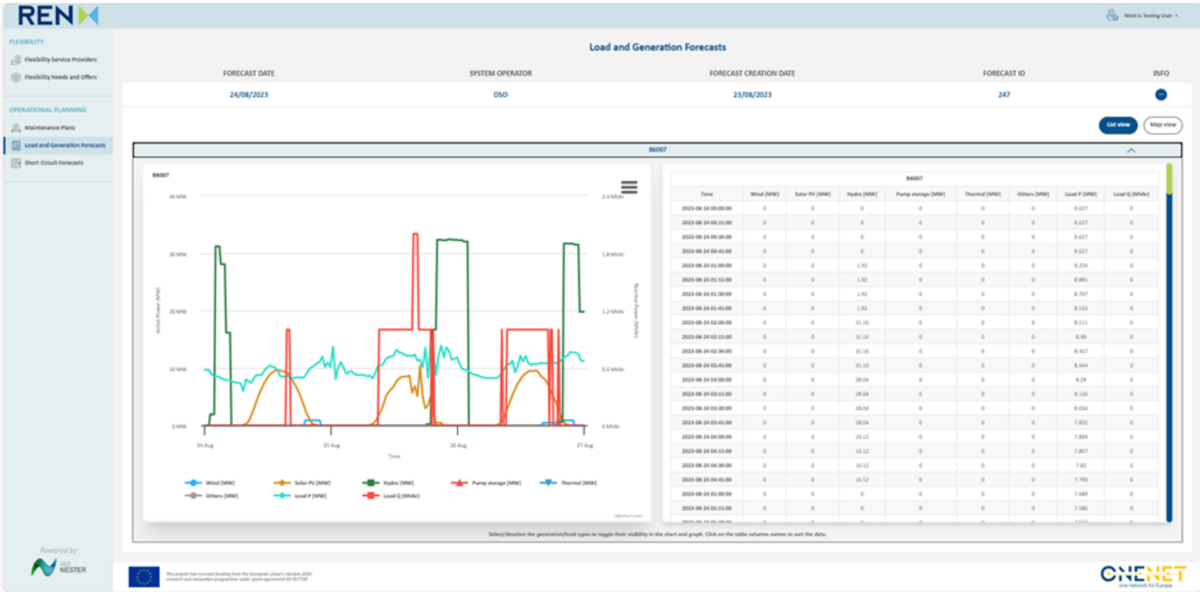

Figure 4.26 - TDEP GUI for SUC07, example for the 24/08, with forecasts for the period between 24/08-26/08.

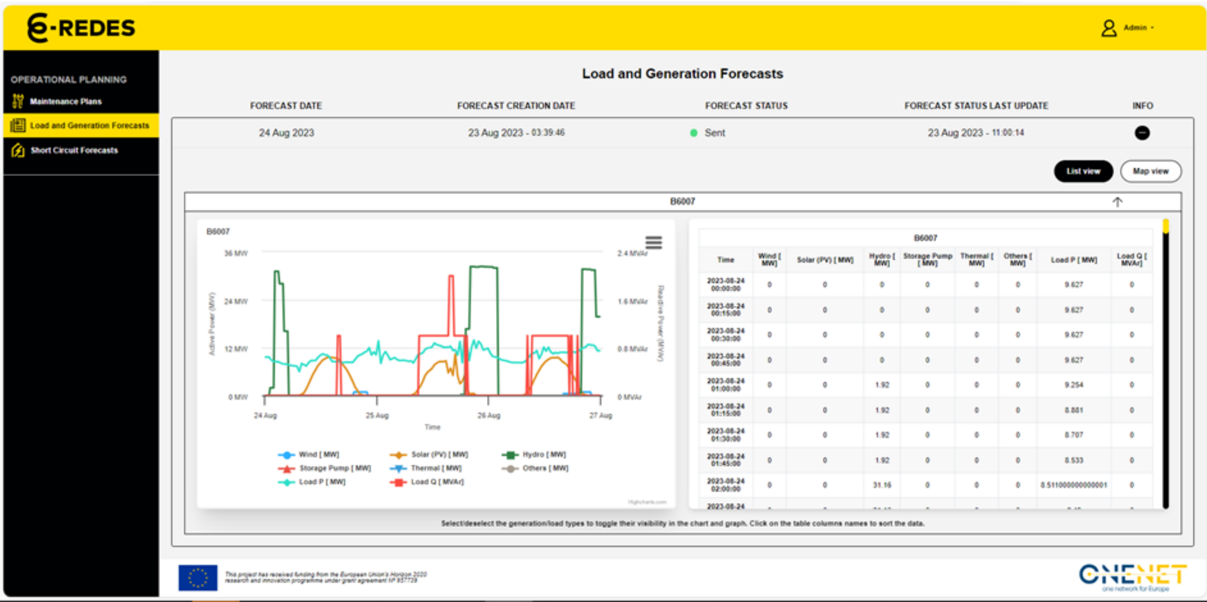

Figure 4.27 - DDEP GUI for SUC07, example for the 24/08, with forecasts for the period between 24/08-26/08.

After this exchange, the forecasts are merged with the TSO forecasts and compared with both the initial forecasts (before the exchange) and the observed values to measure the error and forecast improvement, a result which is presented in section 4.5.4.1 (KPI computation).

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4.5.3.2. 2nd Demo Phase

Similar to the process made during the 1st demo phase, the different forecasts were first prepared by both operators. The DSO compiled them in the corresponding XML format previously defined, stored them in the DDEP database and sent them to the TDEP where it is also stored. Both the generation and consumption profiles are presented in the GUI of both DEPs once stored in the databases, as presented in Figure 4.28 and Figure 4.29. It can be seen that both operators are able to see the same information.

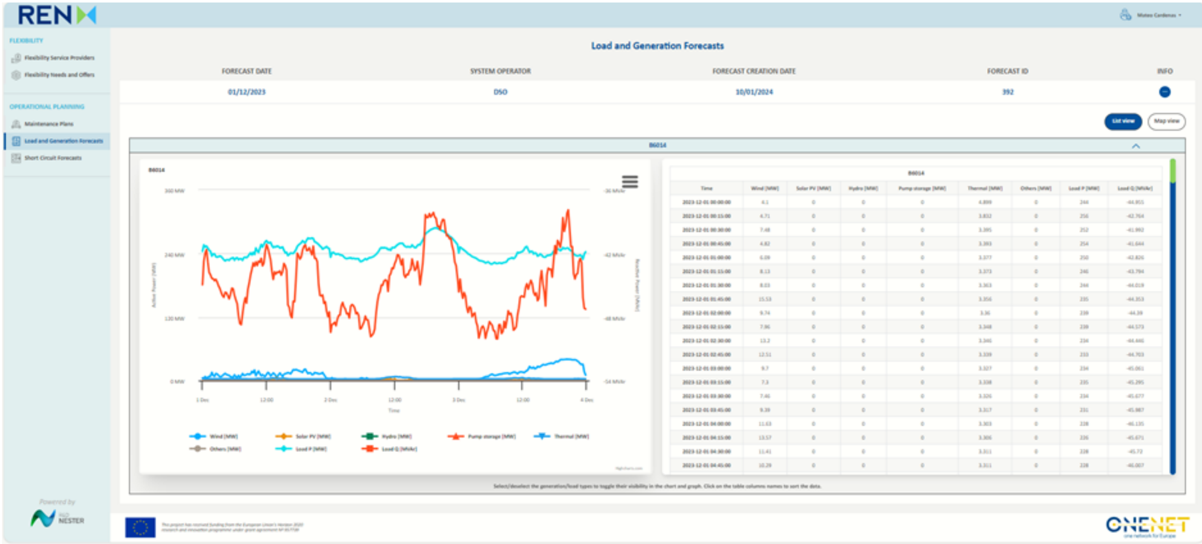

Figure 4.28 - TDEP GUI for SUC07, example for the 01/12, with forecasts for the period between 01/12-03/12.

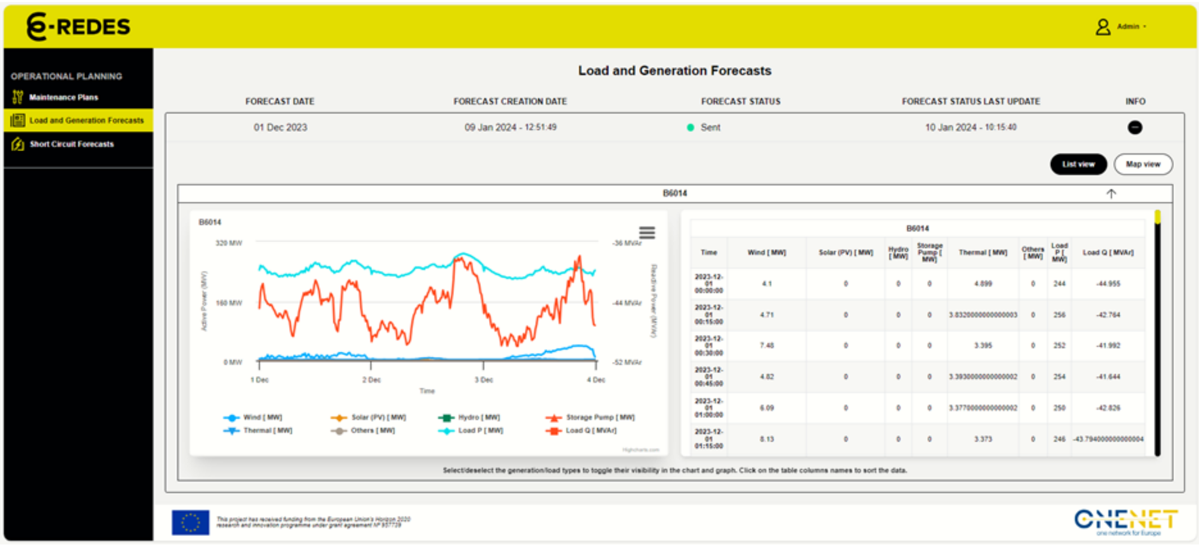

Figure 4.29 - DDEP GUI for SUC07, example for the 01/12, with forecasts for the period between 01/12-03/12.

4.5.4. KPI computation

4.5.4.1. 1st Demo Phase

A summary of the demo KPI results for Pocinho substation that are applicable to SUC07 can be found in Table 4.11 .

Table 4.11 - Computation of demo KPIs applicable to SUC07 for Pocinho substation

KPI name	KPI ID	Target Value	Final Value[7]
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <11,64% Wind: <7,24%	Solar: [1,18; 14,87] %; avg = 4,37% Wind: [1,71; 14,63] %; avg = 5,73%
Error of load forecast calculated 24 hours in advance	KPI_H20B	<54,84%	[2,5; 56,8] %; avg = 20,2%
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [23,0; 87,72] %; avg = 66,42% Wind: [0; 72,89] %; avg = 20,42% Load: [0; 87,5] %; avg = 36,6%

A summary of the demo KPI results for Batalha substation that are applicable to SUC07 can be found in Table 4.12.

Table 4.12 - Computation of demo KPIs applicable to SUC07 for Batalha substation

KPI name	KPI ID	Target Value	Final Value
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <7,87% Wind: <7,58% Thermal: <24%	Solar: [0,63; 3,6] %; avg = 1,9% Wind: [1,96; 22,9] %; avg = 7,46% Thermal: [2,02; 7,18] %; avg = 4,49%
Error of load forecast calculated 24 hours in advance	KPI_H20B	<5,55%	[2,9; 6,6] %; avg = 4,8%
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [47,45; 93,53] %; avg = 74,19% Wind: [0; 30,77] %; avg = 3% Thermal: [68,89; 92,97] %; avg = 80,69% Load: [0; 50] %; avg = 7,2%

[7] Average KPI values

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As a general analysis from SUC07, the data on consumption and generation forecasts was successfully exchanged from the DDEP to the TDEP, allowing the calculation of the KPIs for the SUC. This exchange of information allowed an improvement in the error of the forecast for both RES production (KPI_H20A) and load (KPI_H20B) in both substations, when comparing the final error with the average error of the SOs (target values). Note that, although Pocinho substation has both thermal and hydro production associated to it, these were removed from the analysis due to data quality problems faced during the period of the demonstration.

The error of the daily load forecast calculated 24h in advance for the Pocinho substation had a maximum of 56,8% and a minimum of 2,5% after the information exchanged. Before the information exchange the maximum error was in 182%. This result is atypical because during the demo phase there were maintenance works in this substation that created outliers in the forecast and consequently in the real data. For that reason, this KPIs were really affected because the accuracy of the prediction algorithms was not expecting this change in the consumption profile of the substation caused by load transfer.

Regarding both the maximum and overall share of false positive and negative congestion forecasts, measured by KPI_H28 and KPI_H21, respectively, these are 0, as expected, since no congestions were foreseen for the period under analysis. This relates to the fact that grids are nowadays effectively planned to avoid congestions, however, this scenario is expected to change, as concluded within section 4.3.3.2.

As for KPI_N33, related to the improvement of the forecast, it's noticeable that both solar and thermal generations were the types with higher improvement, standing much higher than both wind and the load, especially in Batalha substation, where the improvements reached were below 10%.

4.5.4.2. 2nd Demo Phase

The results obtained during the 2nd demo phase for the 4 selected substations are collected in Table 4.13 to Table 4.16 for substations Batalha, Mourisca, Portimão and Zêzere respectively. Batalha and Portimão substations do not have hydro generation. The results from Pocinho substation for the 2nd demonstration phase are not included in this deliverable, since there were identified several issues in the modelling of the network, as Pocinho substation forms a mesh network with three other substations, and no solution to solve this situation was found in a timely manner. However, for exploitation purposes the parties involved will seek to solve this issue, namely to isolate Pocinho and the relevant network by opening the mesh.

Table 4.13 - Computation of demo KPIs applicable to SUC07 for Batalha substation (2nd demo phase)

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KPI name	KPI ID	Target Value	Final Value[8]
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <2,26% Wind: <10,67% Thermal: <8,9%	Solar: [0,21; 5,05] %; avg = 2,12% Wind: [0,72; 19,30] %; avg = 10,09% Thermal: [0,71; 8,04] %; avg = 2,94%
Error of load forecast calculated 24 hours in advance	KPI_H20B	<7,20%	[6,30; 10,39] %; avg = 6,16%
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [0; 79,17] %; avg = 7,71% Wind: [0; 78,57] %; avg = 9,42% Thermal: [0; 91,70] %; avg = 46,23% Load: [0; 62,28] %; avg = 8,46%

Table 4.14 - Computation of demo KPIs applicable to SUC07 for Mourisca substation (2nd demo phase)

KPI name	KPI ID	Target Value	Final Value[9]
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <2,77% Wind: <11,34% Thermal: <19,93% Hydro: <27,86%	Solar: [0,41; 6,51] %; avg = 2,75% Wind: [0,12; 9,73] %; avg = 3,44% Thermal: [4,20; 11,25] %; avg = 7,62% Hydro: [12,87; 69,95] %; avg = 27,25%
Error of load forecast calculated 24 hours in advance	KPI_H20B	<9,93%	[3,89; 11,91] %; avg = 6,69%
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [0; 1,88] %; avg = 0,69% Wind: [13,04; 98,07] %; avg = 67,47% Thermal: [0; 82,96] %; avg = 56,59% Hydro: [0; 6,92] %; avg = 0,94% Load: [0; 82,62] %; avg = 12,60%

[8] Average KPI values
[9] Average KPI values

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Table 4.15 - Computation of demo KPIs applicable to SUC07 for Portimão substation (2nd demo phase)

KPI name	KPI ID	Target Value	Final Value[10]
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <10,85% Wind: <9,37% Thermal: <28,55%	Solar: [0,56; 15,71] %; avg = 10,81% Wind: [0,22; 6,92] %; avg = 3,05% Thermal: [3,10; 11,39] %; avg = 9,28%
Error of load forecast calculated 24 hours in advance	KPI_H20B	-	-
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [0; 63,66] %; avg = 2,55% Wind: [41,08; 89,85] %; avg = 65,61% Thermal: [46,43; 82,11] %; avg = 66,32% -

Table 4.16 - Computation of demo KPIs applicable to SUC07 for Zêzere substation (2nd demo phase)

KPI name	KPI ID	Target Value	Final Value[11]
Error of the RES production forecast calculated 24 hours in advance	KPI_H20A	Solar: <4,77% Wind: <9,90% Thermal: <19,25% Hydro: <33,12%	Solar: [0,36; 8,28] %; avg = 4,66% Wind: [1,18; 9,55] %; avg = 6,00% Thermal: [3,01; 25,91] %; avg = 19,25% Hydro: [5,54; 64,79] %; avg = 32,81%
Error of load forecast calculated 24 hours in advance	KPI_H20B	<23,51%	[3,69; 24,89] %; avg = 9,76%
Maximum ratio of false-positive and negative congestion forecasts	KPI_H28	0%	0%
Share of false positive and negative congestion forecasts	KPI_H21	0%	0%
Improvement of forecast	KPI_N33	>0%	Solar: [0; 80,51] %; avg = 5,90% Wind: [0; 73,04] %; avg = 36,88% Thermal: [0; 0] %; avg = 0% Hydro: [0; 35,76] %; avg = 2,76% Load: [0; 82,06] %; avg = 32,99%

For the 2nd demo phase, the data exchange platforms developed proved to be stable and reliable in terms of multiple submission and updates of the files. In addition, usability was reported adequate for the goals of the SUC.

[10] Average KPI values
[11] Average KPI values

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In general terms, solar forecast presented the least error compared to the other technologies and, therefore, the improvement in the forecast after the exchange was small. On the other hand, wind presented more errors in the forecast than solar, but it had the most improvement after the exchange of information. Thermal and Hydro forecast represented a challenge for the comparison of results given that some of those installations are protected in terms of data privacy which caused the observability to be different in each side of the interface. Apart from this, it's also important to highlight that the DSO is considering additional sources then the ones considered from the TSO side (mainly cogeneration), such as biomass and solid residues, and since there is no distinction on the type of resources in internal databases, these additional sources were not removed from the data submitted and were stacked within the "Thermal" category. After this was recognized, some adjustments were required to collect aggregated and not specific data which helped getting the results here provided. Once again, the exchange of information proved to key in the improvement of the forecasts.

Load analysis in Portimão was not included due to the observability that both operators have on the interface that resulted in not comparable profiles.

On a more generic analysis, there have been identified several challenges during the developments and demonstration that will be addressed after the project to maximize the quality of the results in a subsequent exploitation phase. Namely, one of the most important one is related to absence of data on the generation load profiles, with several sites located at the MV network missing generation load profiles. There were also a few consumption sites without load profiles, but the quality procedures implemented have minimized the number of delivery points without load profile.

It is also important to mention that for the distribution network the simulation was executed assuming the standard configuration and that shunt capacitors operation schedule may have not been modelled accurately. This may affect the power flow, mostly regarding the reactive power due to capacitators. Lastly, network model issues were identified, with the most critical ones having been corrected (like the ones affecting the connectivity to client sites), although a few minor ones maybe continue to exist.

4.6. System Use Case 08 (SUC08) demo

4.6.1. Methodology

This SUC aims to exchange the forecasts of short circuit currents in the TSO/DSO interface nodes. The forecasts are exchanged between both the SOs every 24 hours on a day-ahead basis, considering the market clearance results. The data should include the forecast for the next 24 hours, with a granularity of 30 minutes.

After the market clearance results arrive, TSO computes the forecast of short circuit currents from EHV network and HV consumers, connected directly to TSO, creates the XML file and posts on the TDEP, TDEP automatically post the file on the DDEP, where DSO can retrieve this file. Then DSO, using the forecasted short circuit currents from TSO, computes the forecast of short circuit currents from active HV network, updates the

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file and post on DDEP, DDEP automatically post the file to TDEP, where TSO can retrieve updated file so that the TSO is able to compute the KPIs. For more detailed information is recommended the reading of D9.2 [1].

4.6.2. Input data from the demo sites

The input data needed for the TSO demonstration:

1. TSO day-ahead grid topology - refers to the representation of the transmission network structure and its expected operating conditions for the following day. This information is used by TSOs to plan and optimize the operation of the grid, ensuring that it can safely and reliably deliver electricity to meet demand;
2. TSO day-ahead load forecast - refers to an estimate of the electricity demand for the following day;
3. Electricity spot market closure results - refers to the final prices and volumes of electricity traded in a spot market for the following day. In this case the most important information is just to know which will be the generation units in service and consequently the ones that will affect the short-circuit currents;
4. Power Flow simulation files (.raw) including all the previous information - are data files that store the configuration and operating conditions of an electrical power system. These files are used as input for the “Short-Circuit Currents Forecast Tool”.

The input data needed for the DSO demonstration:

1. Complete HV and MV network model – refers to the representation of the HV (60 kV) and MV (30 and 15 kV) network where the DSO has visibility. For determining the short-circuit contributions, standard impedances were applied in the modeling of the equivalent generators of electrical production installations given the scarcity of technical information on the equipment, in particular on generators.
2. Generation and consumption forecasts computed by internal DSO tool (PREDIS) –this data is then sent to the DPlan (E-REDES operational planning tool), which then automatically sends the aggregated forecasts to the DDEP.

The results of the Short-Circuit Currents Forecast Tool are filled into an XML data model agreed between the TSO and DSO. In the example presented next, it is possible to see a snippet of the 5 demo sites short-circuit forecast results for 10/12/2023.


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4.6.3. Demo Results

In the next sections the results for the first demo phase (14/08/2023 – 28/08/2023) and the second demo phase (27/11/2023 – 22/12/2023) are presented.

4.6.3.1. 1st Demo Phase

The first demo phase contains 720 data points (360 hours with granularity of 30 minutes) for 2 substations, 1440 data points in total, of which:

- 888 (61,7% of total forecasted data points) relate to the data points with short-circuit current contribution from HV consumers, connected directly to TSO network;
- 723 (50,2% of total forecasted data points) relate to the data points with short-circuit current contribution from active HV DSO network is 723

Figure 4.30 presents the results gathered during the first demo phase for Pocinho substation, for which we can highlight the following aspects:

- The forecasted short-circuit current contribution do not surpass the maximum value from PDIRT (20,2 kA) and lower than the short-circuit rating of circuit breakers (31,5 kA).

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- The maximum value of the total short-circuit current contribution is approximately 95,8% of the maximum value from PDIRT.

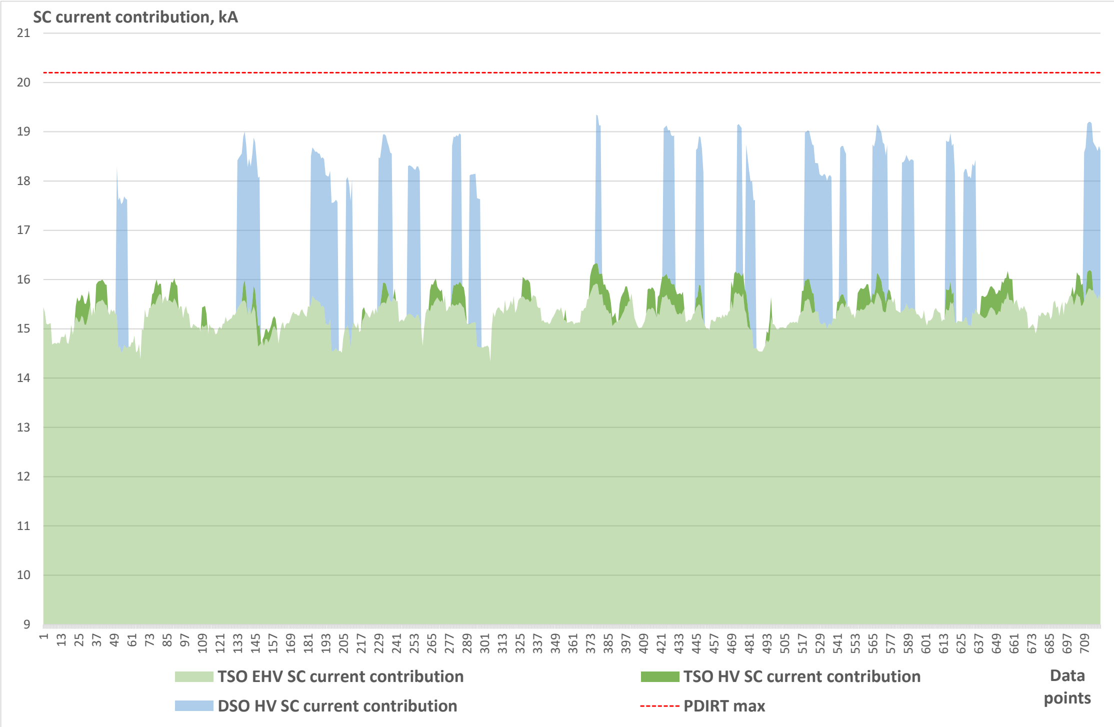

Figure 4.30 - Short-circuit current contribution for Pocinho substation in the first demo phase period.

Figure 4.31 presents the results gathered during the first demo phase for Batalha substation, for which we can highlight the following aspects:

- The maximum value of the short-circuit current contribution from HV consumers, connected directly to TSO network, is 1,799 kA, which corresponds to 7,7% of the total short-circuit current contribution from TSO side;
- The maximum value of the short-circuit current contribution from active HV DSO network is 4,2 kA, which corresponds to the maximum of 17% of the total short-circuit current contribution in observed substation;
- The forecasted short-circuit current contribution surpass the maximum value from PDIRT (27,5 kA) 139 times out of 720 data points, which corresponds to 19,3% of the total time of the first demo phase period. It is important to note, that the forecasted short-circuit current contribution surpass the maximum value from PDIRT only when contribution from active HV DSO network exists.

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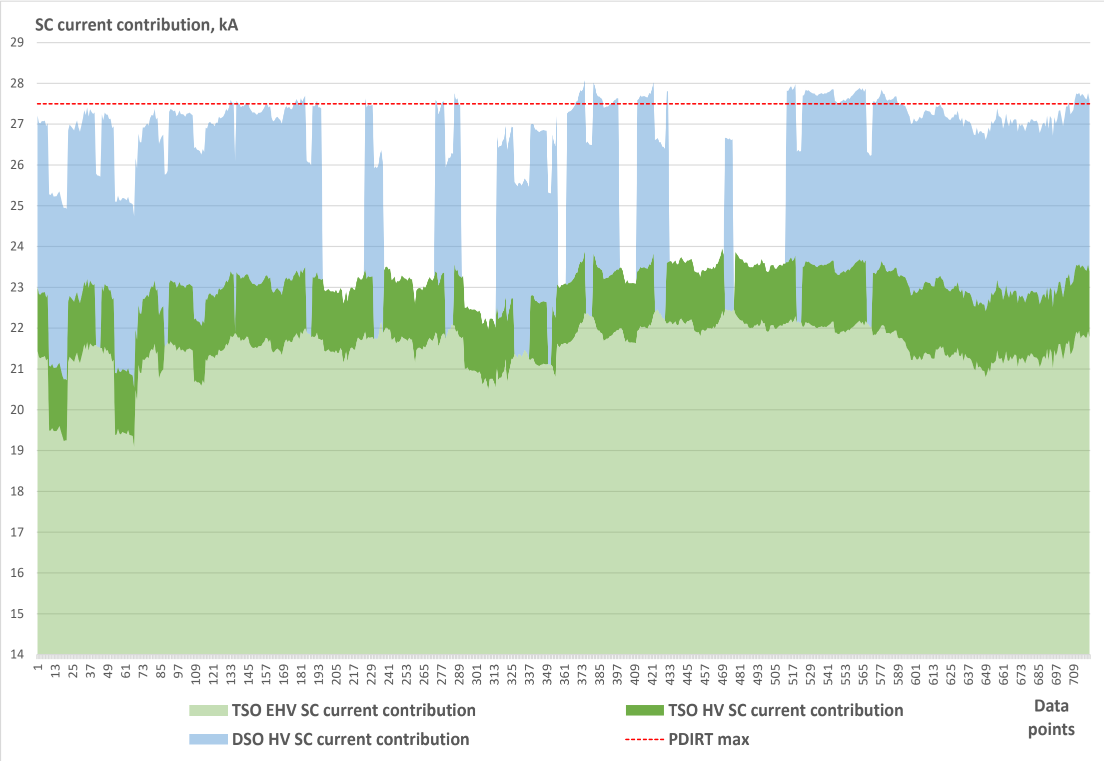

Figure 4.31 - Short-circuit current contribution for Batalha substation in the first demo phase period.

4.6.3.2. 2nd Demo Phase

The second demo phase contains 1248 data points (624 hours with granularity of 30 minutes) for 5 substations, 6240 data points in total, of which:

- 1984 (31,8% of total forecasted data points) relate to the data points with short-circuit current contribution from HV consumers, connected directly to TSO network;
- 6240 (100% of total forecasted data points) relate to the data points with short-circuit current contribution from active HV DSO network.

Figure 4.32 presents the results gathered during the second demo phase for Batalha substation, for which we can highlight the following aspects:

- The maximum value of the short-circuit current contribution from HV consumers, connected directly to TSO network, is 1,788 kA, which corresponds to 6,787% of the total short-circuit current contribution from TSO side;
- The forecasted short-circuit current contribution surpasses the maximum value from PDIRT (27,5 kA) 285 times out of 1248 data points, which corresponds to 22,8% of the total time of the second demo phase period. It is important to note that the forecasted short-circuit current contribution surpasses the maximum value from PDIRT only when considering the contribution from active HV

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DSO network. The maximum value of the total short-circuit current contribution is 28 kA, which corresponds to approximately 101,96% of the maximum value from PDIRT. However, the forecasted short-circuit current contribution does not surpass the short-circuit rating of circuit breakers (31,5 kA) in the observed period and reaches 89%.

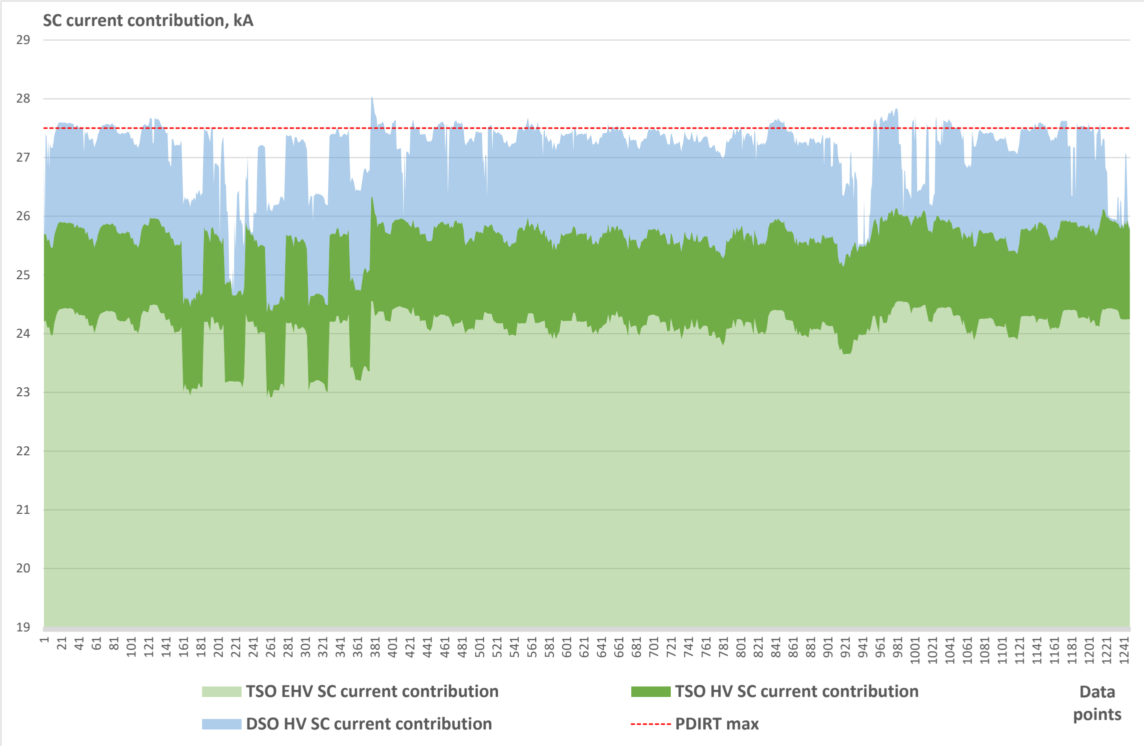

Figure 4.32 - Short-circuit current contribution for Batalha substation in the second demo phase period

Figure 4.33 presents the results gathered during the second demo phase for Portimão substation, for which we can highlight the following aspects:

- The maximum value of the short-circuit current contribution from active HV DSO network is 4,709 kA, which corresponds to the maximum of 28,2% of the total short-circuit current contribution in observed substation;
- The forecasted short-circuit current contribution surpasses the maximum value from PDIRT (14,5 kA) 1043 times out of 1248 data points, which corresponds to 83,6% of the total time of the second demo phase period. The forecasted short-circuit current contribution surpasses the maximum value from PDIRT only when considering the contribution from active HV DSO network.
- The maximum value of the total short-circuit current contribution is 17,7 kA, which corresponds to approximately 121,8% of the maximum value from PDIRT. However, the forecasted short-circuit current contribution does not surpass the short-circuit rating of circuit breakers (31,5 kA) in the observed period and reaches 56%.

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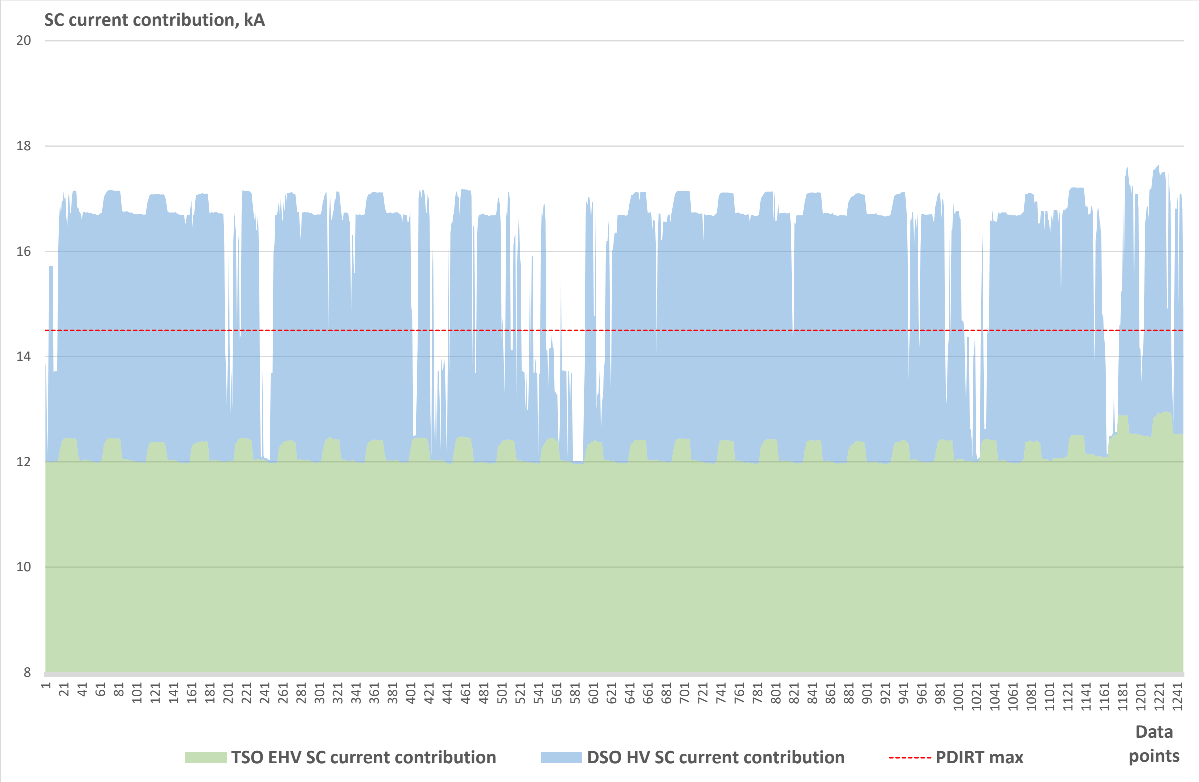

Figure 4.33 - Short-circuit current contribution for Portimão substation in the second demo phase period

Figure 4.34 presents the results gathered during the second demo phase for Zêzere substation, for which we can highlight the following aspects:

- The forecasted short-circuit current contribution does not surpass the maximum value from PDIRT (20,5 kA) and lower than the short-circuit rating of circuit breakers (31,5 kA).
- The maximum value of the total short-circuit current contribution is 20,1 kA, which corresponds to approximately 97,98% of the maximum value from PDIRT.

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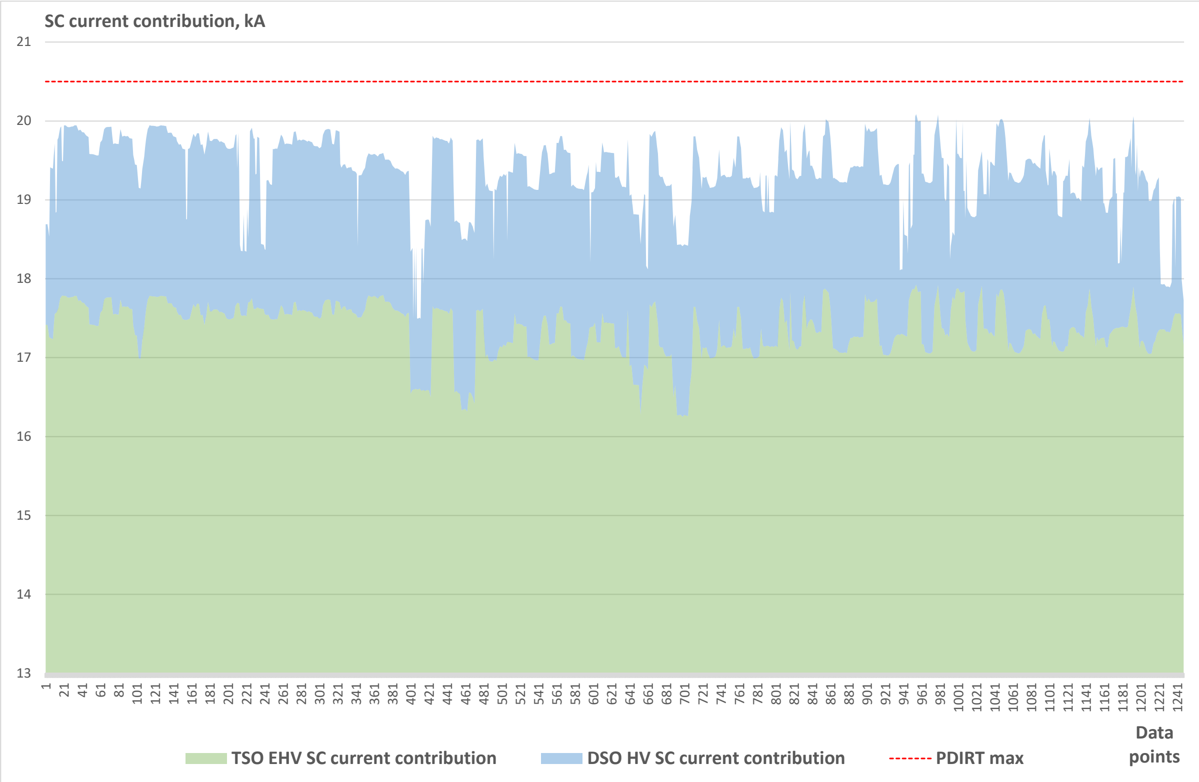

Figure 4.34 - Short-circuit current contribution for Zêzere substation in the second demo phase period

Figure 4.35 presents the results gathered during the second demo phase for Pocinho substation, for which we can highlight the following aspects:

- The forecasted short-circuit current contribution surpasses the maximum value from PDIRT (20,2 kA) 1248 times out of 1248 data points, which corresponds to 100% of the total time of the second demo phase period. The forecasted short-circuit current contribution surpasses the maximum value from PDIRT in every data point even without considering the contribution from active HV DSO network.
- The maximum value of the total short-circuit current contribution is 26,3 kA, which corresponds to approximately 130% of the maximum value from PDIRT. However, the forecasted short-circuit current contribution does not surpass the short-circuit rating of circuit breakers (31,5 kA) in the observed period and reaches 83,3%.
- Comparing the first and the second demo phases, it can be seen that TSO contribution in the second demo period is higher. This is due to the presence of a large amount of hydro generation, connected to Pocinho substation, which was not in service in summer (first demo phase) due to dry season of the year.

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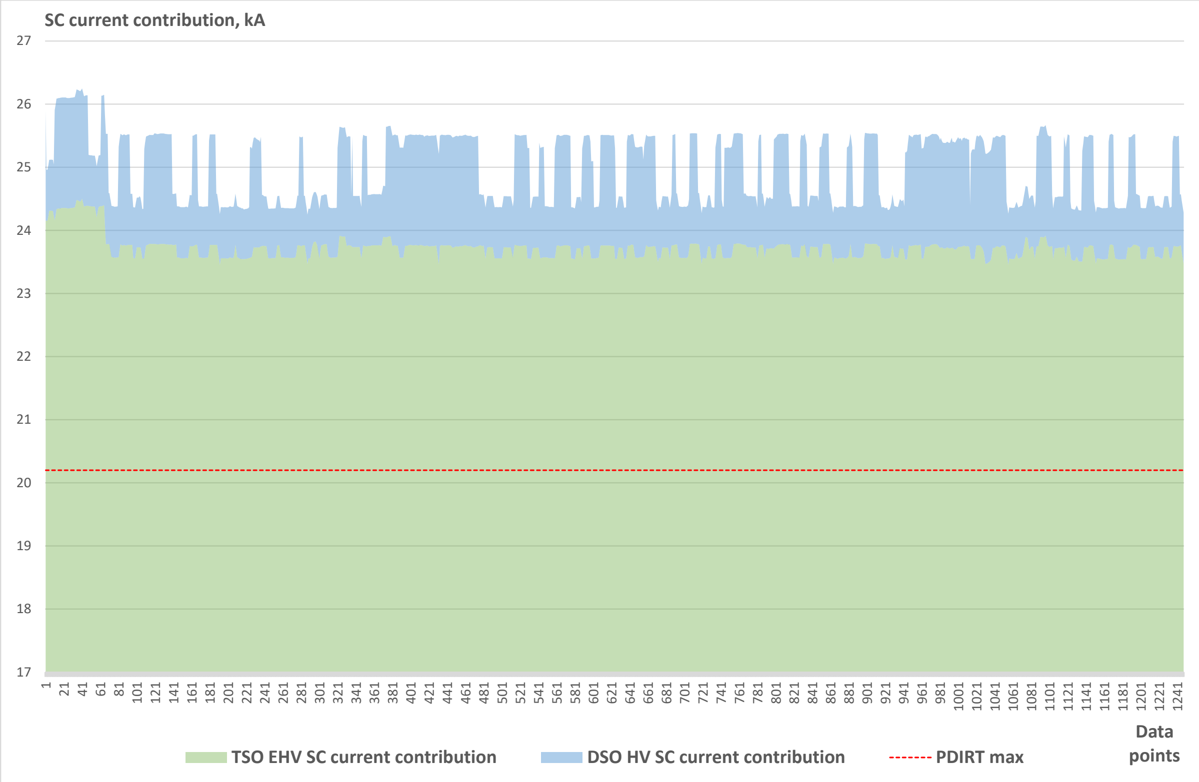

Figure 4.35 - Short-circuit current contribution for Pocinho substation in the second demo phase period

Figure 4.36 presents the results gathered during the second demo phase for Mourisca substation, for which we can highlight the following aspects:

- The forecasted short-circuit current contribution surpass the maximum value from PDIRT (23,7 kA) 544 times out of 1248 data points, which corresponds to 43,6% of the total time of the second demo phase period. Same as in Batalha substation, the forecasted short-circuit current contribution surpasses the maximum value from PDIRT only when considering the contribution from active HV DSO network.
- The maximum value of the total short-circuit current contribution is 24,6 kA, which corresponds to approximately 103,6% of the maximum value from PDIRT. However, the forecasted short-circuit current contribution does not surpass the short-circuit rating of circuit breakers (31,5 kA) in the observed period and reaches 78%.

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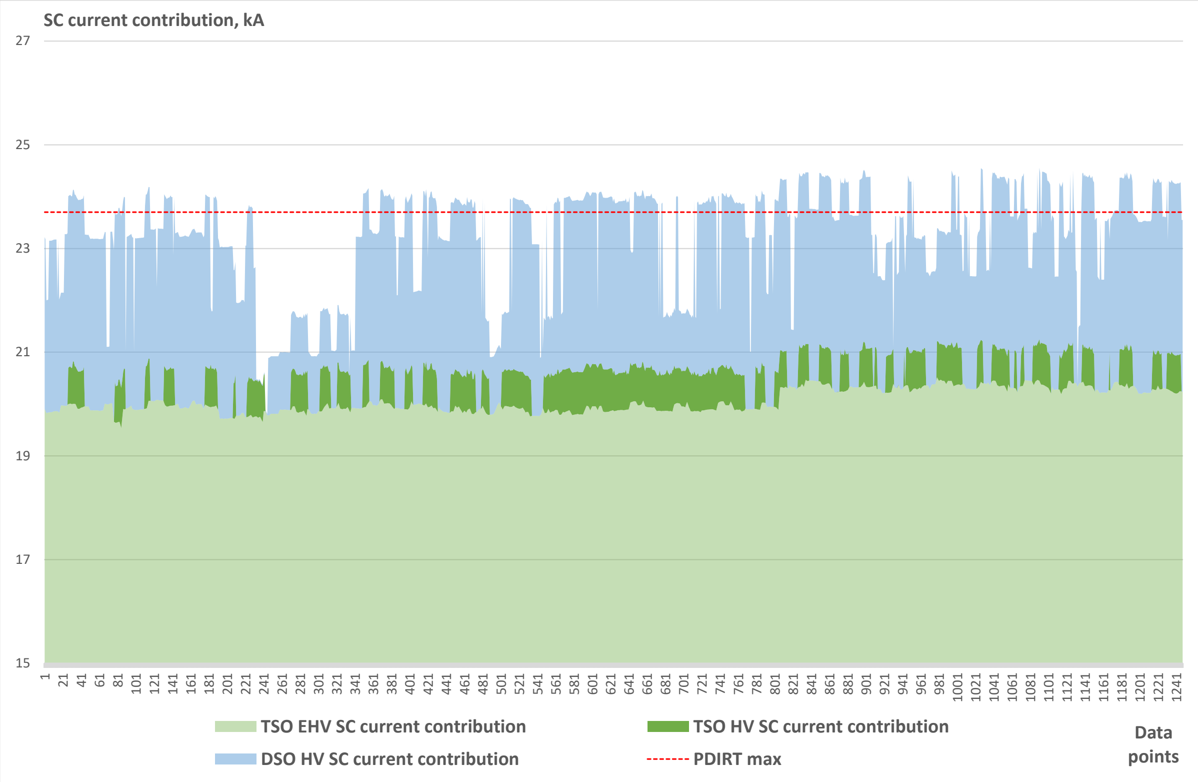

Figure 4.36 - Short-circuit current contribution for Mourisca substation in the second demo phase period

The results for five substations are summarized in Table 4.17.

Table 4.17 - Summarized results for the second demo phase for SUC08

Substation	Zêzere	Pocinho	Batalha	Mourisca	Portimão
Maximum value from PDIRT (kA)	20,5	20,2	27,5	23,7	14,5
Percent of the time when I_{FOR} surpass I_{PDIRT} (%)	0	100	22,8	43,6	83,6
Maximum forecasted value (kA)	20,1	26,3	28	24,6	17,7
Percent of $I_{FOR\text{-}MAX}$ to I_{PDIRT} (%)	97,98	130	101,96	103,6	121,8
Percent of $I_{FOR\text{-}MAX}$ to $I_{SC\ BREAKER\ LIMIT}$ (%)	63,8	83,3	89	78	56

4.6.4. KPI computation

4.6.4.1. 1st Demo Phase

The demo KPIs for the first demo phase applicable to SUC08 for Pocinho demo site are presented in Table 4.18.

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Table 4.18 - KPIs for the 1st demo phase to Pocinho demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	853 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	12 153 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30) and planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25).

The demo KPIs for the first demo phase applicable to SUC08 for Batalha demo site are presented in Table 4.19.

Table 4.19 - KPIs for the 1st demo phase to Batalha demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	-576 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	3 424 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30). This means that the system is secure during all the period under analysis. For 139 data points out of 720 observed (19,3%) the forecasted short circuit current contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25) with the maximum deviation of 576 A.

4.6.4.2. 2nd Demo Phase

The demo KPIs for the second demo phase applicable to SUC08 for Zêzere demo site are presented in Table 4.20.

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Table 4.20 - KPIs for the 2nd demo phase to Zêzere demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	415 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	11 415 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30) and planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25).

The demo KPIs for the second demo phase applicable to SUC08 for Pocinho demo site are presented in Table 4.21.

Table 4.21 - KPIs for the 2nd demo phase to Pocinho demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	-6 052 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	5 248 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30). This means that the system is secure during all the period under analysis. For 1248 data points out of 1248 observed (100%) the forecasted short circuit current contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25) with the maximum deviation of 6 052 A.

The demo KPIs for the second demo phase applicable to SUC08 for Batalha demo site are presented in Table 4.22.

Table 4.22 - KPIs for the 2nd demo phase to Batalha demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	-539 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	3 461 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30). This means that the system is secure during all the period under analysis. For 285 data points out of 1248 observed (22,8%) the forecasted short circuit current contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25) with the maximum deviation of 539 A.

The demo KPIs for the second demo phase applicable to SUC08 for Mourisca demo site are presented in Table 4.23.

Table 4.23 - KPIs for the 2nd demo phase to Mourisca demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	-859 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	6 941 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30). This means that the system is secure during all the period under analysis. For 544 data points out of 1248 observed (43,6%) the forecasted short circuit current contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25) with the maximum deviation of 859 A.

The demo KPIs for the second demo phase applicable to SUC08 for Portimão demo site are presented in Table 4.24.

Table 4.24 - KPIs for the 2nd demo phase to Portimão demo site

KPI name	KPI ID	Target Value	Final Value
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis	KPI_N25	> 0 A	-3 154 A
Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis	KPI_N30	> 0 A	13 846 A

For all observed data points, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side (KPI_N30). This means that the system is secure during all the period under analysis. For 1043 data points out of 1248 observed (83,6%) the forecasted short circuit current contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface (KPI_N25) with the maximum deviation of 3 154 A.

5. Achievements and challenges

The TDEP and DDEP implemented within the scope of the Portuguese demonstration have proven to work well, ensuring effective bidirectional data transmission across a variety of use cases. These platforms have enabled a streamlined and, in certain instances, automated data exchange process. They have also successfully facilitated interaction and integration with existing internal systems and tools. Notably, the integration of the OneNet Connector within SUC02 was executed with success, allowing for the efficient exchange of information regarding flexibility needs and potentials between the TSO and the Aggregator.

Regarding the communication, even though real time is not required in any of the use cases, the importance that the information being exchanged has to the efficient operational activities from the SOs may justify moving from an API-based messaging where synchronous communication exists to an asynchronous communication such as Connective Technology for Adaptive Edge & Distributed Systems - NATS. NATS is more focused on providing fast and efficient messaging capabilities for event-driven and real-time systems but could avoid messages being "lost" at first attempt and avoid repeating commands to reach the endpoint in case of error. This would result in a more robust, reliable and efficient message exchange.

The use of the OneNet Connector was continuously mentioned by all partners in the project. Inside the Portuguese Demonstrator, we encountered challenges that are worth commenting on and which were already shared with the responsible WPs. In first place, the deployment of the OneNet Connector by some parties in the Portuguese Demo was blocked by the cybersecurity measures that were needed. These are non-negotiable inside the companies' IT infrastructure which made necessary the use of other resources such as virtual machines and/or additional equipment using an independent network configuration. Some of those difficulties can be attributed to the early stage of development of the OneNet Connector which require tools and tasks that do not belong to a SO business-as-usual operations. Some of those tools are the use of docker containers and software development environments. The process to overcome those initial difficulties took a long time, affecting the timetable of the project and therefore, the possible benefits and impact it could have on the demonstration phases. However, the partners inside the Portuguese Demo were able to integrate the OneNet Connector for a simple scenario inside SUC02 and successfully exchange flexibility needs and offers for 15 days on a daily basis. An additional testing procedure using the OneNet Connector was included in the demonstration of the Regional Use Case from the Western Cluster, which is not addressed within this deliverable, but which was recorded and shared with the responsible WPs.

Two demonstration phases were conducted – the first in August 2023 and the second between late November and mid-December 2023. These allowed for the identification and incorporation of improvements from the initial phase into the subsequent one. On that note, an area identified for improvement within the first phase was the automation of data computation and its exchange with the DDEP via the DSO operational planning tool. The implementation of this tool encountered delays, rendering it unavailable for the first demonstration

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period. The second demonstration phase saw the incorporation of the aforementioned tool, which facilitated the expansion of the scope of analysis to include additional substations, thereby providing a more comprehensive view of the system's capabilities and performance. This phase allowed for a deeper understanding of the operational effectiveness and the range of application of the implemented technologies.

One important aspect to highlight is that the scale factor of attempting thousands of offerings to the platform was not assessed. It is not clear what the challenges would be, but loss of communication/data and system lag with large quantities of bids are foreseen. These issues could benefit from NATS mentioned in the previous point in terms of message exchange. However, incorporating a large number of offerings could represent handling challenges. In this sense, NATS provides built-in features for message persistence and replay, ensuring messages are not lost even during temporary service outages. This makes it robust for handling failures and maintaining data integrity. Regarding scalability, it would ensure high throughput, since NATS is optimized for high message throughput, making it well-suited for scenarios where rapid communication and handling large volumes of messages are essential.

In terms of collaboration, it is imperative to acknowledge the exemplary level of involvement and teamwork among TSO, DSO and Aggregator teams. This synergy has been instrumental in achieving high levels of dissemination of the demonstration results and ensuring the quality of the implementation process.

For a more detailed examination of the project's accomplishments and the challenges encountered, particularly within the Portuguese context, an analysis focusing on specific use cases is provided below. This targeted analysis is crucial for a granular understanding of the project's impact and the lessons learned during its execution.

Exchange of Information for Congestion Management (SUC01 & SUC02)

No FSPs actively participated in the UCs. Although this didn't have a significant effect in SUC01—focused on data exchange for prequalification—the results did not completely align with those from Portugal's ancillary services market already in place. This discrepancy arose as the demonstration excluded the FSP prequalification step, a critical phase which examines various FSPs capabilities, such as ICT ones. For instance, in the actual ancillary services market it an FSP failing approval at this stage was once seen, an event that could not be captured in the demonstration. Nevertheless, the overall process was deemed successful.

As for SUC02, the primary observation from this use case underscores the utilization of real data for determining flexibility needs. This resulted in the absence of any identified congestions, owing to grids being strategically designed to negate such issues. Even though current designs anticipate no congestion, an upsurge in DER penetration is expected to cause increased congestions in the coming years. This prediction highlights the imperative need for TSO/DSO coordination in assessing flexibility requirements, particularly given the projected rise in non-firm connections that will take place in Portugal in the coming years, since the legislation allowing it has now been published. Accordingly, the Portuguese demo has also analyzed a prospective scenario, from one

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side analyzing the upcoming drivers and changes in the electricity system justifying the need for adoption of flexibility solutions, and from the other side mimicking potential congestions due to increased distributed generation and EV integration.

Apart from this and related to the flexibility potential assessment carried out by INESC-TEC, it is important to highlight that this analysis was carried out using a sample of consumers captured from a survey submitted by E-REDES to its connected customers. The survey resulted in responses from only two consumers, which could have significantly hindered the quality of the results if not for the size of one of the consumers reached, a supermarket chain, that allowed capturing and analyzing data from 230 supermarkets spread across the country, and to more accurately simulate the flexibility potential of this type of consumer. Regarding this analysis, it is also important to highlight data protection and GDPR issues faced for handling metering data from the consumers addressed. This situation required the anonymization of data, impeding the use of location data associated to the metering data, leading to less accurate flexibility estimations, which would be improved if weather data in the exact location could be used.

Also, regarding the flexibility potential analysis and submission of the offers, it's important to highlight that the order of magnitude of the individual offering is an order of magnitude lower than the needs reported. The Aggregator assesses its clients' flexibility in kW and reports it in MW. This may mean losing some flexibility potential by neglecting the decimal places when the offering is transferred to the data exchange platform. Apart from this, the Aggregator does not know what the needs are at a given location. This interferes in assets flexibility allocation that may be covered by different Substation areas to be shared as available to one connection point and not to another. There could be the case that the one chosen does not have any flexibility needs to be fulfilled, while the other one left unattended, has flexibility needs but due to lack of information to the Aggregator, no offers were presented.

Another issue encountered was the definition of the Grid zone itself. Without knowing exactly to which upstream substation the flexible assets are connected to, the bid process may be ineffective. In the demo the JRC methodology was followed and the km^2 area per substation was used, taking into account the European average of the assessed system operators. This may differ immensely between grids. This issue regarding the grid zone definition and allocation of each asset should be further explored and defined.

Finally, another important achievement to highlight was the organization of a workshop to increase consumer awareness regarding flexibility provision processes. The aim of the workshop was to extend the knowledge of potential future participants in flexibility provision, to have them understand the overall process, the benefits to them and to the system, and what do they have to do to be part of upcoming flexibility markets. The workshop had more than 60 participants, representing different stakeholders.

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Exchange of Information for Operational Planning (SUC06, SUC07 & SUC08)

SUC06 has effectively facilitated the exchange of annual maintenance plans via the DEPs and enabled updates on maintenance operations. Notably, no technical constraints were identified during the work, reflecting the network's robust redundancy capabilities.

The exchange of generation and consumption forecasts under SUC07 was executed successfully. However, data quality concerns, particularly at the Pocinho substation, were noted, indicating a substantial variance between DSO and TSO forecasts. To address this, the second demonstration period allocated an extended phase for data rectification, focusing on eliminating detected outliers. These outliers largely stemmed from maintenance activities leading to load transfers and source code errors. An additional challenge identified in SUC07 deals with the different topologies present in the interface substations between TSO and DSO where measurements are taken. In the Portuguese context, it is possible to connect generation directly to transmission substations as well as to distribution substations making the corresponding operator to have a higher visibility in contrast with the counterpart. Afterwards, this affects the forecast calculations of each operator and therefore the information to be exchanged is different. For the corrections needed to be done during the second demonstration phase, each substation had to be studied individually which might affect the scalability of the proposed methodology. A possible solution is the development of collaboration protocols where a common visibility is warranty without compromising the rights of protected data. Both operators participating in the demonstration were notified for them to take the correcting actions they consider adequate.

Several other challenges were identified during the 2nd demo phase within SUC07. Namely, related to the modelling of the network, a particular situation for the Pocinho substation that forms a meshed network with three other substations, and no methodology to isolate each substation is available from the DSO side, an aspect that will be considered for exploitation purposes. Among this, inconsistencies in the characterization of the network were identified, for which a full mapping of such inconsistencies is in place to minimize them and improve the quality of the data.

SUC08 ensured efficient data exchange concerning short-circuit forecasts, allowing the joint calculation of TSO and DSO contributions. A notable observation for the first demo period was that for one substation, the projected short circuit value surpassed the TSO's planning estimate. The same situation happened in the second demo period for four observed substations out of five. It is important to note that for three substations out of these four the short-circuit current value surpassed the TSO’s planning estimate value only with addition of the contribution from DSO side. This emphasizes the need for a combined short-circuit contribution assessment to optimize grid asset planning and enhance operational activities.

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6. Conclusion

This deliverable presents the demonstration IT environment including the data gathering and the results assessment from the Western demo in order to describe the conditions for the use of flexibility in Portugal.

Both TSO and DSO developed a backend and frontend to exchange operational and forecast data to demonstrate the PT SUCs. Not only did the two DEPs developed (TDEP and DDEP) proved to work well for the exchange of the data within the different SUCs, but also the OneNet Connector tested in one of the SUCs also proved to be efficient for the exchange between different actors, demonstrating that upscaling and replication to European markets is possible.

Regarding the Evaluation of the Demonstrations of each SUCs, the two demo periods, two weeks in August 2023 and one month in end of November to mid December 2023, allowed both SOs to adjust internal tools to improve the KPIs. However, it was still possible to identify several aspects where some improvements can be deployed, especially for exploitation purposes. The five selected demo sites in the second demo period, taking in consideration the hydro in the north, wind in the north and center and solar in the south, show the difficult of the challenge task ahead for the SOs to manage flexibility. On this point, several issues related to data quality were faced, which are more emphasized the more granular the data is.

In relation to SUC01 ("Evaluation of the Product & Grid prequalification requirements"), this SUC was only tested during the first demonstration phase (August 2023), both TDEP and DDEP allow an effective prequalification process of the FSPs considered in the different steps addressed (product and grid prequalification), namely relating to the exchange of prequalification information between the DSO and the TSO, since that is the focus of the SUC. One learning from the demonstration of this SUC is that all the prequalification phases should be addressed to fully reflect the capabilities that an FSP has to deliver a certain service, including the actual FSP prequalification, where ICT capabilities are addressed.

Regarding SUC02 ("Day-Ahead & Intraday Flexibility needs"), two different studies were performed, one during the 1st demo phase in which the day-ahead flexibility needs and offers were identified, and another, during the 2nd demo phase related with a network planning analysis for 2030. From the day-ahead flexibility needs analysis performed in August, the results were that no flexibility needs were identified for either DSO or TSO networks. Concerning the flexibility offers, they were identified within the Aggregator environment and ran without errors during the whole demonstration time. The Aggregator tool provided a total average value of 70,7kW and 31,8 kW of available flexibility during flexible hours (KPI_H09A) for Batalha and Pocinho Substations respectively. The relatively low value of available flexibility when compared to the order of magnitude of the substations and potential needs is because only one MV type of costumer was considered, contribution with a wide geographic dispersion of the supermarkets. This resulted in only 10 supermarkets and 3 supermarkets when Batalha and Pocinho Substations were considered. A higher degree of disaggregation would also result in higher

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precision of flexibility availability, which with the data available was only possible to do out of aggregated load consumption data. Disaggregated data would also facilitate the baselining of initial profiles for settlement purposes.

About the planning studies did in the scope of the SUC02, the main conclusions were regarding the necessity of proactive measures to address potential congestion, especially in scenarios dominated by excess solar generation and high peak load. The proposition to leverage the flexibility offered by EVs, distributed generation and demand response stands out as a promising solution, marking a transformative step towards a more resilient and adaptive energy infrastructure for the future.

With respect to the SUC06 “Maintenance plans information exchange”, the exchanges also took place solely during the first demonstration phase. Information on the 2023 yearly maintenance plans for both TSO and DSO, including punctual updates to these plans were successfully exchanged. To allow for an effective interaction, only maintenance plans that impact the connected SO were exchanged, such as maintenance actions in the lines directly connected to the substations under analysis, or even maintenance actions in the transformers of the substations. The results from the SUC06 show that the networks have the necessary redundancy to avoid any congestion or violation resulting from the maintenance activities.

SUC07 “Consumption and generation forecast information exchange” showed the successful process of information sharing between the DSO and TSO by using the developed platforms. It also involved the integration with internal tools from both operators. During both demo phases, it was proven that the exchange of files contributed to the improvement of load and generation forecasts. However, some technical difficulties were encountered, which required further investigation. Namely, the topology of transmission and distribution side in the interfaces included, in some cases, the presence of private connections which were protected in terms of data confidentiality. Some of the assets connected in those places were hydro and thermal (from various technology generations). This led to the need to correct calculations and assumptions in order to improve the results. Those scenarios need to be studied case by case which might produce delays in future implementations. Nevertheless, the calculated KPIs demonstrate an improvement in the load and generation forecast.

Regarding SUC08 “Short-circuit levels information exchange”, for the first demo period for Pocinho demo site, the joint TSO and DSO short-circuit contribution does not exceed the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface and in opposition for Batalha, the joint TSO and DSO short-circuit contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface. This last, only happens when the DSO short-circuit contribution is added to the calculations.

For the second period of the SUC08 it can be seen, that Zêzere is the only demo site in which the joint TSO and DSO short-circuit contribution does not exceed the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface. For Pocinho demo site, the TSO short-circuit contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface even without addition DSO short-circuit contribution. And for

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the remaining 3 demo site testes (Batalha, Mourisca and Portimão), the joint TSO and DSO short-circuit contribution exceeds the planning estimated value by TSO for 2022 for 63 kV TSO/DSO interface only when the DSO short-circuit contribution is added to the calculations. However, in all the selected demo sites for both first and second demo phases, the forecasted short circuit current contribution is lower than the short circuit breaker limit from TSO side, which means that the system is secure during all the periods under analysis. Although these results are clear in demonstrating the importance of performing a TSO and DSO joint analysis of short-circuit currents that can be experienced in TSO/DSO transformers, as distributed generation increasingly affects this interface. Therefore, predicting jointly proves to be the right option for obtaining reliable behavior of short-circuit currents, following the suggested information exchange for that.

Exploitation of the results and next steps:

This document provides the results of the five use cases designed by the Portuguese partners in the scope of the project, during a demonstration period of 1 month and half. The tools/methodologies presented and developed in this scope of the demonstrations are considered of much value for the continuing exploration and improvement in order to bring value to the different stakeholders involved in the PT demo. The list of exploitable tools/methodologies is the following:

- DSO and TSO Data Exchange Platform (DDEP & TDEP)
- Methodology for the estimation of flexibility potential from MV clients
- TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool
- Short-Circuit current forecast Tool in TSO-DSO substations

Regarding the results per se, they were promising, as presented before, showcasing the demo's successes and field for improvement, providing valuable insights for refining and optimizing future demonstrations and TSO's and DSO's internal activities both in the flexibility and in operational planning areas. On that note, these results will be communicated throughout the organizations, for example, through dedicated dissemination and exploitation workshops to discuss the future implementation of the results and possible adaptation for operational use.

Apart from the above list of exploitable results, it's also important to highlight the adaptations made to the DSO operational planning tool (DPlan) to deliver the necessary data for the exchange throughout the different SUCs. On this note, areas of improvement for the tool have been identified and will be addressed in the future, namely, issues related to the modelling and characterization of the network or even absence of data, that once corrected, will have strong repercussions on the quality of the data being exchanged through the DDEP to the TDEP.

The TSO's perspective is to continue improving the Data Exchange Platform in a secure and standardized way to exchange more operational data. This allows for a better quality of the network dataset, through the sharing of connected RES production by technology at nodal point of interconnection. With this new functionality from

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the OneNet project we can avoid using the email to exchange operational data, increasing the database interface between both SOs. The tools and methodologies developed in the projected will be further analyzed and tested with the plan of potentially make part the SO activities and leveraged for future EC projects.

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Annex A Appendices

A.1 Detailed description of the KPIs used in the Portuguese demo:

A.1.1 Demo KPIs applicable to BUCs

Table A-1 presents the Demo KPIs that are applicable and common to all SUCs tested in the Portuguese demonstration, which relate only to the Information and communication technology (ICT) costs needed for the deployment of the DEPs.

Table A-1- ICT costs KPI details.

KPI name	ICT costs
KPI ID	KPI_H04
KPI Demo ID	PT_BUC_KPI_01
Description	The term ICT cost comprises the communications and information technologies directly related to the implementation of the communication infrastructures between DSO and TSO.
Formula	$$ICT_{Cost} = \sum_{i=1}^{N_c} c_i$$
Variables	ICT_{Cost}: Cost of ICT (€). C_i: Generic i^{th} cost directly related to information exchange (€). N_c: Overall number of cost items for all BUC.
KPI baseline explanation	For the baseline, the cost of existing equipment on the DSO and TSO side where APIs for data exchange will be developed can be considered.
Calculation methodology	Calculate a cost estimate for implementing and maintaining the communication infrastructure for information exchanges between DSO and TSO for every SUC. The period considered for this calculation will comprise the whole duration of the demonstration.
KPI target value	[100k€-200k€]

KPI data collection details	**Data ID**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
	N_c	Data collected from AWS, Azure and contracts with developers	Manually	Distribution / Transmission Grid	At the end of the project	M30	E-REDES R&D Nester	Public
	ICT_{cost}	Data collected from AWS, Azure and contracts with developers	Manually	Distribution / Transmission Grid	Distribution / Transmission Grid	M30	E-REDES R&D Nester	Public

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A.1.2 Demo KPIs applicable for SUC01

Table A-2 and Table A-3 present the Demo KPIs that are applicable to SUC01 in the Portuguese demonstration.

Table A-2- Demo KPIs applicable to SUC01- Successful ending of Prequalification Process.

KPI name	**Successful ending of Prequalification Process**							
KPI ID	KPI_N34							
KPI Demo ID	PT_SUC_KPI_11							
Description	This indicator measures the percentage of prequalification processes that were successfully deployed from an ICT point of view.							
Formula	$SPP_{\%} = \frac{Successful}{TPP} . 100$							
Variables	$SPP_{\%}$: Successful prequalification processes (%). $Successful$: Number of successful prequalification processes. TPP: Total number of Prequalification process.							
KPI baseline explanation	No baseline since there is no similar process under implementation nationally.							
Calculation methodology	1) Assessment of the number of prequalification processes for FSPs connected to Transmission/Distribution grid within a specific period under analysis; 2) Determination of successful prequalification processes.							
KPI target value	100%							
KPI data collection details	**Data ID**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
	$Successful$	FSPs requirement list	Analysis of FSPs requirement list	Unit level, aggregated, portfolio level, connected to Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public
	TPP	FSPs requirement list	Simulation	Unit level, aggregated, portfolio level, connected to Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public
	$SPP_{\%}$	FSPs requirement list (Datasets from	Simulation	Unit level, aggregated, portfolio level, connected	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public

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		previous variables)		to Distribution / Transmission grid				

Table A-3 - Demo KPIs applicable to SUC01 - Number of prequalification process that needs additional information.

KPI name	Number of prequalification process that needs additional information
KPI ID	KPI_N46
KPI Demo ID	PT_SUC_KPI_12
Description	This indicator measures the percentage of prequalification processes that require additional information, considering all the fields considered in the data model.
Formula	$PPA_{\%} = \frac{NPPA}{TPP}.100$
Variables	$PPA_{\%}$: Prequalification processes that need additional information (%). $NPPA$: Number of prequalification processes that need additional information. TPP: Total number of prequalification processes.
KPI baseline explanation	No baseline since there is no similar process under implementation nationally.
Calculation methodology	1) Assessment of the number of Prequalification processes for FSPs connected to Transmission / Distribution grid within a specific period under analysis; 2) Determination of prequalification processes that need additional information.
KPI target value	100%
KPI data collection details	

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
$NPPA$	FSPs requirement list	Simulation	Unit level, aggregated, portfolio level, connected to Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public
TPP	FSPs requirement list	Simulation	Unit level, aggregated, portfolio level, connected to Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public

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	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	$PPA_{\%}$	FSPs requirement list (Datasets from previous variables)	Simulation	Unit level, aggregated, portfolio level, connected to Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Public

A.1.3 Demo KPIs applicable for SUC02

Table A-4, Table A-5 and Table A-6 present the Demo KPIs that are applicable to SUC02 in the Portuguese demonstration.

Table A-4 - Demo KPIs applicable to SUC02 – Reduction in RES curtailment.

KPI name	**Reduction in RES curtailment**
KPI ID	KPI_H05
KPI Demo ID	PT_SUC_KPI_05
Description	This indicator measures the reduction in the amount of energy from Renewable Energy Sources (RES) that is not injected into the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions.
Formula	$E_{RES} = \sum_{i=1}^{I}\sum_{t=1}^{T}(E_{i,t}^{prod} - E_{i,t}^{inj})$
Variables	E_{RES}: Reduction in RES curtailment (MWh). ***I*****:** Set of RES facilities under consideration. ***T*****:** Set of time intervals under consideration excluding periods of scheduled maintenance and outages. $E_{i,t}^{prod}$: Available energy production of the i^{th} RES facility at period t (kWh or MWh). $E_{i,t}^{inj}$: Injected energy from the i^{th} RES facility at period t (kWh or MWh).
KPI baseline explanation	Simulation scenarios will be set up based on day-ahead forecast data for the grid areas used in the demonstrator. Different simulation scenarios can be set up based on different load/generation scenarios for the specific grid areas. The baseline of the KPI will be computed according to the scenario before and after the implementation of the SUC.
Calculation methodology	1) Network analysis is performed to detect network constraints; 2) Network Optimization is done; 3) Level of curtailments is assessed after solving the constraints within the specific period under analysis.
KPI target value	0 MWh

KPI data collection details	**Data ID**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
	$E_{i,t}^{prod}$	Historical data	Simulation	Distribution /	On event. (Daily timeframe)	2 weeks in M35 and 4	E-REDES REN	Confidential

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		Forecasted power flow		Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)		weeks in M38-39		
	$E_{i,t}^{inj}$	Historical data Forecasted power flow	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Confidential
	E_{RES}	Historical data Forecasted power flow (Datasets from previous variables)	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public

Table A-5 - Demo KPIs applicable to SUC02 – Requested flexibility.

KPI name	**Requested flexibility**
KPI ID	KPI_H15A
KPI Demo ID	PT_SUC_KPI_04
Description	This indicator measures the amount of flexibility requested by the DSO or TSO for ancillary services from all the flexible resources of the portfolio.
Formula	$P_{Flex_R} = \sum_{t=1}^{T} P_{flex_{Rt}}$ and $E_{Flex_R} = \sum_{t=1}^{T} E_{flex_{Rt}}$
Variables	P_{Flex_R}: Requested flexibility (Power) (kW or MW). $P_{flex_{Rt}}$: The amount of power requested by the DSO/TSO to solve their forecasted constraints at a time T (kW or MW). E_{Flex_R}: Requested flexibility (Energy) (kWh or MWh). $E_{flex_{Rt}}$: The amount of energy requested by the DSO/TSO to solve their forecasted constraints at a time T (MWh or kWh). T: examined period
KPI baseline explanation	No baseline is expected since there is no similar process to be improved.

Calculation methodology	1) It will be performed a network analysis to detect network constraints; 2) A Network Optimization is done; 3) The quantification of flexibility needs for solving the constraints is done for the specific period under analysis.
KPI target value	0 MW

KPI data collection details

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
$P_{flex_{R_t}}$	Historical data Power flows Forecast	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe).	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
$E_{flex_{R_t}}$	Historical data Power flows Forecast	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe).	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
P_{Flex_R}	Historical data Power flows Forecast (Datasets from previous variables)	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe).	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
E_{Flex_R}	Historical data Power flows Forecast (Datasets from previous variables)	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event. (Daily timeframe).	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public

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Table A-6 - Demo KPIs applicable to SUC02 – Total power of avoided congestions through flexibility activation.

KPI name	Total power of avoided congestions through flexibility activation
KPI ID	KPI_N27
KPI Demo ID	PT_SUC_KPI_01
Description	The difference of the total amount of power of the congestions (overloaded elements) in the grid for all periods of observation between the scenarios without flexibility activation (before SUC implementation) and the ones with flexibility activation (after SUC implementation).
Formula	$TPAC = \sum_{t=1}^{T} (\sum_{\substack{i=0 \\ before\ BUC}}^{M} (P_{i,t} - P_i^{max}) - \sum_{\substack{k=o \\ after\ BUC}}^{N} (P_{k,t} - P_k^{max}))$
Variables	$\boldsymbol{TPAC}$: Total power of avoided congestions through flexibility activation (kW). $\boldsymbol{M, N}$: Number of overloaded elements in the scenarios without and with flexibility activation, respectively. $\boldsymbol{T}$: Number of time intervals from the entire period under consideration (e.g., for one day 24 intervals of 1 hour or 96 intervals of 15 minutes). $\boldsymbol{P_{i,t}, P^{k,t}}$: Power flow in overloaded network element ***I*** or ***k*** for time interval ***t*, **respectively for the scenario without and with flexibility activation (kW). $\boldsymbol{P_i^{max}, P_k^{max}}$: Maximum power for network element ***i*** or ***k*** without it being overloaded, respectively for the scenario without and with flexibility activation (kW).
KPI baseline explanation	Simulation scenarios based on historical values, representing the scenario without flexibility activation.
Calculation methodology	Compute congestions for simulations of the starting scenarios (without flexibility activation) and for the resulting scenarios with flexibility activation (after SUC implementation).
KPI target value	0 kW
KPI data collection details	(see below)

KPI data collection details

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
$P_{i,t}$ $P_{k,t}$	Historical Data	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
P_i^{max} P_k^{max}	Historical Data	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
$TPAC$	Historical Data (Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES R&D Nester	Public

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A.1.4 Demo KPIs applicable for SUC06

Table A-7 and Table A-8 present the Demo KPIs that are applicable to SUC06 in the Portuguese demonstration.

Table A-7 - Demo KPIs applicable to SUC06 – Number of congestions/violations on DSO network.

KPI name	**Number of congestions/violations on DSO network**
KPI ID	KPI_N31
KPI Demo ID	PT_SUC_KPI_06
Description	Anticipate distribution grids constraints because of scheduled maintenance actions. By exchanging information of maintenance works between the TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works reschedule. This KPI will evaluate the effectiveness of this information exchange to avoid congestions.
Formula	$$CAD_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} . 100$$
Variables	$CAD_{\%}$: Number of congestions/violations on DSO network (%). $\#congestion\ avoided$: Number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange. $\#congestion\ forecasted$: Number of congestions correctly forecasted, so excluding the false positive congestions forecasts.
KPI baseline explanation	The baseline consists of the number of congestions resulting from the systems' operation without the maintenance works data exchange between TSO and DSO.
Calculation methodology	Simulation of grid scenarios with pre and post predictive actions implementation.
KPI target value	0 %
KPI data collection details	(see table below)

Data ID	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
$\#congestion\ avoided$	Historical data about the grid and maintenance plans (for simulation setup)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public
$\#congestion\ forecasted$	Historical data about the grid and maintenance plans (for simulation setup)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public
$CAD_{\%}$	(Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public

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Table A-8 - Demo KPIs applicable to SUC06 – Number of congestions/violations on TSO network.

KPI name	Number of congestions/violations on TSO network
KPI ID	KPI_N32
KPI Demo ID	PT_SUC_KPI_09
Description	Anticipate transmission grids constraints because of scheduled maintenance actions. By exchanging information of maintenance works information between the TSO and DSO, some congestions might be identified (forecasted) and avoided with corrective actions such as topology reconfiguration, flexibility activation or even maintenance works reschedule. This KPI will evaluate the effectiveness of this information exchange to avoid congestions.
Formula	$CAT_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} . 100$
Variables	$CAT_{\%}$: Number of congestions/violations on the TSO network (%). $\#congestion\ avoided$: Number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange. $\#congestion\ forecasted$: Number of congestions correctly forecasted, so excluding the false positive congestions forecasts.
KPI baseline explanation	The baseline consists of the number of congestions resulting from the systems' operation without the maintenance works data exchange between TSO and DSO.
Calculation methodology	Simulation of grid scenarios with pre and post predictive actions implementation.
KPI target value	100% if any congestion is foreseen, otherwise 0 %

KPI data collection details

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
$\#congestion\ avoided$	Historical data about the grid and maintenance plans (for simulation setup)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN	Public
$\#congestion\ forecasted$	Historical data about the grid and maintenance plans (for simulation setup)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	REN	Public
$CAT_{\%}$	(Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event	2 weeks in M35 and 4 weeks in M38-39	NESTER	Public

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A.1.5 Demo KPIs applicable for SUC07

Table A-9 to Table A-13 present the Demo KPIs that are applicable to SUC07 in the Portuguese demonstration.

Table A-9- Demo KPIs applicable to SUC07 – Error of the RES production forecast calculated 24 hours in advance.

KPI name	Error of the RES production forecast calculated 24 hours in advance							
KPI ID	KPI_H20A							
KPI Demo ID	PT_SUC_KPI_02							
Description	Evaluate the forecast quality after the information exchange between the DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.							
Formula	$$RES_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left|\frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}}\right|\right).100$$							
Variables	$RES_{FA_{24h}}$: Error of the RES production forecast calculated 24 hours in advance (%). $FC_{RES_{prod}}$: RES production estimated 24h in advance (MW). $RL_{RES_{prod}}$: Real RES production (MW). N: Number of available data points.							
KPI baseline explanation	Error in generation forecast before the information exchange.							
Calculation methodology	1) Calculate the error of generation forecast before the information exchange; 2) Calculate the error of generation forecast after the information exchange; 3) Compare the results of the calculated errors.							
KPI target value	It will vary according to the substation, technology considered and the timing of the demonstration: 1st phase: • Batalha: Solar: < 7,87%; Wind: < 7,58 %; Thermal: < 24 % • Pocinho: Solar: < 11,64%; Wind: < 7,24% 2nd phase: • Batalha: Solar: < 2,26%; Wind: < 10,67 %; Thermal: < 8,9 % • Mourisca: Solar: < 2,77%; Wind: < 11,34%; Thermal: <19,93%; Hydro: < 27,86% • Portimão: Solar: < 10,85%; Wind: < 9,37%; Thermal: <28,55% • Zêzere: Solar: <4,77%; Wind: <9,90%; Thermal: <19,25%; Hydro: <33,12% Note: A target value is not presented for Pocinho substation for the 2nd demo phase, since it was not possible to determine KPI due to issues faced in the modelling of the network.							
KPI data collection details	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	$FC_{RES_{prod}}$	Historical meter data and Weather forecast Data (Predis)	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Confidential

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	$RL_{RES_{prod}}$	Historical meter Data	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Confidential
	N	Constant	Manually/ Automatically	-	Only depends on the granularity.	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
	$RES_{FA_{24h}}$	Calculated (Datasets from previous variables)	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES NESTER	Public

Table A-10 - Demo KPIs applicable to SUC07 – Error of load forecast calculated 24 hours in advance.

KPI name	Error of load forecast calculated 24 hours in advance
KPI ID	KPI_H20B
KPI Demo ID	PT_SUC_KPI_03
Description	Evaluate the forecast quality after the information exchange between the DSO and TSO, measuring the error before and after the information exchange. It is a day-ahead forecast with a granularity of fifteen minutes.
Formula	$Load_{FA_{24h}} = \frac{1}{N}\left(\sum_{t=1}^{N}\left\lvert\frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}}\right\rvert\right).100$
Variables	$Load_{FA_{24h}}$: Error of load forecast calculated 24 hours in advance (%). FC_{load}: Load estimated 24 hours in advance (MW). RL_{load}: Real load (MW). N: Number of available data points.
KPI baseline explanation	Error in generation forecast before the information exchange.
Calculation methodology	1) Calculate the error of load forecast before the information exchange; 2) Calculate the error of load forecast after the information exchange; 3) Compare the results of the calculated errors.
KPI target value	It will vary according to the substation considered and the timing of the demonstration: 1st phase: • Batalha: < 5,55% • Pocinho: < 54,84% 2nd phase: • Batalha: < 7,20% • Mourisca: < 9,93% • Pocinho: < 54,84% • Zêzere: < 23,51% Note: A target value is not presented for Portimão substation for the 2nd demo phase due to lack of observability from both SOs.

KPI data collection details	Data ID	Source/ Tools/ Instruments	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level

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		for data collection						
	FC_{load}	Historical meter data and Weather forecast Data (PREDIS)	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Confidential
	RL_{load}	Historical meter Data	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Confidential
	N	Constant	Manually/ Automatically	-	Only depends on the granularity.	2 weeks in M35 and 4 weeks in M38-39	N _PT	Public
	$Load_{FA_{24h}}$	Calculated (Datasets from previous variables)	Automatically	Distribution/ Transmission Grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES NESTER	Public

Table A-11 - Demo KPIs applicable to SUC07 – Maximum ratio of false-positive and negative congestion forecasts.

KPI name	**Maximum ratio of false-positive and negative congestion forecasts**
KPI ID	KPI_H28
KPI Demo ID	PT_SUC_KPI_03
Description	The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.
Formula	$$FFC_{max\%} = Max\left(\frac{P_{fc,c}}{P_{fc}}.100\right)$$
Variables	$FFC_{max\%}$: Maximum ratio of false positive and negative congestion forecasts (%). $P_{fc,c}$: Amount of power of false positive and negative congestion forecasts, meaning the congestions that are forecasted when the analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). P_{fc}: Amount of power from congestions forecasted.
KPI baseline explanation	No baseline is expected since there is no similar process to be improved.
Calculation methodology	1) Forecast congestions; 2) Verify congestions that really occurred; 3) Determine the maximum amount of power of false positive and negative congestions forecasted.
KPI target value	0 %

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KPI data collection details	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	$P_{fc,c}$	Historical Data meters	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
	P_{fc}	Historical Data meters	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
	$FFCmax_{\%}$	Historical Data meters (Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES R&D Nester	Public

Table A-12 - Demo KPIs applicable to SUC07 – Share of false positive and negative congestion forecasts.

KPI name	Share of false positive and negative congestion forecasts
KPI ID	KPI_H21B
KPI Demo ID	PT_SUC_KPI_07
Description	The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.
Formula	$$FFC_{\%} = \frac{C_{fc,c}}{C_{fc}}.100$$
Variables	$FFC_{\%}$: Share of false positive and negative congestion forecasts (%). $C_{fc,c}$: Number of false positive and negative congestion forecasts, so congestions forecasted where analysis of the measurements indicate that no congestion would have occurred, even if no curative actions by the DSO and TSO were taken (I.e., flexibility used). C_{fc}: Total number of congestions forecasted.
KPI baseline explanation	No baseline is expected since there is no similar process to be improved.
Calculation methodology	1) Forecast the congestions; 2) Verify congestions that really occurred; 3) Determine the number of false positive congestions forecasted.
KPI target value	0 %

KPI data collection details	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	$C_{fc,c}$	Historical Data meters	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public

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	C_{fc}	Historical Data meters	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
	$FFC_{\%}$	Historical Data meters (Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES R&D Nester	Public

Table A-13 - Demo KPIs applicable to SUC07 – Improvement of the Forecast.

KPI name	Improvement of the Forecast
KPI ID	KPI_N33
KPI Demo ID	PT_SUC_KPI_10
Description	This indicator measures the improvement of forecast value after the information exchange. The TSO currently has generation and load forecasts, and short circuit currents which include embedded generation for which it does not have visibility. With this information exchange the TSO has a better dataset as it is complemented with data from the DSO regarding the distribution grid outside of the TSO/DSO observability area. It is expected that these extra data contribute to a better forecast.
Formula	$IF_{\%} = \frac{value_{after\ information\ exchange}}{value_{before\ information\ exchange}} . 100$
Variables	$IF_{\%}$: Improvement of the Forecast (%). $value_{after\ information\ exchange}$: Forecast accuracy when extra data from information exchange between TSO and DSO is used in forecast (W, Var, A). $value_{before\ information\ exchange}$: Forecast accuracy when no data is exchanged between TSO and DSO (W, Var, A).
KPI baseline explanation	The baseline for this KPI is the forecast accuracy of the current forecast methods, which is not enhanced by the exchange of the distribution grid data provided by the DSO.
Calculation methodology	1) Calculate the value of the load and generation forecast, short circuit currents before the information exchange; 2) Calculate the value of the load and generation forecast, and short circuit currents after the information exchange; 3) Compare the results of the calculated errors.
KPI target value	> 0 %

KPI data collection details	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	$value_{before\ information\ exchange_b}$	Historical Data	Simulation (based on historical data)	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Confidential

	value after information exchange	Historical Data	Simulation (based on historical data)	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Confidential
	$IF_{\%}$	Historical Data (Datasets from previous variables)	Simulation (based on historical data)	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	NESTER E-REDES	Public

A.1.6 Demo KPIs applicable for SUC08

Table A-14 and Table A-15 present the Demo KPIs that are applicable to SUC08 in the Portuguese demonstration. Note that although not presented in the table below, the KPI related to the "Improvement of the Forecast" described in Table A-13 is also applicable to this SUC.

Table A-14 - Demo KPIs applicable to SUC08 – Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis.

KPI name	**Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis**
KPI ID	KPI_N25
KPI Demo ID	PT_SUC_KPI_06
Description	Deviation between the maximum planning estimated value of Isc (short-circuit current) (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.
Formula	$\boldsymbol{e = iscmax - MAX(I_{sc})}$
Variables	$\boldsymbol{e}$**:** Deviation between the maximum planning estimated value of Isc (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe (A). $\boldsymbol{iscmax}$**:** Maximum planning estimated value of Isc (A). $\boldsymbol{MAX(I_{sc})}$**:** Maximum value effectively forecasted in the D-1 (A).
KPI baseline explanation	The planning estimated value of Isc (iscmax) is presented annually in the national transmission network development and investment plan. For the: - Baseline for TSO: TSO short circuit estimation is used without DSO contribution - Baseline for DSO: DSO short circuit estimation based on TSO planning values is used
Calculation methodology	The short-circuit currents will be computed for certain 63kV substations (interface TSO/DSO). 1) TSO computes the estimation of fault current currents having into consideration just the active contributions that come from upstream (TSO level) to the three-phase short circuit located at the HV bus; 2) These values are sent to the DSO that is responsible to add the active contributions that come from downstream (DSO level) to the three-phase short circuit located at the HV bus; 3) Both have the same total value for the short-circuit level of that substation and can be computed the deviation between the Isc max estimated for the 63kV by the planning (iscmax) and the maximum value effectively estimated (MAX(Isc)).
KPI target value	> 0A

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KPI data collection details	Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
	iscmax	Coming from planning system	Automatically	TSO/DSO substations (63kV level)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
	Isc	Simulation through internal tools of the three-phase short circuit value	Automatically/ Simulation	TSO/DSO substations (63kV level)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES NESTER	Confidential
	e	Calculated (Datasets from previous variables)	Automatically/ Simulation	TSO/DSO substations (63kV level)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES NESTER	Public

Table A-15 - Demo KPIs applicable to SUC08 – Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis.

KPI name	Comparison of the rated short circuit current of the circuit breakers for the 63kV and maximum short circuit value registered for the series under analysis
KPI ID	KPI_N30
KPI Demo ID	PT_SUC_KPI_07
Description	Deviation between the maximum planning estimated value of Isc (short-circuit current) (iscmax) and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe.
Formula	$\boldsymbol{\sigma = I_{sc}63kVlim - MAX(I_{sc})}$
Variables	$\boldsymbol{\sigma}$**:** Deviation between the breaker limit Isc 63kVlim and the maximum value effectively forecasted (MAX(Isc)) in a D-1 timeframe (A). $\boldsymbol{I_{sc}63kVlim}$**:** Circuit breaker short circuit limit (A). $\boldsymbol{MAX(I_{sc})}$**:** Maximum value effectively forecasted in the D-1 (A).
KPI baseline explanation	This is a value of the KPI from simulations, start of the DEMO or historical values to be able to compare the KPI result with, and be able to see if the parameter has improved, or not. Will be defined at the beginning of field tests. In this particular case the KPI baseline can be the real circuit breakers limits. The rated short circuit current of the circuit breakers at the 63kV bays (Isc60kVlim), in Portugal, is defined as 31,5 kA from the TSO side (or 25kA for phase-to-ground current, when there are underground cable outputs). The DSO considers 25kA as the rated short circuit current of the circuit breakers in the interface TSO/DSO.
Calculation methodology	The short-circuit currents will be computed for certain 63kV substations (interface TSO/DSO). The process starts from the TSO side that will compute the estimation of fault current currents have into consideration just the active contributions that come from upstream (TSO level) to the three-phase short circuit located at the HV bus. Then these values are sent to the DSO that is responsible to add the active contributions that come from downstream (DSO level) to the three-phase short circuit located at the HV bus. In the final, both have the same

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	total value for the short-circuit level of that substation and can be computed the deviation between the breaker limit (Isc 63kVlim) and the maximum value effectively estimated (MAX(Isc)).
KPI target value	> 0A
KPI data collection details	(see table below)

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
Isc63kVlim	Company circuit-breakers values limits	Automatically	TSO/DSO substations (63kV level)	It's a fixed value	2 weeks in M35 and 4 weeks in M38-39	REN and E-REDES	Public
Isc	Simulation through internal tools of the three-phase short circuit value	Automatically/ Simulation	TSO/DSO substations (63kV level)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	NESTER and E-REDES	Confidential
$\boldsymbol{\sigma}$	Calculated (Datasets from previous variables)	Automatically/ Simulation	TSO/DSO substations (63kV level)	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	NESTER and E-REDES	Public

A.1.7 Common KPIs

This sub-chapter presents the common KPIs that will be used for the assessment of the Portuguese demonstration, allowing the comparison with several demonstrators within OneNet.

A.1.7.1 Common KPIs applicable to SUC01

Table A-16 and Table A-17 define the common KPIs applicable to SUC01 of the Portuguese demonstration.

Table A-16 - Common KPIs applicable to SUC01 – Number of FSPs.

KPI name	**Number of FSPs**[12]
KPI ID	KPI_H01
KPI Demo ID	-
Description	This SUC aims to decrease the entry barriers for flexibility provision by simplifying the process for FSPs. Overall progress of this aim can be measured by the number of FSPs considered and involved in the demo for testing the prequalification interactions.
Formula	$\boldsymbol{N_{FSPs}}$
Variables	$\boldsymbol{N_{FSPs}}$: Number of FSPs.

[12] This KPI is also applicable to SUC 02

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KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.
Calculation methodology	Counting the total number of FSPs emulated at the TSO side together with the consumers connected at MV level that answered positively to the survey for the estimation of the flexibility potential[13].
KPI target value	310
KPI data collection details	

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
N_{FSP}	-	Counting	Aggregated	On event	2 weeks in M35 and 4 weeks in M38-39	REN, E-REDES	Public

Table A-17 - Common KPIs applicable to SUC01 - Active Participation.

KPI name	**Active Participation[14]**
KPI ID	KPI_H02
KPI Demo ID	-
Description	This indicator measures the percentage of customers actively participating in the demo, meaning, the ones that responded to our survey aimed at evaluating the flexibility potential at MV level, with respect to the total customers that accepted the participation, meaning, the ones that actually provided the necessary data. This indicator will be used to evaluate the customer engagement plan.
Formula	$R = \frac{N_{active}}{N_{accept}} . 100$
Variables	R: Active participation (%). N_{active}: Customers actively participating in the demo. N_{accept}: Customers accepted to participate in the demo.
KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.
Calculation methodology	Compare the number of customers that responded to the survey in comparison with the ones that accepted the use of the necessary data.
KPI target value	100%
KPI data collection details	

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level

[13] This survey relates to a questionnaire that was carried out and sent to MV customers, namely hotels, supermarkets and industry, with the purpose of gathering approval for the use of their data for the analysis carried out by INESC TEC on the flexibility potential estimation.

[14] This KPI is also applicable to SUC 02

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	N_{active}	Survey	Counting	Aggregated	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public
	N_{accept}	Survey	Counting	Aggregated	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public
	R	Survey	-	Aggregated	On event	2 weeks in M35 and 4 weeks in M38-39	E-REDES	Public

A.1.7.2 Common KPIs applicable to SUC02

Table A-18 to Table A-22 show the common KPIs applicable to SUC02. Note that although not presented in the table below, the Common KPIs "Number of FSPs" and "Active participation" stated in Table A-16 and Table A-17 are also applicable to SUC02.

Table A-18 - Common KPIs applicable to SUC02 - Volume of transactions (Power).

KPI name	**Volume of transactions (Power)**							
KPI ID	KPI_H09B							
KPI Demo ID	-							
Description	This indicator measures the volume (in kW) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.							
Formula	$VT_P = \sum_T \sum_I P_{i,t}$							
Variables	VT_P: Volume of selected flexibilities considering active power (kW). P: Volume of selected capacity by the i-th flexible resource at time t (kW). I: Set of flexible resources. T: Examined period.							
KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.							
Calculation methodology	1) A model representing the FSP flexibility parameters will be used, which will include information on the price of each offer; 2) An optimal power flow will compute the volume of power needed from the FSPs to solve the congestions; 3) An optimization algorithm will select from these flexibilities, the optimal ones (either based on price or on resulting grid losses – still to be defined) to solve the grid congestion; 4) The value of the KPI will be the volume, in power, of all the selected flexibilities, aggregated for all nodes and calculated on a daily basis.							
KPI target value	0 kW							
KPI data collection details	**Data ID**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**

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	$P_{i,t}$	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public
	VT_P	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public

Table A-19 - Common KPIs applicable to SUC02 - Volume of transactions – cleared bids (P or Q Availability).

KPI name	**Volume of transactions – cleared bids (P or Q Availability)**							
KPI ID	KPI_H09A							
KPI Demo ID	-							
Description	This indicator measures the volume (in kW) of the available flexibilities to solve grid congestions identified during the examined period T.							
Formula	$VT_{CAV} = \sum_{T} \sum_{I} P_{i,t}$							
Variables	VT_{CAV}: Volume of available flexibility considering active power (MW) and reactive power (MVA). $P_{i,t}$: Volume of available flexibilities (capacity) by the i^{th} flexible resource at time t (MW or MVA). I: Set of flexible resources. T: Examined period.							
KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.							
Calculation methodology	1) A model representing the FSP flexibility parameters will be used, which will include information on the price of each offer; 2) An optimal power flow will compute the volume of power needed from the FSPs to solve the congestion; 3) The value of the KPI will be the volume, in power, of all the available flexibilities, aggregated for all nodes and calculated on a daily basis.							
KPI target value	> 10 kW							
KPI data collection details	**Data ID**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
	VT_{CAV}	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public

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	$P_{i,t}$	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public

Table A-20 - Common KPIs applicable to SUC02 - Volume of transactions – cleared bids (P or Q Activation) (Energy).

KPI name	**Volume of transactions – cleared bids (P or Q Activation) (Energy)**
KPI ID	KPI_H09D
KPI Demo ID	-
Description	This indicator measures the volume (in MWh) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.
Formula	$$VT_{CAC} = \sum_{T} \sum_{I} E_{i,t}$$
Variables	VT_{CAC}: Volume of selected flexibilities considering P·T or Q·T (MWh). $E_{i,t}$: Volume of selected flexibilities by the i^{th} flexible resource at time t (MWh). I: Set of flexible resources. T: Examined period.
KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.
Calculation methodology	1) A model representing the FSP flexibility parameters will be used, which will include information on the price of each offer; 2) An optimal power flow will compute the volume of power needed from the FSPs to solve the congestion; 3) An optimization algorithm will select from these flexibilities, the optimal ones (either based on price or on resulting grid losses – still to be defined) to solve the grid congestion; 4) The value of the KPI will be the volume, in energy, of all the selected flexibilities, aggregated for all nodes and calculated on a daily basis.
KPI target value	0 MWh

	Data ID	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
KPI data collection details	VT_{CAC}	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public
	$E_{i,t}$	Historical data, Power flows forecast algorithm	Simulation	Aggregated	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public

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Table A-21 - Common KPIs applicable to SUC02 - Available Flexibility.

KPI name	Available Flexibility
KPI ID	KPI_H14A
KPI Demo ID	-
Description	Ratio between the flexible power that can be used for congestion management and the forecasted total power demand.
Formula	$$Flexibility_{\%} = \frac{\sum P_{Available\ Flexibility}}{\sum P_{Total\ in\ area}} . 100$$
Variables	$Flexibility_{\%}$: Percentage of available flexible power with respect to the total demand at a specific grid segment in reporting period (%). $\sum P_{Available\ Flexibility}$: Amount of available flexibility at a specific grid segment in reporting period (MW). $\sum P_{Total\ in\ area}$: Total power demand in MW at demo grid segment (MW).
KPI baseline explanation	No baseline will be considered since flexibility services are still to be implemented in Portugal.
Calculation methodology	Calculation methodology will be similar as for the "Volume of transactions – cleared bids (P or Q Availability)", it will consider the output from the OPF to determine the volume of power needed from the FSPs to solve the identified congestions. The value of the KPI will be the ratio between the available flexibility and the demand forecast calculated under SUC07 and will be calculated for each interconnection point and on a daily basis.
KPI target value	It will vary depending on the substation considered: • Batalha: >0,01% • Pocinho: >0,1%

KPI data collection details:

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
$Flexibility_{\%}$	Historical data, Power flows forecast algorithm	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Public
$P_{Available_{Flexibility}}$	Historical data, Power flows forecast algorithm	Simulation	Distribution / Transmission grid (Specific area-not the entire grid with focus on the TSO/DSO interface)	On event (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES, REN	Confidential

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	$P_{Total_{in_{Area}}}$	Historical Data	Simulation (based on historical data)	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	REN E-REDES	Confidential

Table A-22 - Common KPIs applicable to SUC02 - Number of avoided technical restrictions.

KPI name	Number of avoided technical restrictions
KPI ID	KPI_H12
KPI Demo ID	-
Description	Ratio between the number of avoided congestions (overloaded elements) in the grid for all periods of observation scenarios with flexibility activation (after SUC implementation) by the DSO and/or TSO action and the total number of expected restrictions.
Formula	$$ATR_{\%} = \frac{N_{TR_{Flex}}}{N_{TR}}.100$$
Variables	$ATR_{\%}$: Share of avoided technical restrictions (%). N_{TR}: Total number of expected technical restrictions. $N_{TR_{Flex}}$: Total number of technical restrictions solved through activation of flexibility services.
KPI baseline explanation	Simulation scenarios based on historical values, representing the scenario without flexibility activation.
Calculation methodology	Compute congestions for simulations of the starting scenarios (without flexibility activation) and for the resulting scenarios with flexibility activation (after SUC implementation).
KPI target value	0%
KPI data collection details	

Data ID	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
N_{TR}	Historical Data	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
$N_{TR_{Flex}}$	Historical Data	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES REN	Public
$ATR_{\%}$	Historical Data (Datasets from previous variables)	Simulation	Distribution / Transmission grid	On event. (Daily timeframe)	2 weeks in M35 and 4 weeks in M38-39	E-REDES R&D Nester	Public

A.2 Script to POST the availabilities of flexibility during the DEMO:

```
# 1- Authentication in TDEP

import requests
import sys
import base64
from datetime import datetime
import os
import datetime
import pandas as pd
import json
import csv

# Login information for passing to Nester

url = "http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/login/access-token"
headers = { 'accept': 'application/json', 'Content-Type': 'application/x-www-form-urlencoded', }
data = { 'grant_type': '', 'username': 'xxxxxxxx@onenet.com', 'password': 'xxxxxxxx', 'scope': '', 'client_id': '',
'client_secret': '', }
response = requests.post( url, headers=headers, data=data)

# Performs login at Nester and receives jwt access token

print('\n', url)
auth_String = response.json()['token_type'] + ' ' + response.json()['access_token']
print(auth_String)

# 2- Calls the file by the name of the day. The automatic algorithm at 16h every day, checked #the current
date #day, and called the file of the corresponding day saved locally

now = datetime.datetime.now()
from time import gmtime, strftime
now=strftime("%Y-%m-%d", gmtime())
now1=str(now)+ ".csv" #File structure name is for example: 09-08-2023.csv
now1
df1 = pd.read_csv(now1, header=None, encoding='ISO-8859-1', sep=";")
df1.head()

# 3- Flexibility posting for Batalha SE (example)

# Open the CSV with the name of the day and reads in the data

with open(now1) as f: #open ex: '10-07-2023.csv'
    reader = csv.reader(f, delimiter=';')
    data = [[] for _ in range(96)]
    for row in reader:
        for i in range(96):
            data[i].append(row[i])
```


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```
    new_list = []

    for row in data:
    #The Power is converter from kW to MW dividing by 1000
        new_dict = {"node_id": "B6014", "active_power_quantity": float(row[1])/1000, "reactive_power_quantity": float(row[2])/1000,
                    "period_from": row[3], "period_to": row[4]}
        new_list.append(new_dict)

    new_list
    parsed_data = new_list

    # Create a new dictionary with the desired structure
    new_data = {
        "sender_source": 2,
        "grid_nodes": parsed_data,
        "created_at": datetime.now().isoformat(),
        "flex_type": 1
    }

    # Convert the new dictionary to JSON format with integer values
    new_data_json = json.dumps(new_data, indent=4, default=int)

    # # Make the post in Nester Endpoint

    # define the URL endpoint where you want to send the POST request from Nester
    url = "http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/flexibility/needs/offers"

    # send the POST request with the JSON data and headers
    response = requests.post(url, headers={"Authorization": auth_String}, data=new_data_json)

    # print the response status code and content
    print(response.status_code)
    print(response.content)

    #4- Storing a log file locally
    if response.status_code == 200:
    # Define the file path where you want to save the content for response
        file_path_response = r"C:\Users\inesctec\Desktop\response.txt"

    # Open the file in append mode and save the content
        with open(file_path_response, 'a') as file:
    # Write the content to the file
            file.write(str(response.status_code) + '\n')
            file.write(response.content.decode() + '\n')
```


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A.3 Script -Provide Data: PT_Demo _using_the_OneNet Connector

```
#1- Authenticate into the connector user account
import requests
import json
import sys
import time

start_time = time.time()

# Login information for passing to Connector
login = \
   {
      "username": "wc-user1",
      "password": "type password here"
   }

# Performs login at OneNet Connector and receives jwt access token
r = requests.post('http://localhost:30001/api/user/auth', json=login)

# Creates Dictionary from json
r_dict = r.json()

# Prints jwt token
print('Access Token:', r_dict['accessToken'])

# Token information for passing to Connector
token = {"Authorization": "Bearer {}".format(r_dict['accessToken'])}

# Retrieves list of offered services by the user that is log in
r = requests.get('http://cc-cpes-248.inesctec.pt:30001/api/offered-services/list', headers=token)

# Formats json to str for better presentation
json_object = json.loads(r.content)
json_to_str = json.dumps(json_object, indent=2)

#2- Calls the file by the name of the day
import pandas as pd
import json
import datetime

now = datetime.datetime.now()
from time import gmtime, strftime
now=strftime("%Y-%m-%d", gmtime())
now1=str(now)+ ".csv" #File name is: 19-09-2023.csv
now1
df1 = pd.read_csv(now1, header=None, encoding='ISO-8859-1', sep=";")
df1.head()
```


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```
#3- Defines content and Converts it into a JSON file
import requests
from datetime import datetime
import time
import base64
import csv
import json

# Open the CSV with the name of the day and reads in the data
with open(now1) as f: #open ex: '10-07-2023.csv'
   reader = csv.reader(f, delimiter=';')
   data = [[] for _ in range(96)]
   for row in reader:
      for i in range(96):
         data[i].append(row[i])
new_list = []

for row in data:
#The Power is converter from kW to MW dividing by 1000
   new_dict = {"node_id": "B6014", "active_power_quantity": float(row[1])/1000, "reactive_power_quantity": float(row[2])/1000,
            "period_from": row[3], "period_to": row[4]}
   new_list.append(new_dict)

   parsed_data = new_list

# Create a new dictionary with the desired structure
new_data = {
   "sender_source": 2,
   "grid_nodes": parsed_data,
   "created_at": datetime.now().isoformat(),
   "flex_type": 1
}

# Convert the new dictionary to JSON format with integer values
new_data_json = json.dumps(new_data, indent=4, default=int)

# Print the formatted JSON
print(new_data_json)
base64_data = base64.b64encode(json.dumps(new_data_json).encode('utf-8')).decode('utf-8')

url="http://cc-cpes-248.inesctec.pt:30001/api/provide-data"

print(new_data_json)
print("Based64_string encoded msg:", base64_data)
```


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```
#4- Make a Post in the service created
import time
start_time = time.time()

data = {
   "title": "Flexibility_Offers_InescTec",
   "description": "OneNet_PTDemo_Offers",
   "filename": "Flex_Offers",
   "file": base64_data,
   "data_offering_id": "25bc914f-08c0-43e1-81e4-3502d9b29f54",
   "code": "00"}


# define the headers for the request, including the content type
headers = {"Content-Type": "application/json"}

# send the POST request with the JSON data and headers
response = requests.post(url, headers=token, json=data)
response_size = len(response.content) / 1024

# print the response status code and content
print(response.status_code)
print(response.content)
print(f"Posted file size: {response_size:.2f} KB")

end_time = time.time()

# Calculate the elapsed time
elapsed_time = end_time - start_time

print(f"Elapsed time to Post data through the connector: {elapsed_time:.4f} seconds")
# Record the time again after the request is complete

from datetime import datetime

# Get the current time in UTC
current_time = datetime.utcnow()

# Format the current time as a string
formatted_time = current_time.strftime("%Y-%m-%d-%H-%M-%S.%f")

print(formatted_time)
```


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A.4 Script - Consume Data: PT_Demo _using_the_OneNet Connector

```
#1- Authenticate into the connector user account
import requests
import sys
import base64
from datetime import datetime
import os
# Initialize variables
aux_4 = None
count = 0
ip = None
user_ip = None
url = None
r = None
new_time_stamp = None
old_time_stamp = None
# Fetches the last download time stamp and gives it to old_time_stamp
if os.path.isfile('Last_download.txt'):
    with open('Last_download.txt', "r") as file:
        lines = file.readlines()
        if len(lines) == 0:
            old_time_stamp = None
        else:
            old_time_stamp = lines[-1].strip()
else:
    old_time_stamp = None
# Login information for passing to Connector
login = \
    { "username": "wc-user2",
        "password": "insert password here"    }
user_ip = "http://cc-cpes-124.inesctec.pt:30001/api"
# Performs login at OneNet Connector and receives jwt access token
url = user_ip + "/user/auth"
print('\n', url)
r = requests.post(url, json=login, timeout=60)
# Checks if token has been provided and extracts it for future use in headers
if r.status_code == 200:
    # Creates Dictionary from json
    r_dict = r.json()
    # Prints jwt token
    print('\nAccess Token:', 'Provided.', '\n')
    # Token information for passing to Connector
    token = {"Authorization": "Bearer {}".format(r_dict['accessToken'])}
else:
    print("Status Code:", r.status_code, '| Check log in information.')
    sys.exit()
```

```
# Retrieves the login information of the current user and prints it
url = user_ip + "user/current"
r = requests.get(url, headers=token, timeout=10)
if r.status_code == 200:
    r_dict = r.json()
    print('\nYou are logged in as:')
    print('Username: ', r_dict['username'])
    print('E-mail  : ', r_dict['email'])
    print('ID      : ', r_dict['id'], '\n')
else:
    print("Login was successful, however user info is not available", "| Status Code:", r.s
    # sys.exit()
print("\nMonitoring the connector and download every new update")

#2- With a while true loop the script retrieves list of offered services by the user that is log in
while True:
    url = user_ip + "/consume-data/list"
    r = requests.get(url, headers=token, timeout=60)
    if r.status_code == 200:
        jsonResponse = r.json()
        new_time_stamp = jsonResponse[0]['created_on']
        if new_time_stamp != old_time_stamp:
            current_time = datetime.now()
            print('New file found. Current time =', current_time, '\n')
            old_time_stamp = new_time_stamp
            download = {"id": jsonResponse[0]['id']}
            filename = jsonResponse[0]['file_name']
            url = user_ip + "/consume-data/by-id"
            monitor_request = requests.get(url, params=download, headers=token, timeout=180
            if monitor_request.status_code == 200:
                download_dict = monitor_request.json()
                missing_padding = len(download_dict['filedata']) % 4
                if missing_padding != 0:
                    download_dict['filedata'] += '=' * (4 - missing_padding)
                filedata = base64.b64decode(download_dict['filedata'])
                text = filedata
                with open(filename, 'w') as file:
                    file.write(str(filedata))
                    file.flush()
                with open('Last_download.txt', 'a') as file:
                    file.write(str(text) + '\n')
                    file.flush()
            else:
                print("Error.")
                sys.exit()
        elif count == 20:
            current_time = datetime.now()
            print('No new file found yet. Current Time =', current_time, '\n')
            count = 0
        else:
            count += 1
    else:
        print("Connection Lost.")
        sys.exit()
```


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A.5 SUC06 Functional testing procedure

This document presents the steps for coordinated testing procedure on the SUC06 methodology. TSO actions are done by Nester, while DSO actions are done by E-Redes.

Preparation:

Nester to prepare Annual files of TSO and DSO. It must include four assets in each operator. All Coordination Status (CSs) are "request".

Nester to prepare Annual merged validated file. All CS are "confirmed".

Initialization Test:

__ Nester submit Annual Maintenance plans

__ E-Redes submit Annual Maintenance plans

__ Nester receives email notification of successful submission of both files

__ Nester submits Annual merged validated plans

__ Nester sees Annual merged validated plans on the TDEP

__ E-Redes sees Annual merged validated plans on the DDEP

__ On both DEP all plans are confirmed

Interaction test:

__ Nester submits a request on change of date of plan for three DSO-owned assets

__ Nester receives email notification

__ E-Redes sees three requests on the DDEP

__ E-Redes accept one and reject/cancel? one through the "quick action" button. In addition, request another date in edit window for the third work.

__ Nester receives email notification

__ Nester sees the three changes on the TDEP

__ Nester accepts the request from the DSO by using the "quick action" button on the TDEP.

__ Nester receives email notification

<u>Invert roles and repeat the entire Interaction test.</u>

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