



Validation and results of concept test - Portugal

D9.2

Authors:

Madalena Lacerda (E-REDES)
Carlos Damas Silva (E-REDES)
Gonçalo Glória (R&D NESTER)
Mateo Toro-Cárdenas (R&D NESTER)
Aleksandr Egorov (R&D NESTER)
Alexandre Lucas (INESC TEC)
Rui Pestana (REN)

Responsible Partner	E-REDES
Checked by WP leader	Madalena Lacerda (E-REDES), 21/04/2023
Verified by the appointed Reviewers	Sławomir Noske, Joanna Ptak (ENERGA OPERATOR SA), 28/04/2023 Vassi Kujala (Nord Pool), 25/04/2023
Approved by Project Coordinator	Padraic McKeever (Fraunhofer), 28.04.2023

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	30.04.2023
Actual date of delivery	28.04.2023

Version	Date	Author(s)	Notes
0.4	17/04/2023	Madalena Lacerda (E-REDES), Carlos Damas Silva (E-REDES), Gonçalo Glória (R&D NESTER), Mateo Toro-Cárdenas (R&D NESTER), Aleksandr Egorov (R&D NESTER), Alexandre Lucas (INESC TEC), Rui Pestana (REN)	First draft for internal by WP9 partners and external review from EOP and Nord Pool
0.5	21/04/2023	Madalena Lacerda (E-REDES), Carlos Damas Silva (E-REDES), Gonçalo Glória (R&D NESTER), Mateo Toro-Cárdenas (R&D NESTER), Aleksandr Egorov (R&D NESTER), Alexandre Lucas (INESC TEC), Rui Pestana (REN), Vassi Kujala (Nord Pool)	Draft for quality review
0.6	27/04/2023	Madalena Lacerda (E-REDES), Carlos Damas Silva (E-REDES), Gonçalo Glória (R&D NESTER), Mateo Toro-Cárdenas (R&D NESTER), Aleksandr Egorov (R&D NESTER), Alexandre Lucas (INESC TEC), Rui Pestana (REN)	Pre-final version of the deliverable
1.0	28/04/2023	Madalena Lacerda (E-REDES), Carlos Damas Silva (E-REDES), Gonçalo Glória (R&D NESTER), Mateo Toro-Cárdenas (R&D NESTER), Aleksandr Egorov (R&D NESTER), Alexandre Lucas (INESC TEC), Rui Pestana (REN), Joanna Ptak (ENERGA OPERATOR SA), Sławomir Noske (ENERGA OPERATOR SA)	Final deliverable

Disclaimer:

All information provided reflects the status of the OneNet project at the time of writing and may be subject to change. All information reflects only the author's view and the European Climate, Infrastructure and Environment Executive Agency (CINEA) is not responsible for any use that may be made of the information contained in this deliverable.



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 (LC)".

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:

1. 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;
2. 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
3. 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.



Table of Contents

1	Introduction	11
1.1	Task 9.2	11
1.2	Outline of the Deliverable.....	13
1.3	How to Read this Document	14
2	Methodology.....	16
3	Portuguese demonstration description	18
3.1	Portuguese Business Use Cases and System Use Cases.....	18
3.2	Demo site characteristics.....	21
3.3	Key Performance Indicators.....	22
3.3.1	Demo KPIs	23
3.3.2	Common KPIs	32
4	Tools and Platforms	36
4.1	Portuguese Demo High Level Architecture.....	36
4.1.1	Communication layer	38
4.1.2	Operational layer	39
4.1.3	Transmission System Operator Data Exchange Platform	39
4.1.4	Distribution System Operator Data Exchange Platform	40
4.2	APIs Functional Specification	41
4.2.1	SUC 01 - Evaluation of the Product & Grid prequalification requirements	43
4.2.2	SUC 02 - Day-Ahead & Intraday Flexibility needs.....	55
4.2.3	SUC 06 - Maintenance plans information exchange	70
4.2.4	SUC 07 - Consumption and generation forecast information exchange.....	92
4.2.5	SUC 08 - Short-circuit levels information exchange.....	100
4.3	Tools.....	112
4.3.1	TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool	112
4.3.2	Short-Circuit currents forecast Tool.....	113
4.3.3	Methodology for estimating the MV flexibility potential	114
4.3.4	E-REDES Operational Planning Tool	114
5	Consumer approach	116
5.1	Methodology	117
5.2	Simulation	118
6	Evaluation and Results	129
6.1	SUC 02.....	129
6.2	SUC 06.....	137
6.3	SUC 08.....	139
7	Conclusions and next steps.....	146
	References	148

List of Figures

Figure 1.1 – Interconnection between the OneNet Task 9.2 with other tasks and work packages in the OneNet project	13
Figure 1.2 – Outline of OneNet Deliverable 9.2.....	14
Figure 2.1 - Portuguese demonstration methodology	17
Figure 4.1 - Portuguese Demo Architecture	37
Figure 4.2 - DEP API Middleware design.....	38
Figure 4.3 - TDEP AWS Architecture	39
Figure 4.4 - DDEP Azure architecture used by Link Consulting.....	41
Figure 4.5 - SUC 01 scenario 1 diagram	45
Figure 4.6 - SUC 01 Scenario 2 diagram.....	46
Figure 4.7 - SUC 01 Method 01.1 API snapshot	47
Figure 4.8 - SUC 01 Method 01.4 API snapshot	48
Figure 4.9 - SUC 01 Scenario 1 flowchart (TDEP)	51
Figure 4.10 - SUC 01 Scenario 2 flowchart (TDEP)	52
Figure 4.11 - SUC 01 Scenario 1 flowchart (DDEP)	54
Figure 4.12 - SUC 01 Scenario 2 flowchart (DDEP)	55
Figure 4.13 – SUC 02 Scenario 1 diagram	57
Figure 4.14 - SUC 02 scenario 2 diagram	58
Figure 4.15 - SUC 02 Scenario 3 diagram	59
Figure 4.16 - SUC 02 scenario 4 diagram	60
Figure 4.17 - SUC 02 Scenario 5 diagram	61
Figure 4.18 - SUC 02 Method 02.a API snapshot	62
Figure 4.19 - SUC 02 Method 02.1 API snapshot	63
Figure 4.20 – SUC 02 Method 02.5 API snapshot	64
Figure 4.21 - SUC 02 Scenario 1 flowchart (TDEP)	67
Figure 4.22 - SUC 02 Scenario 2 flowchart (TDEP)	68
Figure 4.23 - SUC 02 Scenario 5 flowchart (TDEP)	69
Figure 4.24 - SUC 02 Scenario 1 flowchart (DDEP)	70
Figure 4.25 - SUC 06 scenario 1 diagram	72
Figure 4.26 - SUC 06 scenario 2 diagram	74
Figure 4.27 – SUC 06 Method 06.1 snapshot	75
Figure 4.28 – SUC 06 Method 06.a snapshot.....	76
Figure 4.29 – SUC 06 Method 06.3 snapshot	77

Figure 4.30 – SUC 06 Method 06.2 snapshot	78
Figure 4.31 – SUC 06 Method 06.4 snapshot	79
Figure 4.32 - SUC 06 Scenario 1 flowchart (TDEP)	87
Figure 4.33 - SUC 06 Scenario 2 flowchart (TDEP)	89
Figure 4.34 - SUC 06 Scenario 1 flowchart (DDEP)	90
Figure 4.35 - SUC 06 Scenario 2 flowchart (DDEP)	91
Figure 4.36 - SUC07 diagram	93
Figure 4.37 - Method 07.a snapshot.....	94
Figure 4.38 - Method 07.1 snapshot	95
Figure 4.39 - Method 07.b snapshot	96
Figure 4.40 – SUC 07 flowchart (TDEP).....	99
Figure 4.41 - SUC 07 flowchart (DDEP)	100
Figure 4.42 - SUC 08 Scenario 1 diagram.....	101
Figure 4.43 - SUC 08 Scenario 2 diagram.....	103
Figure 4.44 - SUC 08 Method 08.a API snapshot.....	104
Figure 4.45 - SUC 08 Method 08.b API snapshot.....	105
Figure 4.46 - SUC 08 Method 08.2 API snapshot.....	106
Figure 4.47 - SUC 08 Method 08.1 API snapshot.....	107
Figure 4.48 - SUC 08 Scenario 1 flowchart (TDEP)	109
Figure 4.49 - SUC 08 Scenario 2 flowchart (TDEP)	110
Figure 4.50 - SUC 08 Scenario 1 flowchart (DDEP)	111
Figure 4.51 - SUC 08 Scenario 2 flowchart (DDEP)	112
Figure 5.1 - Resulting dendrogram of the clustering made with the Mahalanobis Distance (MD) focusing on the closing and opening times dynamics	120
Figure 5.2 - Series 00:15-CL1: Best Fit: Lognormal dist., Loc.= -88,06, Mean= 57,04, Std. Dev.= 18,19.....	121
Figure 5.3 - Representative operational load diagrams by cluster.....	121
Figure 5.4 - Event load detection from daily routine dynamics.....	123
Figure 5.5 - Grid Area considered for store quantification identification	126
Figure 5.6 - Flexibility estimation adjusted to P75 (example for 19:15h).....	127
Figure 6.1 – IEEE 14 bus test case single line diagram.....	130
Figure 6.2 – Active Power time-series	131
Figure 6.3 – Active and Reactive Flexibility Needs	134
Figure 6.4 - Flexibility forecast estimation for the 12th of March 2023 (P50 and P75).....	135
Figure 6.5 - Short-circuit current values for SS1 substation on 20/11/2022	143
Figure 6.6 - Short-circuit current values for SS2 substation on 19/11/2022	144

List of Tables

Table 3.1 - Portuguese demonstration SUCs and correspondent BUCs	19
Table 3.2 - Demo KPIs applicable to all SUCs	23
Table 3.3 - Demo KPIs applicable to SUC 01	24
Table 3.4 - Demo KPIs applicable to SUC 02	25
Table 3.5 - Demo KPIs applicable to SUC 06	26
Table 3.6 - Demo KPIs applicable to SUC 07	28
Table 3.7 - Demo KPIs applicable to SUC 08	30
Table 3.8 - Common KPIs applicable to SUC 01	32
Table 3.9 - Common KPIs applicable to SUC 02	33
Table 4.1 - SUC 01 Method 01.1 summary	47
Table 4.2 - SUC 01 Method 01.4 summary	47
Table 4.3 - SUC 01 Method 01.2 summary	48
Table 4.4 - SUC 01 Method 01.3 summary	49
Table 4.5 - SUC 01 Data model	49
Table 4.6 – SUC 02 Method 02.a summary	62
Table 4.7 - SUC 02 Method 02.1 summary	62
Table 4.8 - SUC 02 Method 02.5 summary	63
Table 4.9 - SUC 02 Method 02.2 summary	64
Table 4.10 - SUC 02 Data Model	65
Table 4.11 - SUC 06 Method 06.1 summary	75
Table 4.12 – SUC 06 Method 06.a summary	76
Table 4.13 – SUC 06 Method 06.3 summary	76
Table 4.14 – SUC 06 Method 06.2 summary	77
Table 4.15 – SUC 06 Method 06.4 summary	78
Table 4.16 - SUC 06 Data Model	79
Table 4.17 – Method 07.a details	94
Table 4.18 - Method 07.1 details	95
Table 4.19 - Method 07.b details	95
Table 4.20 - SUC-07 Data Model content	96
Table 4.21 - SUC 08 Method 08.a summary	104
Table 4.22 - SUC 08 Method 08.b summary	105
Table 4.23 - SUC 08 Method 08.2 summary	105
Table 4.24 - SUC 08 Method 08.1 summary	106

Table 4.25 - SUC 08 Data model	107
Table 5.1 - List of main loads in the stores with flexibility ability and flex load category	122
Table 5.2 - Hourly restrictions by load category, with flexible power (in%) per cluster.....	124
Table 5.3 - Example of Total Flexibility identification per category of asset	125
Table 5.4 - Message content of flexibility availability.....	127
Table 6.1 - Step 1 - Power Flow (PF) and Optimal Power Flow (OPF) constraint results.....	131
Table 6.2 – Step 2 – Flexibility Needs result	133
Table 6.3 - Summary of the studies short-circuit simulations for substations SS1 and SS2	145

List of Abbreviations and Acronyms

Acronym	Meaning
AC	Air conditioning
API	Application Programming Interface
APM	Application Performance Management
ASM	Active System Management
BUC	Business Use Case
CCTV	Closed-Circuit Television system
DDEP	DSO Data Exchange Platform
DER	Distributed Energy Resource
DEP	Data Exchange Platform
DSO	Distribution System Operator
ECO	Ecological
EHV	Extra High Voltage
EV	Electric Vehicles
FSP	Flexibility Service Providers
GIS	Geographic Information System
GUI	Graphical User Interface
HV	High Voltage
ICT	Information and communication technologies
INESC TEC	Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência
Isc	Short-circuit Current
JRC	Join Research Centre
KPI	Key Performance Indicator
LV	Low Voltage
MD	Mahalanobis Distance
MV	Medium Voltage
OPF	Optimal Power Flow
PDIRT	Transmission Network Development and Investment Plan
PSS/E	Power System Simulator for Engineering
PV	Photovoltaics
RES	Renewable Energy Sources
RUC	Regional Use Case
SO	System Operator
SUC	System Use Case
TDEP	TSO Data Exchange Platform
TSO	Transmission System Operator
WP	Work Package

Executive Summary

The ongoing energy transition is bringing new challenges and opportunities to the energy system, which has been shifting to become more flexible to cope with the variability brought by renewable generation and new dynamics from the demand side. It is also becoming more digital, with unprecedentedly high amounts of data being generated and processed, essentially brought by the increased number of interactions with Distributed Energy Resources (DERs) connected to the network. To face this ever-changing reality, there is an urgency to develop optimized data-sharing mechanisms between System Operators (SOs) to increase network efficiency and resiliency while also aiming for a higher capacity to incorporate additional variable renewable energy resources that will bring us closer to the sustainability and climate goals that need to be achieved.

In this context, the OneNet project aims to create the needed conditions for a new generation of system services able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for consumers. The Portuguese demonstration focuses on the creation of some of these conditions, especially envisaging an optimised information exchange mechanism between the Portuguese Distribution System Operator (DSO) and Transmission System Operator (TSO) through application-programming interfaces (APIs).

The central pieces of the Portuguese demonstration are the two Data Exchange Platforms (DEPs) created, one for the TSO, the TSO Data Exchange Platform (TDEP), the other for the DSO, the DSO Data Exchange Platform (DDEP). These consist of Cloud systems that will serve as a gateway between the internal systems of the DSO and the TSO with other possible external entities, being also capable of fulfilling the required APIs and the use cases selected for the Portuguese demonstration. These use cases concern the exchange of information for operational planning and related to flexibility, namely: i) for pre-qualification of Flexibility Service Providers (FSPs); ii) daily flexibility needs forecasts; iii) weekly, monthly and annual maintenance plans; iv) daily consumption and generation forecasts; v) daily forecasted short-circuit information. Fitting within the second use case, a dedicated methodology for the estimation of the flexibility potential from MV customers was also developed, which results will also be exchanged with the TSO, with the aim of solving transmission-level congestions.

At the time of writing this document, few components are yet to be finalised, such as the integration with the OneNet connector, the integration with the DSO internal systems for some use cases, the deployment of support tools for operational planning and flexibility needs identification, and the user interfaces for both DEPs. Nonetheless, preliminary results have already been gathered for some use cases and presented within this same deliverable. Namely, the TSO Flexibility Needs Evaluation and FSP provision simulation Tool has been tested with an IEEE test case network and was able to determine the flexibility needs in terms of active and reactive power

in each bus to solve the emulated constraints. For this same use case related to the exchange of information on flexibility needs, the methodology to assess the flexibility potential from MV customers (supermarket chain) has also been tested for one entire day of the year and has already provided a flexibility forecast estimation diagram for that same day. The results gathered show a small potential from the supermarket chain compared to the order of magnitude of the flexibility needs within the substation area considered, however, when aggregated with other flexibility resources not considered in the analysis, it could result in an acceptable level of complementary flexibility for the grid in some locations.

Also, the data model that was agreed between the TSO and DSO, and thus proposed in this deliverable for the exchange of information regarding maintenance works, was also tested and demonstrated for two maintenance works from the 2020 annual maintenance plan from the TSO.

Lastly, preliminary results from the use case related to the exchange of information on short-circuit currents calculated at the TSO/DSO interface were also presented, comprising two different MV/LV substations in Portugal. The results show that for some of the periods simulated, the joint TSO/DSO short-circuit contribution calculated was higher than the maximum short-circuit value established in the transmission network development and investment plan. Although the joint contributions determined don't pose a burden from the circuit breaker rating point of view, this result shows the importance of considering joint short-circuit contribution in asset planning and operational procedures, instead of considering only transmission-level contributions, especially when contributions from the distribution network tend to increase with the increased penetration of distributed generation in the network.

Through these developments, the Portuguese demonstration will contribute as a best practice for an improved coordination between the DSOs and TSOs, replacing common and inefficient interactions, the majority still done via e-mail, with a more efficient and frequent information exchange regarding grid operational planning and the provision of flexibility services.

1 Introduction

The European electricity system is currently experiencing a deep paradigm shift. Now, more than ever, it is moving at a fast pace, from a fully centralised and conventional system, to a decentralised and interconnected one, with a significant share of variable electricity generation and with active participation from the consumer side. This changing reality is being boosted by an ambitious European policy framework, that is setting high standards and objectives to be achieved in the medium-term and a concrete vision for decarbonization in the long-term.

The Fit for 55 and the REPowerEU packages send this clear message of increased ambition, aiming for an overall emissions reduction of 55% by 2030, compared to 1990 values [1], and a renewables' share of 45% for this same year [2]. Apart from this, a transition is also occurring in the demand-side since the publication of the Clean Energy Package, that clearly puts the consumer at center of the transition, through active participation in the markets [3]. The electrification of demand is also undeniable, with the Commission aiming to install 10 million heat pumps over the next 5 years and to replace 30 million cars with zero-emission ones by 2030 [4], leading to more assets being connected to the network and thus, to more data being generated and processed.

These new dynamics will of course require a smarter approach to manage the system, urging the need to develop optimized data-sharing mechanisms between System Operators to face these new developments and, at the same time, increase network efficiency, reliability and resiliency while also aiming for a higher capacity to incorporate additional variable renewable energy resources. This particular objective is addressed within the Portuguese demonstration of the OneNet project, which will aim to develop a data exchange mechanism between the Portuguese TSO and DSO for a better operational planning of the network.

1.1 Task 9.2

This deliverable is part of OneNet's Work Package 9 (WP9) which addresses the work of the demonstration countries from the Western Cluster, namely, Portugal, Spain and France, being segmented into six different tasks. Task 9.1 established the initial alignment and set-up of the three demonstrators, guaranteeing their complementarity, considering as starting point and basis for this alignment the Active System Management (ASM) report [5], aiming for the different phases of flexibility provision processes to be addressed within the Cluster. Task 9.2, Task 9.3 and Task 9.4 focus on the demo implementation for the Portuguese, Spanish and French demos, respectively. Task 9.5 will do the high-level analysis of all the demonstrators and perform the success metric analysis, while Task 9.6 will identify the main lessons learnt and perform the scalability and replicability analysis of the demo solutions.

This document is the first of two deliverables of Task 9.2, which concerns the implementation of the Portuguese demonstrator. This 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 first two.

Under the first sub-task, the set-up of the demonstration was done, leveraging from and extending the work already carried out under Task 9.1, involving not only the adaptations to already implemented systems, such as the operational planning tool used by E-REDES (DPlan), but also the development of new tools such as the TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool and the Short-Circuit currents (Isc) forecast tool. The development of both DEPs, which are core to the demonstration, is also part of this sub-task. These base developments allow the deployment of the technical solutions proposed in the several use cases addressed by the Portuguese demonstrator, namely, the calculation of the data to be exchanged, the integration with internal systems from the DSO and the TSO and the direct and indirect communication between internal tools and the DEPs. These internal tools can either communicate directly with the DEPs via APIs, or they can communicate with an intermediary tool that then sends the data to the DEPs through the APIs. This is the case of the PREDIS tool from E-REDES that resorts to machine learning algorithms to accurately forecast demand and generation at HV and MV level. These forecasts are then fed to the DPlan tool from E-REDES to evaluate the network state, calculate the output data and send it to the DDEP via APIs.

The second sub-task relates to the actual demonstration activities, including the development of concept tests for the solutions deployed and the gathering of participants for the demonstration. Since some of the core developments are yet to be finalised, the concept test results presented under this deliverable will not address all of the use cases developed, and a status of the developments will be provided. Note that this is not a physical demonstration with actual flexibility assets actively participating in it, as it is focused on the interactions and data exchange between the DSO and TSO. The FSP data used will be simulated with public data from the participants in the balancing markets and with metering data from MV customers that have agreed to share their data as input for the estimation of their flexibility potential.

Regarding the interactions between Task 9.2 with other tasks in OneNet, both within and outside WP9, since the demonstration focuses on the deployment and testing of solutions, these solutions need to be aligned with the horizontal work carried out in the project. More specifically, Task 9.2 develops the Business Use Cases (BUCs) described under Task 2.3 (D2.3, [6]), together with the System Use Cases (SUCs) defined both under Task 5.1 (D5.1 [7]) and Task 9.1 (D9.1 [8]). The KPIs defined under Task 2.4 (D2.4, [9]) will be considered under this task and specifically addressed in this deliverable to further advance their definition. The main recommendations from Task 3.1 (D3.1, [10]) and WP4 in general were also considered in the solutions developed

under the Portuguese demonstrator. Lastly, the demo also feeds from WP6 developments, more specifically concerning the OneNet Connector, as it is used and tested under one of the SUCs and on the Regional Use Case (RUC). Apart from this infeed of results to Task 9.2, this task will also provide input to other tasks, mainly tasks within WP9, feeding results to the analysis to be carried out under Task 9.5 and Task 9.6, and to tasks within WP11 that aims to extract conclusions from the demonstrators to allow for their scalability and replicability. Figure 1.1 portrays these interactions, both within and outside WP9.

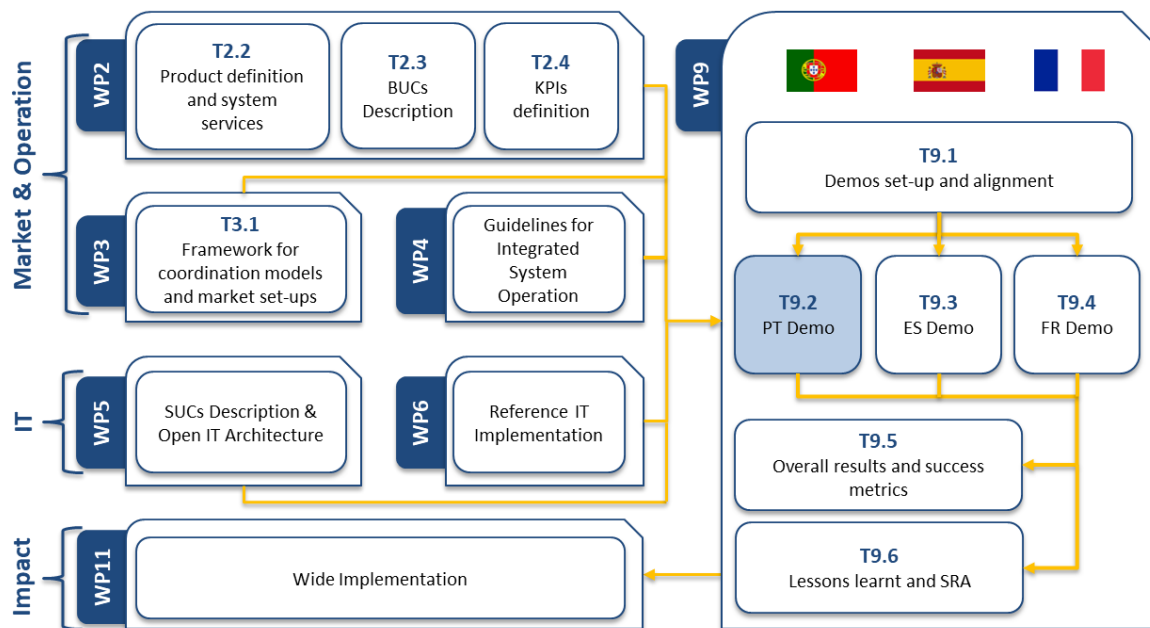


Figure 1.1 – Interconnection between the OneNet Task 9.2 with other tasks and work packages in the OneNet project

1.2 Outline of the Deliverable

The structure of the deliverable is depicted in Figure 1.2. Chapter 1 is the introductory section of the document, including the objectives, outline and the context of the activities carried out in Task 9.2, including how they fit into the general structure of the OneNet project, including horizontal Work Packages and remaining tasks from WP9. Chapter 2 presents the process behind the demonstration itself, including the different phases and interactions developed. Chapter 3 provides a brief overview and description of the demonstration, of the BUCs and SUCs addressed and of the demo site characteristics, information that can be found in greater detail in deliverables D2.3 [6], D5.1 [7] and D9.1 [8]. It also addresses the KPIs that will be used to evaluate the success of the demonstration, including both: (1) demo level KPIs, which have already been briefly defined within D2.4 [9]; and (2) common KPIs, that will allow comparison between OneNet demonstrators. Note that the actual

results of these KPIs will be presented in D9.5 and analysed in subsequent WP9 deliverables (D9.8 and D9.9). Chapter 4 will address the main tools and platforms developed within the demonstration, namely: (1) the architecture for the DDEP) and TDEP where the interactions will take place; (2) the specification of the APIs used for the communication between the two platforms for each of the SUCs developed; (3) the tools and methodologies developed by the TSO and the DSO to derive the information to be exchanged. Chapter 5 focuses on the consumer perspective, namely on the estimation of flexibility potential for consumers connected at the HV and MV levels. Chapter 6 describes the main results gathered so far within the demonstrator. Lastly, main conclusions and next steps are presented in Chapter 7.

Introduction	<ul style="list-style-type: none"> • Objectives and context of Task 9.2 • Interaction with OneNet Work Packages and tasks
PT demonstration process and structure	<ul style="list-style-type: none"> • Overall process behind the Portuguese demonstrator to achieve results
PT demonstration description	<ul style="list-style-type: none"> • Overview of the PT demonstration, BUCs and SUCs • Demo site characteristics • KPIs
Tools and Platforms	<ul style="list-style-type: none"> • High level architecture • APIs Functional Specification • Tools
Consumer approach	<ul style="list-style-type: none"> • Flexibility potential analysis
Evaluation and Results	<ul style="list-style-type: none"> • Main results gathered so far in each SUC
Conclusions and next steps	<ul style="list-style-type: none"> • Main conclusions • Next steps in the PT Demonstration

Figure 1.2 – Outline of OneNet Deliverable 9.2

1.3 How to Read this Document

This deliverable is the second deliverable within the Western Cluster and the first of two from the Portuguese demonstration. It develops from the initial alignment done in the D9.1, where the more generic BUCs were defined, together with a comprehensive list of SUCs, and defines the base conditions for operation of the Portuguese demonstration. This means the definition and description of the high-level architecture common to both DEPs and description of the APIs functional specification applied for the several SUCs, including the

definition of the common data model used and agreed by both SOs, the description of the different scenarios covered within the different SUCs and the API methods used for that data exchange between the DEPs and between the DEPs and the internal systems and tools. Apart from this, the document also describes the KPIs that will be later (in the forthcoming deliverable D9.5) used to assess the final results of the demonstration.

Preliminary results from concept tests are also presented for some SUCs, to test: 1) the tool to assess the flexibility needs; 2) the methodology used to determine the flexibility potential; 3) the data model proposed; and 4) the data exchange process for the SUC related to the maintenance plans, also assessing its impact and relevance in the planning process of grid assets.

This deliverable will be followed by D9.5, which is the second and final deliverable from the Portuguese demonstration, which will present the final results of the Portuguese demonstration and will make use of the KPIs here defined to assess these results. So in summary, D9.2 establishes the bases and presents preliminary results from concept tests and D9.5 presents the final results and assesses them.

Two other deliverables will be published within the Western Cluster that are related to this one, which is D9.8 and D9.9. The first will present the results related to the scalability and replicability analysis of the demonstrators, together with a joint assessment of the demo's KPIs and success metrics. D9.8 will also present the results from the Regional Use Case, that will comprise several partners from the Western Cluster, including its KPI results and assessment. The last one, which is D9.9 will derive main conclusions and lessons learnt from all the demonstrators within the Western Cluster, looking at the different enablers and barriers to implementation of the solutions tested.

2 Methodology

This chapter presents the methodology behind the Portuguese demonstration, including the different interactions, responsibilities and activities that allow the achievement of the objectives and results of the present task (Figure 2.1). The implementation of the Portuguese demonstration (Task 9.2) derives from the alignment, scope (BUCs) definition and set-up done under Task 9.1, that specifically took into account the several steps for flexibility provisioning described within the ASM report [5], so that the use cases developed under the demonstrators are aligned with the agreed positioning of DSOs and TSOs across Europe. This first stage required interaction with horizontal work packages, namely WP2, so that the products and services defined under this WP are duly taken into account in the BUCs to be explored. Based on the BUCs defined (D9.1 [8] and D2.3 [6]), more concrete use cases were identified and characterised (D5.1 [7] and D9.1 [8]), also following interactions and recommendations from horizontal WPs. From internal analysis by the demo partners and taking into account the relevance and complementarity to Western Cluster as a whole, a selection of SUCs (5 out of 8) was carried out, to identify which SUCs would be used for demonstration purposes. The work carried out under the Portuguese demonstration is then directed towards these 5 SUCs.

The two Data Exchange Platforms, DDEP and TDEP, are horizontal to these SUCs and thus form the core of the Portuguese demonstration. They were developed to allow the seamless interaction between the DSO and TSO. The high-level architecture of these platforms and the API specification was developed by R&D NESTER and served as a basis for their technical implementation. Apart from this, a data model and format were also agreed between both parties (E-REDES and REN / R&D NESTER), so that the data shared through the DDEP/TDEP is understandable at both sides. Both the architecture, the API specification and data model are further detailed and described in Chapter 4.

For the actual implementation, two external entities were involved: (1) Watt-IS¹, whose collaboration in the project resulted from the Open-call process and cascading funding carried out under WP12 (Task 12.2); and (2) Link Consulting², a sub-contracting entity from E-REDES to also support with the implementation work. Watt-IS was responsible for the GUI development for the TDEP and integration with the REN / R&D NESTER APIs (developed by R&D NESTER) for all SUCs, including both the RUC and the integration with the OneNet Connector. Watt-IS was also responsible for the implementation of E-REDES APIs, and for the management of the DDEP database, together with the GUI development for the DDEP and integration with E-REDES APIs for SUC 06, SUC 07 and SUC 08. On the other hand, Link Consulting was responsible for these developments for E-REDES for

¹ <https://watt-is.com/>

² <https://linkconsulting.com/>

the remaining SUCs, including SUC 01, SUC 02, the RUC and the integration with the OneNet Connector. As for the TDEP backend, it was fully developed by R&D NESTER. Both Watt-IS and Link Consulting relied on the architecture that had previously been defined by R&D NESTER. Note that following this organisational structure, two front-ends for the DDEP and one front-end for the TDEP were developed, requiring a harmonisation between the two DDEP front ends to avoid major discrepancies.

In complement to the implementation of these platforms, several tools had to be developed and/or upgraded to guarantee the successful achievement of the results from the different SUCs. In that sense, two tools were developed by R&D NESTER, one for the evaluation of TSO flexibility needs and for the simulation of FSP flexibility provisioning, and other for the forecast of short-circuit currents at the TSO-DSO interface, concerning transmission level contributions. The E-REDES operational team is also carrying out an upgrade of its operation planning tool (DPlan), so that it is able to receive daily generation and consumption forecasts from E-REDES PREDIS tool, and with those derive the forecasts of flexibility needs at HV and MV levels and short-circuit contributions forecast from distribution side, and also communicate these data to the DDEP. These tools are further detailed in Chapter 4.3. Apart from the system operators' tools, a methodology was also carried out by the Portuguese R&D institute INESC TEC to estimate the flexibility potential from MV customers, based on a sample of MV customers from a supermarket chain that have agreed, through an external consultation moment (survey), in the use of their metering data for the purpose of carrying out this work. This methodology is described in Chapter 5.

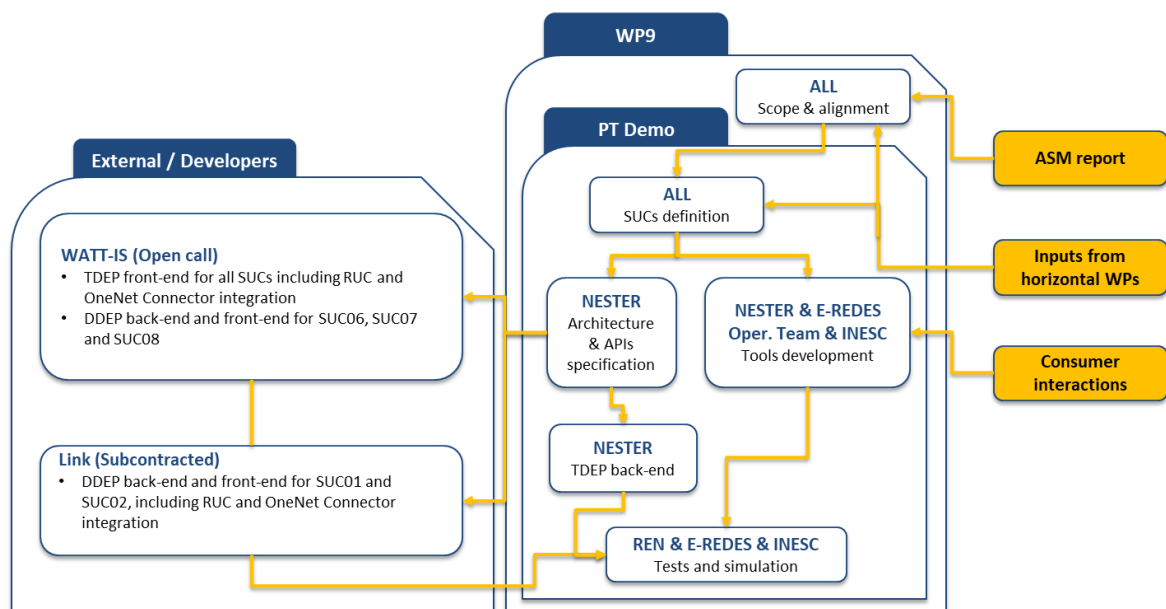


Figure 2.1 - Portuguese demonstration methodology

3 Portuguese demonstration description

3.1 Portuguese Business Use Cases and System Use Cases

The definition of scope for the Portuguese demonstration took into account the several phases of the flexibility procurement process foreseen in the ASM report, which resulted in the identification of three different business use cases (BUCs):

- WECL-PT-01 – Exchange of Information for Congestion Management – Short Term
- WECL-PT-02 – Exchange of Information for Congestion Management – Long Term
- WECL-PT-03 – Exchange of Information for Operational Planning

WECL-PT-01 aims to design and detail the information flows and rules to be established between the DSO and TSO in case of forecasted congestions in transmission and/or distribution systems to optimise power flows and the use of flexibility resources. This BUC addresses each process phase of the ASM report for flexibility provisioning for short-term (daily) congestion management, addressing the different phases stated within the ASM report, namely: 1) Preparation/Pre-qualification; 2) Planning/Forecast; 3) Market Phase; 4) Monitoring and Activation; and 5) Measurement and Settlement. This entails identifying information flows between the DSO and TSO and developing information exchange mechanisms to enable procurement of flexibility products, aiming in the end to coordinate the use of flexibility for different voltage levels. WECL-PT-02 is identical to WECL-PT-01, but is focused on long-term procurement of flexibility, making use of its potential to defer the need for traditional system upgrades. WECL-PT-03 focuses on the exchange of information between the DSO and TSO for operational planning purposes, considering different domains and timeframes. For the long-term, it concerns the expected evolution and development of the networks together with long-term forecasts (supply, demand, flexibility needs,...). Regarding the medium-term, it studies the hosting capacity in each EHV/HV interconnection point and load transfer availability between the different EHV/HV interconnection points. Finally, for the short-term, it addresses short-circuit currents and aggregated consumption and production forecast by technology in each EHV/HV interconnection point, as well as scheduled maintenance actions. A more detailed description of each of the BUCs can be found both in D2.3 [6] and D9.1 [8].

For each of these BUCs, more concrete (system) use cases (SUCs) were identified, for which general description and correspondence to the BUCs can be found in Table 3.1. The conception of the use cases in the Western Cluster was done taking into account the several phases for flexibility provision described in the ASM report [5], and the mapping between these different phases was done and presented in D9.1 [8]. In that sense,

the same mapping was also done for the Portuguese SUCs, which can also be found in the last column of Table 3.1.

Table 3.1 - Portuguese demonstration SUCs and correspondent BUCs

SUC	Tested (Y/N)?	BUC	Phase of the ASM report
WECL-PT-SUC-01: Evaluation of the Product & Grid pre-qualification requirements (SUC 01) This SUC describes and tests the interactions and steps taken by the DSO and TSO for prequalification purposes, including interactions between both actors and procedures taken by each before the interaction moment. This includes the identification and exchange of product requirements (product prequalification) and the grid impact assessment and its results (grid prequalification). This SUC will be further on referred to as SUC 01.	Y	WECL-PT-01 and WECL-PT-02	Prepare / Pre-qualification
WECL-PT-SUC-02: Day-Ahead & Intraday Flexibility needs (SUC 02) This SUC focuses on the information exchange between the DSO and TSO regarding flexibility needs from both sides for a short-term timeframe, including procedures taken by each to determine these needs. 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) will be tested in two different ways under this SUC: 1) Directly via the APIs implemented in both platforms, which will be the solution used for the remaining SUCs; 2) By using the OneNet Connector for the exchange. This SUC will be further on referred to as SUC 02.	Y (only day-ahead)	WECL-PT-01	Plan / Forecast
WECL-PT-SUC-03: Long-term Flexibility needs (SUC 03) This SUC focuses on the information exchange between the DSO and TSO regarding flexibility needs from both sides for a long-term timeframe, including procedures taken by each to determine these needs. It anticipates technical problems, improving network operation security and avoiding investments in the distribution and transmission grids with the activation of active power flexibilities. This SUC will be further on referred to as SUC 03.	Y (only day-ahead)	WECL-PT-01	Plan / Forecast

WECL-PT-SUC-04: Selection of Bids (SUC 04) <p>This SUC describes and tests the bid selection process, more specifically on the (1) identification of bid parameters to be taken into account; (2) coordination between DSO and TSO markets, to allow bid forwarding between both markets; (3) the establishment of a merit order list of the acquired bids. This SUC will be further on referred to as SUC 04.</p>	N	WECL-PT-01 and WECL-PT-02	Market Phase
WECL-PT-SUC-05: Evaluate Grid Constraints (SUC 05) <p>This SUC focuses on the coordination between DSO and TSO in the market and activation phase, aiming to avoid new congestions resulting from bid activation. It involves carrying out impact assessment by the SO where the resource is connected to check if no subsequent congestions are expected. This SUC will be further on referred to as SUC 05.</p>	N	WECL-PT-01 and WECL-PT-02	Market Phase Monitoring and Activation
WECL-PT-SUC-06: Maintenance plans information exchange (SUC 06) <p>This SUC defines and tests the information exchange between the DSO and TSO regarding maintenance plans from both sides in multiple time horizons. This involves 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 be further on referred to as SUC 06.</p>	Y	WECL-PT-03	Plan / Forecast
WECL-PT-SUC-07: Consumption and generation forecast information exchange (SUC 07) <p>This SUC focuses on the information exchange between the DSO and TSO regarding consumption and generation forecasts calculated at the TSO/DSO interface and disaggregated by technology type, including procedures taken to derive these values. This interaction is expected to happen in day-ahead, considering market clearance results. This SUC will be further on referred to as SUC 07.</p>	Y	WECL-PT-03	Plan / Forecast
WECL-PT-SUC-08: Short-circuit levels information exchange (SUC 08) <p>This SUC focuses on the information exchange between the DSO and TSO regarding short-circuit currents forecasts calculated at the TSO/DSO interface, including procedures taken to compute these values, that could be used for operational planning purposes. This SUC will focus only on the three-phase symmetrical short-circuit. This SUC will be further on referred to as SUC 08.</p>	Y	WECL-PT-03	Plan / Forecast

From these SUCs, only five were selected to test within the Portuguese demonstration, namely SUC 01, SUC 02, SUC 06, SUC 07 and SUC 08, which are the ones being addressed throughout the remainder of the deliverable. As it is possible to conclude from Table 3.1, the SUCs selected specifically address the ASM report phases related to Preparation/Pre-qualification and Planning/Forecast. Note that this selection was carried out to optimise the output quality from the implementation of the SUCs, given that the ambition in the initial definition of the SUCs was too high and, after careful consideration of the work to be carried out, the partners concluded that it was not feasible both budget-wise and timewise to test all the eight SUCs. This selection process also took into account the complementarity of the SUCs to the Western Cluster, bringing a strong component from the operational planning point of view. Also, note that at the time of scope definition, the Portuguese regulatory framework on the electricity sector was, and is still undergoing, a significant change, with several concepts and steps within the flexibility provisioning phases still to be agreed upon and defined between the main actors, also reinforcing the need to focus on the aforementioned phases, and not on the Market Phase and Monitoring and Activation. Nonetheless, it's important to highlight that both DEPs are capable of integrating new operational modules for the purpose of fulfilling the remaining SUCs, which is a step to be further discussed after the successful testing of both platforms for the selected SUCs.

Also note that regarding SUC 02 on the “Day-Ahead & Intraday Flexibility needs” and for the purposes of the Portuguese demonstration, only day-ahead interactions are addressed to first align them with the day-ahead electricity market and with the internal processes currently being carried out by both SOs. For the intra-day timeframe, the discussions are ongoing related with the timings of information exchange and procedures needed to implement it. However, all the tools and DEPs were designed in order to identify intra-day flexibility needs from both SOs. Apart from these, another use case will be developed “WECL-REGIONAL-01: Cross-SO grid pre-qualification” which is referred in this document as RUC and is similar to SUC 01, with the difference that it will foresee prequalification across borders, thus involving partners from the different demonstrators within Western Cluster. However, the RUC will not be addressed within this document, given it is a WP9 wide demonstrator, fitting instead within D9.8.

A more detailed description of each of these SUCs, including interaction and process diagrams as well as information exchange needs, are specified in both D5.1 [7] and D9.1 [8].

3.2 Demo site characteristics

The Portuguese demonstration is focused on defining and testing the interactions and data exchange between the DSO and TSO, being more a “system” demonstration, thus, not involving a physical site and assets. Nonetheless, a geographical scope has been defined for the purpose of testing the data exchange interactions

between the DSO and TSO. The aim is to address, first-hand two particular network areas, which are the following: (1) Trás-os-Montes area, which is a network in the northeast of Portugal; (2) Batalha area, which is a network located in the seaside centre of Portugal. Apart from these specific areas, and for the purpose of carrying out a more specific analysis for SUC 08 which was presented in a paper submitted and approved for the CIREN 2023 conference [11], Algarve area (South) and Guarda area (Northwest) were considered. Nonetheless, the aim of the demonstration is, at a second stage, to address the whole mainland Portugal area, comprising 26.000 HV and MV customers connected to the distribution network and 78 EHV customers connected to the transmission network.

The flexibility resources will participate indirectly since the focus is on the information exchanges between DSO and TSO. A model representing the FSP flexibility parameters will be used, considering the group of resources that already provides system services to the TSO, in order to define which product attributes are required by SOs, including a characterization of each FSP, such as the name of FSP, resource, mode of activation, quantity, locational information, SO connected, etc. For the analysis carried out under SUC 02 for the estimation of flexibility potential at MV level, FSPs connected at the distribution level were also considered, including a supermarket chain comprising 236 installations (supermarkets) with an average yearly consumption of 270 GWh/year and an individual contracted power ranging from 250-500 kVA.

Apart from this, the demonstration also requires the use of data owned and/or used by the system operators, related to: (1) grid topology; (2) historical consumption and generation data; (3) metering data from MV-connected customers (supermarkets); (4) market clearance data; (5) weather forecast data.

3.3 Key Performance Indicators

This sub-chapter presents a complete overview of the KPIs that will be used to evaluate the achievement of the results for the Portuguese demonstration, providing not only a description for each of the KPIs, but also the formulation used, calculation methodology, assumptions regarding the baseline calculation and eventual gaps and challenges for definition and quantification. Note that some of these KPIs were generally addressed both in D2.4 [9] and D9.1 [8] of the OneNet Project; in this deliverable more detail will be provided.

Two categories of KPIs are addressed here: Demo KPIs and Common KPIs. The Demo KPIs are the ones already addressed in both deliverables D2.4 [9], D9.1 [8] and relate to KPIs that are specific to the Portuguese Demonstrator, (Demo KPIs), thus, it is not planned to compare them with KPIs of other demonstrators within the OneNet project. The other category is KPIs that were specially drafted to allow comparison of the several demonstrators within OneNet (Common KPIs).

Note that the results of these KPIs will not be presented within this deliverable, but within the forthcoming D9.5, as at the stage of writing the deliverable, development of both DEPs and on necessary tools are being finalised, not allowing the calculation of the KPIs. KPIs concerning the RUC are out of the scope of this deliverable and will be presented in D9.8.

3.3.1 Demo KPIs

This sub-chapter presents the Demo KPIs that will be used for the assessment of the Portuguese demonstration taking into account its scope and main objectives of the different SUCs, which description can be found in Chapter 3.1.

3.3.1.1 Demo KPIs applicable to all SUCs

Table 3.2 presents the Demo KPIs that are applicable and common to all SUCs tested in the Portuguese demonstration.

Table 3.2 - Demo KPIs applicable to all SUCs

KPI name	Definition
ICT costs	<p>Description: The term ICT cost comprises the communications and information technologies directly related to the implementation of the communication infrastructures between DSO and TSO.</p> <p>Formula:</p> $ICT_{Cost} = \sum_{i=1}^{N_c} c_i$ <p>Variables:</p> <ul style="list-style-type: none"> ○ ICT_{Cost}: Cost of ICT (€). ○ C_i: Generic i^{th} cost directly related to information exchange (€). ○ N_c: Overall number of cost items per SUC. <p>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.</p> <p>Calculation methodology: Calculate a cost estimate for implementing and maintaining the communication infrastructure for information exchanges between DSO and TSO for each SUC. The period considered for this calculation will comprise the whole duration of the demonstration.</p> <p>Gaps and challenges for KPI definition and quantification: Regarding the baseline definition for these KPIs, it can be challenging to quantify what the costs of existing equipment for data exchange between DSO and TSO are, due to privacy issues that the ICT teams on the DSO and TSO side are subject to. To tackle this, we will instead assume the baseline as 0, and calculate the surplus in ICT costs.</p>

3.3.1.2 Demo KPIs applicable for SUC 01

Table 3.3 presents the Demo KPIs that are applicable to SUC 01 in the Portuguese demonstration.

Table 3.3 - Demo KPIs applicable to SUC 01

KPI name	Definition
Successful ending of prequalification process	<p>Description: This indicator measures the percentage of prequalification processes approved.</p> <p>Formula:</p> $SPP_{\%} = \frac{\text{Successful}}{TPP} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ SPP_%: Successful prequalification processes (%). ○ Successful: Number of successful prequalification processes. ○ TPP: Total number of Prequalification process. <p>KPI baseline explanation: No baseline is expected since there is no similar process under implementation nationally.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Number of prequalification process that needs additional information	<p>Description: This indicator measures the percentage of prequalification processes that require additional information.</p> <p>Formula:</p> $PPA_{\%} = \frac{NPPA}{TPP} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ PPA_%: Prequalification processes that need additional information (%). ○ NPPA: Number of prequalification processes that need additional information. ○ TPP: Total number of prequalification processes. <p>KPI baseline explanation: No baseline is expected since there is no similar process under implementation nationally.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: Cybersecurity challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>

3.3.1.3 Demo KPIs applicable for SUC 02

Table 3.4 presents the Demo KPIs that are applicable to SUC 02 in the Portuguese demonstration.

Table 3.4 - Demo KPIs applicable to SUC 02

KPI name	Definition
Reduction in RES curtailment	<p>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.</p> <p>Formula:</p> $E_{RES} = \sum_{i=1}^I \sum_{t=1}^T (E_{i,t}^{prod} - E_{i,t}^{inj})$ <p>Variables:</p> <ul style="list-style-type: none"> ○ 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). <p>KPI baseline explanation: Simulation scenarios will be set up based on historical 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.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Requested flexibility	<p>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.</p> <p>Formula:</p> $P_{FlexR} = \sum_{t=1}^T P_{flexRt} \text{ and } E_{FlexR} = \sum_{t=1}^T E_{flexRt}$ <p>Variables:</p> <ul style="list-style-type: none"> ○ P_{FlexR}: Requested flexibility (Power) (kW or MW). ○ P_{flexRt}: The amount of power requested by the DSO/TSO to solve their forecasted constraints at a time T (kW or MW). ○ E_{FlexR}: Requested flexibility (Energy) (kWh or MWh). ○ E_{flexRt}: The amount of energy requested by the DSO/TSO to solve their forecasted constraints at a time T (MWh or kWh). ○ T: examined period <p>KPI baseline explanation: No baseline is expected since there is no similar process to be improved.</p>

	<p>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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Total power of avoided congestions through flexibility activation	<p>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).</p> <p>Formula:</p> $TPAC = \sum_{t=1}^T \left(\sum_{i=0}^M (P_{i,t} - P_i^{max}) - \sum_{k=0}^N (P_{k,t} - P_k^{max}) \right)$ <p style="text-align: center;"><i>before BUC</i> <i>after BUC</i></p> <p>Variables:</p> <ul style="list-style-type: none"> ○ TPAC: Total power of avoided congestions through flexibility activation (kW). ○ M, N: Number of overloaded elements in the scenarios without and with flexibility activation, respectively. ○ 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). ○ P_{i,t}, P^{k,t}: Power flow in overloaded network element <i>i</i> or <i>k</i> for time interval <i>t</i>, respectively for the scenario without and with flexibility activation (kW). ○ P_i^{max}, P_k^{max}: Maximum power for network element <i>i</i> or <i>k</i> without it being overloaded, respectively for the scenario without and with flexibility activation (kW). <p>KPI baseline explanation: Simulation scenarios based on historical values, representing the scenario without flexibility activation.</p> <p>Calculation methodology: Compute congestions for simulations of the starting scenarios (without flexibility activation) and for the resulting scenarios with flexibility activation (after SUC implementation).</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>

3.3.1.4 Demo KPIs applicable for SUC 06

Table 3.5 presents the Demo KPIs that are applicable to SUC 06 in the Portuguese demonstration.

Table 3.5 - Demo KPIs applicable to SUC 06

KPI name	Definition
Number of congestions/violations on DSO network	<p>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.</p> <p>Formula:</p>

	$CAD_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ <i>CAD_%</i>: Number of congestions/violations on DSO network (%). ○ <i>#congestion avoided</i>: Number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange. ○ <i>#congestion forecasted</i>: Number of congestions correctly forecasted, so excluding the false positive congestions forecasts. <p>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.</p> <p>Calculation methodology: Simulation of grid scenarios with pre and post predictive actions implementation.</p> <p>Gaps and challenges for KPI definition and quantification: Cybersecurity challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>
<p>Number of congestions/violations on TSO network</p>	<p>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.</p> <p>Formula:</p> $CAT_{\%} = \frac{\#congestion\ avoided}{\#congestion\ forecasted} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ <i>CAT_%</i>: Number of congestions/violations on the TSO network (%). ○ <i>#congestion avoided</i>: Number of congestions avoided through the implementation of predictive actions resulting from the maintenance works information exchange. ○ <i>#congestion forecasted</i>: Number of congestions correctly forecasted, so excluding the false positive congestions forecasts. <p>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.</p> <p>Calculation methodology: Simulation of grid scenarios with pre and post predictive actions implementation.</p> <p>Gaps and challenges for KPI definition and quantification: Cyber security challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>

3.3.1.5 Demo KPIs applicable for SUC 07

Table 3.6 presents the Demo KPIs that are applicable to SUC 07 in the Portuguese demonstration.

Table 3.6 - Demo KPIs applicable to SUC 07

KPI name	Definition
Accuracy of the RES production forecast calculated 24 hours in advance	<p>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.</p> <p>Formula:</p> $RES_{FA24h} = \frac{1}{N} \left(\sum_{t=1}^N \left \frac{FC_{RES_{prod,t}} - RL_{RES_{prod,t}}}{RL_{RES_{prod,t}}} \right \right) \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ RES_{FA24h}: Accuracy 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. <p>KPI baseline explanation: Accuracy in generation forecast before the information exchange.</p> <p>Calculation methodology: 1) Calculate the accuracy of generation forecast before the information exchange; 2) Calculate the accuracy of generation forecast after the information exchange; 3) Compare the results of the calculated errors.</p> <p>Gaps and challenges for KPI definition and quantification: Cybersecurity challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>
Accuracy of load forecast calculated 24 hours in advance	<p>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.</p> <p>Formula:</p> $Load_{FA24h} = \frac{1}{N} \left(\sum_{t=1}^N \left \frac{FC_{load,t} - RL_{load,t}}{RL_{load,t}} \right \right) \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ $Load_{FA24h}$: Accuracy 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. <p>KPI baseline explanation: Accuracy in load forecast before the information exchange.</p> <p>Calculation methodology: 1) Calculate the accuracy of load forecast before the information exchange; 2) Calculate the accuracy of load forecast after the information exchange; 3) Compare the results of the calculated errors.</p>

	<p>Gaps and challenges for KPI definition and quantification: Cybersecurity challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>
<p>Maximum ratio of false-positive and negative congestion forecasts</p>	<p>Description: The maximum ratio of the incorrectly forecasted power congestions versus the total power of congestions forecasted.</p> <p>Formula:</p> $FFC_{max\%} = \text{Max} \left(\frac{P_{fc,c}}{P_{fc}} \cdot 100 \right)$ <p>Variables:</p> <ul style="list-style-type: none"> ○ $FFC_{max\%}$: 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. <p>KPI baseline explanation: No baseline is expected since there is no similar process to be improved.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
<p>Share of false positive and negative congestion forecasts</p>	<p>Description: The ratio of the incorrectly forecasted congestions versus the total number of congestions forecasted.</p> <p>Formula:</p> $FFC_{\%} = \frac{C_{fc,c}}{C_{fc}} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ $FFC_{\%}$: 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. <p>KPI baseline explanation: No baseline is expected since there is no similar process to be improved.</p> <p>Calculation methodology: 1) Forecast the congestions; 2) Verify congestions that really occurred; 3) Determine the number of false positive congestions forecasted.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
<p>Improvement of the Forecast³</p>	<p>Description: This indicator measures the improvement of forecast value after the information exchange. The TSO currently has generation and load forecasts, and short</p>

³ This KPI is also applicable to SUC 08

	<p>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.</p> <p>Formula:</p> $IF_{\%} = \frac{value_{after\ information\ exchange}}{value_{before\ information\ exchange}} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ 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). <p>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.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: Cybersecurity challenges due to the exchange of information, which comes from the most critical systems for network operation, between DSO and TSO companies.</p>
--	---

3.3.1.6 Demo KPIs applicable for SUC 08

Table 3.7 presents the Demo KPIs that are applicable to SUC 08 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 3.6 is also applicable to this SUC.

Table 3.7 - Demo KPIs applicable to SUC 08

KPI name	Definition
Comparison between the Isc max forecasted for the 63kV by the planning and the maximum short circuit value registered for	<p>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.</p> <p>Formula:</p> $e = ismax - MAX(I_{sc})$ <p>Variables:</p> <ul style="list-style-type: none"> ○ 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). ○ ismax: Maximum planning estimated value of Isc (A).

<p>the series under analysis</p>	<ul style="list-style-type: none"> ○ $MAX(I_{sc})$: Maximum value effectively forecasted in the D-1 (A). <p>KPI baseline explanation: The planning estimated value of I_{sc} (iscmax) is presented annually in the national transmission network development and investment plan. For the:</p> <ul style="list-style-type: none"> - 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 <p>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 I_{sc} max estimated for the 63kV by the planning (iscmax) and the maximum value effectively estimated ($MAX(I_{sc})$).</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
<p>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</p>	<p>Description: Deviation between the breaker limit I_{sc} 63kVlim and the maximum value effectively forecasted ($MAX(I_{sc})$) in a D-1 timeframe</p> <p>Formula:</p> $\sigma = I_{sc} 63kVlim - MAX(I_{sc})$ <p>Variables:</p> <ul style="list-style-type: none"> ○ σ: Deviation between the breaker limit I_{sc} 63kVlim and the maximum value effectively forecasted ($MAX(I_{sc})$) in a D-1 timeframe (A). ○ $I_{sc} 63kVlim$: Circuit breaker short circuit limit (A). ○ $MAX(I_{sc})$: Maximum value effectively forecasted in the D-1 (A). <p>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 ($I_{sc} 60kVlim$), 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) kA. The DSO considers 25kA as the rated short circuit current of the circuit breakers in the interface TSO/DSO.</p> <p>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 total value for the short-circuit level of that substation and can be computed the deviation between the breaker limit (I_{sc} 63kVlim) and the maximum value effectively estimated ($MAX(I_{sc})$).</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>

3.3.2 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.

3.3.2.1 Common KPIs applicable to SUC 01

Table 3.8 defines the common KPIs applicable to SUC 01 of the Portuguese demonstration.

Table 3.8 - Common KPIs applicable to SUC 01

KPI name	Definition
Number of FSPs⁴	<p>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.</p> <p>Formula:</p> N_{FSPs} <p>Variables:</p> <ul style="list-style-type: none"> ○ N_{FSPs}: Number of FSPs. <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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 potential⁵.</p> <p>Gaps and challenges for KPI definition and quantification: Reducing the entry barriers for flexibility provision and simplifying the process for FSPs is not easy to measure. Therefore, in practice this KPI will measure the number of FSP as an indicator.</p>
Active participation⁶	<p>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.</p> <p>Formula:</p> $R = \frac{N_{active}}{N_{accept}} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ R: Active participation (%).

⁴ This KPI is also applicable to SUC 02

⁵ 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.

⁶ This KPI is also applicable to SUC 02

	<ul style="list-style-type: none"> ○ N_{active}: Customers actively participating in the demo. ○ N_{accept}: Customers accepted to participate in the demo. <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: Barriers found in the engagement of customers to respond to our survey.</p>
--	--

3.3.2.2 Common KPIs applicable to SUC 02

Table 3.9 shows the common KPIs applicable to SUC 02. Note that although not presented in the table below, the Common KPIs “Number of FSPs” and “Active participation” stated in **Error! Reference source not found.** are also applicable to SUC 02.

Table 3.9 - Common KPIs applicable to SUC 02

KPI name	Definition
Volume of transactions (Power)	<p>Description: This indicator measures the volume (in kW) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.</p> <p>Formula:</p> $VT_P = \sum_T \sum_I P_{i,t}$ <p>Variables:</p> <ul style="list-style-type: none"> ○ 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. <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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) The value of the KPI will be this volume of power, aggregated for all nodes and calculated on a daily basis.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Volume of transactions – cleared bids (P or Q Availability)	<p>Description: This indicator measures the volume (in kW) of the available flexibilities to solve grid congestions identified during the examined period T.</p> <p>Formula:</p> $VT_{CAV} = \sum_T \sum_I P_{i,t}$ <p>Variables:</p>

	<ul style="list-style-type: none"> ○ 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. <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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 optimisation 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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Volume of transactions – cleared bids (P or Q Activation) (Energy)	<p>Description: This indicator measures the volume (in MWh or MVAh) of the optimal flexibilities selected to solve grid congestions identified during the examined period T.</p> <p>Formula:</p> $VT_{CAC} = \sum_T \sum_I E_{i,t}$ <p>Variables:</p> <ul style="list-style-type: none"> ○ VT_{CAC}: Volume of selected flexibilities considering P-T or Q-T (MWh or MVAh). ○ $E_{i,t}$: Volume of selected flexibilities by the i^{th} flexible resource at time t (MWh or MVAh). ○ I: Set of flexible resources. ○ T: Examined period. <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
Available Flexibility	<p>Description: Ratio between the flexible power that can be used for congestion management and the forecasted total power demand.</p> <p>Formula:</p> $Flexibility_{\%} = \frac{\sum P_{Available Flexibility}}{\sum P_{Total in area}} \cdot 100$

	<p>Variables:</p> <ul style="list-style-type: none"> ○ 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). <p>KPI baseline explanation: No baseline will be considered since flexibility services are still to be implemented in Portugal.</p> <p>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 SUC 07 and will be calculated for each interconnection point and on a daily basis.</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>
<p>Number of avoided technical restrictions</p>	<p>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.</p> <p>Formula:</p> $ATR_{\%} = \frac{N_{TRFlex}}{N_{TR}} \cdot 100$ <p>Variables:</p> <ul style="list-style-type: none"> ○ ATR_%: Share of avoided technical restrictions (%). ○ N_{TR}: Total number of expected technical restrictions. ○ N_{TRFlex}: Total number of technical restrictions solved through activation of flexibility services. <p>KPI baseline explanation: Simulation scenarios based on historical values, representing the scenario without flexibility activation.</p> <p>Calculation methodology: Compute congestions for simulations of the starting scenarios (without flexibility activation) and for the resulting scenarios with flexibility activation (after SUC implementation).</p> <p>Gaps and challenges for KPI definition and quantification: No gaps or risks identified.</p>

4 Tools and Platforms

This chapter provides a detailed description of the software developments that translate the planning and the goals previously described into actions and processes that make up the Portuguese Demonstrator.

This chapter is divided into 3 sub-chapters. In Chapter 4.1 a high-level architecture is presented and explained. It contains a broad vision of how the software developments are organized and how they relate to each other. Given that the operators (E-REDES and REN) took this task separately, the DEP development is explained from each perspective in this subsection.

Chapter 4.2 provides a functional explanation of the task and processes undertaken in order to fulfil the requirements of each SUC. Finally, the tools developed to provide services such as planning, forecasting and system evaluation are presented and described in Chapter 4.3.

4.1 Portuguese Demo High Level Architecture

The Portuguese demonstration will exchange information between the Portuguese DSO (E-REDES) and TSO (REN) through an application-programming interface (API). Both System Operators intend to develop a DEP for each one, which is a cloud-based system that will also serve as a gateway between the internal systems of the DSO and TSO with other possible external entities. These cloud systems serve the necessary IT infrastructure (e.g. servers and databases) to deploy the developed software components, thus being capable of fulfilling the use cases defined and selected in Chapter 3.1 and respective APIs, through modules and information exchange mechanisms within a cloud environment. **Error! Reference source not found.** provides a general view of the architecture design proposed in this demonstrator.

From a general perspective, both operators developed their own DEP over similar principles. An API acts as interface between the operator's infrastructure and the outside environment. By using the corresponding API, the different SUCs are reached, which, at same time, deploy interactions with web services and tools allocated in each operator's premises. In the same way, SUC 02 and RUC processes are also deployed by using the OneNet Connector.

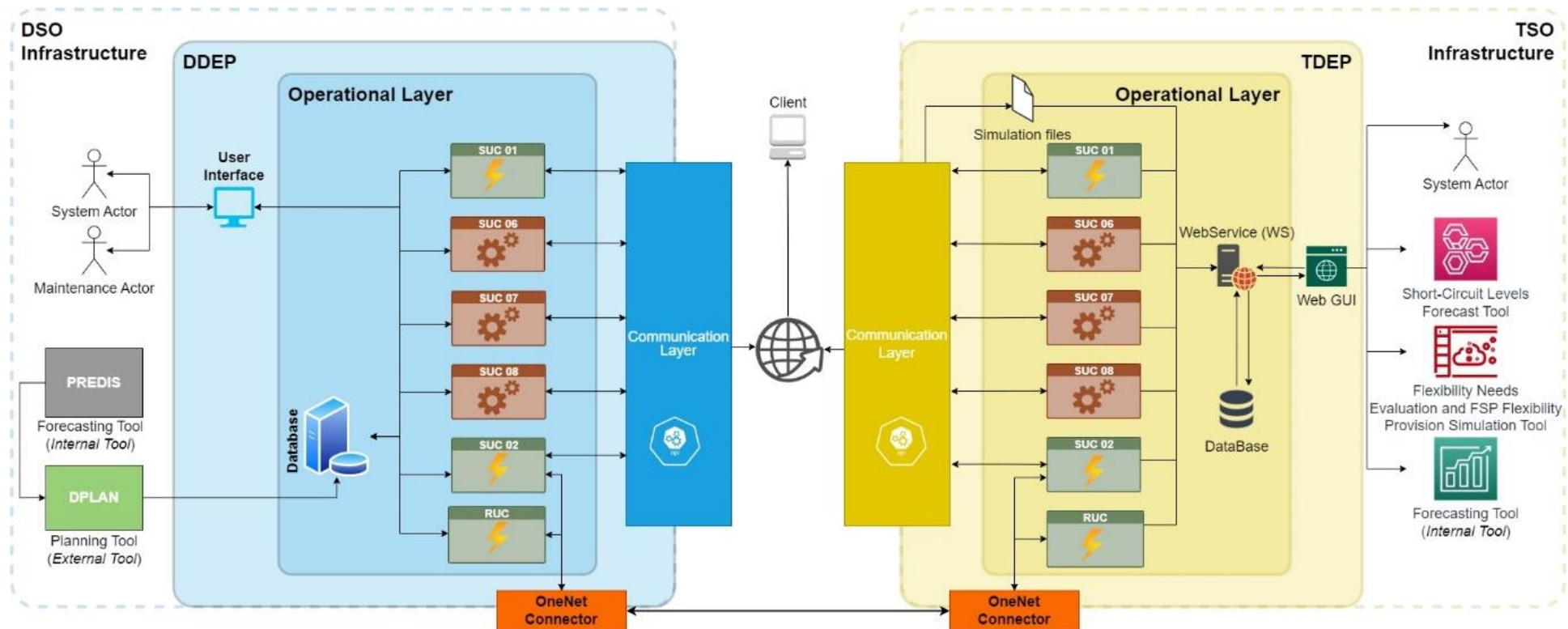


Figure 4.1 - Portuguese Demo Architecture

4.1.1 Communication layer

A communication middleware is developed in order to link external entities to the operational layer of both DEPs (DDEP and TDEP) through the usage of REST APIs or the OneNet Connector. Even though the general concept is the same, the difference between the communication layer in the DDEP and TDEP lies in the software providers chosen to perform the required tasks. The TSO works with AWS and the DSO with Azure.

The API Middleware presented in Figure 4.2 was developed by using REST APIs. It offers two possibilities to exchange data among parties: first, through a Service Middleware explained below and, second, through the OneNet Connector. In relation to the latter, this platform was developed by the OneNet project partners within WP6.

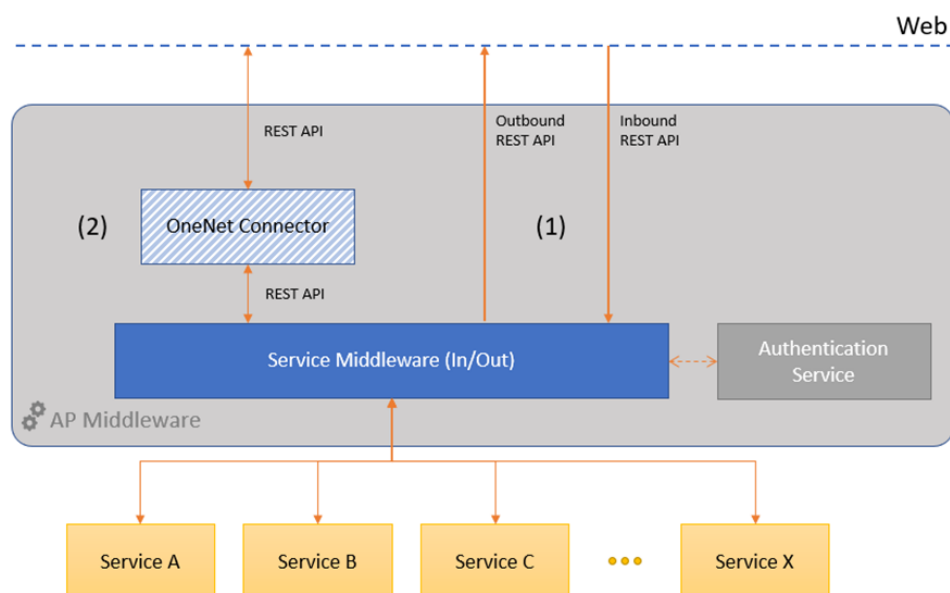


Figure 4.2 - DEP API Middleware design

The Service Middleware is responsible for routing the requests (either inbound or outbound) for the specific SUC services and the developed tools presented in Section 4.3.

The Authentication Service handles the token-based authentication mechanism implemented to allow an application to access the several endpoints that the DEPs contain. It also verifies if a certain entity can request a specific type of information.

4.1.2 Operational layer

The operational layer on the DEP for both parties can be seen in **Error! Reference source not found.** inside the DEP box for each operator. It includes all the blocks related to the different SUCs and the RUC. The detail for each block is presented later in this chapter. In addition, the operational layer includes the way of interaction of those blocks with the selected applications to manage web databases, web user interfaces and the corresponding tools that each party uses. Those tools could be stored and executed online or locally according to the operators' internal requirements.

In addition, a Graphical User Interface (GUI) that collects all the services into a more user-friendly environment is under development and will be integrated and presented in a later stage of the project, namely, in D9.5.

4.1.3 Transmission System Operator Data Exchange Platform

The DEP for the Portuguese TSO, REN, was developed by R&D NESTER. The interaction between DSO and TSO needs to be defined through a set of APIs to cover the foreseen information exchange, as detailed in the use cases. These APIs will make the proper link between the services to be developed and the users.

The TDEP was developed using Amazon Web Service (AWS) applications and platforms by using the architecture seen in Figure 4.3.

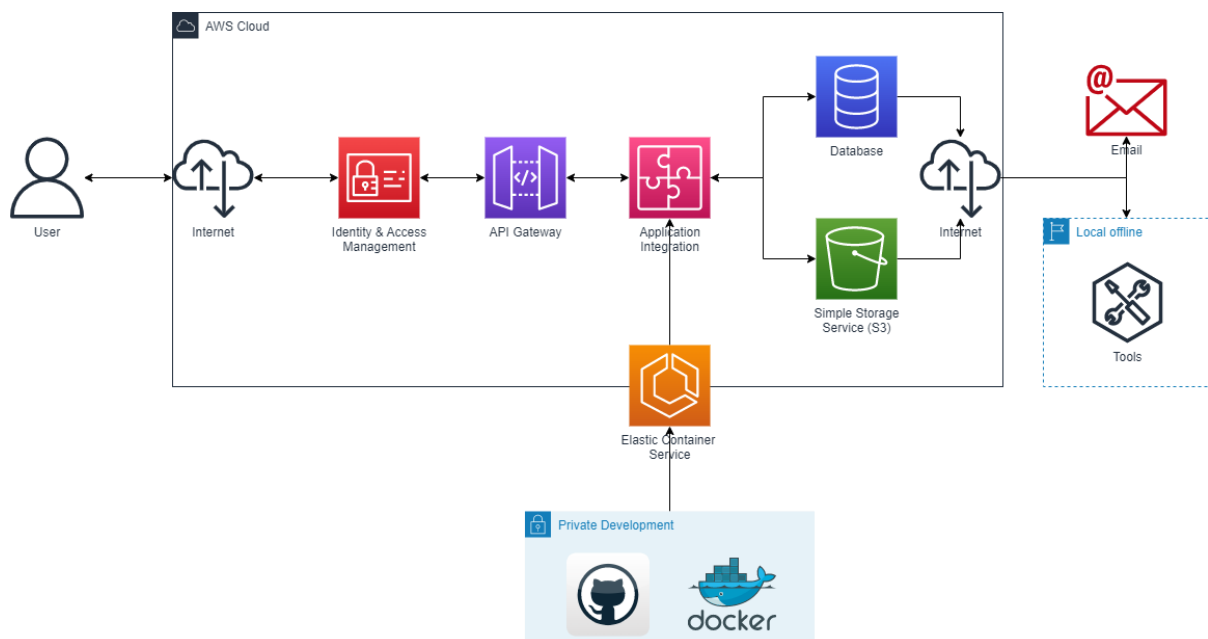


Figure 4.3 - TDEP AWS Architecture

The core of the development is the deployment on an AWS Cloud service of an integrated application that connects three main parts. First, the code is supported using GitHub and Docker containers that, in the same way, uses Elastic Container Service⁷. Second, the API then connects to two storage services, namely, a Database and the Simple Storage Service (S3) to allocate tables of data and files, respectively. The last connection of the integrated application is where the users can access the platform through an Identification and Access Management Service. In addition, from the storage services email notifications are generated when a given SUC requires it, as well, as to retrieve information to be used by the tools in local offline premises as a unique characteristic in the TDEP.

4.1.4 Distribution System Operator Data Exchange Platform

The DEP for the Portuguese DSO, E-REDES, is being developed by two separate entities, Watt-IS and Link Consulting, with the two focusing on the developments for different SUCs, nonetheless, making sure the backend developments are aligned and follow the same architecture. This architecture follows the same structure and rational of the TDEP, as it can be observed in **Error! Reference source not found..**

The DDEP was developed using Azure services and applications. While the developments carried out by Watt-IS relied on simple Azure resources, including 1 virtual machine and 2 disks, the Azure Resource Group used by Link Consulting in its developments covers a series of services mapped within the architecture seen in Figure 4.4. At the API level, the use of Azure API Management service and the Portal will be considered to serve as a Gateway to the APIs and the catalogue of existing services, with the API Management service allowing to have a platform specifically dedicated to managing the APIs exposed by the DDEP. The platform's Data Storage will be ensured by a MySQL Database service instance made available through Azure services.

The solution combines the following components: Azure App Services that host applications, REST APIs and mobile backends; an App Service Plan that defines a set of compute resources for a web app to run; serverless Azure functions; a Key Vault, which is a cloud service for securely storing and accessing confidential information; and, App Insights, that is a feature of Azure Monitor that provides extensible application performance management (APM) and monitoring for live web apps.

⁷ Is a fully managed container orchestration service that simplifies the deployment, management, and scaling of containerized applications.

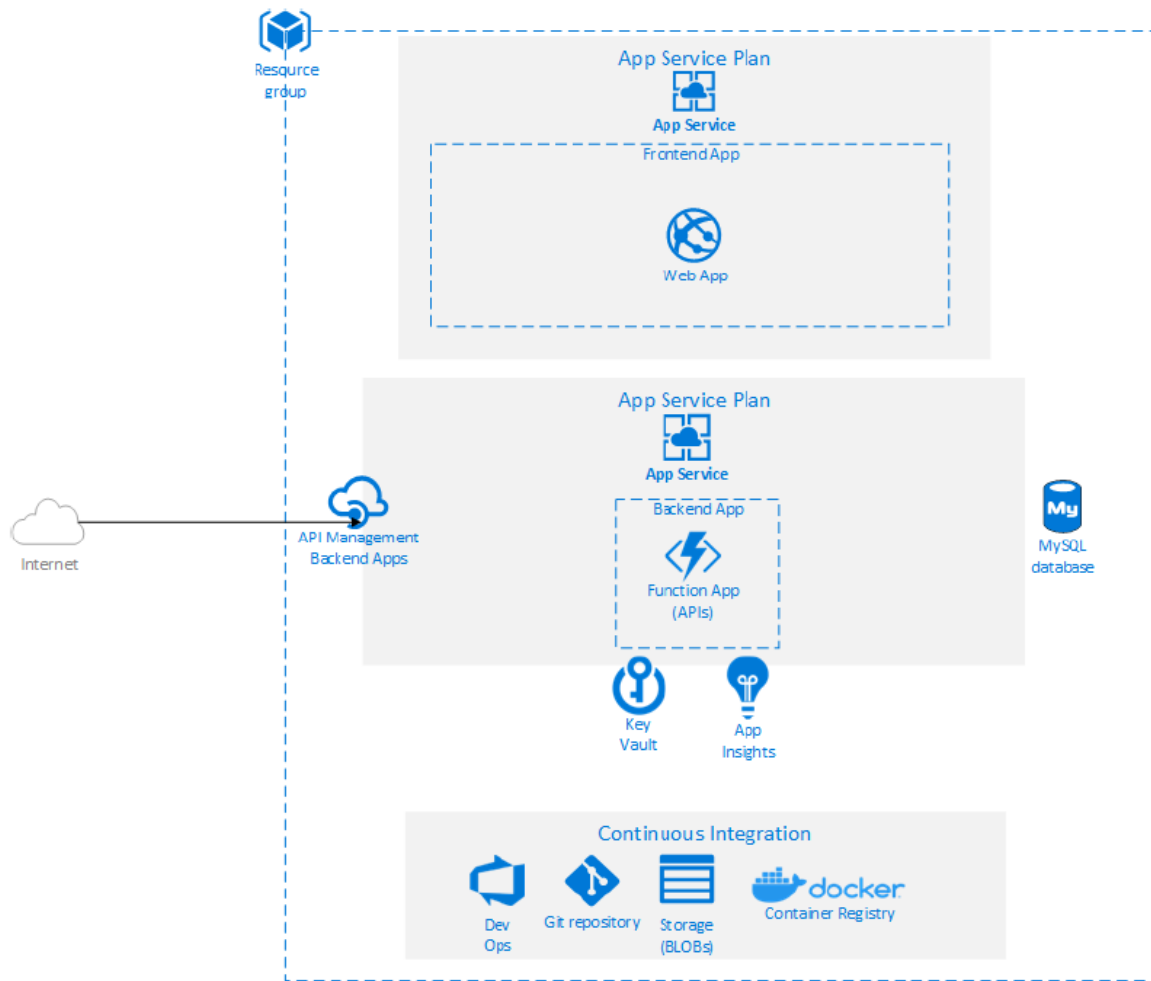


Figure 4.4 - DDEP Azure architecture used by Link Consulting

4.2 APIs Functional Specification

In this section, the developed APIs are explained in detail. In essence, the work here presented translated the goals of each SUC into interactions between the system operators and a proposed IT infrastructure. Those interactions require various actions such as uploading information, executing online and offline tools, managing notifications, among others. For each SUC, the explanation is divided in 5 parts:

- **Scenarios:** It refers to the actions and processes that each actor will execute internally and how those interact with the other actors. Specifically, it is shown the moment when an action either requires an input from other actor or produces an output to another actor. In this section, we will focus only on the characteristics of different scenarios that vary from the perspective of data exchange between

platforms and their impact on the functional definition of APIs. To highlight our focus, the SUC diagrams presented throughout the document have both white and grey areas, with the white areas representing the activities that we will focus on this section due to its impact in the API functional specifications. The grey areas represent the activities that are out-of-scope of the APIs functional specification because they are internal activities. The methods used in each scenario and SUC are introduced graphically and in the text using **green colour** for POST methods and **orange colour** for PUT methods. For more information on all these activities, an intensive description of the overall SUCs scenarios was already provided in D5.1 [7] and D9.1 [8].

- **Methods:** Every interaction among actors in the different scenarios requires a method that executes that interaction. A Method is a concept coming from the Hypertext Transfer Protocol (HTTP) that enables communication between servers and clients. Through these Methods, the operators acting either as servers or as clients can send information to its own or other's IT infrastructure or edit information that the other party already has. For each Method presented in this chapter a table is provided with the following information:
 1. Description: brief explanation of the Method.
 2. Request URL: the URL that should be used by the client to call the endpoint.
 3. Method type: can be POST (used to send data to a server to create a resource), GET (used to request data from a specified resource) or PUT (used to send data to a server to update a resource).
 4. From: who calls the method (client).
 5. To: where the resource is stored (server).
 6. Condition: event/context that needs to occur for the method being called.
 7. Trigger: periodicity in which the Method is called.
 8. Parameters: the needed inputs to call the Method.
 9. Request body: the data model or attachment that is required by the Method.

For the Methods that are already deployed and that already have a URL associated to it, some snapshots from SwaggerHub⁸ are presented to provide some visualization of the endpoints' inputs.

- **Data Model:** In case any of the previously described Methods require exchange of information, this part describes the proposed structure of that information as well as the type of file to be submitted.

⁸ SwaggerHub is an integrated API design and documentation platform, built for teams to drive consistency and discipline across the API development workflow.

- **TDEP Processes:** After providing a general vision of the interactions that will take place in a given SUC, this part presents the processes that the TSO will perform both by using the Methods previously described and the actions to be executed when there is an interaction with its API/DEP. Flow diagrams are presented as well as description that explains in detail such flow of information and processes.
- **DDEP Processes:** This section provides similar flow diagrams and explanations as seen by the DSO.

The TDEP API with all the SUCs endpoints is already up and running and can be accessed in the following URL: <http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/docs#/>. The DDEP API for the flexibility UC is still under development but the API related with the operational planning UCs is already up and running and can be accessed in the following URL: <https://dso-dep-dev.watt-is.com/api-docs/index.html>. Given that the users for those APIs are meant to be only the stakeholders identified for each SUCs (system operators, aggregators, FSPs, etc.), all the endpoints require user name and password to be called.

4.2.1 SUC 01 - Evaluation of the Product & Grid prequalification requirements

In the first use case the data exchanged between DSO and TSO is related to the assessment of an FSP pre-qualification.

The pre-qualification process should start after an FSP expresses interest in entering the flexibility market. This process serves to ensure that a particular FSP is capable of delivering a given product. In order to do that, two types of pre-qualification should be considered: Product Pre-qualification and Grid Pre-qualification. As defined in the ASM report [9], pre-qualification is the process in which a potential provider shall demonstrate that it complies with all the technical requirements that have been established for the provision of the flexibility product (product pre-qualification) and the ability of the grid to which it connects to deliver the required product (grid pre-qualification).

The former ensures that the resource complies with the technical requirements needed to be able to deliver the product and proceed to the market phase and be eventually selected by a system operator. These technical requirements are defined by the DSO and TSO. After indication from the FSP on the attributes of the product it wants to deliver, a pre-qualification test should be performed to verify that all attributes are in compliance with the technical requirements. This test may be repeated on a periodic basis or whenever the characteristics of the product are found to change significantly⁹.

⁹ Technical requirements in the flexibility energy markets may change over time, such as new standards or regulations being introduced, periodic testing helps to ensure that providers stay up-to-date with these changes and can continue to effectively participate in the markets.

The product pre-qualification can be done either by the DSO or TSO, regardless of its location, regarding their own products. In case a system operator wants to activate a product already pre-qualified by another system operator, the former should have access to this information in order to make the process more efficient and not to pre-qualify the same product twice.

Regarding grid pre-qualification, this process ensures that the product provided by the FSP will not cause constraints in the networks where it is connected. This process can be avoided if the System Operators have already identified the areas where flexibility is always allowed. The grid pre-qualification should be performed by the System Operator of the network to which the FSP is connected in order to verify if the maximum capacity of the product does not create any constraint to the network it is connected to.

If the results of the two types of pre-qualification are approved, the entry of the FSP into the flexibility market is allowed.

The Pre-qualification scenario is independent of the timeframe, since it is a process that happens before the market phase.

4.2.1.1 Scenarios

The different scenarios in this SUC are divided according to where the FSP is connected, either to the DSO or to the TSO. In the scope of this document we will only focus on the cases in which is the SO that does not have the FSP connected to its own grid that starts the product prequalification process. However, the SUC design presented in D9.1 [8] includes the case in which the SO who wants to activate a product already pre-qualified by another system operator, to have access to this information in order to make the process more efficient and not to pre-qualify the same product twice.

4.2.1.1.1 Scenario 1 – Prequalification for FSPs connected to Distribution Grid

In this scenario, the TSO shares the result of product prequalification and requests the grid prequalification from the DSO side. For this purpose, four endpoints are created, two in TDEP and two in DDEP. **Method 01.1 – POST** is created in TDEP so that it can receive the product prequalification file from the TSO and **Method 01.2 – POST** is created in the DDEP so that it can receive this product prequalification file from the TDEP. After grid prequalification from DSO side, the file is updated and sent to DDEP via **Method 01.3 – PUT** and then **Method 01.4 – PUT** in the TDEP is used to receive the updated file of the product and grid prequalification from the DDEP.

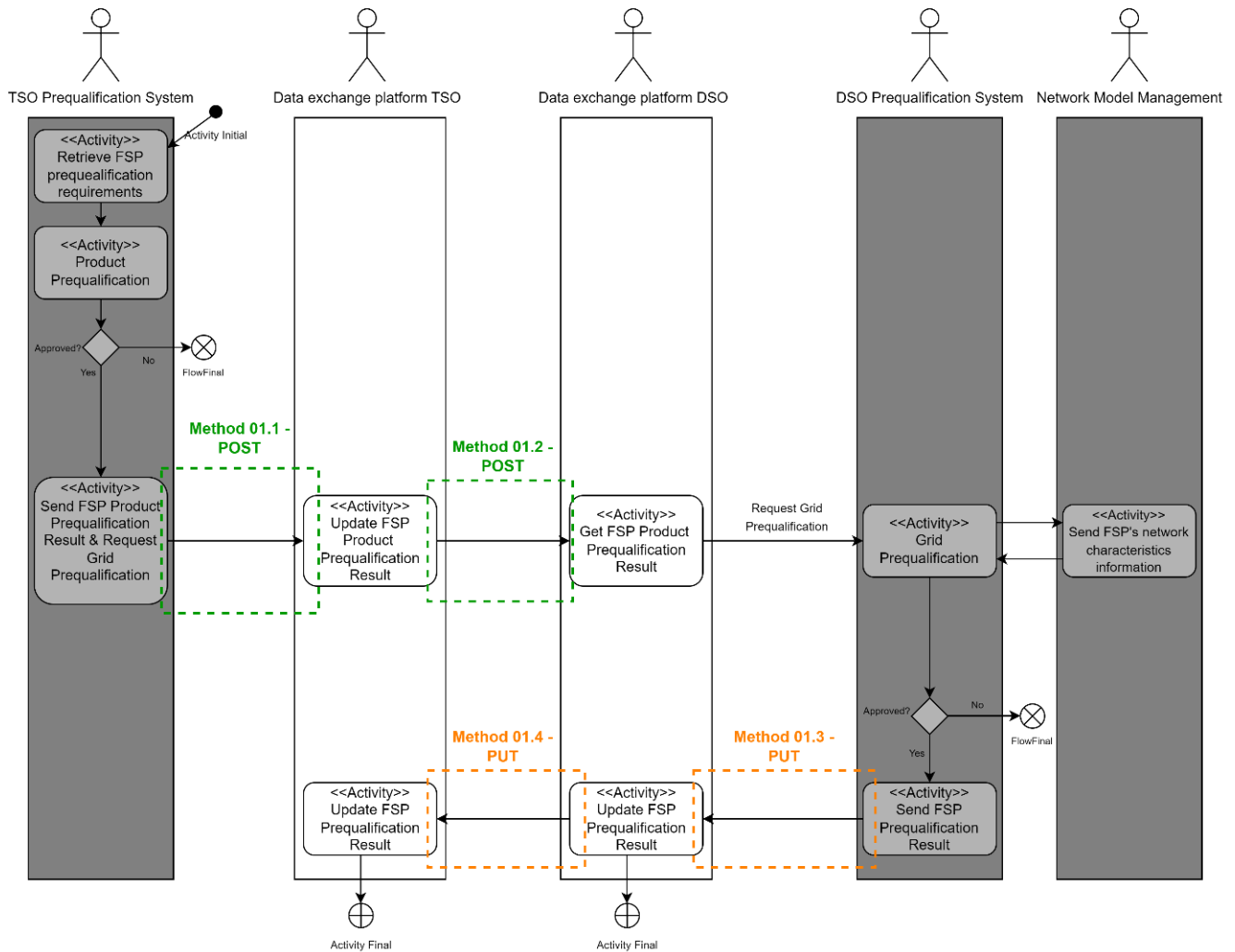


Figure 4.5 - SUC 01 scenario 1 diagram

4.2.1.1.2 Scenario 2 – Prequalification for FSPs connected to Transmission Grid

In this scenario, the DSO shares the result of product prequalification and requests the grid prequalification from the TSO side. For this purpose, the four endpoints that were created in Scenario 1 are used. **Method 01.2 – POST** is used in DDEP to receive the product prequalification file from the DSO and **Method 01.1 – POST** is used in the TDEP to receive this product prequalification file from the DDEP. After grid prequalification from TSO side, the file is updated and sent to TDEP via **Method 01.4 – PUT** and then **Method 01.3 – PUT** in the DDEP is used to receive the updated file of the product and grid prequalification from the TDEP.

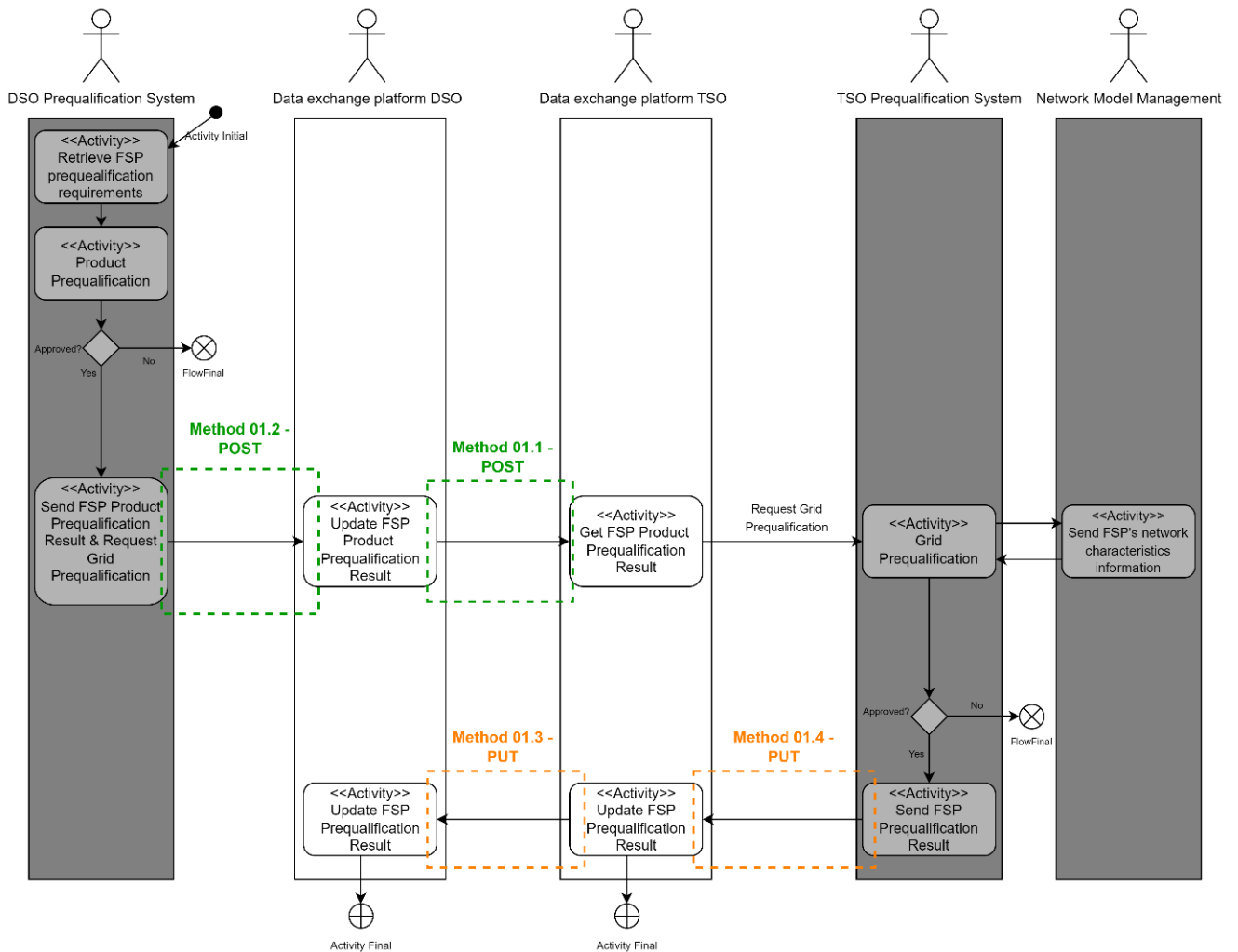


Figure 4.6 - SUC 01 Scenario 2 diagram

4.2.1.2 Methods

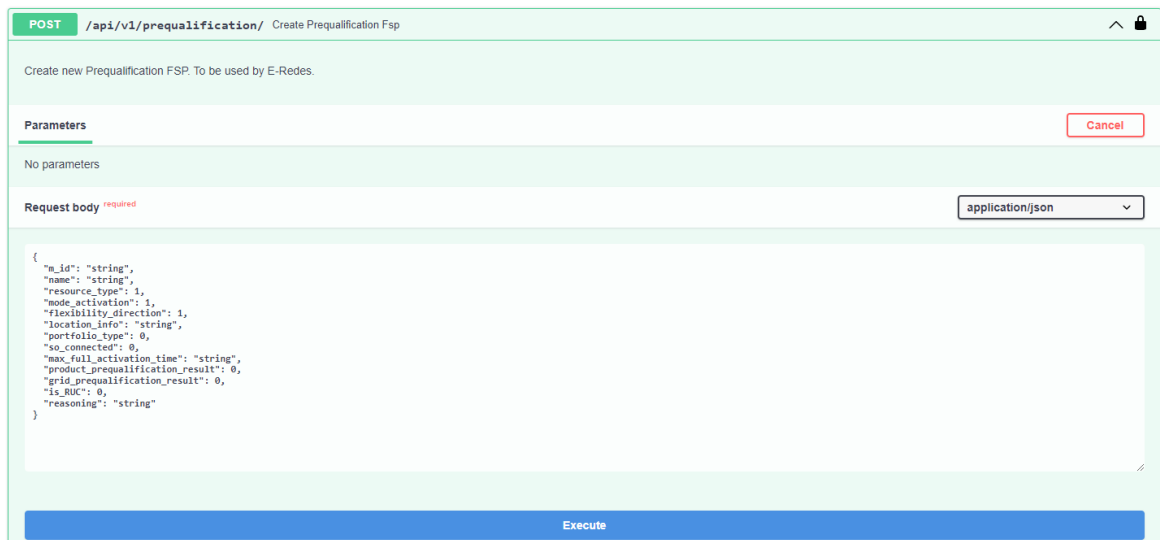
In this sub section the base methods developed in the APIs of the TDEP and DDEP are presented that allow the operationalization of the SUC 01 in the demo. The methods briefly presented previously are here unveiled for both DEPs.

TDEP Methods

The following tables present the API methods that are fundamental to the SUC 01. Some snapshots from SwaggerHub are also presented in order to show an example of the API methods.

Table 4.1 - SUC 01 Method 01.1 summary

Method 01.1	
Description	DDEP or TSO sends to TDEP a prequalification registration.
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/ prequalification
Method type	POST
From	DDEP or TSO (REN)
To	TDEP
Condition	N/A
Trigger	As need
Parameters	N/A
Request body	[Required] JSON file that follows the structure presented in data model (4.2.1.3)



POST /api/v1/prequalification/ Create Prequalification Fsp

Create new Prequalification FSP. To be used by E-Redes.

Parameters

No parameters

Request body required application/json

```
{
  "m_id": "string",
  "name": "string",
  "resource_type": 1,
  "mode_activation": 1,
  "flexibility_direction": 1,
  "location_info": "string",
  "portfolio_type": 0,
  "so_connected": 0,
  "max_full_activation_time": "string",
  "product_prequalification_result": 0,
  "grid_prequalification_result": 0,
  "is_RUC": 0,
  "reasoning": "string"
}
```

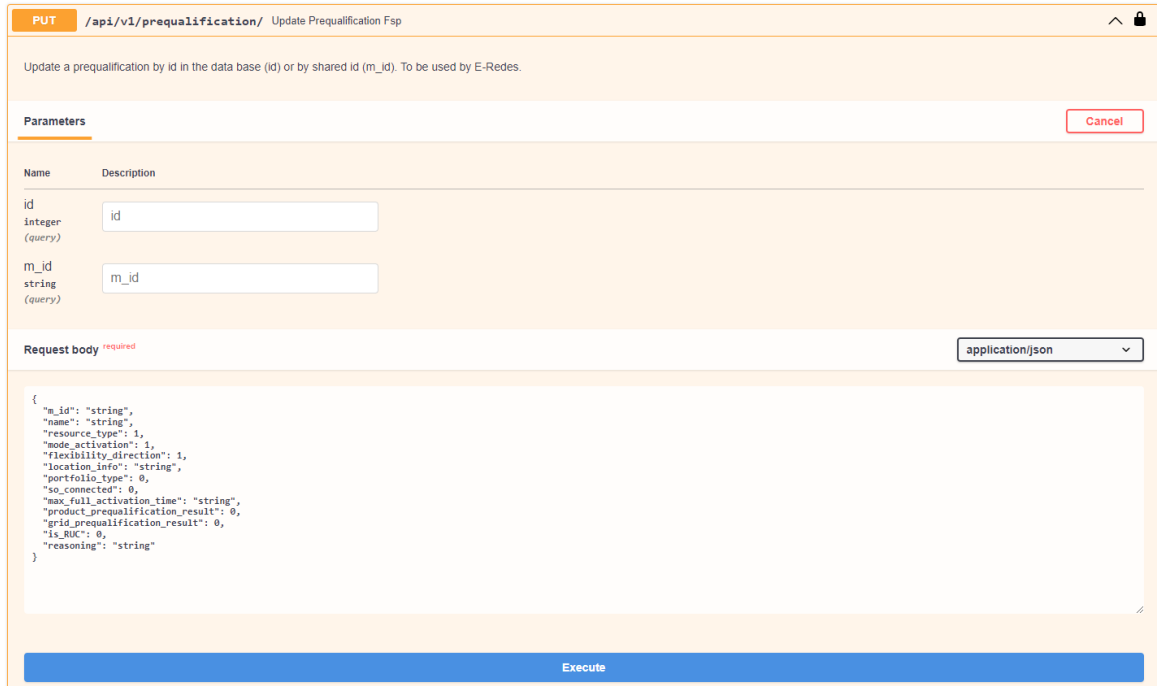
Execute

Figure 4.7 - SUC 01 Method 01.1 API snapshot

Table 4.2 - SUC 01 Method 01.4 summary

Method 01.4	
Description	DDEP or TSO updates a prequalification registration with the grid prequalification result in TDEP.
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/ prequalification
Method type	PUT
From	DDEP or TSO (R&D NESTER)
To	TDEP
Condition	Availability of the product prequalification registration from Method 01.1
Trigger	As need
Parameters	[Optional] id [1] (integer) -> which corresponds to the database entry

	[Optional] m_id [abc] (string) -> which corresponds to the shared id of the prequalification registration
Request body	[Required] JSON file that follows the structure presented in data model (4.2.1.3)



PUT /api/v1/prequalification/ Update Prequalification Fsp

Update a prequalification by id in the data base (id) or by shared id (m_id). To be used by E-Redes.

Parameters

Name	Description
id integer (query)	id
m_id string (query)	m_id

Request body required

application/json

```
{
  "m_id": "string",
  "name": "string",
  "resource_type": 1,
  "mode_activation": 1,
  "flexibility_direction": 1,
  "location_info": "string",
  "portfolio_type": 0,
  "sq_connected": 0,
  "max_full_activation_time": "string",
  "product_prequalification_result": 0,
  "grid_prequalification_result": 0,
  "is_BUC": 0,
  "reasoning": "string"
}
```

Execute

Figure 4.8 - SUC 01 Method 01.4 API snapshot

DDEP Methods

The following tables present the API methods that are fundamental to the SUC 01 for the DDEP. Note that for this SUC, both the URL and the parameters are still to be defined as they concern developments that are still undergoing within the demonstrator. With that said, no snapshots from SwaggerHub are presented for these Methods.

Table 4.3 - SUC 01 Method 01.2 summary

Method 01.2	
Description	TDEP or DSO sends to DDEP a prequalification registration.
Request URL	To be defined
Method type	POST
From	TDEP or DSO (E-REDES)
To	DDEP
Condition	N/A
Trigger	As need

Parameters	To be defined
Request body	[Required] JSON file that follows the structure presented in data model (4.2.1.3)

Table 4.4 - SUC 01 Method 01.3 summary

Method 01.3	
Description	TDEP or DSO updates a prequalification registration with the grid prequalification result in DDEP.
Request URL	To be defined
Method type	PUT
From	TDEP or DSO
To	DDEP
Condition	Availability of the product prequalification registration from Method 01.2
Trigger	As need
Parameters	To be defined
Request body	[Required] JSON file that follows the structure presented in data model (4.2.1.3)

4.2.1.3 Data Model

This sub section presents the data model that was designed to exchange information under SUC 01. The data model created for the exchange of the prequalification results is presented in the Table 4.5.

Table 4.5 - SUC 01 Data model

Field	Sub-field	Type	Description
m_id	-	(str) (Required)	
Name	-	(str) (Required)	
Type of resource	-	(int) (Optional)	1 -> EV Charger 2 -> EV Battery 3 -> PV
Mode of activation	-	(int) (Optional)	1 -> Manual 2 -> Automatic 3 -> Both
Flexibility Direction	-	(int) (Optional)	1 -> Up 2 -> Down 3 -> Both
Location information		(array) (Required)	
	Location	(str) (Required)	(Coordinates)
	For TSO	(str) (Optional)	(Interconnection)
	For DSO	(str) (Optional)	(CPE)
SO Connected		(int) (Required)	0 -> DSO 1 -> TSO

Single or Aggregated Portfolio		(int) (Optional)	0 -> Single 1 -> Agg
Maximum Full Activation time		(str) (Optional)	hh:mm:ss
Product Prequalification Result		(int) (Required)	0 -> Accepted 1 -> Rejected
Grid Prequalification Result		(int) (Optional)	0 -> Accepted 1 -> Rejected
is_RUC		(int) (Optional)	0 -> No 1 -> Yes
Reasoning		(str) (Optional)	

Each field can be described as:

- *m_id* tells the shared ID of the FSP for both TSO and DSO.
- *Name* tells the name of the FSP that expressed the interest in entering the flexibility market.
- *Type of resource* indicates the type of the service that FSP intend to provide, either EV charger or EV battery or PV.
- *Mode of activation* indicates if this service will be activated manually, automatically or that it can be activated in both ways.
- *Flexibility Direction* indicates the service direction of the FSP, either up or down or both ways.
- *Location* provides the location coordinates of the FSP.
- *For TSO* provides the information about the TSO/DSO interconnection below which the FSP is connected.
- *For DSO* provides the information about the code of the point of connection in the DSO network where the FSP is connected.
- *SO connected* indicates to which SO's network the FSP is connected.
- *Single or Aggregated Portfolio* provides the information about the portfolio.
- *Maximum Full Activation Time* provides the information about the maximum activation time of the FSP.
- *Product Prequalification Result* provides the acknowledgement if the product prequalification was successful or not.
- *Grid Prequalification Result* provides the acknowledgement if the grid prequalification was successful or not.
- *is_RUC* tells if this exchange of the information is done on the national level (only Portugal) or on the international level (RUC).
- *Reasoning* indicates the reason of the FSP's intention to participate in flexibility market.

This data model is applied to a JSON format that should be submitted in the request body of **Method 01.1 – POST**, **Method 01.2 – POST**, **Method 01.3 – PUT** and **Method 01.4 – PUT**. Below is an example of the JSON schema message with the prequalification information.

```
{
  "m_id": "ID2023_1",
  "name": "string2023",
  "resource_type": 1,
  "mode_activation": 1,
  "flexibility_direction": 1,
  "location_info": "latitude,longitude",
  "portfolio_type": 0,
  "so_connected": 0,
  "max_full_activation_time": 00:00:15,
  "product_prequalification_result": 1,
  "grid_prequalification_result": 1,
  "is_RUC": 0,
  "reasoning": "Want to participate in TSO flexibility market",
}
```

4.2.1.4 TDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the TDEP API for the different scenarios of the SUC 01 demo. Here is explained how information flows between the client, the server and the database. The methods presented before are here presented as well as some other auxiliary methods.

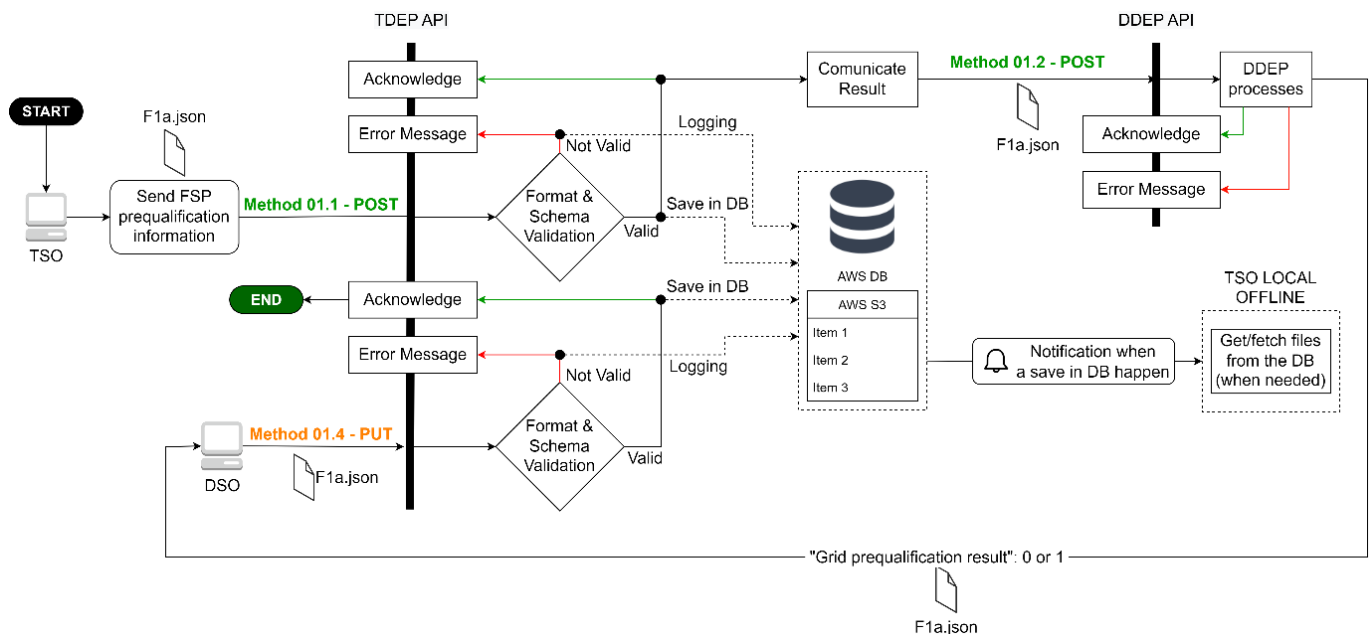


Figure 4.9 - SUC 01 Scenario 1 flowchart (TDEP)

For the scenario 1 (Prequalification for FSPs connected to Distribution Grid) the process can be summarized as presented in the Figure 4.9.

This process starts when an FSP connected to the distribution grid expresses the interest in participating in flexibility market for the TSO. After receiving the request, TSO makes product prequalification, if the product is approved, TSO calls the **Method 01.1 – POST** endpoint of the TDEP API to publish the product prequalification result and request for the DSO to make a grid prequalification. Once the file is received, both the format and the schema of the file are validated by the TDEP API and a synchronous response is provided to the client, either success response (acknowledge) or failure response (error message). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB. An automatic email notification is sent to the TSO (represented by R&D NESTER) informing that new prequalification result files were stored in the DB. After that, the **Method 01.2 – POST** of the DDEP API is called to submit the prequalification information. After the successful grid prequalification, the **Method 01.4 – PUT** of the TDEP API is called to update the TSO with the FSP prequalification result. Once the file is received, both the format and the schema of the file are validated by the TDEP API and a synchronous response is provided to the client, either success response (acknowledge) or failure response (error message). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB.

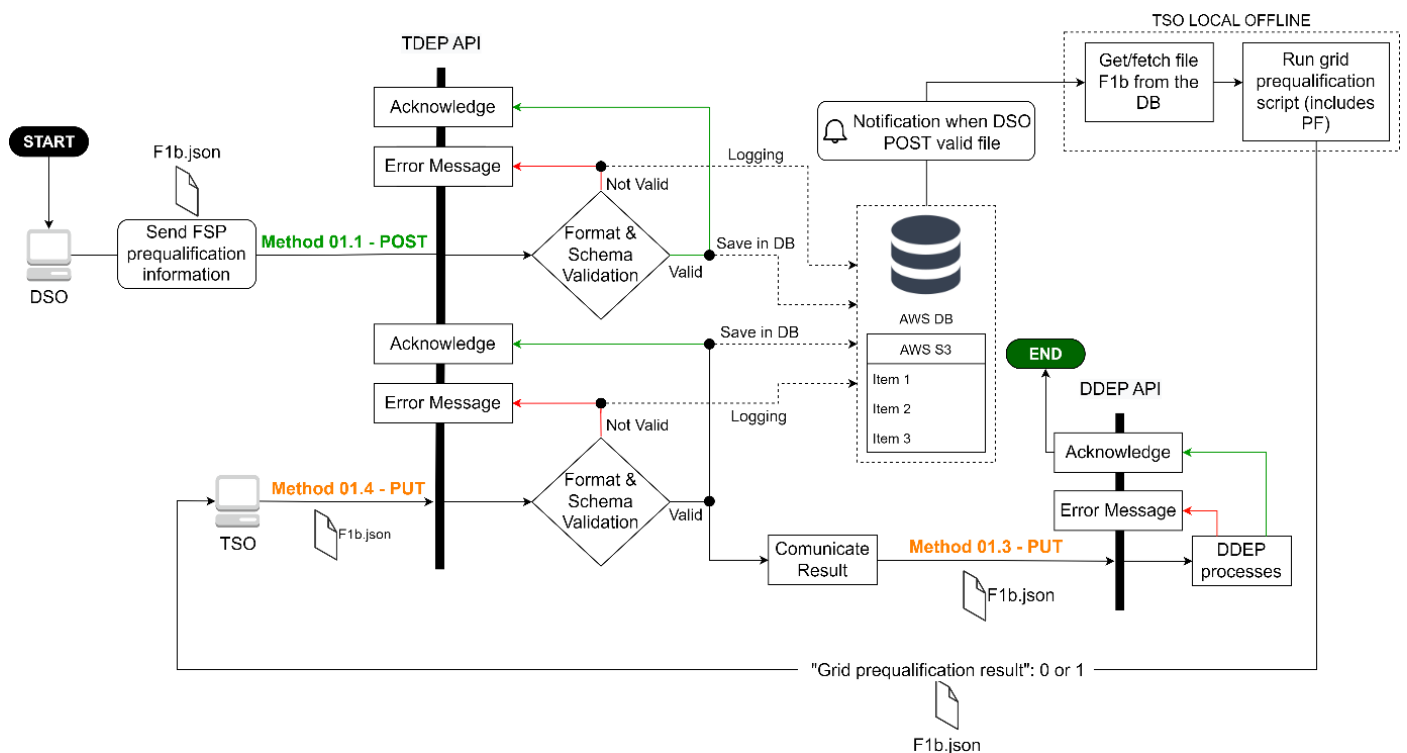


Figure 4.10 - SUC 01 Scenario 2 flowchart (TDEP)

For the scenario 2 (Prequalification for FSPs connected to Transmission Grid) the process can be summarized as presented in the Figure 4.10.

This process starts when an FSP connected to the transmission grid expresses the interest in participating in flexibility market of the DSO. After the successful product prequalification from DSO part, DSO calls the **Method 01.1 – POST** endpoint of the TDEP API to publish the product prequalification result and request for the TSO to make a grid prequalification. Once the file is received, both the format and the schema of the file are validated by the TDEP API and a synchronous response is provided to the client, either success response (acknowledge) or failure response (error message). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB. After notification of receipt of the file, R&D NESTER fetches it and the grid prequalification script is run on the TSO local offline server. After that, the **Method 01.4 – PUT** of the TDEP API is called to update the prequalification information with grid prequalification result from TSO side. Once the file is received, both the format and the schema of the file are validated by the TDEP API and a synchronous response is provided to the client, either success response (acknowledge) or failure response (error message). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB. After that, the **Method 01.3 – PUT** of the DDEP API is called to update the prequalification information.

4.2.1.5 DDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the DDEP API for the different scenarios of the SUC 01. Here is explained the information flows between the client, the server and the database. The methods presented before are here presented as well as some other auxiliary methods.

For the Scenario 1 (Prequalification for FSPs connected to Distribution Grid) the process can be summarized as presented in the Figure 4.11.

This process starts when an FSP connected to the distribution grid expresses the interest in participating in providing flexibility services to the TSO. After the successful product prequalification from TSO side, **Method 01.2 – POST** is used to publish the product prequalification result and request for the DSO to make a grid prequalification. Once the file is received, both the format and the schema of the file are validated by the DDEP API and a synchronous response is provided to the client, either success response (acknowledge) or failure response (error message), after which the files are stored in the DDEP database. Then, the DSO implements the required internal processes to do the grid prequalification, which results will be updated in the received file through **Method 01.3 – PUT** and, afterwards, the **Method 01.4 – PUT** is used to communicate the results with the TDEP to update the prequalification information.

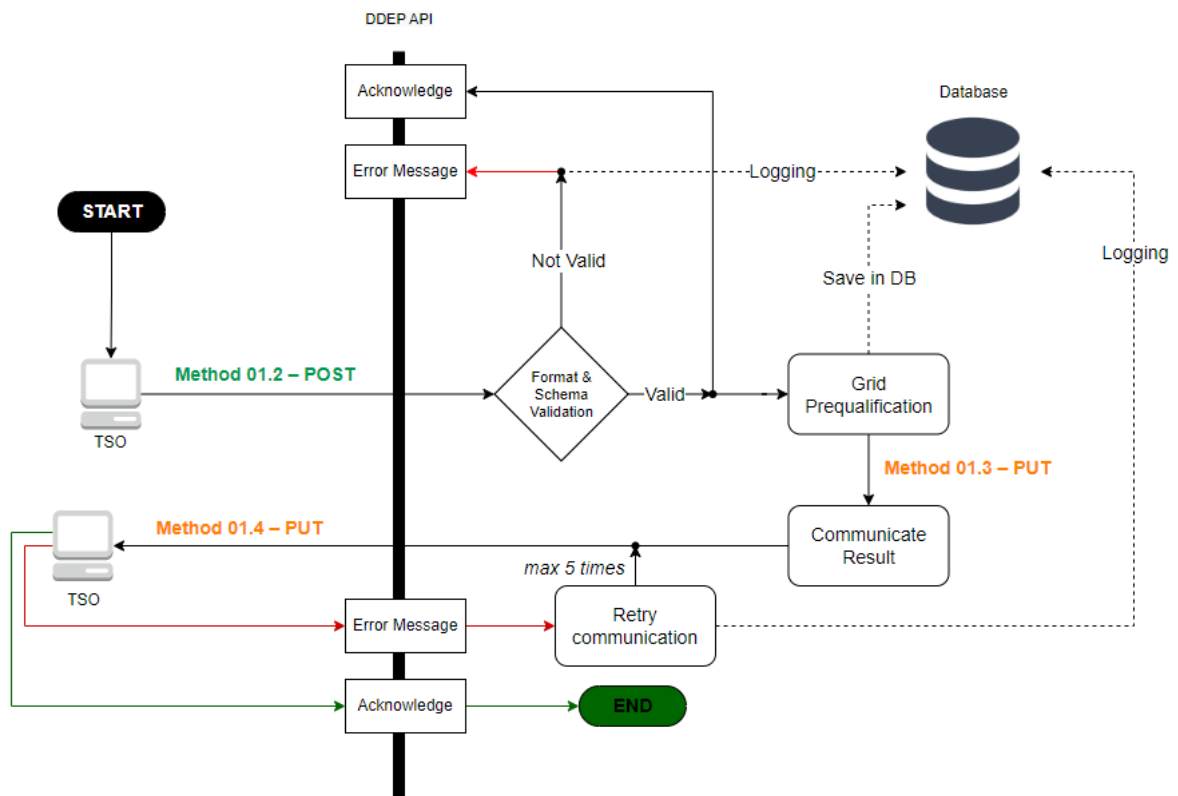


Figure 4.11 - SUC 01 Scenario 1 flowchart (DDEP)

For the Scenario 2 (Prequalification for FSPs connected to Transmission Grid) the process can be summarized as presented in the Figure 4.12.

This process starts when an FSP connected to the transmission grid expresses the interest in participating in flexibility market of the DSO. To accomplish this, a product prequalification is done, which results and request for grid prequalification are published through **Method 01.2 – POST**. Note that if the product prequalification turns out invalid, the process ends there and the information is stored in the database. **Method 01.3 – PUT** of the DDEP API is called to update the prequalification information with grid prequalification result from the TSO side. With a correct validation, this information will be sent through the previously mentioned method using the recurring retry police applied before, with the acknowledge setting in motion the next phase.

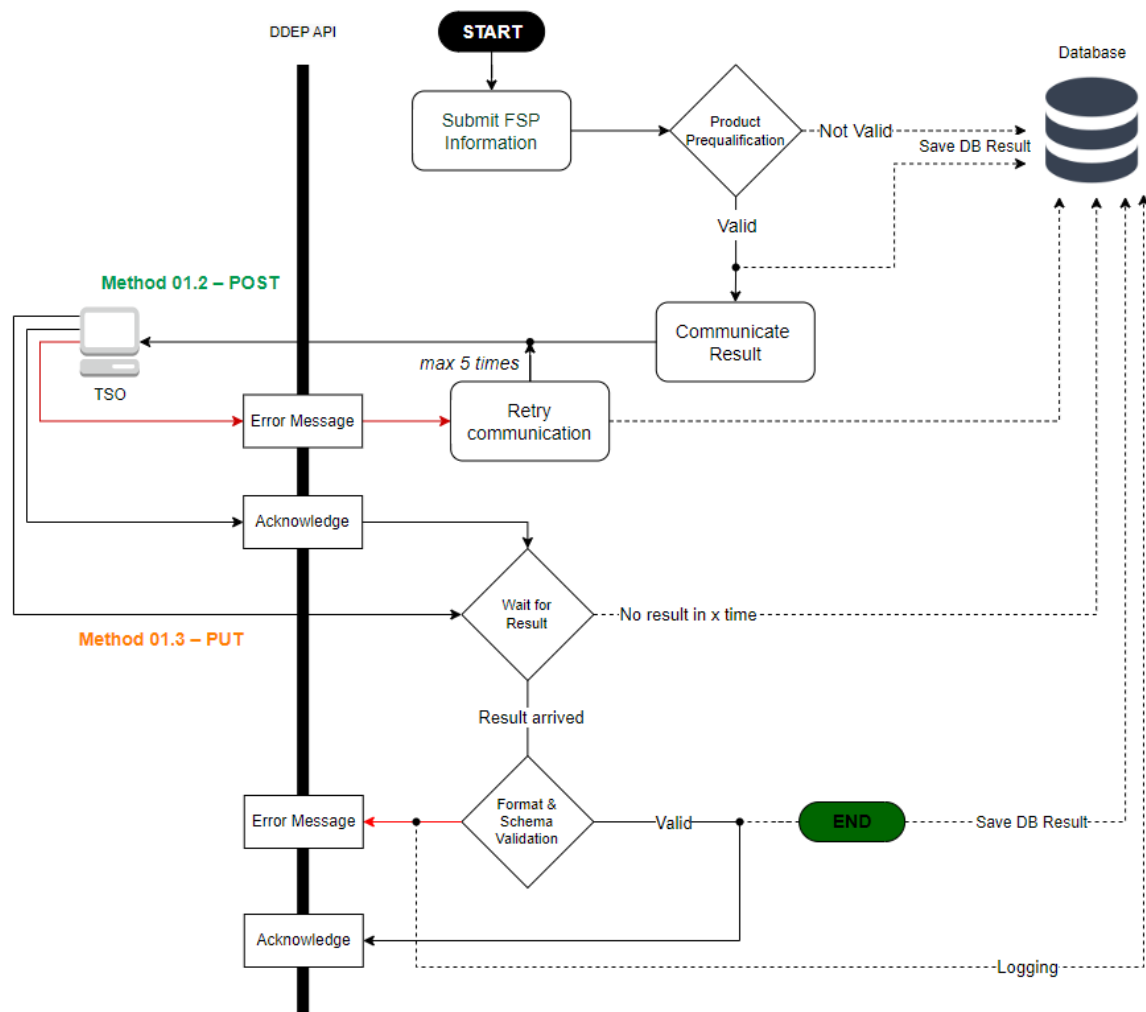


Figure 4.12 - SUC 01 Scenario 2 flowchart (DDEP)

4.2.2 SUC 02 - Day-Ahead & Intraday Flexibility needs

In the second use case the data exchanged between DSO and TSO regards its own Flexibility needs.

In that sense, this SUC supports the coordination between the DSO and TSO so that they can determine how much flexibility they will need to acquire, for a short-term timeframe. The coordination is needed to prevent congestions in the distribution and transmission grids due to activation of active power flexibilities for the needs DSO and TSO. Note that at the time of the definition of this SUC, this short-term timeframe was defined to be daily and intraday, however, for demonstration purposes, a daily timeframe was considered, which will happen

after the closure of the day-ahead market. This coordination process starts day-ahead, after the opening of the intraday flexibility market.

This SUC describes the steps that system operators should go through in order to identify potential network restrictions for the next day and to understand the amount of flexibility they will need to obtain to solve their needs and constraints. In the end, the flexibility needs shared are the ones aggregated for the TSO-DSO interface buses.

Additionally, this SUC will also address the identification of the flexibility potential that exists in the distribution network for MV customers. In that sense, the API was designed in order to be able to receive flexibility offers¹⁰ from FSPs/aggregators. The thorough description of the process to obtain these flexibility potentials is described in Chapter 5.

In this SUC the information exchange will not only occur through the TDEP and DDEP but also through the use of the OneNet Connector. The developments related with the integration of the OneNet Connector within SUC 02 are ongoing and for that reason the developments will not be presented in this deliverable but in the future Deliverable 9.5 together with the demo results.

4.2.2.1 Scenarios

The different scenarios in this SUC are divided according to whom assesses their network needs and also according to the mean used to exchange the respective data. A new scenario (Scenario 5 - Distribution-Connected DERs offers to Solve Transmission-Level Congestions) related with the flexibility offers is also included in this deliverable, as an addition to the scenarios already defined for this SUC under D5.1 [7] and D9.1 [8].

4.2.2.1.1 Scenario 1 - Day-ahead & Intraday Flexibility needs for DSO

In this scenario, the DSO shares its flexibility needs with the TSO. For this purpose, an endpoint (**Method 02.1 - POST**) is created in the TDEP so that it can receive the day-ahead or intraday flexibility needs assessment in the distribution network. The DDEP will have a scheduler that is responsible of sending the flexibility needs every day in an agreed timeframe.

¹⁰ Do not have price associated, just the power offered up or down

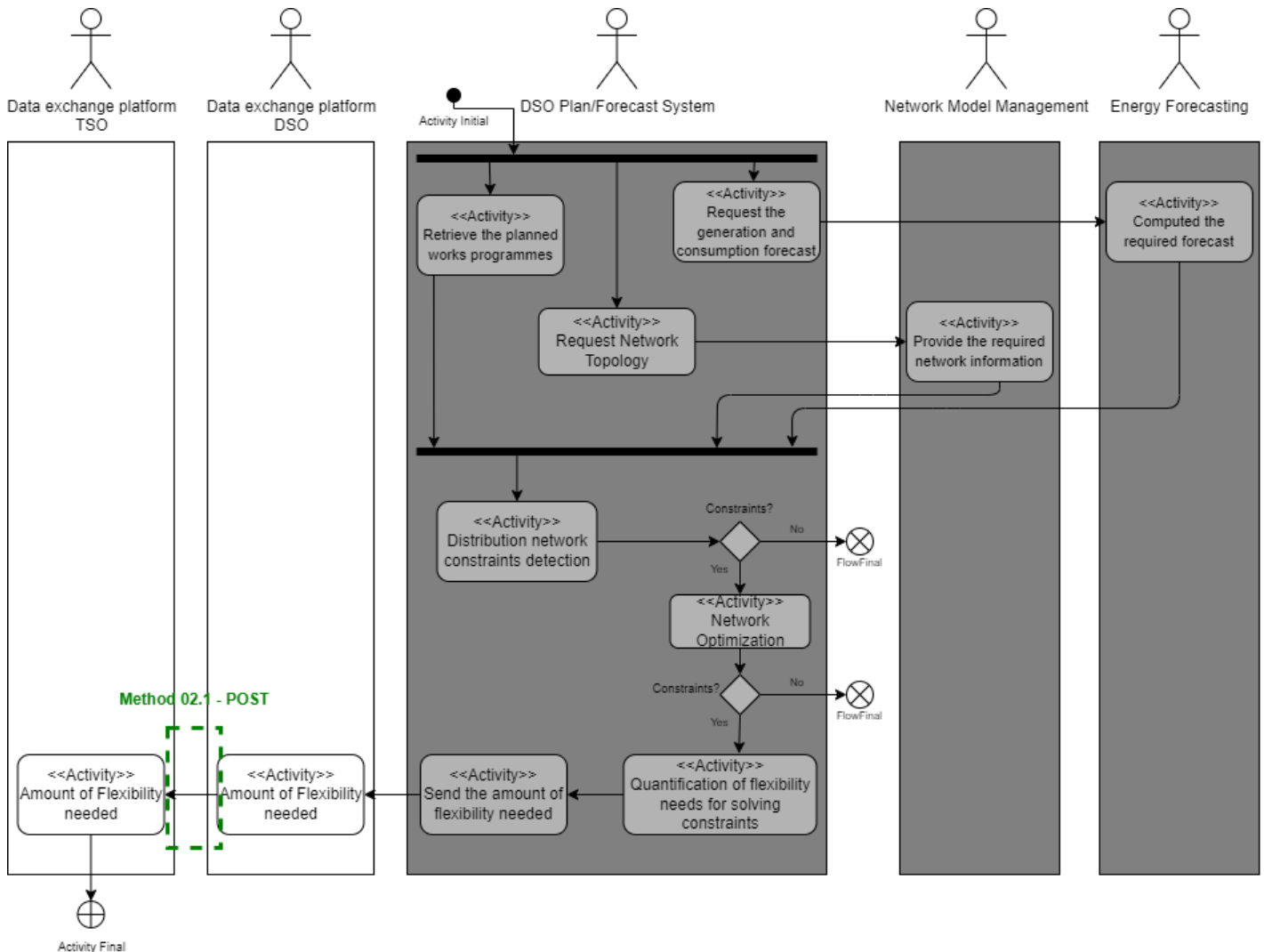


Figure 4.13 – SUC 02 Scenario 1 diagram

4.2.2.1.2 Scenario 2 - Day-ahead & Intraday Flexibility needs for TSO

In this scenario, the TSO shares its flexibility needs with the DSO. For this purpose, an endpoint (**Method 02.2 - POST**) is created in the DDEP so that it can receive the day-ahead flexibility needs assessment in the transmission network. The TDEP will have a scheduler that is responsible by sending the flexibility needs every day in an agreed timeframe.

In the Portuguese demo, R&D NESTER will be responsible by all the TSO activities, taking advantage of the real data provided by REN (Portuguese TSO). For that reason, for the SUC 02 one endpoint was created in the

TDEP just for the provision of data between REN and R&D NESTER (**Method 02.a - POST**)¹¹. After running the grid simulations to identify any network constraints and consequently identify the amount of flexibility needed to solve them, R&D NESTER (playing the role of TSO) will use the endpoint presented in the previous scenario (**Method 02.1 - POST**) to submit the transmission grid flexibility needs.

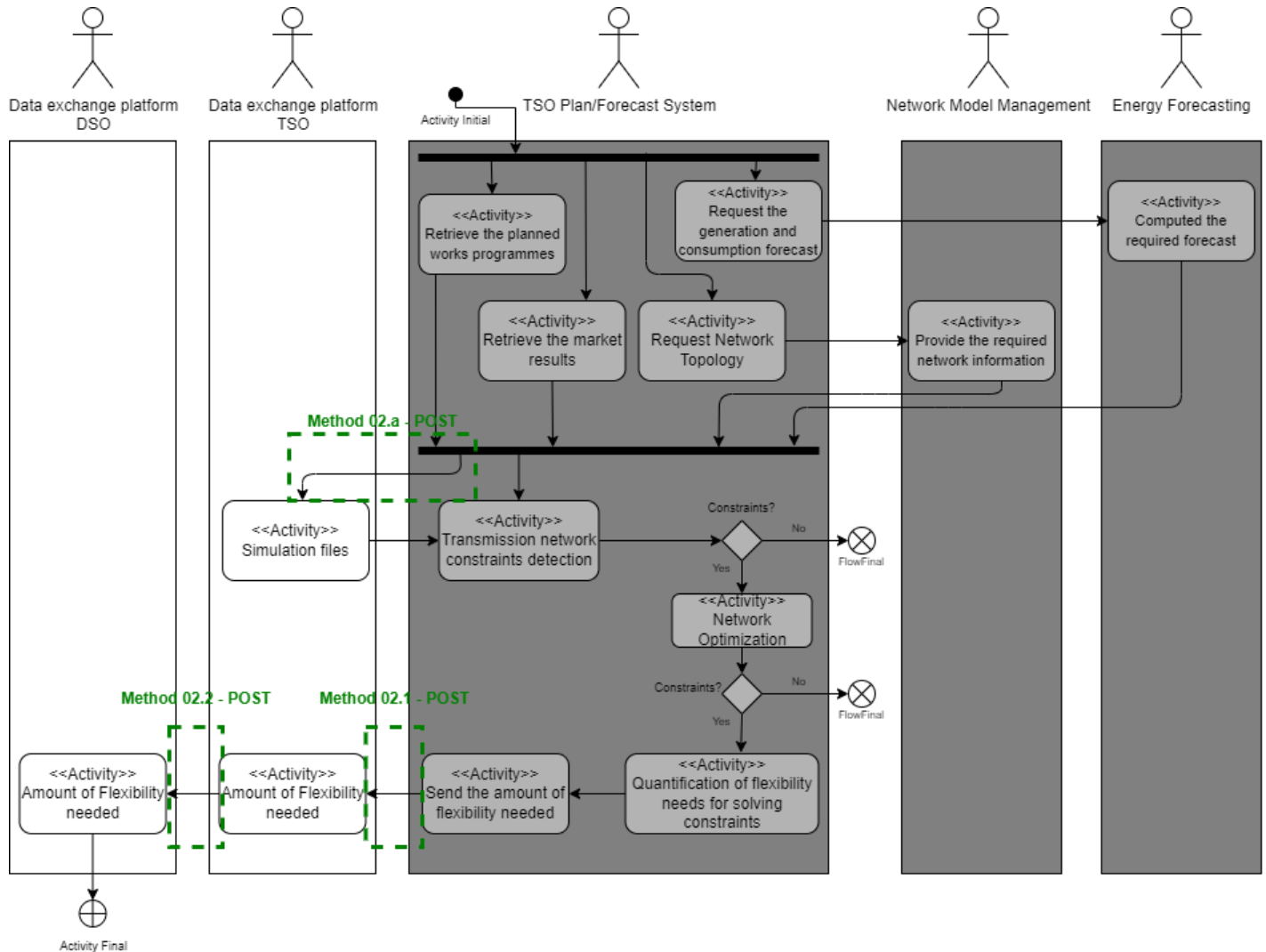


Figure 4.14 - SUC 02 scenario 2 diagram

¹¹ When the confidentiality of REN data is required, the TDEP is not used for exchanging REN data with R&D NESTER, instead, the data exchange is done locally without resorting to Ethernet

4.2.2.1.3 Scenario 3 - Day-Ahead & Intraday Flexibility needs for DSO within OneNet System

This scenario is similar to the Scenario 1, the only change is that in this scenario the OneNet System will be used as means to exchange the DSO flexibility needs. Through the OneNet Connector any authorized stakeholder can have access to the flexibility needs published by E-REDES (Portuguese DSO) following the data governance model defined.

An endpoint (**Method 02.3 - POST**) is created in the OneNet System that allows the DSO to publish the Flexibility Needs. As the integration with the OneNet Connector is yet to be deployed at the time of writing the deliverable, this Method will not be described under the Methods section.

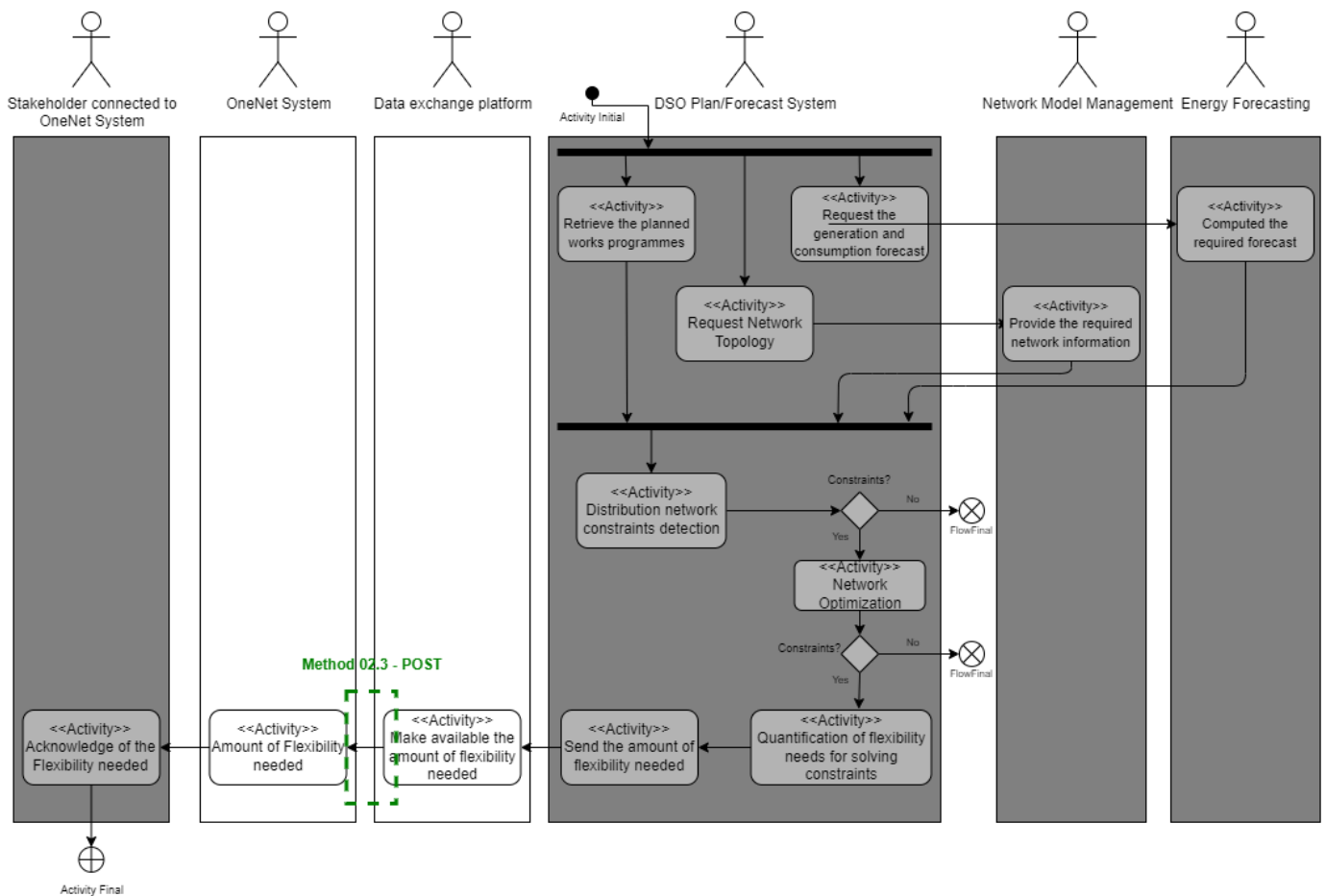


Figure 4.15 - SUC 02 Scenario 3 diagram

4.2.2.1.4 Scenario 4 - Day-Ahead & Intraday Flexibility needs for TSO within OneNet System

This scenario is similar to the Scenario 2, the only change is that in this scenario the OneNet System will be used as means to exchange the TSO flexibility needs. In the demo, through the use of the OneNet Connector,

any authorized stakeholder can have access to the flexibility needs published by R&D NESTER as representative of REN (Portuguese TSO) following the data governance model defined.

An endpoint (**Method 02.4 - POST**) is created in the OneNet System that allows the TSO to publish the Flexibility Needs. As the integration with the OneNet Connector is yet to be deployed at the time of writing the deliverable, this Method will not be described under the Methods section.

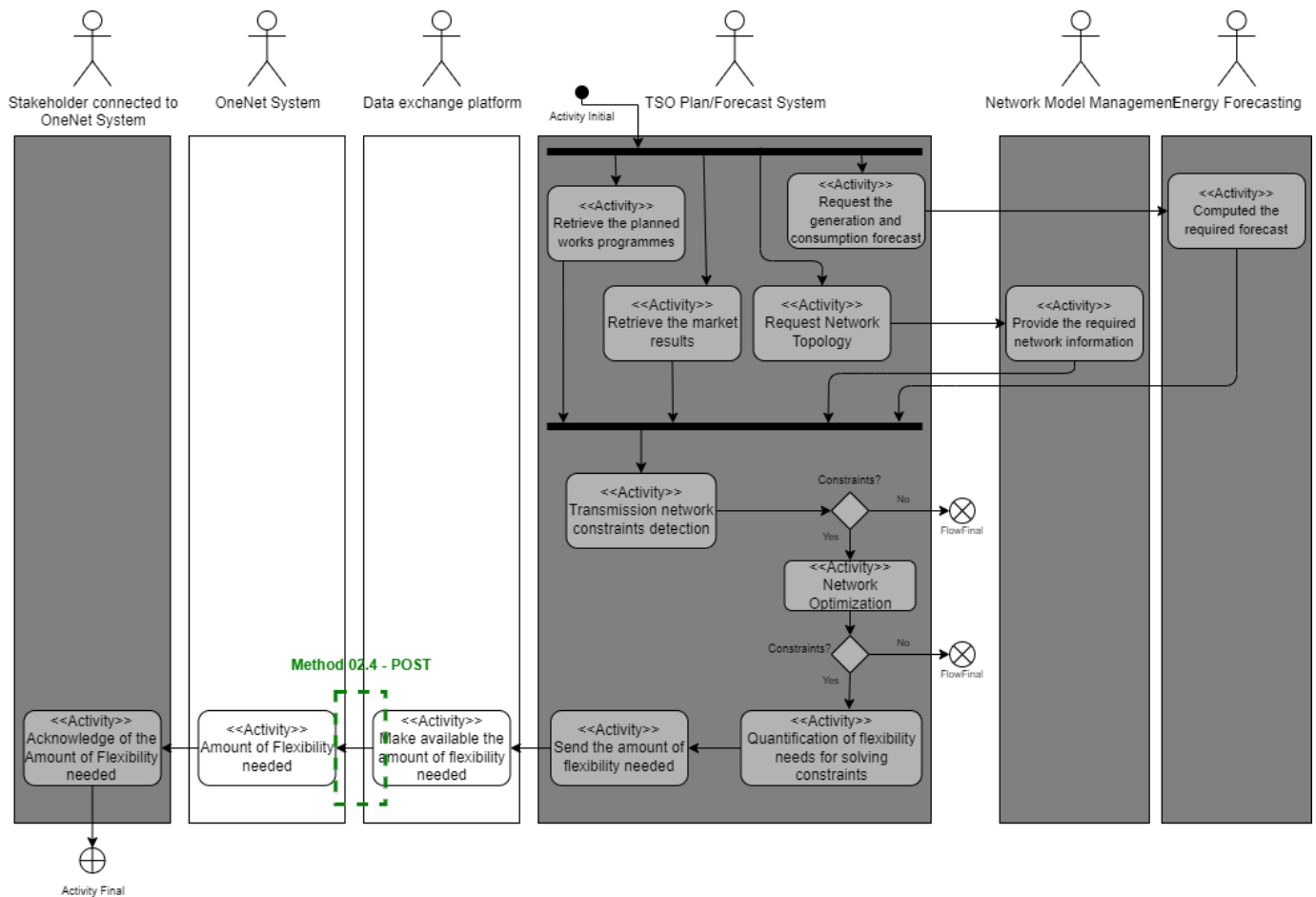


Figure 4.16 - SUC 02 scenario 4 diagram

4.2.2.1.5 Scenario 5 – Distribution-Connected DERs offers to Solve Transmission-Level Congestions

This scenario was not included in the initial descriptions made for the SUC 02 in D5.1 [7] and D9.1 [8]. The purpose of this scenario is to represent the role of an aggregator calculating and evaluating, based on historical data of consumption, the potential flexibility it has to offer in a certain area of the network, in a certain period. Once the amount of aggregated available flexibility has been identified for each of the buses, the aggregator sends to the TSO the aggregated flexibility offers for the TSO-DSO interconnection buses. For that purpose, a

dedicated endpoint (**Method 02.5 – POST**) was created in the TDEP to receive the flexibility offers that, in the context of the demo, will be submitted by INESC TEC playing the role of the Aggregator. Note that the methodology to be used to obtain the exchanged data within this Scenario will be further explained under Chapter 5.

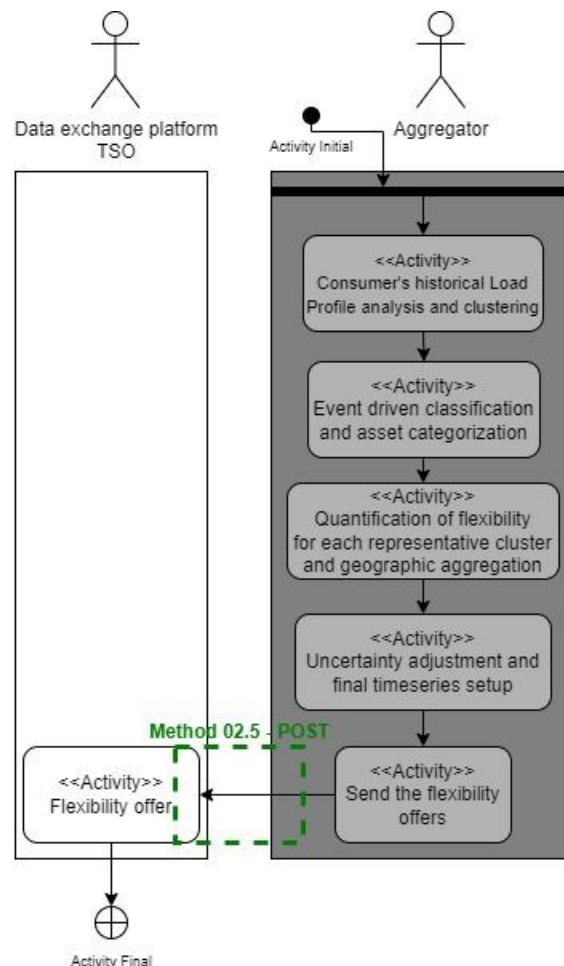


Figure 4.17 - SUC 02 Scenario 5 diagram

4.2.2.2 Methods

This sub section presents the fundamental methods developed in the APIs of the TDEP and DDEP that allow the operationalization of the SUC 02. The methods that were presented in previous section are here unveiled for both data exchange platforms. Some snapshots from SwaggerHub are also presented to show the TDEP API methods, where the request URL for the API is already defined.

TDEP Methods

In the following tables are presented the API methods that are fundamental to the SUC 02 demo.

Table 4.6 – SUC 02 Method 02.a summary

Method 02.a	
Description	TSO provides the simulation files needed for the day-ahead flexibility needs evaluation
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/flexibility/needs/simulation-files
Method type	POST
From	TSO (REN)
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Optional] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed. If empty will assume the date of submission
Request body	[Required] Zip file with 24 simulation files in .raw format (one file per hour)

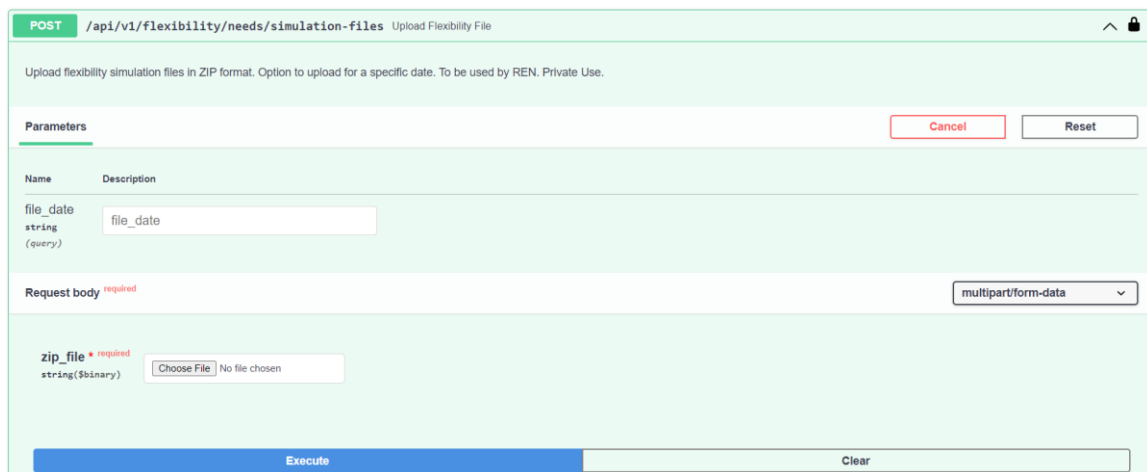


Figure 4.18 - SUC 02 Method 02.a API snapshot

Table 4.7 - SUC 02 Method 02.1 summary

Method 02.1	
Description	Endpoint that enables the submission of the day-ahead Flexibility Needs to the TDEP
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/flexibility/needs/
Method type	POST
From	DSO or TSO (R&D NESTER)
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	N/A
Request body	Json message that follows the structure presented in data model (4.2.2.3)

POST /api/v1/flexibility/needs/ Flexibility Needs

Create new Flexibility Needs. Type in json format. To be used by E-Redes.

Parameters

No parameters

Request body required

application/json

```

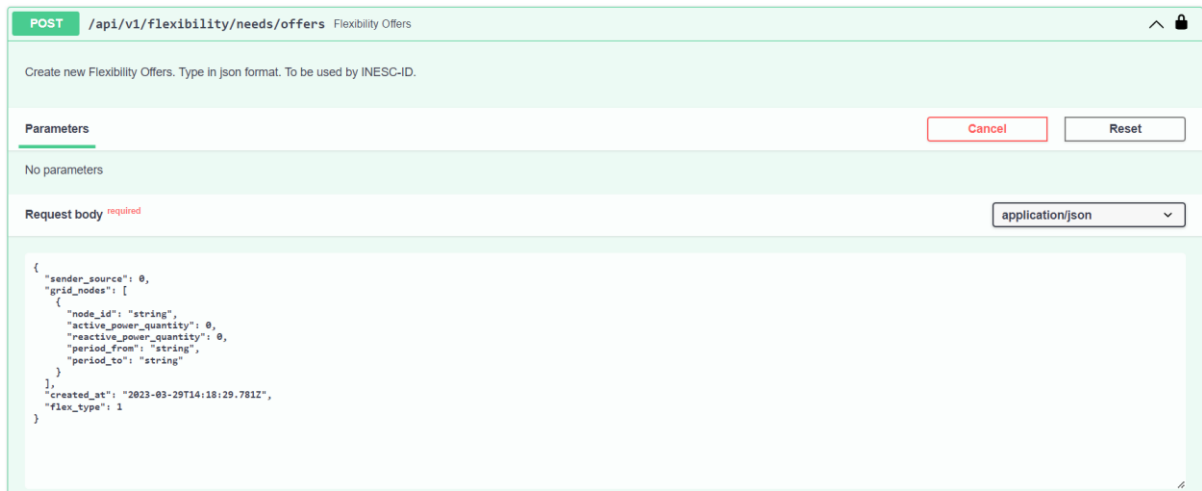
{
  "sender_source": 0,
  "grid_nodes": [
    {
      "node_id": "string",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "string",
      "period_to": "string"
    }
  ],
  "created_at": "2023-03-29T14:08:26.509Z",
  "flex_type": 0
}

```

Figure 4.19 - SUC 02 Method 02.1 API snapshot

Table 4.8 - SUC 02 Method 02.5 summary

Method 02.5	
Description	Endpoint that enables the submission of the Flexibility Offers to the TDEP
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/flexibility/needs/offers
Method	POST
From	Aggregator
To	TDEP
Condition	N/A
Request	Every day (on-schedule)
Parameters	N/A
Request body	Json message that follows the structure presented in data model (4.2.2.3)



POST /api/v1/flexibility/needs/offers Flexibility Offers

Create new Flexibility Offers. Type in json format. To be used by INESC-ID.

Parameters Cancel Reset

No parameters

Request body required application/json

```
{
  "sender_source": 0,
  "grid_nodes": [
    {
      "node_id": "string",
      "active_power_quantity": 0,
      "reactive_power_quantity": 0,
      "period_from": "string",
      "period_to": "string"
    }
  ],
  "created_at": "2023-03-29T14:18:29.781Z",
  "flex_type": 1
}
```

Figure 4.20 – SUC 02 Method 02.5 API snapshot

DDEP Methods

The following tables present the API methods that are fundamental to the SUC 02 for the DDEP. Note that for this SUC, both the URL and the parameters are still to be defined as they concern developments that are still undergoing within the demonstrator. With that said, no snapshots from SwaggerHub are presented for these Methods.

Table 4.9 - SUC 02 Method 02.2 summary

Method 02.2	
Description	Endpoint that enables the submission of the Flexibility Needs to the DDEP
Request URL	To be defined
Method type	POST
From	TSO (R&D NESTER)
To	DDEP
Condition	TSO Flexibility Needs already available in the DB
Trigger	Every day (on-schedule)
Parameters	N/A
Request body	Json message that follows the structure presented in data model (4.2.2.3)

4.2.2.3 Data Model

In this sub-section is presented the data model that was designed to exchange information under the SUC 02 demo. The data model created for the exchange of flexibility needs and offers relies on the information presented in the Table 4.10.

Table 4.10 - SUC 02 Data Model

Field	Sub-field	Type	Description
Sender_source	-	(int) (Required)	0 -> DSO 1 -> TSO 2 -> Aggregator
Grid_nodes	node_id	(str) (Required)	
	Active Power Quantity	(number float) (Optional)	[MW]
	Reactive Power Quantity	(number float) (Optional)	[MVar]
	periodFrom	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
	periodTo	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
Created_at	-	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
Flex_type	-	(int) (Required)	0 -> Flex Needs 1 -> Flex Offers

Each field can be described as:

- *Sender_source* tells which actor is requiring or offering the flexibility service. In the case of grid operators, 0 corresponds to DSO and 1 to TSO. The aggregator role corresponds to a value of 2 in this field.
- *Grid_nodes* collects the information of a flexibility need/offer in a given node of the grid. It has the corresponding *node_id*, known by all the parties, in addition to the *active* and *reactive power* injections or consumptions. *Period from* and *to* is a date and time in string format that indicates the period to which the quantities submitted refer to.
- *Created_at* is the moment when the user does the post. This is assigned automatically.
- *Flex_type* has the value of 0 for flexibility needs and 1 for flexibility offers.

It is important to mention that the quantity of active and reactive power can assume a positive, negative, or null value that must comply with the following common rules. Positive values indicate power injection from the perspective of the grid, while negative values indicate power consumption from the grid's perspective. This convention applies to flexibility needs. Regarding flexibility offers, positive values indicate upward flexibility (i.e., an increase in consumption or decrease in injection), while negative values indicate downward flexibility (i.e., a reduction in consumption or increase in injection).

This data model is applied to a **json** format that should be submitted in the request body of **Method 02.1 – POST** and **Method 02.5 – POST** like it is presented in the Figure 4.19 and Figure 4.20 respectively. Below is presented an example of the json schema message with the flexibility needs information.

```
{
  "sender_source": 1,
  "grid_nodes": [
    {
      "node_id": "BUS_ID_1",
      "active_power_quantity": 7.8,
      "reactive_power_quantity": 7.05,
      "period_from": "2023-03-30T00:00:00+00:00",
      "period_to": "2023-03-30T01:00:00+00:00"
    },
    {
      "node_id": "BUS_ID_1",
      "active_power_quantity": 7.832,
      "reactive_power_quantity": 2.05,
      "period_from": "2023-03-30T01:00:00+00:00",
      "period_to": "2023-03-30T02:00:00+00:00"
    },
    {
      "node_id": "BUS_ID_2",
      "active_power_quantity": 6.832,
      "reactive_power_quantity": 2.05,
      "period_from": "2023-03-30T03:00:00+00:00",
      "period_to": "2023-03-30T04:00:00+00:00"
    },
    {
      "node_id": "BUS_ID_2",
      "active_power_quantity": 5.832,
      "reactive_power_quantity": 2.055,
      "period_from": "2023-03-30T04:00:00+00:00",
      "period_to": "2023-03-30T05:00:00+00:00"
    },
    {
      "node_id": "BUS_ID_1",
      "active_power_quantity": 53.3832,
      "reactive_power_quantity": 23.055,
      "period_from": "2023-03-30T10:00:00+00:00",
      "period_to": "2023-03-30T11:00:00+00:00"
    }
  ],
  "created_at": "2023-03-29T23:32:01.478716",
  "flex_type": 0
}
```

4.2.2.4 TDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the TDEP API for the different scenarios of the SUC02 demo. Here it is explained how information flows between the client, the

For the Scenario 2 (Day-ahead & Intraday Flexibility needs for TSO) the processes can be summarized as presented in the Figure 4.22.

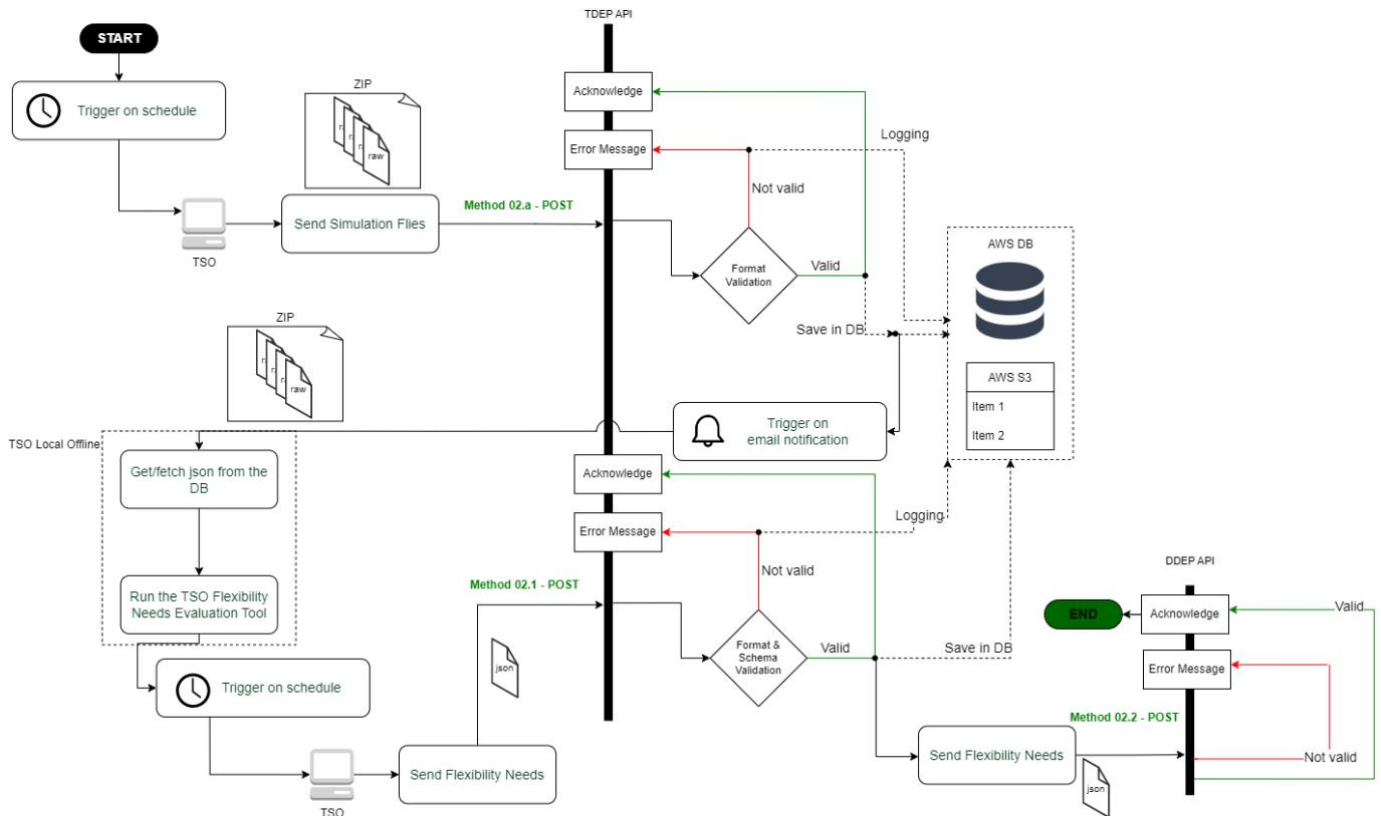


Figure 4.22 - SUC 02 Scenario 2 flowchart (TDEP)

This process starts with the TSO sending to the TDEP API the simulation files needed for the assessment of the flexibility needs in the interface TSO/DSO through the **Method 02.a POST** endpoint.

After passing to the validation check that runs in the API to check if the zip contains 24 .raw files (1 file for each hour of the next day) the zip file is stored in the cloud (AWS). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB. An automatic email notification is sent to the TSO (represented by R&D NESTER) informing that new simulation files were stored in the DB. After that, the files can be fetched and the TSO flexibility needs evaluation can start running the simulations offline. The TSO then updates the results online into the database through the **Method 02.1 POST** that will automatically trigger the communication from the TSO side to the DDEP API. For that, a POST method (**Method 02.2 POST**) endpoint is called and the TSO flexibility needs are submitted. All these processes are already implemented in the R&D NESTER API, once again is missing only the GUIs.

Lastly, for the Scenario 5 (Distribution-Connected DERs offers to Solve Transmission-Level Congestions) the processes are very similar to the ones presented in Scenario 1 but instead of flexibility needs sent by the DSO, here are exchanged flexibility offers by an aggregator using the **Method 02.5 POST**.

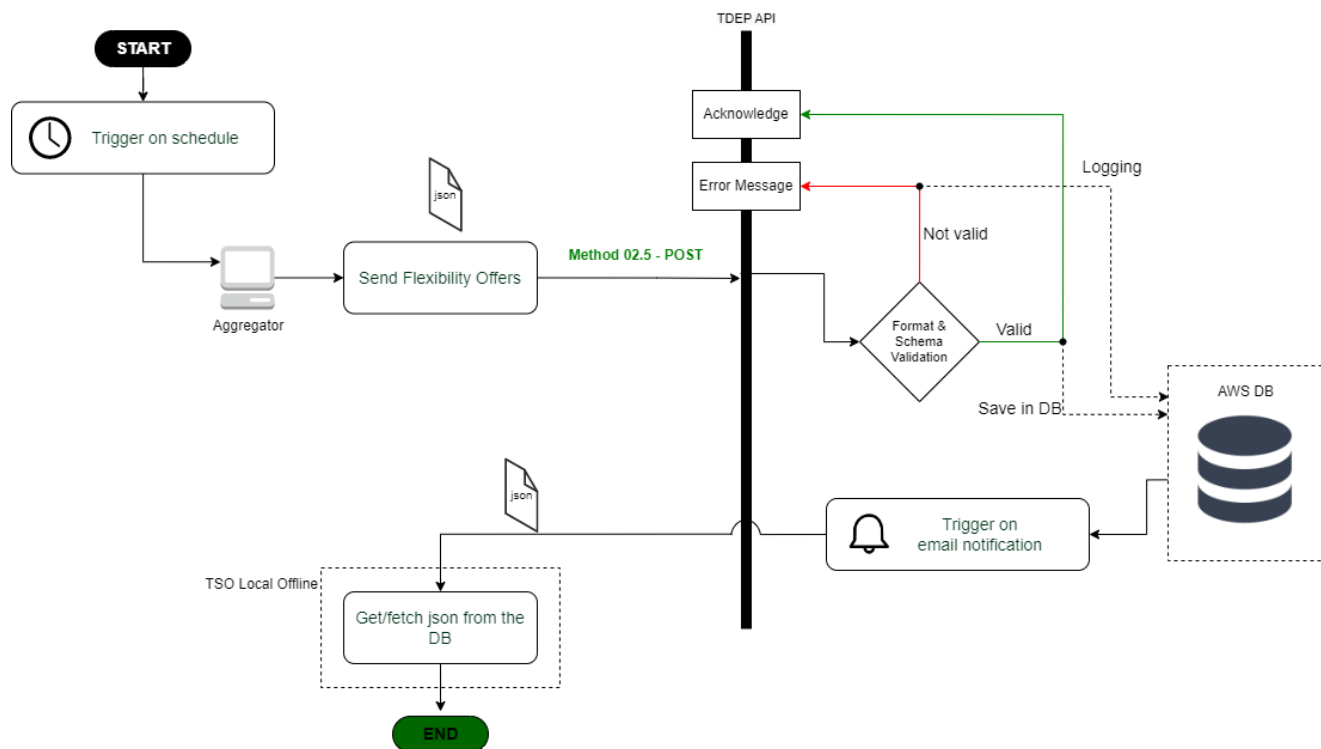


Figure 4.23 - SUC 02 Scenario 5 flowchart (TDEP)

4.2.2.5 DDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the DDEP API for the different scenarios of the SUC 02. Here it is explained how information flows between the client, the server and the database. The methods presented before are here represented as well as some others auxiliary methods.

For the Scenario 1 (Day-ahead & Intraday Flexibility needs for DSO) the processes can be summarized as presented in the Figure 4.24.

The process starts with the daily objective of sending to the transmission operator the amount of flexibility that can solve constraints in the distribution grid of the DSO. Here the previously deposited information on the database is sent to an endpoint of the TSO through the **Method 02.1 – POST**, at this stage the normal retry police takes place.

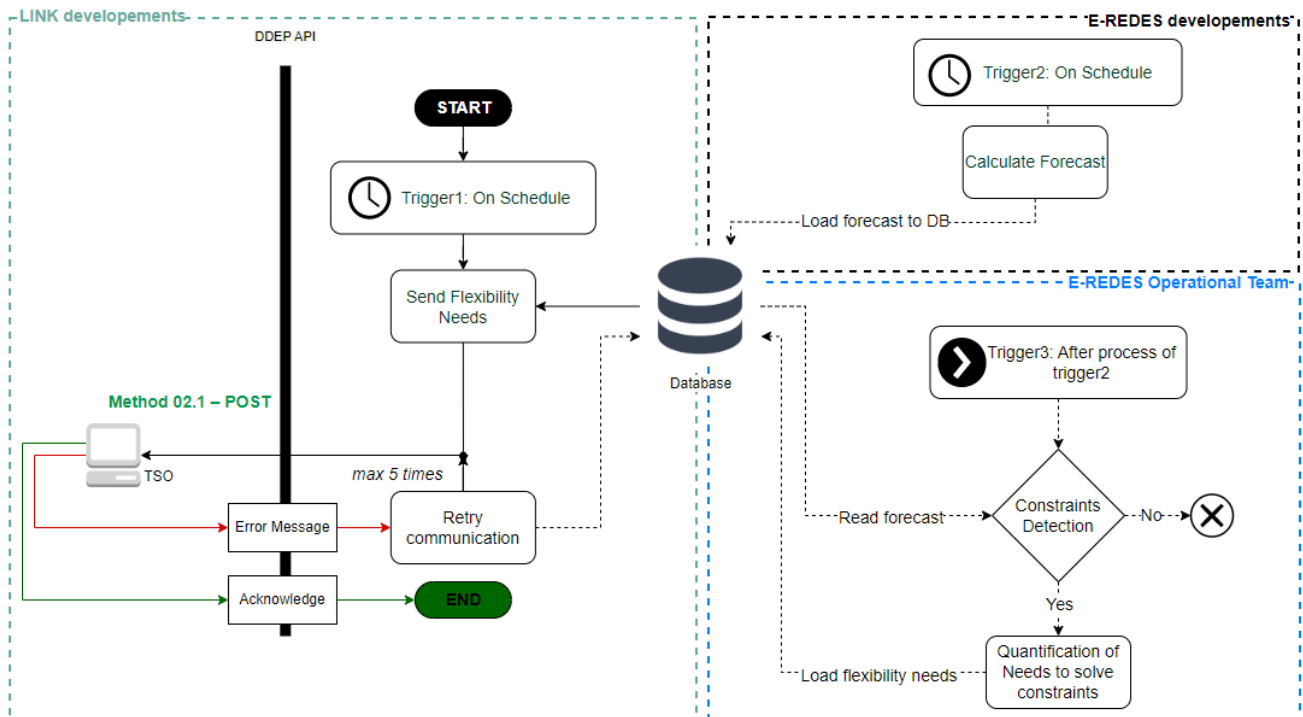


Figure 4.24 - SUC 02 Scenario 1 flowchart (DDEP)

On the other side, what enables this communication is the forecasted data that is stored in the database that will enable to detect the constraints to predict the flexibility needs. This first process of calculating the forecast of consumption and generation will be done through a E-REDES load and generation forecast software PREDIS on a scheduled timeline. Once this process is completed, it will trigger developments from E-REDES Network planning tool DPlan that can detect possible constraints on the grid and make the flexibility needs estimation accordingly.

4.2.3 SUC 06 - Maintenance plans information exchange

The coordination between TSOs and DSOs in developing maintenance plans is critical to ensuring the efficient and reliable operation of the energy grid. Despite the challenges posed by differences in the size and complexity of the infrastructure and maintenance schedules, coordination offers significant benefits, including the optimization of maintenance activities and reduction of costs. 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.

The maintenance work plans should be defined between distribution and transmission operators in an annual basis (long-term). This SUC has as objective to keep track of the maintenance works schedule and update them when needed, by exchanging more detailed information during different timeframes (from medium-term to close to real-time).

Due to the impact that distribution network loops, close to the TSO-DSO interface, can have in the transmission power flows, the share of the information about the scheduled maintenance plans becomes crucial for the TSO operational planning. On the other side, to the DSO, the TSO can share information about the connectivity status and maintenance plans of the transmission lines between EHV/HV substations with some impact in the distribution grids power flows near the border.

In the next sub-chapters are presented the exchange of information specificities between the TDEP and DDEP.

4.2.3.1 Scenarios

The different scenarios in this SUC are divided according to the timeframe in which the maintenance work programmes are submitted (annually or monthly-ahead, weekly-ahead and on event).

4.2.3.1.1 Scenario 1 – Year-ahead works programming

In this scenario, the TSO is the system operator responsible for the merging of the annual maintenance plans from both SOs. For that purpose, the TSO needs to receive from the DSO the planned works for the next year by calling the **Method 06.1 - POST**. Once the TSO has already its planned works for the next year, the TSO can merge both plans and create a jointly annual maintenance plan. In this plan should be presented the works that can affect the neighbour system operator and, in this way, allow coordination between TSOs and DSOs in developing a maintenance plan that ensures that the energy grid operates optimally while under outages. The jointly annual maintenance plan is submitted then to the TDEP by the TSO using the **Method 06.a - POST**. The same information is submitted to the DDEP (calling **Method 06.2 - POST**). This last step ensures that both SOs have the same joint annual maintenance plan that was agreed and validated between both SOs.

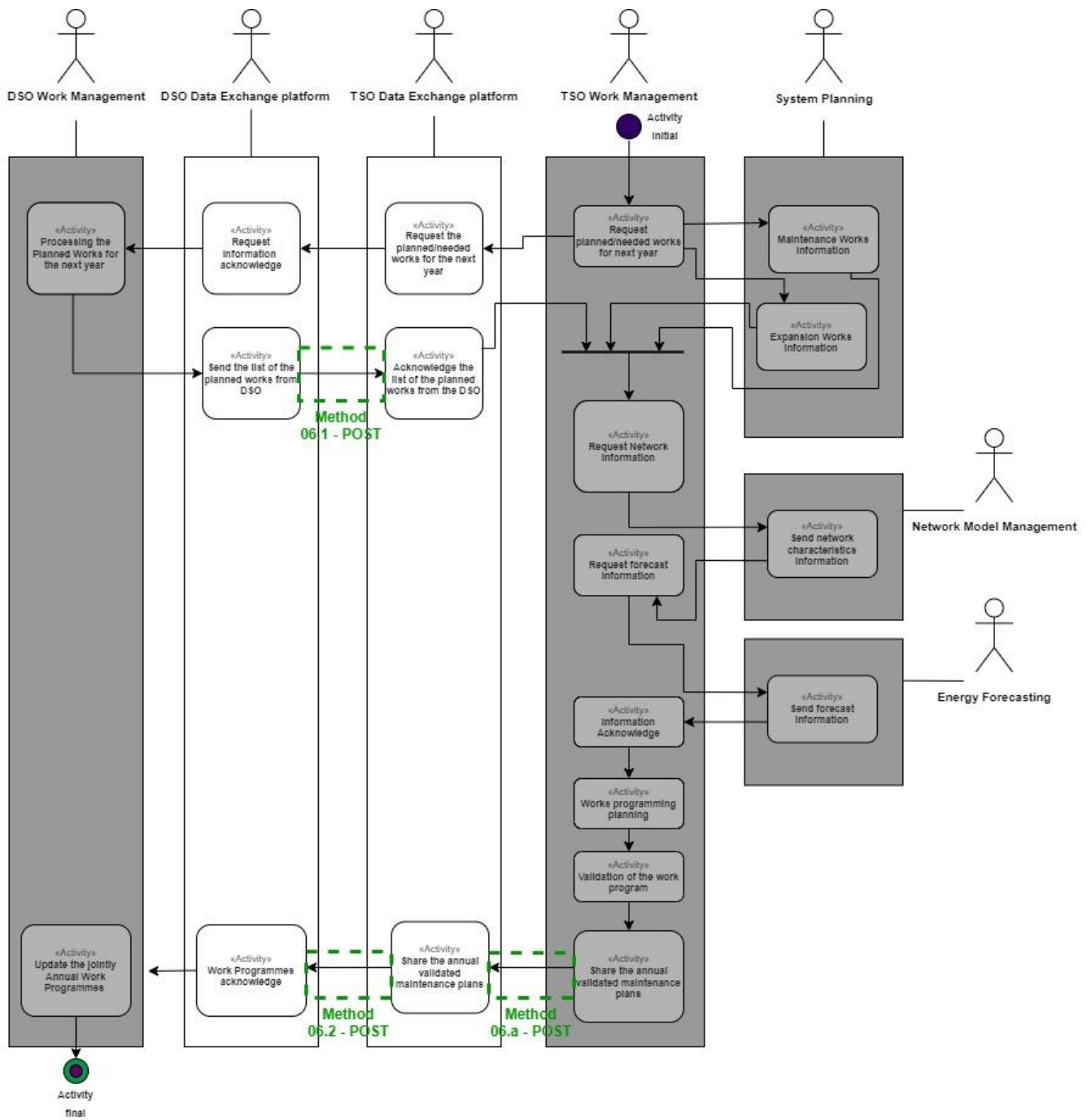


Figure 4.25 - SUC 06 scenario 1 diagram

4.2.3.1.2 Scenario 2 – Monthly-ahead, Weekly-ahead or on event update of maintenance plans

This scenario defines the sequence diagram (**Error! Reference source not found.**) for the SOs being able to request any update of the joint annual maintenance plans in a closer to real-time timeframe. It also comprises:

1. The processes to do the technical validation of the works in the month-ahead and/or week-ahead timeframe.
2. The processes to include a new work or change an existing one due to an expected circumstance (on-event).

The **Method 06.3 – PUT** is used to submit to the TDEP a new work or update a work already present in the annual maintenance plan defined in Scenario 1. The **Method 06.4 – PUT** does the same but for the DDEP side. In the end, the objective is to have both DEPs with the final work programme validated and accepted by both SOs.

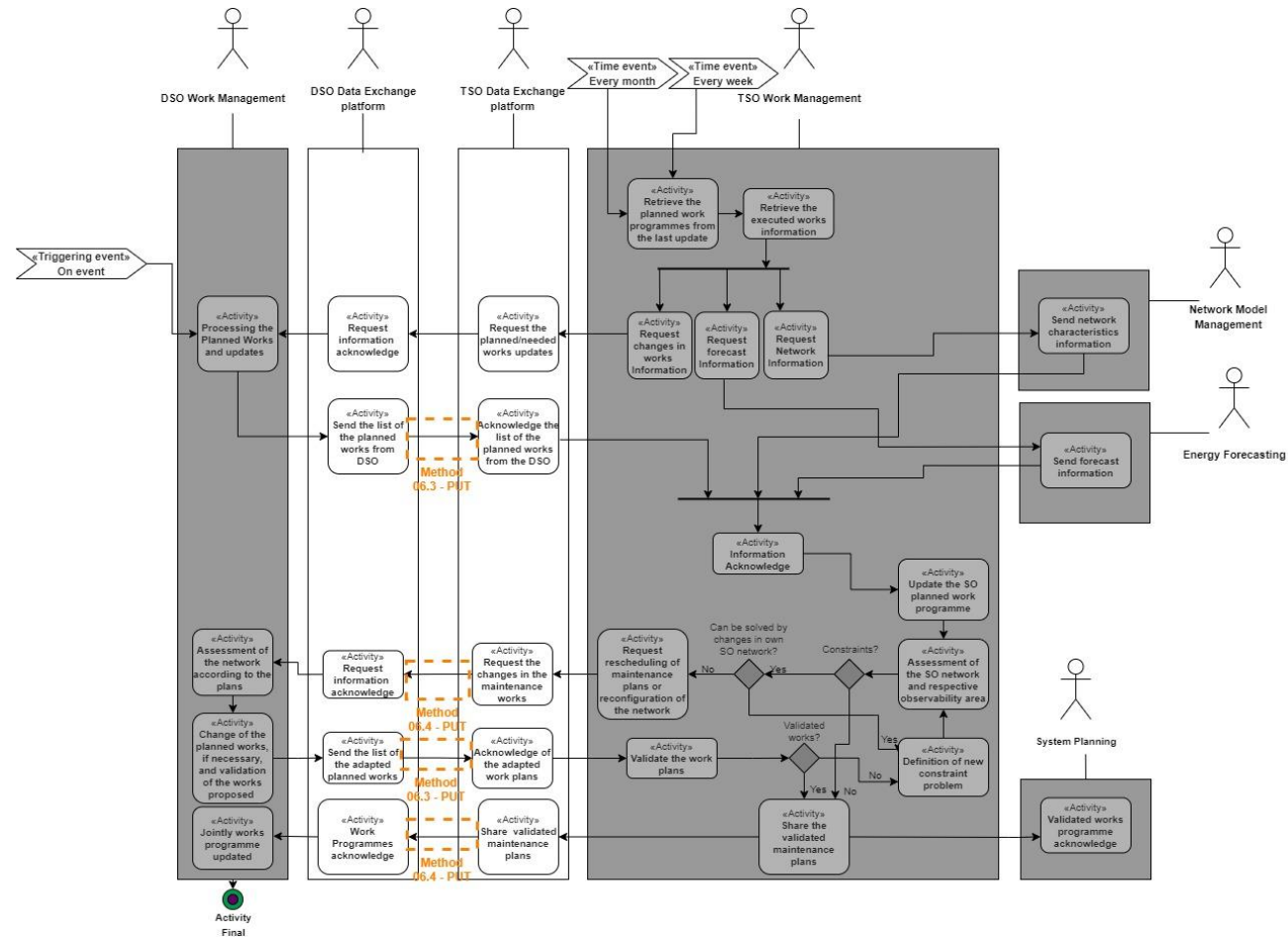


Figure 4.26 - SUC 06 scenario 2 diagram

4.2.3.2 Methods

This sub section presents the fundamental methods developed in the APIs of the TDEP and DDEP that enable the operationalization of the SUC 06 in the demonstrator. The methods that were previously presented are here unveiled for both data exchange platforms. Some snapshots from SwaggerHub are also presented to show the TDEP and DDEP API methods.

TDEP Methods

The following tables present the API methods in the TDEP that are fundamental to the SUC 06.

Table 4.11 - SUC 06 Method 06.1 summary

Method 06.1	
Description	SOs use this endpoint to send their annual maintenance programmes information that can affect the neighbour SOs, to the TDEP
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/maintenance/maintenance-anual
Method type	POST
From	DSO or TSO
To	TDEP
Condition	N/A
Trigger	Yearly (or on need)
Parameters	[Optional] Year [2023] (integer) -> which corresponds to the year to which the work programme refers to. If empty, it will assume the current year.
Request body	[Required] Xml file in the data model agreed (1.1.1.1)

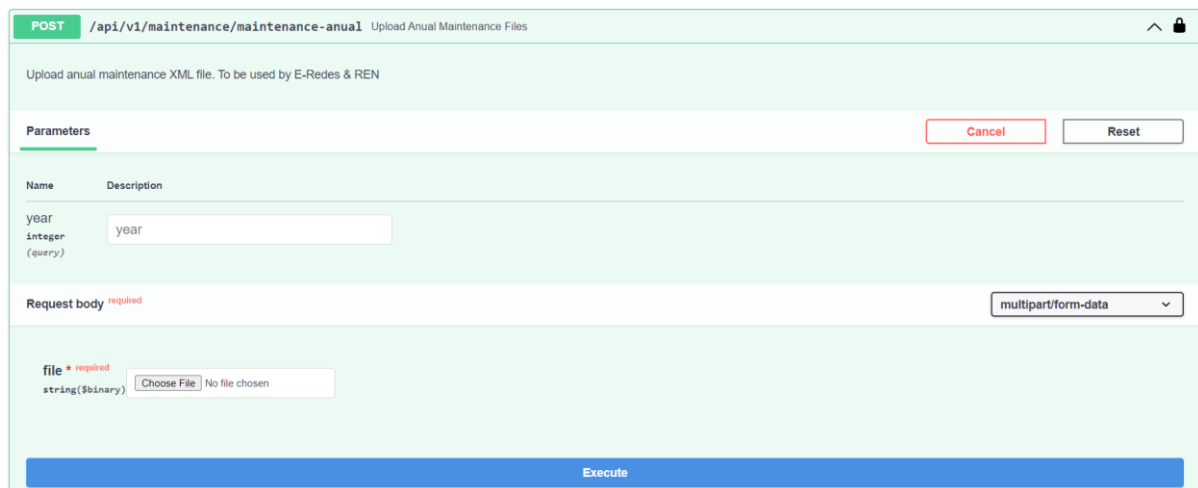


Figure 4.27 – SUC 06 Method 06.1 snapshot

Table 4.12 – SUC 06 Method 06.a summary

Method 06.a	
Description	TSO uploads the merged (TSO/DSO) annual validated maintenance plan
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/maintenance/maintenance-anual-validated
Method type	POST
From	TSO (R&D NESTER)
To	TDEP
Condition	Have the annual maintenance plans (xml files) from both TSO and DSO in the TDEP database
Trigger	Yearly (or on need)
Parameters	[Optional] Year [2023] (integer) -> which corresponds to the year to which the work programme refers to. If empty, it will assume the current year
Request body	[Required] Xml file in the data model agreed (1.1.1.1)

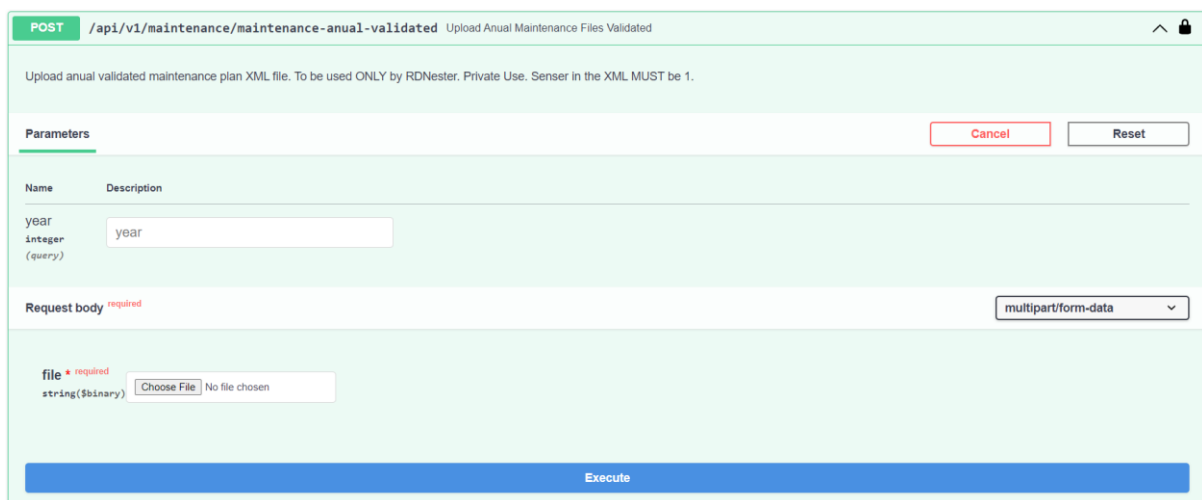


Figure 4.28 – SUC 06 Method 06.a snapshot

Table 4.13 – SUC 06 Method 06.3 summary

Method 06.3	
Description	Update or create a new work in the annual validated maintenance plan, from the TDEP side
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/maintenance/
Method type	PUT
From	DSO or TSO (R&D NESTER)
To	TDEP
Condition	Have the annual validated maintenance plans (xml file) in the TDEP database
Trigger	Yearly (or on need)

Parameters	[Optional] Year [2023] (integer) -> which corresponds to the year to which the work programme refers to. If empty, it will assume the current year [Required] sender [0] (integer) -> corresponds to the SO that is submitting the request for a change. 0 means DSO and 1 means TSO.
Request body	[Required] Xml file in the data model agreed (1.1.1.1)

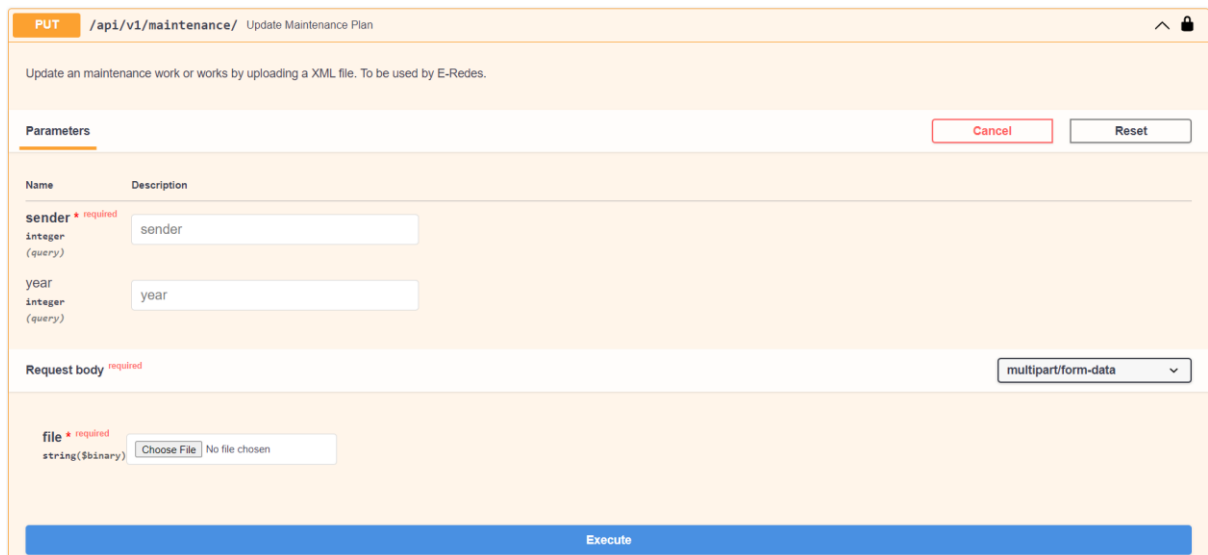


Figure 4.29 – SUC 06 Method 06.3 snapshot

DDEP Methods

The following tables present the API methods in the DDEP that are fundamental to the SUC 06.

Table 4.14 – SUC 06 Method 06.2 summary

Method 06.2	
Description	Endpoint used by the TSO to send the merged (TSO/DSO) annual validated maintenance plan to the DDEP
Request URL	https://dso-dep-dev.watt-is.com/api/v1/maintenance/maintenance-annual
Method type	POST
From	TSO (R&D NESTER)
To	DDEP
Condition	N/A
Trigger	Yearly (or on need)
Parameters	[Required] Year [2023] (integer) -> which corresponds to the year to which the work programme refers to.
Request body	[Required] Xml file in the data model agreed (1.1.1.1)

POST /api/v1/maintenance/maintenance-annual Upload Initial Annual Maintenance Plan

This endpoint receives the Annual Maintenance plans for a given year. First DSO uploads it's plan, then in a later stage the TSO send a merged version of the plan including both sides works.
NOTE: To be used by E-Redes and R&D Nester.

Parameters Cancel Reset

Name	Description
year * required integer (query)	year

Request body multipart/form-data

annual maintenance plan xml file

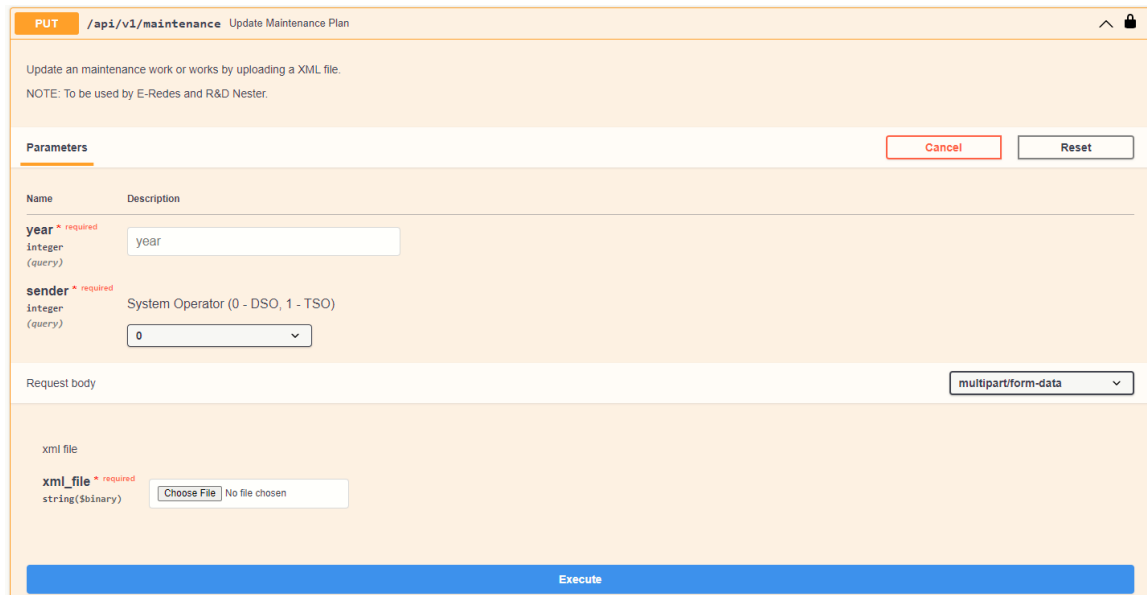
xml_file * required
string(binary) Choose File No file chosen

Execute

Figure 4.30 – SUC 06 Method 06.2 snapshot

Table 4.15 – SUC 06 Method 06.4 summary

Method 06.4	
Description	Update or create a new work in the annual validated maintenance plan, from the DDEP side.
Request URL	https://dso-dep-dev.watt-is.com/api/v1/maintenance
Method type	PUT
From	DSO or TSO (R&D NESTER)
To	DDEP
Condition	Have the annual validated maintenance plans (xml file) in the DDEP database
Trigger	Yearly (or on need)
Parameters	[Required] Year [2023] (integer) -> which corresponds to the year to which the work programme refers to. [Required] sender [0] (integer) -> corresponds to the SO that is submitting the request for a change. 0 means DSO and 1 means TSO.
Request body	[Required] Xml file in the data model agreed (1.1.1.1)



PUT /api/v1/maintenance Update Maintenance Plan

Update an maintenance work or works by uploading a XML file.
NOTE: To be used by E-Redes and R&D Nester.

Parameters Cancel Reset

Name	Description
year * required integer (query)	year
sender * required integer (query)	System Operator (0 - DSO, 1 - TSO) 0

Request body multipart/form-data

xml file

xml_file * required
string(binary) Choose File No file chosen

Execute

Figure 4.31 – SUC 06 Method 06.4 snapshot

4.2.3.3 Data Model

This sub-section presents the data model that was designed to exchange information regarding the SUC 06 demo. The data model created for the exchange of the maintenance plans relies in the information presented in the Table 4.16, that was inspired by the ENTSO-E document Outage Business process and format and in the IEC 62325 standard [12].

Table 4.16 - SUC 06 Data Model

Field	Sub-field 1	Sub-field 2	Type	Description
Revision	-	-	(int) (Required)	
Created By	-	-	(int) (Required)	0 -> DSO 1 -> TSO
Date Created	-	-	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
Valid From	-	-	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
Valid To	-	-	(str date-time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
Sender	-	-	(int) (Required)	0 -> DSO 1 -> TSO

Receiver	-	-	(int) (Required)	0 -> DSO 1 -> TSO
UniqueIDArray	UniqueID	-	(str) (Required)	
	WorkDetailsArray	Element ID	(str) (Required)	
		Owner	(int) (Optional)	0 -> DSO 1 -> TSO
		Type	(int) (Required)	1 -> Load unavailability 2 -> Production unavailability 3 -> Line unavailability 4 -> Transformer unavailability 5 -> Other
		Last-Update-By	(int) (Optional)	0 -> DSO 1 -> TSO
		Voltage Level (kV)	(int) (Required)	1 -> 400 2 -> 220 3 -> 150 4 -> 130 or 132 5 -> 60 or 63 6 -> 30 7 -> 15 8 -> 10 9 -> 6 10 -> 400/220 11 -> 400/150 12 -> 400/60 13 -> 220/150 14 -> 220/60 15 -> 220/30 OR 220/31.5 16 -> 150/130 17 -> 150/60
		Long Name	(str) (Required)	
		Case Type	(int) (Required)	1 -> Outage 2 -> Special exploration regime
		Date From	(str date) (Required)	YYYY-MM-DD
		Time From	(str) (Required)	Thh:mm:ss+hh:mm
		Date To	(str date) (Required)	YYYY-MM-DD
		Time To	(str) (Required)	Thh:mm:ss+hh:mm

		Work Period	(int) (Required)	1 -> Weekdays 2 -> Weekend 3 -> Both
		Daily Replacement	(int) (Required)	1 -> Yes 2 -> No
		Restitution Time Working Days	(str) (Required)	hhh:mm:ss
		Restitution Time Out of Working Days	(str) (Required)	hhh:mm:ss
		Cause of Request	(str) (Required)	Description of the work to do
		Special Condition	(str) (Required)	Safety conditions
		Remarks	(str) (Optional)	
		Person in Charge of the Works	(str) (Optional)	Name Name Tel:+351 XXXXXXXXXX
		Coordination Status	(int) (Required)	1 -> Request 2 -> Confirm 3 -> Reject 4 -> Under Analysis 5 -> Cancelled
		Case ID REN	(str) (Required)	
		Case ID E-Redes	(str) (Required)	
		Unavailable Capacity	(number float) (Optional)	[MW] or [MVar]
		Date of Last Change	(str date- time) (Required)	YYYY-MM-DDThh:mm:ss+mm:ss
		Remarks from Receiver	(str) (Optional)	
		Asked By	(str) (Required)	
		Authorization sender	(str) (Required)	
		Authorization receiver	(str) (Required)	

Each field can be described as:

- *Revision* corresponds to the identification of the version that distinguishes one evolution of the xml file document from another. Should be a consecutive number.

- *Created by* identifies the SO that created the file. Code 0 corresponds to DSO and 1 to TSO.
- *Date created* collects the creation day and time of the file.
- *Valid from* and *to* fields inform the file validity period of the maintenance works programmed that were submitted.
- *Sender and receiver* indicate who is submitting and receiving the maintenance work programme file. Code 0 corresponds to DSO and 1 corresponds to TSO.
- *UniqueIDArray* is the array that comprises the *UniqueID* and the *WorkDetailsArray*. The first (*UniqueID*) corresponds to a unique identifier that is used to identify unequivocally a specific work from the maintenance work programme file. It follows a set of rules in order to be unique and easy to be human readable and identifiable. The second (*WorkDetailsArray*) is the array that has all the parameters needed to characterize each of the works in the *UniqueIDArray*.
- *Element ID* corresponds to the code of the grid element that requires maintenance.
- *Owner* identifies the SO that owns the grid element under analysis. Code 0 corresponds to DSO and 1 to TSO.
- *Type* identifies the nature of the work under analysis. It is identified through a required integer that follows the next rational: 1 - Load unavailability, 2 - Production unavailability, 3 - Line unavailability, 4 - Transformer unavailability and 5 – Other.
- *Last-Update-by* is a field that identifies the latest SO that updated the work under analysis. Again, 0 corresponds to DSO and 1 to TSO.
- *Voltage Level (kV)* identifies the operation voltage of the grid element from the work under analysis. It is identified through a required integer that follows the next dictionary: 1 - 400, 2 – 220, 3 – 150, 4 - 130 or 132, 5 - 60 or 63, 6 – 30, 7 – 15, 8 – 10, 9 – 6, 10 - 400/220, 11 - 400/150, 12 - 400/60, 13 - 220/150, 14 - 220/60, 15 - 220/30 or 220/31.5, 16 - 150/130 and, lastly, 17 - 150/60.
- *Long Name* refers to the long name of the grid element that has to be provided.
- *Case Type* defines if the maintenance work under analysis is an outage (1) or a special exploration regime (2).
- *Date From/Time From and Date To/Time To* corresponds to the start and end date and time for a given scheduled maintenance work.
- *Work Period* is an integer that identifies if the maintenance work can only occur in weekdays (1) or weekends (2). If there is no scheduling restrictions in terms days of the week, *Work period* should assume the value 3.

- *Daily Replacement* indicates if the work includes daily replacement or not. If so, it should assume 1, if not, it should be 0. This field indicates if an element that is out-of-service during the day light time it is put in service at the nighttime or not.
- *Restitution Time Working Days* indicates the time required to return the network element under maintenance during weekdays, if required.
- *Restitution Time Out of Working Days* indicates the time required to return the network element under maintenance during weekends, if required.
- *Cause of request* describes the reason why the maintenance work is needed and lists what kind of work will be done.
- *Special condition* highlights any safety condition that should be considered before, during and after the maintenance work.
- *Remarks* is an optional open field where the SO can make any extra remarks.
- *Person in charge of the Works* provides information about the person responsible for the execution of the maintenance work.
- *Coordination Status (CS)* is the code that allows the TSO and DSO to be coordinated in the actual status of the work under analysis. If CS is 1 (Request), that means that one of the SOs changed a work that can affect the neighbor SO and it requires validation from him. If CS is 2 (Confirm) means that the work is validated by both SOs and can be executed in the specified conditions. If CS is 3 (Reject), means that an SO couldn't accept the conditions proposed for a certain maintenance work. If CS is 4 (Under Analysis), it means that the SO that received a request is analyzing it. Lastly, if CS is 5, it means that one SO just cancelled the scheduled maintenance work under analysis.
- *Case ID REN* is an internal TSO id used to identify the work under discussion.
- *Case ID E-REDES* is an internal DSO id used to identify the work under discussion.
- *Unavailable Capacity* indicates the unavailable capacity induced by the maintenance of the network element. This may be a generation unit, a load or a compensation means. Enter the unavailable capacity in MW for generation units/consumers and in MVar for compensation elements.
- *Date of last change* indicates the time and date of the latest change into the maintenance work details.
- *Remarks from the receiver* is an optional open field in where the SO that receives a request can make any extra remarks.
- *Asked by* identifies the person that did the request.

- *Authorization sender* identifies the person that authorizes the work execution from the sender's side.
- *Authorization receiver* identifies the person that authorizes the work execution from the receiver's side.

This data model is applied to an **xml** format file that should be submitted in the request body of **Method 06.1 – POST, Method 06.a – POST** and **Method 06.2 – POST** like it is presented in the Figure 4.27, Figure 4.28 and Figure 4.30, respectively. Below is presented an example of the xml schema message that could be submitted using the **Method 06.a – POST** (because it is already a merged validated annual maintenance works plan) with just 2 maintenance works, as example.

```
<?xml version="1.0" encoding="UTF-8"?>
<Maintenance>
  <Revision>1</Revision>
  <Created-By>1</Created-By>
  <Date-Created>2020-01-01T19:40:00+00:00</Date-Created>
  <Valid-From>2021-01-01T00:00:00+00:00</Valid-From>
  <Valid-To>2021-12-31T23:59:59+00:00</Valid-To>
  <Sender>1</Sender>
  <Receiver>0</Receiver>
  <UniqueIDArray>
    <UniqueID> MP2022-1 </UniqueID>
  <WorkDetailsArray>
    <Element-ID>1A</Element-ID>
    <Owner>0</Owner>
    <Type>3</Type>
    <Last-Update-By>0</Last-Update-By>
    <Voltage-Level>9</Voltage-Level>
    <Long-Name>LN-LV-120342</Long-Name>
    <Case-Type>1</Case-Type>
    <Date-From>2021-07-21</Date-From>
    <Date-To>2021-07-25</Date-To>
    <Time-From>2021-07-21T12:00:00+00:00</Time-From>
    <Time-To>2021-07-25T20:00:00+00:00</Time-To>
    <Work-Period>3</Work-Period>
    <Daily-Replacement>1</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> Line refurbishment to increase capacity</Cause-of-Request>
    <Special-Condition> Line disconnected, isolated and blocked, and earthed at the en
ds </Special-Condition>
    <Remarks>Nothing to declare</Remarks>
    <Person-in-Charge>John Doe TEL:+351XXXXXXXXXX</Person-in-Charge>
    <Coordination-Status>2</Coordination-Status>
    <Case-ID-REN>1A-12312</Case-ID-REN>
    <Case-ID-E-REDES>1A-AE12333</Case-ID-E-REDES>
    <Unavailable-Capacity>0.00125</Unavailable-Capacity>
    <Date-of-Last-Change>2020-01-01T19:40:00+00:00</Date-of-Last-Change>
    <Remarks-from-Receiver>Nothing to declare</Remarks-from-Receiver>
    <Asked-by> John Doe 2 TEL:+351XXXXXXXXXX </Asked-by>
    <Authorization-Sender> John Doe 3 TEL:+351XXXXXXXXXX </Authorization-Sender>
```

```

    <Authorization-Receiver> John Doe 4 TEL:+351XXXXXXXXX </Authorization-Receiver>
  </WorkDetailsArray>
</UniqueIDArray>
<UniqueIDArray>
  <UniqueID> MP2022-1 </UniqueID>
  <WorkDetailsArray>
    <Element-ID>1B</Element-ID>
    <Owner>1</Owner>
    <Type>3</Type>
    <Last-Update-By>1</Last-Update-By>
    <Voltage-Level>2</Voltage-Level>
    <Long-Name>LN-HV-3252</Long-Name>
    <Case-Type>1</Case-Type>
    <Date-From>2021-08-11</Date-From>
    <Date-To>2021-08-15</Date-To>
    <Time-From>2021-08-11T12:00:00+00:00</Time-From>
    <Time-To>2021-08-15T20:00:00+00:00</Time-To>
    <Work-Period>3</Work-Period>
    <Daily-Replacement>1</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> Line refurbishment to increase capacity</Cause-of-Request>
    <Special-Condition> Line disconnected, isolated and blocked, and earthed at the en
ds </Special-Condition>
    <Remarks>Nothing to declare</Remarks>
    <Person-in-Charge>John Doe TEL:+351XXXXXXXXX</Person-in-Charge>
    <Coordination-Status>2</Coordination-Status>
    <Case-ID-REN>1B-312</Case-ID-REN>
    <Case-ID-E-REDES>1B-TS33</Case-ID-E-REDES>
    <Unavailable-Capacity>1.125</Unavailable-Capacity>
    <Date-of-Last-Change>2020-01-01T19:40:00+00:00</Date-of-Last-Change>
    <Remarks-from-Receiver>Nothing to declare</Remarks-from-Receiver>
    <Asked-by> John Doe 2 TEL:+351XXXXXXXXX </Asked-by>
    <Authorization-Sender> John Doe 3 TEL:+351XXXXXXXXX </Authorization-Sender>
    <Authorization-Receiver> John Doe 4 TEL:+351XXXXXXXXX </Authorization-Receiver>
  </WorkDetailsArray>
</UniqueIDArray>
</Maintenance>

```

The **Method 06.3 – PUT** uses just a set of the data model presented previously, being required only the *Unique ID Array* schema fields. It is also applied to an **xml** format file that should be submitted in the request body of **Method 06.3 – PUT** like it is presented in the Figure 4.29. Below is presented an example of the xml schema message that could be submitted for the **Method 06.3 – PUT** in which the DSO is requesting to change the date of a work that was already validated in the annual maintenance work programme (check example above).

```

<Maintenance>
  <UniqueIDArray>
    <UniqueID> MP2022-1 </UniqueID>
  <WorkDetailsArray>
    <Element-ID>1A</Element-ID>
    <Owner>0</Owner>
    <Type>3</Type>

```

```

<Last-Update-By>0</Last-Update-By>
<Voltage-Level>9</Voltage-Level>
<Long-Name>LN-LV-120342</Long-Name>
<Case-Type>1</Case-Type>
<Date-From>2021-07-26</Date-From>
<Date-To>2021-07-30</Date-To>
<Time-From>2021-07-26T12:00:00+00:00</Time-From>
<Time-To>2021-07-30T20:00:00+00:00</Time-To>
<Work-Period>3</Work-Period>
<Daily-Replacement>1</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-Days>
s>
<Cause-of-Request> Line refurbishment to increase capacity</Cause-of-Request>
<Special-Condition> Line disconnected, isolated and blocked, and earthed at the end
ds </Special-Condition>
<Remarks>Nothing to declare</Remarks>
<Person-in-Charge>John Doe TEL:+351XXXXXXXXXX</Person-in-Charge>
<Coordination-Status>1</Coordination-Status>
<Case-ID-REN>1A-12312</Case-ID-REN>
<Case-ID-E-REDES>1A-AE12333</Case-ID-E-REDES>
<Unavailable-Capacity>0.00125</Unavailable-Capacity>
<Date-of-Last-Change>2021-05-01T15:40:00+00:00</Date-of-Last-Change>
<Remarks-from-Receiver>Nothing to declare</Remarks-from-Receiver>
<Asked-by> John Doe 2 TEL:+351XXXXXXXXXX </Asked-by>
<Authorization-Sender> John Doe 3 TEL:+351XXXXXXXXXX </Authorization-Sender>
<Authorization-Receiver> John Doe 4 TEL:+351XXXXXXXXXX </Authorization-Receiver>
</WorkDetailsArray>
</UniqueIDArray>
</Maintenance>

```

It is possible to see the changes in the *Coordination Status* (passed from 2- Confirm to 1- Request) that announces that a request was made, and also the updates in the *Date From/Time From* and *Date To/Time*, with the new purposed schedule for the work, and in the *Date of Last Change*.

4.2.3.4 TDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the TDEP API for the different scenarios of the SUC 06. The focus is on the information flow between the client, the server and the database. The methods presented before are here represented as well as some others auxiliary methods.

For the Scenario 1 (Year-ahead works programming) the processes in relation to the TDEP are presented in the Figure 4.32.

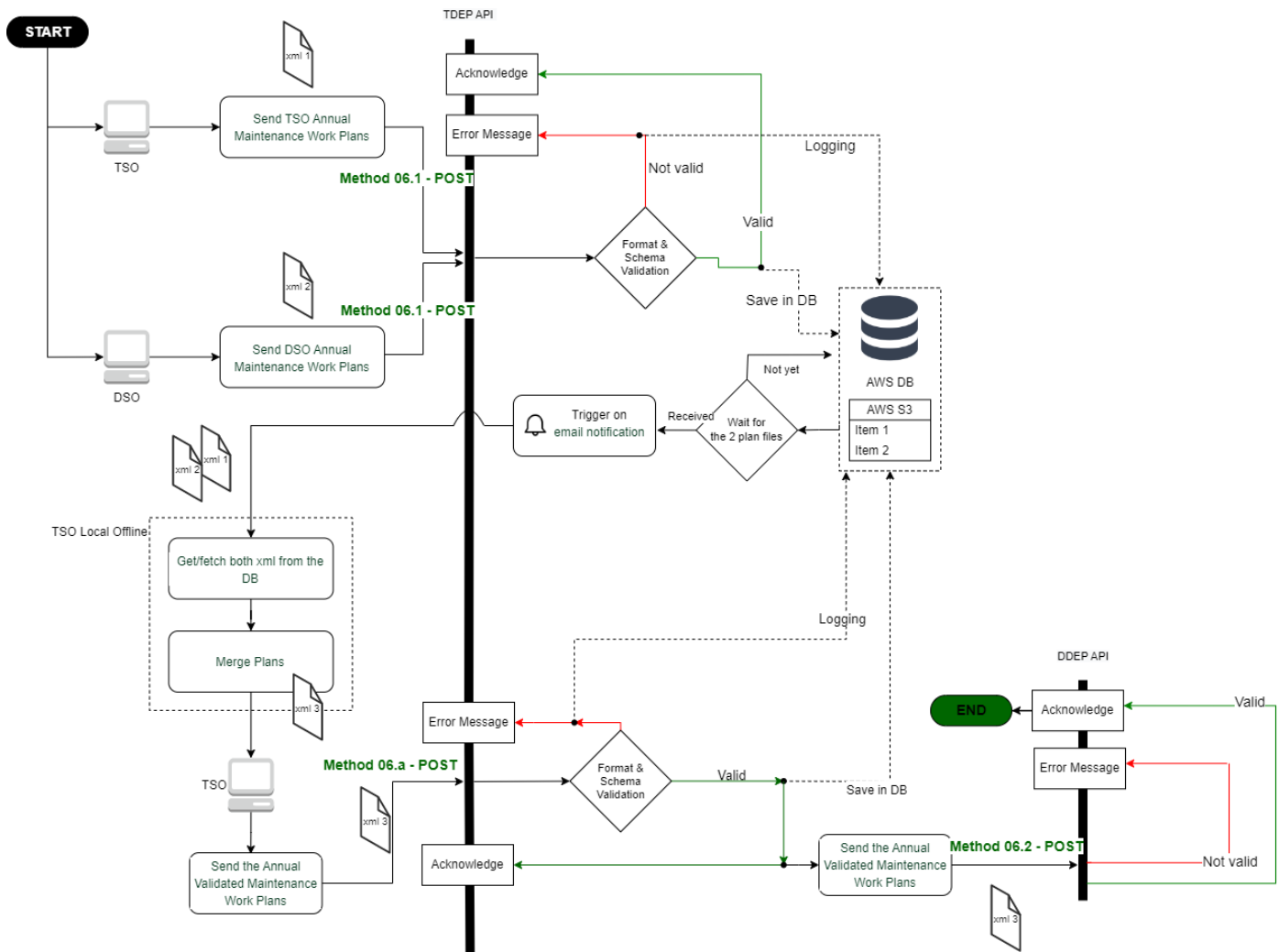


Figure 4.32 - SUC 06 Scenario 1 flowchart (TDEP)

This scenario starts with the submission by both System Operators (SOs) of their annual maintenance work plans to the TDEP API. For that, they need to use the **Method 06.1 - POST**. The AWS environment will be constantly checking for the reception of both annual plans and when they are received and stored in the database, the TSO (played by R&D NESTER) receives a notification informing that both plans were received. That allows the TSO to use some GET methods created in the TDEP to fetch the information stored in the AWS DB. The offline analysis of both plans is done in order to optimize them and create a merged maintenance plan. At this stage, the merged maintenance plan is built upon the tentative of optimization of the works scheduled that can affect the same assets, trying then to shorten the outage time of them by doing simultaneous maintenance works, when possible.

The annual validated maintenance work plan (merged maintenance plan) is sent to the TDEP API by the TSO (represented by R&D NESTER) using the **Method 06.a – POST**. The xml file submitted is stored in the AWS S3 bucket and automatically submitted to the DDEP API through the **Method 06.2 - POST**.

All these processes are already implemented in the TDEP API, only missing the integration with the GUIs.

For the Scenario 2 (Monthly-ahead, Weekly-ahead or on event update of maintenance plans) the processes in relation to the TDEP are presented in the Figure 4.33.

This process can start in two ways: when a new work is created/a work needs to be updated (on event/updates) or when the weekly assessment (month/week ahead assessment) takes place.

For the first case, the TSO or DSO should use the **Method 06.3 - PUT** to request the addition of a new work or to update an existing work from the annual validated merged work programme. Upon receiving these requests, the TDEP API saves them in the data base and checks the *Coordination Status* field in order to assess if it is a new request or an interaction that has already started and confirmed/cancelled (CS=2/5). If the *Coordination Status* is equal to 2, it means that the work under analysis is approved and validated, and for that reason, the process ends with the storing of the information in the data base. If the *Coordination Status* is equal to 5, it means that the work was cancelled, and for that reason, the process ends with the storing of the information in the data base. If it's not one of the previous CS, it means that is a request that still needs validation and for that reason the process should continue until it is accepted. In that case, the TSO receives a notification informing that a new change in the maintenance works has occurred.

In the offline environment from the TSO (represented by R&D NESTER) the requested change in the works is processed/validated and results in an update of the work details accordingly. To submit that information to the API the **Method 06.3 - PUT** is used. Once this method is called and the update is saved in the database, it automatically sends the result from the validation of the work to the DDEP API (**Method 06.4 - PUT**). There the updated maintenance plan is analysed and can result in the end of the process if everything was accepted or in the restart of all the process if some change is needed in the works.

All these processes are already implemented in the TDEP API, only missing the GUIs.

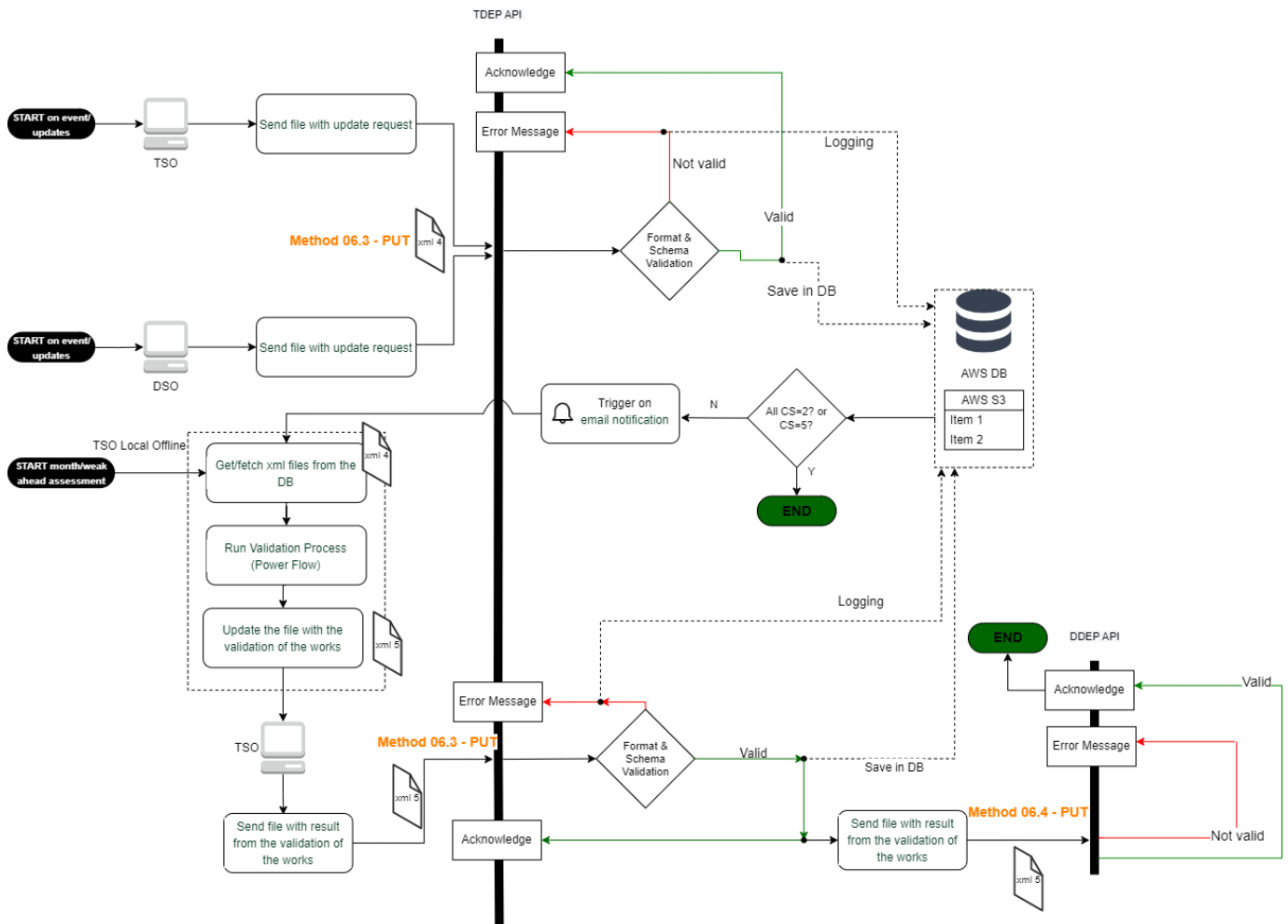


Figure 4.33 - SUC 06 Scenario 2 flowchart (TDEP)

4.2.3.5 DDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the DDEP API for the different scenarios of the SUC 06. The focus is on the information flow between the client, the server and the database. The methods presented before are here represented as well as some others auxiliary methods.

For the Scenario 1 (Year-ahead works programming) the processes in relation to the DDEP are presented in the Figure 4.34.

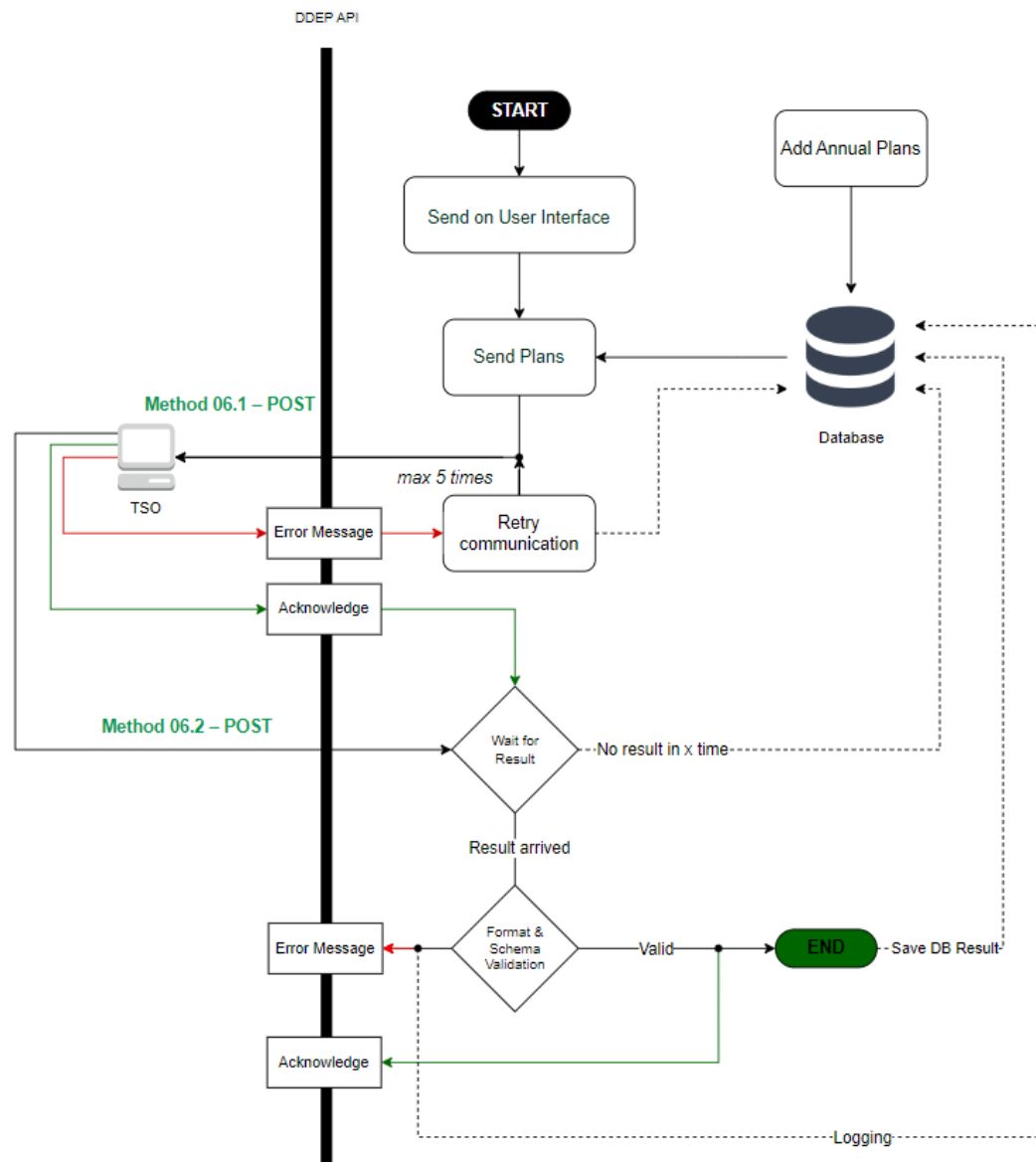


Figure 4.34 - SUC 06 Scenario 1 flowchart (DDEP)

This process starts with the submission by both SOs of their annual maintenance work plans to the TDEP API, through the **Method 06.1 - POST**. Afterwards, a submission request for a prequalification is sent by the TSO via the **Method 06.2 - POST**. This communication shall have a retry communication police, that will log the error into the database in case of failure or wait for a result in case of feedback from the TSO of message received. If no result arrives from the TSO in a determined period of time, the process should terminate, and a log message of this error should be stored. If, on the other hand, a message arrives in the defined time it needs to be validated

in format and schema and either log an error in case of failure or store the response in case of a correct validation.

For the Scenario 2 (Monthly-ahead, Weekly-ahead or on event update of maintenance plans) the processes in relation to the DDEP are presented in the Figure 4.35.

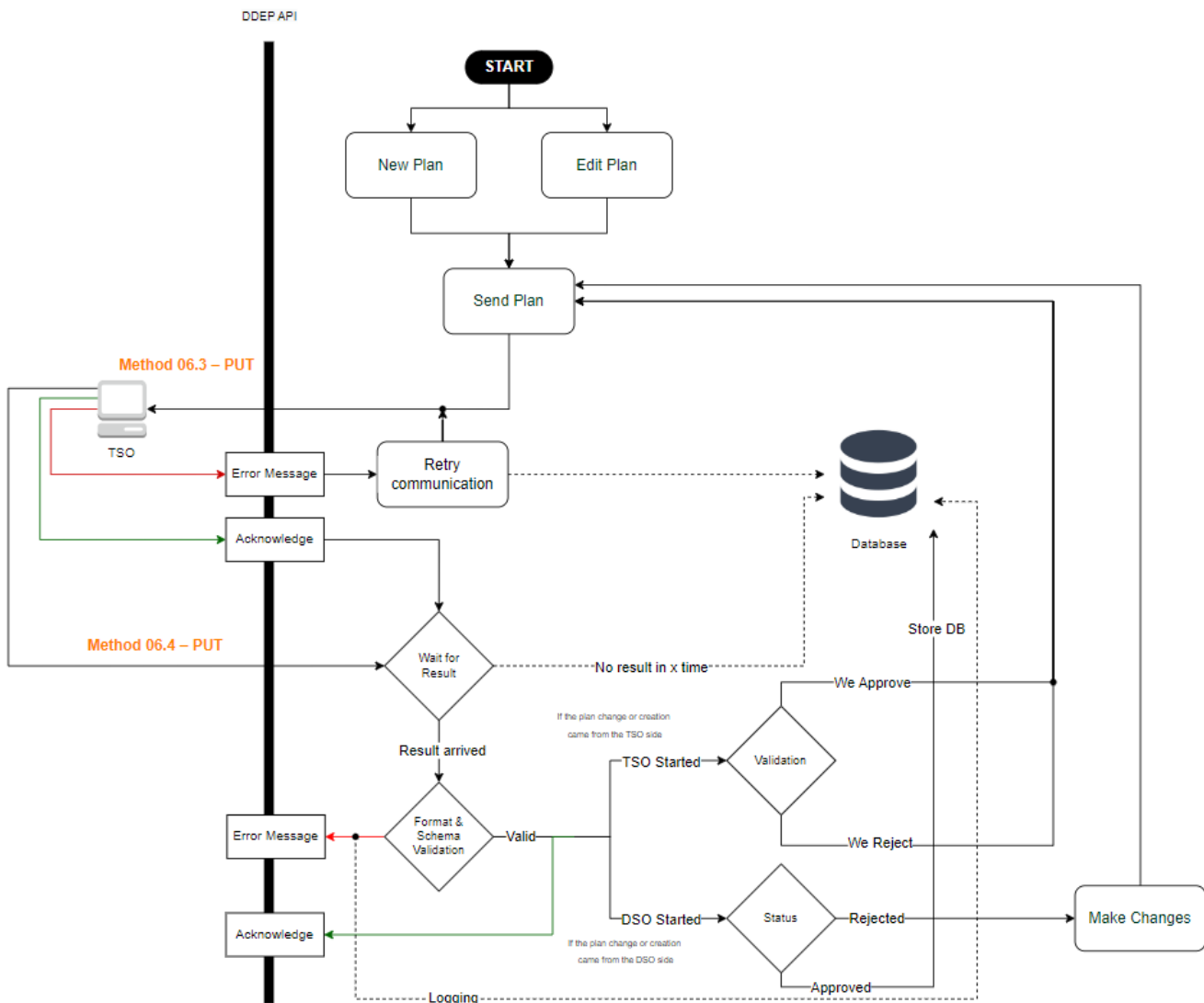


Figure 4.35 - SUC 06 Scenario 2 flowchart (DDEP)

Similarly to the correspondent TDEP processes, this one can start in two different ways, when a new plan is created or when an update is done. In either case the TSO needs to be notified of the changes, so a message is sent through the **Method 06.3 - PUT** with a retry policy in case of failure. As a message is expected in return, the system shall wait the allocated time for a response and store an error message if no answer arrives. When

a message is sent back (**Method 06.4 - PUT**) the necessary format and schema validation is performed, with the following procedures depending on whether the plan was sent/changed by the TSO or by DSO.

For the first case, a validation needs to be performed on the user interface, and when accomplished, the result needs to be sent back to the TSO. For the second, there are two possibilities, if the plan is approved it needs to be stored in the database, but if it came out rejected, the necessary changes need to be performed in the user interface with later communication of this information to the TSO.

4.2.4 SUC 07 - Consumption and generation forecast information exchange

The goal of this SUC is the exchange of forecast of consumption and generation aggregated in the interface TSO/DSO nodes. The forecasts of both consumption and generation are disaggregated by type. For generation, such types refer to technologies such as Solar, Wind, Hydro, CHP, among others, while for consumption such types are the consumers such as residential, industrial, and others. The forecasts are exchanged between operators every 24 hours on a day-ahead basis taking into consideration the market clearance results. The data shall include the forecast for the next 72 hours with a granularity of 15 minutes.

4.2.4.1 Scenarios

There is only one scenario for the SUC 07. On it, each party will generate their respective generation and consumption forecast at a convenient time after the market clearance results arrive. As seen in Figure 4.36, from the TSO side, the obtained files are posted on the TDEP using **Method 07.a – POST**¹². On the other hand, the DSO will use an internal **Method 07.b – POST** to publish the files on the DDEP that will then post those on the TDEP by using the **Method 07.1 – POST**. After both files are received, the TSO will compute the corresponding KPIs, which action is described later in the TDEP processes section.

¹² When the confidentiality of REN data is required, the TDEP is not used for exchanging REN data with R&D NESTER, instead, the data exchange is done locally without resorting to Ethernet.

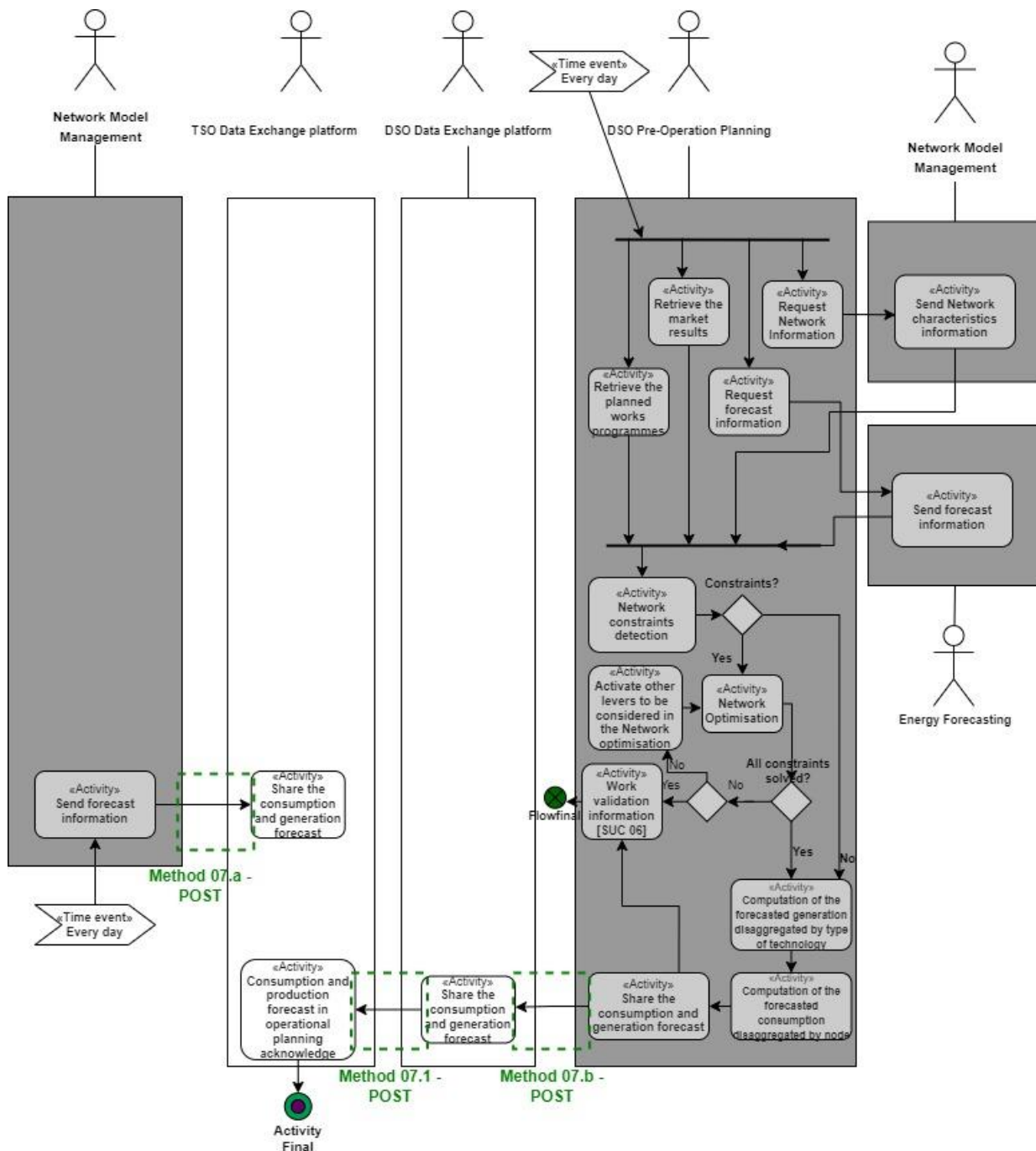


Figure 4.36 - SUC07 diagram

4.2.4.2 Methods

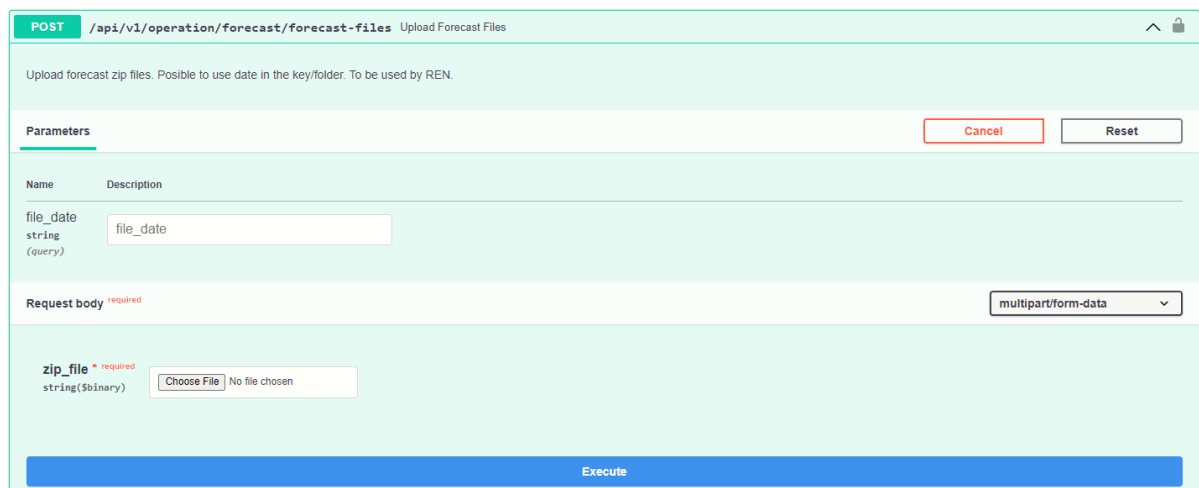
The SUC 07 requires three methods, two of them are located in the TDEP and the remaining one is located in the DDEP. Those are detailed from Table 4.17 to Table 4.19 with a corresponding back-end UI seen from Figure 4.37 to Figure 4.39.

TDEP Methods

The following tables present the API methods in the TDEP that are fundamental to the SUC 07.

Table 4.17 – Method 07.a details

Method 07.a	
Description	TSO provides consumption and generation forecast for the next 3 days.
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/ operation/forecast/forecast-files
Method type	POST
From	TSO (REN)
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Optional] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed. If empty, it will assume the date of submission
Request body	[Required] Zip file with 2 simulation files in .txt and .xlsx format.



POST /api/v1/operation/forecast/forecast-files Upload Forecast Files

Upload forecast zip files. Possible to use date in the key/folder. To be used by REN.

Parameters Cancel Reset

Name	Description
file_date string (query)	file_date

Request body required multipart/form-data

zip_file required
string(binary) Choose File No file chosen

Execute

Figure 4.37 - Method 07.a snapshot

Table 4.18 - Method 07.1 details

Method 07.1	
Description	DSO provides consumption and generation forecast for the next 3 days.
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/ operation/forecast/
Method type	POST
From	DSO
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Optional] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed. If empty, it will assume the date of submission
Request body	[Required] Xml file that follows the structure presented in the data model.

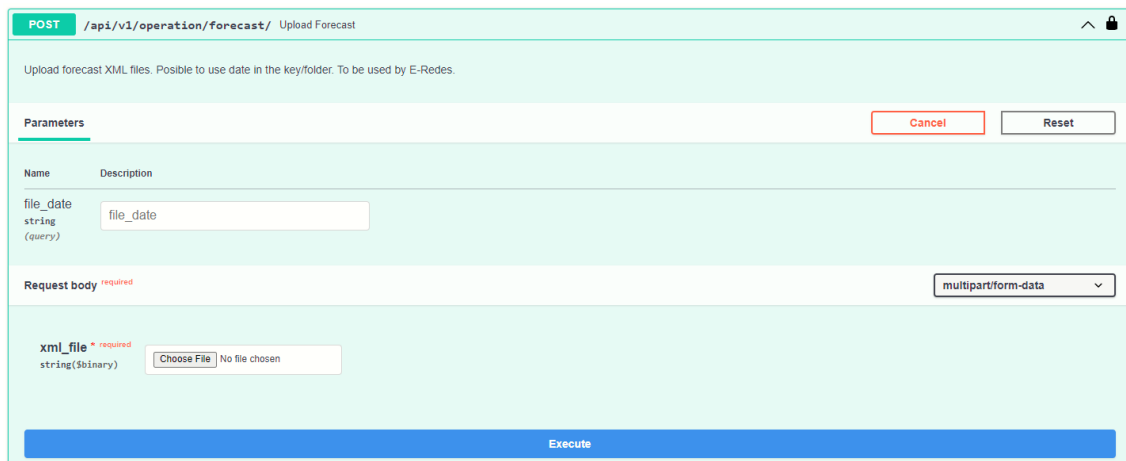


Figure 4.38 - Method 07.1 snapshot

DDEP Methods

The following tables present the API methods in the DDEP that are fundamental to the SUC 07.

Table 4.19 - Method 07.b details

Method 07.b	
Description	Endpoint that enables the submission of Forecast files to the DDEP
Request URL	https://dso-dep-dev.watt-is.com/api/ v1/operation/forecast
Method type	POST
From	DSO
To	DDEP
Condition	N/A
Trigger	Every day (on-schedule)

Parameters	[Required] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed.
Request body	[Required] Xml file that follows the structure presented in the data model.

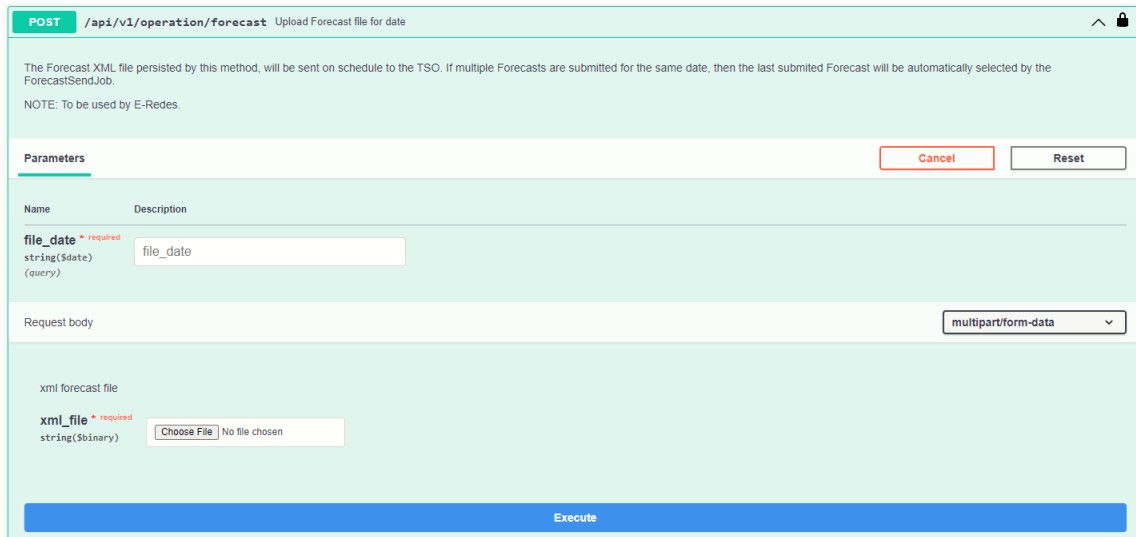


Figure 4.39 - Method 07.b snapshot

4.2.4.3 Data Model

The data model here presented corresponds to the structure to be followed by the DSO while submitting their forecast to the TSO by using **Method 07.1 – POST** and **Method 07.b – POST**.

Table 4.20 - SUC-07 Data Model content

Field	Sub-field 1	Sub-field 2	Sub-field 3	Type	Description
Time of creation	-	-	-	(str date-time) (Required)	
Start time of data	-	-	-	(str date-time) (Required)	
End time of data	-	-	-	(str date-time) (Required)	
Start Time Array	Start Time (of Forecast)	-	-	(str date-time) (Required)	
	Bus ID Array	BusID	-	(str) (Required)	
		Generation Load Array	Generation/load type	(int) (Required)	1 -> Wind 2 -> Solar (PV) 3 -> Hydro 4->Pump Storage

					5 -> Thermal 6 -> Others 7 -> Load P 8 -> Load Q
			Forecasted Value	(number float) (Required)	
			SI-Prefix	(str) (Required)	Table A.5 – Multiplier IEC 61850-7-3

Each field can be described as:

- *Time-of-creation* is the moment when the file was generated.
- *Start-time-of-data* indicates the starting time of the forecast.
- *End-time-of-data* indicates the ending time of the forecast.
- *Start-time-array* is the collection of all the 15-minute intervals that compose the forecast file. Each component of the array contains all the buses for which the forecasts are made.

- *Bus-ID-Array* is the collection of all the buses for which the forecasts are made. Each bus contains all the available types of generation or load that are present at that given bus.

Each type of generation or load is composed of the following three fields:

- *Generation-Load-Type* according to the enumeration provided.
- *Forecasted-Value* is the actual value being predicted, the unit is Watts (W) for default except when *Generation-Load-Type* is labelled as 8 (Reactive Load), which is considered Reactive Volt-amperes (VAR).
- *SI-Prefix* is the exponent of the number 10 in scientific notation context.

The size of the actual file is considerably big given that 288 15-minute time intervals are being considered and each of those contain all the buses available. In addition, each bus contains load P and Q and/or generation from any of the available technology types. In that context and for illustration purposes, the example here presented of the xml file content is only for one 15-minute time interval with two buses. From the available generation/load types, one of the buses contains 3 types while the other bus contains 5 types.

```
<?xml version="1.0" encoding="UTF-8"?>
<Consumption>
  <Time-of-creation>2022-12-08T14:57:50+01:00</Time-of-creation>
  <Start-time-of-data>2022-12-09T00:00:00+01:00</Start-time-of-data>
  <End-time-of-data>2022-12-09T00:15:00+01:00</End-time-of-data>
  <START-TIME-ARRAY>
    <Start-Time-of-Forecast>2022-12-09T00:00:00+01:00</Start-Time-of-Forecast>
    <BUS-ID-ARRAY>
      <BusID>M0_SACT_60kV_B673</BusID>
      <GENERATION-LOAD-ARRAY>
```

```

        <Generation-Load-Type>1</Generation-Load-Type>
        <Forecasted-Value>23525</Forecasted-Value>
        <SI-Prefix>6</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>2</Generation-Load-Type>
        <Forecasted-Value>0.6</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>3</Generation-Load-Type>
        <Forecasted-Value>654654</Forecasted-Value>
        <SI-Prefix></SI-Prefix>
    </GENERATION-LOAD-ARRAY>
</BUS-ID-ARRAY>
<BUS-ID-ARRAY>
    <BusID>M0_SAM_60kV_B611</BusID>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>1</Generation-Load-Type>
        <Forecasted-Value>2</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>2</Generation-Load-Type>
        <Forecasted-Value>5</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>4</Generation-Load-Type>
        <Forecasted-Value>0.1</Forecasted-Value>
        <SI-Prefix>3</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>7</Generation-Load-Type>
        <Forecasted-Value>12</Forecasted-Value>
        <SI-Prefix>6</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
    <GENERATION-LOAD-ARRAY>
        <Generation-Load-Type>8</Generation-Load-Type>
        <Forecasted-Value>2</Forecasted-Value>
        <SI-Prefix>6</SI-Prefix>
    </GENERATION-LOAD-ARRAY>
</BUS-ID-ARRAY>
</START-TIME-ARRAY>
</Consumption>

```

4.2.4.4 TDEP processes

Figure 4.40 presents the processes related to the TDEP, which starts daily and on schedule. It is expected to receive the files coming from both the TSO and the DSO on the TDEP by using **Method 07 a – POST** and **Method 07.1 – POST**, respectively. When those methods are used, the online platform validates the type and the format of the submitted files. A successful validation allows the files to be stored on the DB. When both submissions from the two operators are successfully completed, an email notification for the TSO is generated.

At this point, the TSO is able to fetch to local premises the files stored in the DB by using a dedicated GET method through the TDEP. The calculation of the corresponding KPIs is done offline.

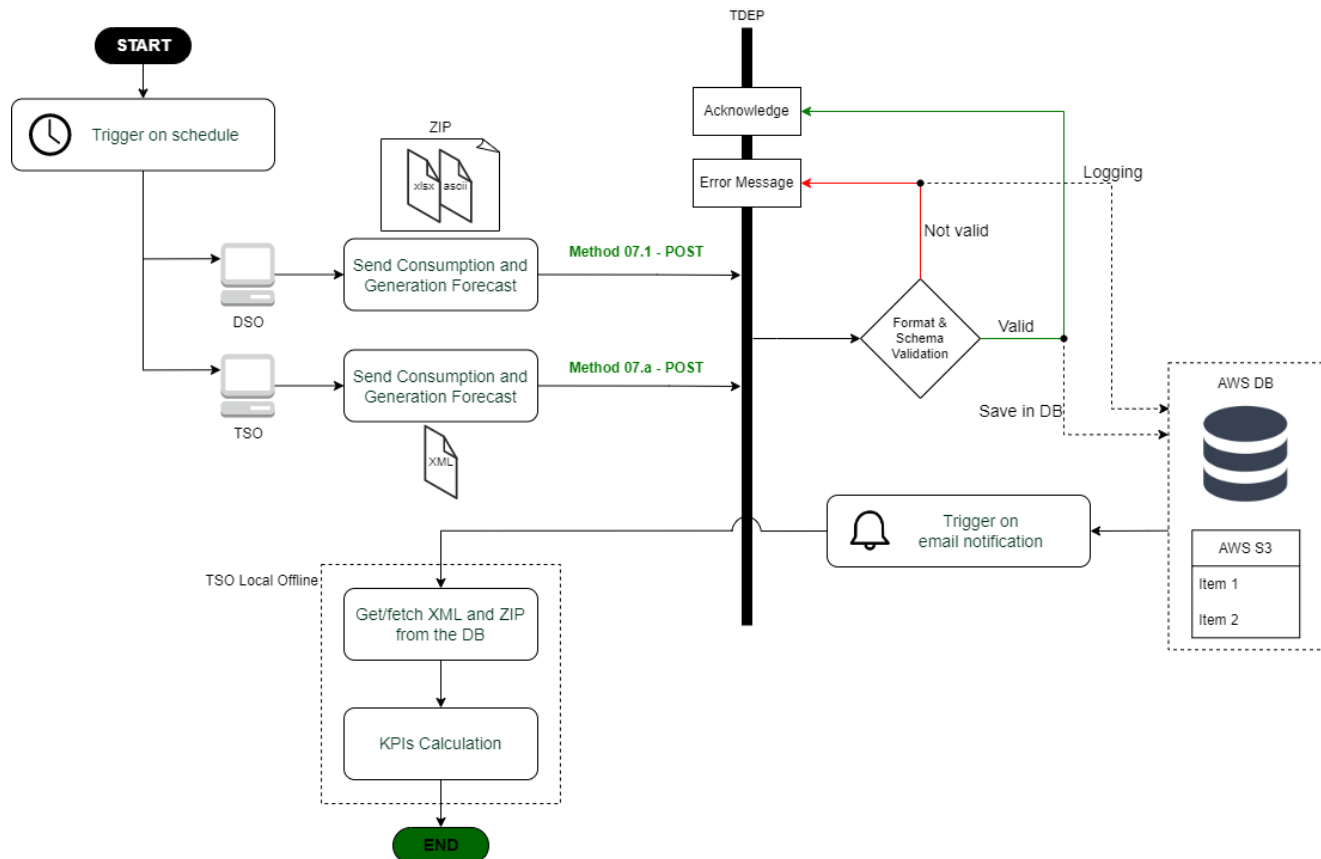


Figure 4.40 – SUC 07 flowchart (TDEP)

4.2.4.5 DDEP processes

Figure 4.41 presents the processes related to the DDEP. This process starts with a daily scheduled trigger that aims to send to the transmission operator the forecasted generation and consumption for the next 72h (**Method 07.1 - POST**). This information will be daily sent to the DDEP database through the internal **Method 07.b - POST**. The communication to the TDEP is done with a retry police in order to ensure the message is sent without errors.

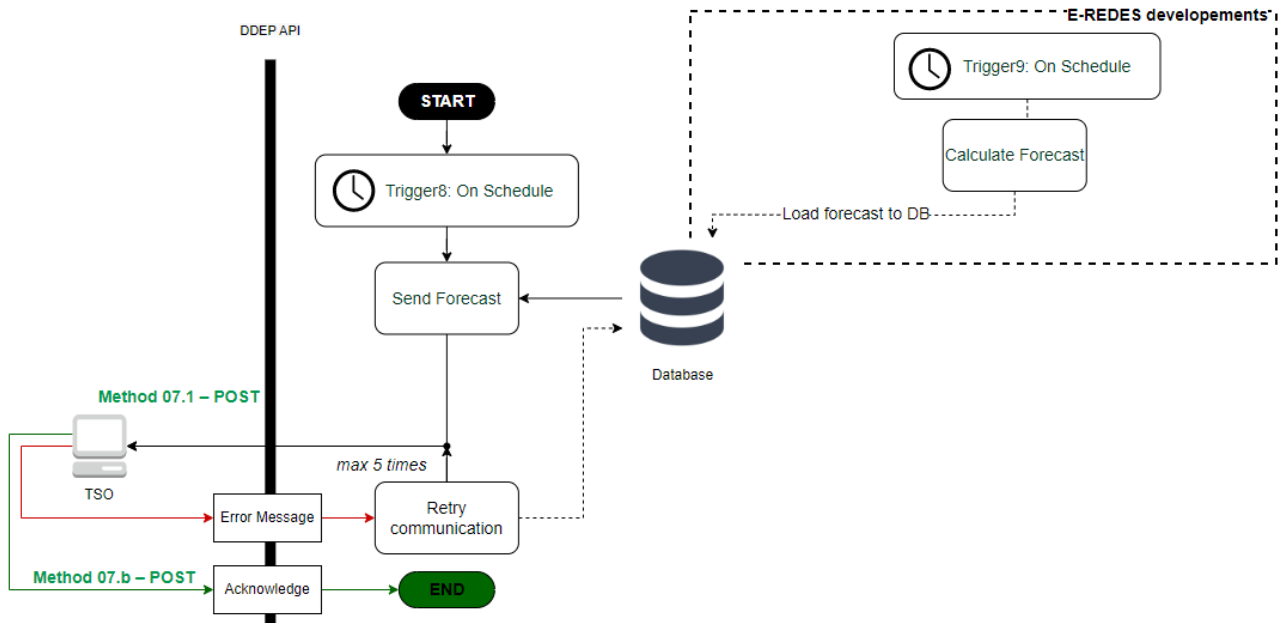


Figure 4.41 - SUC 07 flowchart (DDEP)

4.2.5 SUC 08 - Short-circuit levels information exchange

In this use case the data exchanged between TSO and DSO relates to short-circuit currents in the TSO-DSO interface. This SUC supports the coordination between DSO and TSO so that they can more accurately forecast the short-circuit currents by calculating the contributions from TSO extra high voltage and high voltage network and DSO high voltage network. This coordination is needed to prevent inaccurate forecasts that can lead to the selection of circuit breakers of less power than necessary and the occurrence of short circuits on existing circuit breakers. This coordination process takes place every day and involves the calculation of short circuit currents for the day ahead.

In this SUC, the steps that system operators should go through in order to identify the short circuit currents are described. In the end, these currents are shared for TSO-DSO interfaces buses among involved system operators. In this SUC, the information exchange will occur through the TDEP and DDEP.

4.2.5.1 Scenarios

The different scenarios in this SUC are divided according to which system operator submits the forecasted short-circuit currents to the data exchange platforms.

4.2.5.1.1 Scenario 1 - Short-circuit current definition at bay level considering TSO information

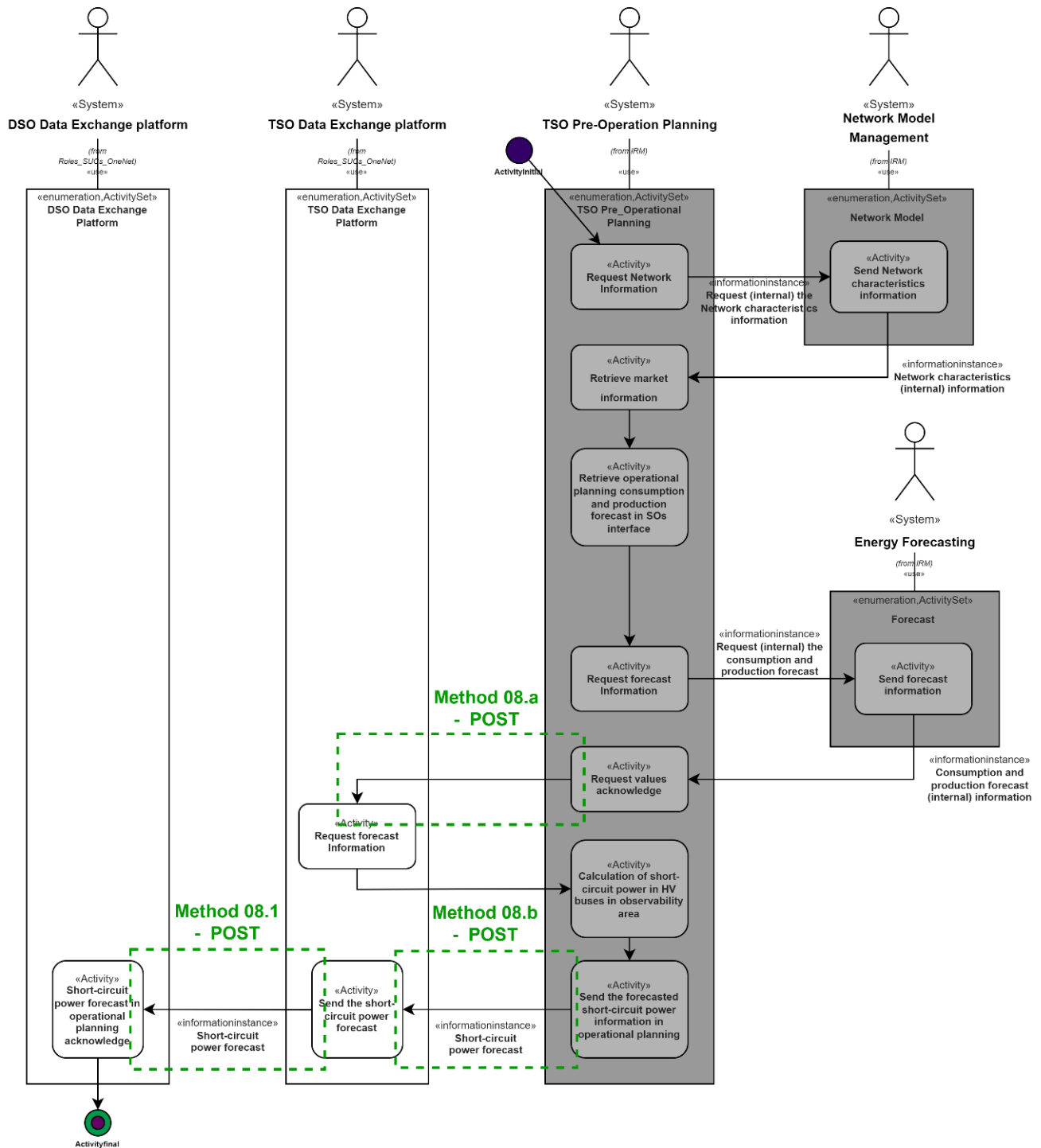


Figure 4.42 - SUC 08 Scenario 1 diagram

In this scenario, the TSO shares its short-circuit currents in the TSO-DSO interface buses with the DSO. For this purpose, an endpoint (**Method 08.1 – POST**) is created in the DDEP so that it can receive the day-ahead information about the short-circuit currents from the TSO from EHV network and HV consumers, connected directly to TSO. In the Portuguese demonstrator, R&D NESTER will be responsible for all TSO activities, taking advantage of the real data provided by REN (Portuguese TSO). For that reason, for SUC 08 two endpoints were created in TDEP for the provision of the data between REN and R&D NESTER (**Method 08.a – POST¹³** and **Method 08.b – POST**).

4.2.5.1.2 Scenario 2 - Short-circuit current definition at bay level considering TSO information

In this scenario, the DSO shares its short-circuit currents in the TSO-DSO interface buses with the TSO. For this purpose, an endpoint (**Method 08.2 – PUT**) is created in the TDEP so that it can receive the updated version of the file that was sent by **Method 08.1 – POST** with additional information from the DSO side.

¹³ When the confidentiality of REN data is required, the TDEP is not used for exchanging REN data with R&D NESTER, instead, the data exchange is done locally without resorting to Ethernet

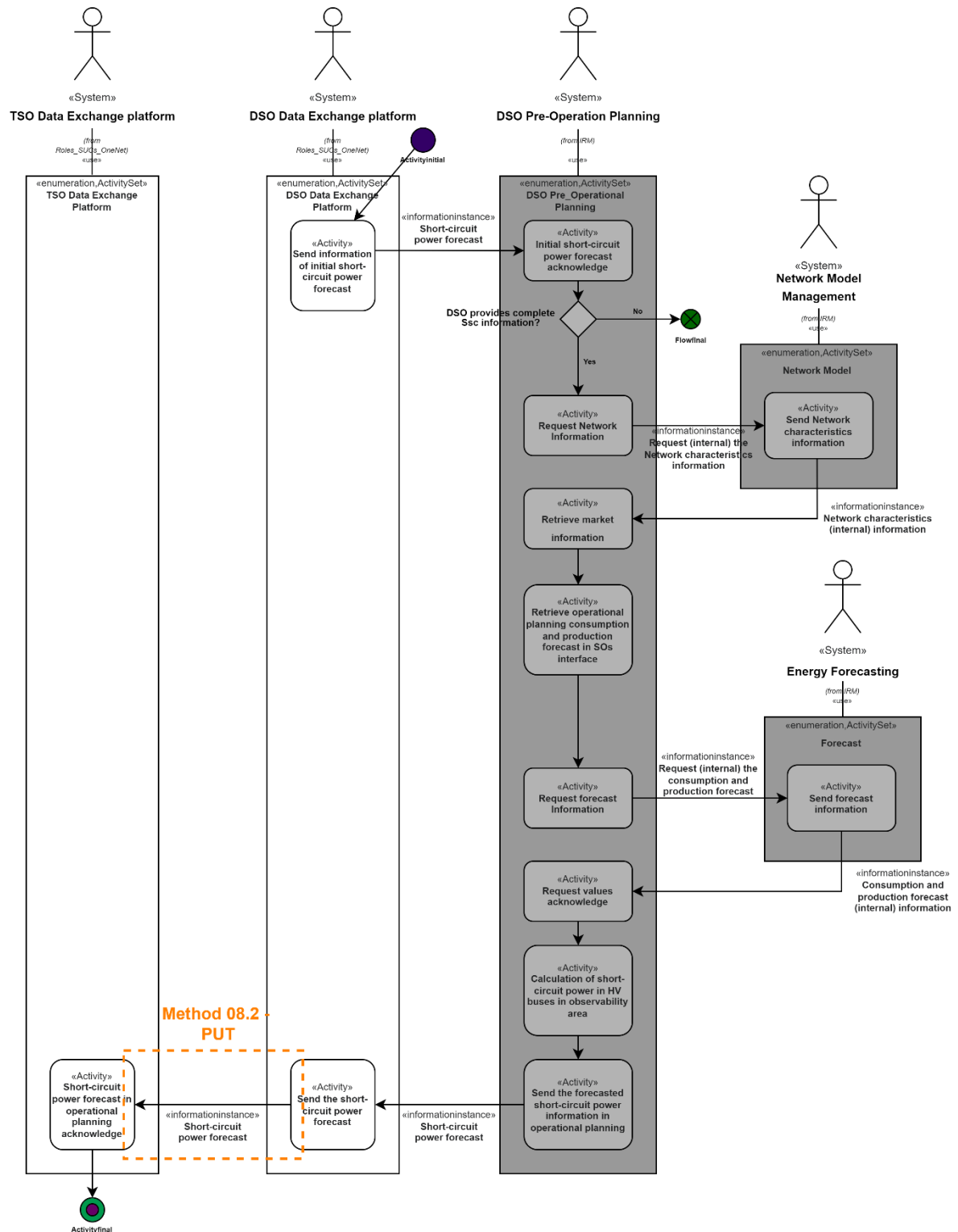


Figure 4.43 - SUC 08 Scenario 2 diagram

4.2.5.2 Methods

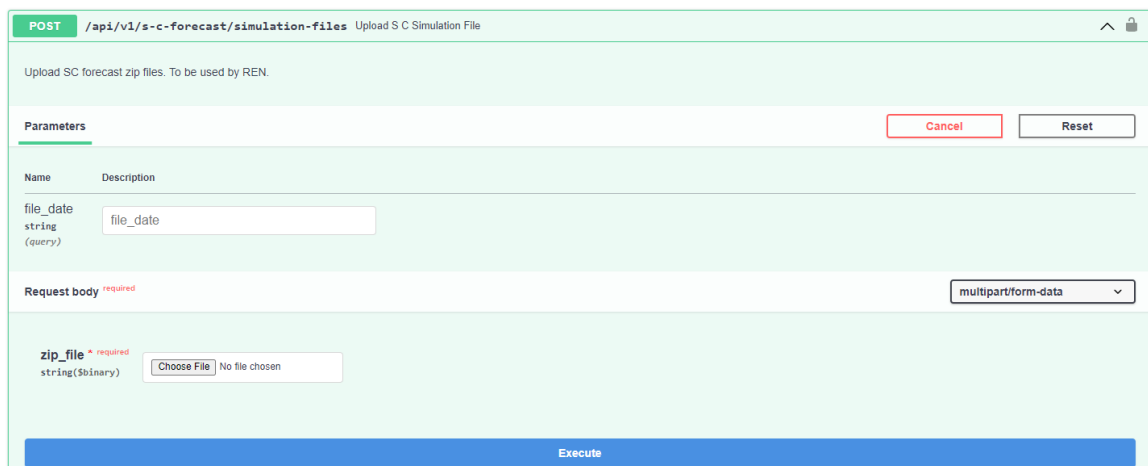
This sub section presents the base methods developed in the APIs of the TDEP and DDEP that allow the operationalization of SUC 08. The methods previously presented are here unveiled for both data exchange platforms.

TDEP Methods

The following tables present the API methods from the TDEP that are fundamental to SUC 08. Some snapshots from SwaggerHub are also presented in order to show the example of the API methods.

Table 4.21 - SUC 08 Method 08.a summary

Method 08.a	
Description	TSO provides the day-ahead simulation files needed for the short-circuit currents calculations
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/s-c-forecast/simulation-files
Method type	POST
From	TSO (REN)
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Optional] File_date [2023-03-28] (string) -> which corresponds to the date of the files obtained
Request body	[Required] Zip file with 48 simulation files in .raw format (one file 30 minutes of the day)

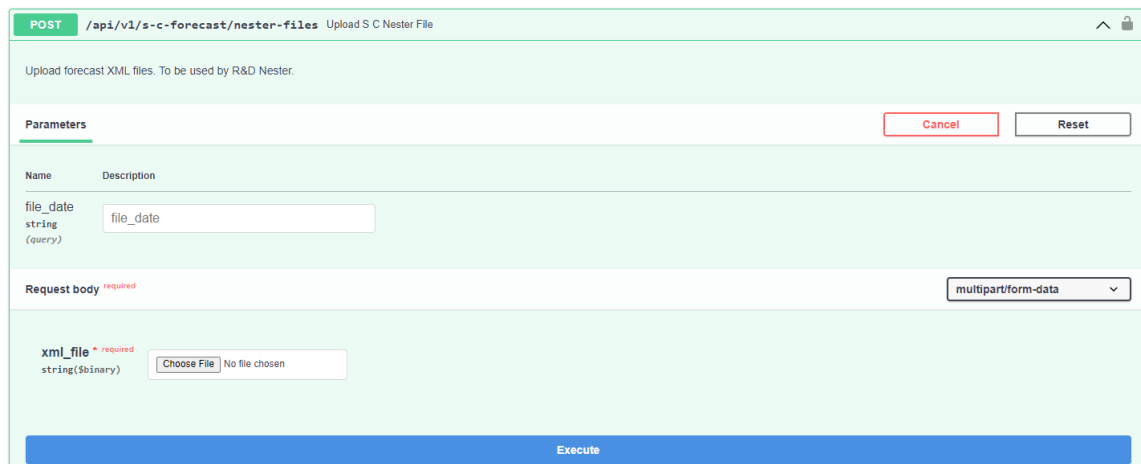


The image shows a SwaggerHub API definition for a POST endpoint: `/api/v1/s-c-forecast/simulation-files`. The description is "Upload S C Simulation File". Below the description, there is a "Parameters" section with a table showing a query parameter `file_date` of type `string`. The "Request body" section is marked as "required" and has a dropdown menu set to "multipart/form-data". Below this, there is a field for `zip_file` (type `string($binary)`) with a "Choose File" button and the text "No file chosen". At the bottom, there is a blue "Execute" button.

Figure 4.44 - SUC 08 Method 08.a API snapshot

Table 4.22 - SUC 08 Method 08.b summary

Method 08.b	
Description	TSO provides the day-ahead short-circuit power forecast
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/s-c-forecast/nester-files
Method type	POST
From	TSO (R&D NESTER)
To	TDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Optional] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed and submitted
Request body	[Required] Xml file that follows the structure presented in data model



POST /api/v1/s-c-forecast/nester-files Upload S C Nester File

Upload forecast XML files. To be used by R&D Nester.

Parameters Cancel Reset

Name	Description
file_date string (query)	file_date

Request body required multipart/form-data

xml_file * required
string(binary) Choose File No file chosen

Execute

Figure 4.45 - SUC 08 Method 08.b API snapshot

Table 4.23 - SUC 08 Method 08.2 summary

Method 08.2	
Description	DDEP provides the day-ahead short-circuit power forecast
Request URL	http://onenet-lb-900160523.eu-west-1.elb.amazonaws.com/api/v1/s-c-forecast/nester-files
Method type	PUT
From	DDEP
To	TDEP
Condition	Availability of the XML File from Method 08.b
Trigger	Every day (on-schedule)
Parameters	[Required] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed and submitted
Request body	[Required] Xml file that follows the structure presented in data model

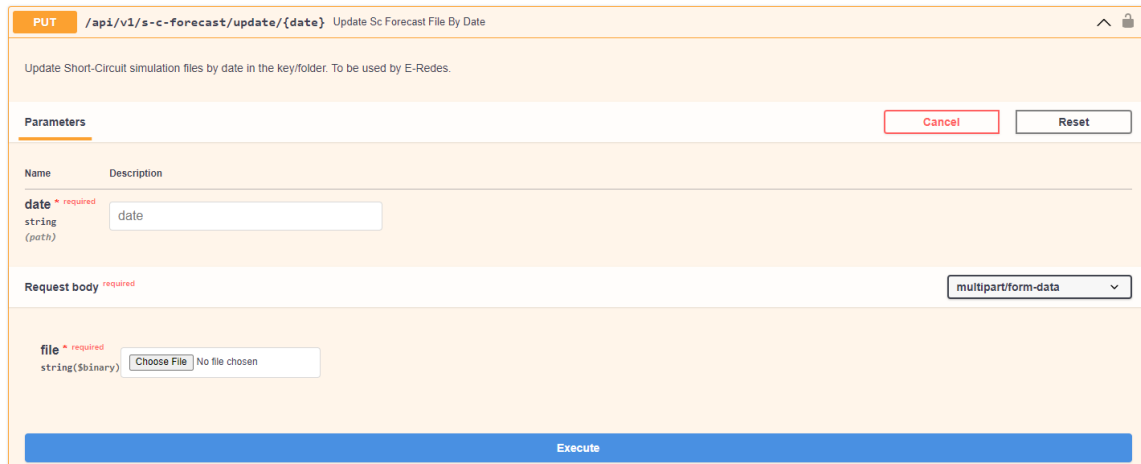


Figure 4.46 - SUC 08 Method 08.2 API snapshot

DDEP Methods

The following tables present the API methods from the DDEP that are fundamental to SUC 08. Some snapshots from SwaggerHub are also presented in order to show the example of the API methods.

Table 4.24 - SUC 08 Method 08.1 summary

Method 08.1	
Description	TSO provides the day-ahead short-circuit power forecast to the DSO
Request URL	https://dso-dep-dev.watt-is.com/api/v1/s-c-forecast
Method type	POST
From	TDEP
To	DDEP
Condition	N/A
Trigger	Every day (on-schedule)
Parameters	[Required] File_date [2023-03-28] (string) -> which corresponds to the date in which the forecast was computed and submitted.
Request body	[Required] Xml file that follows the structure presented in data model

POST /api/v1/s-c-forecast Upload SC Forecast (Nester)

The Data Exchange Platform (TSO) sends to the Data Exchange Platform (DSO) the Short-Circuit power forecast file for a given date.
NOTE: To be used by R&D Nester.

Parameters Cancel Reset

Name	Description
file_date * required string(\$date) (query)	file_date

Request body multipart/form-data

xml forecast file

xml_file * required
string(\$binary)

Choose File No file chosen

Execute

Figure 4.47 - SUC 08 Method 08.1 API snapshot

4.2.5.3 Data Model

This sub section presents the data model that was designed to exchange information regarding the SUC 08 demo. The data model created for the exchange of the short-circuit currents is presented in the Table 4.25.

Table 4.25 - SUC 08 Data model

Field	Sub-field 1	Sub-field 2	Type	Description
Sender	-	-	(int) (Required)	0 -> DSO 1 -> TSO
Time of creation	-	-	(str date-time) (Required)	
Start time of data	-	-	(str date-time) (Required)	
End time of data	-	-	(string date-time) (Required)	
Start Time Array	Start time (of Forecast)	-	(str date-time) (Required)	
	Bus ID array	BusID	(string) (Required)	
		Contribution from EHV network (TSO)	(number float) (Required)	[kA]
		Contribution from HV network (TSO)	(number float) (Required)	[kA]
		Contribution from active HV network (DSO)	(number float) (Required)	[A]

Each field can be described as:

- *Sender* tells which system operator is submitting the short-circuit forecast: 0 corresponds to the DSO and 1 to the TSO.
- *Time of creation* is the moment when the file was generated.
- *Start time of data* indicates the starting time of the short-circuit forecast.
- *End time of data* indicates the ending time of the short-circuit forecast.
- *Start Time Array* collects the information of the short-circuit currents in defined BusIDs in every 30 minutes of the day.

It is important to mention that after generation of this file by the TSO, the volumes “Contribution from active HV network (DSO)” are set as 0 and updated by the DSO.

This data model is applied to an XML format that should be submitted in the request body of **Method 08.1 - POST** and **Method 08.2 – PUT** as presented in the Figure 4.47 and Figure 4.46 respectively. Below is presented an example of the XML schema message with the short-circuit information.

```
<?xml version="1.0" encoding="UTF-8"?>
<SC_forecast>
  <Sender>1</Sender>
  <data_set_creation_GMT>2020-04-01T19:40:00+00:00</data_set_creation_GMT>
  <data_valid_from_GMT>2020-04-01T19:40:00+00:00</data_valid_from_GMT>
  <data_valid_to_GMT>2020-04-01T19:40:00+00:00</data_valid_to_GMT>
  <FORECAST-ARRAY>
    <forecast_time>2020-04-02T00:00:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>Bus_1</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>2.286</Contribution-from-
-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>2.571</Contribution-from-
HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>0.75</Contribution
-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
    <BUS-ID-ARRAY>
      <Bus_ID>Bus_2</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>3</Contribution-from-EHV
-network-TSO>
        <Contribution-from-HV-network-TSO>3.857</Contribution-from-
HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>1.13</Contribution
-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
</SC_forecast>
```

4.2.5.4 TDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the TDEP API for the different scenarios of SUC 08. It explains how information flows between the client, the server and the database. The methods presented before are here represented as well as some other auxiliary methods.

For the Scenario 1 (Short-circuit power definition at bay level considering TSO information) the process can be summarized as presented in the Figure 4.48.

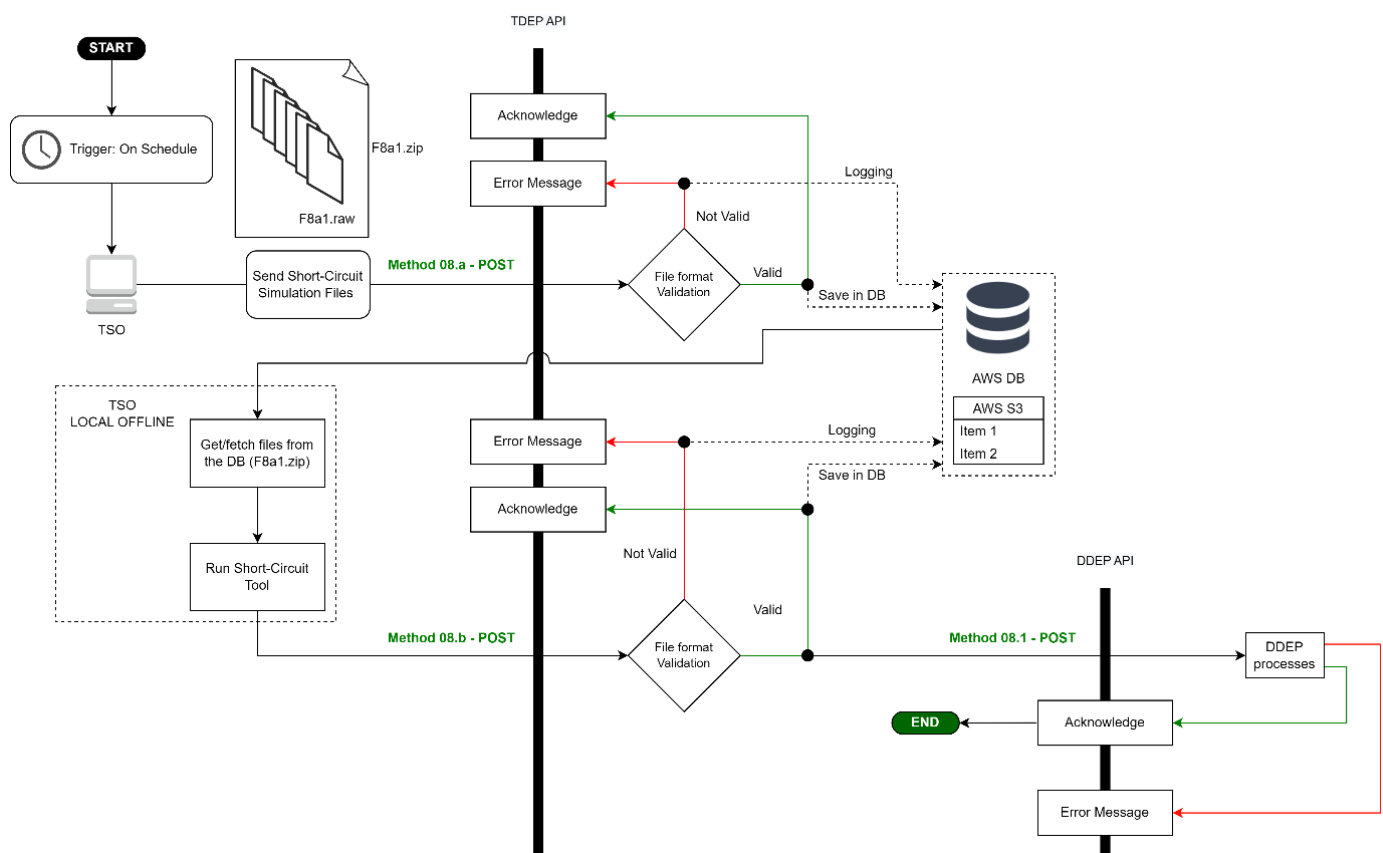


Figure 4.48 - SUC 08 Scenario 1 flowchart (TDEP)

This process starts on a daily basis with the objective of sending to the DSO the short-circuit forecast in the TSO-DSO interface buses in order to complement this data with the contributions from active HV networks, available for the DSO. The TSO calls the **Method 08.a – POST** endpoint of the TDEP API to publish the short-circuit simulation files. Once the file is received, it is validated by the TDEP API to be sure that the file is an archive file in ZIP format and contains 48 files in RAW format and a synchronous response is provided to the client, either a success response (acknowledge) or a failure response (error message). The file goes to the S3

AWS bucket that stores files that are pointed by the AWS DB. An automatic email notification is sent to the TSO (represented by R&D NESTER) informing that new simulation files were stored in the DB. After that, the files can be fetched and the TSO short-circuit evaluation can start running the simulations offline and generates the result file in XML format. The TSO then submits the result file into the database through the **Method 08.b - POST**. Once the file is received, it is validated by the TDEP API and after a success response, the communication from the TSO side to the DDEP API will be automatically triggered. For that, a POST method (**Method 08.1 - POST**) endpoint is called and the TSO short-circuit forecast file is submitted. All these processes are already implemented in the R&D NESTER API.

For the Scenario 2 (Short-circuit power definition at bay level considering DSO information) the process can be summarized as presented in the Figure 4.49.

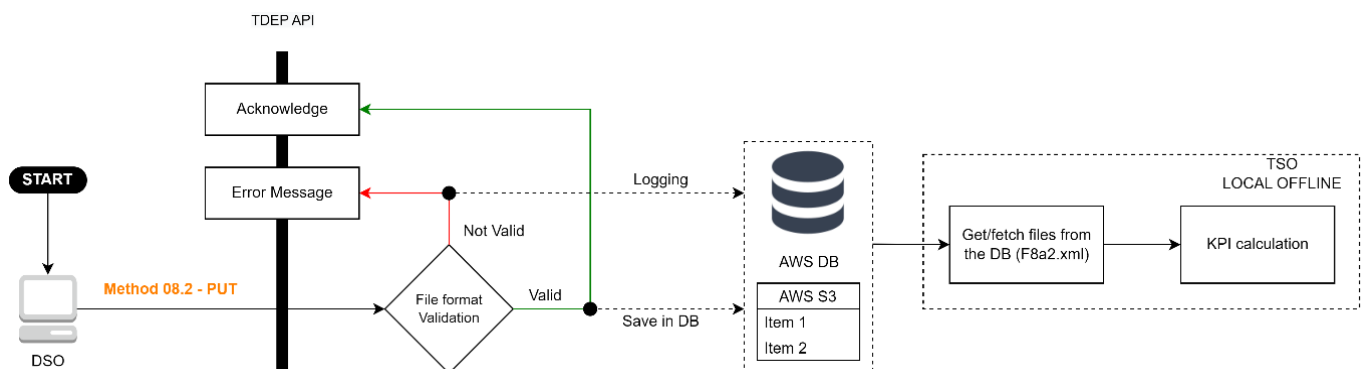


Figure 4.49 - SUC 08 Scenario 2 flowchart (TDEP)

This process starts with the DSO sending to the TDEP API the updated file with the short-circuit forecast. The DSO calls the **Method 08.2 – PUT** endpoint of the TDEP API to publish the short-circuit forecast file. Once it is received, the format of the file is validated by the TDEP API and a synchronous response is provided to the client, either a success response (acknowledge) or a failure response (error message). The file goes to the S3 AWS bucket that stores files that are pointed by the AWS DB. An automatic email notification is sent to the TSO (represented by R&D NESTER) informing that new simulation files were stored in the DB. After that, the files can be fetched, and the TSO KPI evaluation can be completed.

4.2.5.5 DDEP processes

The scope of this sub-chapter is to highlight the processes and procedures within the DDEP API for the different scenarios of SUC 08. It explains how information flows between the client, the server and the database. The methods presented before are here represented as well as some other auxiliary methods.

For the Scenario 1 (Short-circuit power definition at bay level considering TSO information) the process can be summarized as presented in the Figure 4.50.

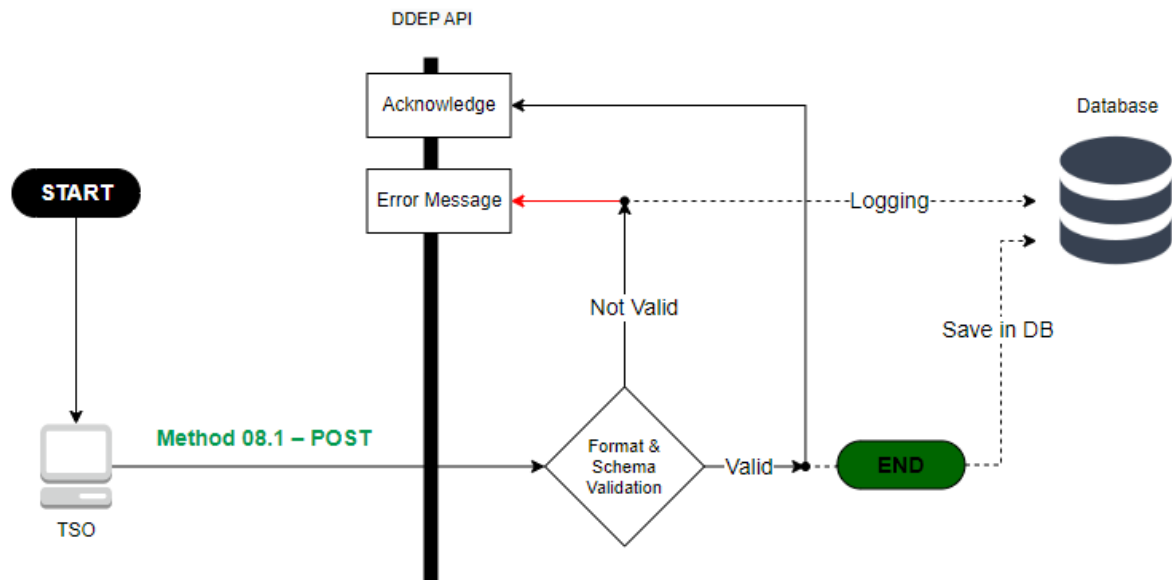


Figure 4.50 - SUC 08 Scenario 1 flowchart (DDEP)

This scenario starts with the TSO sending to the DSO their contribution for the short circuits through **Method 08.1 - POST**. Upon receiving this information, it should be validated in format and schema, and if everything is correct this information is saved in the DDEP database.

For the Scenario 2 (Short-circuit power definition at bay level considering DSO information) the process can be summarized as presented in the Figure 4.51.

On a defined time and on a daily basis, this process will start with the DSO sending to the TSO its own short circuit contributions calculated at the TSO-DSO interface, in order to complement the data already provided by the TSO with its own contributions from active HV networks. The information required will be available on the database, as result from the interactions with E-REDES operation planning tool DPlan, that will communicate directly with the DDEP through a specific endpoint created for that purpose. The updated file with the DSO contributions will be sent to the TDEP through **Method 08.2 - PUT**. A retry police should also be put in place.

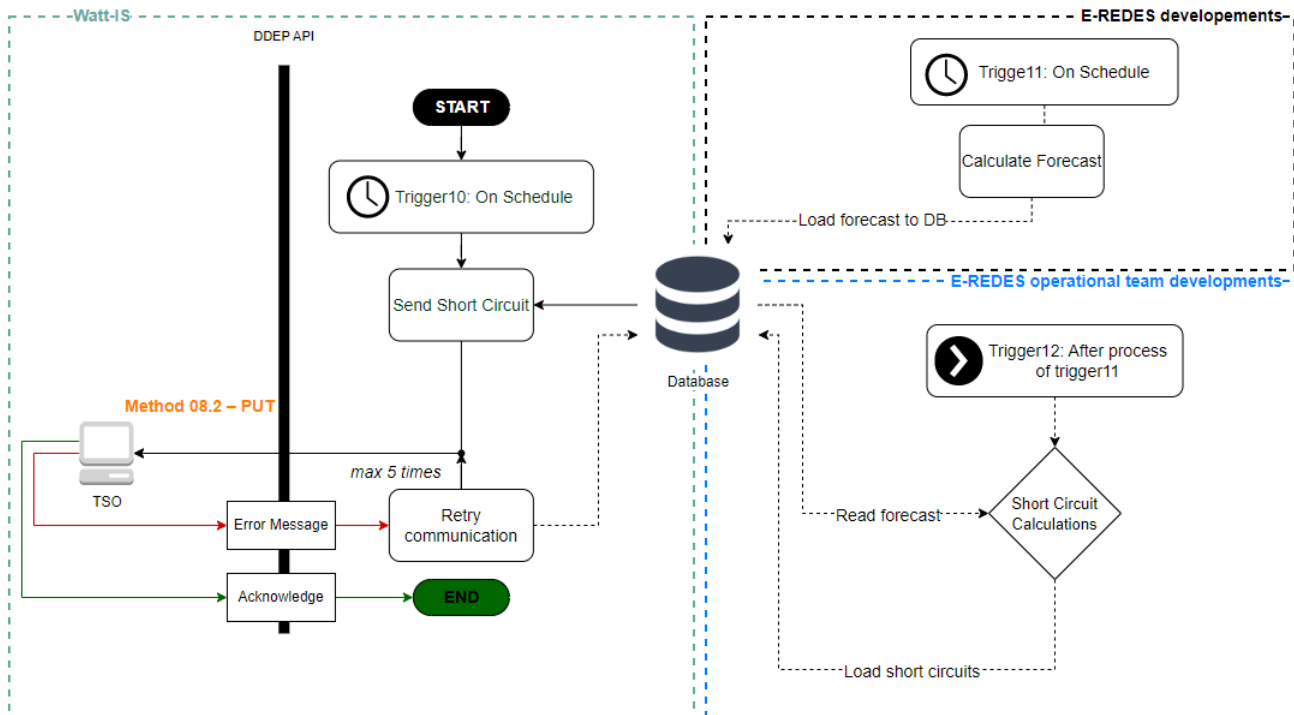


Figure 4.51 - SUC 08 Scenario 2 flowchart (DDEP)

4.3 Tools

Some of the SUCs developed require the development or update of tools to produce the data to be exchanged via the DEPs, allowing also the direct communication with the platforms, characteristics that are not foreseen in the existing operational planning tools under application by the SOs. These tools, together with the methodology proposed under Chapter 5 are here described.

4.3.1 TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool

TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool is a Python/Matlab script that enables the user to assess the flexibility needs of any network and provide the FSP flexibility dispatch that solves any network constraints that could arise. In the PT demo, the tool was applied to the EHV PT network, owned by the TSO.

The tool is composed by 2 modules: one that computes the TSO nodal flexibility needs in the TSO/DSO transformers (EHV/HV) and another that provides 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.

The tool flow is to first perform a grid analysis in order to assess the flexibility needs in the overall system concerning to active and reactive requirements (first module) and then to forecast the multi-period optimal FSP planning based on the grid status for each period (second module).

The first module relies on nonlinear grid analysis and consists of minimizing the amount of active and reactive nodal net injections (flexibility needs) that balance the grid and eliminate grid constraints (overloads and voltages) for all simulation periods.

In the second module, given the flexibility needs, the module is capable of defining the optimal FSP siting, sizing and/or dispatch to fulfil those needs. This minimization relies on a multistage stochastic linear programming approach to find the expected demand response of the FSPs given the input scenarios.

In terms of input data, the tool is prepared to deal with any grid data since it respects a specific input structure and it has all the data needed to run an OPF multi-temporal problem (time-series scenarios). The time step of the simulations carried has of 1-hour intervals, however the tool is able to consider smaller time steps.

The stochastic multi-period OPF framework included in the tool is an innovative solution, that allows the TSOs to identify the grid flexibility needs profile taking into considerations different levels of demand uncertainty as input.

4.3.2 Short-Circuit currents forecast Tool

Short-Circuit currents forecast Tool is a Python script that enables the user to perform short-circuit calculations using the Power System Simulator for Engineering software (PSS/E). It is designed to automate the process of opening and configuring PSS/E, as well as running the simulations and obtaining the results.

The script uses the Python subprocess module to launch PSS/E and execute specific commands within the software. These commands include opening an initial power flow data file in RAW format, defining the parameters of PSS/E power flow and short-circuit calculations to ensure that it can run the short-circuit simulations correctly and according to the Portuguese TSO procedures and running Automatic Sequencing Fault Calculation. This process is repeated 48 times for all the files provided by Portuguese TSO for 1 day with granularity of 30 minutes.

The main parameters that are used for the short-circuit calculations are:

- Running the Automatic Sequencing Fault Calculation in PSS/E software;
- Set options for pre-fault conditions: Default;
- Type of the fault: Three phase fault;
- Synchronous and asynchronous machine active and reactive power outputs are not set to 0;
- I''k contributions to “N” levels away output option;
- Tap ratios are left and phase shift angles are unchanged;
- Generator reactance is presented as subtransient;
- Line charging, shunts and loads are left unchanged;
- Pre-fault bus voltages are taken from the power flow.

After the short-circuit calculation is run for 48 power flow files, it generates the XML file with the structure, presented in Chapter 4.2.5.3, automatically calls the **Method 08.b – POST** in the TDEP API and saves the file in the database.

Overall, Short-Circuit currents forecast Tool is designed for quick calculation with the minimum effort from the user, it provides a convenient and efficient way to perform short-circuit calculations using PSS/E, automating the process and reducing the risk of errors caused by manual calculations and manual creation of the output file.

4.3.3 Methodology for estimating the MV flexibility potential

For the methodology involving the data acquired from the consumers that is further described in Chapter 5, the analysis was done in python, using a machine learning clustering algorithm to apply the Mahalanobis Distance. The uncertainty to the load diagrams was tackled using the Crystal Ball add-in from Excel. A geographic positioning tool is also required to identify the number of stores/consumption points to consider. For this google maps was used.

4.3.4 E-REDES Operational Planning Tool

The implementation of SUC 02, SUC 07 and SUC 08 also requires adaptations to the operational planning tool currently being used by E-REDES in its daily activities (DPlan). These adaptations are currently under development and when deployed they will allow the implementation of new services (webservices) for the communication to the DDEP database through REST APIs of daily flexibility needs at HV and MV level, consumption and generation forecasts, and short-circuit contributions from the distribution side, calculated at the TSO/DSO interface.

The analytical processes for determining these data, namely the calculation of flexibility needs at HV and MV level, the evaluation of congestions associated to future load/generation scenarios (including programmed works data) and the evaluation of short-circuit contributions, are also foreseen in this adaptation.

It is worth mentioning that the adaptations will be deployed in a replica version of the operational tool, with the replica version having connectivity with the operational one via webservices. The actual adaptation of the operational version of the tool will be assessed after the testing and implementation of the demonstration.

5 Consumer approach

With the purpose of incorporating real data into the simulations carried out under the scope of SUC 02 of the Portuguese demonstration, a methodology was developed to evaluate the potential flexibility of a given large consumer. The methodology will have in mind the replicability and scalability to other sectors, and is a way of showing real data, with real consumption values, corresponding to real assets, being considered in the analysis, with all the limitations and assumption that this exercise entails. Such considerations need necessarily to be made for this exercise to be considered possible, as at this stage and at this level, no other information beyond smart meter data exists. One reason is because the focus of the simulations is the information exchange specification, and because flexibility markets do not exist in Portugal (due to lack of regulatory maturity) and so, assets and their corresponding infrastructure are not ready for activation. Other assumptions include:

- Lighting, ventilation/climatization systems and refrigeration systems were considered to be linearly scalable among the store sizes, when compared to their power consumption.
- Estimations for refrigeration were based on measured average values and tests made on a small sample in small supermarkets and hypermarkets and are considered to have eco, normal and boost modes of operation.
- It is assumed that the flexible loads would have the necessary hardware to activate/deactivate/vary the mode of operation such as lighting dimers or air conditioning variation.
- It is assumed that the comfort level of the consumer and operation of the store would not be disrupted but the variation of the load is arbitrary and up to the FSP to decide. The load variations considered in this exercise, are disclosed in the corresponding tables as an example.
- Since only congestion management will be dealt with in the dedicated SUC 02, only decreases in active power from the baseline were considered.
- It is assumed that the flexible activated loads would have submetering or would allow disaggregation for baselining and forecasting.
- It is acknowledged that some of the larger stores (shopping centres and hypermarkets) have Electric vehicles (EV) charging infrastructure, which could have been useful assets to consider. However, by analysing the aggregated load diagrams from the stores, it is not visible when these loads (EVs) were connected, hence we assume that they are under a different metering infrastructure and are not considered here as flexible assets.
- No other information regarding the collected profiles were made available such as temperature, location or any other characterization, which could provide deeper explainability/interpretability or

personalized analysis. In this sense the historical data was the driver for the future prediction, with all the errors this can entail.

In this sense, a survey was launched requesting several large consumers to provide access to their data. To narrow down the invitations, only a portion of activities were considered such as retail supermarket chains, hotels and touristic commercial sectors. After a careful analysis of the data quality, we decided to work with one large consumer, a supermarket chain, which has geographic dispersion and a relatively large portion of consumption locations (stores). The data used were based on 236 time-series from smart meters, corresponding to consumption profiles of each store for the full year of 2019, with 35040 observation each (corresponding to 15-minute time step). From the csv files retrieved by the DSO, dully authorized by the owner of the data (which will remain undisclosed), we have considered only the active power (column A+ under the Portuguese terminology). This is because the use case in which the data will be applied will cover congestion management where active power flexibility is in general enough.

5.1 Methodology

The following steps were defined for the methodology and will be followed with step-by-step detailed explanations throughout the chapter, each referred to as n^{th} step of the methodology:

1. **Clustering** – Acknowledging the fact that different types of behaviours can be identified among the stores, a clustering exercise was performed for each day of the year; This resulted in clusters corresponding to small stores, medium stores and large stores.
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 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 store category (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 store sizes (clusters).
7. **Define constraints:** A percentage of that power of arbitrarily identified as flexibility available, not considered as disruptive for the potential store 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 stores in a grid zone** - The area of the substation is identified through google maps, and the number of each store 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 75 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.

5.2 Simulation

A random weekday was chosen to exemplify the methodology. For the example hereafter presented, the 12th of March 2023 was used for the flexibility availability evaluation.

The first step (1) of the methodology is the clustering exercise. For this analysis, only the active power was considered from the historical data. It was observed however, that some of the files contained readings of reactive power, and others had local generation of electricity. The well fit of the profiles into clusters (if only similarities between load profiles were considered), could be impacted by the fact that some stores have self-consumption and may impact on the dynamics of the load profile during the day, which means that they should be in different clusters. Several clustering approaches were considered, analysing patterns, consumption

dynamics and magnitude of the power consumption. However, the first results were not solid enough as a visual analysis could detect that stores with different magnitudes of power were placed under the same cluster. This may be related to self-consumption, of correlation of consumption between some hours of the day. The approach in the end, considered the starting and closing hours, which ended up being a more robust result, since they have distinct hours and closing procedures. Also, looking at the individual files in Excel format, we could observe that on two days of the year, the stores were apparently closed (day 25th of December and 1st of January). This gave us an opportunity to use the average individual profile of these two days which we assumed to be critical service loads (not subject to flexibility or change) and subtract it to the total load profile.

Since the reference profile varies from store to store, with the difference in relation to these values, we will have a proxy of the variations associated with the store opening and closing. It turned out to be effective. Since the distributions were being used, the Mahalanobis Distance (MD) was used [13], which in simple terms is, the distance metric that measures the distance between a point and a distribution.

The clustering taking into account the distributions at the opening and closing time in relation to the reference, resulted in the dendrogram below. The dendrogram in Figure 5.1 suggests the differentiation of the data into groups (clusters). From the top it is observable from the start that two distinct groups emerge with significant hight (from 140 to 50). At Height 50, three distinct branches emerge with sufficient balanced amount of data, to characterize each of the clusters and so this number of three clusters was followed.

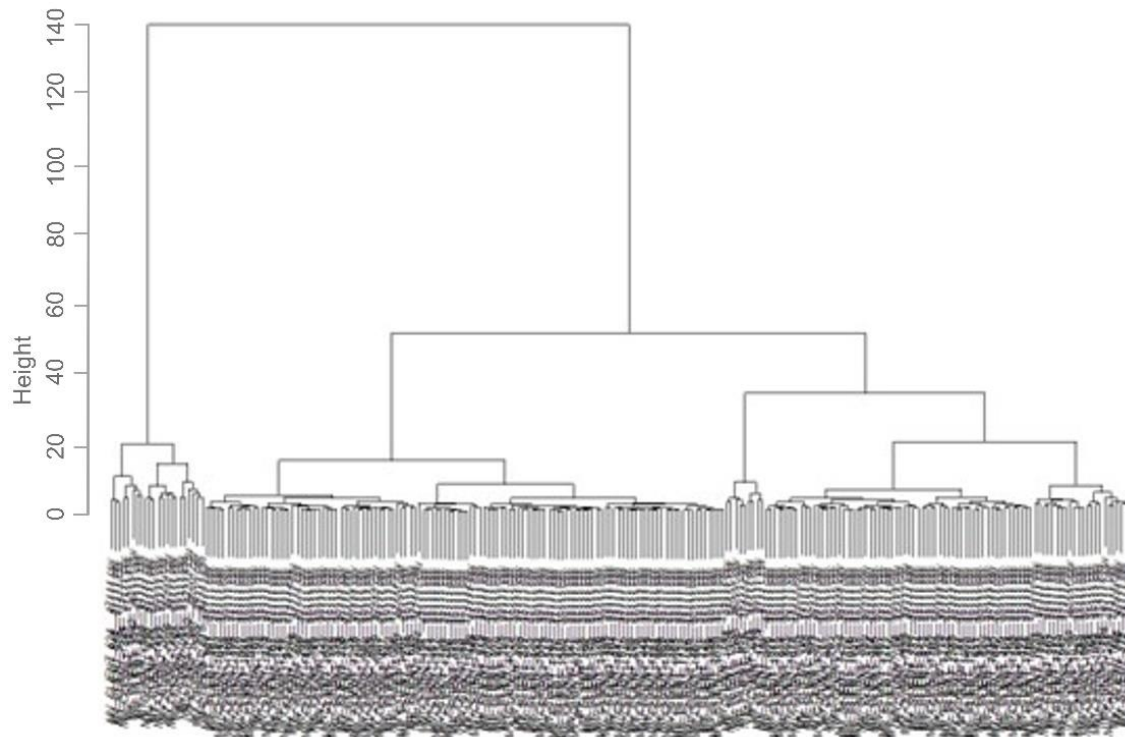


Figure 5.1 - Resulting dendrogram of the clustering made with the Mahalanobis Distance (MD) focusing on the closing and opening times dynamics

The application of Bootstrap technique [14] using python allowed for multiple testing of the clustering outcomes. Bootstrapping is any test or metric that uses random sampling with replacement and falls under the broader class of resampling methods. Bootstrapping estimates the properties of an estimand (such as its variance) by measuring those properties when sampling from an approximating distribution. Two initial clusters are clearly divided (C1 -120 surfaces and C3- 22 surfaces) and a third C2, formed by the remaining 94 stores. With the magnitude of the values of power observed from elements of each cluster, it was possible to interpret that the clusters corresponded to small, medium and large stores, which was in line with the classification provided by the supermarket chain manager.

The next step was to create a representative load diagram (step 2) for each of the clusters, for the 12th of March (picked randomly day). This was done by fitting the best statistical distribution to every 15-minute interval in each cluster. This was done using the Crystal Ball add-in from Oracle [15]. For example, for the 120 observations (belonging to Cluster 1) for the first period of the day (00:15), the several power registries were fit into a distribution (shown in Figure 5.2 as example). It does so automatically while it performs a goodness of fit test such as the Anderson–Darling test [16][16], which is a statistical test to find if whether a given sample of data is drawn from a given probability distribution.

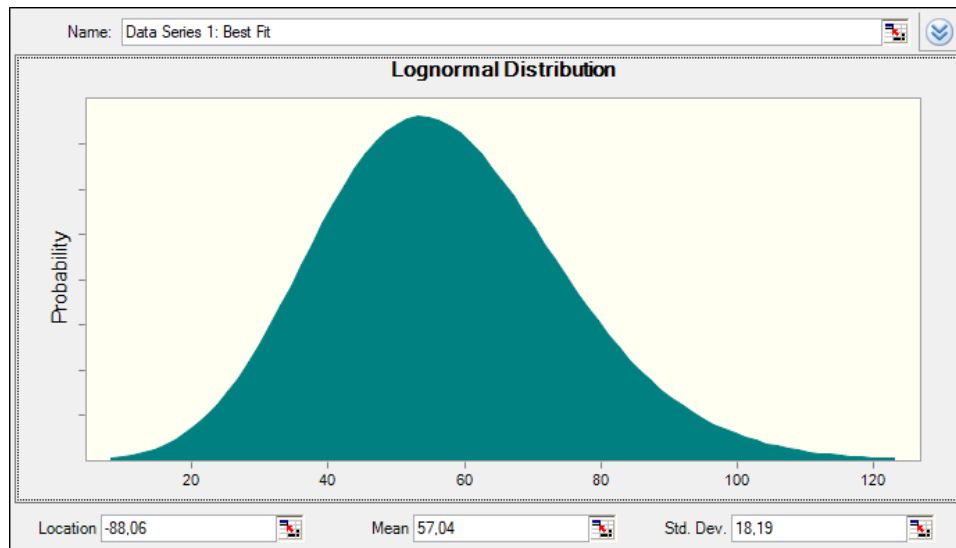


Figure 5.2 - Series 00:15-CL1: Best Fit: Lognormal dist., Loc.= -88,06, Mean= 57,04, Std. Dev.= 18,19

Next, the same was done using the Crystal Ball tool for all the 96 time periods in the 3 clusters. Afterwards, in step (3) the operational load diagrams were found, simply by deducing the power observed in the stores closed days (the average of both), to the representative load diagram. The resulting profiles are shown in Figure 5.3 for each cluster.

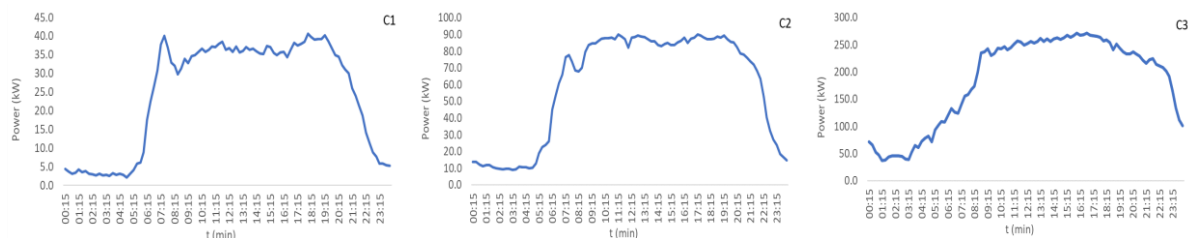


Figure 5.3 - Representative operational load diagrams by cluster

In step (4) and (5) of the methodology a listing of the main typical loads was carried out. Preference was given to long duration loads (more than 1 hour) and high-power consumption. Smaller loads were put together as general loads. For the EVs, PVs and heat pumps, no submetering exists and so there is no way of understanding if they are present and when they operate. This is why they were not considered. All the others were assigned a category (depending on their type) from the following ones:

- variable and shiftable (VS);
- not variable but shiftable (NVS);
- not variable nor shiftable (NVNS).

In addition, for those in the first two categories (VS and NVS), three types of Flex load symbols were given:

- Illumination (I);
- refrigeration (R);
- Climatization and ventilation (C) according to their nature.
- The remaining were put under Others (O)

Table 5.1 - List of main loads in the stores with flexibility ability and flex load category

Loads	Category	Symbol for flex loads
General indoor and outdoor lighting	VS	I
Lighting displays	VS	I
Lighting warehouses and emergency	VS	I
Ovens (bread and cooked)	VS	R
Cutting & processing machines (cold cuts, butcher, etc.)	NVNS	O
Positive cooling cabinets	VS	R
Negative cooling arcs	VS	R
Forced ventilation	NVS	C
Cafeteria	NVNS	O
Electrical lifting and logistic platforms store	NVNS	O
Access systems, surveillance, fire and security (treadmills, automatic doors, CCTV, central pcs...)	NVNS	O
Payment equipment, PC, registers, product treadmills	NVNS	O
Heat cabins (pre-made food)	NVNS	O
Air conditioning main yard	VS	C
Office and restricted spaces AC	VS	C
Dryers and lighting WCs	NVNS	O
Elevators	NVNS	O
Photovoltaic panels	NVNS	O
Heat pumps	NVNS	O
EV chargers	NVNS	O
Other generic loads	NVNS	O

Step (6) of the methodology is based on the operating profile of each cluster, (given by the percentile 50 of each 15-minute observation) a stratification of the grouped nomenclature (I, R and C) was done, by identifying their connection and disconnection times at the beginning and end of day, in leaps or gradual rises/declines as observed in Figure 5.4. This amount was treated as a percentage of the nominal power during the day. This helped replicating the consumption to other store sizes (clusters 2 and 3).

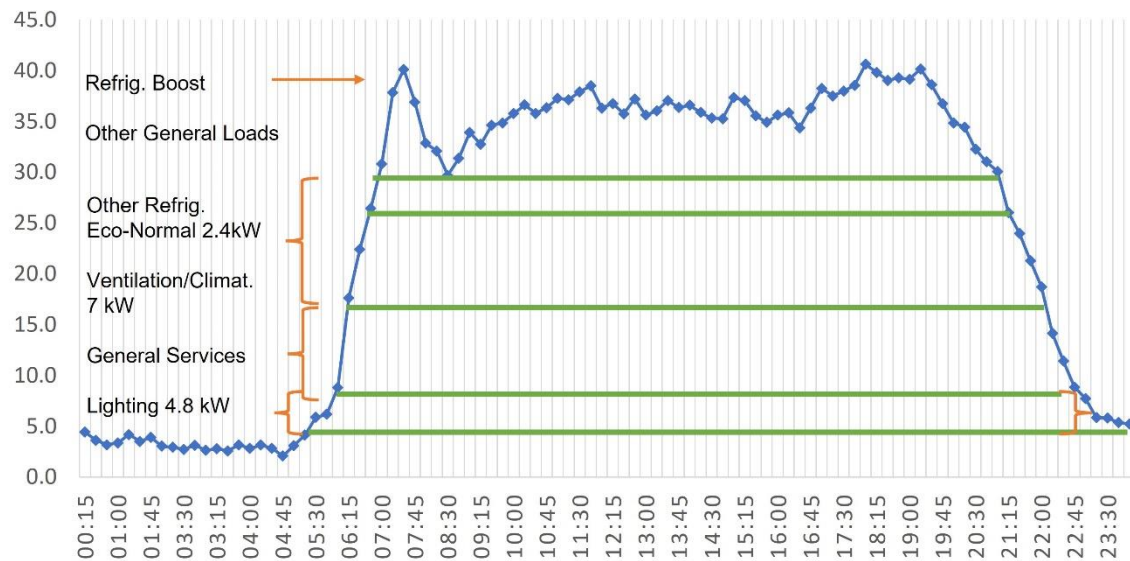


Figure 5.4 - Event load detection from daily routine dynamics

From this event analysis, based on the store's daily routines it was possible to estimate step (7), when and how much power belongs to each category of assets. Lighting corresponded to 14% of the maximum average power and 10% was considered as an acceptable change without disrupting the comfort of users. As an example, the first line of Table 5.2, this will result in 1.4% of flexibility for the stores in the cluster 1 (C1) from 6:30 to 21:45. The variation values were taken from the literature as reference[17]. For the refrigerated cabinets and arcs, the powers were based on tests carried out under the Interconnect project which allowed finding the nominal power in each mode. It was observed that the cabinets and arcs have four cycles of defrosting during the day, plus several at night. It is considered that they all have three modes of operation: the Eco mode during the night which consumes less, the normal mode and the boost mode to quickly reset temperatures to the desired level. The maximum difference found between modes is 14.63 kW (boost - echo), and if we make the difference between adjacent modes, we get 8.83kW (normal - echo) and 9.83 kW (boost - normal). However, these maximum differences are far from the means, which are 4.15 kW (boost - eco); 2.40 kW (normal - eco); 1.76 kW (boost - normal) taken into account. This analysis was done by grouping the available data by hour of day and by operation mode, using the mean as a grouping rule. The average of total consumptions per mode are the following: Normal - 17.52 kW; Eco - 15.12 kW; Boost - 19.27 kW.

Table 5.2 - Hourly restrictions by load category, with flexible power (in%) per cluster

Category	C1	Hours	C2	Hours	C3	Hours
Lighting power						
Lighting	1.4%	06:30-21:45	1.9%	06:30-22:45	1.0%	06:30-22:45
Lighting	0%	21:45-06:30	0%	22:45-06:30	0%	22:45-06:30
Refrigeration/heat						
Defrosting of cabinets	0%	5:45 - 6:30	0%	5:45- 6:30	0%	5:45- 6:30
ECO mode (no flexibility)	0%	6:30 - 6:45	0%	6:30 -6:45	0%	6:30 -6:45
Boost may be shifted 100%	12%	6:45-7:30	11%	6:45-7:30	11%	6:45-7:30
Normal mode (variable to eco)	7%	7:30 - 11:45	7%	7:30-11:45	5%	7:30 - 11:45
Defrosting of cabinets	0%	11:45-12:30	0%	11:45- 12:30	0%	11:45-12:30
Normal mode (variable to eco)	7%	12:30-17:45	7%	12:30-17:45	5%	12:30 -17:45
Defrosting of cabinets	0%	17:45-18:30	0%	17:45- 18:30	0%	17:45-18:30
Normal mode (variable to eco)	7%	18:30-21:00	7%	18:30 -21:00	5%	18:30 -21:00
Modo eco	0%	21:00-23:45	0%	21:00-23:45	0%	21:00-23:45
Defrosting of cabinets	0%	23:45-00:30	0%	23:45-00:30	0%	23:45-00:30
ECO mode	0%	00:30-5:45	0%	00:30-5:45	0%	00:30-5:45
Climatization and ventilation						
Climatization & ventil.	1%	07:00-21:30	1%	07:00-22:30	1%	07:00-22:30
Climatization & ventil.	0	21:30-07:00	0%	22:30-07:00	0%	22:30-07:00

For the Climatization and ventilation it follows the opening and closure times with an hour of difference and considers that 20% is the power (7kW) of an operating average of 35kW. The power spent on air conditioning depends a lot on the occupation of space and the outside temperature. However, since this is unknown, we assume that the air conditioning intends to adjust the cold that is caused by the reference of a midpoint of 0 degrees (negative and positive cold), to comfort ambient temperature of +- 20 degrees. Assuming a linear progression (temperature and power), we assume 1% per degree and assume that we can vary 1°C without impacting on the feeling of prolonged comfort of customers.

Step (8) of the methodology is simply matching the flexibility restriction with the corresponding observed operational power in each 15-minute interval per cluster. This value is then multiplied by the number of stores within a grid zone. If we take as an example the Lighting category, if the corresponding percentage from Table 5.3 is considered (1.4%), when it is multiplied by the consumption in that 15 min time slot (30.82 kW), results in 0.43 kW. An example for three time slots of 15-minutes for the three clusters is presented in the table below.

Table 5.3 - Example of Total Flexibility identification per category of asset

Cluster1	07:00	07:15	07:30
Operations Consumption (kW)	30.82	37.84	40.19
Lighting (kW)	0.43	0.53	0.56
Climatization (kW)	0.31	0.38	0.40
Refrigeration (kW)	3.66	4.50	2.75
Stores in grid Zone (kW)	3	3	3
Total Flexibility (kW)	13.21	16.22	11.14
Cluster2	07:00	07:15	07:30
Operations Consumption (kW)	65.82	76.54	77.77
Lighting (kW)	1.23	1.44	1.46
Climatization (kW)	0.66	0.76	0.78
Refrigeration (kW)	7.40	8.61	5.33
Stores in grid Zone (kW)	6	6	6
Total Flexibility (kW)	55.78	64.87	45.41
Cluster3	07:00	07:15	07:30
Operations Consumption (kW)	124.59	140.69	156.21
Lighting (kW)	1.25	1.41	1.56
Climatization (kW)	1.25	1.41	1.56
Refrigeration (kW)	13.70	15.47	7.81
Stores in grid Zone (kW)	1	1	1
Total Flexibility (kW)	16.19	18.29	10.94
Total (kW)	85.19	99.38	67.49

This grid zone is the area of influence of the substation, which is determined in step (9) of the methodology initially stated in Chapter 5.1. The area used was based on the report by the JRC from the DSO Observatory [18], in which several indicators for electricity networks were studied, based on actual data from system operators. The indicators have been devised in such a way to allow for a comparative analysis of the DSOs and can be divided in three main categories: Network structure, Network design and Distributed generation. For the purpose of this exercise the indicator “Area per capacity of HV substations” was used from this report. It is identified in the report that the median value is 2.3 km²/MVA, which corresponds to the reliability indicator 4.5 based on the data collected from 79 European DSOs. Since the substation we are using for this exercise in Portugal, has 3 power transformers of 170MVA (total of 510MVA), we get an area of influence of 1173Km². By inputting the area around Batalha city in GIS, google maps or similar tools, we get the stores positioning and quantity. Figure 5.5 shows the area considered with the 1173km².

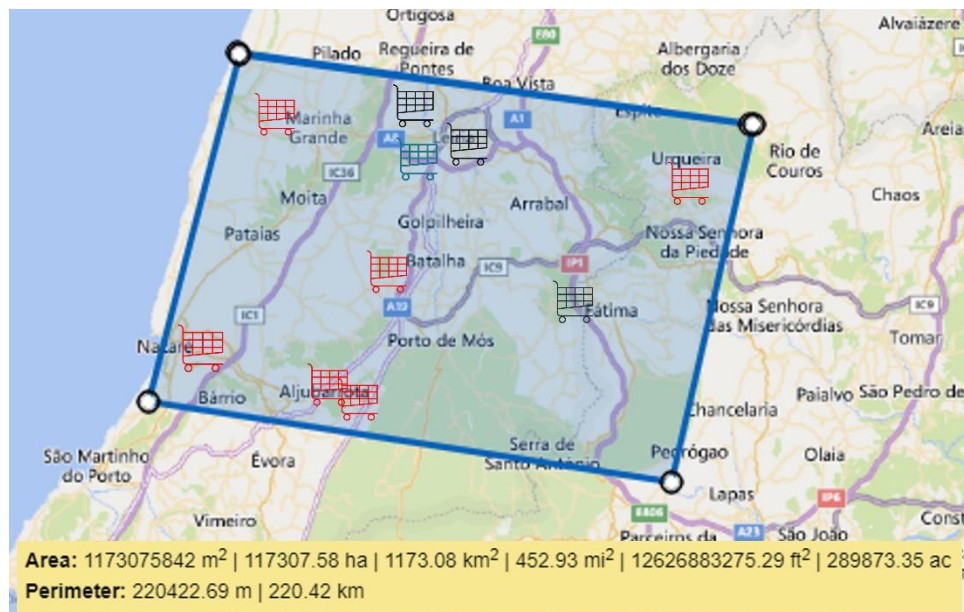


Figure 5.5 - Grid Area considered for store quantification identification

In the area identified, 3 small stores for cluster 1 (black), 6 medium stores for cluster 2 (red) and 1 large supermarket for cluster 3 (blue) were found. The flexibility found per cluster representative store was then multiplied by the number of supermarkets.

In Step (10) the Monte Carlo simulation is run 1000 times to take into account all the statistical distributions inserted in step 2. Monte Carlo technique is nothing more than, massively running random samples of an uncertain event to estimate the possible outcomes.

Step (11) of the methodology is up to the provider to choose according to the risk he wants to take in the offer it presents. This will depend on the risk adversity the provider has in order not to cause an imbalance in its commitments by not fulfilling its availability. In order to do so, it may adjust the output according to a risk tolerance level by considering the appropriate Percentile. In the example given the percentile P75 is chosen, but if the consumer accepts the 90%, 95% or higher it is up for debate. In theory, an aggregator may aggregate different offers assuming a gaussian distribution. This will allow increasing the weight of the mean value and reduce the variance and consequently the standard deviation. This is because the standard deviation is the square root of the variance. This analysis can be visible in Figure 5.6, in which the mean is 81.86 kW, and the median (P50) has a much lower value of 74.54 kW. To have a level of certainty of 75% that, at least the value provided will in fact exist, the exact value of flexibility for the 19:15 slot would be 58.14kW. This is about 70% of the mean value just by considering P75 instead of the mean. It must be said however that, even if the total value of flexibility is not accurately provided, the risk is just not fulfilling the offer entirely, but it still does it partially.

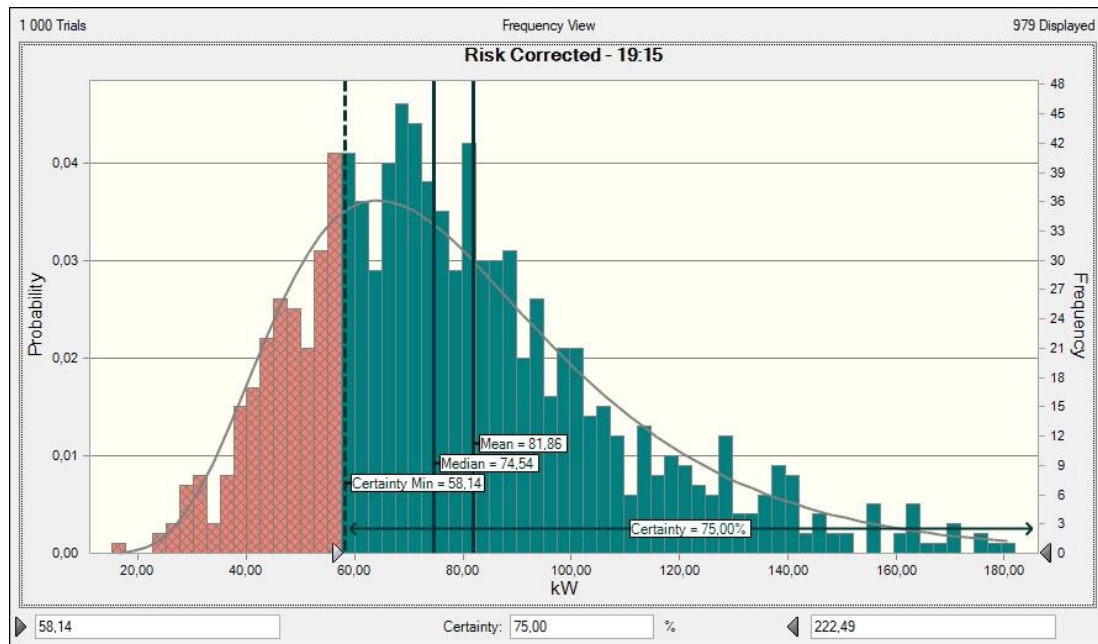


Figure 5.6 - Flexibility estimation adjusted to P75 (example for 19:15h)

The last step (12) of the methodology is to create a message with an array with 96 entrances, in which the availability for the specific day under analysis is provided, with the contents structure defined. Below is an example of the message, for the interval between 19:15-19:30 as an example.

Table 5.4 - Message content of flexibility availability

Field	Example
sender_source	1
grid_nodes	integer
node_id	integer
Active_power_quantity	float
Reactive_power_quantity	float
period_frtom	"string" ex: 2023/03/12 19:15
period_to	"string" ex: 2023/03/12 19:30
created_at	"2023-02-02T10:00:16.042038"
id	Integer

Each field can be described as:

- **Sender_source** - tells which actor is requiring or offering the flexibility service. In case of grid operators, 0 corresponds to DSO and 1 to TSO. INESC TEC will take the role aggregator that corresponds to a value of 2 in this field.

- **Grid_nodes** - collects the information of a flexibility need/offer in a given node of the grid. It was the corresponding **node_id** known by all the parties in addition to the **active and reactive power** injections or consumptions. Here a common rule is followed: Positive values indicate injection of power (from the grid point of view) and negative values indicate consumption of power (from the grid point of view), this convention for flex needs. In relation to flex offers positive values indicate upwards flexibility (increase consumption or decrease injection) and negative values indicate downwards flexibility (reduce consumption or increase injection) **Period from and to** is a date and time in string format.
- **Created_at** - is the moment when the FSP offer was submitted. This is assigned automatically.
- **Id** - is a R&D NESTER internal id that is assigned automatically, identifying the offer.

Having developed the methodology, as part of the project's goals, we aimed at reaching out to consumers. For this reason, a workshop is part of this activity, in order to increase awareness of the flexibility provision process. The aim of the workshop is 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. In the example provided to showcase the methodology, an initial analysis of the load diagrams is required to treat data, such as discard useless data (in this case the demand from the closed days). The classification names of assets and the restrictions will vary depending on the nature of the industry under analysis, however the procedure is common. The mitigation of risk and uncertainty are necessary approaches to minimize imbalances from the flexibility providers and are completely replicable and scalable.

In the example provided of a supermarket chain, with a relatively fair store geographic density, and with a very conservative risk approach, a daily maximum flexibility level of approximately 60kW was obtained. This value is very low, in comparison to the order of magnitude of the flexibility needs, that can be assessed by the substation area (which is in the order of MVA). However, it is only fair to mention that, on one hand, significant flexible assets were not considered in the analysis (due to lack of data), and that are foreseen to play a major role in flexibility provision. These include EVs in the parking lots, PVs, electrolyzers or Heat pumps just to mention a few. On the other hand, only one type of consumer is being considered in this example, which is not even a heavy industrial consumer. An aggregated participation of several industrial partners (and commercial) could in fact result, in an acceptable level of complementary flexibility for the grid in some locations. The timely review of these options by the consumers will support investment decisions for future flexibility provision. These include among others: i) Infrastructure set up; ii) Digitalization; iii) Submetering and load disaggregation; iv) Design and dimensioning of assets; v) Considering flexibility roadmaps from system operators (foreseen location, needs) for investment decisions.

6 Evaluation and Results

In this chapter, the main results achieved so far in the Portuguese demonstration will be presented. Given that the demonstrator's final results will be presented in D9.5, this chapter should be read as an initial glimpse of results, showing not only the current status of the developments in several SUCs, but also indicating the expected next steps required to fulfil the objectives of the demonstrator. Hence, not all the SUCs will be addressed, only SUC 02, SUC 06 and SUC 08 since intermediate results gathering for the remaining SUCs are dependent from developments yet to be achieved within the demonstrator.

6.1 SUC 02

The TSO Flexibility Needs Evaluation and FSP provision simulation Tool is still being refined and tuned; thus, this sub-chapter will present the test results obtained in a testing workbench phase before to applying it to the demo data.

For that purpose, an IEEE test case network (IEEE 14 bus test case) was selected for performing the tool tests. The IEEE 14 bus test case is a widely used standard test case in power system analysis and has been used as a benchmark for the development and testing of various power system analysis tools and techniques. The data used was converted from IEEE Common Data Format (ieee14cdf.txt [19]). The network has no capacity limits defined for any branch. It has 14 buses, 5 generators (located in Bus 1,2,3,6 and 8) and 11 loads (located in Bus 2, 3, 4, 5, 6, 9, 10, 11, 12, 13 and 14). The Bus 1 is the reference bus. Figure 6.1 presents the single line diagram of the IEEE 14 bus test case.

As mentioned, the capacity limits of the branches are not included in the IEEE 14 bus base case and for that reason, values were given to them in the network model in order to perform power flow analysis. The capacity limits were selected in order to provoke potential grid constraints in the area of the Bus 13.

The first step of the tool is to perform a power flow and/or optimal power flow (OPF) analysis in order to identify the actual status of the grid, looking for any overloads and violations of voltage limits. The power flow is run first, in order to identify the steady-state operating condition of the network, and after that an OPF is run, that gives the optimal dispatch of the generators, subject to a set of constraints, with the goal of improving the system's performance and ensuring that it is operating within safe and reliable limits.

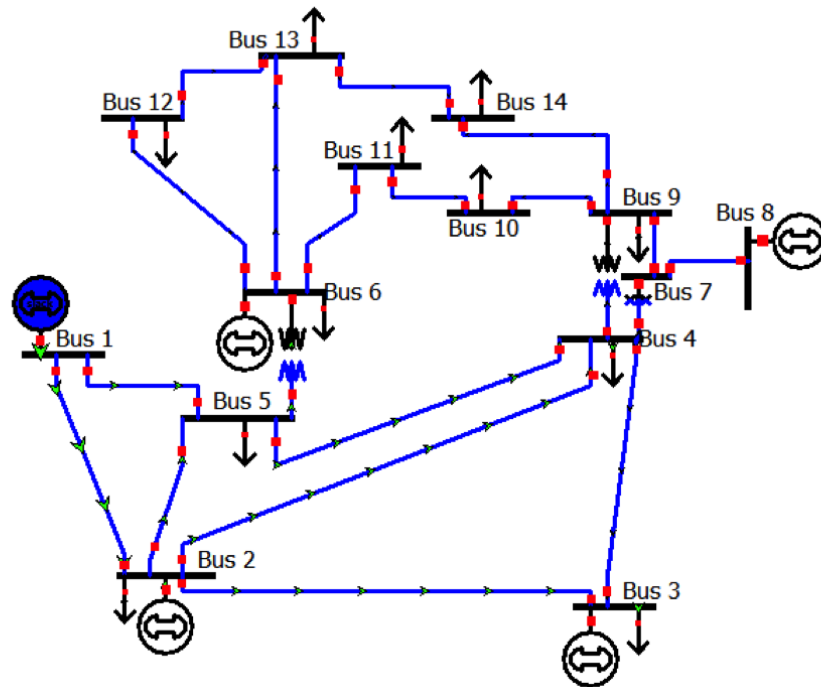


Figure 6.1 – IEEE 14 bus test case single line diagram

For applying this first step of the tool the time-series of consumption and generation is also needed as input. For testing purposes we created a script to generate consumption time-series for the 11 loads. The rationale behind the script for generating the load time-series follows the next steps:

- 1) Get for each load the active power value from the base case (IEEE 14 bus test case). This value will be the mean value of the Gaussian distribution.
- 2) A 3% standard deviation is considered for all the loads.
- 3) The time series are generated following a Gaussian distribution with a generation of random number from a normal distribution with mean in the active power value from the base case and standard deviation of 3%.
- 4) To provide a typical consumption profile behaviour during one day to the load time-series, a scale factor was applied. To not have all the load with the same profile, again, some randomness scaling factor was added to the load profiles, allowing it to have an “uncertainty” level.
- 5) Once the active power time-series are defined, the reactive power time-series are computed following the same behaviour as the active power ones.

Figure 6.2 presents the generated active power time-series used for the concept tests. Each line corresponding to one load.

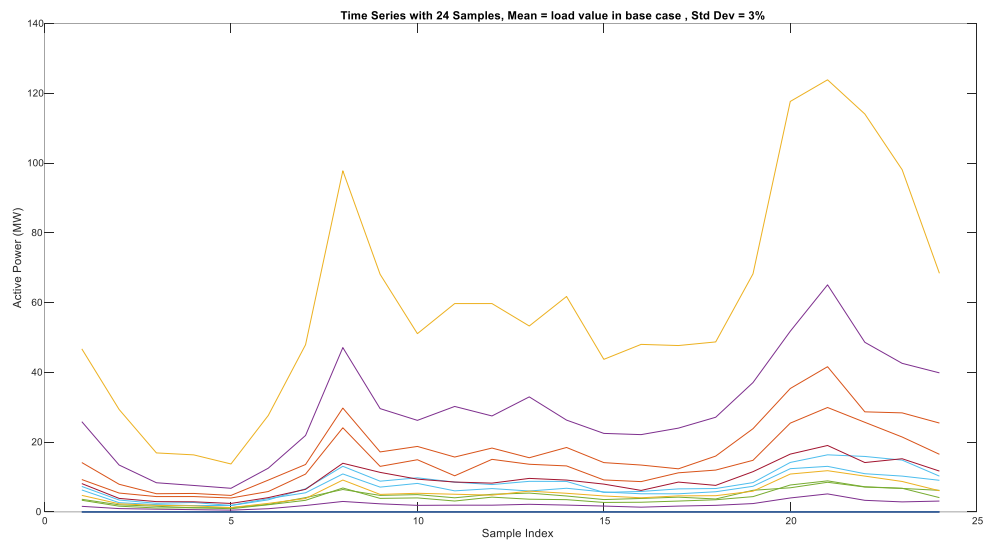


Figure 6.2 – Active Power time-series

Once the load time-series is generated and the network model settled, the step one of the tool is ready to be called and the overloads identified. A power flow and an optimal power flow were run in order to evaluate the status of the grid during the 24 periods (each hour of the day) under analysis. The results of both regarding the lines overloaded are presented in the Table 6.1.

Table 6.1 - Step 1 - Power Flow (PF) and Optimal Power Flow (OPF) constraint results

Period	Lines overloaded	PF results (% overloaded)	OPF results (% overloaded)
1	From Bus 6 -13	185%	-
7	From Bus 6 -13	163%	-
8	From Bus 6 -13	376%	245%
	From Bus 13 -14	111%	-
9	From Bus 6 -13	242%	133%
10	From Bus 6-13	242%	134%
	From Bus 13-14	-	109%
11	From Bus 6-13	212%	111%
	From Bus 13-14	-	106%
12	From Bus 6-13	210%	106%
	From Bus 13-14	-	107%
13	From Bus 6-13	226%	120%
	From Bus 13-14	-	101%
14	From Bus 6-13	225%	120%
	From Bus 13-14	-	101%
15	From Bus 6-13	159%	-
16	From Bus 6-13	149%	-

17	From Bus 6-13	176%	-
18	From Bus 6-13	181%	-
19	From Bus 6-13	259%	144%
20	From Bus 6-13 From Bus 13-14	434% 149%	297% -
21	From Bus 1-5 From Bus 6-13 From Bus 13-14	104% 513% 184%	- 356% -
22	From Bus 6-13 From Bus 13-14	421% 101%	288% -
23	From Bus 6-13 From Bus 13-14	406% 110%	275% -
24	From Bus 6-13	286%	167%

From the Table 6.1 it is possible to see that there are several periods in which the lines that feed the Bus 13 are overloaded. This happens mainly during the periods with higher demand. The OPF results show that some of the constraints can be solved with an improved dispatch of the generation units, however, during 12 periods of the day under analysis, the capacity limit of at least one of the branches is violated. Having that into consideration, the second step of the tool will be to identify what are the flexibility needs in order to solve the constraints identified in the first step.

The second step of the tool checks, for any set of buses selected by the user, what flexibility is needed to solve the network issues identified in the previous power flow analysis (step 1). In this conceptual test, we considered that all the buses with loads connected are candidates to provide flexibility, whereas in the demonstration phase we will consider all the TSO/DSO substations. This second step is again an Optimal Power Flow Analysis but now providing the option to have in the selected buses a dispatchable load model and a generator model that will act as the consumption/generation buffer in order to identify the flexibility needs.

The goal of the OPF is to minimize the cost of operating a power system subject to a set of physical and operational constraints. In that regard the grid model is settled in order to prioritize the generator injections instead of the flexibility activation. The OPF takes as input the power system model selected (in this case the IEEE 14 bus test case), which includes all the information about the topology, loads, generators in the system, as well as the cost and operational constraints. The function then uses an optimization algorithm to determine the optimal set points for the controllable parameters in the system, such as generator output levels that minimize the overall cost of operating the system while ensuring that the constraints are satisfied. In that regard, in the step 2 of the tool, the cost of the different models (generators and dispatchable loads) was adapted in order to prioritize the resolution of the constraints through the re-dispatch of the generator in the grid, instead

of flexibility activation. The step 2 also allows the definition of a power factor restriction that we considered $\cos \Phi \geq 0.9$ for the concept tests carried.

Following the rationale exposed, in the Table 6.2 are presented the flexibility needs that solve all the constraints identified in the Table 6.1.

Table 6.2 – Step 2 – Flexibility Needs result

Period	Bus	Active power Needed (MW)	Reactive power Needed (MVar)	$\cos \Phi$
8	13	11.76	3.92	0.95
9	13	2.88	1.08	0.93
10	13	2.93	1.18	0.93
11	13	1.09	0.34	0.95
12	13	0.95	3.57×10^{-4}	1
13	13	1.89	0.82	0.92
14	13	1.78	0.80	0.91
19	13	3.87	1.29	0.95
20	13	15.60	5.14	0.95
21	13	20.15	6.44	0.95
	14	1.36	0.66	0.9
22	13	14.87	5.18	0.94
23	13	13.99	4.85	0.94
24	13	5.59	2.06	0.94

From the analysis of the step 2 results, it is possible to see that the flexibility needs are only in the Bus 13 and 14. This was expected since the constraints were identified only in the branches From Bus 6-13 and From Bus 13-14. The active and reactive power needs results can be seen as the amount of power that is required to inject in that point of the grid or, in another perspective, the amount of consumption that needs to be reduced. A more visual representation of the flexibility needs is depicted in the Figure 6.3.

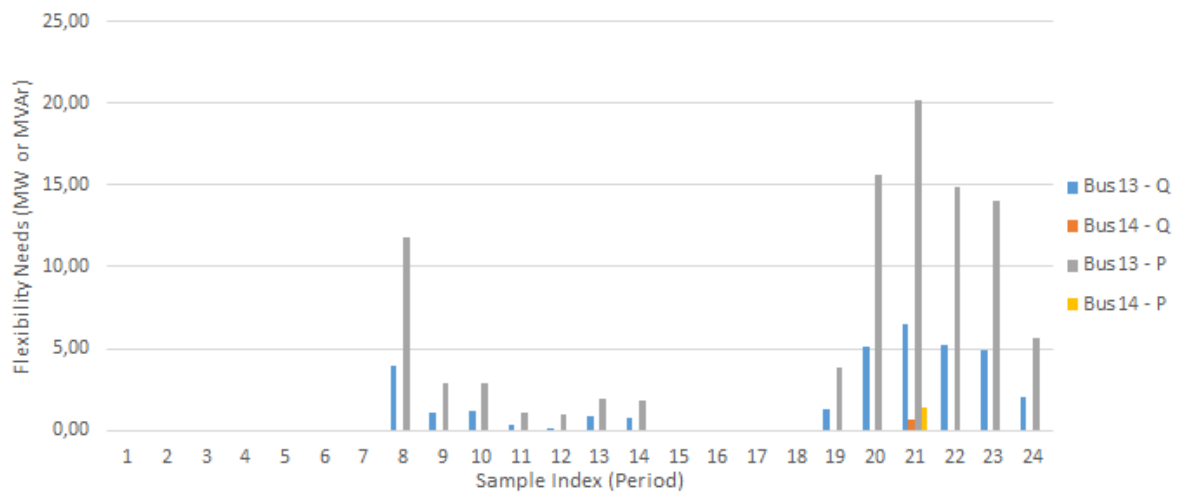


Figure 6.3 – Active and Reactive Flexibility Needs

The 3rd and last step of the tool will not be demonstrated in the scope of this deliverable because it is out of scope, since the consumer flexibility provision will be identified by INESC TEC playing the role of an aggregator. However, a brief explanation of the third step of the tool provides a full picture of its capacities. The last step consists in the FSP flexibility provision optimization, thus, for the identified flexibility needs, this step allows to do the siting, sizing and dispatch optimization to fulfil those needs. This optimization relies on the possibility to use a multistage stochastic linear programming approach to find the expected demand response of the FSP models over the set of scenarios that can be provided as input by the user. The FSP model is a multi-vector energy storage steady-state model that was developed in order to fully characterize the several different technical characteristics of each flexibility source which consumption can be shiftable and shapeable (EV, batteries, prosumers, etc.). The result in the end is the optimal FSP dispatch (active and reactive power response) in order to resolve the grid's flexibility needs while maximizing the power factor of the demand response and the quality of service in the network.

In order to measure the optimal FSP dispatch, the actual flexibility potential from the FSPs needs to be measured. This was accomplished by an analysis carried out by INESC TEC, as previously mentioned, considering a group of MV consumers from a supermarket chain. This analysis answers to the newly added Scenario 5 (Distribution-Connected DERs offers to Solve Transmission-Level Congestions) and was done through the methodology described in Chapter 5 for the consumer flexibility estimation. The example day of the 12th of March 2023 was used for the purpose of gathering results for this deliverable, resulting in the flexibility diagram shown in Figure 6.4 (top orange line). The top orange line represents the flexibility in each 15-minute interval resulting from the Monte Carlo simulation. In blue is the 75 percentile, which is chosen as a risk-taking/mitigation option.

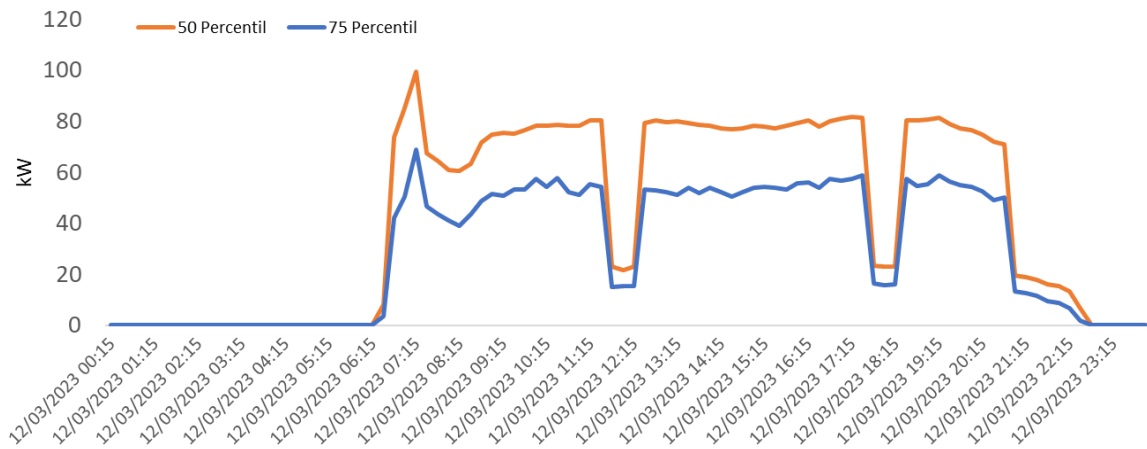


Figure 6.4 - Flexibility forecast estimation for the 12th of March 2023 (P50 and P75)

As explained in Chapter 4, the Scenario 5 of SUC 02, foresees the flexibility potential calculated and evaluated by the Aggregator to be sent to the TSO. This includes the amount of aggregated available flexibility for each of the TSO-DSO interconnection buses. For that purpose, the flexibility for each time slot is then specified according to the message exchange described in the methodology. This is done by converting the csv file exported from excel tool (using crystal ball add-in) to a JSON format in python using the following code steps:

Import the csv file and define the JSON structure

```
import csv
import json
# Open the CSV file and read in the data
with open('12_03_2023.csv') as f:
    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:
    new_dict = {"node_ID": row[0], "active__power_quantity": row[1], "reactive__power_quantity": row[2],
                "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

```
new_data_json = json.dumps(new_data)

# Parse the JSON string into a dictionary
data = json.loads(new_data_json)
key_order = ["sender_source", "grid_nodes", "created_at", "flex_type"]

# Sort the keys of the dictionary based on the key order
sorted_data = {k: data[k] for k in key_order if k in data}

# Convert the dictionary into a formatted JSON string
formatted_json_string = json.dumps(sorted_data, indent=4)

# Print the formatted JSON string
print(formatted_json_string)
```

An example of the resulting JSON file, only for a single time slot, is provided below. The complete daily array will be composed of 96 internal contents. The message will be sent on the previous day of the activation (n-1):

```
{
  "sender_source": 2,
  "grid_nodes": [
    {
      "node_ID": "1",
      "active_power_quantity": 55.40312802,
      "reactive_power_quantity": 0,
      "period_from": "12/03/2023 19:00",
      "period_to": "12/03/2023 19:15"
    }
  ]
}
{all the other time slots}
] "created_at": "2023-03-11T09:25:39.521058",
  "flex_type": 1
}
```

Once the JSON file is obtained, it is ready to be sent as an offer using a POST request to the provided endpoint by R&D NESTER assuming the market clearance role. Below is the code snippet of the POST method used:

Use the URL endpoint where we want to send the POST request to R&D NESTER

```
import requests
import json
url = http://NesterURL_ENDPOINT/api

# send the POST request with the JSON data and headers
response = requests.post(url, data=formatted_json_string)

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

The SUC 02 is concluded with the cleared offers matching with the need reported by the system operator. This will allow the KPI estimation, namely the amount of flexibility offered and the amount of flexibility captured.

6.2 SUC 06

Regarding SUC 06, the 2020 maintenance plans from the TSO were already gathered and they will be used as a proof of concept to try the application of the data model suggested in the Chapter 4.2.3.3. To perform that exercise from the 2020 maintenance plans, two maintenance works were selected and the data model applied filled with the available information:

- Transmission line maintenance work

```
<Maintenance>
<UniqueIDArray>
  <UniqueID> MP2020-1 </UniqueID>
  <WorkDetailsArray>
    <Element-ID>LSV.Moscavide2</Element-ID>
    <Owner>1</Owner>
    <Type>3</Type>
    <Last-Update-By>1</Last-Update-By>
    <Voltage-Level>MISSING</Voltage-Level>
    <Long-Name>MISSING</Long-Name>
    <Case-Type>1</Case-Type>
    <Date-From>2020-01-02</Date-From>
    <Date-To>2020-01-29</Date-To>
    <Time-From>MISSING</Time-From>
    <Time-To>MISSING</Time-To>
    <Work-Period>MISSING</Work-Period>
    <Daily-Replacement>0</Daily-Replacement>
    <Restitution-Time-Working-Days>MISSING</Restitution-Time-Working-Days>
    <Restitution-Time-Out-of-Working-Days>MISSING</Restitution-Time-Out-of-Working-Days>
  >
  <Cause-of-Request>Renovation of the Line</Cause-of-Request>
  <Special-Condition>MISSING</Special-Condition>
  <Remarks>MISSING</Remarks>
  <Person-in-Charge>ACIN</Person-in-Charge>
  <Coordination-Status>1</Coordination-Status>
  <Case-ID-REN>MISSING</Case-ID-REN>
  <Case-ID-E-REDES>MISSING</Case-ID-E-REDES>
  <Unavailable-Capacity>MISSING</Unavailable-Capacity>
  <Date-of-Last-Change>2020-01-02T15:40:00+00:00</Date-of-Last-Change>
  <Remarks-from-Receiver>MISSING</Remarks-from-Receiver>
  <Asked-by>MISSING</Asked-by>
  <Authorization-Sender>MISSING</Authorization-Sender>
  <Authorization-Receiver>MISSING</Authorization-Receiver>
  </WorkDetailsArray>
</UniqueIDArray>
</Maintenance>
```

- TSO/DSO Transformer maintenance work

```

<Maintenance>
<UniqueIDArray>
  <UniqueID> MP2020-2 </UniqueID>
  <WorkDetailsArray>
    <Element-ID>AT 1 400/220 SLGC</Element-ID>
    <Owner>1</Owner>
    <Type>4</Type>
    <Last-Update-By>1</Last-Update-By>
    <Voltage-Level>10</Voltage-Level>
    <Long-Name>MISSING</Long-Name>
    <Case-Type>1</Case-Type>
    <Date-From>2020-03-16</Date-From>
    <Date-To>2020-03-20</Date-To>
    <Time-From>MISSING</Time-From>
    <Time-To>MISSING</Time-To>
    <Work-Period>MISSING</Work-Period>
    <Daily-Replacement>MISSING</Daily-Replacement>
    <Restitution-Time-Working-Days>MISSING</Restitution-Time-Working-Days>
    <Restitution-Time-Out-of-Working-Days>MISSING</Restitution-Time-Out-of-Working-Days>
  >
  <Cause-of-Request>MISSING</Cause-of-Request>
  <Special-Condition>MISSING</Special-Condition>
  <Remarks> Subject to opinion by the producer of the limitations of the Douro; With
influence on the NTC (dates agreed in the REN-REE plan).</Remarks>
  <Person-in-Charge>ELEX-RD</Person-in-Charge>
  <Coordination-Status>1</Coordination-Status>
  <Case-ID-REN>MISSING</Case-ID-REN>
  <Case-ID-E-REDES>MISSING</Case-ID-E-REDES>
  <Unavailable-Capacity>MISSING</Unavailable-Capacity>
  <Date-of-Last-Change>2020-01-02T15:40:00+00:00</Date-of-Last-Change>
  <Remarks-from-Receiver>MISSING</Remarks-from-Receiver>
  <Asked-by>MISSING</Asked-by>
  <Authorization-Sender>MISSING</Authorization-Sender>
  <Authorization-Receiver>MISSING</Authorization-Receiver>
</WorkDetailsArray>
</UniqueIDArray>
</Maintenance>

```

From the analysis of these 2 examples it is possible to understand that the new data model contains a lot of information that is not readily available in the 2020 annual maintenance plans. However, it is important to mention that after several iterations between the OneNet PT teams, Portuguese TSO (REN) and DSO (E-REDES) maintenance departments we came out with the suggested data model that was validated and agreed between all. For the D9.5 we will use the 2020 maintenance plan, that we have available, as basis for the demonstration but will consider some assumptions in order to fulfil the data model accordingly, adapting the missing fields with proper data. With this approach we want to test and show the feasibility of the suggested data model for the exchanging of complete information about maintenance plan between TSO and DSO. After this implementation, the ultimate goal is to receiving feedback from the field teams and the maintenance departments about these new processes how much it can improve the operational activities.

6.3 SUC 08

The goal of this use case is to improve the process of the information exchange between the DSO and TSO regarding short-circuit current forecasts at the TSO/DSO interface. In order to test the information exchange, two substations were chosen in the TSO/DSO interface to perform a full set of the procedures, which includes Scenario 1 and Scenario 2 procedures of the use case, as described in Chapter 4.2.5. Due to confidentiality reasons, the names of the substations are anonymized, however TSO and DSO have all necessary information about the name, location and connection of these substations. In order to have more various options, the SS1 substation was chosen in the northeast of Portugal in the Guarda district, SS2 substation was chosen in the south of Portugal in Faro district. Also, two different days were chosen to show the diversity of the tests: November 20th, 2022 and November 19th, 2022 for SS1 and SS2 substations respectfully.

In the first step, which represents the Scenario 1, the TSO ran the short-circuit currents forecast tool to obtain the XML files with the short-circuit currents from EHV and HV TSO network in two defined substations for the respective day with a granularity of 30 minutes. Since the simulations represent two different days, the results of the calculations were summarized in two different files. The structure of the files is presented below (only 2 hours from the complete files are presented as an example):

- Substation SS1

```
<?xml version="1.0" encoding="UTF-8"?>
<SC_forecast>
  <Sender>1</Sender>
  <data_set_creation_GMT>2023-02-06T14:42:28+00:00</data_set_creation_GMT>
  <data_valid_from_GMT>2022-11-20T00:00:00+00:00</data_valid_from_GMT>
  <data_valid_to_GMT>2022-11-20T23:30:00+00:00</data_valid_to_GMT>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-20T00:00:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS1</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>17.073</Contribution-from-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>1.8815</Contribution-from-HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>0</Contribution-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-20T00:30:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS1</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>17.021</Contribution-from-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>1.8579</Contribution-from-HV-network-TSO>
```

```

        <Contribution-from-active-HV-network-DSO>0</Contribution-from-active-HV-net
work-DSO>
        </SC-TYPE-ARRAY>
        </BUS-ID-ARRAY>
        </FORECAST-ARRAY>
        ---
        ---
</SC_forecast>

```

- Substation SS2

```

<?xml version="1.0" encoding="UTF-8"?>
<SC_forecast>
  <Sender>1</Sender>
  <data_set_creation_GMT>2023-02-86T10:18:53+00:00</data_set_creation_GMT>
  <data_valid_from_GMT>2022-11-19T00:00:00+00:00</data_valid_from_GMT>
  <data_valid_to_GMT>2022-11-19T23:30:00+00:00</data_valid_to_GMT>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-19T00:00:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS2</Bus_ID>
    <SC-TYPE-ARRAY>
      <Contribution-from-EHV-network-TSO>11.286</Contribution-from-EHV-network-TS
0>
      <Contribution-from-HV-network-TSO>0</Contribution-from-HV-network-TSO>
      <Contribution-from-active-HV-network-DSO>0</Contribution-from-active-HV-net
work-DSO>
    </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-19T00:30:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS2</Bus_ID>
    <SC-TYPE-ARRAY>
      <Contribution-from-EHV-network-TSO>11.276</Contribution-from-EHV-network-TS
0>
      <Contribution-from-HV-network-TSO>0</Contribution-from-HV-network-TSO>
      <Contribution-from-active-HV-network-DSO>0</Contribution-from-active-HV-net
work-DSO>
    </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
  ---
  ---
</SC_forecast>

```

Due to ongoing development of the Methods in DDEP API, these files were sent to the DSO by email instead of **Method 08.1 - POST**.

In the second step, which represents the Scenario 2, the DSO calculated the short-circuit currents from active HV network by the DSO Network Planning Tool (DPlan) to add these values to the XML files and update them.

The structure of the updated files is presented below (only 2 hours from the complete files are presented as an example):

- Substation SS1

```
<?xml version="1.0" encoding="UTF-8"?>
<SC_forecast>
  <Sender>0</Sender>
  <data_set_creation_GMT>2023-02-07T11:13:39+00:00</data_set_creation_GMT>
  <data_valid_from_GMT>2022-11-20T00:00:00+00:00</data_valid_from_GMT>
  <data_valid_to_GMT>2022-11-20T23:30:00+00:00</data_valid_to_GMT>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-20T00:00:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS1</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>17.073</Contribution-from-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>1.8815</Contribution-from-HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>1.984</Contribution-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-20T00:30:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS1</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>17.021</Contribution-from-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>1.8579</Contribution-from-HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>1.984</Contribution-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
  ---
  ---
</SC_forecast>
```

- Substation SS2

```
<?xml version="1.0" encoding="UTF-8"?>
<SC_forecast>
  <Sender>0</Sender>
  <data_set_creation_GMT>2023-02-09T11:46:23+00:00</data_set_creation_GMT>
  <data_valid_from_GMT>2022-11-19T00:00:00+00:00</data_valid_from_GMT>
  <data_valid_to_GMT>2022-11-19T23:30:00+00:00</data_valid_to_GMT>
  <FORECAST-ARRAY>
    <forecast_time>2022-11-19T00:00:00+00:00</forecast_time>
    <BUS-ID-ARRAY>
      <Bus_ID>SS2</Bus_ID>
      <SC-TYPE-ARRAY>
        <Contribution-from-EHV-network-TSO>11.286</Contribution-from-EHV-network-TSO>
        <Contribution-from-HV-network-TSO>0</Contribution-from-HV-network-TSO>
        <Contribution-from-active-HV-network-DSO>2.834</Contribution-from-active-HV-network-DSO>
      </SC-TYPE-ARRAY>
    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
```

```

    </BUS-ID-ARRAY>
  </FORECAST-ARRAY>
<FORECAST-ARRAY>
  <forecast_time>2022-11-19T00:30:00+00:00</forecast_time>
  <BUS-ID-ARRAY>
    <Bus_ID>SS2</Bus_ID>
    <SC-TYPE-ARRAY>
      <Contribution-from-EHV-network-TSO>11.276</Contribution-from-EHV-network-TS
0>
      <Contribution-from-HV-network-TSO>0</Contribution-from-HV-network-TSO>
      <Contribution-from-active-HV-network-DSO>2.834</Contribution-from-active-HV
-network-DSO>
    </SC-TYPE-ARRAY>
  </BUS-ID-ARRAY>
</FORECAST-ARRAY>
---
---
</SC_forecast>

```

Again, due to ongoing development of the Methods in TDEP API, these files were sent to the TSO by email instead of **Method 08.2 - PUT**.

In step 3, the KPIs were calculated for the substations. Two KPIs are considered in SUC 08:

- Comparison between the maximum short-circuit current forecasted for the 63kV by the planning and the maximum short circuit value registered for the series under analysis.
- 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.

The rated short-circuit current of the circuit breakers for these substations is defined by the regulatory documents of TSO [20] and DSO [21] and has the values of 31.5 kA and 25 kA, respectfully. The maximum short-circuit current forecasted for the 63kV by the planning is defined by the transmission network development and investment plan (PDIRT) 2022-2031 [22], which is updated every 2 years. The maximum value on each bus is determined, per year, from the maximum value of the relevant peak, valley and off-peak network scenarios simulated for each year, for two types of weather regimes (wet and dry), and for winter and summer seasons, retaining the highest value determined between them. The maximum three phase short-circuit current foreseen for 2022 in PDIRT is 23.6 kA for SS1 and 14.5 kA for SS2, which means that for these substations the value from the second KPI from the list above is lower comparing to the first KPI.

The simulation results are presented for the whole day, firstly for SS1 substation and lastly for SS2 substation and the impact of the distribution level contributions to the total short-circuit current value at the interface bus is assessed.

From Figure 6.5, it can be seen that short-circuit current values for the SS1 substation on the 20th of November 2022 do not surpass the maximum value from PDIRT and are lower than the short-circuit ratings of circuit breakers for TSO (31.5 kA). The maximum value of the total contribution is approximately 94 % of the maximum value from PDIRT. The lowest percentage contribution from the DSO network is 6.98 % (in hour 21:00), when the contribution from the DSO network is the lowest and equal to 1.50 kA and the contribution from the TSO (both step-down transformers and 60 kV private lines, connected to the TSO bay) is the highest and equal to approximately 20 kA.

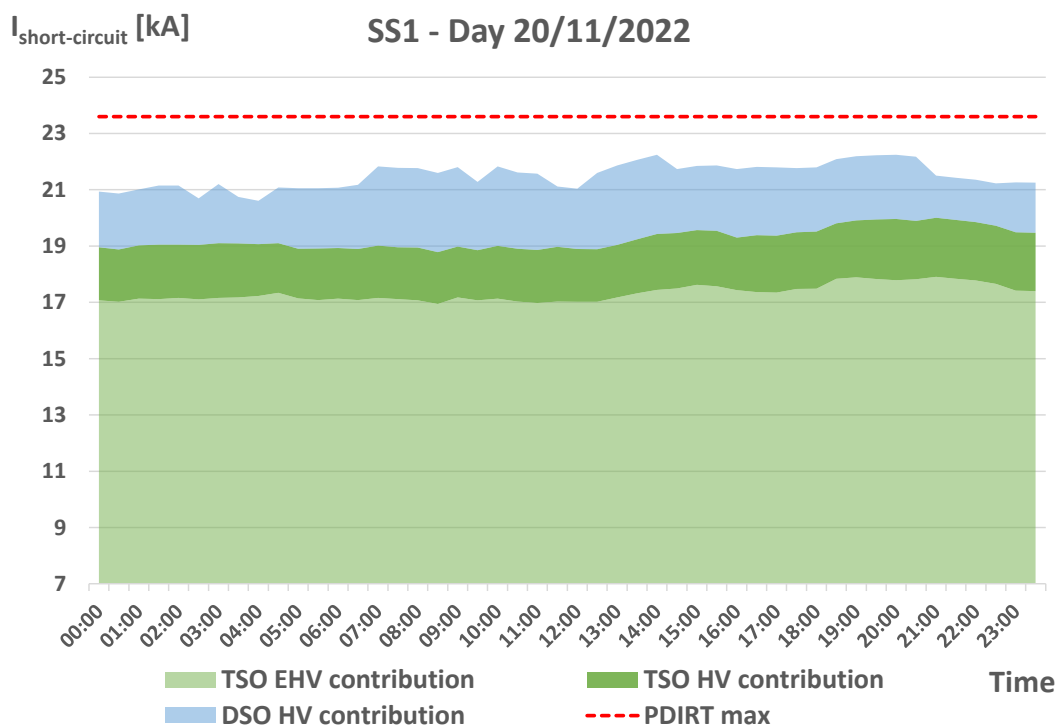


Figure 6.5 - Short-circuit current values for SS1 substation on 20/11/2022

The highest percentage contribution from the DSO network is 13.06 % (in hour 08:30), when the contribution from the DSO network is the highest and equal to 2.82 kA and, at the same time the contribution from the TSO (both transformers and 60 kV private lines, connected to the TSO bay) is the lowest and equal to approximately 18.8 kA. The contribution from the 60 kV lines, owned by the private entity (from which only the TSO has visibility), falls in the range from 9.2 % to 10.8 % of the total contribution from the TSO.

The total short-circuit current value is close to the DSO short-circuit rating (25 kA). Given the fact that the value is measured at the TSO-DSO interface, it would decrease when reaching the MV/LV substations, as the lines contribute to the Short-circuit current reduction. Nevertheless, in situations where the total short-circuit

current is greater, actions such as opening the tie-breakers or transferring producers to another injection point can be considered, or even the possible substitution of these circuit-breakers.

Figure 6.6 shows the short-circuit current values on the 19th of November 2022 for the SS2 substation at the 60 kV TSO-DSO interface bus and the respective PDIRT maximum value. In 5 periods during the day, the total short-circuit current surpasses the maximum value from PDIRT (at 10:00, 11:00, 12:00, 13:00 and 16:30). The maximum short-circuit current occurs at 11:00, corresponding to 14.63 kA which is less than 1 % above the maximum value from PDIRT (14.5 kA). Nevertheless, this value is far from the short-circuit ratings of the TSO and DSO circuit breakers (31.5 kA and 25 kA, respectively).

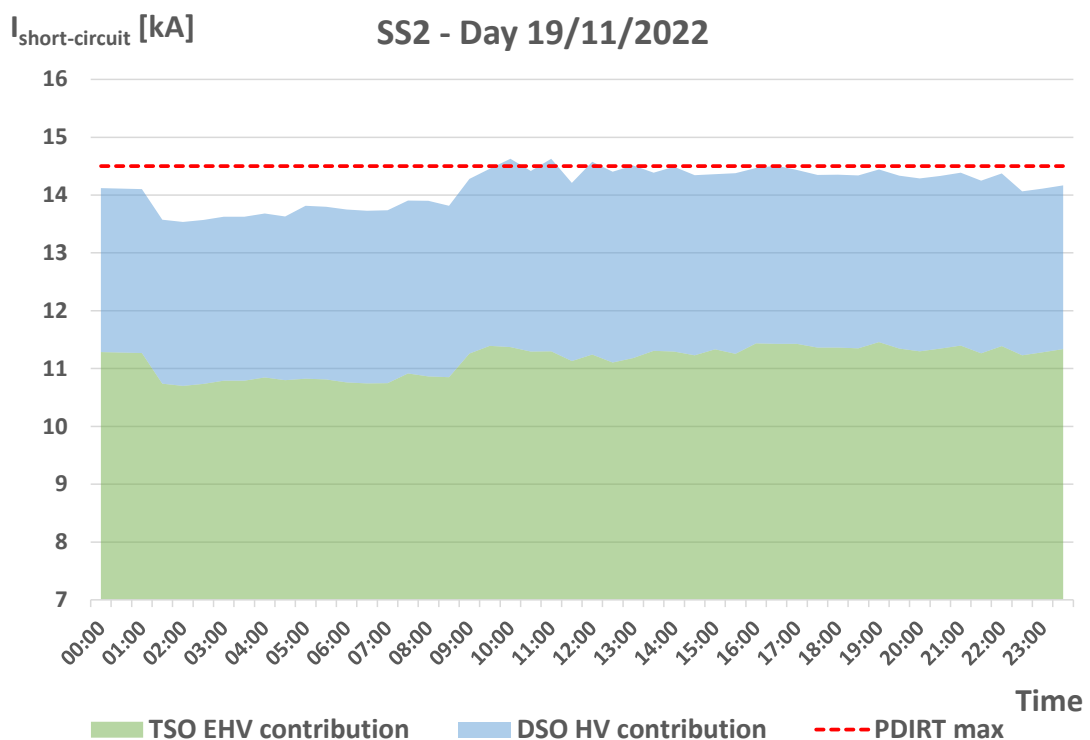


Figure 6.6 - Short-circuit current values for SS2 substation on 19/11/2022

The lowest percentage contribution from the DSO network is 20 % (at 23:30) and occurs during the off-peak period (from 22:30 until 04:30) when the contribution from the distribution side is the lowest and equal to 2.83 kA. Due to the large amount of solar distributed generation integrated within the DSO area correspondent to the SS2 substation, the DSO short-circuit contribution is higher during the peak sun hours given that more PV panels are in service. The highest percentage contribution from the DSO network is 22.96 % (at 13:00) with a contribution of 3.33 kA. The contribution from the DSO network is highest (in value) and equal to 3.34 kA at noon. The short-circuit current values computed are far from the circuit breakers ratings, so, in this case, it can

be confirmed that the security of the grid assets is ensured by the current TSO and DSO short-circuits breakers, having no need of special operational planning measures to control the short-circuit power. Table 6.3 summarizes the main findings from the short-circuit simulations analysis of the two case studies.

Table 6.3 - Summary of the studies short-circuit simulations for substations SS1 and SS2

Case study	Contributions					
	TSO EHV range		TSO HV range		DSO HV range	
SS1	kA	%	kA	%	kA	%
	[16.95-17.91]	[78.40-83.57]	[1.76-2.17]	[8.27-9.78]	[1.50-2.82]	[6.98-13.06]
SS2	kA	%	kA	%	kA	%
	[10.70-11.46]	[77.04-80.00]	0	0	[2.83-3.34]	[20.00-22.96]

From the table it can be seen that, in the SS2 substation, without considering the DSO active contribution, the PDIRT maximum short-circuit current forecast value would not be violated. In this substation the percentage DSO contribution from the total short-circuit value on the interface is between 20 % and 22.96 %. In SS1 substation, the contribution from the DSO is less relevant, however, its maximum value represents 13.06 % of the total short-circuit current value in the TSO/DSO interface.

Although the joint contributions for both case studies are still not a burden from the circuit breaker ratings point of view, the fact that they were higher, in some of the periods analysed, than the PDIRT maximum values (for SS2 substation) shows the added value considering both contributions for asset planning purposes. This is especially true considering that contributions from the distribution side are expected to rise substantially with increased DER penetration. Thus, and taking this ever-changing framework into account, it is clear the relevance of the coordination process defined and tested within this SUC, allowing a more accurate short-circuit current forecast at the interface level and, consequently, a more accurate planning of grid assets and enhancement of the operational activities.

7 Conclusions and next steps

The OneNet project aims to provide a seamless integration of all the actors in the electricity system, fostering the optimisation of the EU electricity system as a whole. The Portuguese demonstration perfectly aligns with this ideal, addressing the interaction between two key actors, the DSOs and TSO, that now, more than ever, need to ensure coordinated activities not only to cope with the uncertainty introduced by variable renewable energies, but also to make the best use of the flexibility potential from assets connected to their networks. In this sense, the demonstration aims for the optimisation of the data exchange between the Portuguese DSO and TSO and clearly defined the steps, processes and methods used, to allow replication in different realities.

Tools, platforms and methodologies developed:

The main objective of the Portuguese demonstration is to optimise the information exchange processes between the DSO and TSO, regarding operational planning and flexibility, with the two corner stones behind this optimisation being the two DEPs developed in the demonstration, the DDEP and the TDEP. The option of developing both DEPs avoids the exchange of sensitive or confidential information, with each DEP having its own database, while, at the same time, guaranteeing synchronisation of these same databases after a request/information is sent from one DEP to the other and approved.

These DEPs are capable of communicating with one another via REST APIs or through the use of the OneNet Connector, the latter, a component that can bring further replicability and scalability of the solutions tested, allowing interaction with external entities. Note that these API-based solutions for these interactions are an advance considering the actual and common practices, which mainly rely on the exchange via e-mail or SFTP, with lower frequency and scope of data. Thus, the testing of these solutions for the exchange of data on operational planning and flexibility between DSOs and TSOs, is important, to understand the benefits and optimisation potential that these would bring.

These also have specific modules directed to the actual deployment of the use cases, including not only the required steps and processes that are internal to the DEPs, but the means of interaction between these modules and the selected applications to manage web databases, web user interfaces and the corresponding tools that each party uses, namely, the tools for flexibility needs assessment, consumption and generation forecast, and short-circuit currents forecast. Although the solutions implemented are tailored to the reality and size of the Portuguese system, which is particular in its scope, comprising one single TSO and one main DSO, these solutions can still be adaptable to different realities. For that purpose, the Portuguese demonstration discloses and thoroughly describes the API methods used, the step-by-step processes for each use case, the architecture of both DEPs and exemplary xml and json code used.

Preliminary results gathering:

Although some developments are still pending and yet to be finalised, preliminary results have been gathered under SUC 02, SUC 6 and SUC 08. Namely, the TSO flexibility needs evaluation and FSP provision simulation tool, that is still being refined, has been tested in a workbench phase to determine the flexibility needs to solve constraints that were emulated in an IEEE test case network (IEEE 14 bus test case), and was able to determine the flexibility needs in terms of active and reactive power in each bus to solve the emulated constraints. Related to these needs identification, are the results already presented from the methodology to determine the flexibility potential from MV consumers from a supermarket chain, where a flexibility forecast estimation diagram was determined for one day of March 2023, and the message to exchange these data with TSO described. The results presented show that the daily maximum flexibility potential from the supermarket chain analysed is very low (~60 kW), in comparison to the order of magnitude of the flexibility needs, that can be assessed by the substation area (which is in the order of MVA). However, since only one type of consumers was considered, it was missing a significant number and type of flexibility assets, thus, an aggregated participation of several industrial partners (and commercial) could in fact result, in an acceptable level of complementary flexibility for the grid in some locations.

Within the use case related to the exchange of maintenance plans, the data model defined has been tested for two works from the 2020 maintenance plans from the TSO, which have been described in this deliverable.

One last use case has already produced results, that is the one related to the information exchange between the DSO and TSO regarding short-circuit current forecasts at the TSO/DSO interface, portraying the relevance of considering both contributions for assets planning and in operational activities. In fact, one of the days analysed presenting contributions from the distribution network higher than 20%, and for some periods in that same day, the joint contribution was higher than the maximum threshold established in the network investment and development plan. Thus, the adoption of such TSO/DSO cooperation procedures provide for a more accurate planning and sizing of grid assets and the overall enhancement of the operational activities. Note that this specific use case and its results were analysed and documented in an approved paper for the CIRED 2023 conference [11].

Next steps:

This document provides an initial overview of the results gathered so far, together with the status of developments within the demonstrator, meaning there are further developments to be done, which implementation will lead to the results to be presented and analysed in the final deliverable of the demonstrator, that is D9.5, which is planned to be published by the end of September 2023.

Regarding backend developments, the integration with the OneNet System is still envisaged, to allow not only the testing and deployment of the RUC, but also its alternative use within SUC 02. This integration is yet to be achieved for both data exchange platforms, DDEP and TDEP. Apart from this, the effective deployment of SUC 01, SUC 02 and RUC are still pending on the DDEP side, from the integration with E-REDES internal systems.

The frontend of both the DDEP and TDEP are near completion and their final layout will be presented in D9.5. As mentioned, this will also be the deliverable where final results and KPI values will be presented, taking into account the calculation methodology, formulation and assumptions described under Chapter 3.3.

Finally, the deployment of SUC 02, SUC 07 and SUC 08 require adaptations to the operational planning tool used by E-REDES in daily activities, so it is capable of not only calculating daily flexibility needs, disaggregated generation and consumption forecasts and short-circuit contributions from the distribution level, but also to be able to interact directly and automatically with the DDEP. These adaptations are also expected for the coming months.

References

- [1] European Commission, “Fit for 55: delivering the EU's 2030 Climate Target on the way to climate neutrality”, July 2021 [Online]. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550>
- [2] European Commission, “REPowerEU Plan”, May 2022 [Online]. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF
- [3] European Commission, “Clean Energy For All Europeans”, November 2016 [Online]. Available: https://eur-lex.europa.eu/resource.html?uri=cellar:fa6ea15b-b7b0-11e6-9e3c-01aa75ed71a1.0001.02/DOC_1&format=PDF
- [4] European Commission, “Digitalising the energy system – EU action plan”, October 2022 [Online]. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0552>
- [5] CEDEC, EDSO, ENTSO-E, Eurelectric, and GEODE, “TSO.DSO Report: An Integrated Approach to Active System Management”, 2019 [Online]. Available at: https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf

- [6] OneNet Project, “D2.3 - Business Use Cases for the OneNet”, 2021 [Online]. Available: <https://onenet-project.eu/wp-content/uploads/2022/10/D2.3-Business-Use-Cases-for-the-OneNet.pdf>
- [7] OneNet Project, “D5.1 – OneNet Concept and Requirements”, 2021 [Online]. Available: <https://onenet-project.eu/wp-content/uploads/2022/10/D51-OneNet-Concept-and-Requirements.pdf>
- [8] OneNet Project, “D9.1 – Specifications and guidelines for Western Demos”, 2021 [Online]. Available: <https://onenet-project.eu/wp-content/uploads/2022/10/D9.1-Specifications-and-guidelines-for-Western-Demos.pdf>
- [9] OneNet Project, “D2.4 – OneNet priorities for KPIs, Scalability and Replicability in view of harmonized EU electricity markets”, 2021 [Online]. Available: https://onenet-project.eu/wp-content/uploads/2022/10/OneNet_Deliverable_D2.4_v2-28122021.pdf
- [10] OneNet Project, “D3.1 – Overview of market designs for the procurement of system services by DSOs and TSOs”, 2021 [Online]. Available: <https://onenet-project.eu/wp-content/uploads/2022/10/D31-Overview-of-market-designs-for-the-procurement-of-system-services-by-DSOs-and-TSOs.pdf>
- [11] Lacerda, M., Glória, G., Cardenas, M., Pestana, R., Egorov, A., Silva, C. D., Lucas, A., Louro, M., “Short-Circuit Currents Information Exchange Between DSO and TSO, an Approach from the Portuguese Demonstration of the OneNet Project”, 2023.
- [12] ENTSO-E, “Outage Business Process and Format”, VERSION 1.1. [Online]. Available at: https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/cim_based/Outage_Business_Process_and_Format_V1R1.pdf
- [13] P.C. Mahalanobis, “On the Generalized Distance in Statistics”, Proceedings of the National Institute of Sciences (India), Vol. 2, No. 1, 1936, pp. 49-55.
- [14] B. Efron. "Bootstrap Methods: Another Look at the Jackknife." Ann. Statist. 7 (1) 1 - 26, January, 1979. [Online]. Available at: <https://doi.org/10.1214/aos/1176344552>
- [15] Oracle, “Crystallball” [Online]. Available at: <https://www.oracle.com/applications/crystalball/>
- [16] T. W. Anderson & D. A. Darling (1954), “A Test of Goodness of Fit”, Journal of the American Statistical Association, 49:268, 765-769, DOI: 10.1080/01621459.1954.10501232
- [17] Lucas, A.; Jansen, L.; Andreadou, N.; Kotsakis, E.; Masera, M. Load Flexibility Forecast for DR Using Non-Intrusive Load Monitoring in the Residential Sector. Energies 2019, 12, 2725. [Online]. Available at: <https://doi.org/10.3390/en12142725>
- [18] Prettico G., Gangale F., Mengolini A., Lucas A. and Fulli G, “DISTRIBUTION SYSTEM OPERATORS OBSERVATORY: From European Electricity Distribution Systems to Representative Distribution Networks”; EUR 27927 EN; 10.2790/701791. [Online]. Available at: <https://publications.jrc.ec.europa.eu/repository/handle/JRC101680>

- [19] University of Washington, “Power Systems Test Case Archive”. [Online]. Available at:
<http://www.ee.washington.edu/research/pstca/>
- [20] REN, 2022, “Caracterização da Rede Nacional de Transporte para efeitos de acesso à rede - situação a 31 de dezembro de 2021”.
- [21] E-REDES, 2022, “Caracterização das Redes de Distribuição a 31 de dezembro de 2021”.
- [22] REN, 2021, “Plano de desenvolvimento e investimento na rede de transporte de eletricidade para o período 2022-2031 (PDIRT-E 2021)”, Annex 16.