Validation & results of Concept Test - France

D9.4

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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.

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List of Abbreviations and Acronyms

Acronym	Meaning
API	Application Programming Interface
ASM	Active System Management
BNO	Business Network Operator
CIM	Common Information Model
CRUD	Create Read Update Delete
DApp	Decentralized Application
DER	Distributed Energy Resources
DSO	Distribution System Operator
gRPC	Google Remote Procedure Calls
HIM	Human Interface Machine
HV	High Voltage. HTB site in France
IAM	Identity and Access Management
ICS	Information Commercially Sensitive
IS	Information System
KMS	Key Management System
KPI	Key Performance Indicator
MV	Medium Voltage. HTA site in France
MWh	Megawatt hour
NAZA	NAZA for New Adaptative Zonal Automata are automata designed to detect and solve congestions thanks to diverse existing levers in order to avoid building expensive additional network. It involves an optimisation algorithm that choses the most efficient decision between topological action, batteries storage or HV/MV flexibility activations. It is under development on several areas of RTE's network and operates near real time to optimise the amount of curtailed energy.
PDC	Private Data Collection
REX	Return on Experience
RTE	Réseau de Transport d'Electricité (French TSO)
TSO	Transmission System Operator

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Executive Summary

This document D9.4 contains the definition, methodology of evaluation and test results of the use case scenarios tested in the French demonstration, conducted by French TSO RTE and main DSO Enedis.

TSO-DSO coordination and cooperation is at the very heart of RTE and Enedis participation of OneNet project.

Thanks to an unprecedented shared governance framework between RTE and Enedis, this joint participation has translated into two business use cases (BUCs) experimenting with various flavors of how this cooperation can help transmission and distribution system operators solve DER activation management issues both in the aftermath of an activation (BUC WECL-FR-01), or prior to an activation, to prevent any contingency (BUC WECL-FR-02).

This document focuses in detail on the business and technical presentation of the two following use cases:

- ⇨ WECL-FR-01 aiming at simplifying and optimizing the management of renewable production curtailments, by covering the entire life cycle of a flexibility order, from the formulation of contract conditions by the DER flex providers to the back-office financial settlement. This BUC results in the creation of a platform underpinned by distributed ledger technology.
- ⇨ WECL-FR-02 reflecting on improving TSO-DSO information exchange for DER activation, to envision a larger toolbox for pre-concerted, technically and economically efficient measures, thanks to improved coordination.

This document presents, for each BUC, the methodology applied all along the experimentation, from functional and technical scoping to the implementation (or "build") phase, and the definition and description of the key performance indicators (KPIs) selected to evaluate the effectiveness of the French demonstration. These KPIs cover quantitative aspects such as the number of FSPs, of DER activations, the available flexibility, the degree of engagement of the flex providers as well as the volume of transactions.

The French demonstration envisaged the creation of the STAR platform that aims to meet the objectives of simplicity and transparency aimed by the first business use case The main characteristics of this platform, including its architecture and components, are showcased in this document, also including the comprehensive user journey illustrated by visuals of the platform. The platform has been thoroughly and continuously tested, prior to, and during production phase and during the opening of the service to DER flexibility providers. The results of the tests can be found in these pages and demonstrate a successful robust test coverage, carrying the planned tests and implementing production data. In a nutshell, the STAR platform was successfully designed to meet the requirements of the use cases' scenarios in terms of data model, shared governance and architecture. As envisioned, the blockchain technology helped achieve transparency and data uniqueness goals, and further analysis on pros and cons of the technology choices will be developed in deliverable D9.7 [8]. As all technical

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and functional tests were successfully executed, STAR has been running in experimental phase, focusing on registering automated and manual flexibility orders related to local congestion management.

The results of the experimentation, including the learnings in terms of data collection and standardization shall be found in the One Net Deliverable D9.7 [8] of the French Demo.

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1 Introduction

Constantly evolving electricity management and production leads actors to adapt to these changes by using innovative ideas and technologies. As seen in **Error! Reference source not found.**, the scenario is leading to the creation of new types of actors and a growing number of Distributed Energy Resources (DERs) being integrated in the networks. France is no exception and faces this problematic within its context of electricity network management.

The transmission network is managed by a historical player, the TSO RTE (Réseau Transport Électricité). RTE is responsible for the balance between supply and demand in the French network.

Enedis is the main French DSO and ensures 95% of power distribution in France and serves around 37 million clients that are connected to low and medium voltage grids.

The distribution network is evolving with more and more energy producers being connected directly to the distribution network. France is encouraging the development of electricity production of renewable energy (wind, solar, etc.), which leads to a multiplication of small- and medium-sized FSPs. In addition, the exchanges between the System Operators and the FSPs are becoming more complex due to this growth.

The OneNet French Demonstration is divided in two parts: the implementation of STAR (System of Traceability of Renewables Activations) and the study on innovative ways for TSO-DSO information exchange for DER activation. In the STAR project, the objective was to ensure a better integration of FSPs into the French electricity grid. It is in this context that STAR was born with the vision of a decentralized platform bringing together France's TSO RTE, its main DSO Enedis and RES producers, identified as Flexibility Service Providers (FSPs) in the current document, and building trust between them, focusing, up until now, on demonstrating its potential in the case of simple congestion management. The OneNet project aims at creating the 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 the consumer. The STAR project aims at being fully integrated and involved in the OneNet project philosophy, by streamlining congestion management in a transparent way for flexibility providers and system operators. In parallel, RTE and Enedis have reflected on further coordination means between TSO and DSO, focusing on possible new data exchange in order to improve both entities' flexibility usage optimizations in a broader context than congestion management.

The present deliverable is part of the Work Package 9, with a focus on one of the three Western Cluster demonstration countries which is France.

The work conducted in Document D9.4 can be divided into different steps:

1. Overview of the French demonstration
2. Focus on the first Business Use Case: STAR Platform

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3. Focus on the second Business Use Case
4. Provision of a study of the evaluation and results related to the entire French demonstration.

1.1 Task 9.4 objectives

The French demonstration is part of the Work Package 9, which addresses the work of the three Western Cluster demonstration countries: Portugal, France and Spain. Its contribution is the result of task 9.4 which is focused on implementing and experimenting enhanced information sharing related to congestion management using the STAR platform, and further reflection on coordination between TSO and DSO. Task 9.4's objectives are the following:

- Implementation of the STAR platform using open source blockchain technologies and assessing their performance and relevance;
- Tests of its functionalities on real flexibilities activations related to congestion management;
- Collection and analysis of data registered during the experiment;
- Reflection on further ways that TSO and DSO can coordinate on flexibility usage.

1.2 Interaction with WP9 and other WPs

Task 9.4 has interactions with other tasks and work packages in which definitions affecting the French demonstration were taking place. The main interactions are summarized in the Figure 1: Interaction within WP9 and other WPs below:

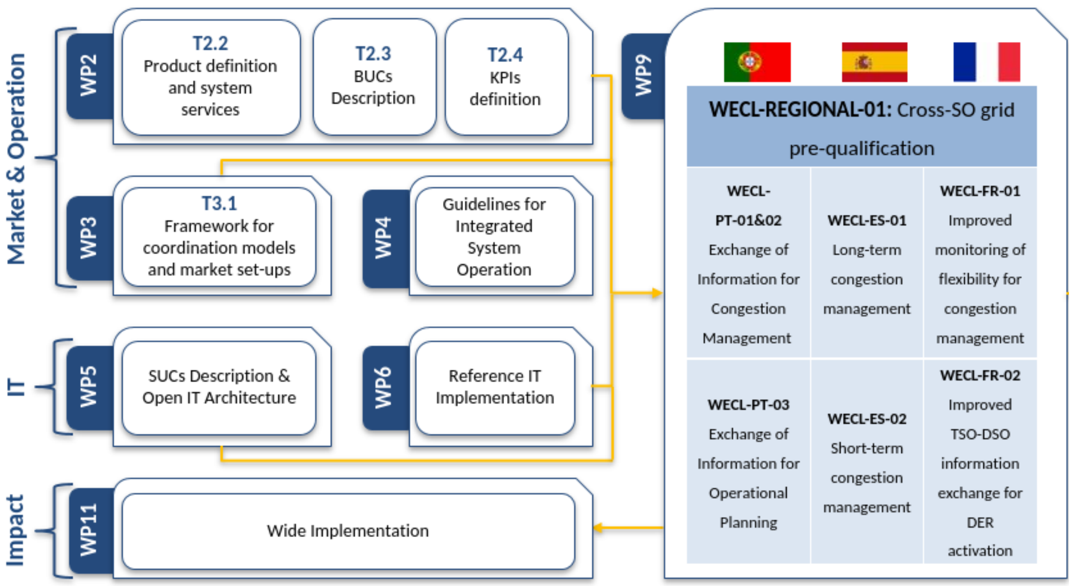

Figure 1: Interaction within WP9 and other WPs

- WP2 "Products and services definition in support of OneNet" provided a standardized understanding of products and services [1], Business Use Cases (BUCs) definition [2] and Key Performance Indicators (KPIs) definition and overall alignment [3].
- WP3 "Integrated and coordinated markets for OneNet" provided definition of coordinated and scalable markets for the procurement of system services by DSOs and TSOs [4].
- WP5 "Open IT Architecture for OneNet" provided System Use Cases (SUC) definition and technical requirements for platform development and the OneNet system description [5].

The output of this task is an input for Task 9.5, which will integrate the results coming from the three different member states involved in WP9, and for Task 9.6, which will provide a vision and strategy in the form of main findings and lessons learned for the comparative assessment of the overall results coming from the four different demos clusters: Western, Southern, Nordic and Eastern. Additionally, the data obtained in this task will be collected from the demo site and aggregated for further analysis in WP11 and linked to direct collaboration with different projects in WP12.

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2 Methodology

2.1 Methodology Overview

Figure 2 below summarises the methodology used to perform an evaluation and provide results of concept tests on STAR project. This methodology covers only the scope of STAR use case WECL-FR-01, as the second use case refers to a study and doesn't require the same approach.

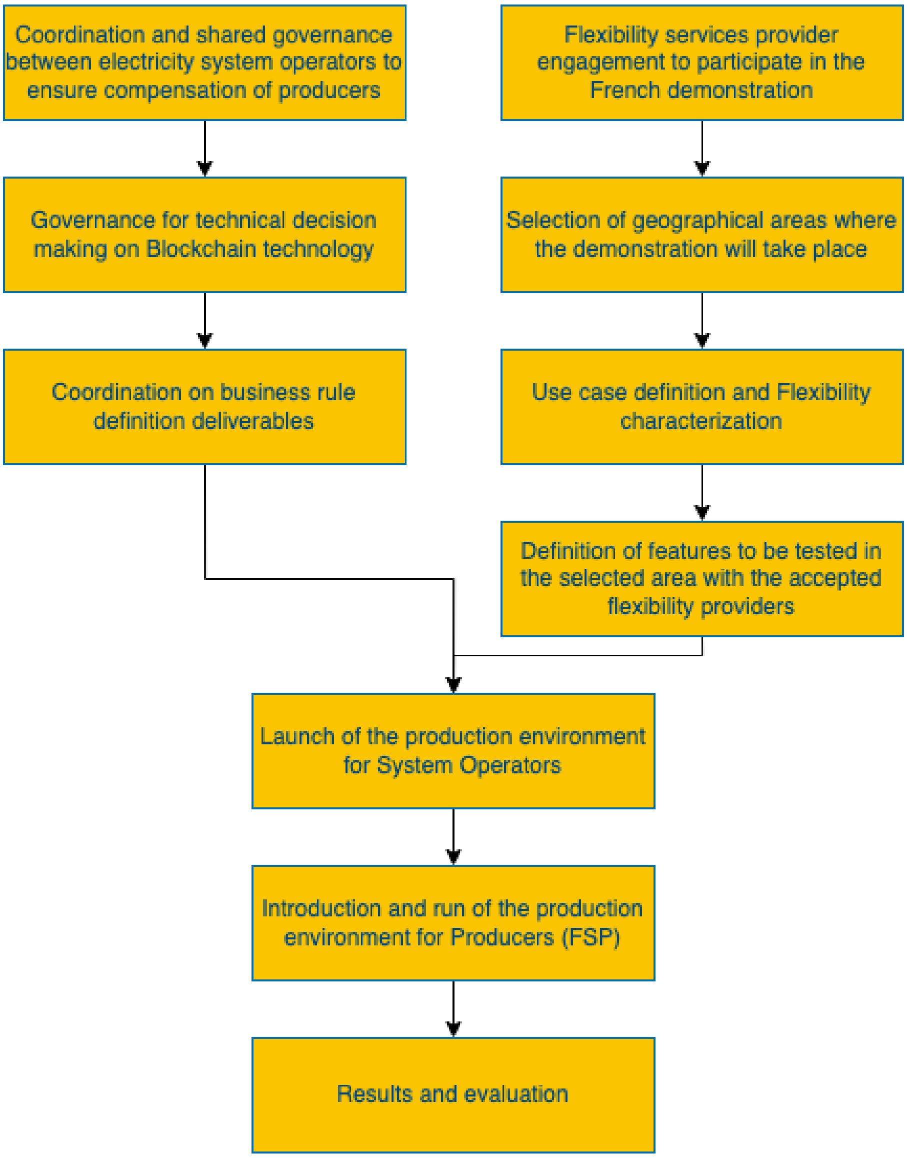

Figure 2 : Methodology process

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2.2 Governance principles of the STAR project

The management of the STAR project is based on a formalized process of decision making, situation assessment, consultation, and communication between RTE and Enedis managers and STAR project members. While keeping as a main objective the integration of renewable energy FSPs, the STAR project allows the creation of a complete ecosystem around the flexibilities of the French electrical network.

Decisions are taken by RTE and Enedis unanimously and according to a principle of consensus building. This applies to the following elements:

- The principles and objectives of the STAR project;
- Definition of the scope of the STAR project;
- The definition of the business rules;
- Definition of the STAR rights matrix and data model;
- Project monitoring and prioritization of developments along the way;
- The elements of the feedback (REX) and the orientations for replicability and scalability of STAR.

During this project, the challenges addressed are multiple, and include:

- Considering the specificities of a blockchain network, involving the definition and implementation of organizational, operational, and technical governance between the stakeholders;
- The definition of a joint business process and the standardization of data exchanges, based on existing standards: this is reflected in the definition of the use cases and in the data model;
- The respect of confidentiality requirements, in the context of sharing commercially sensitive information (CIS). STAR's confidentiality rules are set out in the rights matrix.

The data model, defining the objects of STAR, their attributes, and the links between these objects, as well as the rights matrix, defining the read and write rights of each type of participant in STAR at the level of each object, are therefore the result of consultation between RTE and Enedis within the framework of the experimentation.

2.3 Governance principles during development and Run phases

2.3.1 Development phase

During the development phase, the requirements were decided by the System Operators RTE and Enedis.

This phase allowed the creation of a first version of the platform that was used by the whole ecosystem: System Operators and FSPs.

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The needs were collected during business workshops where the progress of developments were presented. The System Operators jointly defined the prioritization of the developments with the aim of having the functionalities with the most impact for the FSPs. The main outcome of the prioritization workshops have been to start on the technical set up of the platform, the key master data input, before focusing on the upstream phase of activation of flexibilities (curtailment) and, lastly, downstream phase, in a sequence of features following logical order (for instance: energy amount calculation before compensation).

Also, in a second phase some specific business workshops with FSPs allowed the System Operators to define their specific needs, on the basis of dashboards and mockups presented to narrow down the user experience.

2.3.2 Run phase: Platform in Production with FSPs

Once the platform was released for production, we organized 2 workshops to collect the specific requirements of the FSPs in relation to their use, in a more advanced phase of the project. Three FSPs were particularly active in providing feedback. For example, the FSPs discussed the importance of having a way to provide their input on data shared by system operators, while avoiding having to stop systematically the back-office management process. This feedback resulted in a product feature regarding the integration of producers' feedback flow, being addressed by system operators. A request for feedback was sent to each FSPs in order to evaluate the methodology of use of the platform and its relevance to the initial needs for both FSPs and system operators.

In parallel, the platform continues to be improved according to the feedback of the System Operators RTE and Enedis. This can result in new functionalities or operational needs by improving the existing functionalities.

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3 Overview of the French demonstration

3.1 Overview of the French demonstration

The OneNet French Demonstration is divided into two parts: the implementation of STAR (System of Traceability of Renewables Activations) and the study on innovative ways for TSO-DSO information exchange for DER activation.

3.1.1 Overview of the STAR platform

STAR is a monitoring platform that allows sharing relevant information for the settlement but not directly undertaking the physical activations at grid level. Encompassing use case WECL-FR-01, the STAR project aims to build a shared ledger to simplify and optimise the management of renewable production curtailments by covering the entire life cycle of a flexibility order, from its formulation to the monitoring of the invoicing process from their activation. The final goal has been to build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network. The generation curtailment monitored by the STAR platform is determined by the French energy code and the nature of the contract between the system operators and generators. Therefore, the active power generation curtailment is similar to the activation of flexibility for congestion management purposes.

The flexibility services tracked by STAR are mainly focused on congestion management. The STAR platform only tracks information regarding curtailments orders but does not activate any of them. The activation remains the responsibility of System operators. The core of the STAR demonstrator is proving the technical feasibility of the platform. Aspects related to the flexibility procurement are out of the scope of the French demonstration. The platform to be built in the STAR project only tracks the producers' production, curtailments orders and compensation rights.

The analysis of the implementation of STAR, which tracks the active power generation curtailment of renewable generators, is linked to the mechanisms used to define the network access agreements that specify the producers' curtailment obligations and compensation. The STAR platform uses existing mechanisms; therefore, no new markets or flexibility procurement mechanisms are developed within this OneNet demonstrator. As mentioned in the deliverable D3.1 [6], the compensation mechanisms in which STAR will be used as a data register are the connection agreement contracts (both for TSO and DSO).

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3.1.2 Overview of the Improved TSO-DSO information exchange for DER activation

RTE and Enedis are regularly required to activate flexibilities on the transmission and/or distribution network for various reasons (e.g. balancing, voltage and congestion management). These activations are carried out either manually or automatically, through various mechanisms (direct activations and/or market mechanisms) and are expected to play an increasingly important role in the management of networks and the power system, on the different time scales.

Both Enedis and RTE support the development of these flexibilities' use at the lowest cost for the community, from the grid planning phase to the activation of these flexibilities. Whatever the chosen scheme, the activation of a flexibility must be done while guaranteeing that the impacts for each SO on its perimeter are checked (safe and secure operation of the networks and more widely of the power system). However, examples presented in the study suggest that further cooperation between SOs will be necessary to maximize renewables' flexibility potential.

The aim is then to reflect on post OneNet future coordination means that would enhance and optimize flexibility usages, in a technically and economically efficient way.

3.2 French Use Case WECL-FR-01 - Improved monitoring of flexibility for congestion management

3.2.1 Scope and Objectives

Faced with the challenges of the energy transition, Enedis and RTE are experimenting with new technological solutions to integrate new flexibility mechanisms to manage congestions on their networks. The improvement of monitoring of flexibility for congestion management purposes is the focus of this BUC.

This use case is based on blockchain technology. It aims to simplify renewable production curtailments by improving the back-office of the transactions, reducing administrative burden and risks of dispute. It should provide enhanced monitoring during the entire life cycle of a flexibility order, from the traceability of the renewable production curtailment to checking their activations for invoicing. The final goal is to build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network.

BUC ID	WECL-FR-01
BUC Name	Improved monitoring of flexibility for congestion management
Scope	Simplify the management of renewable production curtailments

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Objectives	1. Simplify the management of renewable production curtailments, by covering the entire life cycle of a flexibility order, from the formulation to the control of their activations for invoicing using blockchain technology; and 2. Build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network.
Services	Corrective active power management for congestion management (CM)
Type of coordination	Technical based TSO-DSO coordination

Table 1: Overview of Business Use Case

3.2.2 Short Narrative and BUC overview

Permissioned blockchain technology define particular distributed ledger technologies where known actors receive a permission to join a network to share data within this network. Contrary to public blockchains, where anonymous or pseudonymous actors exchange data in an open network, permissioned blockchains are crafted for the needs of company data exchanges, allowing for a high level of confidentiality, and performance, in an identified network.

Using permissioned blockchain technologies, a shared ledger has been implemented to establish a decentralized trust framework among renewable energy generators, market participants (producers), the DSO and the TSO. All participants have access to the STAR platform to provide more transparency and visibility while preserving business confidentiality. Shared governance rules have been defined to account for the role and needs of each involved party. The platform hosts and gives access to the following information: curtailment activation orders and metering data.

The blockchain-based demonstrator is validated in two experiments (see Figure 4):

- The first one will be coupled with a new grid automation system so called NAZA which had been studied during CPS4EU project [6] that will act in near real-time to resolve grid constraints by activating the most technically and economically optimal remedial action including topological modifications or generation curtailment;
- The second one will focus on manual curtailment activations orders sent by the DSO for DSO or TSO needs.

The area of Melle-Longchamp (Figure 3) located in the South-West of France has been chosen to conduct these two cases that will involve TSO, DSO and generators.

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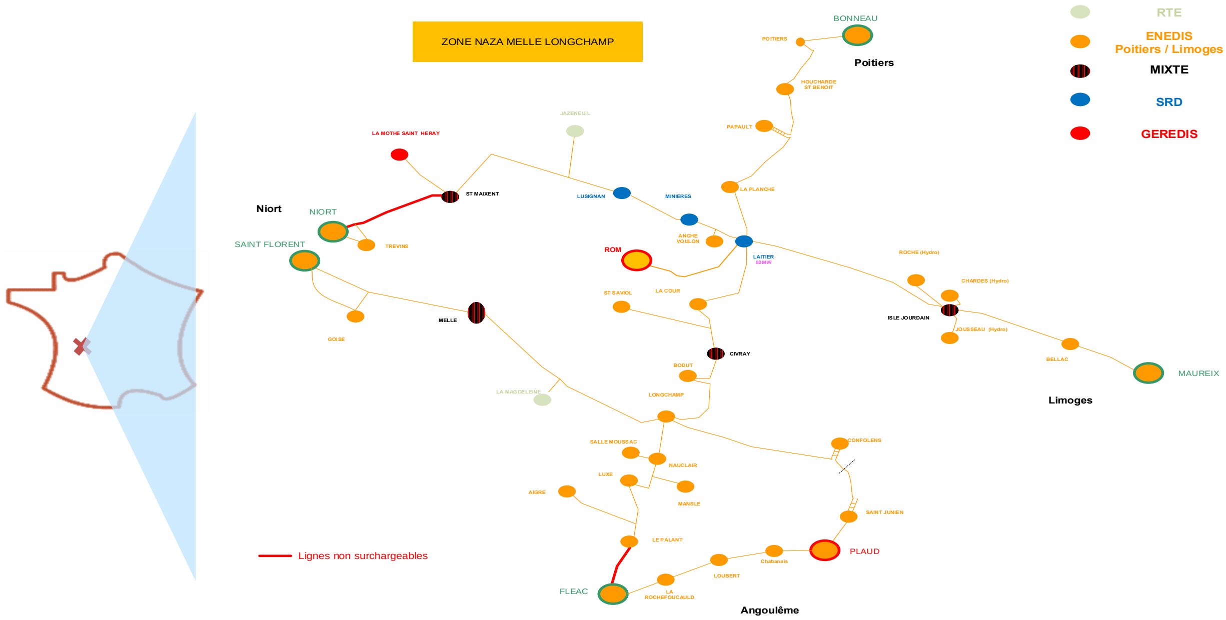

Figure 3 : Area of Melle Longchamps chosen for both use cases

It is worth mentioning that this BUC (described in the OneNet deliverable D2.3 [2]) makes use of the two SUCs designed in the French demonstration, as described below:

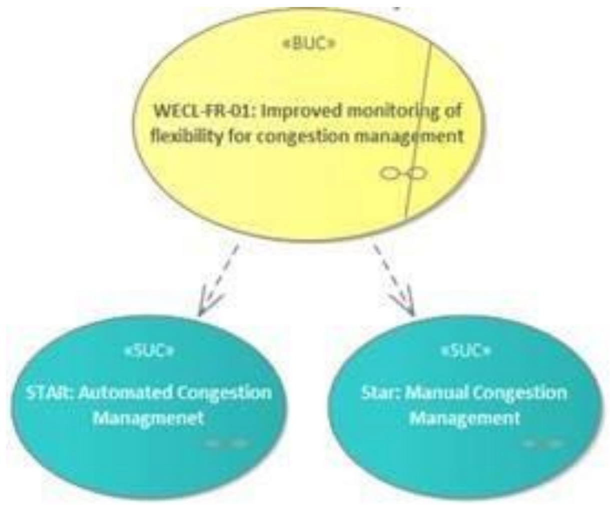

Figure 4 : Overview diagram of BUC WECL-FR-01

- SUC-FR-01 - Automated congestion management (described in the OneNet deliverable D5.1 [5]): to simplify and optimize the management of renewable production curtailments, upon the development of the STAR platform, it is required to define the information exchanges and processes

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needed to perform the related BUC's traceability objectives in the case of TSO automated activations, which are presented in Figure 5 below.

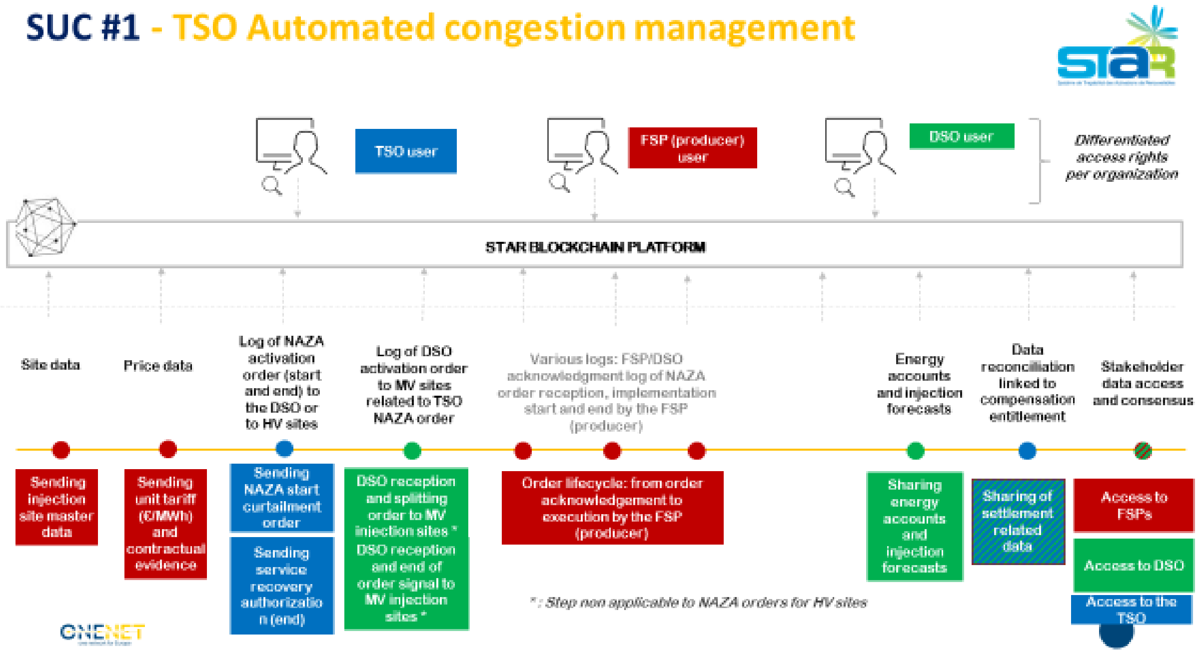

Figure 5: SUC FR-01

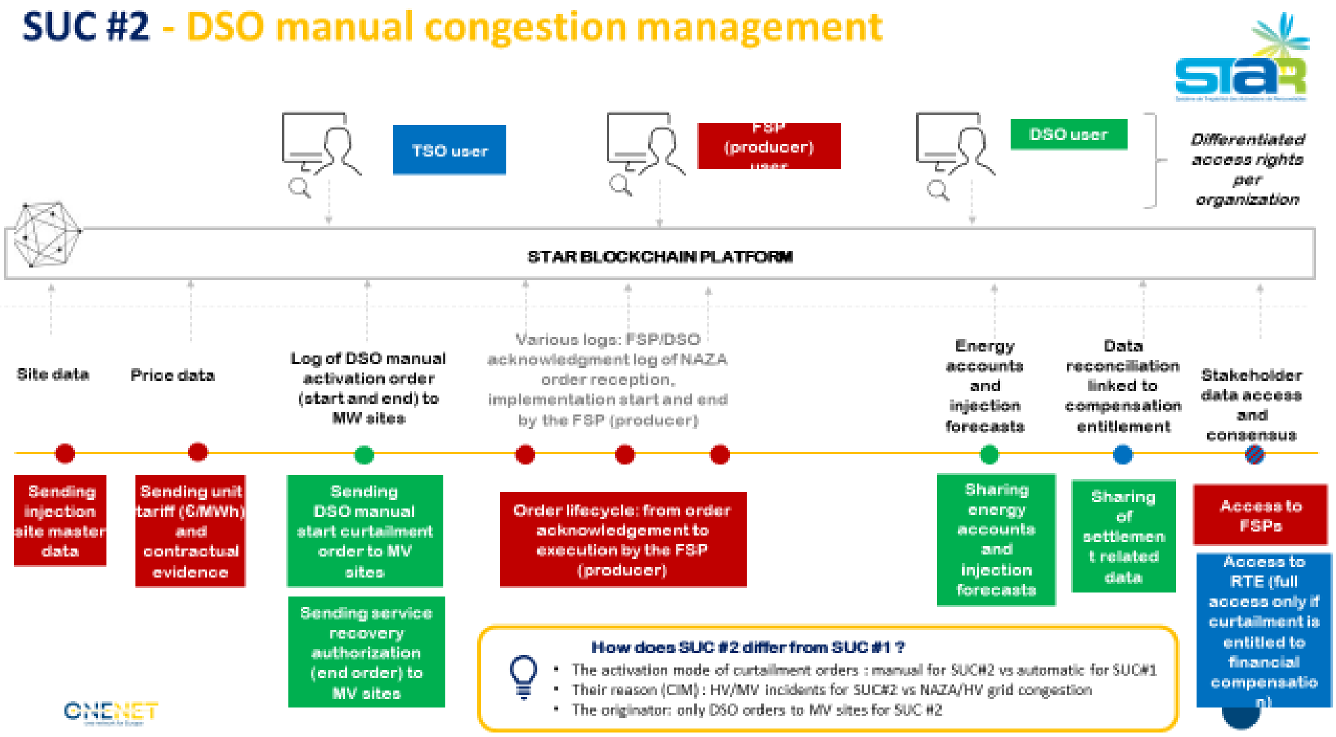

Figure 6: SUC FR-02

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- SUC-FR-02 – Manual congestion management (described in the OneNet deliverable D5.1 [5]): this SUC provides requirements for data exchanges and processes (see Figure 6) between TSO, DSO, FSPs / FSPs for the STAR platform to handle the related BUC's traceability objectives in the case of DSO manual flexibility activations.

Figure 7 below illustrates the scope of responsibilities of actors in BUC WEC1-FR-01:

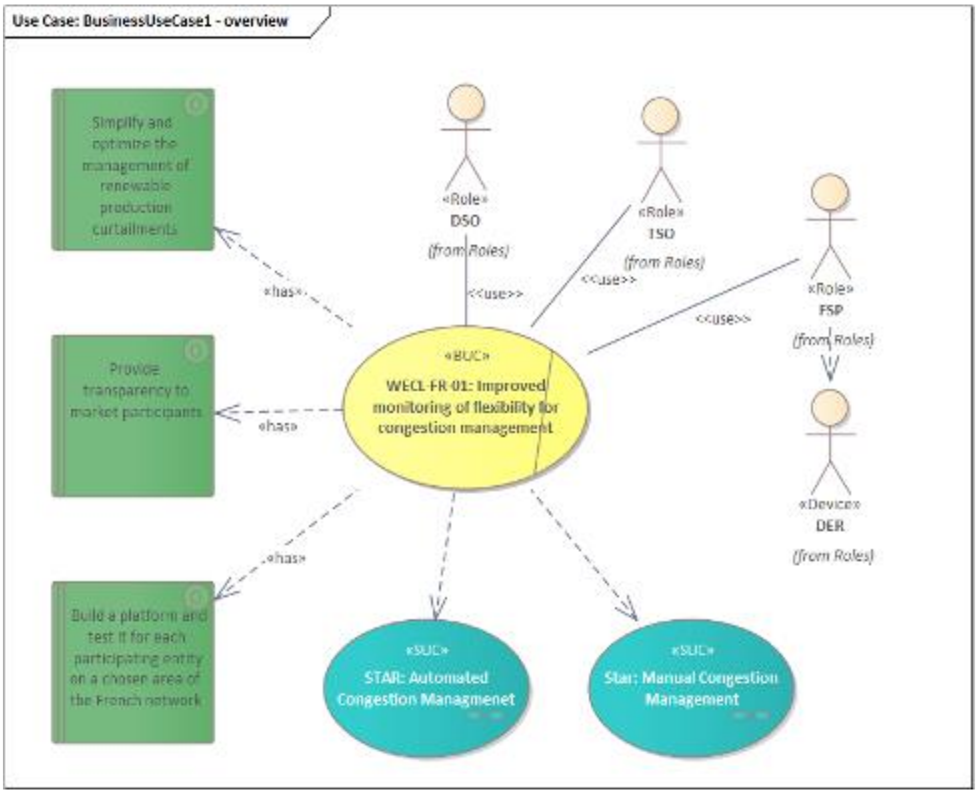

Figure 7: WECL-FR-01 actors' contribution on the project

3.2.3 Demo site characteristics

3.2.3.1 Network characteristics

The experiment will take place in the southwest part of France, in the area of Melle-Longchamp (see Figure 3 and Figure 8). It encompasses 30 power lines ranging from 63 kV up to 400 kV, which sometimes face congestions due to a strong power generation west of the area and a high demand in the area. Curtailment NAZA automata are already under experimentation on this network that uses renewable generation curtailments to manage these congestions, with around a dozen executed flexibility activation orders last year. It will be one of the demo's objectives to track these orders in this area.

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Figure 8: Network for the French demonstration

3.2.3.2 Resources characteristics

The Melle-Longchamps area has five substations that are connected to the NAZA automata. On the DSO network, twelve wind powerplants (from 2,3 MW to 12 MW) and two solar power plants (from 2,3 MW to 4,4 MW) are involved in the demo, but only wind powerplant is concerned by the SUC 1 (Traceability by automating activation). Workshops were scheduled with considered producers in order to determine their level of commitment in providing the relevant data and implementing the designed processes.

3.2.4 French Platforms and Architecture Approach

The demo’s architecture is presented in Figure 9 . It illustrates a distribution between RTE, Enedis and FSPs.

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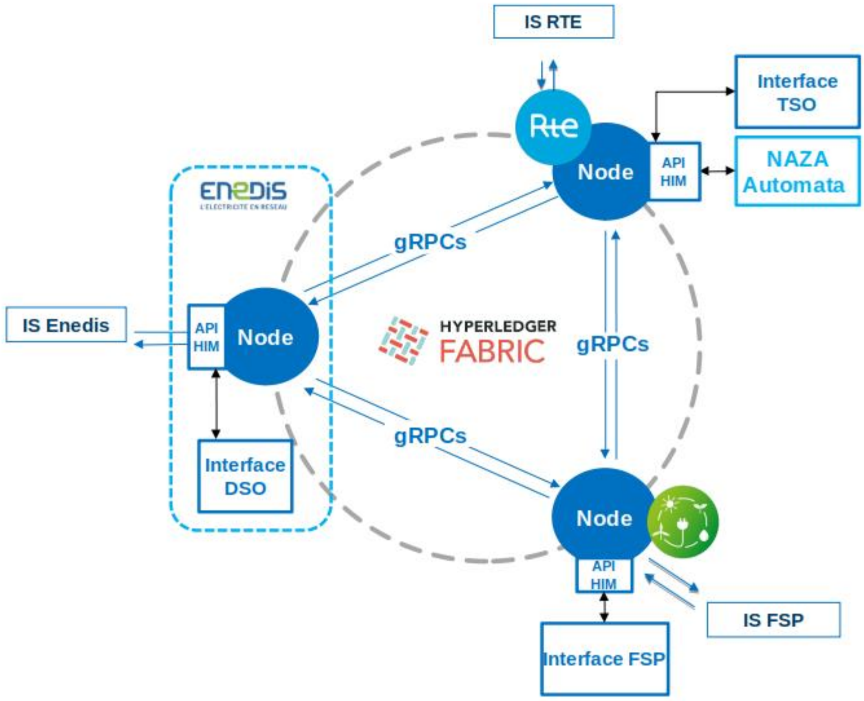

Figure 9: Preliminary architecture of platforms in the French demonstration[1]

The platform consists in a decentralized, shared register that will enable to track flexibility activations. It relies on a blockchain technology using the Hyperledger Fabric framework. It should be hosted in three different nodes: one managed by the TSO, another by the DSO and the last one for the FSPs.

The platform is planned to build REST API and HMI for the different actors to store either manually or automatically relevant information such as activation order, execution logs, metering data, etc… For instance, flexibility orders formulated by RTE's NAZA automata should be automatically transmitted thanks to a link to the blockchain. The access to these APIs will be subject to restrictions according to the posting and reading rights defined for each actor.

3.3 French Use Case WECL-FR–2 – Improved TSO-DSO information exchange for DER activation

3.3.1 Scope and Objectives

Regarding the limitation of MV and HV generation to manage congestion related constraints:

[1] The French architecture will also communicate with the OneNet System, Nevertheless, as the definitions are not completed, interactions are not yet depicted.

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- Enedis, in its role as a distribution network operator, chooses the best lever (set of production sites to be curtailed) on its perimeter, and is responsible for distributing the power variation set point to the connected sites to ensure optimal management of local flows (local technical-economic precedence), taking into account the need expressed by RTE at the networks interface
- For its part, RTE anticipates the need to take into account the technical and economic precedence of the various levers, including those requested at both networks interface (today mainly MV renewable flexibilities) when activating them in order to minimize the cost of network development for the community. Finally, the trend is for MV sites to participate in balancing services in a similar way to HV sites. Only RTE is managing the HV grid; this does not include Enedis. In the current state, the interaction mechanisms between these 3 "optimizing" processes (optimizing DSO, optimizing TSO, including balancing) are insufficient to ensure an optimal coordination and the approximation of a global optimum. Indeed:
- It is possible that an activation of flexibility connected to the distribution network or the transmission network leads to unforeseen constraints on the DSO or TSO networks (one could think of a postponement of transits causing new congestion, or voltage constraints).
- RTE cannot for the moment take into account the technical and economic precedence of the distributed levers available when activating, as it has no visibility downstream of the source substation, and thus minimise the cost of network management for the community.

Originally, as presented in deliverable D9.1 [7], the purpose of the BUC was to propose a method that would guarantee that the activation of curtailments by one TSO or DSO will not trigger other constraints on one or another network. Given the ongoing discussions between RTE and Enedis on this field, a decision has been taken to adopt a larger approach rather than focusing the study on a topic where a sufficient level of joint maturity was not yet reached. Hence, it has shifted towards a broader reflection on what coordination means should RTE and Enedis consider in the future to enhance and optimize flexibility usages, without jeopardizing each SO's prerogatives.

Hence the following BUC description:

BUC ID	WECL-FR-02
BUC Name	Improved TSO-DSO information exchange for DER activation
Scope	RTE and Enedis are regularly required to activate flexibilities on the transmission and/or distribution network for various reasons (e.g. balancing, voltage management and congestion following network sizing methods). These activations are carried out either manually or automatically, through various mechanisms (direct activations and/or market mechanisms) and are expected to play an increasingly important role in the management

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	of networks and the power system, on the different time scales. Both Enedis and RTE support the development of these flexibilities' use at the lowest cost for the community, from the network sizing phase to the activation of these flexibilities. Whatever the chosen scheme, the activation of a flexibility must be done while guaranteeing that the impacts for each TSO on its perimeter are controlled (safe and secure operation of the networks and more widely of the power system). However, it seems that further cooperation between SOs will be necessary to maximize renewables' flexibility potential. The aim is to reflect on future coordination leads that would enhance and optimize flexibility usages, without jeopardizing each SO's prerogatives
Objectives	1. List TSO and DSO common flexibility usages 2. Describe examples of situations involving flexibility activations where further TSO/DSO cooperation is needed 3. Reflect on what coordination principles should be considered in the future
Services	Service agnostic
Type of coordination	Technical based TSO-DSO coordination

Table 2: Overview of WECL-FR-02 Business Use Case

3.3.2 Short Narrative and BUC overview

RTE and Enedis will work on a common methodology to determine the "shared information TSO/DSO congestion management in case of activation of distributed flexibility" as described in the section above and have determined the sub-tasks of such a work.

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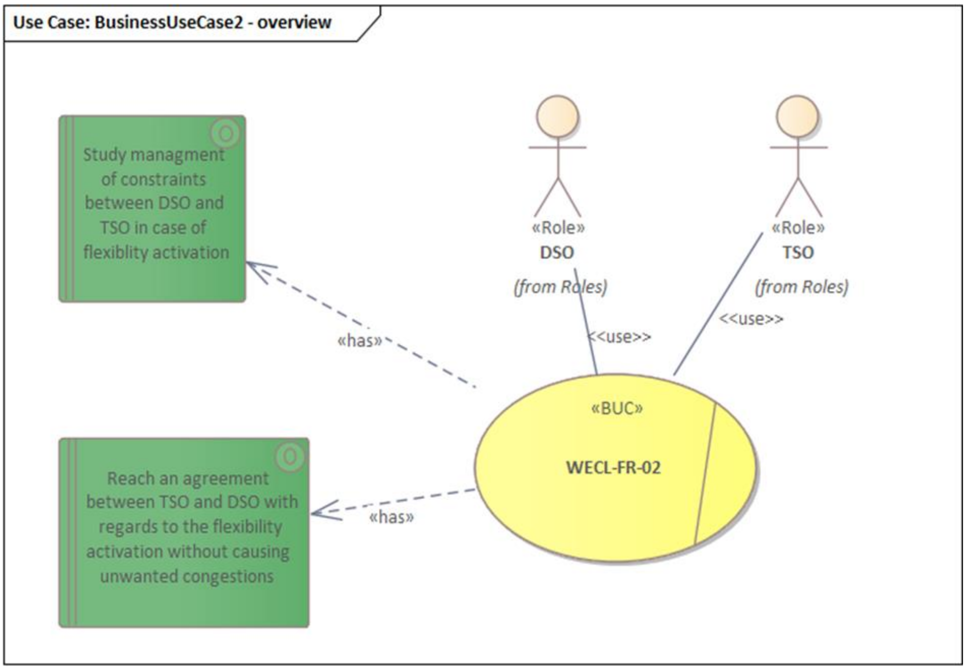

Figure 10: WECL-FR-02 Business Use case actors' contribution

3.4 Key Performance Indicators

According to the KPIs provided in WP2 [5], this part represents a definition of the KPIs related to the whole OneNet French demonstration. The objective is to expose their definition and the criteria associated with them. All the results corresponding to these KPIs will be presented in deliverable D9.7 [8].

3.4.1 Number of service providers

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
General Information	**1. KPI ID**	KPI_H01
	2. KPI Demo ID	FR_BUC_KPI_01
	3. Name	Number of Service provider involved
	4. KPI domain	Technical
	5. KPI category	General descriptive
	6. Description	Number of FSPs involved in the demonstrator
	7. OneNet Pillar	
	8. OneNet Objective	
	9. OneNet Cluster	Western cluster (WP9)
	10. OneNet Demonstrator	French demo
	11. Related UC(s)	WECL-FR-BUC-01
	12. Link with other projects	Harmonized KPI

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	13. KPI responsible	RTE and Enedis
Calculation information	**14. Formula**	Nb_{FSP}
	15. Variables	Nb_{FSP}: number of service provider involved in the demonstrator
	16. Unit of measurement	-
	17. KPI baseline explanation	No historical or simulation value available, the value at the start of the demo when no FSP is involved would be 0.
	18. KPI baseline source	No historical or simulation value available, the value at the start of the demo when no FSP is involved would be 0.
	19. Baseline responsible	Not applicable
	20. KPI target value	2 to 3
	21. Calculation Methodology	Counting the FSP involved or not in the demo and computing the defined formula.
	22. KPI computation timing	M28
	23. Gaps and challenges for KPI definition and quantification	Potential wrong estimation of producers' engagement

KPI DATA COLLECTION SECTION

BUC	Data ID	Data Description	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
WECL-FR-01	N_FSP_FR	Nb_{FSP}	Inventory list	Manually through STAR platform	Area of Melle-Longchamp	At the end of the project	M18-M28	RTE and Enedis	Public for OneNet project

Table 3: KPI Definition Number of service Providers

3.4.2 Number of tracked flexibility activations

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
General Information	**1. KPI ID**	KPI_N26
	2. KPI Demo ID	FR_BUC_KPI_02; FR_SUC_KPI_01; FR_SUC_KPI_02
	3. Name	Number of tracked flexibility activations
	4. KPI domain	Technical
	5. KPI category	Data processing performance
	6. Description	Number of tracked flexibility activations automatically or manually triggered
	7. OneNet Pillar	
	8. OneNet Objective	
	9. OneNet Cluster	Western cluster (WP9)

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	10. OneNet Demonstrator	French demo
	11. Related UC(s)	WECL-FR-BUC-01; WECL-FR-SUC-01
	12. Link with other projects	New KPI
	13. KPI responsible	RTE and Enedis
Calculation information	**14. Formula**	NAa_{Flex}
	15. Variables	NAa_{Flex}: Number of tracked flexibility activations
	16. Unit of measurement	-
	17. KPI baseline explanation	No historical or simulation value available, the value at the start of the demo when no FSP is involved would be 0.
	18. KPI baseline source	Not applicable
	19. Baseline responsible	Not applicable
	20. KPI target value	7 to 15
	21. Calculation Methodology	Counting manually orders that have been registered in STAR platform
	22. KPI computation timing	M28
	23. Gaps and challenges for KPI definition and quantification	Potential wrong estimation of the number of orders to be triggered, as it is dependent on unpredictable congestion events on RTE and Enedis networks

KPI DATA COLLECTION SECTION

BUC	Data ID	Data Description	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
WECL-FR-BUC-01	N_FLEX_FR	Number of tracked flexibility activations	Inventory list	Manually through STAR platform	STAR platform	Once at the end of the project	M18-M28	RTE-Enedis	Public for OneNet project
WECL-FR-SUC-01	N_FLEX_NAZA_FR	Number of tracked flexibility activations triggered automatically by NAZA	Inventory list	Manually through STAR platform	STAR platform	Once at the end of the project	M18-M28	RTE-Enedis	Public for OneNet project
WECL-FR-SUC-01	N_FLEX_MAN_FR	Number of tracked flexibility activations	Inventory list	Manually through STAR platform	STAR platform	Once at the end of the project	M18-M28	RTE-Enedis	Public for OneNet project

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		triggered manually							

Table 4: KPI Definition Tracked Flexibility

3.4.3 Available flexibility

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
General Information	1. **KPI ID**	KPI_H14A
	2. **KPI Demo ID**	FR_BUC_KPI_04;
	3. **Name**	Available flexibility
	4. **KPI domain**	Technical
	5. **KPI category**	Congestion management performance
	6. **Description**	Flexible power that can be used for congestion management at a specific grid segment, i.e., the available power flexibility in a defined period (e.g., per day) that can be allocated by the DSO at a specific grid segment. It relates to the total amount of power in the specific grid segment in the same period. It is measured in MW. One KPI for each test. The term power is used to refer to measure demand in the area in reporting time at the specific grid location.
	7. **OneNet Pillar**	
	8. **OneNet Objective**	
	9. **OneNet Cluster**	Western cluster (WP9)
	10. **OneNet Demonstrator**	French demo
	11. **Related UC(s)**	WECL-FR-BUC-01;
	12. **Link with other projects**	Harmonized KPI
	13. **KPI responsible**	RTE Enedis
Calculation information	14. **Formula**	$Flexibility\% = \sum PAvailableFlexibility / \sum PTotalinArea \cdot 100$
	15. **Variables**	$Flexibility\%$: Percentage of available flexible power with respect to the total demand at a specific grid segment in reporting period (%) $\sum PAvailableFlexibility$: Power in MW of available flexibility at a specific grid segment in reporting period (MW). $\sum PTotalinArea$: Total power demand in MW at Demo grid segment (MW)
	16. **Unit of measurement**	%
	17. **KPI baseline explanation**	N/A
	18. **KPI baseline source**	N/A
	19. **Baseline responsible**	N/A
	20. **KPI target value**	>0
	21. **Calculation Methodology**	Define the affected specific area to obtain the power to compare with the flexibility capacity
	22. **KPI computation timing**	M28
	23. **Gaps and challenges for KPI definition and quantification**	Define the specific affected area to be considered

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KPI DATA COLLECTION SECTION									
BUC	Data ID	Data Description	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
WECL-FR-BUC-01;	FR-PA-01	$\sum PAvailable\_Flexibility$	Sites attributes	Through STAR platform	STAR platform	Once	(M18-M28)	RTE Enedis	Public (for OneNet project)
WECL-FR-BUC-01;	FR-PT-01	$\sum PTotal\_in\_Area$	Grid information	Through grid internal data base information	Grid internal data base information	Once	(M18-M28)	RTE Enedis	Public (for OneNet project)
WECL-FR-BUC-01;	FR_BUC_KPI_03	$Flexibility\%$	N/A (calculated value	N/A (calculated value)	project SharePoint	N/A (calculated value)	M28	N/A (calculated value)	Public (for OneNet project)

Table 5: KPI Definition Available Flexibility

3.4.4 Active participation

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
General Information	1. **KPI ID**	KPI_H02
	2. **KPI Demo ID**	ES_BUC_KPI_05
	3. **Name**	Active participation
	4. **KPI domain**	Social
	5. **KPI category**	General descriptive
	6. **Description**	This indicator measures the percentage of customers actively participating in the demo with respect to the total customers that accepted the participation. This indicator will be used to evaluate the customer engagement plan. 1 KPI for the whole French demo.
	7. **OneNet Pillar**	
	8. **OneNet Objective**	
	9. **OneNet Cluster**	Western cluster (WP9)
	10. **OneNet Demonstrator**	French demo
	11. **Related UC(s)**	WECL-FR - BUC-01
	12. **Link with other projects**	Harmonized KPI
	13. **KPI responsible**	RTE Enedis
	14. **Formula**	$R=Nactive/Naccept\cdot 100$

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Calculation information	15. **Variables**	R: Active participation (%) *Nactive*: Customers actively participating in the demo *Naccept*: Customers accepted to participate in the demo.
	16. **Unit of measurement**	%
	17. **KPI baseline explanation**	N accept will include currently accepted customers plus contracted by cascading funds
	18. **KPI baseline source**	RTE Enedis
	19. **Baseline responsible**	RTE Enedis
	20. **KPI target value**	100%
	21. **Calculation Methodology**	Compare accepted with active customers at the end of demos run
	22. **KPI computation timing**	M28
	23. **Gaps and challenges for KPI definition and quantification**	Customer engagement

KPI DATA COLLECTION SECTION

BUC	Data ID	Data Description	Source/ Tools/ Instruments for data collection	Methodology for data collection	Location of data collection	Frequency of data collection	Monitoring period	Data collection responsible	Data classification level
WECL-FR-BUC-01	FR-Act	*Nactive*	Demos run	Manually: after demo run	French demo	Once	M28	RTE Enedis	Public (for OneNet project)
WECL-FR-BUC-01	FR-Acc	*Naccept*	French demo documentation	Manually: French demo documentation	French demo	Once	M20	RTE Enedis	Public (for OneNet project)
WECL-FR-BUC-01	FR_BUC_KPI_05	R	N/A (calculated value)	N/A (calculated value)	project SharePoint	N/A (calculated value)	M28	N/A (calculated value)	Public (for OneNet project)

Table 6: KPI Definition Active Participation

3.4.5 Volume of transactions (Energy)

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
General Information	1. **KPI ID**	KPI_H09D
	2. **KPI Demo ID**	FR_BUC_KPI_06
	3. **Name**	Volume of transactions (Energy)
	4. **KPI domain**	Technical
	5. **KPI category**	Market performance

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	6.	**Description**	This indicator measures the volume of transactions in kW. This indicator will be used to measure the volume of transactions (cleared bids) during the examined period T for each product. This indicator will give a measure of power magnitude demo range.
	7.	**OneNet Pillar**	
	8.	**OneNet Objective**	
	9.	**OneNet Cluster**	Western cluster (WP9)
	10.	**OneNet Demonstrator**	French demo
	11.	**Related UC(s)**	WECL-FR-BUC-01
	12.	**Link with other projects**	Harmonized KPI
	13.	**KPI responsible**	RTE Enedis
Calculation information	14.	**Formula**	$VTP=\sum T \sum I\ E_{i,t}$
	15.	**Variables**	VTP: Volume of transaction considering active power (kW) $E_{i,t}$: Volume offered or cleared capacity by the i-th flexible resource at time t (kW) I: Set of flexible resources. T: Examined period.
	16.	**Unit of measurement**	MWh
	17.	**KPI baseline explanation**	0 (no volume of transactions)
	18.	**KPI baseline source**	N/A
	19.	**Baseline responsible**	N/A
	20.	**KPI target value**	>0
	21.	**Calculation Methodology**	Collect platform transaction information
	22.	**KPI computation timing**	M28
	23.	**Gaps and challenges for KPI definition and quantification**	Define the examined period

KPI DATA COLLECTION SECTION									
BUC	**Data ID**	**Data Description**	**Source/ Tools/ Instruments for data collection**	**Methodology for data collection**	**Location of data collection**	**Frequency of data collection**	**Monitoring period**	**Data collection responsible**	**Data classification level**
WECL-FR-BUC-01	FR-Eit	$E_{i,t}$	Market platform	Through STAR platform	STAR platform	During a specific time, T	(M18-M28)	RTE Enedis	Public (for OneNet project)
WECL-FR-BUC-01	FR_BUC_KPI_06	VTP	N/A (calculated value)	N/A (calculated value)	project SharePoint	N/A (calculated value)	M28	N/A (calculated value)	Public (for OneNet project)

Table 7: KPI Definition Volume of Transactions (Energy)

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4 WECL-FR-01: Business Case Details

4.1 Components and platforms

The solution is based on the use of Hyperledger Fabric technology (HLF) [9], a decentralized ledger technology, that serves as:

- ⇨ A single source of truth: all critical data shared between members are stored on chain to provide transparency and immutability.
- ⇨ A distributed privacy preserving storage system: using Private Data Collections, a feature proposed since HLF members can share data while limiting their visibility to a subset of the consortium.
- ⇨ A trustless execution environment: each member executes algorithms to process on chain of data using the same and shared chaincodes in a consensual manner.

To achieve a fully decentralized system in which members do not have to rely on a trusted third party and can autonomously process their data, each member of the network should host its own HLF node and participate in the Distributed Ledger. However, this constraint could dissuade some FSPs from adhering to STAR. Thus, the architecture shall consider small FSPs who are not willing to maintain their HLF node by proposing them to delegate the task to a BNO (Business Network Operator). The BNO will be in charge of providing an infrastructure and a service to host HLF nodes on behalf of some consortium members.

4.1.1 Architecture summary of STAR platform

The table below presents the business role of each actor and their needs.

Role	Description	Needs
TSO (RTE)	Transmission system operator, i.e. balancing of supply and demand and management of electricity flows from the production centers to major industrial sites, distribution sites and distribution networks.	Reconciliation of data and automation of the compensation process in the context of a limitation orders emitted by NAZA automata or by Enedis on behalf of RTE
DSO (Enedis)	Distributes electricity, i.e., delivers it to the end customer. In this capacity, the DSO operates, manages and maintains the network of power lines through which the electricity flows.	Reconciliation of data emanating from manual limit orders

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BNO (Business Network Operator)	A stakeholder that deploys or administers a STAR solution node for FSPs that do not want to implement and operate a dedicated STAR node.	Provides a hosting service for the solution for FSPs and manages FSPs roles
FSPs	Renewable energy producers. In this project, all FSPs use the BNO as a service provider hosting the STAR Application. Therefore, the functional role of FSPs is represented by the BNO on the technical level.	Reconciliation of data and automation of the compensation process for undergone limitations. Certify the supply data on the marketplace and the data of its production site.

Table 8: Description of business roles in STAR project

Figure 11 gives a global view of the STAR technical solution. All the roles defined in the table above can be found in this summary diagram.

The coloured big rectangles correspond to the different infrastructures or physical/logical subnetworks that are under the responsibility of each organizational participant:

- Blue zones are infrastructures of RTE divided into the Server Infrastructure and the agent's internet browser running on their personal computer (i.e. human operators working for RTE);
- Red zones are the corresponding infrastructures for Enedis;
- Green zones are the corresponding infrastructures of the FSPs;
- The brown zone corresponds to the infrastructure of the BNO (i.e., Business Network Operator);
- The gray zone represents the blockchain network, a virtual zone where the chaincodes are executed. For the sake of simplicity, we did not duplicate the representation of chaincodes on each member's zone. Indeed, the same chaincodes are stored and executed on each participant's node.

Following this idea, we could have represented the "Ledger" database within the blockchain zone as well. However, since data confidentiality is a major subject in this project, we preferred to show the ledger data duplicated on each member's zone for more clarity.

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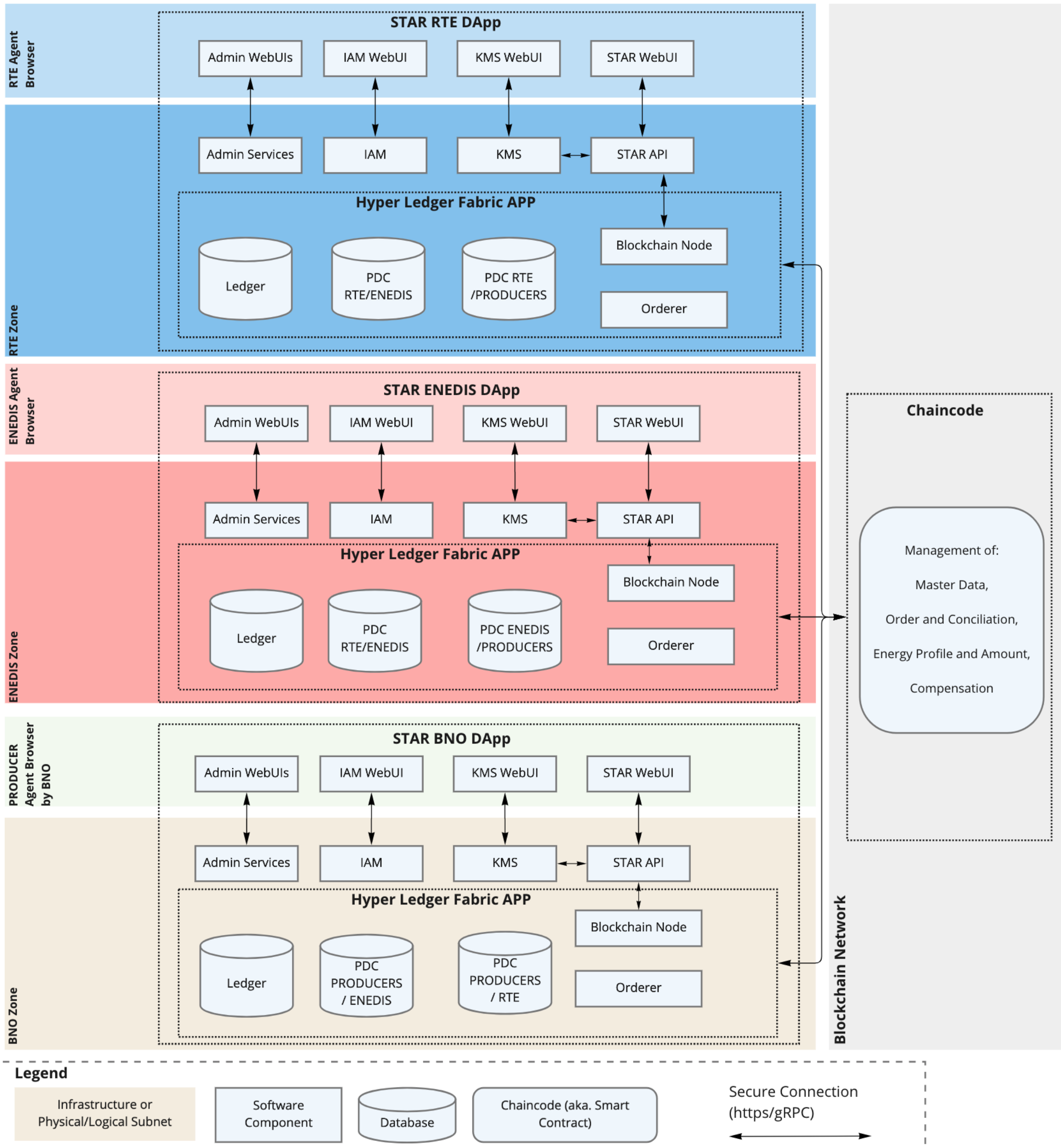

Figure 11: STAR Technical Architecture Solution

Acronyms	**Description**
API	Application Programming Interface
BNO	Business Network Operator
DApp	Decentralized Application

gRPC	Google Remote Procedure Calls
IAM	Identity and Access Management
KMS	Key Management System
PDC	Private Data Collection (Documentation Hyperledger Fabric Private Data Collection)

Table 9 : Description of technical acronyms relative to architecture in STAR

4.1.2 Main components of STAR Platform

4.1.2.1 Chaincodes

The chaincodes [9] are computer programs that are executed by each HLF node. The representation of chaincodes in the diagram is a simplified view, where chaincodes are executed in the blockchain network, in the gray zone. Chaincodes are applied to onchain data (i.e. the ledger and PDCs data) and are themselves data in the ledger. Since all participants share the same input data, the same algorithms, the same blockchain node technology, they can thus compute the same outputs.

Chaincodes and Confidentiality - Members of the Blockchain network only have access to PDCs in which they have read and/or write access rights. Therefore, chaincodes won't always be executable by all the members in our solution: chaincodes will only update the state of relevant members. For instance, RTE sends a transaction that calls the execution of a chaincode with a parameter that points to data only accessible in RTE/Enedis PDC. The transaction is broadcast to the whole network. However, since other members won't be able to access the referenced data, they won't be able to execute the chaincode. Only RTE and Enedis nodes can execute it properly and update their PDC state.

STAR Chaincodes - Our solution embeds one chaincode responsible for:

- Master Data Manager: in charge of applying defined reading and writing rights (CRUD: Create, Read, Update, Delete) for Master Data stored in the chain;
- Order and Conciliation Manager: in charge of CRUD of orders and their conciliation;
- Energy Account Manager: in charge of CRUD of energy accounts;
- Compensation Manager: in charge of computing the compensation of FSPs based: on the orders, their conciliation, price, energy accounts and eligibility.

4.1.2.2 Functionalities: DApp and API definition

Decentralized applications (DApps) are digital applications or programs that exist and run on a blockchain or peer-to-peer (P2P) network of computers instead of a single computer. DApps are thus outside the purview and control of a single authority.

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An API is an IT solution that allows applications to communicate with each other and exchange services or data. Application programming interfaces generally offer a set of functions that facilitate access to an application's services via a programming language that allows requests to be made.

The API details will be presented in D9.7 [8].

4.1.2.3 User Interface: STAR WebUI

The STAR WebUI provides all the graphical interface in the form of web pages accessible from an internet browser. STAR DApp users can access all the functionalities from this component. The website is hosted and served from the infrastructure of the corresponding member. Each STAR DApp has its own STAR WebUI instance that exposes the functionalities accessible to its target users (e.g., RTE DApp provides a STAR WebUI that offers only functionalities allowed to RTE users).

The WebUI also interacts with the STAR API that implements the logic of the solution, described in the previous section.

4.1.3 Business rule deliverables for STAR platform implementation

The purpose of this section is to provide an understanding, as part of the STAR pilot, of the governance on the construction of the STAR data model and rights matrix. The data model describes how data is represented in a business organisation. While the rights matrix defines, in our case, the access rights of the roles of each project participant.

The management of the STAR project is based on a formalized process of decision making, situation assessment, consultation, and communication between RTE and Enedis managers and STAR project members. Decisions are taken by RTE and Enedis (System Operators) unanimously and according to a consensus principle. This applies to the following elements:

- The principles and objectives of the STAR project
- The definition of the scope of the STAR pilot project
- The definition of the business rules
- Definition of the STAR rights matrix and data model
- Monitoring of the project and prioritisation of developments in accordance with a high business value functionality
- The elements of the feedback and the orientations for an industrialisation of STAR.

The data model, defining the objects of STAR, their composition, and the links between these objects, as well as the rights matrix, defining the read and write rights of each type of participant in STAR at the level of each object, are therefore the result of consultation between System Operators within the framework of the

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experimentation. In the context of our demo, System Operators represent the interests of FSPs (Flexibility Service Provider) in the business rules construction.

Data Model:

The data model of Figure 12meets the requirements of the two STAR use cases as well as the need for standardisation, in the context of RTE and Enedis' participation in the OneNet project. This document has been designed with the objective of converging as closely as possible to the IEC standards (CIM IEC62325 ESMP) used by Transmission and Distribution Operators for data exchanges in the context of international interconnection mechanisms and wholesale electricity markets.

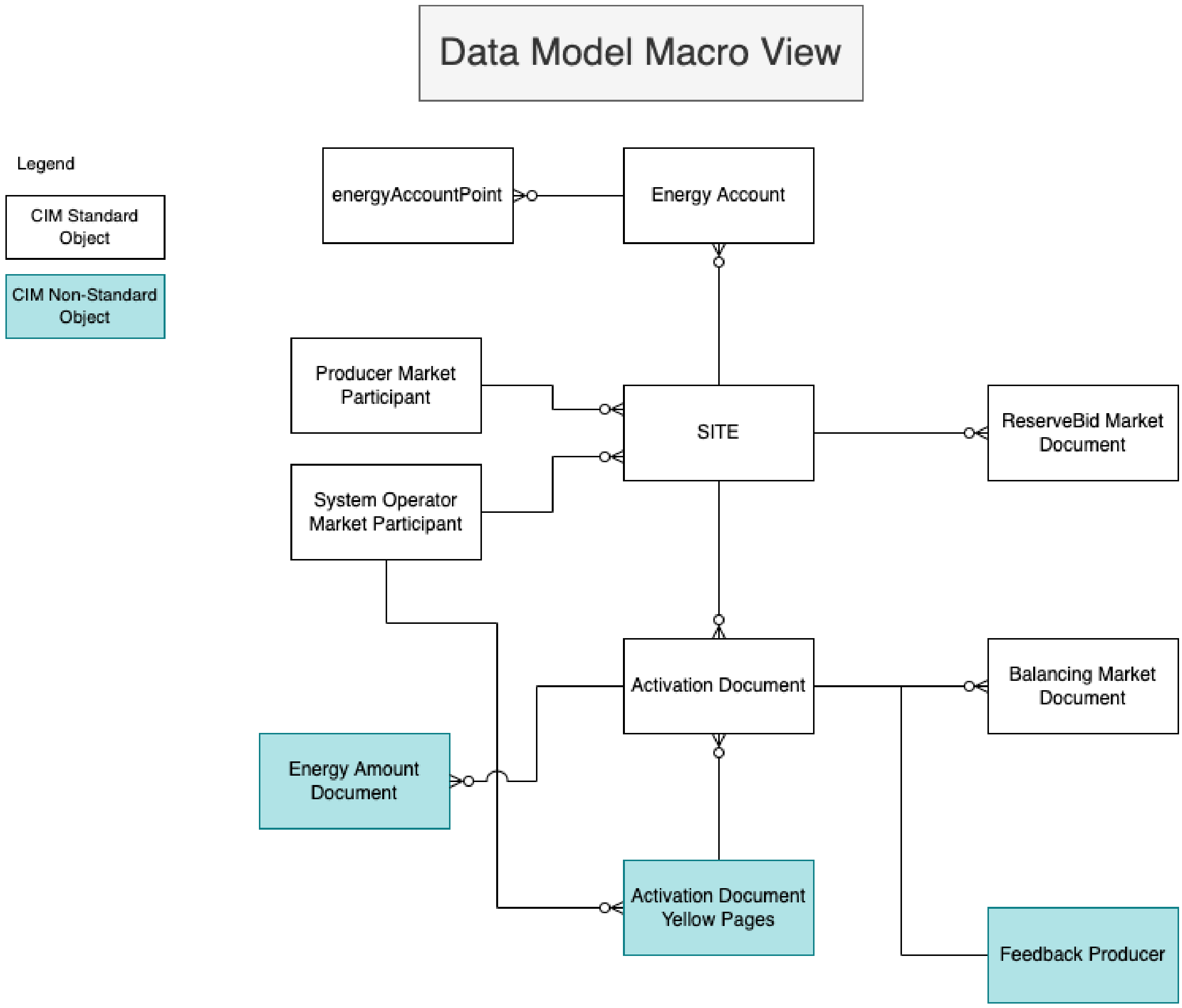

Figure 12: Data Model Macro View

Rights matrix:

The visibility rules operate at the level of each object defined earlier in the Data Model section. The rights matrix is consistent with the implementation of a private blockchain project using Hyperledger Fabric

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technology. This security ensures the adherence to the project of network operators but also of FSPs, for whom the respect of confidentiality commitments, especially for confidential data, is essential.

Briefly, the main rules defined by the rights matrix are the following:

- The FSPs present on STAR only have access to the curtailment data that concerns their own network of production sites.
- The DSO has access to the data of its customers on the MV sites and to the TSO's activation order data when they are destined to a MV site generator.
- The TSO has access to the data of its customers on sites connected to the HV network (HV sites and to the data on MV sites, managed by the DSO, on a need-to know basis.

4.2 Flexibility service providers

4.2.1 User guide Overview

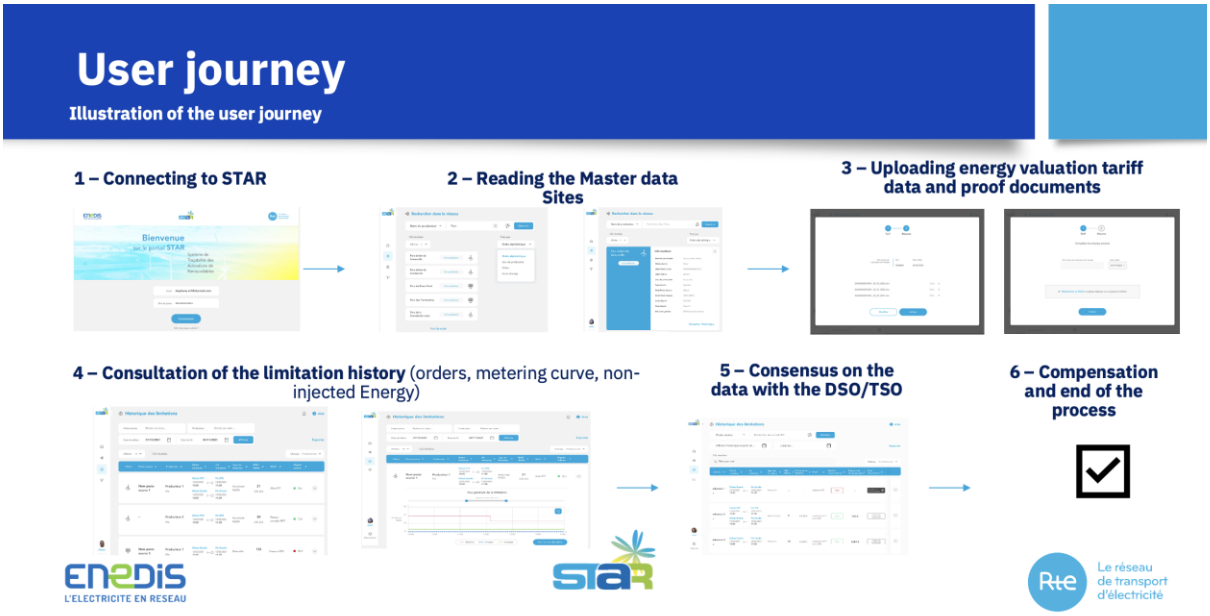

Figure 13: User Guide overview

As shown in Figure 13, the journey of a user is realised as follows:

1. Connecting to STAR
    a. Credentials are generated by a system administrator from System Operator organizations.
2. Reading the Master Data Sites
    a. A user FSP can have multiple locations of production sites.
    b. A user FSP can visualize the tariff data uploaded on the next step.
3. Uploading energy valuation tariff data and proof documents (specific to user FSPs)

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   a. Each tariff is linked to the mesh of a production site.
   b. The tariff is valid from an effective date determined by a contract between the FSPs and the System Operator.
   c. Any new tariff with a later effective date will update the end date of the previous tariff.
4. Consultation of the limitation history (orders, metering curve, non-injected energy)
   a. The System Operator is responsible for sending the production data (specific to System Operators).
   b. This data is the foundation for the traceability aspect of the use case in STAR.
5. Consensus on the data with the DSO/TSO/FSP
   a. A consensus will be possible in the STAR platform thanks to the possibility for the FSPs to give feedback on a specific data (e.g.: time stamps of the order, value of a curve, ...).
   b. This feedback from the FSPs may lead to a response from the System Operator in order to detect any anomalies in the data sent.
   c. If no feedback is given by the FSP, the consensus on the data for a limitation becomes implicit.
6. Compensation and end of the process
   a. STAR allows the FSPs user to receive a status on the curtailment compensation (energy amount non injected, unit price per MWh and total amount of the compensation).
   b. The invoicing and billing process concluding the back-office curtailment management is then treated in dedicated systems, outside of STAR platform.

4.2.2 Access to the STAR platform

A participation agreement must be signed between RTE, Enedis and the FSPs who are customers of one of the system operators. This agreement defines the legal, technical and financial conditions for the use of STAR platform. This agreement commits the FSPs to participate in the STAR experiment and therefore to authorize the sharing of production data on the Blockchain network. A user-FSP who joins the STAR platform ecosystem may have one or more production sites in the area defined by the experimentation.

Depending on the reimbursement terms associated with the contract, the FSPs will have to interact with the STAR platform to communicate the feed-in tariff for each production site. This tariff will be defined by an amount and a validity period.

The system operator is then in charge of checking the data provided by the FSPs on the value-added tariff, which will then lead to the compensation of the FSPs following a limitation order on their production site.

After all these steps, the platform is finally accessible via a web interface for FSP users. Access is still permitted by the system operators (TSO & DSO) following the completion of the steps presented previously.

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4.2.3 User journey

The users access the STAR platform and can use the main functionality of the limitation history as shown in Figure 14 below. The user has several search criteria at his disposal:

- Substation;
- Production site code;
- Name of the production site;
- Start and end dates corresponding to the effective dates of the curtailment orders.

Once the search is completed, a table showing the history of the limitations will be displayed. Filters have been added for a better user experience:

- Type of limitation;
- Reason for the limitation order;
- Compensation status;
- The possibility to hide/show columns to have a better visibility of the table.

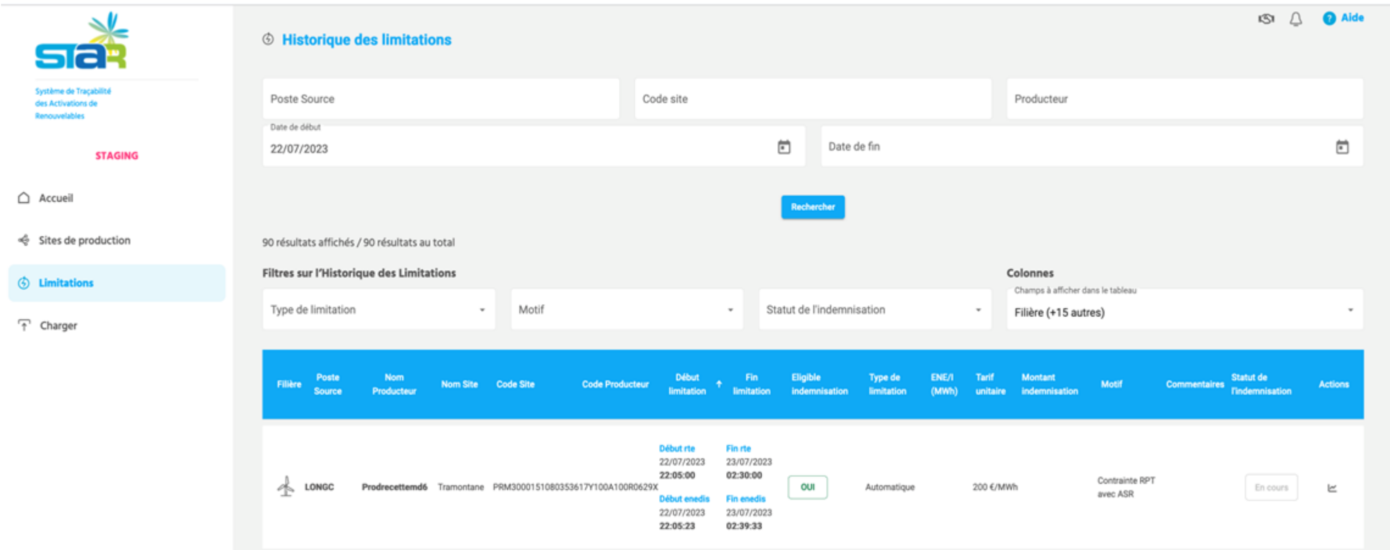

Figure 14: Limitation History search criteria

Once the search is complete, a limitation history table is displayed with the following information (as in the two images below):

- Pathway;
- Substation;
- Production site name;
- Production site code;
- FSPs code;

- Start and End Limitation dates (RTE & Enedis);
- Eligibility for compensation;
- Type of limitation;
- ENE/I: Non-injected energy;
- Unit rate of valorization (€/MWh);
- Amount of compensation;
- Reason for the limitation;
- Comments FSPs;
- Status of the compensation;
- Button to access the graphs.

This limitation history tables shown in Figure 15 or Figure 16 represent a synthesis of all the important information for the traceability of the limitations that have occurred on its production sites.

Filière	Poste Source	Nom Producteur	Nom Site	Code Site	Code Producteur	Début limitation ↑	Fin limitation	Eligible indemnisation	Type de limitation	ENE/I (MWh)	Tarif unitaire	Montant indemnisation	Motif	Commentaires	Statut de l'indemnisation	Actions
	LONGC	Prodrecettemd6	Tramontane	PRM3000151080353617Y100A100R0629X		Début rte 22/07/2023 **22:05:00** Début enedis 22/07/2023 **22:05:23**	Fin rte 23/07/2023 **02:30:00** Fin enedis 23/07/2023 **02:39:33**	OUI	Automatique		200 €/MWh		Contrainte RPT avec ASR		En cours	
	MANSL	Prodrecettemd6	Vent d ouest	PRM5004106381967617Y100A100R0629X		Début enedis 22/07/2023 **22:05:24**	Fin enedis 23/07/2023 **02:34:21**	OUI	Automatique	29	200 €/MWh	5800 €	Contrainte RPT avec ASR		En cours	
	AIGRE	Prodrecettemd6	Levante	PRM3000151085718817Y100A100R0629X		Début enedis 22/07/2023 **22:05:24**	Fin enedis 23/07/2023 **02:40:33**	OUI	Automatique	36	100 €/MWh	3600 €	Contrainte RPT avec ASR		En cours	
	MANSL	Prodrecettemd6	Noroit	PRM3000151080364817Y100A100R0629X		Début enedis 22/07/2023 **22:05:25**	Fin enedis 23/07/2023 **02:36:06**	OUI	Automatique	18			Contrainte RPT avec ASR		En cours	

Figure 15: Limitation History table example 1

Filière	Poste Source	Nom Producteur	Nom Site	Code Site	Code Producteur	Début limitation ↑	Fin limitation	Eligible indemnisation	Type de limitation	ENE/I (MWh)	Tarif unitaire	Montant indemnisation	Motif	Commentaires	Statut de l'indemnisation	Actions
	CONF6	Prodrecettemd6	Ghibli	PRM3000151085538617Y100A100R0629X		Début enedis 25/07/2023 **15:29:10**	Fin enedis 25/07/2023 **15:40:47**		Manuelle	766	80 €/MWh	61280 €	Incident Enedis		En cours	
	CONF6	Prodrecettemd6	Bora	PRM3000151085593717Y100A100R0629X		Début enedis 25/07/2023 **15:29:10**	Fin enedis 25/07/2023 **15:41:03**		Manuelle	432	100 €/MWh	43200 €	Incident Enedis		En cours	
	CONF6	Prodrecettemd5	Themis	PRM5007302789991017X100A100R01235		Début enedis 25/07/2023 **15:29:36**	Fin enedis 25/07/2023 **15:58:24**		Manuelle	358			Incident Enedis		En cours	

Figure 16: Limitation History table example 2

At the level of each limitation, the System Operator will provide the FSPs with the data related to the limitation (as shown in Figure 17 below):

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- Order setpoint
- Metering curve
- Reference curve

These elements serve as proof of the values calculated in the table, such as the non-injected energy.

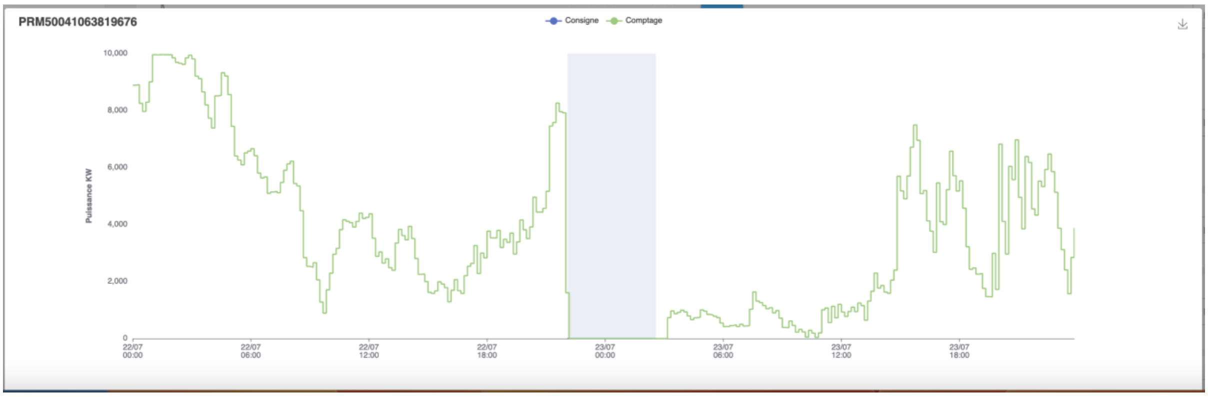

Figure 17: Limitation History Graphics by Limitation

The FSPs have the possibility to have visibility of all their production sites that are registered on the STAR platform. As shown in Figure 18 below, the FSPs can see the general data of the production site as well as the tariffs that are associated with the production site.

FSPs are responsible for providing the feed-in tariff with an effective date. This data is then verified by the responsible System Operator to allow the calculation of the compensation amount on each limitation.

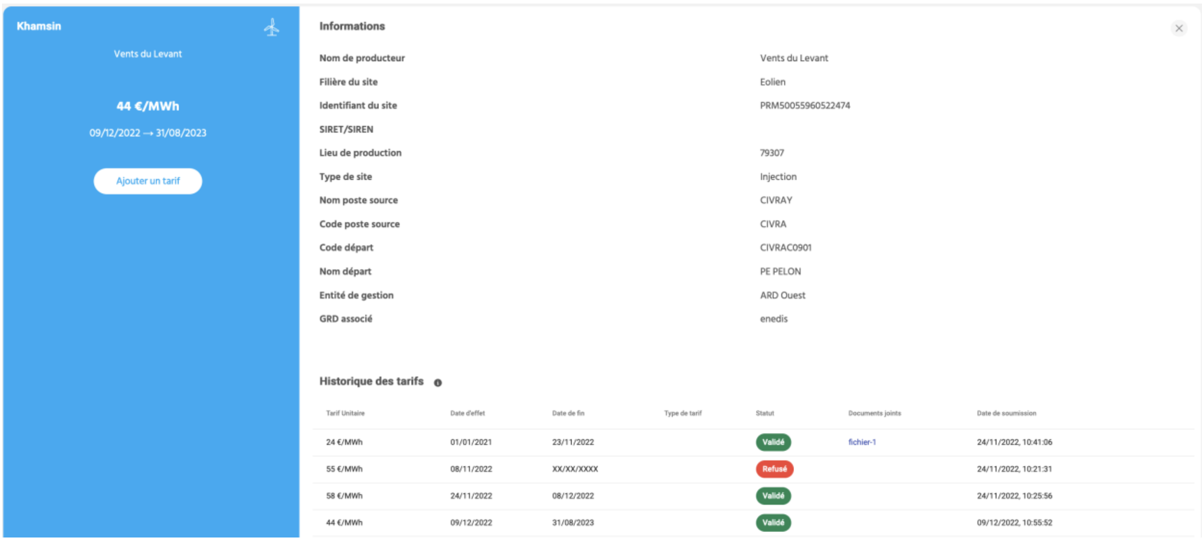

Figure 18: Limitation History Master Data of Production Site

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4.3 Demo developments explanation

4.3.1 Tests of the developments

The test methodology has been defined to allow the validation of the developments. It must allow the release of each functionality at each deadline on the developments.

The steps of the test methodology is illustrated by Figure 19 as detailed below :

- ⇨ Test results strategy used on the STAR project.
  - o Carried out at the level of each major functionality of the project;
  - o Use of a RACI matrix (Responsible, Accountable, Consulted, Informed) to identify the RTE and Enedis actors involved for each functionality;
  - o Common governance of the Electricity System Operators to decide on the validation of a functionality in test environment.
- ⇨ Shared coordination for task prioritization divided between:
  - o Non-conformity of a feature;
  - o Evolution of a feature.
- ⇨ Shared coordination for considering feedback from FSP customers.
  - o Feedback is given in relation to the production environment.
- ⇨ Implementation of business indicators to check the validation of tests on a feature.

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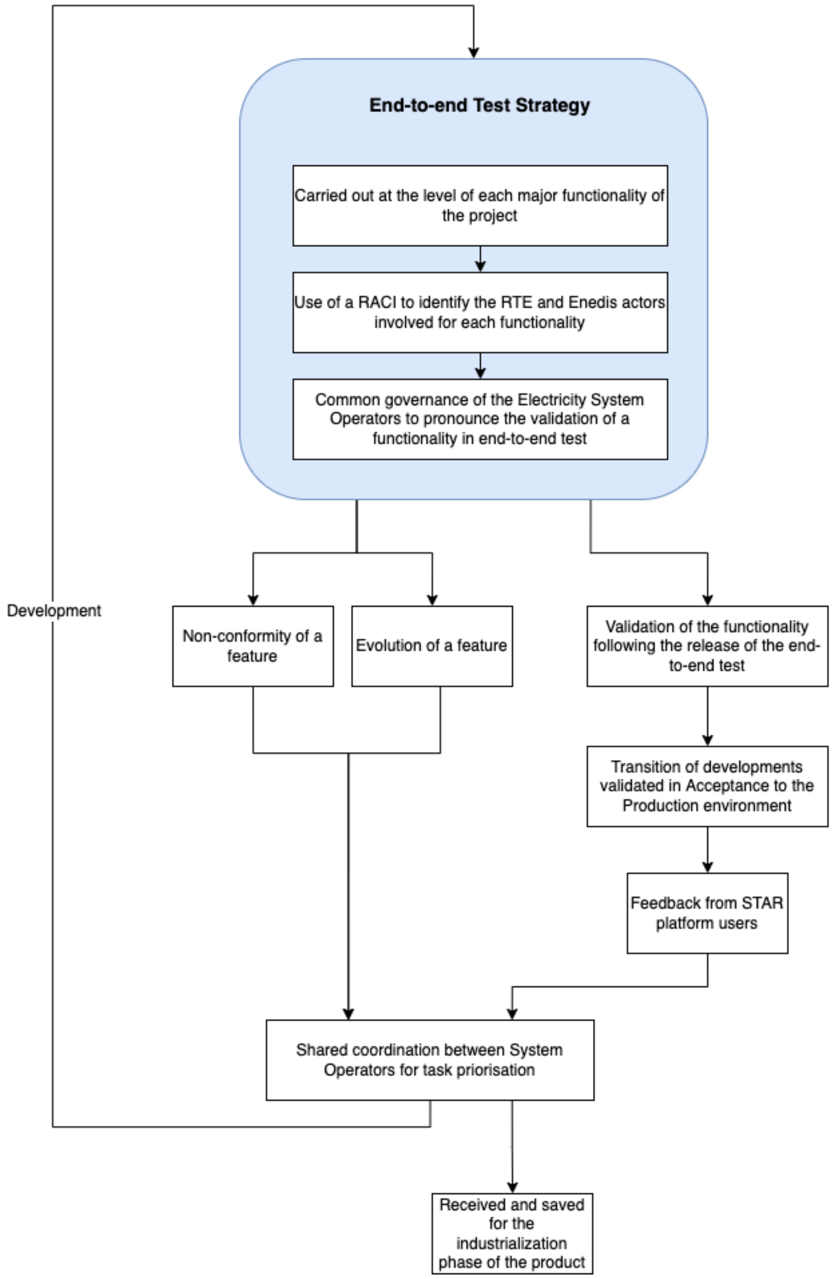

Figure 19: End-to-end test Process used for the STAR project

5 WECL-FR-02: Business Use Case Details

The STAR platform was designed as a solution to improve transparency and ease the compensation process between SOs (RTE and Enedis), and participating FSPs in the specific case of congestion management. Particular attention has been given to coordination aspects from the blockchain governance to the information exchange protocols and the sequence of the flexibility activation process. These aspects are part of the broader framework of SOs coordination principles that may pave the way for distributed flexibility in general. This chapter aims at illustrating what could be next foreseeable coordination needs stemming from examples of current or future flexibility usages from both sides.

5.1 The broader context of flexibility coordination

5.1.1 What do we call here 'flexibility'?

The notion of 'flexibility' is not explicitly defined in the regulatory literature and is still complex and discussed in France even if it address in many European working groups and white papers but we consider it here as a power modulation one or more sites, during a given period and in response to an external signal, to provide a service, for example temporarily modifying its electricity consumption to help manage a constraint (including both Active and Reactive power).

Flexibilities can render several types of service to help in electrical networks and system operation. We can retain the following list of distributed flexibility services, among others:

- Balancing;
- Grid capacity and congestion management;
- Voltage Control...

Several customers connected to the grids are or would be able to adjust either their active power or their reactive power, or both, in order to provide one or more flexibility services:

- Means of Production (RES, gas...;
- Consumers (e.g. electrochemical industry, paper manufacturer, residential …);
- Storage (including possibly EVs).

These are connected either to HV, MV or LV, and addressed either individually or in aggregate form.

5.1.2 Several mechanisms coexist

Several technical and contractual schemes and mechanisms coexist to enable network operators to take advantage of flexibility, from contract to remuneration or financial compensation, via activation. Some schemes are based, for example, on regulatory requirements (obligations set out in network access contracts), while

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others are based on voluntary market mechanisms. Similarly, some incentives are called 'tariff incentives' (e.g. penalties in case of non-compliance), while others involve remuneration.

The 'ASM' report [10] evokes a set of tools ('toolbox') at the hand of Network Managers to support them in their missions of managing local and global magnitudes:

a) Technical solutions based on networked equipment (e.g. change of topology);

b) Solutions of the tariff signal type (implicit flexibility) – e.g.: Peak Hours Off-peak Hours;

c) Market mechanisms (voluntary or compulsory participation, and prices possibly set by the SOs –cost-based regulation-);

d) Agreements established in relation with the connection of certain users so that they provide certain services;

e) Capping based on rules described in the network codes (mentioned in case of last resort or state of alert of the electrical system):

Various timesteps from planning mechanisms to solve any constraint. Descriptions of each step are summarized below:

1. Years to months before activation
   - ✓ Optimise schedule of significant works on networks and substations
   - ✓ Assess impacts of the works on network operation, the entailed risks and the need for available levers activations, including limitations on generation.
   - ✓ Ensure consultation with concerned FSPs and inform them of the forecasted impacts.

2. Weeks before activation
   - ✓ Validate the feasibility of works, excluding planned works, by verifying the compatibility of the projects with the proper functioning of the network.
   - ✓ Evaluate the impact on customers.
   - ✓ Update the impact analysis of planned works and inform FSPs of this update.
   - ✓ Ensure, according to the contractual elements of the flexibility services contracts, the prior information of the holders of these contracts.

3. Day - 1
   - ✓ Optimize network operation through topology adaptations and available levers (FSPs limitations, battery storage, etc...), taking into account the latest forecasts and the current network topology.
   - ✓ Share forecast data between TSO and DSO, taking into account these optimizations and updates.

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- ✓ Ensure, according to the contractual elements of the flexibility services contracts, the prior information of the holders of these contracts.

4. Real time
   - ✓ Ensure constraints' monitoring on targeted zones (e.g. linked to works) or on demand.
   - ✓ Ensure the optimization of the limitations in relation with the programmed works (see above)
   - ✓ Help operators to identify the best techno-economic lever to solve the identified constraints, taking into account the contractual elements.
   - ✓ Process the flexibility orders triggered by grid automation systems (NAZA automated orders for example).
   - ✓ Help the operator to ensure service resumption after an incident and to manage the resulting constraints.
   - ✓ Produce an update of the forecast data, taking into account the most recent information, the current and future network topology.

5. Post real time
   - ✓ Enable the proper qualification of events in order to apply the contractual follow-up of the flexibilities' activations.
   - ✓ Follow up on compensation and invoicing for flexibility services.

5.2 French experiences on the use of flexibility to manage congestions in HV and MV

5.2.1 Flexibility as a key in RTE's network development strategy by 2035 (DOE)

For years, the French network evolved at the same pace as the increase in consumption. This is no longer the case as it is now the evolution of the production mix that constitutes the main driver of network adaptations. Although the current network seems sufficiently sized to cope with foreseeable changes in electricity consumption over the next 10-15 years, the map of the electricity transmission network, on the other hand, has not changed fundamentally since the 1990s and it is not able to accommodate, without structural adaptations, the planned mix by 2035 (5-fold increase in wind and solar capacities in 15 years as illustrated in Figure 20, closure of 12 nuclear reactors, closure of coal-fired power plants). A 2019 report of the European Smart Geids Task Force [11] showed that despite the high variability of the results (up to approximately 50 GW of installed capacity for wind and solar power which double the current level), "soft" adaptations would drastically reduce the need for new network development. This would imply the use of "smart grids" solutions (Dynamic line rating, topological or curtailment automata) and require the adoption of the "optimal network development" principle

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that is to say accepting partial curtailment of installed production, particularly in areas of high renewable density, in order to avoid building network infrastructure that would only be useful for a few hours a year. To put it simply, it is more beneficial that a wind farm connected by a slightly under-dimensioned line is given curtailment orders a few hours per year than deploying a new line allowing full production of the plant.

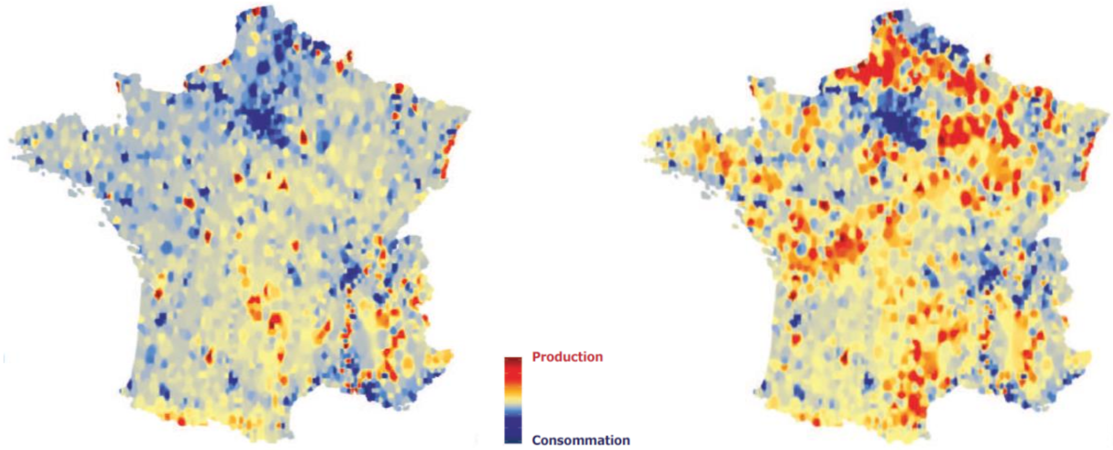

Figure 20: Production/Consumption profiles in 2019 vs 2035

In this view, it is essential that the increasing amount of renewable production can become subject to curtailments in order to reach such a network sizing optimum. Such flexibility activation orders can be done manually prior to foreseen congestions but renewables are not easily predictable, and this means cutting production a little too soon before a potential congestion and thus wastes energy that could have been transmitted. In order to operate closer to the real time window, so-called NAZA zonal automata have been tested by RTE to determine the more efficient way to manage detected congestions in a given area of the French network. It relies on an optimization algorithm whose action options are topological reconfigurations, battery usage or curtailment orders.

Taking into account the natural abundance of renewable energy production, RTE estimated in 2019 that the curtailed volume by such automata would only be 0.3% by 2035, with considerable savings (7000 million euros for the community over fifteen years, i.e. a division by two of the investments required for the adaptation of networks, excluding connections) although this will lead to an increase in redispatching costs over the next few years. This principle requires the implementation of a specific and demanding industrial strategy, which should trigger the reinforcement of the digital framework and the deployment of a thousand automated systems over the next 15 years (a few are in service for now). This strategy is a necessary condition to push the limits of the current infrastructure, with significant savings.

When renewables to curtail are connected to distributed networks, future curtailments are embraced through technical and contractual implementation in tight coordination with the DSOs.

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5.2.2 Enedis Reflex initiative

With an established legislative framework, RTE and French DSOs collaborate to design the best HV and HV/MV primary substation reinforcements in order to connect the anticipated pool of renewable energy sources in the long-term planning. They produce the regional energy network connection plan (S3REnR in French). Then, real connection applications are regularly used to trigger actual reinforcement works.

By permanently integrating flexibilities into the network design to expand the hosting capacity for RES while lowering TOTEX costs, the ReFlex (Renewable Energy Flexibilities) project seeks to further optimize S3REnR. This is shown in Figure 21 below.

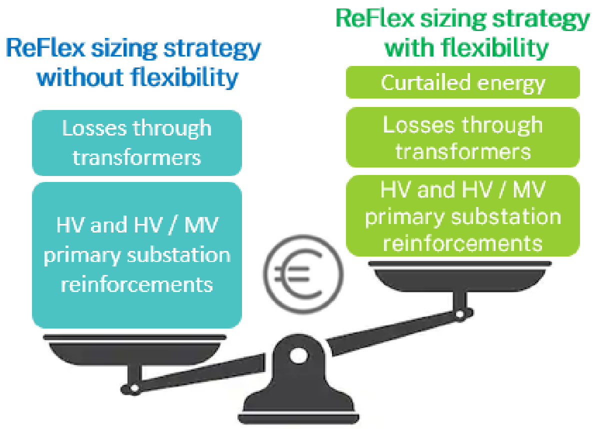

Figure 21: Components of the economic assessments of the design strategies for distribution assets when using ReFlex flexibilities

In 2019, Enedis estimated that the ReFlex project will provide an immediate 2.5 GW increase in RES connection capacity throughout the whole Enedis network. While saving around one-third of the CAPEX required to grow the transformation capacity, it may reach 7.4 GW by 2035. The average amount of needed energy restriction would be less than 0.06%. The overall savings would be 250 M€, or a net balance of 300 M€ CAPEX savings and 50 M€ more OPEX (compensation for non-injected energy).

Enedis is now testing the ReFlex project in 10 primary substations in France using a regulatory sandbox (see Figure 6). ReFlex eliminates the need for 4 transformer expansions and 2 transformer renovations while increasing hosting capacity on these 10 primary substations by more than 210 MW.

5.3 TSO-DSO coordination as a key to enhance flexibility

The TSO-DSO interaction is key to allow system operators to promote the development of flexibilities while continuing to guarantee that each SO operates its network in complete security. Indeed, on the one hand, the needs of network security and optimization of the cost of flexibilities activations plead for coordination

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mechanisms between the TSO and the DSO. On the other hand, it is necessary to comply with the prerogatives of each party and the confidentiality requirements when they apply.

RTE and Enedis are regularly required to activate flexibilities on the transmission and/or distribution network for various reasons (e.g. balancing, voltage management and congestion following network sizing methods). These activations are carried out either manually or automatically, through various mechanisms (direct activations and/or market mechanisms) and are expected to play an increasingly important role in the management of networks and the power system, on the different time scales. Both Enedis and RTE support the development of these flexibilities' use at the lowest cost for the community, from the network sizing phase to the activation of these flexibilities.

Whatever the chosen scheme, the activation of a flexibility must be done while guaranteeing that the impacts for each SO on their respective grid are controlled (safe and secure operation of the networks and more widely of the power system). In other words, TSOs and DSOs must have the means to observe and control flows on the network they operate in order to ensure safe and efficient operation. Among others, it implies that:

⇨ Activation (or non-activation) for grid congestion usually needs to take precedence over balancing needs. This priority is justified by the local dimension inherent in solving grid congestion, whereas flexibilities for balancing needs can be aggregated at a national level.

⇨ TSO and DSOs manage congestion and control voltage on their network with regards to network forecasts and observations. To do so, each system operator must be enabled, on a merit-order basis, to activate all so-called levers including flexibilities connected to its network and call upon neighboring network flexibilities. This capacity becomes all the more crucial that intermittent generation and flexibilities (EV, storage...) in general develop mainly on DSO networks. Such increased distributed flexibilities induce network and decision monitoring to control the networks as close as possible to real time. This is particularly true for voltage control since consequences of reactive procurement by the TSO on the DSO network can be dramatically different depending on the localization of the product.

Illustration in France: in consultation with stakeholders, RTE and French DSOs are developing an automatized process to manage HV congestion on RTE's grid. This process intends to activate, on a global merit order basis, the optimal set of HV and MV levers. RTE´s so-called NAZA system implements the merit order between TSO connected flexibilities and DSO connected flexibilities and results in the expression of need (in MW) at the TSO/DSO interface (at each HV/MV substation) for the DSO flexibilities activation. DSO then activates flexibilities connected on its network on a merit order basis, matching TSO needs and own DSO congestion management and voltage control needs.

Let's now illustrate quick examples of technical issues that could arise from a lack of coordination in the context of flexibility use:

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⇨ One can imagine scenarios where the local activation of a flexibility (due to balancing for example), if it is not anticipated by the DSO to which the flexibility source is connected, creates locally voltage or current constraints. In other words, if this takes the network out of its static dimensioning operation mode, or if the resulting dynamics are not consistent with the dynamic "self-secure" management of the network. As an example, in France, MV voltage is regulated based on transformer tap changers whose dynamics are of the order of a minute: if the local activation of a flexibility induces a consequent voltage variation with a dynamic faster than this dynamic, the DSO should be able to check that this does not induce transient voltage problems.

⇨ Similarly, the activation of flexibility to solve local constraints could impact, if the volumes become very large, management mechanisms such as balancing.

In addition to this aspect of safe and secure operation of each network, RTE and Enedis anticipate the need to take into account the technical and economic precedence of the various levers, including those requested at both networks interface (today mainly MV flexibilities) when activating them in order to minimize the cost of network development for the community. Finally, the trend is for MV sites to increasingly participate in balancing services. The interaction mechanisms between these 3 "optimizing" processes (optimizing DSO, optimizing TSO, balancing) should be defined to ensure an optimal coordination and the approximation of a global optimum. The coordination process will then be a matter of compromise between, on the one hand, the benefits of mimicking the global optimum through extensive sharing of information, and on the other hand, the moderation of the technical complexity of the coordination process.

These types of issues have been reflected on at the European and entailed in 2019 the ASM report [10] which gives several key recommendations regarding TSO-DSO coordination. Among them, the concept of flexibility resources register is defined as a “collection of information of the connection points that can provide flexibility services to system operators, to ensure a better vision for the system operators of the flexibility capabilities connected to different voltage levels”, and thus may be likely to answer the optimization needs exposed previously.

The ASM report [10] defines also "dynamic pre-qualification" as a re-examination at regular time intervals of flexibilities pre-qualification. The idea here is to maximize flexibilities potential by qualifying them whenever the grid can manage their delivery, contrary to rough pre-qualification that validates its use once and for all, with less precise results. Such a goal requires the definition of a certain level of coordination between TSO and DSO on many aspects of the method such as:

- Timeframes to be considered in the re-evaluation of a flexibility (possibly regular or dependent on the current dynamic of the grid);
- In case of common simulations, modeling precision and complexity;

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- Definition of grid constraints needed to be avoided consequently to a flexibility activation (additional congestion, voltage limits violations, etc.);
- In general, the level of information sharing between TSO and DSO in order to implement the dynamic pre-qualification methods in a technically and economically efficient way.

Finally, it is worth noting that the ASM recommendation applies in a general use of flexibilities, considering long to short term timeframes that could lead to different ways of performing dynamic pre-qualification. In our context of close to real time automated congestion management, original coordination schemes could be needed to achieve fast enough qualification.

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6 French Demonstration: Evaluation and results

The results presented in this section mainly concern the BUC WECL-FR-01. These results are fed by the Test Acceptance phases carried out at the end of the development of each functionality. These results provide a macro view and are the outcome of each of the first Acceptance phases. The details of the results will be presented in document D9.7 [8].

6.1 Upstream functionalities: network data traceability

6.1.1 Results on Activation Document

The ***Activation Document*** object is used to represent a limitation order (injection curtailment) from a system operator.

A curtailment order can take two forms:

⇨ A limitation order between system operators: RTE (TSO) sends an automatic order to Enedis (DSO) via the NAZA (New Adaptive Zone Automats) controller.

⇨ The system operator sends the limitation order to a generator connected to its network:

- Enedis to a FSPs at the level of a site connected to the MV network (Public Distribution Network);
- RTE to a FSPs at the grid cell of a site connected to the HV network (Public Transport Network).

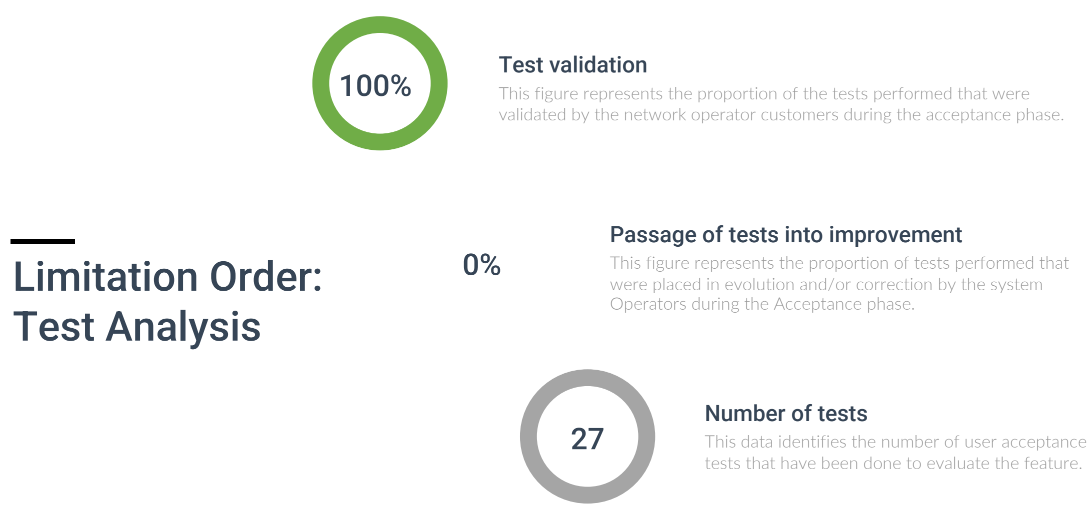

Figure 22: Limitation Order Test Analysis

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6.1.2 Results on Energy Amount

The ***Energy Amount*** object is a non-standard CIM derivative of the ***Energy Account*** object. This object represents the calculation of the ENE/I (Energy Not Evacuated/Injected) by the system operators at the mesh of a given limitation for a given site. An ***Energy Amount*** is unique for a given limitation even if the limitation order is active on multiple days. Calculation results from an energy amount based on the difference between the reference curve and the metering curve.

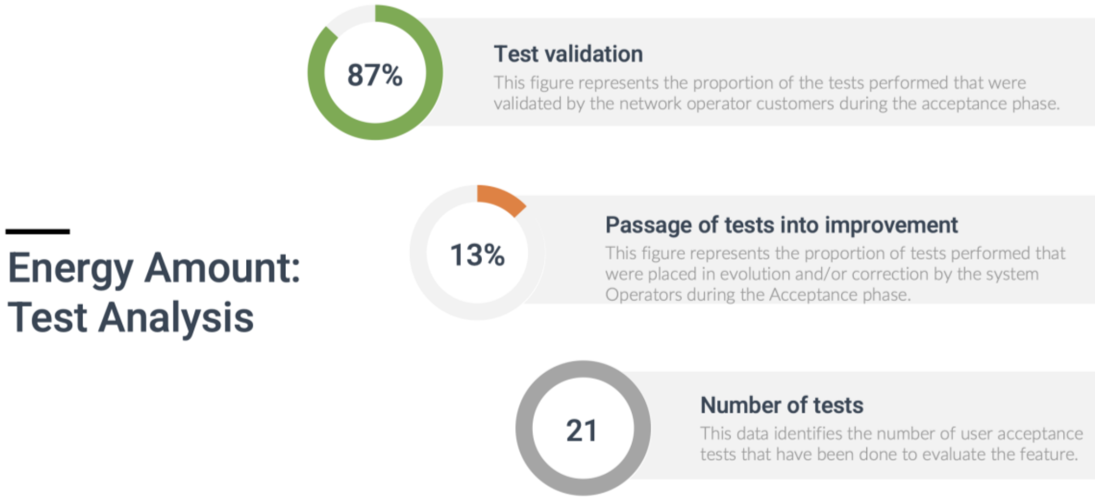

Figure 23: Energy Amount Test Analysis

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

6.1.3 Results on Energy Account

The ***Energy Account*** objects, used in STAR, correspond to:

- ⇨ Metering curves
  - o The effective power injection log, at the grid of a given site (site ID) recorded by the system operator's metering tools at each time step.
  - o Physical quantity: Power.
- ⇨ Reference curves (specific for RTE in the pilot phase)
  - o Predicted power injection log for each time step, representing the electrical power that the Flexibility Service Provider would have injected in the absence of limitation order.
  - o Physical quantity: Power.

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The Energy Account object provides a direct link with the ***Site*** object, via the meteringPointMrid labelled site code.

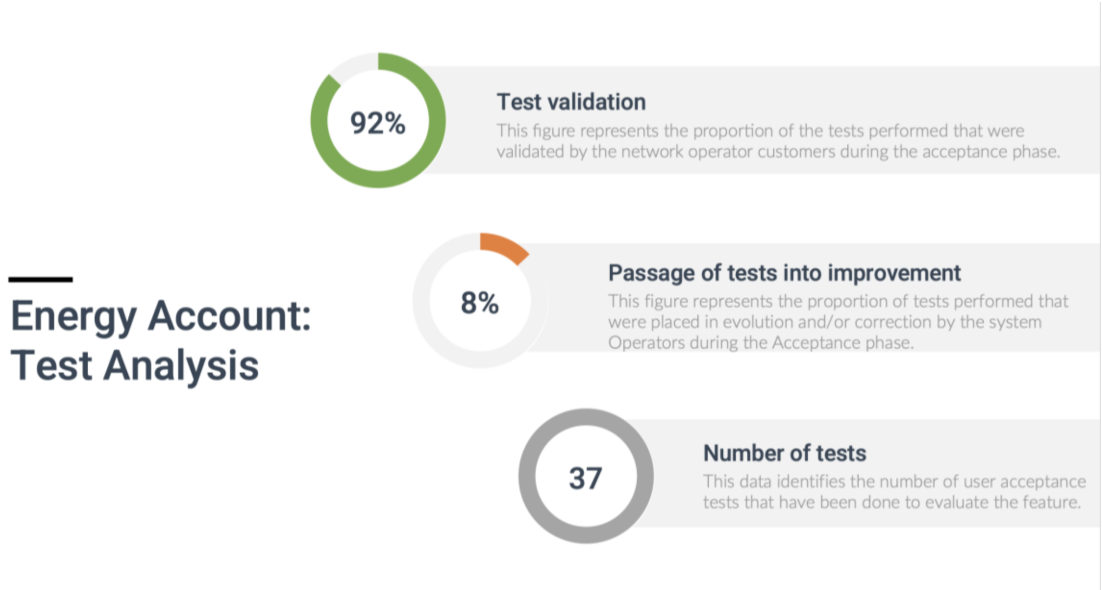

Figure 24: Energy Account Test Analysis

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

6.1.4 Results on Limitation History

The Limitations history table is the main functionality of the STAR platform. It represents an assembly of the entire data model in a synthesized view.

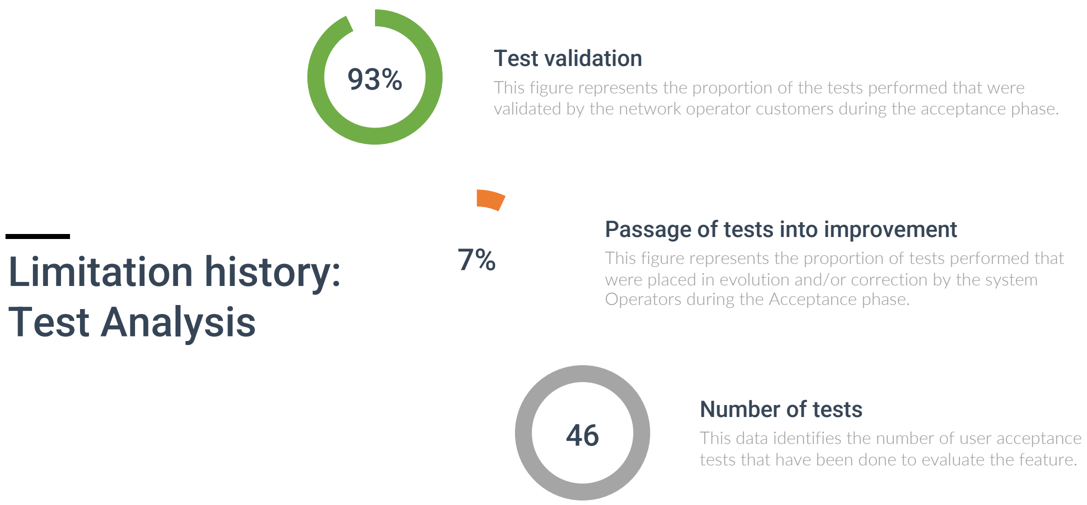

Figure 25: Limitation History Test Analysis

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It is the functionality that has evolved the most in terms of developments, the interface must adapt to each addition. The history of limitations is complex because, due to confidentiality rules, each actor does not have the same view on the data of a limitation.

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

6.2 Downstream functionalities: financial and compensation management

6.2.1 Results on Eligibility for Compensation

Eligibility for compensation is information that indicates the compensation status of a limitation by the FSPs. This information is contained in the ***Activation Document*** object.

This data is very important for confidentiality management rules as well as for the management of compensation amount calculations. It must be stored in the back-office by the System Operators and then displayed on an interface for the FSPs.

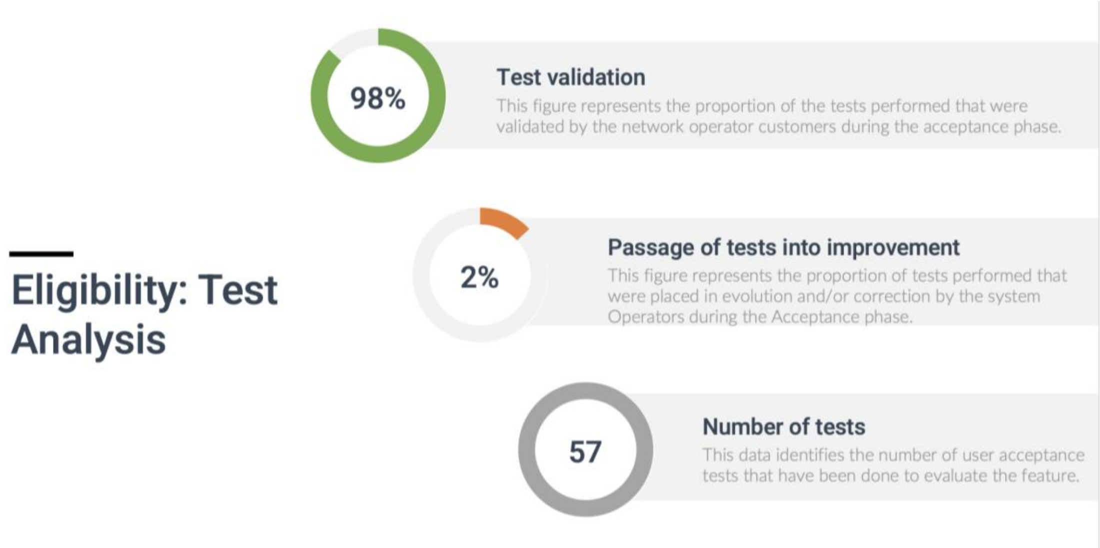

Figure 26: Eligibility Test Analysis

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

6.2.2 Results on Tariff & Compensation

The valuation unit tariff is represented by the CIM ***Reserve Bid Market Document*** object.

The valuation unit tariff corresponds, in the context of STAR, to the price per MWh of ENE/I.

The calculation of compensation for FSPs is represented by the ***Balancing Market Document*** object.

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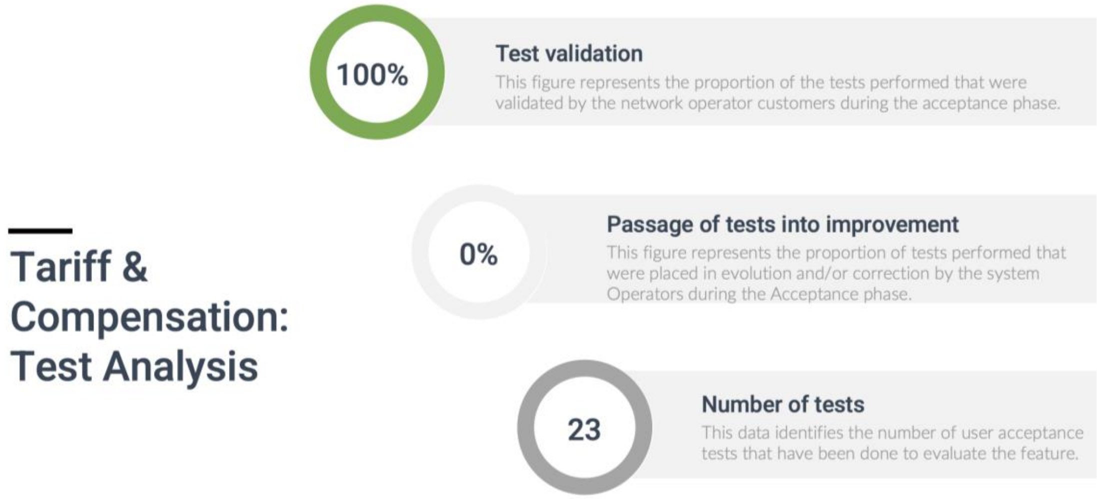

Figure 27: Tariff & Compensation Test Analysis

6.2.3 Results on Feedback FSPs

The ***FSPs Feedback*** object is a non-standard CIM object, associated with a given limitation. It meets a need raised during the scoping of the STAR project: the management of anomalies/feedback on the data in the above sections linked to a limitation.

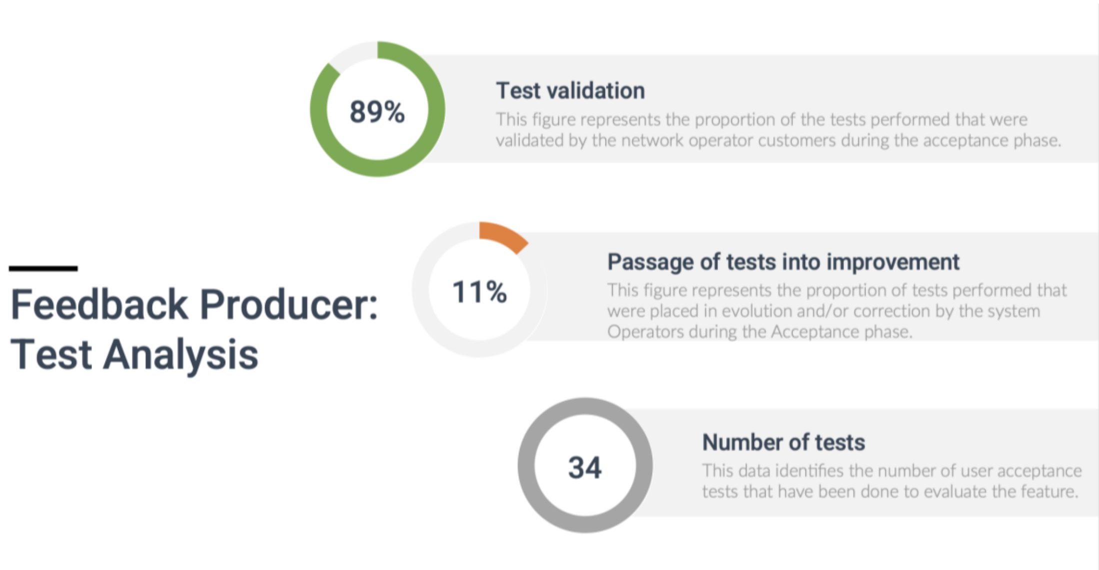

Figure 28: Feedback FSPs Test Analysis

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

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6.3 Administration: market participant & confidentiality

6.3.1 Results on Master Data

Master Data includes all data related to the management of the platform's network participants according to three main types of actors:

- TSO: Transmission System Operator;
- DSO: Distribution System Operator;
- FSPs.

In addition, the Master Data takes into account the network mapping of the production sites in the experimentation area. Any new FSPs wishing to join the STAR experimentation in the defined area, must have one or more wind or solar production sites to be integrated in STAR.

Finally, the Master data is also used by the network operators to manage the reconciliation between the TSO activation orders and those of the DSO. A mapping has been created according to the source stations of each operator.

It is therefore on these three main aspects that was carried out the Acceptance phase to validate the functionality of the Master Data.

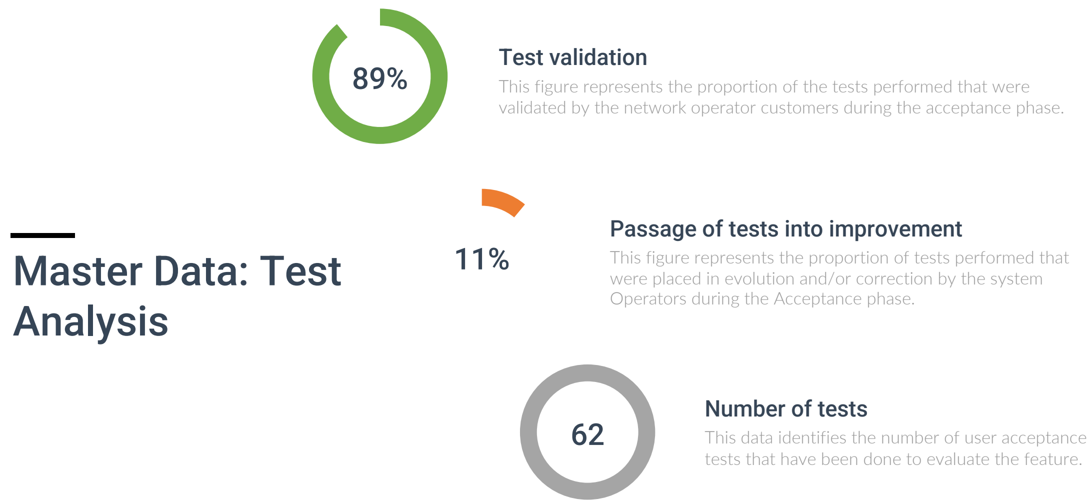

Figure 29: Master Data Test Analysis

All the tests that needed to be passed in the improvement phase have been corrected to allow them to pass the Acceptance phase completely.

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7 Conclusion

The French demo has managed two use cases:

- The development and experimental usage of the STAR (System for Tracking Activations of Renewables) platform built to register and share data related to the life cycle of flexibility activations between TSO, DSO and FSPs. Based on Hyperledger Fabric blockchain technology, it has aimed at improving transparency between actors, reducing the administrative burden and stimulating cooperation.
- A reflection on coordination between DSO and TSO, pondering on possible leads to come up with more technically and economically efficient methods.

The platform was successfully designed to meet the requirements of the use case's scenarios in terms of data model, shared governance and architecture. As envisioned, the blockchain technology helped achieve transparency and data unicity goals, and further analysis on pros and cons of the technology choices will be developed in deliverable D9.7 [8]. As all technical and functional product tests were successfully executed during the development, STAR has been implemented in production and thus has been running in experimental phase, focusing on registering automated and manual flexibility orders related to local congestion management.

Finally, KPIs described in this document will be computed in deliverable D9.7 which will also present the data collected during the experiment, and conclude on the results and lessons learned within the demonstrator.

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